K.W. Chau · Isabelle Y.S. Chan
Weisheng Lu · Chris Webster
Editors

Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate

Springer

Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate

K.W. Chau · Isabelle Y.S. Chan
Weisheng Lu · Chris Webster
Editors

Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate

Springer

Editors
K.W. Chau
Department of Real Estate and Construction
The University of Hong Kong
Hong Kong
Hong Kong

Weisheng Lu
Department of Real Estate and Construction
The University of Hong Kong
Hong Kong
Hong Kong

Isabelle Y.S. Chan
Department of Real Estate and Construction
The University of Hong Kong
Hong Kong
Hong Kong

Chris Webster
Faculty of Architecture
The University of Hong Kong
Hong Kong
Hong Kong

ISBN 978-981-10-6189-9 ISBN 978-981-10-6190-5 (eBook)
https://doi.org/10.1007/978-981-10-6190-5

Library of Congress Control Number: 2017950275

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

1 **A Cluster Analysis of Real Estate Business Models in China** 1
K.J. Li, Y. Zhou, A. Shrestha and G.W. Liu

2 **A Comparison of Barrier-Free Access Designs For the Elderly Living in the Community and in Care and Attention Homes in Hong Kong** 11
Ibukun Famakin and Mei-yung Leung

3 **A Comparison of Green Building Policies in Asian Countries or Regions** 19
Xiaosen Huo and Ann T.W. Yu

4 **A Comparison of Public Private Partnership Environment Between Australia and China** 35
Yongjian Ke, Marcus Jefferies and Peter Davis

5 **A Conceptual Model of Cloud-Based Virtual Community for BIM Innovation and Promotion** 45
C.W. Keung

6 **A Dynamic Analysis on the Urban Carbon Footprint and Carbon Carrying Capacity—A Case Study of Chongqing** 53
S.P. Li, Q.J. Zheng, D.H. Zeng, Z.H. Huang and L.Y. Shen

7 **A Framework for Quantifying Carbon Emissions Generated During Demolition Waste Processing** 67
Y. Li, H.Y. Wu, Z.Z. Wu, J.Y. Wang, H.B. Duan, J. Zuo, Z.D. Li and X.L. Zhang

8 **A Framework for Utilizing Automated and Robotic Construction for Sustainable Building** 79
Mi Pan, Thomas Linner, Hui Min Cheng, Wei Pan and Thomas Bock

9 A Literature Review of Sustainable Urbanization in China 89
Y.T. Tan and H. Xu

10 A Macro-Micro Framework of ADR Use in the Malaysian Construction Industry 97
Chia Kuang Lee, Tak Wing Yiu and Sai On Cheung

11 A Preliminary Study on the Effects of HSR on Station Area 107
Guo Liu and Kunhui Ye

12 A System Dynamics Framework of Drivers and Constraints to Enhancing Productivity of the Hong Kong Construction Industry 117
A.A. Javed, Zhan W and W. Pan

13 A Whole Life Cycle Group Decision-Making Framework for Sustainability Evaluation of Major Infrastructure Projects 129
B. Xue and H. Xu

14 Adaptive Reuse of Inner-City Buildings: Methods for Minimising Waste and Stimulating the Economy 141
N. Udawatta, Zillante George, A. Elmualim, R. Rameezdeen and J. Zuo

15 An AHP-ANP Integrated Framework of Evaluating Innovative Business Models for Sustainable Building 153
X. Zhao, L. Chen, W. Pan and Q. Lu

16 An AHP-GIS Based Model of C&D Waste Landfill Site Selection: A Triangulation of Critical Factors 163
Zhikun Ding, Menglian Zhu, Yifei Wang and Jiasong Zhu

17 An Alternative Model for Regional Sustainability Evaluation: A Case Study of Chongqing 175
C.Y. Shuai, Y.T. Tan and L.D. Jiao

18 An Empirical Analysis of the Effect of Prefabrication on Fostering Sustainable Construction 185
Peter S.P. Wong, Michael Phillip Kanellopoulos and Luke Edmonson

19 An Empirical Investigation of Construction and Demolition Waste Management in China's Pearl River Delta 197
J.K. Liu, Y.S. Pang, D. Wang and J.W. Zhou

20 An Intelligent Decision Support System for Improving Information Integrity in Procuring Infrastructures in Hong Kong 213
L. Chen and W. Pan

21 **An Investigation of Waste Reduction Measures Employed in Construction Industry: Case of Shenzhen** 223
Y. Gao, J.Y. Wang, H.Y. Wu and X.X. Xu

22 **An Optimization-Based Semantic Building Model Generation Method with a Pilot Case of a Demolished Construction** 231
F. Xue, K. Chen, D. Liu, Y. Niu and W.S. Lu

23 **Analysis and Optimization of Key Index of Public Investment Building Project's Performance Evaluation Based on Project Governance** 243
Y.S. Wang, F.f. Liu, W.Z. He, Y. Zhang, H.Y. Li and J.F. Li

24 **Analysis on the Influencing Factors of Building Energy Consumption—A Southwest China Case Study** 259
Z.N. Zhao, H.M. Zhang, Y.F. Ding and L.Y. Shen

25 **Analysis on the Influencing Factors of Multidimensional LMDI Energy Consumption—A Case Study of Chongqing** 273
H.M. Zhang, Z.N. Zhao, L.Y. Shen, W.W. Wen and M. Chen

26 **Application of Building Information Modeling (BIM) in Site Management—Material and Progress Control** 289
A. Nadeem, A.K.D. Wong, G. Akhanova, S. Azhar and S.N. Wong

27 **Application of SWOT Analysis in Turkish Construction Industry** 299
Z. Işık, H. Aladağ, G. Demirdöğen and Ç. Aygün

28 **Assessment of Energy Efficiency for Retrofit Versus Reconstruction Projects by Building Information Modeling** 311
G. Demirdöğen and Z. Isık

29 **Barriers to and Enablers for Lessons Learned Practices in International Infrastructure Development Projects—A Case Study** 321
Tiendung Le, Eric Too and Viet Anh Tran

30 **Benchmarking Innovation Potentials in Large Projects by Public Private Partnerships** 331
Cut Sarah Febrina and Palaneeswaran Ekambaram

31 **Benefits of Using Constructability, Operability, and Maintainability in Infrastructure Projects: A Meta-Synthesis** 347
S. Jadidoleslami, E. Saghatforoush, N. Kordestani Ghaleenoe and C. Preece

32 **Big Data in Urban Planning Practices: Shaping Our Cities with Data** 365
Ruiqu Ma, Patrick T.I. Lam and C.K. Leung

33 Board of Director's Role in Preventing Corporate Misconduct in the Construction Industry . . . 375
C.J. Lee, R. Wang, S.C. Hsu and C.Y. Lee

34 Bridging Knowledge Gap Between Green and Non-green Facilities Management in Singapore . . . 383
Yujie Lu and Ngiam Min Li Joyce

35 Bridging the Cyber and Physical Systems for Better Construction: A Case Study of Construction Machinery Monitoring and Utilization . . . 393
D.D. Liu, W.S. Lu, Y.H. Niu, F. Xue and K. Chen

36 Building Information Modeling (BIM) in Architecture, Engineering and Construction (AEC) Industry: A Case Study in Malaysia . . . 401
N.F. Azmi, C.S. Chai and L.W. Chin

37 Carbon Emission Modelling for Construction Logistics Process Through Activity-Based Method . . . 413
Y. Fang, Z.D. Ma and Y.Z. Luo

38 Causal Loop Analysis on the Impact of Schedule Risks in Prefabrication Housing Production in Hong Kong . . . 425
W.K. Huang, X.X. Xu, K. Chen, H.Y. Wu and Z.D. Li

39 Causes of Delays in Mega Projects—Case of the Zambian Transmission Power Projects . . . 435
Chaali Kalebuka, Erastus Mwanaumo and Wellington Didibhuku Thwala

40 Characterization of Carbon Emissions from the Construction Activities: A Case Study of Shenzhen, China . . . 451
L.N. Zheng, H. Zhang., H.B. Duan, X.H. Wang, Y.N. Niu and J.Y. Wang

41 China's Ongoing Policy Instrument for Building Energy Efficiency: Drives, Approaches and Prospects . . . 461
B. He, X.L. Zhang, L.D. Jiao and L.Y. Shen

42 Chinese Building Energy Service Industry Evolution Based on Ecological Niche . . . 471
Saina Zheng, Pengpeng Xu, Guiwen Liu and Jinxi Jing

43 Clean Development Mechanism in Airports: The Colombian Case . . . 481
J.D. González-Ruiz, E.A. Duque and J.C. Restrepo

44 **Conflict Analysis of Concentrated Rural Settlement Development During Post-disaster Reconstruction in China: A Multi-agent Simulation** 491
Y Peng, Q.X. Li and H.J. Bao

45 **Construction and Demolition Waste Management: Experiences Learning from Developed Countries and Their Enlightenment to China** 503
X.H. Wang, H. Zhang, L.N. Zheng, H.B. Duan, Y.N. Niu and J.Y. Wang

46 **Construction Project Manager Health and Safety Interventions Towards Improving Workers' Performance** 513
W. Ayessaki and J. Smallwood

47 **Construction Work Productivity in South Africa: A Case of Gauteng Province Construction Industry** 523
A.S. Sibande and N.J. Agumba

48 **Contractors' Organisational Culture Towards Health and Safety Compliance in Ghana** 535
Z. Mustapha, C. Aigbavboa and W.D. Thwala

49 **Convention and Exhibition Center Integrated into High Speed Rail Station: Experience and Idea** 543
Yue Li and Yuzhe Wu

50 **Corporate Social Responsibility Localization in International Construction Business** 553
Meng Ye, Weisheng Lu and Roger Flanagan

51 **Correlation Analysis of Key Influencing Factors to the Total Factor Productivity of the Hong Kong Construction Industry** . . . 565
W. Zhan, W. Pan, A.A. Javed and K.W. Chau

52 **Critical Impact Factors Affecting Carbon Emission: Evidence from STIRPAT Model with Panel Data Analysis** 577
C.Y. Shuai, X.N. Song and S.P. Li

53 **Critical Risks Associated with BIM Adoption: A Case of Singapore** 585
Xianbo Zhao, Josua Pienaar and Shang Gao

54 **Critical Success Factors of Joint Ventures in the Construction Industry: Literature Review** 597
M.F. Bekale Mba and N.J. Agumba

55 **Detection and Quantification of Spalling Distress in Subway Networks** 607
T. Dawood, Z. Zhu and T. Zayed

56 **Determinants of Business Overdraft Accessibility Within Small and Medium-Sized Enterprises in the South African Construction Industry: A Case of Gauteng Province** 617
O.A. Balogun, N.J. Agumba and N. Ansary

57 **Determination of Project Management Competence Risks in Build Operate Transfer (BOT) Transportation Projects** 629
H. Aladağ and Z. Işık

58 **Does the Development of China's Building Industry Influence the Global Energy Consumption and Carbon Emissions? an Analysis Based on the GVAR Model** 641
Hong Zhang, Jiawei Chen, Yang Li and Michael J. Seiler

59 **Driving Factors for Promoting Urbanization of Small Townsin Southwest China** 651
Ning Xiong, Zhenhua Huang, Shanshan Zhao and Liyin Shen

60 **Estimating the Walking Accessibility Premiums** 665
Linchuan Yang

61 **Evaluating the Critical Risk Factors of Reconstruction Urban Renewal Projects: The Developer's Perspective in China** 677
W.D. Wu, G.W. Liu, Z.H. Cai and S.N. Zheng

62 **Evaluating the Effects of Alleviating Urban Traffic Congestion Using Real-Time Traffic Information on Mobile Devices** 689
M.W. Hu, W.K. Huang and Y. Chen

63 **Evaluation of Construction Waste: Management Problems and Solutions** 701
T. Quinn and J.J. Smallwood

64 **Evaluation of Procurement Systems of Public Sector Funded Projects** 709
A.E. Oke, C.O. Aigbavboa and B.A. Tong

65 **Evolutionary Game Analysis on the Low-Carbon City Construction Between Central and Local Government in China** 717
Yingli Lou, Xiangnan Song and Hui Yan

66 **Examining Critical Factors Affecting Knowledge Transfer in Public-Private Partnership (PPP) Projects** 727
T.T. Liu and Y.C. Wang

67 **Explication of Challenges with Acceptance of Marketing Functions in the Management of Construction Business Enterprise** 745
J.E. Yankah, C. Aigbavboa and W. Thwala

68 **Factors Influencing Safety Training Transfer on Construction Sites: A Literature Review** 759
R. Prasad, Y. Feng and M. Hardy

69 **Factors Influencing the Construction Time and Cost Overrun in Projects: Empirical Evidence from Pakistani Construction Industry** 769
Ahsen Maqsoom, Muhammad Umar Khan, Muhammad Tariq Khan, Shahfahad Khan, Naeemullah and Fahim Ullah

70 **Feasibility Analysis of Using Construction and Demolition Waste in Sea Reclamation Projects in Hainan** 779
X.L. Li, Y. Li, H.Y. Wu, J.Y. Wang, H.B. Duan and X.X. Xv

71 **Female Student Enrolments in Construction Management Programs** 789
B.L. Oo and E.C. Widjaja

72 **Financial Simulation in Operation and Maintenance of Railway Transportation: A Case Study of Greater Jakarta Light Rail Transit** 799
H.Z. Rahman, P. Miraj and J.S. Petroceany

73 **Finding Academic Concerns on Real Estate of U.S. and China: A Topic Modeling Based Exploration** 807
Z.R. Zhang, M.S. Qiang and H.C. Jiang

74 **From Paper-Based to Cloud-Based Safety Information System in Infrastructure Construction Projects** 819
Patrick X.W. Zou, Percy K.Y. Lun, Palaneeswaran Ekambaram, Sheirf Mohamed and Dean Cipolla

75 **Game Analysis of Stakeholders in Urban Renewal Based on Maximization of Social Welfare** 835
J.F. Li, Y.S. Wang, N. Lu, Y. Du, Y. Zhang and F.F. Liu

76 **Game-Based Construction Process Learning for Students' Education: A Case Study of Concreting Game** 851
Fei Feng, Zhiyang Lin, Wenfeng Yue, Ke Chen, Ming Kang and Yonghong Cao

77 **Identification and Assessment of Particulate Matters in Asphalt Fumes from Road Construction** 859
D. Chong, M. Kobzeva and Y.H. Wang

78 **Identifying the Relationship Between Housing Market Development and Urbanization Process: Evidence from Jiangsu, China** 869
Jing Du, Yifan Yang and Bing Jiang

79 Impacts of Large Construction Projects on Residents' Living Status in China: A Reservoir Project Case 879
W.S. Lin, Y. Ning, Y.L. Huang and M.J. Liu

80 Improving Construction Safety Performance Through Error Management: A Literature Review 891
Minh Tri Trinh and Yingbin Feng

81 Improving Mentoring Relationships of Construction Management Professionals 899
A.E. Oke, C.O. Aigbavboa and M.M. Mutshaeni

82 Index Decomposition Analysis of Building Energy Consumption in Chongqing: 2000–2014 907
Xia Wang, Hong Ren, Weiguang Cai and Yan Liu

83 Indicators for Guiding Sustainable Development of Townships in Mountainous Regions in Southwest China 917
Y. Chen, Y.T. Ren, Y.L. Huang and L.Y. Shen

84 Influential Factors in Construction Industry of Yemen 927
Najib AL-Fadhali, Ng Kim Soon, Rozlin Zainal, Abd Rahman Ahmad and Abdel Hafiz Ali Hasaballah

85 Investigating the Relationship Between Student Characteristics and Progression: An Archive Study 945
Josua Pienaar, Xianbo Zhao and Nadine Adams

86 Key Parameters on Financial Loss of Construction Accidents in Hong Kong Construction Industry 957
Kai-Chi Ying, Guomin Zhang and Sujeeva Setunge

87 Knowledge Transfer Between R&D Projects and Commercial Projects: A Conceptual Framework 969
Eric Too and Stewart Bird

88 Life Cycle Costing for Insulated Pitched Roof Structures 981
I.M. Chethana S. Illankoon, Vivian W.Y. Tam and Khoa N. Le

89 Life-Cycle Cost Assessment of Durable Repair of Concrete Structures Based on Environmental Costs 995
X.M. Mi, C.Y. Liu, D.W. Li, N.X. Han and F. Xing

90 Literature Review on the Research Discipline of Low Carbon Cities in China 1005
X.Y. Du, T.K. Li, Z.H. G and L.Y. Shen

91 Management Strategies for 5D-BIM Adoption in Hong Kong 1023
I.Y.S. Chan, A.M.M. Liu and B. Chen

92 **Method for Urban Rail Transit Project Financing Decision-Making Based on Triangular Fuzzy Number** 1041
L.L. Yuan, Y.S. Wang and Y. Sun

93 **On Territorial Planning Reconfiguration in China: A Critical Review of the Existing Planning System** 1055
Liping Shan, Yuzhe Wu and Sheng Zheng

94 **On the Garbage Classification Mechanism Based on Repeated Games in Urban Network Organization** 1065
Teng Su and Yuzhe Wu

95 **Optimizing Life-Cycle Carbon Emissions for Achieving Concrete Credits in Australia** 1077
Vivian W.Y. Tam, Khoa N. Le and Cuong N.N. Tran

96 **Paradigm Shift Towards Green Industry Restructuring: A Review of Industrial Land in China** 1089
Jiaojiao Luo, Yuzhe Wu and Xiaoling Zhang

97 **Pilot Case Study of New Engineering Contracts (NECs) in Hong Kong—Joy or Tears?** 1103
D.W.M. Chan and J.H.L. Chan

98 **Potentials of TDR for Balancing Built Heritage Conservation and Compact Development in Hong Kong** 1113
Jun Hou and Edwin H.W. Chan

99 **Prioritizing Best Value Contributing Factors for Contractor Selection: An AHP Approach** 1121
Muhammad Hasnain, Fahim Ullah,
Muhammad Jamaluddin Thaheem and Samad M.E. Sepasgozar

100 **Recycled Aggregate in Concrete Production: A New Approach** 1133
Vivian W.Y. Tam, Anthony Butera and Khoa N. Le

101 **Recycled Ceramic Fine Aggregate for Masonry Mortar Production** 1141
A.C.J. Evangelista, Vivian W.Y. Tam and J. Santos

102 **Remaking the Physical Disability Inclusion Score (PDIS) and the Visual Impairment Inclusion Score (VIIS) to Assess the Disability Inclusiveness of Commercial Facilities: A Pilot Study** 1149
W.K. Lau, T.Y.M. Lam, W.M. Ho and W.K. Wu

103 **Research of Housing Price Based on Bid-Rent Theory** 1167
Donglang Yang, Zhongfei Cui and Luyao Zhao

104 **Research on Cost Risks for EPC Project Using Entropy-Weight Evaluation Method** 1175
Jiali Liu, Jinjin Chen and Liyin Shen

105 **Research on Dynamic Fuzzy Multi-objective Optimization of Engineering Projects Considering Risk Factors** 1185
R.X. Ding, X.Q. Wang, T.T. Han, M.X. Li and N.N. Xia

106 **Research on Evaluation of Xi'an Shantytown Renovation Projects' Social Benefit** 1203
Yang Donglang, Zhao Luyao and Cui Zhongfei

107 **Research on Performance of Construction Enterprises Based on Informatization and Contract Management** 1215
Bing Zhang and Sujie Hu

108 **Research on the Comprehensive Economic Strength of Macro Regional Distribution in Urbanization** 1225
Min Tian, Na Tang and Jie Han

109 **Research on the Housing Affordability of University Graduates in Guangzhou** 1239
Fan Wu, Linghin Li, Mingjie Dai, Yiming Gao, Ruoshi Tang, Kaihang Lin, Kaijian Li and Haoqi Huang

110 **RFID-Enabled Management System Adoption and Use in Construction: Passing Through the Labyrinth with an Improved Technology Acceptance Model** 1251
Y.H. Niu, W.S. Lu and D.D. Liu

111 **Risk and Risk Factors in Brownfield Development** 1259
Hao Wu, Piyush Tiwari, Sun Sheng Han and Toong-Khuan Chan

112 **Risk Management in the Supply Chain of Essential Medicines** 1275
Mario M.J. Musonda, Erastus M. Mwanaumo and Didibhuku W. Thwala

113 **Rural Residential Land Transfer in China: Government-Driven or Market-Driven?** 1289
Zhibin Mo, Yuzhe Wu and Jianfeng Ye

114 **Scenarios for Applying Big Data in Boosting Construction: A Review** 1299
X. Chen and W.S. Lu

115 **Smart Gateway for Bridging BIM and Building** 1307
K. Chen, W.S. Lu, F. Xue, L.Z. Zheng and D.D. Liu

116 Spatial-Temporal Effects of Housing Price Caused by Metro Construction: A Perspective of Price-to-Rent Ratio 1317
Fen Wang and Yuzhe Wu

117 Stakeholder Analysis of Sustainable Construction in China 1335
Hongyang Li, S. Thomas Ng and Yahong Dong

118 Strategic Factors Influencing Bid/No-Bid Decision of Pakistani Contractors 1345
Ahsen Maqsoom, Malik Muhammad Farjad, Muhammad Sadaat Abbas, Muhammad Ehtesham-Ul-Haque, Muhammad Irfan and Aman Ullah Malik

119 Study on the Affordable Housing Policy in China's Urbanization Process 1355
Wei Wang, Zhengrong Liu and Yuzhe Wu

120 Suggestion for Improving Project Management Competency of Project General Contractors in China 1365
Weiping Jiang

121 The Analysis of Rural Undergraduates' Separation of Registered and Actual Residences and the Separation's Influences on Land Use 1375
Qiong Lin and Yanmei Ye

122 The Decoupling Analysis Between Regional Building Energy Consumption and Economic Growth in China 1385
Ya Wu and Hang Yan

123 The Demand for Senior Housing Grows. The Answer Is to Be Found in Various Models of Social "Enterprise" 1397
A.S. Pavesi, A. Ciaramella, M.Y. Leung and M. Gechelin

124 The Effect of Contract Control on Contractors' Cooperative Behavior: The Moderating Role of Owner Power 1407
X.K. Jiang and S.J. Zhang

125 The Evaluation of Urban Renewal Policies in Shenzhen, China (2009–2016): An Analysis Based on Policy Instruments 1419
Z.Y. Yi, A. Shrestha, L.Z. Wei and G.W. Liu

126 The Improvement of Safety Climate of Migrant Workers Based on Social Mining Technologies 1429
Sheng Xu

127 The Potential Cost Implications and Benefits from Building Information Modeling (BIM) in Malaysian Construction Industry . . . 1439
LiWei Chin, ChangSaar Chai, HeapYih Chong, Aminah Md Yusof and NurFakhira bt Azmi

128 The Researches on Construction Project Manager Competency and Its Application . . . 1455
Jingru Li, Junpeng Li and Ruirui Xia

129 The Rise of the Smart Circular City: Intelligent Modelling of Cities for Improved Waste Reuse and Environmental Effects . . . 1463
R. Vrijhoef

130 The Simulation and Evaluation Method and Technology of Passenger Flow in Urban Rail Terminal . . . 1473
W.K. Huang, M.W. Hu and S.Y. Zhai

131 The Supply and Demand for Green Housing in China: A Micro-Perspective . . . 1487
L. Zhang, H. Liu, X. Wang and X. Tang

132 Trend Analysis of the Labor Supply and Demand in China's Construction Industry: 2016–2025 . . . 1499
H. Ye and Y. Zhang

133 Understanding Construction Technology Transfer from a 'SCOT' Perspective . . . 1509
K. Oti-Sarpong and R. Leiringer

134 Urban Green Land Carbon-Sink in Different Functional Cities: The China Case . . . 1521
Z.H. Huang, N. Xiong, X.L. Zhang, S.P. Li and L.Y. Shen

135 Use of a Mobile BIM Application Integrated with Asset Tracking Technology Over a Cloud . . . 1535
J. Park and Y.K. Cho

136 Using Switching State-Space Model to Identify Work States Based on Movement Data . . . 1547
Xincong Yang, Heng Li, Fenglai Wang, Xiaochun Luo and Dongping Cao

About the Editors

Prof. K.W. Chau (鄒廣榮) B.Sc. (B.S.), B. Building, Ph.D. (HKU), FRICS, FHKIS, FCIOB

Chair Professor and Head, Department of Real Estate and Construction, The University of Hong Kong.

Director, Ronald Coase Centre for Property Rights Research, The University of Hong Kong.

Professor K. W. Chau is a currently Chair Professor and Head of the Department of Real Estate and Construction and Director of the Ronald Coase Centre for Property Rights Research at The University of Hong Kong. He is also Honorary President of the Chinese Research Institute of Construction Management (CRIOCM). His main areas of research include real estate finance and economics, real estate price index, construction economics and urban analysis. Most of his works are empirical studies with implications for policy makers and practitioners. He received the International Real Estate Society Achievement Award in 1999. He founded Asian Real Estate Society in 1996 and served as the first President (1996–7). He also served as President of the International Real Estate Society (2000–1). He was elected as President of the Hong Kong Institute of Surveyors (2009–10) and President of the Chinese Research Institute of Construction Management (2014–17).

Professor Chau has many years of experience in real estate research and consultancy. He has done many consultancy works for private and public organizations. Professor Chau has also served and is serving on many government committees.

Dr. Isabelle Y.S. Chan B.Eng.(Hons), M.Phil., Ph.D., MCIOB, FISHP

Lecturer, Department of Real Estate and Construction, The University of Hong Kong.

Isabelle is a Lecturer at the Department of Real Estate and Construction, University of Hong Kong, PRC. In the past few years, she has participated in more than 10 government-/university-/industry-funded research projects covering areas of construction health and safety, stress management in construction, sustainable development, innovation in construction and so on. In line with these projects, she has over 50 international publications in books, journals and conferences. Isabelle is a Chartered Construction Manager. She also the Vice-chairman of the Institute of Safety and Health Practitioners in Hong Kong.

Dr. Weisheng Lu Ph.D., M.Sc., B.Eng., MCIOB, MCRIOCM

Associate Professor, Associate Dean (Research), Faculty of Architecture (FoA), The University of Hong Kong, Hong Kong.

Dr. Weisheng Lu's research interests mainly including Building Information Modelling (BIM), smart construction, big data in construction waste management and international construction. He is the Associate Dean of the Faculty of Architecture (FoA), looking after research and knowledge exchange (KE) in the Faculty. Dr. Lu is also steering the development of *iLab*, which is an urban big data hub under the umbrella of the HKUrbanLab, the research arm of the FoA at HKU. *iLab* facilitates multidimensional and multidisciplinary urban big data collection, storage, analysis and presentation to inform all sorts of decision-making throughout the life cycle of urban development. *iLab* also has its own unique research remit to integrate big data in pursuit of integrated modelling of smart urban development, combining smart community, smart infrastructure, smart construction, smart property and facilities management and Internet of Things (IoTs). His recent research projects fostered in *iLab* include how BIM can be used for construction cost management, smart construction, logistic and supply chain management and facility maintenance.

Prof. Chris Webster Dean and Chair Professor, Faculty of Architecture, The University of Hong Kong.

Professor Chris Webster is Dean of the Faculty of Architecture, the University of Hong Kong, and leads the HKUrbanLab. He has degrees in urban planning, computer science, economics and economic geography and is a leading urban theorist and spatial economic modeller. He has published over 150 scholarly papers on the idea of spontaneous urban order and received over US$20M grants for research and teaching and learning projects. He was co-editor of Environment and Planning B for 10 years. Books include Webster and Lai (2003) *Property Rights, Planning and Markets*, Cheltenham, Edward Elgar; Glasze, Webster and Frantz, (2006) *Private Cities*, London, Routledge; Wu, Webster, He and Liu, (2010) *Urban Poverty in China*, Cheltenham: Edward Elgar; and Wu and Webster (Editors) *Marginalisation in Urban China*, London: Palgrave MacMillan; and Sarkar, Webster and Gallacher (2014) *Healthy Cities: Public Health Through Urban Planning*, Cheltenham: Edward Elgar. Professor Webster has nine prize-winning academic papers on urban theory.

He has many research interests on the go, including leading HKU's Healthy High Density Cities research group. His current research agenda for this group is to establish systematic evidence for the relationship between urban configuration (planned and spontaneous) and individual health. To do this, he has teamed up with the Oxford University-based UKBiobank (N = 500,000), the HKU LKS Faculty of Medicine's Family cohort (N = 40,000) and other national-scale epidemiology studies (N = 500,000) to create large-scale medical-built environment platforms for healthy city science. He also co-leads HKU's One Belt One Road Observatory (OBORObs), which has the objective of modelling and predicting connectivity improvements in the Eurasian urban network and advising city governments on smart land policy to capture more of the land value uplift of OBOR infrastructure for the urban poor.

Chapter 1
A Cluster Analysis of Real Estate Business Models in China

K.J. Li, Y. Zhou, A. Shrestha and G.W. Liu

1.1 Introduction

The globalized construction market leads to globally-interconnected projects and boosts competition between emerging players. To survive in such a challenging environment, companies are forced to embrace innovations for their business model. A business model can be understood as the approach that a company takes to generate revenue and makes profits (Ovans 2015). The model articulates the logic, the data, and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value (Teece 2010). It emphasizes organizational activities in a systems perspective of doing business which seeks to explain both value creation and capture (Pan and Goodier 2012). For example, the business model for Walmart, the world's largest company in revenue, was to sell products at a lower price by decreasing service. In the real estate industry, the "current trader" business model consists of a cycle of land acquisition, development, and outright sale (Pan and Goodier 2012).

Despite increasing academic interest and attention in this area, no commonly accepted definition of real estate business models have yet been established. Also, there is a lack of quantitative studies for the main streams of real estate business models in China. In order to fill on this perceived knowledge gap, and to facilitate cross-context learning, the aim of this paper is thus to reveal the clusters of real estate business models in China. The paper first examines the variables for studying the business model of the real estate market. It then examines 117 real estate companies identified through a two-step cluster analysis, and subsequently elaborates on the revealed real estate business model clusters in China. Coupling results provide a tool to depict real estate business model and quantifiable evidence for

K.J. Li · Y. Zhou (✉) · A. Shrestha · G.W. Liu
Faculty of Construction Management and Real Estate,
Chongqing University, Chongqing 400045, China
e-mail: zhouyang@cqu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_1

Chinese real estate practitioners to understand the main stream of real estate business models in China.

1.2 Methodology

1.2.1 Samples Selection

Chinese enterprises with more than 70% of their total revenue generated from the real estate development were selected as the samples in this study. As of December 2014, there were 143 enterprises listed on the Shanghai and Shenzhen real estate sector. All 143 companies were investigated and based on the inclusion criteria, 117 companies were selected as the research samples while the remaining 26 enterprises that did not meet the criteria were excluded.

1.2.2 Variables Considered for Cluster Analysis

In order to establish the variables for depicting real estate business models, this study reviewed the papers on business model published between 1998–2016. Seven items for measuring the construct of business model were derived from studies including Moore (2004), Johnson et al. (2008a, b) and Brege et al. (2014). According to our knowledge, this is the first study that analyses clusters of enterprise business models applying multiple dimensions and using a large sample size. The selected indicators were greatly represented the model of comprehensive and data available.

The variables are discussed individually below.

(1) Target customers: This variable was used primarily to measure the enterprise customer groups. According to the income of target customers, which were mainly derived from corporate annual reports, the target customers were divided into: (i) ordinary customers (ordinary-income groups), (ii) high-end customers (high-income groups) and (iii) integrated customers (both ordinary and high income groups).
(2) Product: Product refers to the product types of the enterprise. According to the analysis of the income data obtained from the corporate annual reports regarding the enterprises' main businesses, they were divided into: (i) residential oriented; (ii) commercial oriented; and (iii) others. If residential construction accounted for more than 70% out of the main business income for the enterprise, the enterprise was classified into residential oriented; if commercial buildings account for 70% out of the main business income for the enterprise, the enterprise was classified as business oriented; and for the enterprises with

70% of their income not being generated from either residential or commercial construction were classified as others.

(3) Market orientation: This variable was used to identify the proportion of sales income based on where the location of the enterprises' market. The proportion of domestic sales income and the proportion of foreign sales income was used as the basis of classification. In addition, regional division was based on the administrative regions in China, i.e., East China, North China, South China, Central China, Northeast, Southwest, Northwest. Enterprises whose regional sales accounted for more than 70%, were classified as local leading type, while the others were classified as domestic leading type.

(4) Finance: This variable was mainly used to measure whether the corporate finance structure was adequate to support the sustainable development of enterprises. If the debt-to-assets ratio index was less than 40%, the enterprise was classified as risk-adverse. If the debt-to-assets ratio index was greater than 40% but less than 70%, the enterprise was classified as risk-neutral and if the debt-to-assets ratio index was higher than 70%, the enterprise was the classified as risk-seeking. Risk adverse enterprises may not use full leverage of funds to create greater value for shareholders. Risk neutral enterprises use funds to generate medium level of earnings. Risk seeking enterprises may take more financial risks by making full use of financial leverage to obtain high profits.

(5) Collaboration network: This variable was mainly used to measure the cooperation relationships between enterprise and stakeholders (such as government, contractors, suppliers, investors, etc.). The industrial chain theory divides stakeholders into the upstream stakeholders (such as government and financial institutions), the peer stakeholders (such as designers and contractors) and downstream stakeholders, (such as business partners and terminal customers). We examined whether sample enterprises had established long-term cooperative relationship with the three types of stakeholders. Therefore, this study classified the relationship between enterprises and stakeholders into: (i) upstream cooperation type; (ii) peer cooperation type; and (iii) downstream cooperation type; (iv) upper and peer cooperation type; (v) peer and downstream cooperation type; (vi) upstream and downstream cooperation type; and (vii) the industry-wide cooperation type.

(6) Core capability: This variable was mainly used to compare the competitive advantage between enterprises and the competitors. Looking at the descriptions of the core capabilities in the annual reports of the real estate enterprises, it was found that it generally included competencies such as skilled staff, supply relations, relationship with government, technical resources and capabilities, sources of capital, management capability, brand influence and so on. This variable was further investigated using surveys the combines findings from the two methods were used to divide the enterprises into three types: (i) external enterprise; (ii) internal enterprise; and (iii) integrated enterprise. External enterprises' core capabilities lie in the integration with the industry chain regarding the interests of the relevant parties (including upstream and downstream industries, consumers and government resources) and the relevant

Table 1.1 The business model scales of real estate enterprise

Logical level	Components	Dimension	Reference	Data sources
Value orientation	Target customers	Ordinary; high-end; integrated	Brege et al. (2014)	Interview
	Product	Residential oriented; commercial oriented; others	Brege et al. (2014)	Financial statement, interview
	Market orientation	Local leading type; domestic leading type	Self-designed	Financial statement
Value creation	Finance	Risk-adverse; risk-neutral; risk-seeking	Pan et al. (2012)	Financial statement
	Collaboration network	Upstream; peer; downstream; upper and peer; peer and downstream; upstream and downstream; and the industry-wide	Self-designed	Interview
	Core capability	External; internal; integrated	Chesbrough (1996)	Interview
Value source	Revenue	Sales oriented; rental oriented; integrated	Chesbrough (1996)	Financial statement

sources (including land, funds, raw materials, etc.). Internal enterprises' core capabilities lie in their own strong management and technological capabilities, including human resources, life cycle management and control ability and so on. Integrated enterprises' core capabilities lie in the integration of the external and internal capabilities mentioned above.

(7) Revenue: This variable was used to measure the enterprise's main source of income. Through the analysis of the annual income for the listed enterprises, it was found that the real estate business revenue sources include property sales, property rental, hotel experience, property management, design and decoration, etc. Based on the availability of the data, the real estate enterprises' source of income was divided into: (i) sales oriented; (ii) rental oriented; and (iii) integrated type. Enterprises with more than 50% of their income coming from property sales were classified as sales oriented, while enterprises with more than 50% of their income coming from property rental was classified as rental oriented. All other enterprises were classified as integrated type (Table 1.1).

1.2.3 Data Collection

The data was collected in two parts. Firstly, in terms of data resources, the variables, i.e., target research customers, products, market positioning, capital structure, source of income and cost structure of data were collected from the published corporate annual reports of the listed enterprises. Secondly, the data of cooperation network and the core resources and capabilities were collected through questionnaire surveys.

Data from corporate annual reports were obtained by examining the contents of the reports as well as the sections that offered prospectus. Data was also collected from other published sources as well as enterprises' websites. Subsequently, based on the analysis of the data collected, we divided the core capabilities into: (i) platform type enterprise; (ii) managing type enterprise and (iii) comprehensive type enterprise. The cooperation network was divided into: (i) short-term cooperation; and (ii) long-term cooperation.

The questionnaire items used 7-point Likert scale, and the respondents provided answers mainly based on their personal experience and opinions. One of the issues with subjective questionnaire data is that the accuracy can be partly affected due to the respondents' bias (Podsakoff et al. 2003). However, in order to improve the quality of the data, the only the data from experienced respondents were used in the analysis. Particularly, the data collected from respondents who were familiar with business models in the real estate industry and experts who had more than 5 years' research experience in business modeling were considered. In addition, data from any respondents who were employees of the enterprises under investigation were also excluded from the analysis.

The questionnaires were administered to experts. The progress of scoring involved two stages. In the first stage, three experts (authors, academics and industry experts) were asked to provide scores through discussion. In the second stage, 15 experts were asked to provide their scores separately. Once the filled out questionnaires were collected, we compared the results from the two different stages. The enterprises showing large deviations (in the findings from the two stages) were selected for in-depth analysis in order to determine the category of each enterprise.

1.2.4 Method of Cluster Analysis

The SPSS 'Two Step Cluster' method was applied to reveal the clusters of the business models of house developers in china. This method is designed to discriminate natural groups from a set of variables stabilizing the nearness criterion, with a hierarchical agglomerative clustering whose centres are far apart (Fraley and Raftery 1998). Compared to classical cluster analysis methods, SPSS 'Two Step Cluster' can deal with both continuous and categorical attributes. Also, this method can automatically determine the optimal number of clusters. Likelihood was selected as the distance measure, which defines the normal density for continuous variables and the multinomial probability mass function for categorical variables. The cluster analysis involved two steps:

(1) Pre-clustering step: the data records were scanned one by one and the algorithm decided whether the current record could be added to one of the previously formed clusters or it started a new cluster, based on the distance criterion;
(2) Clustering step: the clustering stage had sub-clusters resulting from the pre-cluster step as input and grouped them into the optimal number of clusters. To determine which number of clusters was optimal, each of these cluster solutions was compared using Schwarz's Bayesian Information Criterion (BIC) as the clustering criterion. An optimal number of clusters will have a smaller value of the BIC, a reasonably large Ratio of BIC Changes and a large Ratio of Distance Measures.

Silhouette Coefficient (Rousseeuw 1987), a measure of density of all the data in the cluster, was utilized to measure the goodness-of-fit of the outcome. This index combines both, cohesion (based on the average distances between all the objects in a cluster) and separation (based on the average distance of any object to all the other objects not contained in the same cluster), and can range between −1 and +1; values below 0 are indicative of inappropriate fit, between 0 and 0.2 are poor, between 0.2 and 0.5 are fair, and above 0.5 are good.

1.3 Results and Analysis

1.3.1 The Optimal Number of Clusters and Relevant Variables

With the seven variables, each of the cluster solutions was compared using Schwarz's BIC as the clustering criterion in order to determine the optimal number of clusters. The optimal number of cluster should have a smaller value of the BIC, a reasonably large Ratio of BIC Changes and a large Ratio of Distance Measures. The results of this analysis suggest that the optimal number of clusters was five, with a smaller value of the BIC (2353.658), a larger Ratio of BIC Changes (0.311) and a larger Ratio of Distance Measures (1.549) (Table 1.2). These results suggest that goodness-of-fit was achieved, with fair average silhouette coefficient equal to 0.30.

1.3.2 The Clusters Revealed

Through the two-step cluster analysis five clusters of the 'real estate business models' (117; 81.8%) were revealed. These clusters involved the use of seven variables consisting of target customers, product contents, market region, capital structure, external relations, core resources and capabilities, sources of income. These five clusters (Fig. 1.1) were with the sample size of 18 (15.4%), 26 (22.2%), 20 (17.1%), 31 (26.5%), and 22 (18.8%). The ratio of sizes comparing the largest to

Table 1.2 The indices for identifying the optimal number of clusters

Number of clusters	Schwarz's Bayesian Information Criterion (BIC)	BIC change[a]	Ratio of BIC changes[b]	Ratio of distance measures[c]
1	3435.351	–	–	–
2	2965.696	−469.655	1.000	1.403
3	2658.389	−307.306	0.654	1.584
4	2499.766	−158.623	0.338	1.052
5	**2353.658**	**−146.108**	**0.311**	**1.549**
6	2293.357	−60.301	0.128	1.001
7	2233.150	−60.207	0.128	1.231
8	2202.264	−30.885	0.066	1.160
9	2188.877	−13.388	0.029	1.105
10	2185.910	−2.966	0.006	1.199
11	2199.344	13.434	−0.029	1.125
12	2221.933	22.589	−0.048	1.001
13	2244.584	22.651	−0.048	1.061
14	2271.461	26.878	−0.057	1.017
15	2299.496	28.034	−0.060	1.355

Bold represents the optimal number of clusters based on results of the analysis
[a]The changes are from the previous number of clusters in the table
[b]The ratios of changes are relative to the change for the two cluster solution
[c]The ratios of distance measures are based on the current number of clusters against the previous number of clusters

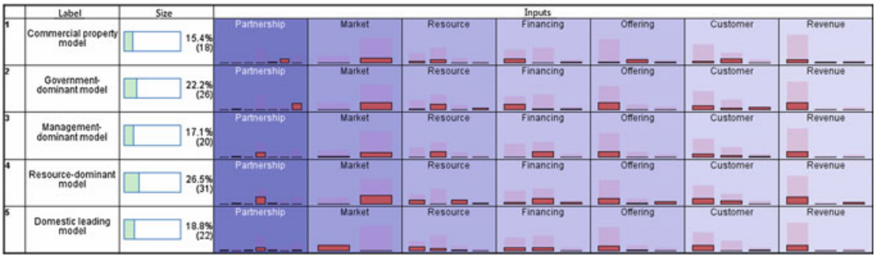


Fig. 1.1 Profiles of the revealed clusters of real estate business models

smallest cluster was 1.72. Figure 1.1 illustrates the accumulative distribution of the building cases grouped in the five revealed clusters against the seven critical variables.

The revealed five clusters were:

- Cluster 1 was dominated by peer-to-upstream cooperative (72.2%), internal capabilities (55.6%), risk-neutral (77.8%), commercial oriented (66.7%), regional (100%) enterprises which sales (66.7%) for high-end customers (72.2%).

- Cluster 2 was dominated by upstream cooperative (88.5%), internal capabilities (73.1%), risk-neutral (73.1%) residential oriented (96.2%), regional (100%) enterprises which sales (96.2%) for ordinary customers (53.8%).
- Cluster 3 was dominated by peer cooperative (85.0%), internal capabilities (100%), risk-seeking (100%), residential oriented (100%), regional (85.0%) enterprises which sales (100%) for ordinary customers (55.0%).
- Cluster 4 was dominated by peer cooperative (83.9%), external capabilities (48.4%), risk-seeking (64.5%), residential oriented (67.7%), regional (96.8%) enterprises which sales (83.9%) for ordinary customers (61.3%).
- Cluster 5 was dominated by peer cooperative (45.5%), comprehensive capabilities (59.1%), risk-seeking (54.5%), residential oriented (81.8%), nationwide (95.5%) enterprises which sales (90.9%) for ordinary customers (86.4%).

1.4 Discussion and Conclusions

This paper has identified clusters of 'real estate business models'. The examination was carried out through a two-step cluster analysis of 117 'real estate enterprises' that have emerged and have been reported in China. Five 'real estate business models' clusters were revealed: (1) commercial property model; (2) government-dominant model; (3) management-dominant model; (4) resource-dominant model; and (5) domestic leading model. The findings indicate that the 117 enterprises were spread across five clusters evenly and every cluster has its distinct characteristics. This goes on to show that there are a variety of real estate business models, with each one varying from the other based on their applicability conditions. So, an enterprise should not replicate the business model of successful enterprises, but instead, should choose a suitable business model that fits their purpose.

The findings should help with understanding the complex profiles of real estate business models and support cross-context learning of the real estate practices. However, such learning should take into account the different characteristics of the house developers against the relevant variables. The variables examined in this paper provide a useful framework for developing cross-context learning of practices. The examined variables were descriptive and explanatory: target customer, product, market orientation, finance, collaboration network, core capability and revenue. Future research may analyze the relativity between the clustered results of variables in each type of business model.

References

Brege S, Stehn L, Nord T (2014) Business models in industrialized building of multi-storey houses. Constr Manage Econ 32(1):208–226

Chesbrough H (1996). Business model innovation: it's not just about technology anymore. Strateg Leadersh 35(16):12–17

Doganova L, Eyquem-Renault M (2009) What do business models do?: innovation devices in technology entrepreneurship. Res Policy 38:1559–1570

Fraley C, Raftery AE (1998) How many clusters? Which clustering method? Answers via model-based cluster analysis. Comput J 41(8):578–588

Hamel G (1998) The challenge today:changing the rules of the game. Bus Strateg Rev 9(9):19–26

Harvard business review on business model innovation (2010) Harvard Business Press, Boston, MA

Johnson MW, Christensen CM, Kagermann H (2008a) Reinventing your business model. Harvard Bus Rev 86(12):50–59

Johnson MW, Christensen CM, Kagermann H (2008b) Reinventing your business model. Harvard Bus Rev 87(12):52–60

Magretta J (2002) Why business model matter. Harvard Bus Rev 80(5):86–92

Moore GA (2004) Darwin and the demon: innovating within established enterprises. Harvard Bus Rev 82(7):86–99

Ovans A (2015) What is a business model? Harvard Bus Rev 27:167–178

Pan W, Goodier C (2012) House-building business models and off-site construction take-up. J Archit Eng 18:84–93

Podsakoff PM, Mackenzie SB, Lee JY, Podsakoff NP (2003) Common method biases in behavioral research: a critical review of the literature and recommended remedies. J Appl Psychol 88(5):879–903

Rousseeuw PJ (1987) Shilhouettes: a graphical aid to the interpretation and validation of cluster analysis. J Comput Appl Math 20:53–65

Teece DJ (2010) Business models, business strategy and innovation. Long Range Plan 43:172–194

Thomas R (2001) Business value analysis: coping with unruly uncertainty. Strateg Leadersh, 29(2):16–24

Timmers P (1998) Business models for electronic markets. Electron Markets 8:3–8

Voelpel S, Leibold M, Tekie E (2004) The wheel of business model to leapfrog competitors. J Change Manage 4(3)

Weng JY (2004) Mesoscopic business model: nano research of management areas. China Econ Stud 01:34–40

Yuan L (2007) Reconstruction of business model. China Ind Econ (6):72–81

Chapter 2
A Comparison of Barrier-Free Access Designs For the Elderly Living in the Community and in Care and Attention Homes in Hong Kong

Ibukun Famakin and Mei-yung Leung

2.1 Introduction

As in other developed countries, Hong Kong is experiencing changes in the age structure of its population. The number of elderly people is rapidly growing, which has been attributed to increasing life expectancy and declining fertility (Hui and Yu 2009). The proportion of the elderly aged 65 years and over is expected to reach about 1.74 million (i.e., 22% of Hong Kong's population) in the next 10 years (Census and Statistics Department 2012). The rate of increase of the elderly population is creating concerns for research and policy makers, due to the high prevalence of disabilities in this age group (Cutler 2001; Spillman 2004).

In order to moderate the effects of medical intervention, reducing the levels of elderly people's dependence has been identified as a means of sustaining the elderly. A recognised method for enhancing elderly independence is the installation of barrier-free access to support their mobility and activities of daily living in the living environment. This study therefore seeks to compare the levels of satisfaction with barrier-free access designs between the elderly living in community buildings and the elderly living in C&A homes in Hong Kong.

2.2 Housing Types for the Elderly in Hong Kong

To meet the diverse needs of the elderly in Hong Kong, different housing types provide accommodation designed to sustain their daily life activities: community buildings and C&A homes. Community buildings are defined in this study as housing programmes designed to meet the needs of independent elderly people,

I. Famakin (✉) · M. Leung
Hong Kong, China
e-mail: iofamakin2-c@my.cityu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_2

while C&A homes take care of the elderly with poor health, disabilities and impairments in activities of daily living (Social Welfare Department 2005). In fact, the government has introduced the principle of a universal design in new residential developments, to ensure aging in place for the elderly in Hong Kong (Planning Department 2002). Similarly, some building regulations and modifications in designs have been provided for residential developments, in order to help residents remain in their living environments without any interruption to their daily activities. C&A homes are specially designed to cater for the needs of the elderly, as part of the government policy regarding independent living.

2.3 Barrier-Free Access Designs

Barrier-free access, which is also one of the features of a universal design, refers to the concept of designing a living environment for the use of every individual, irrespective of age, ability and status in life. Due to the increasing rates of both life expectancies and survival from injuries, the concept of barrier-free access designs is receiving global attention and growing interest in regard to the way in which it encourages independent living for every individual. Some features of the concept include handrails, signage, accessibility, width of doors and non-slip flooring. *Handrails* serve to support weak elderly people who may have difficulty turning and manipulating taps, switches and door handles (Buildings Department 2008). They help the elderly to maintain balance and reduce the risk of falling, collision and the straining of joints during the performance of daily activities (Donoghue et al. 2003). *Signage* employs the use of signs and information to direct elderly residents and their visitors in the residential unit (Cynthia 2000). The information conveyed could either be typographic (i.e., it communicates through letters, digits, words or phrases) or pictographic (e.g., symbols or icons), representing realities (Bajaj 2003). Changes in the elderly, such as the development of a curved spine or weak arm strength affects their ability to reach the standard heights installed for general adults. Hence, installations for accessibility, such as the height of toilets, lift bars and power supplies, should consider these changes, so as to ensure the elderly's independence in the living environment. The *width of doors* is required to provide reasonable and adequate access, enabling the safe and easy movement of people, including those with disabilities (Department of Building and Housing 2011). In addition to this, slips and falls contribute significantly to incidents, injuries and fatalities experienced by the elderly due to the poor slip resistance properties of the floor (Kim et al. 2001, 2013). Therefore, *non-slip flooring* is important in all rooms, in order to ensure adequate grip between the floor and shoes.

2.4 Research Method

A questionnaire survey was conducted to compare the levels of satisfaction with BFA items between the elderly in community buildings and the elderly in C&A homes in Hong Kong. A total of 11 BFA items were identified, including width of doors (B1), non-slip flooring in bedroom (B2), non-slip flooring in living room (B3), non-slip flooring in bathroom and toilet (B4), light switches (B5), height of power supply (B6), height of lifting bar in bathroom and toilet (B7), handrails in living room and bedroom (B8), height of toilet (B9), visible signage (B10) and tactile signage (B11). The satisfaction level was assigned a range from one (very unsatisfied) to seven (very satisfied) for each of the survey questions regarding the BFA items.

Two housing types in Hong Kong were identified; namely, community buildings (i.e., residents in public and subsidised (P&S) housing and private domestic (PD) buildings) and C&A homes in Hong Kong. The survey respondents were purposively selected based on certain criteria: (1) aged 60 years or older at the time of the survey; (2) residing in community buildings or C&A homes in Hong Kong; and (3) had sufficient cognitive ability to understand and respond to the questions. Two housing estates were selected from the New Territories and one each from Hong Kong Island and Kowloon for the different housing types. The survey questions were translated into Chinese and responses were received through face-to-face interviews, in order to ensure that any misunderstanding of the questions was eliminated in the course of the study. Between 15 and 25 elderly people were selected in each of the housing estates. A total of 269 responses were received from the elderly residents, including 189 community-dwelling elderly people and 80 elderly people in C&A homes; 20.1%, 37.0% and 42.9% of the respondents were aged 60–69, 70–79, and 80 years or older, respectively. A simple qualifying test was used to ascertain the cognitive ability of the elderly participants.

The data collected were analysed using SPSS 22.0. First, mean scores were calculated to indicate the levels of satisfaction of the elderly with BFA items in regard to the different housing types. Then, an independent samples t-test was used to compare the levels of satisfaction with BFA items in the two housing types.

2.5 Statistical Results

The results of the mean scores show that only four out of the 11 BFA items were higher than 5.00 in both housing types (i.e., width of doors—B1, light switches—B5, height of power supply—B6, and height of toilet—B9 for the community-dwelling elderly; and width of doors—B1, height of lifting bar in bathroom and toilet—B7, handrails in living room and bedroom—B8, and height of toilet—B9 for those in C&A homes). An independent samples t-test was used to compare the levels of satisfaction across the different housing types (see Table 2.1).

Table 2.1 Independent samples t-test for BFA items by housing type

BFA items	Community buildings (*x*)		C&A homes (y)		Mean Diff. (*x*−y)	t	Sig.
	M	SD	M	SD			
B1—Width of door	5.106	1.021	5.304	1.136	−0.198	−1.399	0.183
B2—Non-slip flooring in bedroom	**4.476**	1.620	**4.548**	1.965	−0.072	−0.278	0.782
B3—Non-slip flooring in living room	**4.476**	1.620	**4.575**	1.978	-0.099	−0.382	0.703
B4—Non-slip flooring in bathroom and toilet	**4.487**	1.603	**4.644**	1.946	−0.157	−0.614	0.541
B5—Light switches	5.190	0.879	**4.952**	1.184	0.238	1.468	0.146
B6—Height of power supply	5.059	1.071	**4.658**	1.336	0.401	2.295	**0.024***
B7—Height of lifting bar in bathroom and toilet	**4.048**	1.908	5.250	1.383	−1.202	−5.788	**0.000*****
B8—Handrails in living room and bedroom	**3.206**	2.025	5.269	1.474	−2.063	−9.266	**0.000*****
B9—Height of toilet	5.159	0.965	5.494	1.061	−0.335	−2.419	**0.017***
B10—Visible signage	**4.884**	1.040	**3.838**	1.608	1.045	4.998	**0.000*****
B11—Tactile signage	**4.746**	1.091	**3.352**	1.782	1.394	5.464	**0.000*****

Note Bold items are mean scores less than 5.00, indicating low levels of satisfaction

Six out of the 11 BFA items show significant differences in the satisfaction levels; namely, height of power supply (B6: t = 2.295, p = 0.024), height of lifting bar in bathroom and toilet (B7: t = −5.788, p = 0.000), handrails in living room and bedroom (B8: t = −9.266, p = 0.000), height of toilet (B9: t = −2.419, p = 0.017), visible signage (B10: t = 4.988, p = 0.000) and tactile signage (B11: t = 5.464, p = 0.000).

2.6 Discussion

2.6.1 Levels of Satisfaction with BFA Items

The average level of satisfaction with seven out of 11 BFA items in both housing types (B2–4, B7–8 and B10–11 for the elderly living in the community and B2–6 and B10–11 for those in C&A homes) indicates that the elderly are not completely satisfied with their residential units. In fact, the elderly people in both housing types were not totally satisfied with items measuring non-slip flooring (B2–4) and signage (B10–11) in their apartment. Due to the decline in the muscle elasticity and strength of the elderly, it becomes easier to lose flexibility and to fall or slip when walking or performing daily life activities as a person ages. The elderly's satisfaction with the non-slip surface of the flooring (B2–B4) in the different housing types can encourage independent walking and ensure the safety of the elderly within their residential apartments. On the other hand, the failure of ciliary muscles results in the combination of long- and short-sightedness, while the accumulation of earwax in the middle ear affects the conduction of sound waves and interferes with hearing (Schmall 2000). In addition to this, memory loss creates difficulty for the elderly in finding their way through space in complex residential arrangements, such as those found in Hong Kong. Hence, poor visible and tactile signs (B10–B11) create difficulty for elderly people with impaired vision and hearing to get information about their way around their flats in the different housing types. The elderly spend most of their time in their living rooms or bedrooms and may need to support themselves while moving around their living environment. The satisfaction of the elderly with the handrails in the living room and bedroom (B8) is essential in regard to sustaining their body structures during their daily activities. Therefore, the provision of handrails in the living room and bedroom, particularly for the elderly living in the community, will minimise the risk of falling and collisions in the residential apartment. The spinal bones of the elderly become curved, which affects their ability to stand upright. Therefore, they may not be able to reach facilities in their flat that are placed at heights for standard adults. The height of power supply (B6) and height of lifting bar in the bathroom and toilet (B7) should, thus, consider this before installation, so as to ensure the satisfaction of the elderly.

2.6.2 Satisfaction in the Different Housing Types

In comparing the levels of satisfaction between the housing types, the results show that the elderly living in community buildings were significantly dissatisfied with the BFA items in their unit flats when compared with those in C&A homes in Hong Kong. The residential apartments for the elderly living in C&A homes are specifically designed or modified to meet the needs of those with disabilities and impairments. In fact, the government of Hong Kong has an established policy objective to provide barrier-free environments for people with disabilities, with a view of facilitating their independent living. Hence, most C&A homes take into consideration the varying disabilities of the elderly when designing or modifying the homes. This has contributed to the elderly's significantly higher satisfaction with some of the BFA items than that of their counterparts living in the community. However, there are either non-elderly specific or no guidelines for the elderly living in the community, which has affected their levels of satisfaction with the BFA items.

Furthermore, the elderly mostly reside in old flats, where handrails may be installed in bathroom and toilets but may not be available in the living room and bedroom. The reduction in the grip strength of the elderly necessitates the provision of *handrails* (B8) in the living room and bedroom, where they spend most of the time. This factor contributed to the significantly low satisfaction regarding the handrails in the living rooms and bedrooms of the elderly living in the community. In fact, the *handrails* (B7) provided in the bathrooms and toilets of old flats may not meet the elderly's needs due to the curvature of the spine, which reduces the height required for the installations. In addition to this, residential developments for community-dwelling elderly people in Hong Kong are mostly high rise buildings, which are very large and complex to navigate. Hence, *signage* (B10–11) is generally installed in the buildings, in order to relay efficient information and direction to residents. Although C&A homes are often on the ground and first floors of a residential complex, expectations for signage are higher here, due to severe incidences of disabilities and memory loss. The installation of simple signage details may not be sufficient for the elderly to find their way within the living environment, which may affect their satisfaction levels.

2.7 Recommendations

2.7.1 Practical Implications

The results of the study have revealed the levels of satisfaction of the elderly in different housing types with BFA items in Hong Kong. Based on the findings, the following recommendations are suggested to facilities managers, to improve the satisfaction of the elderly in their living environments. The study suggests that universal design guidelines specifically considering the changes in elderly people's abilities should be established for those residing in the community, in order to address specific BFA items in their residential apartments. In addition to this, the study recommends the use of ceramic tiles in wet areas, such as bathrooms, toilets or kitchens, and PVC tiles with non-slip granules for dry areas, such as living rooms, dining rooms or bedrooms, with the edges of the tiles fixed firmly to the base (Building and Construction Authority 2007). Moreover, designers and facilities managers should improve upon signage details and the height of power supplies, to enable the elderly to navigate through the building and perform instrumental activities of daily living independently, so as to, in turn, increase their levels of satisfaction.

2.7.2 Further Research

The current study has subjectively assessed the satisfaction of the elderly in the different housing types; namely, community buildings and C&A homes in Hong Kong. Further studies can conduct anthropometric measurements of the elderly in order to specifically design the BFA items to meet their physical and cognitive strengths, capabilities and limitations, as well as to match their body dimensions.

In addition to this, the effect of barrier-free items on quality of life can be considered for the elderly in different housing types, in order to provide detailed guidelines for the elderly, based on their different characteristics and preferences. Moreover, interviews can be conducted for different housing types in the future in order to understand the reasons for their dissatisfaction with current barrier-free design facilities in their residential apartment. This will be helpful for facilities managers so as to consider such factors when designing new residential units.

2.8 Conclusion

The different housing types in Hong Kong are required to meet the diverse needs of the elderly. Due to the heterogeneous nature of the elderly population, the design of a supportive and enabling environment in the various forms of residential development may affect their satisfaction in later life. This study therefore compared the levels of satisfaction of the elderly living within the community and the elderly living in C&A homes with the BFA items in their residential apartments. The results revealed that the satisfaction of the elderly was low in regard to seven out of 11 BFA items, for both community-dwelling elderly people and their counterparts in C&A homes in Hong Kong. In addition to this, six of the BFA items were significantly different between the housing types. This study recommends the development of universal guidelines specifically designed to meet the changing needs of the elderly, particularly in regard to BFA items. Ceramic tiles are suggested for use in wet areas, such as bathrooms, toilets and kitchens, and PVC tiles with non-slip granules in dry areas, such as living rooms, bedrooms and dining rooms. In addition to this, designers and facilities managers should improve upon signage details and the height of power supplies, to increase the elderly's levels of satisfaction, particularly for those in C&A homes.

Acknowledgements The work described in this paper was fully supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. CityU 115113).

References

Bajaj P (2003) Physical environmental cues that support activities of residents with dementia in special care units (Unpublished Master's Thesis). University of Florida, Gainesville, USA

Building and Construction Authority (2007) Code on accessibility in the built environment. Building Plan Department, Singapore

Buildings Department (2008) Design manual barrier free access 2008. Available at: http://www.bd.gov.hk/english/documents/code/bfa2008/content.pdf. Accessed 3 March 2016

Census and Statistics Department (2012) Hong Kong population projections 2012–2041. Available at: http://www.censtatd.gov.hk/press_release/pressReleaseDetail.jsp?charsetID=1&pressRID=2990. Accessed 6 April 2014

Cutler DM (2001) Declining disability among the elderly. Health Aff 20(6):11–27
Cynthia AL (2000) Design details for health: making the most of interior design's healing potential. Wiley, New York
Department of Building and Housing (2011) Compliance document for New Zealand building code: access routes, 2nd edn. New Zealand Government, Wellington, NZ
Donoghue J, Graham J, Gibbs J, Lewis SM, Blay N (2003) Validating components of a fall risk assessment instrument. Int J Health Care Qual Assur 16(1):21–28
Drews R (1983) Federal subsidies for public housing: issues and options. Congressional Budget Office, United States
Hong Kong Housing Authority (2013) Public housing: growing from strength to strength (2012/2013 Annual Report). Government Publications, Hong Kong
Hui ECM, Yu KH (2009) Residential mobility and aging population in Hong Kong. Habitat Int 33:10–14
Kim IJ, Smith R, Nagata H (2001) Microscopic observations of the progressive wear on the shoe surfaces that affect the slip resistance characteristics. Int J Ind Ergon 28(1):17–29
Kim IJ, Hsiao H, Simeonov P (2013) Functional levels of floor surface roughness for the prevention of slips and falls: clean-and-dry and soapsuds-covered wet surfaces. Appl Ergon 44:58–64
Planning Department (2002) Aging population and planning for the elderly (Working Paper No. 12). Hong Kong: Hong Kong Government
Schmall VL (2000) Sensory changes in later life. Available at: http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/15925/pnw196-fromarchive.pdf?sequence=1. accessed 5 October 2015
Social Welfare Department (2005) Care and attention homes for the elderly. Available at: http://www.swd.gov.hk/doc/elderly/(P16).pdf. Accessed 15 July 2015
Spillman BC (2004) Changes in elderly disability rates and the implications for health care utilization and cost. Milbank Q 82(1):157–194

Chapter 3
A Comparison of Green Building Policies in Asian Countries or Regions

Xiaosen Huo and Ann T.W. Yu

3.1 Introduction

According to green building related research, when concerning about the barriers in green building implementation, an outstanding barrier is insufficient policy implementation efforts (Glavinich and DE 2008, Zhang et al. 2011, Samari et al. 2013). Therefore, the government has the responsibilities to introduce related policy and regulations on green issues. To propose a green framework for attaining a sustainable construction industry, the first key requirement is to set up a sustainable policy (Nwokoro and Onukwube 2011), especially in Chinese green building practice, the policy issue has very important impacts (Yang et al. 2014). Many public sector organizations adopt policies that help their facilities to be designed as green, it is because that the benefits of green building include cost savings and improved worker productivity (Dubose et al. 2007). Cupido et al. (2010) evaluated institutional green building policies, which showed that policies in the institutions do reduce the building operating costs, and the green building template is a valuable tool in implementing institutional level policy.

To form green building policy, Pearce et al. (2007) pointed out that there were three basic categories of options including policy options, program options and evaluation options. The environmental policies should focus on the areas of waste reduction and diversion; energy conservation; water conservation and air quality (Smith 2009). The related researchers also make a good effort to improve the green building policy development. The suggestions for government policy makers and the green building policy directions are as follow: adding the municipal policies about green premium's revenue, moderating energy price relating to buildings, imposing mandatory requirement to regulate green building quality standards,

X. Huo (✉) · A.T.W. Yu
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Hong Kong SAR
e-mail: xiaosen.huo@connect.polyu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_3

providing education and awareness champions, creating more opportunities for social learning and related translation activities involved in green project, and so on (Ross et al. 2007, Chan et al. 2009, Hojem et al. 2014). It is vital to understand the true performance of end-users so that they can divert the major attention to those areas that end-users have weaker preferences in their resources allocation and pursuit of sustainability excellence (Chau et al. 2010). Last but not the least, it is important to promulgate the underlying value, long-term cost benefits and inherent contribution of green building to the consumers, then improve the green building awareness of the public and end-users (Chan et al. 2009). Considering the data issued by the World Bank, International Monetary Fund, United Nations Development Programme, and US Central Intelligence Agency, the developed countries or regions in Asia include Japan, Korea, Singapore, Taiwan, Hong Kong, Macao and Israel (IMF 2008). Considering the green building development process and the accessibility of related data, this paper chooses four developed regions or countries in Asia, namely Japan, Singapore, Taiwan, and Hong Kong for comparison of their policy development process and experiences.

3.2 Research Methodology

In order to explore the policy development and application in these regions, literature review was conducted to review the development process. Keywords such as green building policy, green building incentive, sustainable development policy were searched in google, google scholar, and related official websites in each region. Corresponding policies and regulations are organized one by one chronologically, which laying the foundation of the policy comparison in the paper.

Content analysis is defined by Krippendorff (2012) as "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use." According to the research conducted by Yu et al. (2006), Zuo et al. (2014), content analysis is a common approach for qualitative data analysis in built environment-related studies. In this paper, qualitative content analysis was used to analyse the policy development in each region. For qualitative content analysis, the emphasis is to determine the meaning of the data. Hence words or phrases which have similar meanings were noted in the analysis.

3.3 Green Building Policy Processes in Asian Regions

3.3.1 Green Building Policies Process in Japan

3.3.1.1 Implementation Mechanism

As there are limited energy and resources in Japan, green building promotion and building energy efficiency has started early through establishing regulations, laws and institutional policies. It is government dominated pattern in Japan's green building development. The government organizes specialists to develop green building standards and promote the implementation gradually, and even take coercive measures to manage green buildings from the planning and design stage.

3.3.1.2 Development Process

Green building development in Japan started early. The establishment of *Energy Conservation Law* lays a foundation to energy management in Japan. Through continuous promotion and innovation in nearly 40 years, Japan has formed relatively completed legal system about green building, which is shown in Fig. 3.1.

1979: *Law concerning the Rational Use of Energy (Energy Conservation Law)* was launched, which was revised several times in 1983, 1993, 1998, 2002, 2005 and 2008. The aim of launching this law is to ensure the efficient use of fuel resources, and promote the rational energy use of factories, transportation, buildings and mechanical equipment.

1993: *Basic Environment Law* was established. Through the development of the basic concept of environmental protection, making it clear that the responsibilities

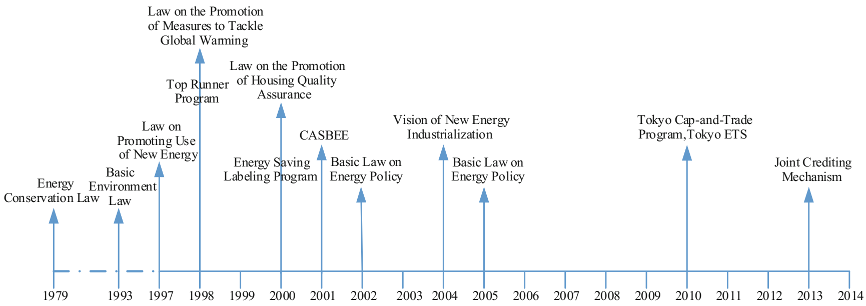


Fig. 3.1 Green policy development in Japan

of the nation, local public organization, and the public in environmental protection. Then promote a comprehensive and well-planned environmental protection policy and contribute to the mankind in the future.

1997: *Law on Promoting Use of New Energy* was formulated and revised in 1999, 2001 and 2002. This law is established to adapt to the changing economic and social environment, to ensure stable and adequate energy supply, and to promote citizens to use new energy sources.

1998: *Law on the Promotion of Measures to Tackle Global Warming* was issued by the Japanese parliament. And this is the first law in Japan specifically addressing the issue of global warming.

1998: *Top Runner Program* was launched by the government, which is committed to the continuous improvement of energy conversion and performance standards of the latest products.

2000: The establishment of *Law on the Promotion of Housing Quality Assurance* fully guarantee the residential quality and the rights of the occupants.

2000: *Energy Saving Labeling Program* was introduced to inform consumers of energy efficiency and to promote energy-efficient products, which covers 18 Top Runner Products.

2001: *Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)* was developed by Japan Sustainable Building Consortium (JSBC). This criterion is developed from the perspective of building environmental efficiency, and evaluate the degree of how the buildings reducing the environmental impact in certain environmental performance.

2002: *Basic Law on Energy Policy* was issued. This law sets out the basic principle of energy policy in Japan, which means ensuring the stable supply of energy, meeting the environmental requirements and applying the market mechanism flexibly at the same time.

2004: *Vision of New Energy Industrialization* was announced to promote new energy development in Japan and increase the proportion of new energy industry before 2030, such as solar energy industry, wind power industry, biomass power generation.

2005: *Kyoto Protocol Achievement Plan* was published in 2005, which putting more demands on construction sector, and the housing sector was prioritized as one main area of national energy policy.

2010: *Tokyo Cap-and-Trade Program, Tokyo ETS* was issued. This program is targeting on enterprises and institutions, who are subject to a duty of reducing carbon emissions from energy consumption during the five-year plan period from 2010 to 2014.

2013: *Joint Crediting Mechanism* was published and promoted actively, hoping to achieve carbon emission quota and its national emission reduction target by helping less developed countries reduce carbon dioxide emissions.

3.3.1.3 Economic Incentive System

In promoting green building in Japan, there are not only mandatory provisions, but also a number of related economic, financial guidance policy and subsidy system, which are attractive to both the builders and the owners. Some of the economic incentive measures are as follows.

(1) Residential eco-point systems are implemented in which eco-point can be provided for environmental renovation or new developed environmental-friendly buildings. The eco-point can be used to exchange gift certificates, prepaid cards, goods that helping to revitalize the area, goods with outstanding energy saving performance, additional projects by the construction party of new developed environmental-friendly or environmental renovation.
(2) Implementing system of encouraging to purchase high-quality residential buildings. Under the asset securitization framework of housing finance support organizations, lending rates will be lowered within a certain period for the purchase of outstanding performance residential buildings. The excellent performance includes one of the following: energy saving, shock resistance, accessibility, durability, degeneration. Existed buildings within certain energy saving or accessibility are also included in the support.
(3) Implementing system of energy saving promotion. Except for encouraging to improve renovation market, it should also be encouraged to improve the lifespan of buildings, and CO_2 emission reduction technology. Subsidies should be paid on promoting residential building renovation, promoting high-quality buildings and promoting CO_2 emission reduction.

3.3.2 Green Building Policies Process in Singapore

3.3.2.1 Implementation Mechanism

Singapore has the tropical climate, with small area, lack of resources and large populations. Though the economic development in Singapore makes it an international financial center and important aviation hub, Singapore also suffers from environmental crisis brought by globalization. The government plays a leading role in green building development in Singapore. To ensure sustainable development, an interdepartmental commission on sustainable development is set up, which is leading by ministry of national development and national environment agency. This commission works at developing long-term development strategies and frameworks for sustainable development in Singapore.

3.3.2.2 Development Process

The Singapore government recognizes the importance of energy efficiency enhancement, and the better approach is to encourage low-energy consuming and high-environmental friendly green buildings, which ensuring the quality and comfort of the built environment. The process of green policies in Singapore is shown in Fig. 3.2.

1989: *Building Control Act* was published to ensure building works complying with standards of safety, amenity and matters of public policy. This is an act "to provide for the establishment of building control authorities and the making of building regulations and building control regulations and to provide for matters relating to the construction of buildings and to the construction of buildings and to provide for other matters connected therewith" (Building Control Act 1990).

2005: *The BCA Green Mark Scheme* is launched in 2005, which aiming at initiating the construction industry in Singapore towards more environmental friendly buildings. This scheme intends to promote the sustainability of the built environment, and enhance the environmental awareness of related participants in the whole life cycle.

2006: The First Green Building Masterplan is launched, which is a $20 million *Green Mark Incentive Scheme for New Buildings*, which offering cash incentives to developers, owners, project architects that achieving at least a Green Mark Gold rating or higher rating in the design and construction of new buildings.

2008: *The Building Control Act* is amended to impose minimum environmental standards on new buildings.

2009: The BCA issues the Second Green Building Masterplan, a $100 million *Green Mark Incentive Scheme for Existing Buildings*, which aiming at encouraging the building owners to carry out the building energy saving upgrade and retrofit.

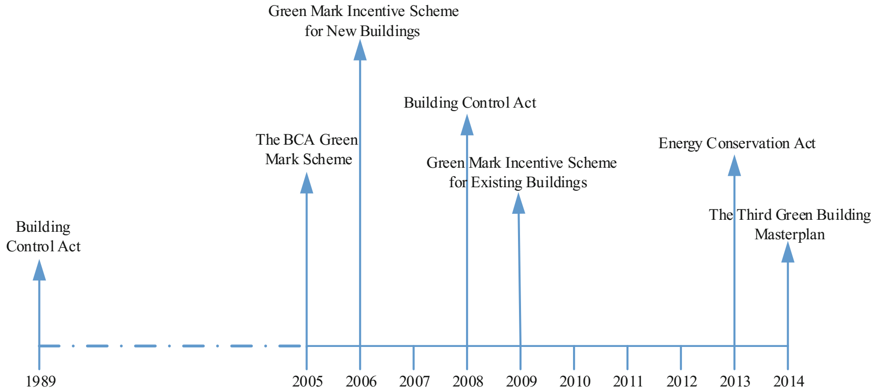


Fig. 3.2 Green policy development in Singapore

2013: *Energy Conservation Act* is issued to mandate energy efficiency requirements and energy management practices, aiming at promoting energy conservation, improving energy using efficiency and reducing environmental impacts.

2014: *The Third Green Building Masterplan* is announced by the BCA, including a $102 million investment aiming at encouraging the energy saving behavior and practices of building users. This scheme set strategies for green building development in Singapore in the next 5–10 years. The ultimate goal is to create a high-quality living environment which is beneficial to people's health and well-being.

3.3.2.3 Economic Incentive System

As one of the sustainable targets in Singapore is that realizing 80% of the buildings are green buildings until 2030, the government establishes numbers of economic incentive policies. Singapore launched a 100 million Singapore dollar valued "Green Mark Incentive Scheme—Existing Building", 20 million Singapore dollars for new building and 5 million for green design award. Meanwhile, the government provides 50 million renovation funding for existing buildings and property to encourage tenants and owners in small and medium enterprises to use energy saving programs. In addition, the Singapore government launched "Green Mark Incentive Scheme for construction area" for private developers. For Green Mark Gold ^{Plus} level green building, there are no more than 1% and 2500 m^2 construction area, and for Green Mark Platinum level green building, there are no more than 2% and 5000 m^2 construction area as reward.

3.3.3 Green Building Policies Process in Taiwan

3.3.3.1 Implementation Mechanism

Taiwan is belonging to sub-tropical climate, where energy supply and water usage are serious problems because of the special geographical factors. Therefore, it is essential to develop ecological, energy saving, waste reduction and healthy buildings in Taiwan. Taiwan is the first region in Asia to establish green building rating system. The system mainly focuses on Ecology, Energy saving, Waste reduction and Health, which is called EEWH then. Green building in Taiwan is promoted by the actively guide of administrative institutions, and the development is from top to bottom. At the beginning, green building system is imposed on administrative institutions invested projects and large public projects. Meanwhile, financial incentives are also provided for green renovation of existing buildings, renewable energy applications. through the combination of "mandatory" and "incentive", green building technology and market development are promoted in Taiwan.

3.3.3.2 Development Process

In Taiwan, the building energy saving has been taken seriously since the second energy crisis in 1979. Green policies in Tai Wan follow the principle of local conditions, which is suitable for the subtropical climate. The green policy development in Taiwan is shown in Fig. 3.3 (Kuo et al. 2016).

1981: The Bureau of Energy, Ministry of Economic Affairs issued *Energy Auditing System*.

1983: *The Building Technical Regulations-Draft of Building Energy Saving Specification* was developed, which making a significant step forward about building energy efficiency in Taiwan.

1999: *Evaluation manual for green building* was published to provide quantifiable operations for evaluation index system and its evaluation mechanism (Kuo et al. 2016).

2001: *Green building promotion program* was launched, which accelerating both the public and private buildings to conduct green building design, and establishing a basis for green building policies.

2004: *Green Building Labeling System* was implemented, which providing the certification of four types of green building materials, such as "ecological green building materials", "healthy green building materials", and so on.

2005: *Green building label rating assessment system* was implemented, where Green Building Label are classified into five ranks, i.e. eligible, bronze, silver, gold and diamond, with appropriate incentives policies.

2008: To solve the energy scarcity and global climate change challenges, the Executive Yuan announced the *"Framework of Sustainable Energy Policy"* in June, which has taken "economic development" and "environmental protection" into account on the premise of "energy security", and looked forward to creating a win-win-win solution for energy, environment, and economy.

2009: *Renewable Energy Development Bill* was launched in order to encourage the green power industry. The government promises the purchase, cost and profit of renewable energy such as solar energy, wind power, hydraulic power.

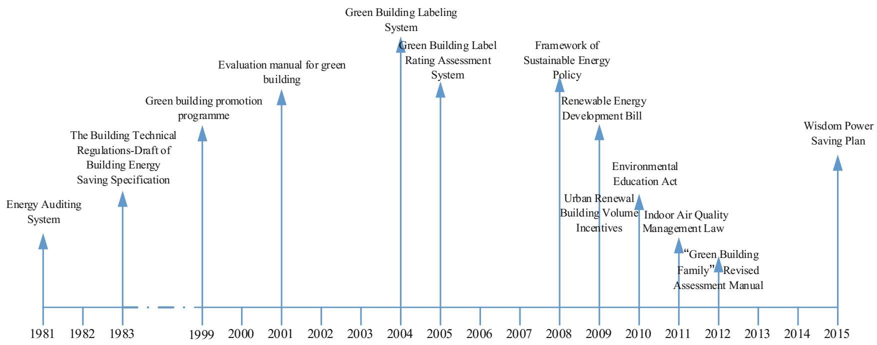


Fig. 3.3 Green building development in Taiwan

2009: *Urban renewal building volume incentives* was implemented to provide maximum 10% volume incentive for private buildings.

2010: To promote the environmental education and promote the public to understand the interdependence between the person/society and the environment, t*he Environmental Education Act* was launched, which aiming at enhancing the general environmental ethics and responsibility, thus maintaining the balance of ecological environment and achieving permanent sustainable development.

2011: *Indoor Air Quality Management Law* was enacted to improve the indoor air quality, which in order to maintain the public health.

2012: *"Green building family" revised assessment manual* was announced to bring existing buildings in.

2015: *Wisdom Power Saving Plan* was issued, which aiming at promoting the central and local organizations collaborating to energy saving, combining with incentive grants and citizen participation, then leading to behaviors change to energy saving.

3.3.3.3 Economic Incentive System

There are several economic incentive systems in green building policies, under the framework of Green building promotion program, the Architecture and Building Research Institute, Ministry of the Interior sets up "green remodeling projects" and "green air conditioning improvement", and provides a budget of 2–3 billion Taiwan dollars per year for green building renovation for government owned agencies and universities existing buildings. For public-owned new buildings that more than half of the financial subsidy is provided by the government, and the construction cost is more than 50 million Taiwan dollars, it is mandatory to have green building certification review (Fang and Yang 2011).

3.3.4 Green Building Policies Process in Hong Kong

3.3.4.1 Implementation Mechanism

In Hong Kong, the concerns of environment protection began from 1990s, and the Government has made considerable efforts to promote green building and energy efficiency of buildings, including collaborating with building professionals. The policies and regulations development in Hong Kong are dominated by the Electrical and Mechanical Services Department, which is belonging to Environment Bureau and Development Bureau. The political development mainly focuses on the development environmental legislation, the development and utilization of sustainable energy and energy-saving technology, the limitation of the carbon emission of energy suppliers, the encouragement of agencies to join in carbon audit, and the promotion of energy saving and carbon reduction measures which aiming at improving equipment and energy efficiency.

3.3.4.2 Development Process

The green building related policies development is shown in Fig. 3.4.

1995: *Building (Energy Efficiency) Regulation* is established by the Buildings Department of Hong Kong SAR in July 1995. This regulation stipulates the implementation of *Buildings Energy Efficiency Ordinance* under the voluntary framework from 1998 to 2002, including the Energy Codes of air-conditioning, lighting, electricity, lifts.

1996: Based on the UK BREEAM, the Hong Kong Building Environmental Assessment Method *HK-BEAM* is launched by BEAM Society. This method is aiming at reducing the environmental impacts of buildings within the best available techniques and reasonable additional costs.

1997: *The Environmental Impact Assessment Ordinance* is established by the WWF-Hong Kong, which enable the public access to project profiles, and aim at reducing environmental impacts from development.

1998: EMSD launches *the HK Energy Efficiency Registration Voluntary Scheme for Buildings,* which serve to promote the application of Building Energy Codes (BECs). There are five codes included, i.e. lighting, air conditioning, electrical and lift & escalator installations. If a building successfully meets the BEC standard, it can be issued a registration certificate, and it can also use the "Energy Efficient Building Logo" to publicize the energy performance.

2003: EPD implements a voluntary *IAQ (Indoor Air Quality) Certification Scheme* for Offices and Public Places since 2003, which aiming at improving IAQ and promote public awareness. Hong Kong is the first region in East Asia to introduce such a certification scheme.

2005: The Hong Kong Green Building Council launched the *HK 3030 campaign*, which is an initiative to control the electricity consumption by the approach

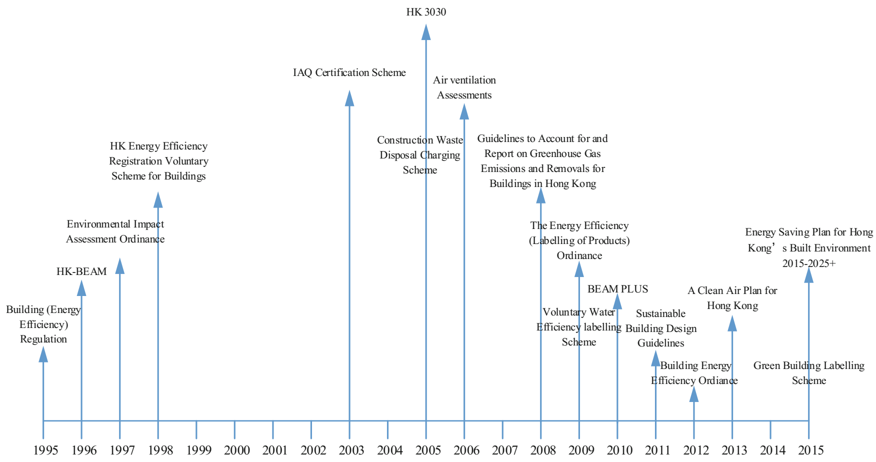


Fig. 3.4 Green building policies development in Hong Kong

of focusing and coordinating the demand-side management. This campaign aims to reduce 30% electricity consumption by 2030, and the baseline is 2005.

2005: The Environmental Protection Department enact *the Construction Waste Disposal Charging Scheme*, which formulates that the waste producer should open a billing account with the Environmental Protection Department before using government waste disposal facilities and pay for the construction waste disposal charge.

2006: *Air ventilation Assessments* is issued by Development Bureau, which can help project proponents to assess the impacts of proposal on pedestrian wind environment.

2008: *Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings in Hong Kong*. The Guidelines are intended primarily to be used to "account for and to report on emissions and removals from buildings which are entirely used for commercial or residential purposes. They are also applicable to most of the buildings used for institutional purposes, which include schools/universities, community centers, sports complexes" (Hong Kong's climate action plan 2030+ 2017).

2009: *The Energy Efficiency (Labelling of Products) Ordinance* is established by the Electrical and Mechanical Services and Department, which provides the legal basis for the introduction of a mandatory Energy Efficiency Labelling Scheme, covering the major electricity consuming categories, i.e. room air-conditioners, refrigerating appliances and compact fluorescent lamps. Under the scheme, to state the energy efficiency performance of these three types of products, enegy labels are required to be displayed, which helping the customers choose more environmentally friendly and higher energy efficient products.

2009: Water Supplies Department issued *Voluntary Water Efficiency Labelling Scheme*, which covering the common types of plumbing fixtures and water-consuming appliances. Products participating in this scheme will incorporate a water efficiency label which help the consumers be clear about the water consumption level and water efficiency of the products.

2010: *BEAM PLUS* is launched by the HKGBC (Hong Kong Green Building Council), including two assessment tools, i.e. BEAM PLUS New Building and BEAM PLUS Existing Building, which is a further development of BEAM to meet higher expectations of the public and community.

2011: The Building Department promulgated *Sustainable Building Design Guidelines*, covering building separation and permeability, building set back and site coverage of greenery of buildings. This guideline helps improve the new building design standard in Hong Kong and foster a sustainable built environment.

2012: *Buildings Energy Efficiency Ordinance* has come into full operation since 2012, which is based on the Energy Efficiency Registration Scheme for Building launched by EMSD (Electrical and Mechanical Services Department) in 1998.

2013: The environment Bureau unveiled *A Clean Air Plan for Hong Kong*, outlining the air quality challenges in Hong Kong and relevant policies, measures and plans of how to tackle the issue.

2015: The HKGBC launched the *Green Building Product Labelling Scheme* (the Scheme) on 6 January 2015, which establishes a reliable and transparent guideline to evaluate the whole life cycle environmental impacts of building materials and products, and awards the materials with appropriate classes of Green Building Product Label according to their environmental performance.

2015: *Energy Saving Plan for Hong Kong's Built Environment 2015–2025* + is established by the Environment Bureau. This plan sets a new target of reducing the energy consumption in Hong Kong by 40% by 2025, which is the first-ever energy saving blueprint for Hong Kong. It analyzes the energy use in Hong Kong and sets out the appropriate policy, strategy, and key actions to achieve the new target.

3.3.4.3 Economic Incentive System

There are several financial incentives for new buildings in Hong Kong such as provide incentives on Gross Floor Area (GFA) concession and site coverage concessions for the provision of environmentally friendly features in private buildings so as to promote green buildings in the private sector. Besides, a "Green Hong Kong…Carbon Audit" Campaign was launched to invite organizations from different sectors to commit to implementing carbon reduction measures and conducting carbon audits.

3.4 Discussions and Recommendations

3.4.1 Green Building Policy Characteristics of the Four Asian Regions

For most Asian regions, the dominant force of green building promotion is the government who organizing the standards formulation and promotion, or even taking coercive management measures from the planning and design stage. The green building policy development process in Asia reveals that the governments promote green building policy guide, and improve green building rating systems jointly with the research institutes. Meanwhile, the third-party certification displays the market advantage and promotes the healthy development of green building market.

For green building in Japan, it should be learnt that their system construction in green economy, such as the wide application of new energy technology. Through the transparent policies and systems to guide corporate behavior effectively and efficiently. Japan is almost the first country in Asia started to concern about energy saving and sustainable development. System design in Japan is also useful. From the perspective of policy environment, the type of policy instrument has evolved from simple to complex and diverse, meanwhile, the integrated use of economic incentive and social management tools is increasing. From the perspective of institutional mechanisms, important guarantees include sound top-level design, robust administration, reasonable division of the environmental management responsibilities between central authorities and local authorities, and the broad participation of the whole society.

For green building development in Singapore, it should be learnt from their green building strategy blueprint and stringent standards. The government launched $20 million Green Mark Incentive Scheme for New Buildings, which offering cash incentives to developers, owners, project architects to achieve green building standards. The government also issued a $100 million Green Mark Incentive Scheme for Existing Buildings to encourage the enterprises, tenants and owners take energy-saving programs in existed building renewal. In Singapore, national ideology on green building is also fostered through strict punishment mechanism and education.

For green building in Taiwan, it has taken a lead in green building policies around the world, and has formatted the popularity of “green building reform movement”. Especially, “green remodeling projects” are supported by national budgets, which is an example of global green building administration.

For green building in Hong Kong, the policy and regulation development is unique. There are two main lines, i.e. the government organization and non-government organization, which are independent from each other but influential to each other. Government agencies mainly focus on the formulation and implementation of policies and regulations, while non-government organizations focus on the promotion and application of green building rating systems. While in the context of voluntary implementation and application, the popularity of green building regulations relies on the market support.

3.4.2 Green Building Policy Experiences and Suggestions in Asia

Through the aforesaid description, green building policy development in Asian regions can be improved from the perspectives of mandatory regulations and economic incentives:

Promoting green building development through mandatory policy. Since the importance of energy saving has been recognized by many countries, these countries also realize that mandatory policies are of importance in encouraging energy saving. Numerous energy efficiency standards and specific legislations have been established to promote green building practice. For the follow-up green building policy promotion, the policy makers should focus on effective use of tax policy and discount policy. Most of the developed countries in the world encourage green building development by tax and discount policy, including positive incentive policy and reserve restrictive policy. For positive incentive policy, it means encouraging green building development by applying tax reduction, tax exemptions, and tax subsidy on energy saving buildings. For restrict policy, it means restricting or prohibiting non-energy-saving activities by levying consumption tax or energy tax.

Providing economic incentive for green buildings based on market. (1) Increasing financial budgets of energy efficiency in green buildings, for supporting items in energy saving, such as government procurement, new energy and renewable energy utilization, energy-saving technology demonstration, energy-saving products research and development, energy-saving management and supervision system construction. (2) Establishing green building investment funds to attract social capital. As the limitation of government financial capital, absorbing social capital and giving full play the "leverage" role of financial resources, which is adopted by market economic country to develop green buildings. One of the feasible approaches is to establish energy investment fund and support energy saving projects. The fund can be sourced from both the direct financial investment of the government and from private funds. (3) Reasonable use of other incentive measures. Improving the energy saving awareness and consumer demand of the public through some incentive measures. Such as providing approval priority for active green technology use projects, simplifying license procedures, and saving the administrative costs of the projects.

3.5 Conclusions

Green building development is inseparable from the support and promotion of the national and regional policies. As the promotion of green building assessment in various Asian countries and regions, the support and guide of related national and regional policies are key components in getting the green building rating standards widely used. According to the discussion aforesaid, it can be seen that many countries and regions has started to promote green building development on government level, where taking the governments as forerunners and practitioners to drive the effective green building development in Asia.

In this paper, four developed countries or regions in Asia are chosen to analyze the green building policy development, including Japan, Singapore, Taiwan and Hong Kong. The analysis was conducted from the perspectives of implementation mechanism, development process, and economic incentive system. In Asian regions, the dominant forces of green building promotion are the governments, who organized the standards formulation and promotion, or even taking coercive management measures in promoting green building policy development. Each of the four regions has its own characteristics in green policy development. For example, in Japan, they have sound system construction in green economy. In Singapore, their green building strategy blueprint and stringent standards are worth learning. In Taiwan, their green building remodeling has taken a lead around the world. In Hong Kong, the governmental agencies and non-governmental organizations are complement to each other.

Finally, recommendations for improving the policy development in Asia are also proposed. For example, effective use of tax policy and discount policy should be promoted, long-term and practical energy saving incentives mechanism should be established by making use of public finance. Through these good green building policy direction and development paths, green buildings in Asia can be improved both from the quality and quantity.

References

Building Control Act (1990) Retrieved September 29, 2017, from http://www.irishstatutebook.ie/eli/1990/act/3/enacted/en/html

Chan EH, Qian QK, Lam PT (2009) The market for green building in developed Asian cities-the perspectives of building designers. Energy Policy 37(8):3061–3070

Chau CK, Tse MS, Chung KY (2010) A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes. Build Environ 45(11):2553–2561

Cupido AF, Baetz BW, Pujari A, Chidiac S (2010) Evaluating institutional green building policies: a mixed-methods approach. J Green Build 5(1):115–131

DuBose JR, Bosch SJ, Pearce AR (2007) Analysis of state-wide green building policies. J Green Build 2(2):161–177

Fang DP, Yang J (2011) Green building policy, regulation and rating systems analysis—green building policy, regulation and rating systems in Hong Kong and Taiwan. Constr Sci Technol 6:70–71

Glavinich TE, DE P (2008) Contractor's guide to green building construction: management, project delivery, documentation, and risk reduction. Wiley, New York, 163–188

Hojem TS, Sørensen KH, Lagesen VA (2014) Designing a 'green' building: expanding ambitions through social learning. Build Res Inf 42(5):591–601

Hong Kong's climate action plan 2030+ (2017). Retrieved September 29, 2017, from https://www.climateready.gov.hk/. (2017, January)

IMF (International Monetary Fund) (2008) Research Department. World Economic Outlook, April 2008: Housing and the Business Cycle. World Economic Outlook

Krippendorff K (2012) Content analysis: an introduction to its methodology. Sage, UK

Kuo CFJ, Lin CH, Hsu MW (2016) Analysis of intelligent green building policy and developing status in Taiwan. Energy Policy 95:291–303

Nwokoro I, Onukwube H (2011) Sustainable or green construction in Lagos, Nigeria: principles, attributes and framework. J Sustainable Dev 4(4):166

Pearce AR, DuBose JR, Bosch SJ (2007) Green building policy options for the public sector. J Green Build 2(1):156–174

Ross B, López-Alcalá M, Small AA III (2007) Modeling the private financial returns from green building investments. J Green Build 2(1):97–105

Samari M, Ghodrati N, Esmaeilifar R, Olfat P, Shafiei MWM (2013) The investigation of the barriers in developing green building in Malaysia. Mod Appl Sci 7(2):1

Smith L (2009) Sustainability of an industry: green buildings and green events. J Green Build 4(2):63–89

Yang RJ, Zou PX (2014) Stakeholder-associated risks and their interactions in complex green building projects: a social network model. Build Environ 73:208–222

Yu AT, Shen Q, Kelly J, Hunter K (2006) Investigation of critical success factors in construction project briefing by way of content analysis. J Constr Eng Manage 132(11):1178–1186

Zhang X, Shen L, Wu Y, Qi G (2011) Barriers to implement green strategy in the process of developing real estate projects. Open Waste Manage J 4:33–37

Zuo J, Xia B, Barker J, Skitmore M (2014) Green buildings for greying people: a case study of a retirement village in Australia. Facilities 32(7/8):365–381

Chapter 4
A Comparison of Public Private Partnership Environment Between Australia and China

Yongjian Ke, Marcus Jefferies and Peter Davis

4.1 Introduction

Since 2013, the Chinese central government has supported the participation of social capital investors in infrastructure development which has led to significant levels of interest in Public Private Partnership (PPP) projects. However, China is still considered to have immature regulatory and institutional PPP frameworks. By contrast, PPP projects have enjoyed significant success in Australia, which is one of the most mature PPP markets globally. This paper, therefore, aims to review the PPP environment in both Australia and China and consequently identify trends and potential innovations.

Economist Intelligence Unit (2012, 2015) summarized a benchmark index to assess the readiness and capacity of countries to carry out sustainable PPPs. This index comprises six components: (1) legal and regulatory framework (weighted 25%); (2) institutional framework (weighted 20%); (3) operational maturity (weighted 15%); (4) investment climate (weighted 15%); (5) financial facilities (weighted 15%); and (6) subnational adjustment factor (weighted 10%). Table 4.1 shows the scores of Australia and China in the above-mentioned benchmark index in the 2011 and 2014 Infrascope studies by EIU (2012, 2015). Unfortunately, the reasons behind the scores were not sufficiently discussed in EIU (2012, 2015).

Y. Ke (✉)
School of Built Environment, University of Technology Sydney, Broadway, Ultimo, NSW 2007, Australia
e-mail: Yongjian.Ke@uts.edu.au

M. Jefferies · P. Davis
School of Architecture and Built Environment, University of Newcastle, Callaghan NSW 2308, Australia
e-mail: Marcus.Jefferies@newcastle.edu.au

P. Davis
e-mail: Peter.Davis@newcastle.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_4

Table 4.1 Results of Australia and China in EIU (2012, 2015)

	Australia		China	
	EIU (2012)	EIU (2015)	EIU (2012)	EIU (2015)
Overall index	92.3	91.8	49.8	55.9
Legal and regulatory framework	100	100	31.3	34.4
Institutional framework	100	100	25.0	33.3
Operational maturity	66.5	60.2	78.1	75.8
Investment climate	87.4	90.5	51.6	78.3
Financial facilities	94.4	94.4	66.7	66.7
Subnational adjustment factor	100	100	75.0	75.0

Therefore, this paper will adopt the above six components index to examine the environment for PPP in Australia and China and to provide more detailed discussions.

4.2 Legal and Regulatory Framework

The legal and regulatory framework, weighted 25%, includes the consistency and quality of PPP regulations, effective PPP selection and decision-making, fairness/openness of bids, contract changes and dispute-resolution mechanisms (EIU 2012, 2015). EIU (2012, 2015) both rated Australia 100 out of 100 on this component. Australia does not have a specific legislative framework for PPPs, but rather the National PPP Policy and Guidelines set out a consistent framework that authorities should follow in the investment, procurement, development and operations stages of PPPs, along with standard risk allocations and commercial principles to be adopted (Donnelly et al. 2015). Australian guidance on PPP implementation is widely regarded as representing best practice and has been influential on the policy development of other Asian governments.

The legal and regulatory framework for PPPs is immature and still evolving in China. EIU (2012, 2015) rated China 31.3 and 34.4 out of 100 on this component respectively. A large number of PPP regulations are considered to lack a strong legal force in the forms of Opinion, Notice, and Decision. They were issued by the State Council and its ministries, who only took into account their own responsibilities. As a result, these regulations lack completeness and consistency (Ke et al. 2014). The PPP law was identified as one of the near future legislations at the 12th National People's Congress in March 2013. However, there are two streams of PPP-related law preparation, one being the "Infrastructure and Public Utilities Franchise Law" led by the National Development and Reform Commission (NDRC), and the other being the "Public Private Partnership Law" led by the Ministry of Finance (MOF).

One of the main differences in the legal and regulatory frameworks between Australia and China is the level of complexity. In Australia, there is only one set of

National PPP Policy and Guidelines, along with specific requirements by each of the state governments that must comply with the national policy framework. China, however, is in the process of developing a national PPP law and has a large number of related PPP governmental documents issued by the State Council and its ministries, provincial governments, and even city governments. It is much more difficult for practitioners in China to fully understand the legal and regulatory framework for PPPs.

In terms of key policies of PPPs, another main difference lies in the adoption of mechanisms for value for money (VFM) assessments or other decision-making frameworks to ensure that PPP is the most appropriate procurement option. In the Australian National PPP Policy and Guidelines issued in 2008, it is clearly stated that VFM is a critical focus of PPP procurement. Several volumes of detailed guidance materials are provided to deal with key points involved in the VFM assessment such as procurement options analysis, public sector comparator, and discount rate methodology. On the other hand, VFM assessment was firstly required by the MOF in China in December 2015. The effectiveness of "VFM Assessment Guidance (draft)" issued by the MOF is still not validated by the market. A concern has been raised that because of the immense budgetary pressure on the subnational governments to provide infrastructures, the decision to employ PPP is made despite specific conditions of target projects. The concern is evident in the huge total PPP pipeline projects of 7110 in the PPP project database of MOF (2016).

4.3 Institutional Framework

The institutional framework, weighted 20%, includes the quality of institutional design and PPP contract, hold-up, and expropriation risk (EIU 2012, 2015). According to EIU (2012, 2015), Australia has sound institutions for planning, evaluating, and ex-post oversight of PPP contracts, and also possess well-designed mechanisms for managing many of the complexities of PPP contracts, thereby obtaining a 100 out of 100 on this component in both surveys. Among the six components, China scored the lowest (25.0 in 2011 Infrascope and 33.3 in 2014 Infrascope) in the component of institutional framework (EIU 2012, 2015). This may be due to the fact that all the various infrastructure projects including PPP projects are governed dually by subnational governments horizontally and the ministries of the State Council vertically (Zhang et al. 2015).

In both countries, economic and social infrastructure planning and delivery are primarily subnational government responsibilities, with only a small minority of infrastructure projects procured centrally. However, in China, the complicated administrative structure for PPP development, though evolving, still acts as a negative constraint, because different government departments have discrete functions and none of them want to lose their administrative power or lessen control, thereby causing problems when PPP projects go through administrative procedures (Zhang et al. 2015).

Another kink in the institutional framework for PPPs in China could be perceived due to parallel bids for control between the MOF and NDRC, which have emerged as the lead bodies responsible for PPP regulations and oversight. There is no clear central direction and internal coordination of the provision of responsibilities between these two agencies (EIU 2015). As a result, they have both been developing PPP-related laws, guidance materials, and PPP project databases.

4.4 Operational Maturity

The operational maturity, weighted 15%, includes public capacity to plan and oversee PPPs, methods and criteria for awarding projects, regulators' risk-allocation record, experience in transport, water and electricity concessions, and quality of transport and water concessions (EIU 2012, 2015).

Even though the regulatory and institutional frameworks for PPPs are still underdeveloped, China has registered 1237 projects reaching financial closure from 1990 to the first half of 2015 in the World Bank Private Participation in Infrastructure Database (World Bank 2016), and 7110 pipeline projects as of April 2016 in the PPP project database of MOF (2016). The mismatch between the phenomenal experience wealth and the underdeveloped regulatory and institutional frameworks is driven by the high rates of economic growth and ambitious government plans for infrastructural development (EIU 2012). As a result, China scored high in this component (78.1 in 2011 Infrascope and 75.8 in 2014 Infrascope).

In China, PPP projects are currently handled in a similar fashion to state infrastructure projects (Zhang et al. 2015), in which government officials have rich experience developed from their exposure to the huge infrastructure market. The government is also keen to employ consultants to conduct project financing, risk evaluation, bidding and contract negotiation. In addition, methods and criteria for PPP procurement are usually the primary focus of current PPP regulations in China. Factors such as price, technical and financial status, credit standing, services, performance, and the response to the bid invitation documents are commonly taken into account when selecting a private partner. Although there is yet no official guidance on risk allocation in place, risk allocations have been basically fair between the public and private sectors, because of the rich past experience (Ke et al. 2013, 2010). In particular, on the issue of post-bid opportunism, it is typically well prevented by the limitation clauses on project interest transfer or price adjustment.

On the other hand, PPPs only represent less than 10% of total government infrastructure procurement in Australia (Hayford 2013). Due to the significantly smaller transaction numbers, Australia scored lower in this category than China in both surveys. Australian PPPs are regarded as generally more complex than those in other countries, because of the strong focus on VFM and the complex tax system (KPMG 2010). It is hence understandable that Australia lost ground in the operational maturity given the limited past project experience. It was suggested by KPMG (2015) and Hayford (2013) that the Australian governments need to become more flexible and create a range of new models of partnership, thus increasing the pool of projects. In addition, although Australia is considered as one of the most mature PPP markets globally, little has been done to confirm PPP performance during the operational phase (KPMG 2015).

4.5 Investment Climate

The investment climate, weighted 15%, includes political distortion, business environment and political will (EIU 2012, 2015). EIU (2012, 2015) rated Australia 87.4 and 90.5 out of 100 respectively and scored China 51.6 and 78.3. It could be seen that the infrastructure market in Australia has been attractive to investors, which is consistent with the findings of KPMG (2015) and NZ Controller and Auditor General (2011) that the Australian infrastructure market is one of the most mature markets globally. A significant improvement was found in the investment climate of China in the second survey. The reason behind would no doubt be the recent strong promotion of PPPs by the central government as well as the continuing demand for infrastructure development.

In Australia, because of the high requirements of VFM and project disclosure, PPPs do not have a large share in the infrastructure market (Hayford 2013). But even then, PPP investment opportunities are still very attractive, partly because most Australian state governments have an AAA or AA+ credit rating, and the legal and institutional frameworks for PPPs are mature. There are no legal restrictions on foreign entities engaging in the PPP process, thereby resulting in many foreign entities being involved in consortia that have bid for and won Australian PPP projects (Donnelly et al. 2015).

In China, the continuing strong economy growth and high infrastructural demands have created favourable opportunities for private investments. The central government has a highly proactive attitude towards the adoption of private investment in infrastructure development since 2013. Similar to Australia, there are no restraints on foreign investment in infrastructure projects or any rules of guidelines that suggest a preference for companies with local capital or foreign investors in general (Xie et al. 2016). The lure of a sizable market and a reasonable operating environment have resulted in a significant level of PPP usage in China, which will continue to be critical. However, PPPs projects in China come with no guarantee of sustainability because of weak regulatory frameworks and underdeveloped institutions for PPPs (EIU 2012, 2015). Weak government effectiveness remains a threat to fostering sustainable and efficient PPP infrastructure projects.

4.6 Financial Facilities

The financial facilities, weighted 15%, includes government payment risk, capital market: private infrastructure finance, marketable debt, government support and affordability for low-income users (EIU 2012, 2015).

Australia had a high score of 94.4 on the component of financial facilities in both surveys. Project finance is readily available for Australia because of its well-developed capital market and robust sovereign credit ratings (EIU 2015). A snapshot of recent trends and innovations in PPP funding and financing includes: (a) economic infrastructure PPPs have utilised the availability payment approach that is typically seen in social infrastructure PPPs (Donnelly et al. 2015); (b) these availability-style economic infrastructure PPPs are beginning to incorporate future provision of tolling securitisation (KPMG 2015); (c) state governments have offered syndication guarantee to achieve financial close, in which state governments commit to underwriting the transaction's shortfall in finance until it could be fully syndicated; (d) a partial capital contribution model has been commonly seen in Australia with a quantum between 30–70% (KPMG 2015); (e) Bond financing has been seen as a potential source of project finance in PPPs especially in the secondary markets (KPMG 2015); (f) Australia also has a considerable superannuation/pension fund allocation to infrastructure investment; and (g) a new inverted bid model was proposed to further encourage the industry super fund investments in infrastructure development (Industry Super Australia 2014).

China obtained 66.7 in the financial facilities in both surveys. Subnational governments have insufficient capacity to levy taxes and thereby make an extensive use of off-budget financing options for infrastructure. The majority of subnational government debt is financed by bank loans, while the majority of these loans are provided by the state-owned banks. Subnational governments have also been increasing their use of bonds in recent years as evident from the fact that several subnational governments now have direct access to bond market finance under pilot schemes (Chong and Poole 2013). In most of China's PPP projects, private partners have the sole responsibility for the financing component, although they may receive support in the form of government capital contribution, loans from development banks and credit enhancement. Private investors' debt constitutes a large proportion of PPP infrastructure financing. However, in China, debt financing in a PPP is still made up of loans from banks, because the syndicated loan market is not prevalent as a source of debt finance and the bond market is not sufficiently mature (Ke et al. 2014).

4.7 Subnational Adjustment Factor

Subnational adjustment factor, weighted 10%, evaluates whether infrastructure concessions can be carried out at a regional, state or municipal level, and the relative success and consistency of these frameworks (EIU 2012, 2015). In Australia, around 90% of PPPs are administered at the state level, resulting in an important and diverse subnational programme (EIU 2012). New South Wales, Victoria, and Queensland are the most active state governments. Policy guidelines for PPPs issued by these state governments are consistent with the National PPP Policy and Guidelines and clearly specify state requirements such as how to deal with unsolicited proposals. Australia obtained a full score of 100 in this component in both surveys.

In China, however, subnational governments are empowered to develop infrastructure assets at the subnational level and have a wealth of experience with provincial- and city-driven PPP projects. But it is worth noting that public capacity varies significantly across the provinces and cities (EIU 2012). Therefore, China obtained 75 out of 100 in this component in both surveys. The central government in China is responsible for the regulatory framework and approval of all major infrastructure projects. Subnational governments take the lead role in PPP implementation, as well as provide guidelines for PPPs at the subnational government level. However, most of the PPP-related subnational government documents are based on the regulations issued by the central government and do not provide many differences in essence among the subnational frameworks.

4.8 Conclusions

This paper reviewed the PPP environment in both Australia and China based on the six components benchmark index proposed by EIU (2012, 2015). The rationality of the benchmark index and the scores of Australia and China are excluded in the scope of the study and instead, this paper mainly contributed to the discussion behind the scores by EIU (2012, 2015).

It was found that although the overall environment is still evolving, China has a wealth of experience with PPPs. Given the tremendous economic growth and immense demand for infrastructure, China will continue to have a huge market for future PPP projects. International investors who are considering involvement in China's PPP market should pay close attention to recent PPP 'fever' and the progressive updates of the legal and institutional frameworks which are relatively weak components of Chinese PPP environment. It would also be recommended to establish a joint venture with local entities or to consult with local professional PPP consultants in China. Another lesson learnt from the comparison with Australia is that the consistency, transparency and effectiveness of the PPP-related law are particularly important. For instance, a clear central direction and internal coordination of the provision of PPP guidance especially between the MOF and NDRC should be provided.

In Australia, notwithstanding the maturity of the Australian PPP market, very little has been done to confirm PPP performance during the operational phase. There is a call for Australian governments to take up a leadership challenge and attract private investment in public infrastructure. Such need for significant private investment in the nation's infrastructure is expected to result in the emergence of a variety of innovative funding and financing models.

This paper makes an important contribution by comparing the PPP environment between Australia and China and the findings provide a better understanding of PPPs for both the public and private sectors in order to deliver cost-effective and VFM infrastructure. The issues raised in the paper could also offer a starting point for Australian PPP stakeholders to sell its huge technical, financial and legal PPP expertise to enable entry to the high risk-high reward Chinese PPP market.

References

Chong S, Poole E (2013) Financing infrastructure: a spectrum of country approaches. RBA Bull, 65–76

Donnelly D, Ng N, Donaldson B (2015) Australia. In: Werneck B, Saadi M (eds) The public-private partnership law review. Law Business Research Ltd, London, UK, pp 10–19

Economist Intelligence Unit (2012). Evaluating the environment for public private partnerships in Asia-Pacific: the 2011 infrascope. The Economist Intelligence Unit Ltd., and Asian Development Bank

Economist Intelligence Unit (2015). Evaluating the environment for public private partnerships in Asia-Pacific: the 2014 infrascope. The Economist Intelligence Unit Ltd., and Asian Development Bank

Hayford O (2013) Improving the outcomes of public private partnerships. http://www.claytonutz.com.au/docs/improving_%20outcomes_ppp_2013.pdf. 11 Apr 2016

Industry Super Australia (2014). The inverted bid model. http://www.industrysuperaustralia.com/assets/Reports/The-Inverted-Bid-Model-Final.pdf. 14 April 2016

Ke Y, Wang S, Chan APC, Lam PTI (2010) Preferred risk allocation in China's public-private partnership (PPP) projects. Int J Project Manage 28(5):482–492

Ke Y, Wang S, Chan APC (2013) Risk misallocation in public-private partnership projects in China. Int Pub Manage J 16(3):438–460

Ke Y, Jefferies M, Shrestha A, Jin X (2014) Public private partnership in China: where to from here. Organ Technol Manage Constr Int J 6(3):1156–1162

KPMG (2010) PPP procurement: review of barriers to competition and efficiency in the procurement of ppp projects. https://www.kpmg.com/NZ/en/IssuesAndInsights/ArticlesPublications/SmarterProcurement/Documents/Review-of-barriers-to-compeition.pdf. 12 April 2016

KPMG (2015). Public private partnerships: emerging global trends and the implications for future infrastructure development in Australia. https://www.kpmg.com/AU/en/IssuesAndInsights/ArticlesPublications/Documents/public-private-partnerships-june-2015.pdf. 12 April 2016

MOF (2016) Public-private partnerships center—PPP project database. http://www.cpppc.org:8082/efmisweb/ppp/projectLivrary/toPPPMap.do. 11 April 2016

NZ Controller and Auditor General (2011) Managing the implications of public private partnership. http://oag.govt.nz/2011/public-private-partnerships/docs/public-private-partnerships.pdf. 14 April 2016

World Bank (2016) Private participation in infrastructure database—Country snapshots—China. http://ppi.worldbank.org/snapshots/country/china. 11 April 2016

Xie J, Wang SQ, Jefferies M, Ke Y (2016) Public-private partnerships (PPPs) in China: the past, present and future. In: Jefferies M, Rowlinson S (eds) New forms of procurement: PPP and relational contracting in the 21st century. Routledge, New York, USA, pp 216–234

Zhang S, Gao Y, Feng Z, Sun W (2015) PPP application in infrastructure development in China: Institutional analysis and implications. Int J Project Manage 33(3):497–509

Chapter 5
A Conceptual Model of Cloud-Based Virtual Community for BIM Innovation and Promotion

C.W. Keung

5.1 Introduction

BIM is a new design and construction solution in the construction industry and the aim of its adoption in construction projects is to improve efficiency of overall construction process. BIM potentially can be applied throughout the project life-cycle and all project participants are required to contribute the BIM process. As a result, BIM implementation needs multi-disciplinary efforts throughout project period (Becerik-Gerber et al. 2012) and every project participant is expected to work collaboratively in order to achieve success in BIM project (Eastman et al. 2008). Although traditional BIM collaboration platforms have provided opportunities for project participants working collaboratively (Singh et al. 2011), their approach is project-based and lack of continuity for extension to new projects. Further, lack of proper channel for knowledge sharing between professionals causes barriers to diffusion of BIM knowledge. Some research contributions in construction have observed that effective project networks can assist project participants to improve their communications, solving the fragmentation problem in turn (Cheng et al. 2001; Chinowsky et al. 2008; Keung and Shen 2013).

Through the effective networks established for construction projects, project participants can improve communication and information exchange. In addition, the established networks can facilitate learning opportunities as well as knowledge sharing. The successful networks can extend the relationships of project participants after project completion and sustain them to new projects. The nature of BIM projects like networks in which project participants are connected and pursue the same goal under BIM project execution plan. As such, this study develops a network-based community that enables engagement of BIM professionals to sustain

C.W. Keung (✉)
Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon Tong, Hong Kong SAR
e-mail: cwkeung@cityu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_5

their relationships and energises multi-disciplinary collaboration in BIM projects. In the construction field, few BIM studies are conducted in the networking perspective. Thus, an alternative approach is proposed for promoting collaborative BIM implementation. A virtual community that integrates BIM professional networks with multiple collaboration platforms can connect BIM talents around the globe and cultivate new idea to realise improvement in BIM project performance and productivity. In some countries, BIM implementation in construction is developing slowly and the BIM resources are not fully exploited. As a result, the ultimate goals of this study are to inspire innovative BIM and push BIM development forward.

5.2 BIM Networks: A Solution for BIM Sustainability

There are lots of positive outcomes from BIM deployment in construction projects such as increase in productivity and effectiveness, time and cost saving, rapid visualisation, etc. However, BIM projects are not only working in a digital environment. They are more about collaboration between project participants in construction like clients, project manager, architects, engineers, surveyors and contractors. BIM allows design and construction teams to communicate about design and coordinate information across different levels. As such, BIM is the management of information through the whole project life cycle and project participants are connected to share information under BIM environment (Rezgui et al. 2013). Construction projects like project networks in which a number of network members work together to deal with problems that require team collaboration. As a result, the network theory has incentivised various researchers to develop insights into construction research. Networking has been studied prominently in the fields of anthropology, psychology, sociology, etc. and it is popularly used to explore relationships among a group of people or organisations, and focuses on building and sustaining these relationships (Keast and Hampson 2007). Social networks have become increasingly attractive in the past decade and they enable people to build and sustain relationships for certain purposes. With regard to the significant role of online social network in personal and commercial interactions in recent years, the possible outcomes arising from effective social networks are creativity, expertise and collective intelligence (Kasavana et al. 2010). Additionally, most research findings have demonstrated that networking is a useful strategy for organisations to stimulate competitive advantages over competitors (Álvarez et al. 2009; Rollyson 2009). Thus, the network concept inspires the development of computer-supported networks that form the bases of virtual community (Wellman et al. 1996).

BIM potentially can be applied throughout project life-cycle and all project participants are required to contribute the BIM process. During the project period, BIM database files, models, data, etc. are exchanged among project participants. Incompatibilities among computer systems adopted by different project participants are considered one of the barriers for BIM adoption in the construction industry

(Linderoth 2010). Thus, some project-based collaboration platforms were developed for BIM projects and the purposes of those platforms are to support communication, cooperation, collaboration and coordination among the BIM team members (Singh et al. 2011). Typically, BIM coordinators of each construction discipline are involved in the collaboration platform to ensure that all parties work collaboratively to resolve conflicts in the most efficient way. However, in contrast to factory mass production, construction projects are project-based in nature and project teams are temporarily formed for a single project (Dainty et al. 2007). Such project teams like temporary networks and are usually re-group for new construction projects. Past network dissolves when the project is completed and in the consecutive project a network composed of new actors will be formed. One of the constraints for fast BIM development is the challenge to maintain and re-construct the network for consecutive BIM projects (Linderoth 2010). Thus, there is a need to explore how the temporary coalitions of project participants using BIM can be connected in order to enhance the understanding of current challenges of adoption and use of BIM in previous, current and future construction projects.

In addition, the BIM bandwagon already swept across the construction industry worldwide and the boom in global BIM adoption causes rising BIM talents demand and BIM professionals become hard-to-find resources in the construction market. In a BIM project, client typically takes the initiative to BIM adoption for construction project and develops BIM project execution plan with the lead consultant or BIM manager during the concept stage of a project. As such, acquisition of BIM professionals at early project stage is important for clients and competency of BIM professionals critically affects the achievement of clients' BIM requirements. In the business landscape, development of professional network is popular for social networking and recruitment. The formation of professional network creates talent pool that not only builds relationships but also offers recruiting and talent acquisition solutions. This networking approach enables employers proactively find the best people for the job, rather than waiting for the right candidates to come to them. However, in the construction industry, there is no existing coalition of BIM professionals that dedicates to promote BIM talents and assists clients to hire skilled and competent BIM professionals. Thus, an innovative approach for BIM talent acquisition is necessary in the construction market for promoting BIM implementation.

The BIM virtual community is proposed in this study to integrate BIM professional networks with multiple BIM collaboration platforms. Each BIM collaboration platform facilitates project participants to conduct cooperative activities and devise solutions for eradicating the problems. With the embedment of BIM networks, project participants from different BIM projects are connected and interacted with each other. Strong and close connections between network members create cohesive BIM networks that can facilitate communication and promote efficient knowledge sharing. As a result, a learning entity can be created through BIM networks which develop the ability to cooperate between network members for learning collectively. Further, the BIM virtual community is delivered via cloud-based platform. Cloud computing has been envisioned as the next-generation

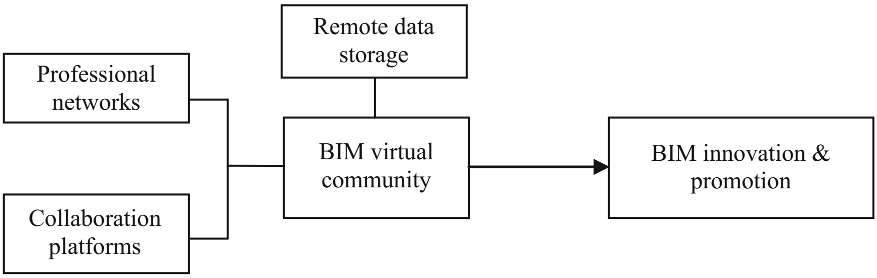


Fig. 5.1 Conceptual model of the proposed BIM virtual community

of computer technology. Compared with the traditional IT model, cloud computing can offer the advantages of data accessibility and real-time team collaboration. Thus, this study aims to develop an innovative tool that not only enhances BIM project performance but also pushes BIM development forward in the construction industry. Figure 5.1 demonstrates the conceptual framework proposed in this study and it hypothesises that the BIM virtual community can contribute BIM innovation and promotion of BIM adoption in the construction industry.

5.3 Data Collection and Analysis

This study aims to develop a conceptual model of cloud-based virtual community for BIM innovation and promotion. Thus, a questionnaire survey was administered for data collection. The questionnaire consists of three parts. Part one is about the professional background of the respondents. Part two and three are the questions relating to the features of the cloud-based virtual community and the solutions of BIM innovation and promotion respectively. A total 155 questionnaires were sent to the construction professionals practicing in Hong Kong. Finally 61 replies were received and the response rate is 39.4%. The returned questionnaires were examined to check any irregularities in answers and it was found that all questionnaires were in order for data analysis. The target respondents are practitioners involved in BIM projects and the results show that over 65% of them had more than three years BIM project experience. The questionnaires were analysed by Pearson correlation analysis that was adopted to validate the conceptual model developed in this study. The correlation analysis was used to describe the strength and direction of the relationships among two groups of variables by examining the correlation coefficients. The conceptual model shows the hypothetical relationships between BIM virtual community and BIM innovation and promotion. The variables under BIM virtual community describe the three embedded key features: professional network (PN), collaboration platform (CP) and remote data storage (RS). On the other hand, the variables for the solutions of BIM innovation and promotion are: knowledge diffusion (KD), intelligence creation (IC), talent acquisition (TA) and real-time collaboration (RC). The significant relationships between the two groups of variables were identified by the correlation analysis. The results demonstrate that the feature of professional network (PN) is positively related to the solutions of knowledge diffusion (KD: 0.623), talent acquisition (TA: 0.725) and intelligence creation (IC: 0.561). In addition, the features of collaborative platform (CP) and remote data storage (RD) were significantly correlated with the solutions intelligence creation (IC: 0.684; 0.708) and real-time collaboration (RC: 0.517; 0.589).

5.4 Developing a Cloud-Based Virtual Community Model

This study aims to develop an innovative cloud-based virtual community that integrates BIM networks with traditional collaboration platforms. Effective networks are ideal for involving BIM professionals in virtual community engagement. The cloud-based BIM virtual community not only assembles BIM professionals from the world but also stimulates real-time communication and collaboration for BIM projects. The coalition of BIM professionals in the virtual community supports communication, information exchange and knowledge sharing for BIM projects. In addition, the established BIM networks can facilitate sourcing of BIM talents from the globe and is useful to manage staffing resources by client effectively. Based on the personal profile of each network member, all network members can be classified intelligently under different BIM competencies according to their BIM skills, experiences and qualifications. The BIM networks can serve as an intelligent talent pool that can facilitate planning and management of staffing resources for BIM projects. Moreover, with the embedment of the BIM networks to the collaboration platform, BIM professionals from around the globe can connect and interact with each other to exchange information, promote new BIM ideas, and establish common BIM interest. The BIM networks that integrate with traditional collaboration platform are committed to establishing communication linkages within the BIM virtual community and have the ability to create many distant relationships. Through the interaction and communication within the virtual community, network members' creativity can be enriched through the BIM related interactivities. In addition, expert tools can be built in the virtual community by exhibiting new trend of BIM knowledge and technology shared by the members around the globe. The ultimate goal arising from the virtual community is the construction of intelligent hub which aligns individual BIM professionals to produce collaborative intelligence in future BIM projects. Additionally, the BIM virtual community makes use of cloud-based platform for data storage. Cloud computing is quickly becoming the next trend in computer technology and its concept is about the delivery of computing services from a remote location. Many studies realise the advantages of cloud adoption such as efficiency, accessibility, collaboration, rapidity of innovation and reliability (Figliola and Fischer 2015). Nowadays a lot of organisations are increasingly realising its benefits by placing their applications and data into cloud server. A great number of data from global BIM professionals are collected to

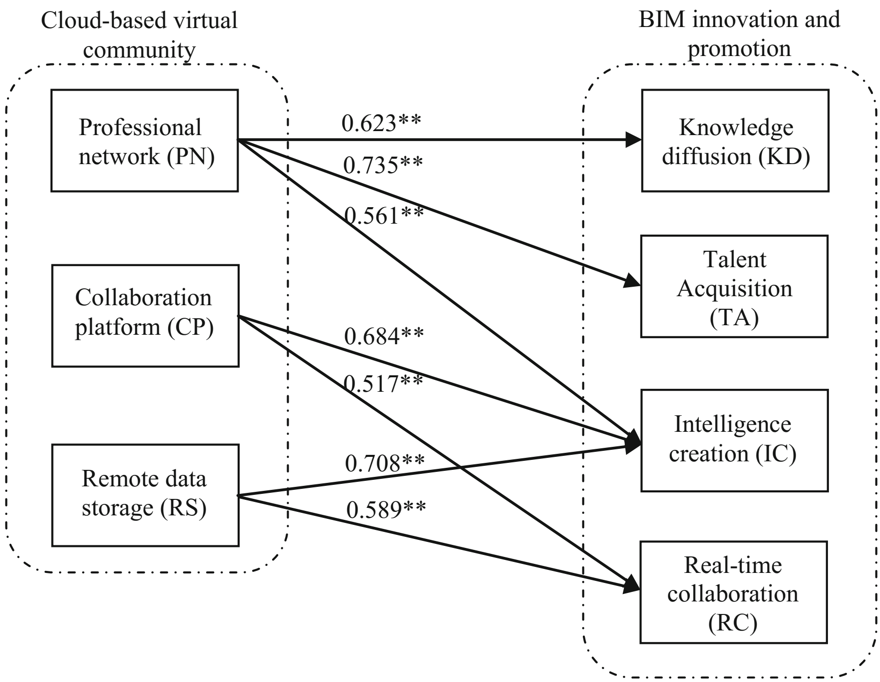


Fig. 5.2 A cloud-based virtual community model for BIM innovation and promotion

develop the BIM virtual community. The data include shared documents between network members, user profiles, drawings, videos, photos, etc. As such, cloud servers can relief the burden of local data storage and maintenance. Further, the BIM networks within the virtual community also vary in the extent to which they incorporate new BIM information and apply communication tools, such as mobile connectivity, blogging, wikis, chat and photo/video-sharing. Thus, BIM network members in cloud-based platform can be assessed from anywhere, at any time and with any device. Figure 5.2 demonstrates the model of the cloud-based BIM virtual community.

The virtual community comprises the BIM networks and several collaboration platforms for concurrent BIM projects. The BIM project participants are the network members who are connected within the BIM networks. Project experience and knowledge of each network member can be shared through the BIM networks and e-learning. Network members can build relationship through the BIM networks and such relationship can enhance the collaboration in the individual BIM projects. The BIM networks also can serve as a talent pool to facilitate recruitment of competent BIM professionals. Under a cloud-based platform, multiple network members can work on the same BIM document at the same time, and the BIM documents are stored on remote servers in the cloud. In short, establishment of the BIM virtual community is a driving force for collaborative BIM implementation and a new solution for BIM workforce in the construction market. The developed virtual community not only enables the newly recruited BIM professionals to enrich the network in turn but also cultivates new knowledge and idea to enhance the performance of collaboration platforms adopted for BIM projects. Thus, any organisations pursuing BIM in construction can benefit from the virtual community in the perspectives of BIM project management and BIM talent recruitment. In long term, BIM evolution in the slow BIM development countries can be significantly improved and they can keep pace with some leading practice countries.

5.5 Concluding Remarks

With regard to slow-moving BIM development in many countries, the goal of this study is to promote BIM through the establishment of a cloud-based virtual community that facilitates sourcing of BIM talents and supports BIM knowledge diffusion for consecutive new projects. The results support the hypothesis that the BIM virtual community can contribute BIM innovation and promotion of BIM adoption in the construction industry. The model shows that the key features of the virtual community highly correlate with the solutions of BIM innovation and promotion. Several benefits and impacts to BIM were identified. Firstly, the current problem of BIM talent acquisition in the construction market can be solved. The proposed BIM network that synchronises with traditional collaboration platform aims to attract BIM professionals based on contemporary BIM themes. The database of the BIM networks can facilitate efficient talent acquisition for the BIM projects and help them to stay competitive in the construction market. Secondly, the construction industry is often defined as project-based and fragmented. This unique nature causes many problems such as mistrust, inefficient communication, a lack of cohesion and adversarial relationships between project participants. Through the formation of the virtual community, the BIM networks promote interpersonal relationships that aim to enhance the communication and relationship between project participants and solve the problem of adversarial relationship. Finally, the cloud-based virtual community assists project participants to work collaboratively and efficiently. The technology of cloud computing can increase productivity in construction projects. Outsourcing data into the cloud is economically attractive for the cost and complexity of data storage. Thus, the cloud-based virtual community develops an integrative platform that can store, share and manage all BIM issues in an easy and efficient way. The platform can be assessed by the project participants from anywhere, at any time and with any device.

References

Álvarez I, Marin R, Fonfría A (2009) The role of networking in the competitiveness of firms. Technol Forecast Soc Chang 76(3):410–421

Becerik-Gerber B, Ku K, Jazizadeh F (2012) BIM-enabled virtual and collaborative construction engineering and management. J Prof Issues Eng Educ Pract 138:234–245

Cheng WL, Li H, Love ED, Irani Z (2001) Network communication in the construction industry. Corp Commun Int J 6(2):61–70

Chinowsky P, Diekmann J, Galotti V (2008) Social network model of construction. J Const Eng Manage 134(10):804–812

Dainty A, Green S, Bagilhole B (2007) People and culture in construction: contexts and challenges. In: Dainty A, Green S, Bagilhole B (eds) People and culture in construction: a reader. Taylor & Francis, London

Eastman C, Teicholz P, Liston K (2008) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors. Wiley, New York

Figliola PM, Fischer EA (2015) Overview and issues for implementation of the federal cloud computing initiative: implications for federal information technology reform management. Congressional Research Service

Kasavana ML, Nusair K, Teodosic K (2010) Online social networking: redefining the human web. J Hospitality Tourism Technol 1(1):68–82

Keast R, Hampson K (2007) Building constructive innovation networks: the role of relationship management. Constr Eng Manage 133(5):364–373

Keung CW, Shen LY (2013) Measuring the networking performance for contractors in practicing construction management. J Manage Eng 29(4):400–406

Linderoth H (2010) Understanding adoption and use of BIM as the creation of actor networks. Autom Constr 19:66–72

Rezgui Y, Beach T, Rana O (2013) A governance approach for BIM management across lifecycle and supply chains using mixed-modes of information delivery. J Civ Eng Manage 19(2):239–258

Rollyson CS (2009) Realizing value from social networks: a life cycle model. In: New strategy for enterprise competitiveness. CSRA, Chicago

Singh V, Gu N, Wang X (2011) A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Autom Constr 20:134–144

Wellman B, Salaff J, Dimitrova D, Garton L, Gulia M, Haythornthwaite C (1996) Computer networks as social networks: collaborative work, telework, and virtual community. Ann Rev Sociol 22:213–238

Chapter 6
A Dynamic Analysis on the Urban Carbon Footprint and Carbon Carrying Capacity—A Case Study of Chongqing

S.P. Li, Q.J. Zheng, D.H. Zeng, Z.H. Huang and L.Y. Shen

6.1 Introduction

The problem of global warming is becoming more and more serious in line with the rapid growth of global population and economic scale. The Fourth Assessment Report of Intergovernmental Panel on Climate Change (IPCC) stated that, by the end of the 21st century, the average global temperatures could rise by 1.1–6.4 °C (Izrael et al. 2007). Emissions of greenhouse gases is considered as the main cause of global warming, among that, the carbon dioxide contributes about 65% to the total greenhouse gases. As the center of the human activities, cities bring together more than half of the world's population, where greenhouse gases emissions account for 75% of the total emissions (Change 2007). This problem is typical particularly in those densely populated cities such as a number of Chinese cities. China is in a period of rapid urbanization, urbanization level has risen rapidly from 17.9% in 1978 to 56.1% in 2015 (Zheng 2012). With the growth of China's urbanization rate, the conflicts between population, resources and environment faced by its urban development have become increasingly prominent, and the carbon dioxide emissions in this country have been increasing, far higher than the global average emissions (China Meteorological Administration 2016). Chongqing is one of four municipal cities and the six old industrial bases in China, its energy consumptions and carbon emissions have been increasing dramatically. Experts estimated that the total amount of carbon dioxide emissions in Chongqing increased to 57,597,340 tons in 2014 (Wei 2015). In response to climate change, more and

S.P. Li (✉) · Q.J. Zheng · D.H. Zeng · Z.H. Huang · L.Y. Shen
School of Construction Management & Real Estate, Chongqing University,
Chongqing, China
e-mail: 13452920662@163.com

S.P. Li · Q.J. Zheng · Z.H. Huang · L.Y. Shen
International Research Centre for Sustainable Built Environment,
Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_6

more countries have been devoting efforts in combating against carbon emissions by releasing regulatory documentation related to development of low-carbon, such as the "United Nations Framework Convention on Climate Change" and "Paris Agreement" (Rui 2011).

The concepts of "carbon footprint" and "carbon carrying capacity" arise from "ecological footprint". The former refers to the amount of greenhouse gases that human generate in the process of production and consumption, and the later refers to the amount of carbon dioxide absorbed by the photosynthesis of all the vegetation in a region (Wang et al. 2010; Xiao et al. 2013; Rees 1992; Wackernagel et al. 1996). Hertwich et al. have analyzed the carbon footprint of 73 countries all over the world (Hertwich and Peters 2009). Wiedmann et al. have studied carbon footprint of Britain from 1990 to 2008 (Wiedmann and Barrett 2011). Kenny et al. have chosen Ireland as an example for comparing the effect of six types of carbon footprint calculation models (Kenny and Gray 2009). Zhao et al. have analyzed pressure of the carbon footprint and the carbon recycle in Nanjing (Zhao et al. 2014). Kai Fang and Wanbin Shen pointed out that the ecological footprint did not consider the carrying capacity of CO_2 emissions. They built CO_2 emission capacity calculation model by considering net primary productivity and ecological footprint (Fang 2010).

Researches on the carrying capacity have covered different areas. The concept of resources carrying capacity, environmental carrying capacity, ecological carrying capacity and urban comprehensive carrying capacity have been introduced by scholars in various disciplines (Wang et al. 2013; Guan 2012; Gao 2001; Guang-Ming 2009). In line with this development, there are various mature research methods for evaluating carrying capacity, including net primary productivity method, the ecological footprint method, energy value method, comprehensive evaluation method (Lieth 1975; Brown and Ulgiati 1997; Wiedmann et al. 2006; Flalan 2008; Haberl et al. 2001). However, the study on carbon carrying capacity is still in the initial stage. For the calculation of carbon carrying capacity, Zhao et al. (2013) have considered the capacity of the forest, Xiao (2013) and Junyu et al. (2013) have considered the capacity of forest and grassland comprehensively, and Caihong (2012) has added an additional element, namely, the capacity of cultivated field. On the other hand, for the calculation of carbon footprint, most of the existing researches involves only the part of urban energy consumption. Xiuping Zhang, Qidi Liao and Yusheng Huang respectively studied the carbon footprint generated by energy consumption in Shanxi Province, Xiamen and various provinces all over China (Xiuping and Guozhang 2016; Liao and Gong 2014; Huang et al. 2016). Ling Xiao has estimated the carbon footprint generated by the fossil energy and cement in Shandong Province (Xiao et al. 2013). Xiangui Zhao has calculated the carbon footprint generated in the fossil energy consumption, electricity consumption, rural biomass and special industrial production in Beijing (Zhao et al. 2013). However, these studies on the calculation methods of carbon carrying capacity and carbon footprint are not comprehensive enough.

In view of the existing research, this paper studied the carbon footprint from a comprehensive perspective by considering the emissions generated in the process of energy utilization, industrial production, microbial metabolism, and the carbon carrying capacity of forest land, cultivated land, landscape and grassland. The data used for analysis is from Chongqing for the period of 1998–2013. A number of indexes are used for the calculation, including carbon footprint, carbon carrying capacity, net carbon footprint, carbon footprint per capita and carbon carrying capacity per capita. This paper can provide a dynamic analysis on the carbon emissions and carbon sequestration in a region and provides a reference for developing measures to improve energy structure and reduce carbon emissions.

6.2 Methodology

In this paper, carbon footprint in Chongqing is calculated and analyzed according to the type of carbon dioxide emission sources: energy utilization, industrial production, microbial metabolism. Carbon carrying capacity is based primarily on the carbon sequestration of forest, cultivated land, landscape and grassland. The indicators of carbon footprint per capita, carbon carrying capacity per capita, net carbon footprint per capita are to conduct evaluation in order to eliminate the influence of population scale.

6.2.1 Carbon Footprint

(1) **Energy utilization**

The process of energy production and consumption is an important source of carbon dioxide emissions, which usually accounts for 90% of the total. Carbon footprint caused by energy utilization, mainly includes fuel combustion and power transportation.

① Fuel combustion

There are mainly two kinds of methods to calculate the carbon footprint of fuel combustion. One is top-down and the other is bottom-up. This paper adopts the former one. In top-down calculation method, inventory method developed by IPCC allows for modifying the method and localizing emission factors according to research objects. This method has been widely recognized and become the most popular method, and has been also adopted by UNFCC, IPCC, IEA and so on. The calculation in this paper is based on the method provided by IPCC (2006), with the following formula:

$$CF_{fc} = \sum \left[(A_i \times e_i \times c_i - S_i) \times o_i \times \frac{44}{12} \right] \tag{6.1}$$

where CF_{fc} is the carbon footprint from fuel combustion; A_i is the apparent consumption of fuel i; e_i is the heat conversion factor of fuel i; c_i is the average carbon content of the fuel i, also called carbon emission factor; S_i is carbon sequestration of fossil fuels used by non-fuel i; o_i is the carbon oxidation factors of fuel i.

In model (6.1), A_i can be calculated according to the follows:

$$\mathrm{A}_i = \mathrm{A}_1 + \mathrm{A}_2 + \mathrm{A}_3 - \mathrm{A}_4 \tag{6.2}$$

where A_1 is the final consumption, A_2 is the thermal power consumption, A_3 is the heating consumption, A_4 is the non-fuel consumption.

S_i in model (6.1) can be calculated as:

$$S_i = P \times PC \times m \tag{6.3}$$

where P is the output of carbon sequestration products, PC is carbon content in per unit of product, m is the rate of carbon sequestration.

The values for other variables in model (6.1) are given in Table 6.1.

② Power transportation

The carbon footprint of power transportation can be calculated as:

$$CF_{power\ import} = W_1 \times q \tag{6.4}$$

$$CF_{power\ export} = W_2 \times q \tag{6.5}$$

where W_1 is the power imported from other provinces, regions or cities; W_2 is the power exported from local province, regions or cities; q is the average emission

Table 6.1 Energy sources heat conversion factor, carbon emission factor and carbon oxidation factor

Energy type	Heat conversion factor (e_i)	Carbon emission factor (c_i)	Carbon oxidation factor (o_i)
Raw coal	20.52	24.74	0.98
Cleaned coal	20.52	24.74	0.90
Other cleaned coal	20.52	24.74	0.90
Biquette	20.52	24.74	0.90
Coke	28.20	29.50	0.97
Crude oil	42.62	20.00	0.98
Gasoline	44.80	18.90	0.98
Kerosene	44.67	19.55	0.98
Diesel	43.33	20.20	0.98
Fuel oil	40.19	21.10	0.98
Liquefied petroleum gas	47.31	17.20	0.98
Natural gas	48.00	15.30	0.99

Source IPCC, China Climate Change Country Study Group factor of regional power supply, which is 0.801 kg/KWh provided by The Provincial Greenhouse Gas Inventories Guidelines (Trial).

The carbon emission from power import is considered as a positive value, and the export is a negative value. Therefore, the net carbon footprint of power transportation can be calculated as:

$$CF_{power\ transportation} = CF_{\text{power import}} + CF_{\text{power export}} \tag{6.6}$$

By integrating (6.1) and (6.6), the total carbon footprint from energy utilization can be calculated as:

$$CF_{energy} = CF_{fc} + CF_{\text{power transportation}} \tag{6.7}$$

(2) **Industrial production**

Carbon footprint in industrial production can be divided into two categories. One is the carbon dioxide emissions from the chemical reactions, the other is the carbon dioxide emissions from fuel combustion. The carbon footprint from fuel combustion has been addressed in (6.1), the carbon emissions from chemical reaction in industrial production process, mainly include the carbon footprint from the cement production process, the carbon footprint from steel production process, the carbon footprint from calcium carbide and soda ash production (Chen 2012). It can be calculated as:

$$CF_{industry} = K_{cem} \times D_{cem} + K_{ste} \times D_{ste} + K_{CaC2} \times D_{CaC2} + K_{sod} \times D_{sod} \tag{6.8}$$

where $CF_{industry}$ is the carbon footprint of industrial production, $K_{cem}, K_{ste}, K_{CaC2}, K_{sod}$ are the carbon emission factors of cement, steel, calcium carbide and soda ash respectively, which are shown in Table 6.2, $D_{cem}, D_{ste}, D_{CaC2}, D_{sod}$ are the outputs of cement, steel, calcium carbide and soda ash respectively.

(3) **Biological metabolism**

Carbon footprint from biological metabolism mainly refers to carbon dioxide emitted by human and animal respiration. It can be calculated as follows:

$$CF_{human} = N_{peo} \times f_{peo} \tag{6.9}$$

where CF_{human} is carbon footprint emitted by human respiration, N_{peo} is the number of resident population of the region, and f_{peo} is the respiration parameters per capita.

Table 6.2 Carbon emission factors in the production process of major industrial products

Major industrial products	Cement	Steel	Calcium carbide	Soda ash
Carbon emission factor	0.427	1.06	2.19	0.138

Source 2006 IPCC Guidelines for National Greenhouse Gas Inventories

$$CF_{animal} = \sum N_{ani-i} \times f_{ani-i} \tag{6.10}$$

where CF_{animal} is carbon footprint emitted by animal respiration, N_{ani-i} is the amount of animal i in the region, and f_{ani-i} is the respiration parameters of animal i.

Therefore, the total carbon footprint in biological metabolism can be calculated as:

$$CF_{biology} = CF_{human} + CF_{animal} \tag{6.11}$$

(4) **Total carbon footprint**

By integrating (6.7), (6.8) and (6.11), the total carbon footprint can be calculated as:

$$CF = CF_{energy} + CF_{industry} + CF_{biology} \tag{6.12}$$

where CF is the total carbon footprint of an area.

6.2.2 Carbon Carrying Capacity

Carbon carrying capacity refers to the annual amount of carbon dioxide that the various vegetation in an area can sequestrate (Xiao et al. 2013; Zhao et al. 2013). The main land types for carbon sequestration include forest land, cultivated land, landscape and grassland. The measurement method of carbon carrying capacity used in this paper is based on the average net carbon storage of the main carbon sequestration land in different ecosystem, then multiply the area of ecosystem respectively (Fang 2007; Wittkop et al. 2009). The formula is as follows:

$$\mathrm{CC} = \sum A_i \times b_i \tag{6.13}$$

where CC is carbon carrying capacity; A_i is the usage area of land i for carbon sequestration; b_i is the carbon carrying capacity of per unit area, it refers to the average net carbon storage volume of carbon sequestration land i, which also can be called carbon sequestration rate. The carbon sequestration rate of cultivated land, landscape, forest land and grassland are 5.0, 3.98, 4.75 and 3.37 respectively.

6.2.3 Net Carbon Footprint

Net carbon footprint derives from the “ecological deficit” in “ecological footprint”. Its definition is the difference between carbon footprint and carbon carrying capacity in a region. If the value is zero, it refers to a carbon balance. If the net carbon footprint is a negative value, it represents there is surplus carbon carrying capacity and it's at carbon sequestration state, can curb global warming. If the value is positive, there appears carbon footprint deficit, indicating a carbon crisis and inducing climate warming. The net carbon footprint can be calculated as:

$$NCF = N \times d = A \times D_d = CF - CC \tag{6.14}$$

where NCF is net carbon footprint, N is the population in the region, d is net carbon footprint per capita, A is the area of the region, D_d is the net carbon footprint per unit area.

6.3 Case Study

6.3.1 Research Data

The sample data in this paper are about Chongqing since it became a municipality (1998–2013). The data to calculate Chongqing's carbon footprint is mainly from the following three sources: data related to energy utilization from China Energy Statistical Yearbook (1999–2014); the industrial production data from Chongqing Statistical Yearbook (1999–2014); and data about biological metabolism from China Rural Statistical Yearbook and Chongqing Statistical Yearbook (1999–2014). Data for Chongqing's carbon carrying capacity calculation is from the following two sources: Chongqing Municipal Land Resources and Housing Management Statistical Bulletin (2010–2014), and Analysis Report of the Utilization of the Urban Land in Chongqing (1999–2009).

6.3.2 The Dynamic Analysis on Carbon Footprint and Carbon Carrying Capacity of Chongqing

(1) **Carbon footprint**

The calculations for the models (6.1–6.12) have been conducted. And their results are summarized as follows. In Table 6.3 and Fig. 6.1, Chongqing's carbon footprint shows a significantly upward trend after it became a municipality in 1997. The total carbon footprint increased from 67,641,200 tons (in 1998) to 176,227,300 tons (in 2013) and reached an increase of 160.53%. From 1998 to 2013, the carbon footprint of energy utilization increased from 56,465,700 to 131,739,100 tons, increased by 133.31%. During this period, the carbon footprint of industrial production increased by 513.04%, from 6,495,800 to 39,821,900 tons, in this process, cement takes the largest proportion, accounting for 73.24%. The carbon footprint of

Table 6.3 Changes in composition of the carbon footprint in Chongqing from 1998 to 2013

Year	Biological metabolism (ton)	Energy utilization (ton)	Industrial production (ton)	Total (ton)
1998	4,679,700	56,465,700	6,495,800	67,641,200
1999	4,778,100	62,538,800	6,635,500	73,952,400
2000	4,877,000	64,779,100	7,701,500	77,357,600
2001	4,934,900	59,445,900	8,176,300	72,557,100
2002	4,919,400	66,134,900	9,378,900	80,433,200
2003	4,977,000	59,589,400	10,795,100	75,361,500
2004	4,920,300	67,987,100	11,255,500	84,162,900
2005	4,942,500	81,641,800	12,151,800	98,736,100
2006	4,849,700	88,468,100	1,492,100	94,809,900
2007	4,287,300	94,013,800	16,722,900	115,024,000
2008	4,352,000	117,651,300	18,575,700	140,579,000
2009	4,524,400	123,970,500	20,616,600	149,111,500
2010	4,576,000	131,222,900	27,199,800	162,998,700
2011	4,560,300	152,887,700	31,280,500	188,728,500
2012	4,615,300	150,861,500	35,859,100	191,335,900
2013	4,666,300	131,739,100	39,821,900	176,227,300

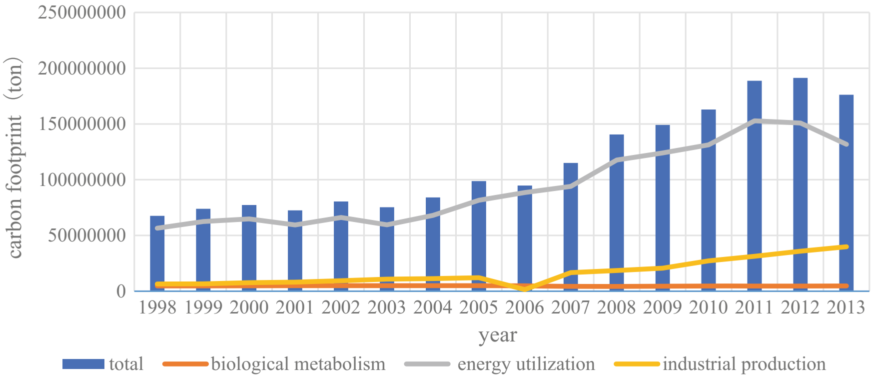


Fig. 6.1 Changes in composition of the carbon footprint in Chongqing from 1998 to 2013

biological metabolism was relatively stable in these years. Although there was a fluctuation between 1998 and 2013, the amount was almost unchanged.

From the perspective of the structure of carbon footprint. The proportion that carbon footprint of energy utilization takes up in total carbon footprint increased from 74.76 to 93.31% from 1998 to 2013. And the carbon footprint of industrial production takes up 9.60% in 1998 and 22.6% in 2013. Its proportion shows a notable upward trend with fluctuation. Biological metabolism accounts for the smallest proportion of the total carbon footprint, and there is a downward trend. The proportion of biological metabolism in 1998 is 6.92% but 2.65% in 2013. So, the increasing energy utilization is the main cause for the growth of carbon footprint in Chongqing.

(2) **Carbon carrying capacity**

Based on formula (6.13) and the different types of land use data in related years, carbon carrying capacity of Chongqing from 1998 to 2013 can be calculated as shown in Table 6.4 and Fig. 6.2.

Chongqing's carbon carrying capacity is between 28,212,900 and 32,434,000 tons from 1998 to 2013. The annual carbon carrying capacity is about 29,675,181 tons, and the overall trend is upward. The annual carbon carrying capacity increased by 14.73% in 16 years, average annual increase is 0.97%. Except an obvious increase in 2009, Chongqing's carbon carrying capacity is basically stable, without sharp fluctuations. In detail, carbon carrying capacity of forest land shows an upward trend on the whole. Carbon carrying capacity of cultivated land, landscape, grassland don't show obvious variation, except a surge in 2009.

In the composition of the carbon carrying capacity, cultivated land and forest land are two important parts. The average annual carbon sequestration amount of them accounted respectively for 40.60 and 53.38%. This is accordance with the fact that cultivated land and forest land take up the largest area in Chongqing land-use type. They are the good resources to sequestrate carbon dioxide. The amount of carbon carrying capacity of landscape accounts for 2.32% in 1998 and 3.33% in

Table 6.4 Changes in composition of the carbon carrying capacity of Chongqing from 1998 to 2013

Year	Cultivated land (ton)	Landscape (ton)	Forest land (ton)	Grassland (ton)	Total (ton)
1998	12,686,000	656,300	14,124,600	803,100	28,270,000
1999	12,648,000	656,300	14,111,300	799,000	28,214,600
2000	12,614,500	667,800	14,126,500	804,100	28,212,900
2001	12,596,000	679,400	14,144,100	803,400	28,222,900
2002	12,329,000	726,400	14,412,500	803,700	28,271,600
2003	11,738,000	835,800	15,153,500	803,400	28,530,700
2004	11,437,000	879,200	15,443,700	802,400	28,562,300
2005	11,313,500	936,500	15,547,200	801,700	28,598,900
2006	11,210,000	970,300	15,634,600	800,000	28,614,900
2007	11,195,500	967,500	15,643,200	800,000	28,606,200
2008	11,179,500	956,000	15,632,700	799,400	28,567,600
2009	12,190,000	1,106,400	18,012,000	1,125,600	32,434,000
2010	12,214,500	1,096,900	17,994,900	1,117,500	32,423,800
2011	12,244,500	1,091,300	17,974,000	1,108,700	32,418,500
2012	12,256,500	1,085,700	17,974,000	1,104,300	32,420,500
2013	12,281,500	1,081,400	17,968,300	1,102,300	32,433,500

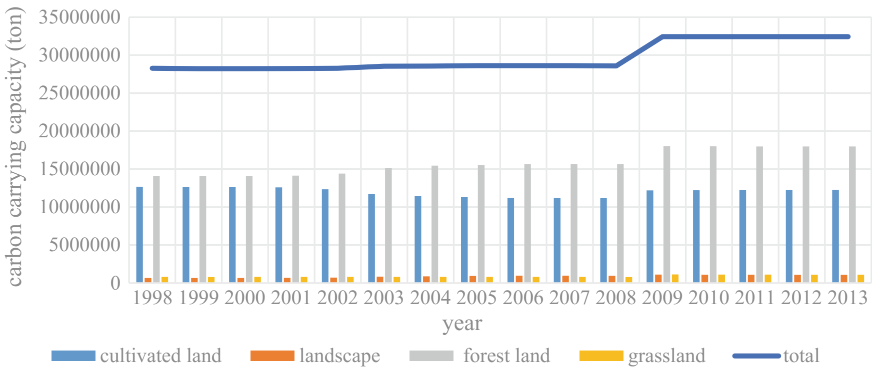


Fig. 6.2 Changes in composition of the carbon carrying capacity in Chongqing from 1998 to 2013

2013, it's a very small part. And the amount of carbon carrying capacity of grassland accounts for 2.84% in 1998 and 3.40% in 2013.

(3) **Net carbon footprint**

Based on the model (6.14), net carbon footprints can be analyzed and summarized in Fig. 6.3.

Figure 6.3 shows that Chongqing's carbon footprint is always much larger than its carbon carrying capacity from 1998 to 2013 and keeps rapid growth, while the carbon carrying capacity keeps stable. It results in that the net carbon footprint keep growing, from 39,371,200 tons in 1998 to 143,793,800 tons in 2013 and increased by 265.23% (Annual growth rate is 9.72%). The net carbon footprint has been in a serious imbalance. Wherein the annual net carbon footprint was barely growing from 1998 to 2004, while the growth during the period between 2005 and 2012 was the fastest. In this period, the net carbon footprint increased 88,778,200 tons. In

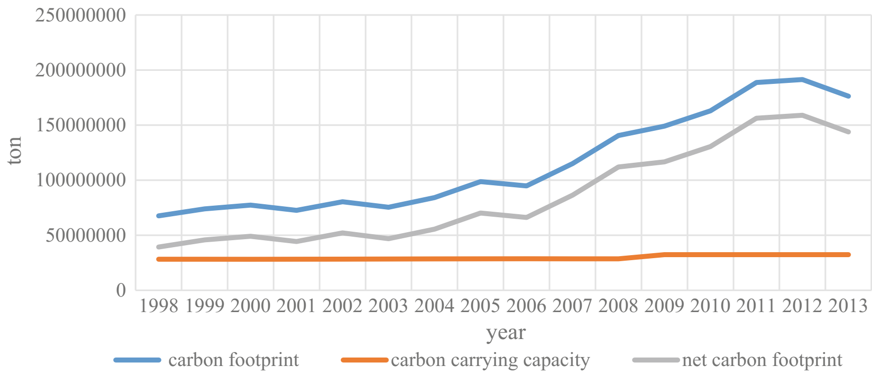


Fig. 6.3 Dynamic changes of net carbon footprint in Chongqing from 1998 to 2013

2013, the growth rate slowed down. Therefore, the net carbon footprint in Chongqing keeps growing while the growth rate gradually declined.

6.3.3 The Dynamic Analysis of Carbon Footprint, Carbon Carrying Capacity and Net Carbon Footprint Per Capita

The carbon footprint, carbon carrying capacity and net carbon footprint per capital can be analyzed accordingly, and their results are summarized in Fig. 6.4. As presented in Fig. 6.4, the carbon footprint, carbon carrying capacity and net carbon footprint per capita all show an upward trend from 1998 to 2013. The carbon footprint per capita increased by 169.55%, from 2.20 to 5.93 tons. The carbon carrying capacity per capita increased by 18.48%, from 0.92 to 1.09 tons. And net carbon footprint per capita rose from 1.28 to 4.84 tons, the growth rate was 278.13%. According to results of previous researches, the goal of carbon footprint per capita at global level in response to climate change is 2.0 tons. Chongqing's net carbon footprint per capita is 1.1–3.25 times of the global level. It means that carbon emissions reduction in Chongqing is still a very hard task, and carbon emissions reduction measures must be taken as soon as possible.

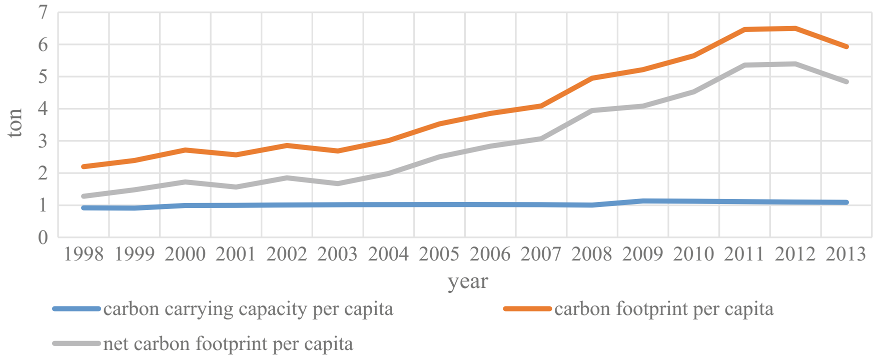


Fig. 6.4 Dynamics of carbon footprint, carbon carrying capacity and net carbon footprint per capita in Chongqing (1998–2013)

6.4 Conclusion

This study found that the total carbon footprint of Chongqing is significantly more than its carbon carrying capacity. There are two causes to explain this. One is due to the fact that Chongqing's urbanization stepped into the rapid development stage. The continuous growth trend of the energy consumption and industrial production output is irreversible. And which causes the continuous growth of Chongqing's total carbon footprint. The other cause is cultivated land area grew slowly, forest land and landscape area even showed negative growth. These resulted in the slow growth of Chongqing's carbon carrying capacity. However, Chongqing is still in the critical period of urban expansion and transition. This situation determines that it's impossible for Chongqing to balance the two goals of economic growth and carbon emissions reduction without strengthening the implementation of low-carbon approaches. The study suggests the importance of further investigating the key factors contributing to the dynamic changes of carbon footprint.

Acknowledges This research was supported by a grant from the Key Project of National Social Science Foundation of China (No. 15AZD025).

References

Brown MT, Ulgiati S (1997) Emergy-based indices and ratios to evaluate sustainability: monitoring economies and technology toward environmentally sound innovation. Ecol Eng 9 (1–2):51–69

Caihong MA (2012). Comparison of carbon footprint of energy consumption and carbon capacity of vegetation in china. Ecol Econ

Change IPOC (2007) Climate change 2007: synthesis report. Environ Policy Collect 27(2):408

Chen QH (2012) Timing analysis of the change of carbon source and carbon sink in hunan province. Resources & Environment in the Yangtze Basin

China Meteorological Administration (2016) China greenhouse gas bulletin [EB/OL]. Retrieved from http://www.cma.gov.cn/2011xwzx/2011xqxxw/2011xqxyw/201601/t20160112_301731.html

Fang JY (2007) Looking for missing carbon sinks from terrestrial ecosystems. Chin J Nat

Fang K (2010) Construction and application of calculation model for CO_2 emission carrying capacity. Ecol Sci 29(6):558–562

Flalan N (2008) Measuring sustainability: why the ecological footprint is bad economics and bad environmental science. Ecol Econ 67(4):519–525

Gao JX (2001) Exploration on sustainable development theory: method and application of ecological carrying capacity. China Environmental Science Press

Guan LJ (2012) Study on carbon dioxide emission carrying capacity ratio in Qingdao. Ocean University of China

Guang-Ming L (2009) A study on urban comprehensive carrying capacity under sustainable development theory. Urban Studies

Haberl H, Erbk H, Krausmann F (2001) How to calculate and interpret ecological footprints or long periods time: the case of Austria 1926–1995. Ecol Econ 38(6):25–45

Hertwich EG, Peters GP (2009) Carbon footprint of nations: a global, trade-linked analysis. Environ Sci Technol 43(16):6414–6420

Huang Y, Qu J, Liu L (2016) Research on the differences of carbon footprint and carbon carrying capacity based on provincial level in China. Ecol Econ

IPCC (2006) IPCC Guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change

Izrael YA, Semenov SM, Anisimov OA, Anokhin YA, Velichko AA, Revich BA et al (2007) The fourth assessment report of the intergovernmental panel on climate change: working group ii contribution. Russ Meteorol Hydrol 32(9):551–556

Junyu LU, Huang X, Chen Y et al (2013) Spatiotemporal changes of carbon footprint based on energy consumption in China. Geogr Res 32(2):326–336

Kenny T, Gray NF (2009) Comparative performance of six carbon footprint models for use in Ireland. Environ Impact Assess Rev 29(1):1–6

Lieth H (1975) Modeling the primary productivity of the world. Primary Prod Biosph. Springer, Berlin, Heidelberg

Qidi L, Gong F (2014) Analysis of carbon footprint and carbon capacity of Xiamen. Fujian Architecture and Construction

Rees E (1992) Ecological footprints and appropriated carrying capacity: what urban economics leaves out. Environ Urbanization, 2:121–l30

Rui Y (2011) Review of researches on low-carbon policy in various countries. Border Econ Cult 6:9–10

Wackernagel M, Rees WE, Testemale P (1996) Our ecological footprint: reducing human impact on the earth. Popul Environ 1(3):171–174

Wang W, Lin JY, Cui SH, Lin T (2010) An overview of carbon footprint analysis. Environ Sci Technol 33(7):71–78

Wang S, Yang FL, Xu L et al (2013) Multi-scale analysis of the water resources carrying capacity of the Liao he Basin based on ecological footprints. J Clean Prod 53(16):158–166

Wei M (2015) A study on development of Chongqing low-carbon economy based by system dynamics theory. Chongqing University, Chongqing

Wiedmann T, Barrett J (2011) A greenhouse gas footprint analysis of UK Central Government, 1990–2008. Environ Sci Policy 14(8):1041–1051

Wiedmann T, Minx J, Barrett J et al (2006) Allocating ecological footprints to final consumption categories with input-output analysis. Ecol Econ 56(1):28–48

Wittkop CA, Teranes JL, Dean WE et al (2009) A lacustrine carbonate record of Holocene seasonality and climate. Geology 37(8):695–698

Xiao L, Zhao XG, Hua-Xing XU (2013) Dynamics of carbon footprint and carbon carrying capacity of Shandong province. J Ecol Rural Environ 29(2):152–157

Xiuping Z, Guozhang Z (2016) Dynamics of carbon footprint and carbon carrying capacity of Shanxi province. J Shanxi Agric Univ (Nat Sci Ed) 36(2):128

Zhao XG, Cai-Hong MA, Xiao L et al (2013) Spatiotemporal changes of carbon footprint in Shaanxi province. Sci Geogr Sin 33(12):1537–1542

Zhao X, Caihong MA, Xiao L et al (2013b) Dynamic of carbon footprint and vegetation carbon fixation quantity in Beijing. J Arid Land Res Environ 27(10):8–12

Zhao RQ, Huang XJ, Liu Y et al (2014) Urban carbon footprint and carbon cycle pressure: the case study of Nanjing. J Geog Sci 24(1):159–176

Zheng Y (2012) A review of researches on low-carbon city evaluation index system. Bus Econ

Chapter 7
A Framework for Quantifying Carbon Emissions Generated During Demolition Waste Processing

Y. Li, H.Y. Wu, Z.Z. Wu, J.Y. Wang, H.B. Duan, J. Zuo, Z.D. Li and X.L. Zhang

7.1 Introduction

The construction industry represents a large share of carbon emissions. In the United States, the commercial and residential buildings take up 39% of the total CO_2 emissions annually (USGBC 2016). In order to mitigate global climate change, many countries have set CO_2 emission reduction goals (Gustavsson et al. 2010). Nowadays,

Y. Li · H.Y. Wu · Z.Z. Wu · J.Y. Wang (✉) · H.B. Duan
School of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: wangjy@szu.edu.cn

Y. Li
e-mail: 1183754186@qq.com

H.Y. Wu
e-mail: szwhyme@163.com

Z.Z. Wu
e-mail: wuzezhou88@gmail.com

H.B. Duan
e-mail: huabo@szu.edu.cn

J. Zuo
School of Architecture and Built Environment,
The University of Adelaide, Adelaide, Australia
e-mail: Jian.Zuo@adelaide.edu.au

Z.D. Li
Department of Building and Real Estate,
The Hong Kong Polytechnic University, Hung Hom, Hong Kong
e-mail: clydelee718@gmail.com

X.L. Zhang
Department of Public Policy, College of Liberal Arts and Social Sciences,
City University of Hong Kong, Kowloon Tong, Hong Kong
e-mail: xiaoling.zhang@cityu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_7

as there is a large scale of urban renewal in China, the generation of demolition waste is very huge (Wu et al. Wu et al. 2015a, 2016). In the treatment and disposal procedures of demolition waste, tremendous carbon emissions are generated due to energy consumption and exhaust emission from machines and vehicles operation. Thus, there is a necessity to quantify the carbon emissions from demolition waste.

In academic, efforts have been made to quantify carbon emissions from buildings. Nässén, et al. (2007) assessed the direct and indirect energy use and carbon emissions in the production phase of buildings. Kneifel (2010) estimated the estimate life-cycle carbon emission reduction of energy efficiency measures in new commercial buildings. Gustavsson et al. (2010) evaluated the carbon emissions of an eight-stores wood-framed apartment building. Yu et al. (2011) compared the carbon emissions of a bamboo-structure building with an alternative brick-concrete building. Shao et al. (2014) found that materials contributed up to 90% of the energy consumption and carbon emission in buildings. Chau et al. (2015) conducted a critical review of life cycle carbon emissions assessment on buildings. Wu et al. (2015b) quantified carbon emissions of construction waste using streamlined life cycle assessment. From the literature review, it can be found that no attempt has been tried on quantifying the carbon emission of demolition waste. Therefore, the aim of this paper is to propose a framework for quantifying the carbon emission of demolition waste processing.

7.2 Framework of the Quantification Method

There are several steps involved in the framework of SLCA based theory designed to quantifying carbon emission of demolition waste process, as shown in Fig. 7.1.

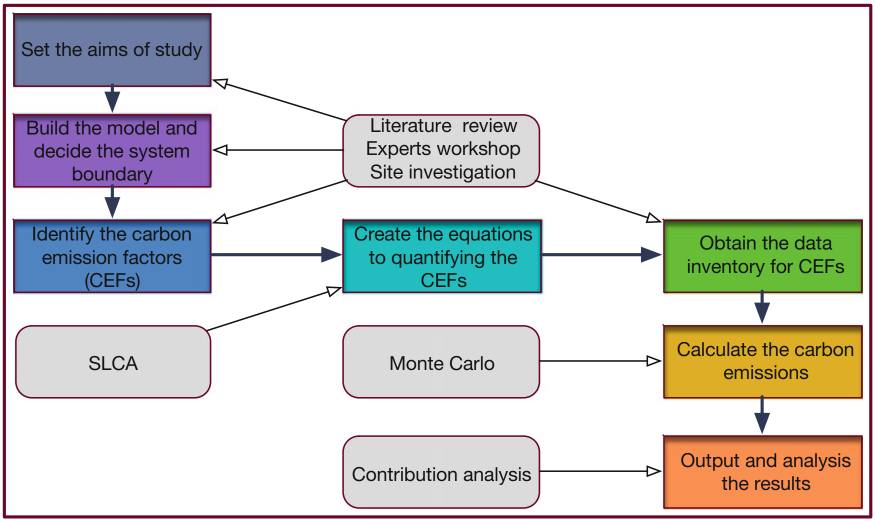


Fig. 7.1 Framework of the quantification method

(1) Set the aims of study. Similar to any scientific study, the first step is to set the aims of the study. The aims of study are usually proposed to fill the gaps of previous studies or solve the problems in the practice by reviewing academic literature or institute reports. For this study, we design the model to quantify the carbon emission of demolition waste processing to find out the highest/lower carbon emission waste process activities, which is a matter of great significance in waste management practice. Meanwhile, the model proposed in this study also improves the shortages in previous carbon emission assessment tools.
(2) Build the model and decide the system boundary. After decided the aims of study, it is necessary to build the model that illustrates the key subjects and activities in the process flow. This step is not only helpful to decide the system boundary, but also helpful to present knowledge to gain the understanding of how demolition waste is processed in the practice. It also provides an opportunity to identify and refine the scientific questions to be addressed. This work is usually started by reviewing literature and closed by discussing frequently with scholars and experts in industry.
(3) Identify the carbon emission factors (CEFs). This work is actually on going with the above step, but it is also acceptable to be conducted after completing the model. The carbon emission factors can be identified by reviewing related literature at the beginning of this step, but the emission factors list should be refined by discussing with scholars as well as practical experts.
(4) Create the equations to quantifying the CEFs. Once the system boundary has been decided and carbon emission factors have been identified, quantification equations would be created based on the theory of SLCA. These equations should be structured logically and clearly, and every notation should have real sense. This is the corn stage of the quantification framework.
(5) Obtain the data inventory for CEFs. There are normally hundreds of data set involved in the quantification equations, so it is unlikely to obtain all of them from single data source. That means there are usually several data sources provided data for the study and the reliability of them are difference. Therefore, it is necessary to consider the uncertainty of data, which could make the final results more robust.
(6) Calculate the carbon emissions. Since some indicators have a set of data which may obey a certain distribution, it is uncertain whether the mean values can really reflect the true values of these indicators. Therefore, Monte Carlo statistical simulations are performed to capture the uncertainty and sensitivity by using Crystal Ball software. 1000 trials for each parameter are drawn for each run. After each run of 1000 trials, the average, standard deviation, and the range encompassing 95% of observed results are recorded and analyzed. The step can measure, prioritize, and potentially minimize uncertainty in the final results. Understanding uncertainty helps to improve confidence in results comparisons as well as any decisions that might be made based on the results.
(7) Output and analysis the results. Along with the common results analysis like maximum-minimum analysis, a contribution analysis is also undertaken to sort the impacts of activities within the whole process flow. The goal of contribution

analysis is to determine the set of interest (SOI), which is helpful in characterizing the object's overall impacts. In addition, the SOI allowed us to identify which activities contribute the most/least to the results, leading to an understanding of which activities could be targeted for further analysis.

7.3 Demolition Waste Process Flow and Carbon Emission Factors

In order to identify the process flow and carbon emission factors of demolition waste, an interview was conducted during November 2014–February 2015 in Shenzhen city by interviewing 15 managers and engineers who participated demolition works and demolition waste process. The demolition waste process flow and involved carbon emission factors are illustrated in Fig. 7.2.

The carbon emission during demolition waste processing refers CO_2 generated during the processing of demolition waste from its generation to final disposal, including the direct generation and indirect generation parts. The direct generation parts indicate CO_2 produced from the operation of machines and chemical reaction of materials; the indirect generation parts indicate the CO_2 related to energy consumed by transport vehicles and diverse machines.

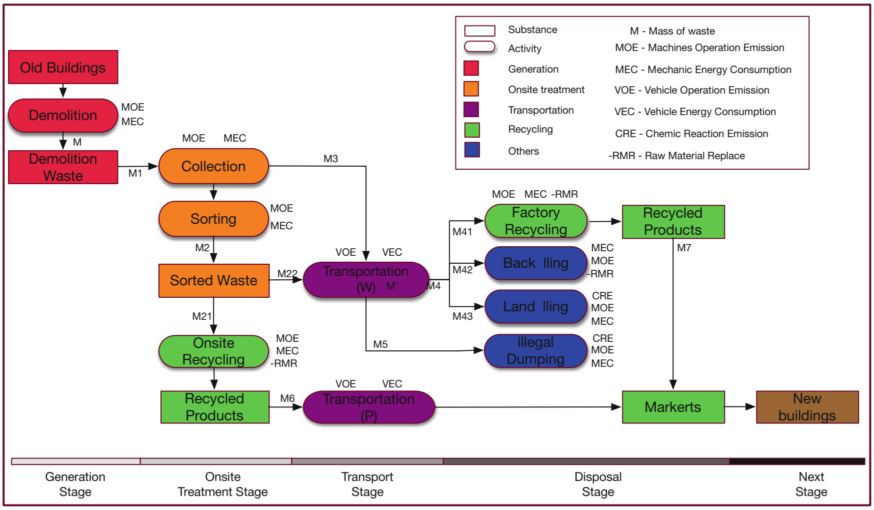


Fig. 7.2 Demolition waste process flow and carbon emission factors

Generally, from the generation to the final disposal, demolition waste process involves four main stages: generation, onsite treatment, transport and disposal. However, the first two stages are difficult to be distinguished since onsite treatments are normally ongoing during the demolition activities. And sometimes, some compositions of demolition waste (i.e. concrete, mortar, bricks, etc.) are produced into recycled aggregates or backfilled.

In the generation stage, demolition waste is generated due to the demolition of old buildings, so demolition actives are important considerations of quantifying carbon emissions. Although there are more than four demolition ways, including manual demolition, mechanic demolition, manual-mechanic demolition, blasting demolition, etc., but the most common demolition method is manual-mechanic demolition. Therefore, the carbon emission factors that be considered in this stage include machine operation exhaust, mechanic energy consumption. After/during demolition process, demolition waste is often sorted based on material composition by hands or machines. This is discarded based on the size of waste blocks.

After that, the sorted demolition waste groups would be packed and transported to different destinations, which may include landfills, recycling factories, illegal dumps, etc. In this stage, transport vehicle exhaust and energy consumption are considered as the carbon emission factors. The carbon emissions of these two factors are mainly influenced by the amount of transported waste, transport vehicle model, transport frequency, transport distance, transport working hours, transport vehicle idle running time, transport speed, etc.

In the disposal stages, demolition waste is disposed in different ways due to its compositions as well as the waste disposal plan. Landfill is the most common way to dispose demolition waste in China, although the majority of demolition waste compositions can be disposed in the way of recycling, which is also the way highly recommended by governments and scholars. The alternate ways include backfill and illegal dumping. In these ways, the carbon emissions are attributed to mechanic operation exhaust, mechanic energy consumption, material chemical reaction emissions.

7.4 Quantification Model

Consider the process of demolition waste of a demolition project, as shown in Fig. 7.2, in which several stages and activities that create carbon emission are involved. For every carbon emission factors, they can be calculated by considering several indicators (175 indicators are considered in the full quantification model), a shorted list of notations is show in Table 7.1.

Table 7.1 List of notations

Notation	Description
E_x (kg-eqv)	Carbon emission
dm_x (day/kg)	Machine working day per mass of demolition waste
f_x (kg-eqv/day)	Carbon emission quantity per working day of machine
fu_x (kg-ecq/day)	Fuel consumption quantity per working day of machine/vehicle
el_x (kw/day)	Fuel consumption quantity per working day of machine
$f_{x_{fu}}$ (kg-eqv/kg-ecq)	Carbon emission quantity per fuel consumption of machine/vehicle
$f_{x_{el}}$ (kg-eqv/kw)	Carbon emission quantity per electricity consumption of machine
M (kg)	Mass of waste
L_0 (kg)	Load capability of single vehicle
n (times)	Transport times
L_x (km)	Distance from site to site
v (km)	Average driving speed
h_x (h)	working hour of driving/waiting
e_x (kg-eqv/kg)	Carbon emission quantity per mass of raw materials replaced

7.4.1 Equations for Generation Stage

As shown in Fig. 7.2, we can observe that the carbon emission of generation stage E_{Ge} is contributed by the demolition activity only, so E_{Ge} is equal to E_{De}, which concludes the direct emission of machine' operation E_{De-MOE} and the mechanic energy computation E_{De-MEC}, as show in Eq. (1). For these two factors, they can be calculated by Eqs. (2) and (3). Specifically, fuel (*fu*) and electricity (*el*) are two energy sources used by demolition machines, so they are separately considered when calculating E_{De-MEC}.

$$E_{Ge} = E_{De} = E_{De-MOE} + E_{De-MEC} \tag{1}$$

$$E_{De-MOE} = \sum M * dm_{De-MOE} * f_{De-MOE} \tag{2}$$

$$\begin{aligned} E_{De-MEC} = & \sum M * dm_{De-MEC} * fu_{De-MEC} * f_{De-MEC} \\ & + \sum M * dm_{De-MEC} * el_{De-MEC} * f_{De-MEC_{el}} \end{aligned} \tag{3}$$

Where the subscript Ge of E_{Ge} refers to the generation stage; De of E_{De} refers to the demolition activity, De–DOM refers machine operation emission in demolition activity and De–MEC refers to mechanic energy consumption in demolition activity, respectively. We can find that the notations in subscripts before the symbol "–" refer to stage or activity, and the notations after "–" refer to emission factors labor/machine operation emission/mechanic energy consumption, and the meanings of notations alternate with the subscripts

7.4.2 Equations for Onsite Treatment Stage

Similar to the generation stage, carbon emission factors of onsite treatment stage also consider machine operation emission and mechanic energy consumption. However, as shown in Fig. 7.2, unlike the demolition stage, this stage includes three potential activities: collection, sorting and onsite recycling, so the carbon emission in this stage E_{OT} is calculated by plus these three emission factors: E_{Co}, E_{So} and E_{OR}, which is shown in Eq. (4) and the calculation of them are shown in Eqs. (5–7), respectively. Specifically, since sometimes generated waste will be transported out of site after collection, and sometimes they will be sorted before transportation and after collection, the notations M_{x} are introduced in the equation to reflect the different scenarios. The mass of collected waste M_1 equals mass of sorted waste M_2 plus mass of transported waste without sorting M_2, and M_1 equals the mass of generated waste M. Besides, since the recycled products can replace the use of according raw materials, so when calculation the emission of onsite recycling E_{OR}, it is reasonable to deduct the carbon emission produced by replaced raw materials E_{OR-RWR}, as shown in Eq. (7).

$$E_{OT} = E_{Co} + E_{So} + E_{OR} \tag{4}$$

$$\begin{aligned} E_{Co} = E_{Co-MOE} + E_{Co-MEC} = & \sum M_1 * dm_{Co-MOE} * f_{Co-MOE} \\ & + \sum M_1 * dm_{Co-MEC} * fu_{Co-MEC} * f_{Co-MEC} \\ & + \sum M_1 * dm_{Co-MEC} * el_{Co-MEC} * f_{Co-MEC_{el}} \end{aligned} \tag{5}$$

$$\begin{aligned} E_{So} = E_{So-MOE} + E_{So-MEC} = & \sum M_2 * dm_{So-MOE} * f_{So-MOE} \\ & + \sum M_2 * dm_{So-MEC} * fu_{So-MEC} * f_{So-MEC} \\ & + \sum M_2 * dm_{So-MEC} * el_{So-MEC} * f_{So-MEC_{el}} \end{aligned} \tag{6}$$

$$\begin{aligned} E_{OR} = E_{OR-MOE} + E_{OR-MEC} - E_{OR-RWR} = & \sum M_{21} * dm_{OR-MOE} * f_{OR-MOE} \\ & + \sum M_{21} * dm_{OR-MEC} * fu_{OR-MEC} * f_{OR-MEC} \\ & + \sum M_{21} * dm_{OR-MEC} * el_{OR-MEC} * f_{OR-MEC_{el}} - M_6 * e_{RWR} \end{aligned} \tag{7}$$

Where M_2 equals mass of waste transported out of site M_{22} plus mass of waste being recycled onsite M_{21}, and when the project does not use the onsite recycling method M_{21} is 0 and M_{22} equals M_2. Besides, M_6 equals M_{21} multiplied by the recycling conversation rate which is normally 0.9.

7.4.3 Equations for Transport Stage

As shown in Fig. 7.2, there two activities indicate transport and Eq. (8) for the carbon emission of transport stage E_{Tr} also considers $E_{Tr(w)}$ and $E_{Tr(P)}$, which is logically correct and appropriate, but in fact, the transportation (P) for recycled products will not exist if the project does not use the onsite recycling, and vice versa. Since the carbon emission and fuel consumption of transportation varies when vehicle is unloaded or fully loaded, so the emissions of vehicle under these two situations are considered separately, using $E_{Tr(w)-VOE_e}$ and $E_{Tr(w)-VOE_f}$ in Eq. (9) as well as using $E_{Tr(w)-VEC_e}$ and $E_{Tr(w)-VEC_f}$ in Eq. (10) to highlight this difference. This is also the reason why we use L_e and L_f to represent the unloaded driving distance and fully loaded driving distance in Eq. (11), although they are both calculated by using transport times n multiplied by distance from site to site L. Since the equations for $E_{Tr(P)}$ are similar to $E_{Tr(w)}$, except the differences of inputted parameters, we do not lie them out in order to save the pages.

$$E_{Tr} = E_{Tr(w)} + E_{Tr(P)} = E_{Tr(w)-VOE} + E_{Tr(w)-VEC} + E_{Tr(P)} \tag{8}$$

$$\begin{aligned} E_{Tr(w)-VOE} &= E_{Tr(w)-VOE_e} + E_{Tr(w)-VOE_f} \\ &= L_e * fe_{Tr(w)-VOE_e} + L_f * fe_{Tr(w)-VOE_f} \\ &= \mathrm{n} * \mathrm{L} * fe_{Tr(w)-VOE_e} + n * L * fe_{Tr(w)-VOE_f} \\ &= \frac{\mathrm{M}'}{l_0} * \mathrm{L} * fe_{Tr(w)-VOE_e} + \frac{\mathrm{M}'}{l_0} * L * fe_{Tr(w)-VOE_f} \end{aligned} \tag{9}$$

$$\begin{aligned} E_{Tr(w)-VEC} = {} & E_{Tr(w)-VEC_e} + E_{Tr(w)-VEC_f} = L_e * fu_{Tr(w)-VEC_e} * f_{Tr(w)-VEC_{fu}} \\ & + L_f * fu_{Tr(w)-VEC_f} * f_{Tr(w)-VEC_{fu}} = \mathrm{n} * \mathrm{L} * fu_{Tr(w)-VEC_e} * f_{Tr(w)-VEC_{fu}} \\ & + \mathrm{n} * \mathrm{L} * fu_{Tr(w)-VEC_f} * f_{Tr(w)-VEC_{fu}} = \frac{\mathrm{M}'}{l_0} * \mathrm{L} * fu_{Tr(w)-VEC_e} * f_{Tr(w)-VEC_{fu}} \\ & + \frac{\mathrm{M}'}{l_0} * \mathrm{L} * fu_{Tr(w)-VEC_f} * f_{Tr(w)-VEC_{fu}} \end{aligned} \tag{10}$$

7.4.4 Equations for Disposal Stage

Four typical disposal ways are considered in this model as shown in Fig. 7.2, so Eq. (11) to calculating carbon emission in disposal stage E_{Dis} is calculated by plus carbon emission of recycling $E_{Dis,R}$, backfilling $E_{Dis,B}$, landfilling $E_{Dis,L}$ and illegal dumping $E_{Dis,ID}$ together. It is noticeable that all four disposal ways are not always used in one project and usually there is only one or two used, so 0 is assigned to the notation of disposal way which is not used in the project. As the recycled products of recycling and the waste used to backfill can replace the use of raw materials, so the emissions of raw materials replaced $E_{Dis,R-RWR}$ and $E_{Dis,B-RWR}$ are deducted in Eq. (12) and (13). This is based on the same reason that mentioned in the calculation of onsite recycling part above. Since waste disposed in landfills and illegal dumps would generate carbon emission due to the chemic reaction, Eq. (14) considers the $E_{Dis,L-CRE}$ along with $E_{Dis,L-La}$, $E_{Dis,L-MOE}$ and $E_{Dis,L-MEC}$, and so Eq. (15).

$$E_{Dis} = E_{Dis,R} + E_{Dis,B} + E_{Dis,L} + E_{Dis,ID} \tag{11}$$

$$\begin{aligned} E_{Dis,R} &= E_{Dis,R-MOE} + E_{Dis,R-MEC} - E_{Dis,R-RWR} \\ &= \sum M_{41} * dm_{Dis,R-MOE} * f_{Dis,R-MOE} \\ &\quad + \sum M_{41} * dm_{Dis,R-MEC} * fu_{Dis,R-MEC} * f_{Dis,R-MEC} \\ &\quad + \sum M_{41} * dm_{Dis,R-MEC} * el_{Dis,R-MEC} * f_{Dis,R-MEC_{el}} - M_7 * e_{RWR} \end{aligned} \tag{12}$$

$$\begin{aligned} E_{Dis,B} &= E_{Dis,B-MOE} + E_{Dis,B-MEC} - E_{Dis,B-RWR} \\ &= \sum M_{42} * dm_{Dis,B-MOE} * f_{Dis,B-MOE} \\ &\quad + \sum M_{42} * dm_{Dis,B-MEC} * fu_{Dis,B-MEC} * f_{Dis,B-MEC} \\ &\quad + \sum M_{42} * dm_{Dis,B-MEC} * el_{Dis,B-MEC} * f_{Dis,B-MEC_{el}} - M_8 * e_{RWR} \end{aligned} \tag{13}$$

$$\begin{aligned} E_{Dis,L} &= E_{Dis,L-MOE} + E_{Dis,L-MEC} + E_{Dis,L-CRE} \\ &= \sum M_{43} * dm_{Dis,L-MOE} * f_{Dis,L-MOE} \\ &\quad + \sum M_{43} * dm_{Dis,L-MEC} * fu_{Dis,L-MEC} * f_{Dis,L-MEC} + M_{43} * f_{Dis,L-CRE} \end{aligned} \tag{14}$$

$$\begin{aligned} E_{Dis,ID} &= E_{Dis,ID-MOE} + E_{Dis,ID-MEC} + E_{Dis,ID-CRE} \\ &= \sum M_{44} * dm_{Dis,ID-MOE} * f_{Dis,ID-MOE} \\ &\quad + \sum M_{44} * dm_{Dis,ID-MEC} * fu_{Dis,ID-MEC} * f_{Dis,ID-MEC} + M_{44} * f_{Dis,ID-CRE} \end{aligned} \tag{15}$$

7.5 Data Inventory Sources

As there are hundreds of factors and indicators involved in the model, it is difficult to obtain all the data from a single data source. So an identification of data inventory sources can help to make the quantification work in an easier and précised way. According to the attributions of individual indicators, these data can be found

Table 7.2 List of recommended data inventory sources

Indicators	Recommended data source order
M (kg)	Int
dm_x (day/kg)	Int, IPR, LR, CBD
f_x (kg-eqv/day)	CBD, IPR, LR, Int
fu_x (kg-ecq/day)	Int, IPR, LR, CBD
el_x (kw/day)	Int, IPR, LR, CBD
$f_{x_{fu}}$ (kg-eqv/kg-ecq)	CBD, IPR, LR, Int
$f_{x_{el}}$ (kg-eqv/kw)	CBD, IPR, LR, Int
L_0 (kg)	Int
v (km)	Int, IPR, LR, CBD
h_x (h)	Int, IPR, LR, CBD
e_x (kg-eqv/kg)	CBD, IPR, LR, Int

by conducting literature review (LR), institution published reports (IPR), commercial data base (CDB) and investigation (Int). The reliability of the data source can be ordered as: Int > CBD > IPR > LR, which is ordered from the first hand data to second/third hand data. But for some indicators, it is more recommended to use the data from CBD, since they are difficult to be measured and need big size of samples, such as f_x (kg-eqv/day), $f_{x_{fu}}$ (kg-eqv/kg-ecq), $f_{x_{el}}$ (kg-eqv/kw), etc. Considering the reliability and obtainability, namely chose the more obtainable source when the reliabilities are at the same level, we recommend the list of data inventory sources, which is shown in Table 7.2.

7.6 Conclusions

Since there is no attempt that has been tried on quantifying the carbon emission of demolition waste, the aim of this paper is to propose a framework for quantifying the carbon emission of demolition waste processing. The framework for quantifying carbon emissions from demolition waste processing involves seven main stages: set the aims of study, build the model and decide the system boundary, identify the carbon emission factors, create the equations to quantifying the CEFs, obtain the data inventory for CEFs, calculate the carbon emissions, and output and analysis the results. From the generation to the final disposal, demolition waste process involves four main stages: generation, onsite treatment, transport and disposal. When using the quantification model, both direct and indirect carbon emission need to be considered. This paper is value at providing a practical framework for scholars to quantify carbon emission from demolition waste processing.

Acknowledgements This study was supported by the Scientific Research Foundation of Introduced High Talent Financial Subsidies of Shenzhen University (000044), National Natural Science Foundation of China (NSFC) (21507090), NSFC (71272088), and NSFC (51478267).

References

Chau CK, Leung TM, Ng WY (2015) A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. Appl Energy 143: 395–413

Gustavsson L, Joelsson A, Sathre R (2010) Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. Energy Build 42(2):230–242

Kneifel J (2010) Life-cycle carbon and cost analysis of energy efficiency measures in new commercial buildings. Energy Build 42(3):333–340

Nässén J, Holmberg J, Wadeskog A, Nyman M (2007) Direct and indirect energy use and carbon emissions in the production phase of buildings: an input–output analysis. Energy 32(9): 1593–1602

Shao L, Chen GQ, Chen ZM, Guo S, Han MY, Zhang B et al (2014) Systems accounting for energy consumption and carbon emission by building. Commun Nonlinear Sci Numer Simul 19(6):1859–1873

USGBC (2016) Buildings and climate change. Available at website: http://www.eesi.org/files/climate.pdf

Wu H, Wang J, Duan H, Ouyang L, Huang W, Zuo J (2015a) An innovative approach to managing demolition waste via GIS: a case study in Shenzhen city, China. J Cleaner Prod

Wu H, Duan H, Wang J, Wang T, Wang X (2015b) Quantification of carbon emission of construction waste by using streamlined LCA: a case study of Shenzhen, China. J Mater Cycles Waste Manage 17(4):637–645

Wu H, Duan H, Zheng L, Wang J, Niu Y, Zhang G (2016) Demolition waste generation and recycling potentials in a rapidly developing flagship megacity of South China: prospective scenarios and implications. Constr Build Mater 113:1007–1016

Yu D, Tan H, Ruan Y (2011) A future bamboo-structure residential building prototype in China: life cycle assessment of energy use and carbon emission. Energy Build 43(10):2638–2646

Chapter 8
A Framework for Utilizing Automated and Robotic Construction for Sustainable Building

Mi Pan, Thomas Linner, Hui Min Cheng, Wei Pan and Thomas Bock

8.1 Introduction

Automation and robotics has been regarded as a leading area of innovation in construction, for the betterment of the industry. Research has been spread out for decades, and new automation and robotics technologies continue to be developed for the general manufacturing industry as well as for the construction industry (Bock and Linner 2015a). In the meantime, the building sector has received increasing attention under the worldwide agenda for sustainable development, since buildings account for more than 30% of global greenhouse gases (GHG) emissions and more than 40% of global energy consumptions (Unep 2009). Nevertheless, the development of sustainable buildings (SBs) has experienced problematic implementation on all levels [design, construction, operation, etc. (Pan and Ning 2014)]. Performance gaps, poor operation and management exist to impede the achievement of SBs, requiring advanced technologies and intelligent approaches (Goodier and Pan 2010). Construction automation and robotics has the potential to improve sustainability performance in terms of construction waste reduction, resource saving, workplace safety improvement, intelligent living environment, etc. Recently, the EU, for example, started to initiate and fund projects in which improvements in construction automation and prefabrication shall bring down cost for sustainable, highly energy-efficient components and buildings in order to foster their adoption in Europe in a large scale (BERTIM 2016; ZERO-PLUS 2016). Also, some construction companies already use advanced production technologies to reduce waste and resource consumption (Bock and Linner 2015a), and first approaches are on the

M. Pan (✉) · W. Pan
Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong SAR
e-mail: panmi@hku.hk

T. Linner · H.M. Cheng · T. Bock
Chair of Building Realization and Robotics, Technical University of Munich, Munich, Germany

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_8

way to use automation technology for controlled disassembly of buildings and urban-mining (Lee et al. 2015).

However, in general, in the architecture and civil engineering filed, up to date most of the relevant research was focused on the adoption of new approaches and technologies in the operation and maintenance stages (Wood 2011) of buildings (e.g. smart grids, building automation, green building technologies, the use of information technology for maintenance automation, etc.), whilst the potential of automated/robotic technologies to achieve sustainability through the construction stage is a field that needs yet to be analyzed and developed in a comprehensive manner. Activities during the construction stage have significant impacts on SB: (e.g. on various types of pollution, construction waste and resource consumption, work conditions and public welfare, cost efficiency (Akadiri et al. 2012), reusability and flexibility of buildings, etc.) which can be controlled and influenced for better outcomes through automated/robotic technologies.

The aim of this paper is to build the basis for the development of a systematic framework and assessment tool for the utilization of automated and robotic construction technologies for achieving SBs. The remainder of the paper is structured as follows. Section 8.2 reviews the state of the art of technology and approaches in construction automation and SB. Based on this, Sect. 8.3 outlines the key dimensions of the framework, and identifies relevant mechanisms and indicators summarized in a framework matrix. Section 8.4 provides a brief outlook on the future work which will detail the indicators, define quantifiable variables, and verify and validate the framework through application in case studies and real world projects.

8.2 Background

This section reviews the state of the art of technology and approaches in construction automation and SB that build the basis for the development of the framework.

8.2.1 Development of Automated and Robotic Technology for Building Construction

Construction automation and robotics generally refers to a wide spectrum of machinery applications for automating construction processes across the whole project lifecycle, from the initial design, on-site and off-site construction, maintenance and operation control, to the eventual disassembly/demolition (Castro-Lacouture 2009). Mahbub (2008) defined that construction automation and robotics as the use of self-control mechanical and electronic machinery with intelligent control to conduct construction tasks automatically. Examples of construction automation are shown in Fig. 8.1.

Historically, the first introduction of automation in construction can be traced back to the manufacturing of industrialized building components and the prefabrication of modular homes in Japan in the 1970s (Bock and Linner 2015a). That introduction laid the foundation for later world-wide exploration of automation in construction. In the 1980s, many single-task prototype robots have been developed, primarily in the consideration of the low productivity and possible future labor shortfall and issues. Later on, full-scale application of on-site automated construction was introduced, with the first building project completed in 1991 in Japan (Bock and Linner 2016a). The adoption of on-site automated construction systems demonstrated multiple benefits including a large reduction of waste, significant time saving, flexible working conditions, and improved quality, but a high capital expenditure (Bock and Linner 2016b; Hasegawa 1999). Recently, the actual R&D activities on a worldwide level are concentrating more on the emerging software and IT technologies, like sensor-based monitoring and tracking, the utilization of robots for automated facade installation (Iturralde et al. 2015), robots and technologies for building renovation (e.g. asbestos removal robots) (Bock and Linner 2015a), and robotic technologies for building deconstruction (Lee et al. 2015).

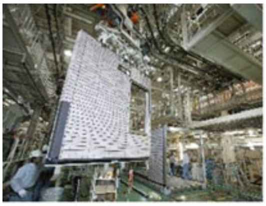
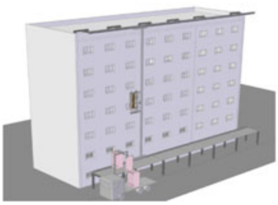
		
Large-scale deployment of sustainable buildings through advanced prefabrication (Image: Sekisui Heim)	Enhanced skills and knowledge workers though cooperative single-task robots (Image: Exoskeleton "Fortis"/ Photo Courtesy of Lockheed Martin Corporation. Copyright 2016)	Improved resource efficiency through automated high-rise construction (Image: Obayashi/ T. Bock)
		
Improvement of renovation rate through automated façade renovation (Image: K. Iturralde/TUM)	Automated building disassembly for urban-mining (Image: HAT DOWN system by Takenaka Corporation/ T. Bock)	Robots for asbestos removal and building renovation (Image: Takenaka Corporation)

Fig. 8.1 Examples for construction automation utilized in the context of sustainable building (Bock and Linner 2015, 2016a, b; this image of Takenaka's asbestos removal robot is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization [NEDO])

8.2.2 The Development of SB

SB is regarded as a holistic and transparent approach for addressing sustainability related to buildings and construction in the consideration of triple bottom line aspects, i.e. economic, environmental and social (ISO 2008). It has been defined in different ways, along with the evolution of the concept of sustainable development (Berardi 2013). Kibert (1994) proposed an early definition of sustainable construction which should produce a healthy built environment in view of resource-efficient and ecological principles in the First International Conference on Sustainable Construction. The term "sustainable building" appeared in journal papers since 1996, followed by a fast-growing trend (Pan and Ning 2014).

Principles and sustainability assessment methods have been developed to interpret the concept of SB. Despite of the diffusions, most of the proposed principles share the common framework of sustainability with economic, environmental and social aspects (Pan and Ning 2014; ISO 2008). However, in terms of assessing the sustainability of a building, most developed methods concern only environmental criteria, covering the efficiency in the resource use, and impacts on human health and environment (Berardi 2013). Accordingly, energy performance and GHG emissions are the most commonly used parameters to assess sustainable buildings (Berardi 2013). In addition, the operational phase, which is responsible for the majority of energy consumption and GHG emission, is often the main or only focus (Unep 2009; ISO 2008; Berardi 2013). Latest studies indicated that greater importance should be attached to the social and economic contexts (Berardi 2013; Selberherr and Girmscheid 2013).

8.3 A Systems Framework of Automation and Robotics for SB

According to the developments and tendencies in automated construction and SB outlined in the previous section, a strategy for the development of the framework and its key dimensions was developed (Fig. 8.2). In the technological dimension, three main automated and robotic technologies (Bock and Linner 2015a, 2016a, b) are considered for achieving SB in the construction phase as follows: (1) Automation in prefabrication: automation and robotics for customized and prefabricated components and modules; (2) Single-task construction robots: elementary technologies and single-task construction robots; (3) automated/robotic on-site factories (AROFs). In the sustainable dimension, impacts pertaining to the triple bottom line can be outlined as follows (ISO 2008), notwithstanding uncertainties exist in the consideration of economic and social aspects in different countries (Unep 2009): (1) Environmental: impacts to resources (materials) and environment; (2) Economic: economic value and productivity; (3) Social: health, satisfaction, cultural value, and equity. This strategy will be used in the subsequent works, to categorize our literature and research findings and identify the relevant indicators and mechanisms through integration across two dimensions. Sustainable dimension will be mapped to technological dimension, to explore how each type of automated and robotic technology can contribute to SB during the construction stage.

8.3.1 Automation in Prefabrication of SB

Automation in prefabrication or robotic industrialization, refers to the automation and robotics applied in the prefabrication of buildings, or components thereof, in the off-site factories (Neelamkavil 2009). Prefabrication as an innovative way of construction, enabling strategies from manufacturing sector, like mass production, to be applied, and allow mechanization, automation, and robotization to easily trespass into the construction industry (Neelamkavil 2009). It is reported that automation in prefabrication has the ability to control the continuous life-cycle flow of energy, resources, information and workforce, achieving sustainability in every aspect of the triple bottom line (Bock and Linner 2015a). Prefabrication has commonly been recognized as an environmentally friendly practice in construction industry, as it contributes to the reduction of environmental impact during construction though the reduced material use, energy consumptions and waste production (Steinhardt et al. 2013; Hampson and Brandon 2004; Linner and Bock 2012). Automated approaches can catalyze the efficient use of natural resources in many ways. For example, optimization of resource utilization can be achieved by scheduling automation in prefabricated flow-shops under different circumstances. Sensor-based control can not only track the material and components for better interactions, but also detect geometry of waste for reuse (Neelamkavil 2009). With industrial robots and automated control, the collection and sorting of waste can be well harmonized and integrated into the prefabrication process (Bock and Linner 2015a). Energy consumption and carbon emissions linking to the working process can therefore be cut down. The negative impacts of prefabrication approach

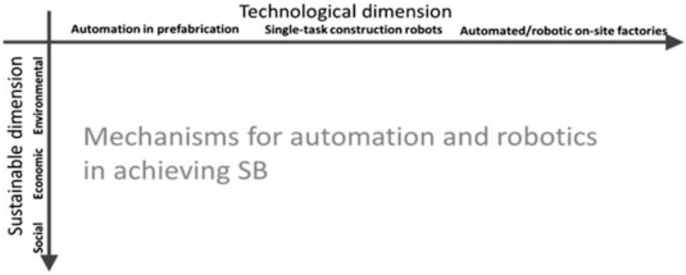


Fig. 8.2 A systems framework of mechanisms of utilizing automated and robotic technologies for SB

on environment lie in the additional energy use and GHG emissions associated with the transportation of prefabricated components. In this respect, automation techniques, like systematization of transportation, can reduce these effects to the minimum (Neelamkavil 2009).

8.3.2 Single-Task Construction Robots for SB

Single-task construction robots are those designed for a single, specific construction task, to be conducted in repetitive manner, which largely emerged in 1980s. Examples like mobile handling robots, concrete finishing robot, ceiling board installation robots, and fire proofing robots (Castro-Lacouture 2009; Cousineau and Miura 1998). These robots can help to do lots of repetitive, dangerous or sophisticated works, relieving pressures on labor shortage and skill mismatch, but also challengeable since they can hardly be cooperative with human beings and be integrated with upstream and downstream processes (Bock and Linner 2016a). Economic factors are sometimes recognized as barriers for single-task construction robots to be implemented on-site (Neelamkavil 2009). Bock and Linner (2016a) reported that experience has demonstrated the poor economic performance of the majority of developed construction robots. Thus, the core of single-task robots in the first place is to replace human workers in hazardous jobs and improving occupational health and safety (Bock and Linner 2016a). Recently, new forms of single-task robots emerged building on aerial approaches, additive manufacturing technologies, exoskeletons, swarm robotic approaches, self-assembling building structures, and even humanoid robot technology, which bring the new tendency goes towards collaborative robots that work together with and assist the human being instead of substituting it. In this respect, human workers are still required to operate complicated machines such as robots. To achieve good social sustainability of applying single-task robots, continuous education and training of workers to upgrade the professional skills is of great importance (Bock and Linner 2016a).

8.3.3 Automated/Robotic on-Site Factories for SB

Automated/robotic on-site factories (AROFs) are complete and integrated on site automation systems used mainly in high-rise construction (Bock and Linner 2016b; ISO 2008). Reduced waste is the major benefit of AROFs, according to the tests of existing prototypes. The first applied AROF in the world, named SMART, achieved a 70% reduction in waste with the integration of off-site prefabrication and on-site automation (Cousineau and Miura 1998). Additionally, the whole process can be integrated and the energy efficiency of machines can be optimized (Bock and Linner 2015b). The environmental value of AROFs can also be linked to component re-use and urban-mining focused deconstruction (Lee et al. 2015). The tendency towards automated construction and deconstruction would allow materials and components be reused so that high-rise buildings and city areas can act as an urban mine. With AROFs, the building under deconstruction can be dis-assembled instead of demolished, and the components do not have to be melted down for energy consumed recycling but can be refreshed and re-used directly in the construction of another building (Lee et al. 2015). AROFs can offer better working environment, improve worker safety and health, and minimize disturbances to neighbors, ensuring the wellbeing of both workers and the public (Cousineau and Miura 1998). Meanwhile, the full scale automation of the building construction can have more significant impacts, compared to the single-task robots, on the employment. The requirement of manual workers on site can be dramatically reduced, whilst more skilled knowledge workers should be engaged in R&D relevant works. Jobs and roles should be redefined to a social sustainable development.

8.3.4 Identification of Indicators and Mechanisms

It is possible to identify the main streams from the literature and outline the potential mechanisms as a guide to future practice of automation and robotics in SB. The implications of automation and robotics on environmental, economic and social sustainability in the construction stage are manifold. The adoption of automation and robotics, including automation in prefabrication, single-task construction robots, and AROFs, has the capability to reduce environmental impacts and improve resource efficiency, long-term economic value, productivity, quality, wellbeing of workers, industry and the public. Basic indicators and mechanisms identified by the research presented in this paper are outlined in the following.

Indicators:

See Fig. 8.3.

Mechanisms:

1. ***The relationship between automation and SB is mutually-reinforcing***: Automation in construction is not new, but the real world application is still in its infancy (Bock and Linner 2015b). The lack of economic interest is the main hurdle (Mahbub 2008; Cousineau and Miura 1998). Recently, the industry is embarking on a new paradigm with the upsurge of the concept of SB, and the focus has begun to shift from short-term financial interest to long-term sustainable value (Unep 2009), offering a new cut-in point to automation. Additionally, previous literature has demonstrated that automation and robotics can make a significant contribution to SB in the construction stage from a multifaceted concern (Castro-Lacouture 2009; Cousineau and Miura 1998; Bock and Linner 2015b). Therefore, automation and SB, although often seen as two academic branches with little in-depth blending, can certainly reinforce each other. To expedite their co-production, a new paradigm should be established,

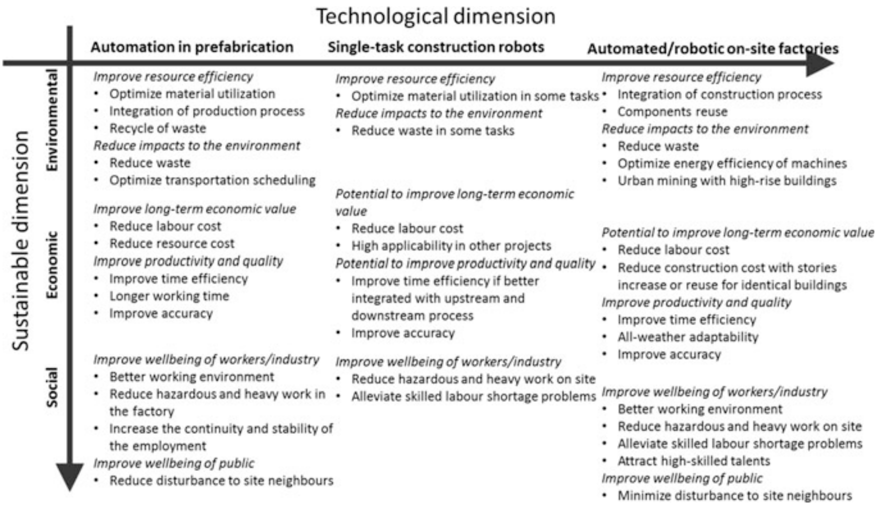


Fig. 8.3 Framework matrix: summarization of identified mechanisms/indicators relevant for characterizing the use of construction automation for SB

considering automation and robotics for achieving SB, which, in turn, could stimulate the uptake of automation in construction.

2. ***Flexibility of automation and robotics is the key to unleash the potential of achieving SB***: The literature has provided evidence of achieving SB in construction stage with automation and robotics (Castro-Lacouture 2009; Cousineau and Miura 1998; Bock and Linner 2015b). But the potential has been strangled in certain scenarios, and economic sustainability cannot be well embodied. For example, AROFs are hardly suit for other buildings in different architecture, single-task robots have fixed functions and the ability to adjust the complicated and dynamic construction workplace is limited (Warszawski and Navon 1998). Meanwhile, automation in prefabrication often enables the use of multipurpose unit to achieve flexible production in a sustainable manner, dramatically improving the efficiency and lowering down the production cost. Therefore, flexibility is the key to unleash the potential of automation and robotics for achieving SB. Technological breakthroughs are needed for greater flexibility and adaptability.
3. ***Attention is needed to the impacts of automation on sustainable labor market***: Safety is apt to be the primary concern for introducing automation. But beyond safety, SB in construction stage also needs to maintain a stable and harmonious labor market. Automation and robotics can alleviate labor shortage (Linner and Bock 2012), but may also lead to a massive labor surplus and high unemployment rate (Sandberg et al. 2008), which inevitably pose a threat to social sustainability. Thus, to minimize these negative impacts, it is essential for continuous training and early identification of irreplaceable skills to enable a gradual shift of workforce from onerous physical labors to light physical or

mental works. Jobs and roles have to be redefined to offer more opportunities in R&D activities.

8.4 Future Work: Detailing and Validation of the Framework

Sustainability considerations require guidelines for making construction automation choices in tune with global sustainability development trends. The work presented in this paper will in a next step be translated into quantifiable indicators and variables. Ultimately the framework will be validated through application in case studies and real world projects as a tool that can be used to guide development and assessment of technologies, strategies and business models for utilizing robotic construction for SB. The framework will also be used to complement and extend existing building standards such as BREEAM (2016) or LEED (2016).

Acknowledgements The work presented in this paper partly financed by a grant from the Germany/Hong Kong Joint Research Scheme sponsored by the Research Grants Council of Hong Kong (Reference No. G-HKU704/15) and the German Academic Exchange Service (DAAD Grant No. 57217359).

References

Akadiri PO, Chinyio EA, Olomolaiye PO (2012) Design of a sustainable building: a conceptual framework for implementing sustainability in the building sector. Buildings 2(2):126–152
Berardi U (2013) Clarifying the new interpretations of the concept of sustainable building. Sustain Cities Soc 872–878
BERTIM (2016) http://www.bertim.eu/
Bock T, Linner T (2015a) Robotic industrialization: automation and robotic technologies for customized component, module and building prefabrication. Cambridge University Press, Cambridge
Bock T, Linner T (2015b) Robot oriented design. Cambridge University Press, Cambridge
Bock T, Linner T (2016a) Construction robots: elementary technologies and single-task-construction robots, Cambridge
Bock T, Linner T (2016b) Site automation: automated/robotic on-site factories. Cambridge University Press, Cambridge
BREEAM (2016) http://www.breeam.com/
Castro-Lacouture D (2009) Construction automation. In: Handbook of automation. Springer, Berlin
Cousineau L, Miura N (1998) Construction robots: the search for new building technology in Japan. ASCE Publications
Goodier CI, Pan W (2010) The future of UK housebuilding. RICS, London
Hampson KD, Brandon P (2004) Construction 2020-A vision for Australia's property and construction industry. CRC Construction Innovation
Hasegawa Y (1999) Robotization in construction. Kogyo Chosakai Publishing, Tokyo

ISO (2008) Sustainability in building construction—general principles, Geneva
Iturralde K, Linner T, Bock T (2015) Development and preliminary evaluation of a concept for a modular end-effector for automated/robotic facade panel installation in building renovation. In: 10th conference on advanced building skins 4662–4671, Bern, Switzerland
Kibert CJ (1994) Establishing principles and a model for sustainable construction. In Proceedings of the first international conference on sustainable construction, 6–9, Tampa Florida, Nov
Lee S, Pan W, Linner T, Bock T (2015) A framework for robot assisted deconstruction: process, sub-systems and modelling. In: Proceedings of the 32nd international symposium on automation and robotics in construction and mining, Oulu, Finland
LEED (2016) http://www.usgbc.org/leed
Linner T, Bock T (2012) Evolution of large-scale industrialization and service—innovation in Japanese prefabrication industry. J Constr Innovation Inf Process Manage 12(2):1471–4175
Mahbub R (2008) An investigation into the barriers to the implementation of automation and robotics technologies in the construction industry. Queensland University of Technology
Neelamkavil J (2009) Automation in the prefab and modular construction industry. In 26th symposium on construction robotics ISARC
Pan W, Ning Y (2014) Dialectics of sustainable building: evidence from empirical studies 1987–2013. Build Environ 82:666–674
Sandberg M, Johnsson H, Larsson T (2008) Knowledge-based engineering in construction-the prefabricated timber housing case. J Inf Technol Constr (ITcon) 13408–13420
Selberherr J, Girmscheid G (2013) An interdisciplinary cooperation network for the optimisation of sustainable life cycle buildings. International Council for Research and Innovation in Building and Construction (CIB) Brisbane
Steinhardt DA, Manley K, Miller W (2013) Reshaping housing: the role of prefabricated systems
UNEP SBCI (2009) Buildings and climate change. UNEP, France, Paris
Warszawski A, Navon R (1998) Implementation of robotics in building: current status and future prospects. J Constr Eng Manage 124(1):31–41
Wood BR (2011) Rethinking automation in the sustainable building. In: 28th international symposium on automation and robotics in construction, IAARC, Seoul, Korea
ZERO-PLUS (2016) http://www.zeroplus.org/

Chapter 9
A Literature Review of Sustainable Urbanization in China

Y.T. Tan and H. Xu

9.1 Introduction

China's road to urbanization has been considered unique because it is neither identical with that of the developed economies nor does it duplicate the model found in developing countries (Young and Deng 1998; Dong and Putterman 2000; Zhang and Zhao 2003). A great amount of ink has been spilled to paint the picture of China's urbanization by economists, planners, geographers in recent decades (Zhang et al. 2003; Zhang and Song 2003; Wang et al. 2009; Chen et al. 2011). China's urbanization can be classified into three periods, the rapid stage of decline (1960–1978), the stable stage of ascension (1979–1995), and the rapid development stage (after 1995), which have brought vast profits for the stakeholders (Che et al. 2013). However, the rapid urbanization and economic development have caused many problems for the environment, society and governance. Sustainable urbanization is an effective way to promote the sustainable development of China's urban area and has been emphasized by many researchers along with the rapid process of urbanization (Ma et al. 2011; Li et al. 2009; Enserink and Koppenjan 2007; Zhao 2010). The implementation of sustainable urbanization from various aspects has been attempted by many cities in China, and many experiences have been accumulated. However, a review of these experiences, using existing studies on sustainable urbanization in China, is yet to be presented.

This paper provides a critical review of recent studies on sustainable urbanization in China, especially for the case studies of China's major cities. After an

Y.T. Tan (✉)
Department of Building & Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
e-mail: bstan@polyu.edu.hk

H. Xu
School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_9

overview of the sustainable urbanization, the review of studies on sustainable urbanization in China was conducted. The review includes three parts, comprising of viewing sustainable urbanization in China from different perspectives, four types of sustainable urbanization at the city scale of China, and evaluation of sustainable urbanization. The discussion section gives a brief summary of the findings and recommendations for future studies.

9.2 An Overview of Sustainable Urbanization

Urbanization is directly related to expansion of urban areas and growth of the proportion of total population leaving rural areas and moving to live in urban areas. Since 1978, China has been experiencing a rapid and unprecedented process of urbanization, created by the world's largest rural-urban migration flow after the government's strict regulation of intra-country migration slackened (Kojima 1995). The level of urbanization in China was less than 20% in 1978, and the data first crossed over the 50% threshold in 2011 (Zhang and Lin 2012). Many studies have been done on China's urbanization from different perspectives of rural and urban population migration, such as history of the migration (Chan and Xu 1985), the migration trend (Chan 1994), the patterns and driving force of the migration (Zhang and Song 2003).

Henderson et al. (2009) have identified distinctive features of China's urbanization by comparison with other countries (Henderson et al. 2009). These features are: (1) the comparative high rate of urbanization, (2) large and growing urban-rural income gap, (3) too many cities with too few people, (4) unbalanced economic structure of cities, and (5) strict administrative hierarchy. The large gap in income between urban and rural residents is the main reason for rural to urban migration in China. Many cities have unbalanced economic structures due to excessive development of land and land scarcity problem becomes more serious (Chen 2007). Three questions regarding urbanization in China have been raised, including influence factors, outcomes, and policy interventions. A more balanced approach to urban policy interventions in China are needed in the context of market-based development (Heikkila 2007). China's transition to sustainability should take full use of its advantage to implement effective measures that can infiltrate every side of the society rapidly (Liu 2010).

In the context of China, the process of sustainable urbanization is of high significance. China has gained tremendous achievements in economic growth and poverty reduction after nearly four decades of urbanization. Many policies and actions have been established and implemented for the degraded ecological environment caused by the rapid urbanization process. Strategies such as proper consumers' consumption patterns, low resource consumption, and sustained economic growth have been adopted. However, China still faces enormous arduous tasks to improve people's livelihood and needs to go through a very long way to coordinate the improvement of ecological degradation and the economic development.

The only way to alleviate the problems is to follow the strategy of sustainable development (Zhang and Wen 2008; National Development and Reform Commission (NDRC) 2012). To better achieve sustainable development, the government of China considered sustainable development as the national strategy in the Ten Strategic Policies for Environment and Development (National Environmental Protection Agency (NEPA) 1993). The connotations of sustainable urbanization in China have been enriched in recent years.

9.3 Methodology

The reviewed papers are mainly retrieved from the SCI and SSCI database. The key words used in literature searching include "sustainable urbanization", "sustainable development", "urbanization + sustainability", "urbanization + China", etc. When searching by using the key words "sustainable urbanization"/"sustainable development"/"urbanization + sustainability", the resulting papers related to case study of China's cities are selected. When using the key word "urbanization + China", papers related to the sustainable development are selected. The searching results include journal papers and reports. Along with the search rule, the time span of the selected papers is from 1985 to 2015.

9.4 Review of Existing Studies on Sustainable Urbanization in China

Cities as ecosystems have to be placed in a context of global economic activity, where political, human, economic and social organizations are responsible for the organizational structure, development, and supply chains (Pincetl 2012). Sustainable urbanization is an integrated complex concept with many aspects. Ng et al. (2001) and Ng (2002) pointed out that sustainable urban regeneration is a community-based process, achieving changes in many aspects, including economic, environmental, and social well-being (Ng et al. 2001; Ng 2002). A multi-perspective review provides a comprehensive evaluation of the concept of sustainable urban development. The review of the selected papers includes three parts: (1) viewing sustainable urbanization in China from different perspectives; (2) sustainable urbanization of four types of China's cities; and (3) evaluation of sustainable urbanization, all as shown in Fig. 9.1. The multi-perspectives of sustainable urbanization include views of eco-environmental protection, land development, energy utilization, population growth and migration, housing, and policy. The four typical types of cities include compact city, mining city, coastal city, and megacity. The third part focuses on the evaluation of sustainable urbanization, which is related to the previous two parts.

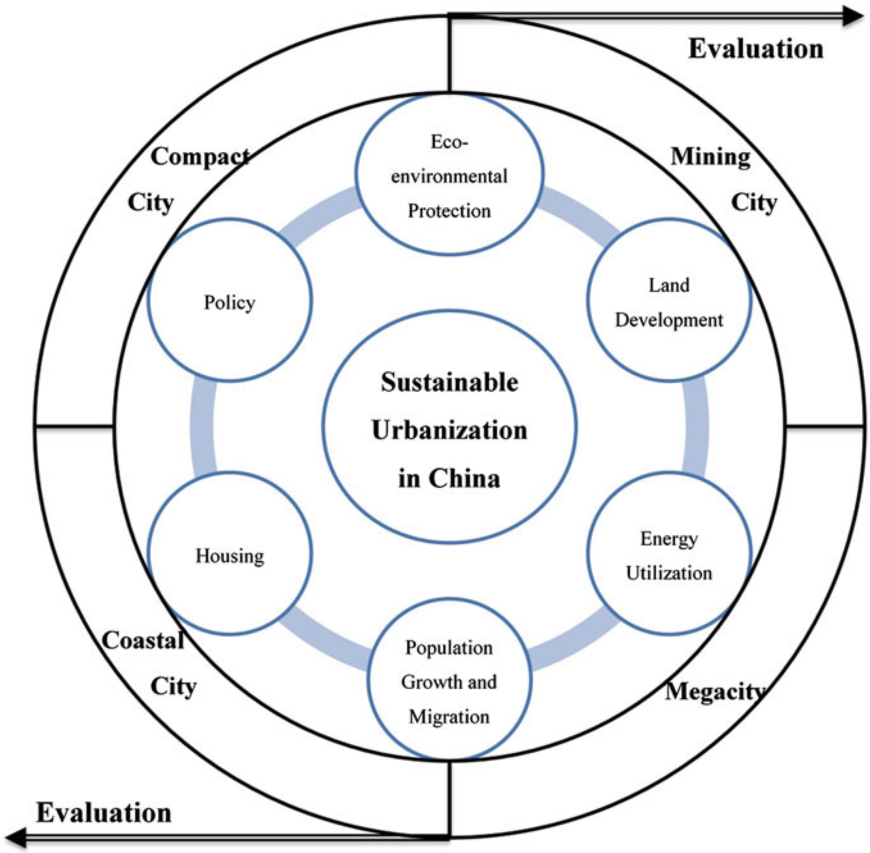


Fig. 9.1 Framework of sustainable urbanization in China

9.5 Discussion

Urban development can be viewed as a complex system (Munoz 2003). There is a need to focus on the main issues. Based on this literature review, three areas are considered important for sustainable urbanization in China, as shown in Fig. 9.2. The complexity of a city can be evaluated by using an appropriate method, and the problems relating to sustainable development can be found. To tackle these problems, innovative solutions should be proposed. For evaluation and solution, there is a need for the engagement of all stakeholders in decision-making to nurture a sustainable culture in a city. Furthermore, the possible research directions will be discussed in this section because researchers are always at the frontier in solutions in sustainable development. The relationship between the three concepts, namely Evaluation, Innovative Solutions and Engagement of Stakeholders, is shown in Fig. 9.2.

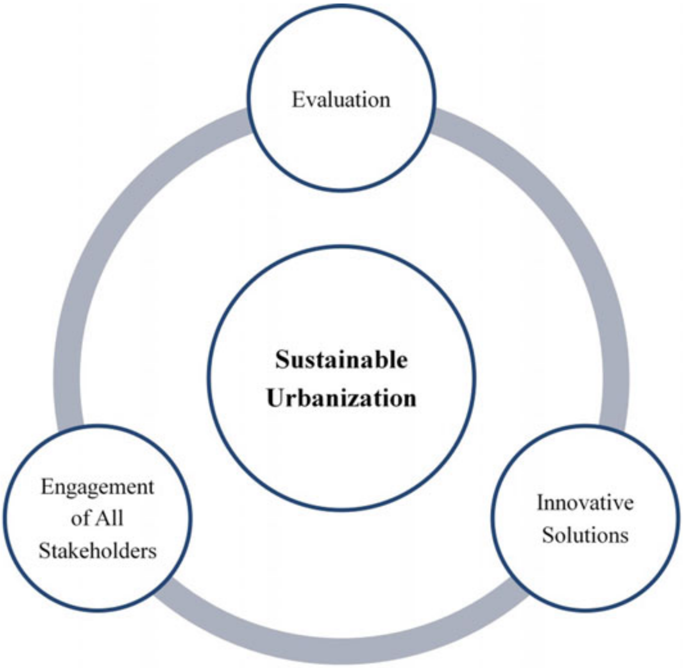


Fig. 9.2 Three key areas for sustainable urbanization in China

9.5.1 Evaluation

Evaluation is a process of collecting, selecting, and analyzing information in order to provide a summary report. The evaluation is considered as an effective way to have a better understanding of a city's current status and pressures in sustainable development. Based on the evaluation results, effective responses can be made to solve the existing problems and find ways for sustainable development. The indicator system has often been used for sustainability evaluation, and various indicator systems have been developed and been reviewed above. It can be seen that different indicators systems were developed for different cities and with different indicators. Therefore, the results cannot be compared and may be inconsistent by using different systems. Another problem is that the urbanization process is dynamic and few studies have considered the system in a dynamic way. Therefore, there is a need to develop a comprehensive and dynamic system for evaluation of sustainable urbanization. The third problem is the availability of data. It is not difficult to get the data of hard indicators and assess them. For those soft indicators, such as governance, corruption, poverty, it is not easy to get data and assess. This could be another research direction in future.

9.5.2 Innovative Solutions

After evaluation, the stakeholders should make their response to the existing problems. According to the evaluation results, relevant solutions should be formulated. The solutions include relevant policies, urban planning, urban regulations, enterprise action programmes, non-governmental organizations' (NGOs) participation scheme, public participation planning, etc. To solve existing problems, the conventional methods may not be effective. Therefore, there is a need for the engagement of all stakeholders to find out some innovative solutions. For example, best practices in sustainable urbanization are very useful because the experiences can be transformed into knowledge for supporting future practice. Therefore, experience mining from best practices in sustainable urbanization is considered as a new research direction.

Furthermore, China is facing four emergent issues caused by urbanization, including environmental protection, land use, energy use, and population & housing. These four issues could be the future research directions. For environmental protection, the environmental cost should be considered during the development of a city. For land usage, all stakeholders' opinions should be taken into consideration. For energy use, an energy-saving target should be made for sustainable development. For population & housing, a long term plan should be made because the population growth rate in China is doing down.

9.5.3 Engagement

Sustainable urbanization requires the engagement of all stakeholders in a city. Government and other stakeholders should make response to the existing problems. Government plays an important role in urban development, which can promote sustainable urbanization effectively through policies, planning regulations and schemes. Furthermore, Government's support on sustainable urbanization is also important, such as incentive schemes. "*Provision of good regulatory frameworks and incentives could help increase the engagement of the private sector in sustainable urbanization*" (UNECS 2014). To better achieve sustainable urbanization, all stakeholders need to find ways to solve their problems in sustainable development (Rudd 2004). For example, the enterprises should consider to minimize their environmental impact and to take corporate social responsibility when developing their business in new regions. NGOs can provide more supports to developing countries for their cities' sustainable development. The public should actively participate in a city's sustainable development. Public participation in decision-making processes of a city should be strengthened. A sustainable culture should be nurtured because culture is a driver of sustainable urban development (UNECS 2014). Sustainable urban development can be achieved by the engagement of all stakeholders, exchange of goals, expectations and resources (Enserink and Koppenjan 2007). Therefore, the engagement of all stakeholders in decision-making process is another potential research direction in future.

9.6 Conclusions

China has been experiencing a rapid urbanization process during the past 4 decades. Many environmental and social problems have been raised due to unbalanced development. These problems are not only affecting China, but also the whole world. China needs to find solutions to tackle these problems because more people will move to cities in the next few decades. This paper gives a comprehensive review of sustainable urbanization in China, including academic papers and reports. The eco-environmental protection, land development, energy utilization, population growth and migration, housing and policy issues and four typical cities were discussed in the paper. Based on the review, it is concluded that three areas are critical to the success of sustainable urbanization in China. They are evaluation, innovative solutions and engagement of all stakeholders. Furthermore, future potential research directions were also discussed for exploring new research areas of sustainable urbanization. For research on evaluation, most studies only focus on one or two aspects of sustainable urbanization and do not consider the dynamic processes of a city. Comprehensive and dynamic evaluation methods should be developed in future research. Experience mining from best practice is another research direction because cities can learn from those best practices and perform better in sustainable development.

Acknowledgements This research was supported by (1) The Departmental Research Fund for New Academic Staff (Project No.: 4-ZZDX) of the Department of Building & Real Estate, The Hong Kong Polytechnic University; (2) MOE (Ministry of Education in China) Project of Humanities and Social Sciences “The Operational Risk Pressure and Resilient Response Strategies of the Complex Urban Public Spaces” (No. 17YJC630189).

References

Chan KW (1994) Urbanization and rural-urban migration in China since 1982. Mod China 20 (3):243–281

Chan KW, Xu X (1985) Urban population growth and urbanization in China since 1949: reconstructing a Baseline. China Q 104(7):583–613

Che M, Liu W, Tao X (2013) Evolution and assessment on China’s urbanization 1960-2010: under-urbanization or over-urbanization? Habitat Int 38(1):25–33

Chen J (2007) Rapid urbanization in China: a real challenge to soil protection and food security. CATENA 69(1):1–15

Chen J, Guo F, Wu Y (2011) One decade of urban housing reform in China: urban housing price dynamics and the role of migration and urbanization, 1995-2005. Habitat Int 35(1):1–8

Dong XY, Putterman L (2000) Prereform industry and state monopsony in China. J Comp Econ 28:32–60

Enserink B, Koppenjan J (2007) Public participation in China: sustainable urbanization and governance. Manage Environ Qual Int J 18(4):459–474

Heikkila EJ (2007) Three questions regarding urbanization in China. J Plan Edu Res 27(1):65–81

Henderson JV, Quigley J, Lim E (2009) Urbanization in China: policy issues and options. China Economic Research and Advisory Programme

Kojima R (1995) Urbanization in China. Dev Econ 33(2):151–154

Li F, Liu X, Hu D, Wang R, Yang W, Li D, Zhao D (2009) Measurement indicators and an evaluation approach for assessing urban. Landscape Urban Plan 90:134–142

Liu J (2010) China's road to sustainability. Science 328(5974):50

Ma L, Liu P, Fu F, Li Z, Ni W (2011) Integrated energy strategy for the sustainable development of China. Energy 36(2):1143–1154

Munoz F (2003) Lock living: urban sprawl in Mediterranean cities. Cities 20(6):381–385

National Development and Reform Commission (NDRC) (2012) China's National Report on sustainable development. China Environmental Science Press, Beijing

National Environmental Protection Agency (NEPA) (1993) Ten strategic policies for environment and development. China Environmental Science Press, Beijing

Ng MK (2002) Sustainable urban development issues in Chinese transitional cities: Hong Kong and Shenzhen. Int Plan Studies 7(1):7–36

Ng MK, Cook A, Chui EWT (2001) The road not travelled: a sustainable urban regeneration strategy for Hong Kong. Plan Pract Res 16(2):171–183

Pincetl S (2012) Nature, urban development and sustainability—what new elements are needed for a more comprehensive understanding? Cities 29(SUPPL.2):S32–S37

Rudd MA (2004) An institutional framework for designing and monitoring ecosystem-based fisheries management policy experiments RID C-1244-2009. Ecol Econ 48(1):109–124

UNECS (2014) 2014 integration segment: sustainable urbanization. United Nations Economic and Social Council

Wang YP, Wang Y, Wu J (2009) Urbanization and informal development in China: urban villages in Shenzhen. Int J Urban Reg Res 33(4):957–973

Young D, Deng H (1998) Urbanisation, agriculture and industrialisation in China, 1952–91. Urban Studies 35(9):1439–1455

Zhang C, Lin Y (2012) Panel estimation for urbanization, energy consumption and CO_2 emissions: a regional analysis in China. Energy Policy 49:488–498

Zhang HK, Song SF (2003) Rural–urban migration and urbanization in China: evidence from time-series and cross-section analyses. China Econ Rev 14(4):386–400

Zhang KM, Wen ZG (2008) Review and challenges of policies of environmental protection and sustainable development in China. J Environ Manage 88(4):1249–1261

Zhang L, Zhao SX (2003) Reinterpretation of China's under-urbanization: a systemic perspective. Habitat Int 27(3):459–483

Zhang L, Zhao SXB, Tian JP (2003) Self-help in housing and chengzhongcun in China's urbanization. Int J Urban Reg Res 27(4):912–937

Zhao P (2010) Sustainable urban expansion and transportation in a growing megacity: consequences of urban sprawl for mobility on the urban fringe of Beijing. Habitat Int 34 (2):236–243

Chapter 10
A Macro-Micro Framework of ADR Use in the Malaysian Construction Industry

Chia Kuang Lee, Tak Wing Yiu and Sai On Cheung

10.1 Introduction

As disputes are almost inevitable in complex projects (Cheung and Yiu 2006), the use of Alternative Dispute Resolution (ADR) is important in resolving any manifested disputes. Despite its importance, the use of ADR in the Malaysian construction industry was low (Chong and Mohamad-Zin 2009). Appreciation towards ADR as a whole was also found to be discouraging (Chong and Mohamad Zin 2012). To promote and improve the level of ADR use in the Malaysian construction industry, the key players should strategize effective means of interventions and policies. Inspired by Coleman's scheme, this paper considers the importance of modelling decision making process of ADR users.

Coleman's scheme entails four important nodes. Node A represents propositions of macro conditions; Node B represents descriptions of micro conditions, which are independent variables in assumptions about regularities of individual behaviour; Node C represents micro-outcomes, which describe individual behaviour; and Node D represents propositions of macro outcomes (Raub et al. 2011). Each node is linked with arrows. Macro conditions influence micro conditions (arrow 1), and micro-outcomes is the result of regularities of individual behaviour (arrow 2). Finally, macro outcomes stem from myriads of effects at the micro level. The scheme has plausible account of transitions in rational choice explanations (Little 2012), and was used to understand decision-making in a macro-micro perspective (Liefbroer 2015; Klobas and Ajzen 2015). Due to the merits offered by this scheme,

C.K. Lee (✉) · T.W. Yiu
Department of Civil and Environmental Engineering, Faculty of Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
e-mail: chiakuang85@gmail.com

S.O. Cheung
Department of Architecture and Civil Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_10

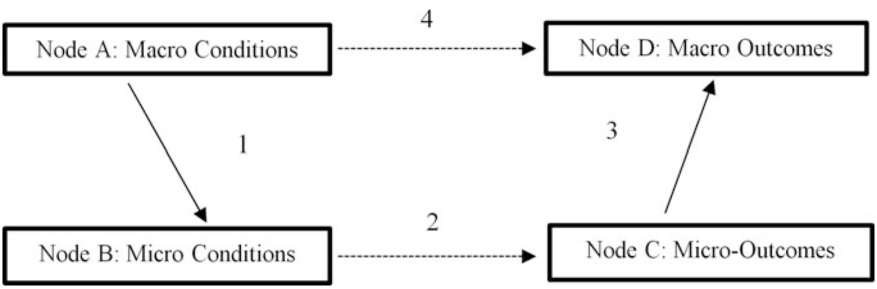


Fig. 10.1 Coleman's scheme (1987, 1990)

it is thus adopted as a framework to explain decision making in ADR use (Fig. 10.1).

For interventions to be carried out effectively, existing beliefs of decision makers must be altered and similarly exposed to new beliefs in using ADR. This can only be achieved if the assumptions about the regularities of individual behaviour in ADR use are strongly founded. Drawing on **Theory of Planned Behaviour**, this paper further demonstrates an individual's decision making process in ADR use. Meanwhile, macro conditions, such as institutional isomorphism derived from **Institutional Theory** systematically influence individual's decision to use ADR.

10.2 Macro-Micro Perspective of ADR Use

Based on Coleman's micro-macro links (Coleman 1987; Coleman 1990), this section offers practical premise of understanding on how micro phenomena (such as frustration and lack of preference in using ADR), and macro phenomena (such as low rates of ADR use) can be improved by attentively focusing on user's decision making process. Figure 10.2 shows the application of Coleman's scheme in ADR use.

As shown in Fig. 10.2, Node A represents the propositions of macro conditions (such as institutional conditions) leads to macro outcomes (Level of ADR use in the construction industry). This macro to macro relationship is linked with dotted arrow 4, which represents assumptions about empirical regularity at macro level (Raub et al. 2011). However, this macro level condition to macro outcomes is not a direct effect. The overall macro outcomes (Node D) is an aggregate result of individual's ADR actual use behaviour (Node C), which in turn is the result of decision maker's decision making process in ADR (Node B). The micro conditions (node B), is actually influenced by macro conditions (Node A).

In this connection, this paper explores the macro-micro domain and conceptualize the effect of macro conditions (Node A) to micro conditions (Node B), and to micro-outcomes (Node C). It further reveals the assumptions on how social

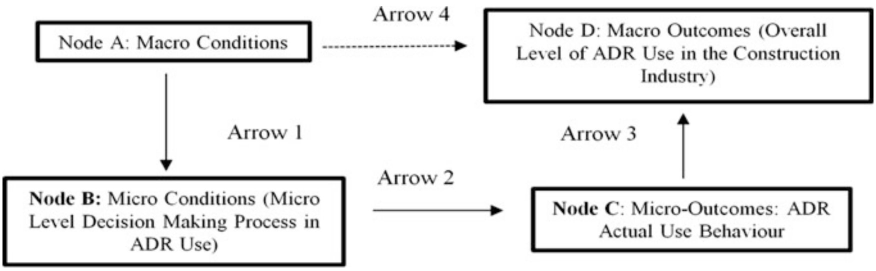


Fig. 10.2 Macro-micro perspective of ADR use [Modified based on Coleman's scheme (1987, 1990)]

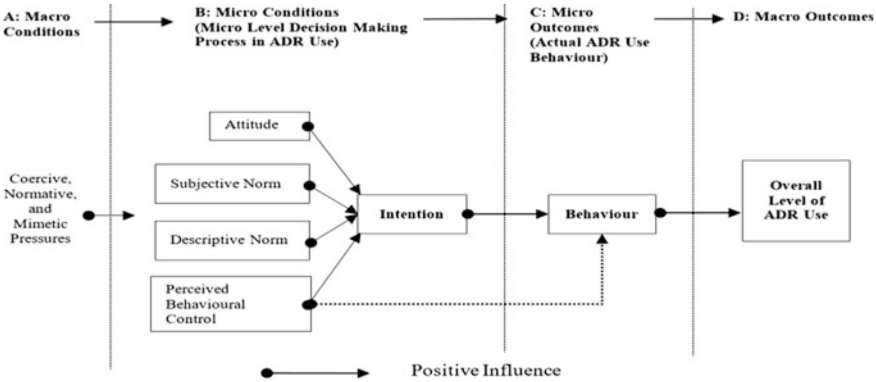


Fig. 10.3 A macro-micro framework of ADR use and its determinants

conditions affect individual's decision making process (dynamics of Arrow 1), and actual behaviour (dynamics of Arrow 2).

10.3 Macro-Micro Framework of ADR Use and Its Determinants

The determinants of ADR use is conceptualized in the form of macro-to-micro relations. The overall framework shown in Fig. 10.3 below depicts how macro outcomes (Overall level of ADR use in the construction industry) are determined by the micro-level decision making process, which is actually embedded in a macro-level configuration. The basic tenet of this framework is as follows: **Macro Conditions (A)** which comprise coercive, normative & mimetic pressures influence decision making process in ADR use (B). The construction of individual ADR use decision-making process would yield its corresponding outcomes of actual ADR use (C), and this regularity would eventually influence **Macro Outcomes (D)**—Overall level of ADR use in the construction industry.

Macro conditions refers to social conditions such as networks, and institutions which can be conceived as opportunities or constraints that determines decision making (Raub et al. 2011). Drawing on **Institutional Theory**, the effect of micro conditions fits with the prescription of institutional isomorphism, which posits that organisations have the tendency to behave congruently with socially accepted norms and institutional environment (DiMaggio and Walter 1983). Three basic types of institutional isomorphism include *coercive, mimetic* and *normative*. Institutional isomorphic pressures which exist in the form of coercive, normative, and mimetic pressures ultimately influence organisation's crucial decision makers and shape organizational behaviour (Cao et al. 2014; Teo et al. 2003). Coercive pressures is defined as "formal and informal pressures exerted on organisations by other organisations upon which they are dependent" (DiMaggio and Walter 1983). In the context of ADR use in construction projects, coercive pressures could stem from regulatory agencies, professional institutions, industry associations, and even government mandates. Normative pressures are associated with professionalisation (DiMaggio and Walter 1983). There are two aspects of professionalisation. The first refers to formal education by university specialists, while the second is the growth and elaboration of professional networks (DiMaggio and Walter 1983). These two embodiments can share norms and expectations through exchange of information and diffusion of values and beliefs (Cao et al. 2014). Mimetic pressures cause organization to imitate other organisations in its environment (DiMaggio and Walter 1983). Mimetic isomorphism occurs as organisations respond to uncertainties by modelling themselves after others who perceived to be more successful and legitimate (DiMaggio and Walter 1983; Cao et al. 2014; Liang et al. 2007).

Micro conditions refer to the micro level of decision making process of ADR users. The description of micro conditions refers to independent variables in assumptions about regularities of individual behaviour (Raub et al. 2011). According to Theory of Planned Behaviour (TPB), intention is the most proximal determinant of actual behaviour (Ajzen 1991). Similarly, perceived behavioural control also affords considerable contribution to the prediction of actual behaviour. Intentions can be overall defined as the instructions that people give themselves to perform particular behaviour (Triandis 1980). Intentions are culmination of decision making process (Sheeran et al. 2005). Most immediate predictor of a behaviour is a person's decision, or intention to act (Fife-Schaw et al. 2007). Formation of intention is fundamental in TPB (Liefbroer 2015). The determinants of intention are ***attitude***, ***subjective norm***, and ***perceived behavioural control*** (Ajzen 1991).

10.4 A Conceptual Macro-Micro Decision Making Framework

Although previous research investigated the factors influencing ADR use, yet the decision making process in ADR selection and use remains lacking (Lee et al. 2016). Based on the discussion above, this section presents a conceptual decision making model which describes the underpinning sequence and macro forces that drives ADR use behaviour. Drawing on both Theory of Planned Behaviour and Institutional Theory, the conceptual model is illustrated in the following sections and depicted in Fig. 10.4.

10.4.1 Predictors of Actual ADR Use—A Theory of Planned Behaviour Framework

Theory of Planned Behaviour (TPB) denotes that both intention and perceived behavioural control jointly predicts actual behaviour. When a behaviour is not under complete volitional control, perceived behavioural control may contribute significantly to the prediction of behaviour (Fife-Schaw et al. 2007); however if volitional control is high, intentions alone is a good predictor. This implies that although both intention and perceived behavioural control predicts behaviour, only one of it may contribute significantly to the prediction of behaviour (Ajzen 1991).

Intention is determined and formed by attitude, subjective norm, and perceived behavioural control (Ajzen 1991). Intention indicates how hard people are willing to try, or the level of effort willed in performing a behaviour (Fishbein and Ajzen 2010). Adapted from Ajzen (Ajzen 1991), intention can be mathematically represented as $I = (W1)\ A + (W2)\ SN + (W3)\ PBC$, where I is intention, A refers to

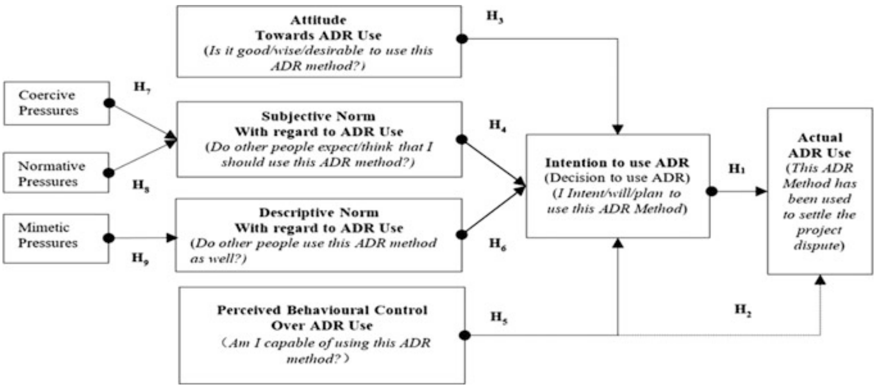


Fig. 10.4 A conceptual macro-micro ADR decision making framework

attitude, SN is subjective norm, PBC refers to perceived behavioural control, while W1, W2, and W3 are empirically determined weights. This theory depicts that the more favourable attitude and subjective norms, and the greater the perceived behavioural control, the stronger should be the intention to perform the behaviour of interest (Hrubes et al. 2001). Attitude toward a behaviour refers to the degree to which a person has a favourable or unfavourable appraisal of the behaviour (Doll and Ajzen 1992). People's attitude consistently derives from beliefs accessible in memory (Ajzen and Fishbein 2000), and is determined by salient beliefs about the behaviour (Ajzen 1985). Attitude is equated with the attitudinal salient belief (b_i) that performing the behaviour would produce the outcome in question, combined in a multiplicative fashion with evaluation of the desirability of that outcome (e_i) (Taylor and Todd 1995). If the resulting products are summed over *n* attitudinal salient beliefs, a person's attitude is directly proportional to this summative attitudinal belief: $A \propto \sum_{i=1}^{n} b_i e_i$ (Ajzen 1991). Subjective norm refers to pressure felt by a person with regard to the performance of an intended behaviour (Ajzen 1991). It is a social factor which refers to the perceived social factor to perform, or not to perform the behaviour (Ajzen and Madden 1986). Subjective norm is formed by an individual's normative beliefs (n_i) related to a referent weighted by the motivation to comply with the referent's beliefs (m_i) (Taylor and Todd 1995). If the product is summed over *n* normative salient beliefs, subjective norm is directly proportional to this summative normative belief: $SN \propto \sum_{i=1}^{n} n_i m_i$ (Ajzen 1991). Perceived behavioural control refers to control beliefs that deals with presence or absence of resources, opportunities, experiences that influences the perceived ease or difficult in performing a behaviour (Ajzen 1991). Perceived behavioural control is formed by the sum of control beliefs (c_i) weighted by the power of belief of the control factor in deterring or enabling the behaviour (Taylor and Todd 1995). If the product is summed over *n* control beliefs, it would give rise to the perception of behavioural control. Thus the perceptions about facilitating resources and opportunities can be written as: $PBC \propto \sum_{i=1}^{n} c_i p_i$ (Ajzen 1991). Decision to use ADR can be conceptualized as the intention to use ADR, and the factors influencing this decision making can be similarly influenced by attitude towards ADR, subjective norm with regard to use ADR, and perceived behavioural control over using ADR (Lee et al. 2016). Therefore, this conceptual Macro-Micro ADR Decision Making Framework postulates that:

Hypothesis 1 (H_1): Intention to use ADR will have a positive direct effect on actual ADR use; **Hypothesis 2 (H_2)**: Perceived behavioural control over ADR use will have a positive direct effect on actual ADR use; **Hypothesis 3 (H_3)**: Attitude towards ADR use will have a positive direct effect on intention to use ADR; **Hypothesis 4 (H_4)**: Subjective norm with regard to ADR use will have a positive direct effect on intention to use ADR; **Hypothesis 5 (H_5)**: Perceived behavioural control over ADR use will have a positive direct effect on intention to use ADR.

10.4.2 Additional Variables on TPB Framework

Descriptive norm is an additional factor that influences intention. Descriptive norm is defined as something that has been done, rather than ought to be done (Forward 2009). Descriptive norm measure perceptions of significant other's own behaviour (Rivis and Sheeran 2003). It describes what most others do (Li et al. 2014). Notably, descriptive norm are less likely to draw their influences from reward, coercive or legitimate power as others do not necessary have the power to expect, punish or reward the observer (Fishbein and Ajzen 2010). Drawing on this explanation, **Hypothesis 6 (H_6) postulates that**: Descriptive Norm with regard to ADR use will have a positive direct effect on the intention to use ADR.

10.4.3 Influence of Isomorphic Pressures

Coercive pressures on ADR use could stem from regulatory agencies, professional institutions, and industry associations. On the other hand, normative pressures could be derived from professionalization, where professional bodies within similar fields may form shared norms and diffusion of expectations through education, conferences, and professional consultations (Cao et al. 2014; Teo et al. 2003). In Malaysia, the Malaysian Bar Council is known for its assertive roles and representation of legal professionals that advocates for the establishment of specialist construction court (Ameer Ali 2010). Two major construction associations in Malaysia are the Construction Industry Development Board (CDIB), and Master Builders Association Malaysia (MBAM). Other professional construction bodies in Malaysia include the Board of Quantity Surveyors, Board of Engineers, Board of Architects, and the Professional Services Development Centre (PSDC). Nevertheless, ADR methods such as mediation or arbitration stipulated in Malaysian Construction Standard Form of Contracts are subject to professional institutional rules. Mimetic pressures on the other hand drive organisations to imitate and benchmark other successful organisations. Mimicry on peer projects with similar project characteristic and institutional backgrounds nevertheless grants decision makers legitimacy and sustain for competiveness in future projects (Cao et al. 2014). Facing disputes with uncertainties, imitating peer projects in ADR use can be seen as a way to hedge risk. Thus, **Hypothesis 7 (H_7) postulates that**: Coercive pressures will have a positive direct effect on subjective norm with regard to ADR use; **Hypothesis 8 (H_8) postulates that**: Normative pressures will have a positive direct effect on subjective norm with regard to ADR use; **Hypothesis 9 (H_9) postulates that**: Mimetic pressures will have a positive direct effect on descriptive norm with regard to ADR use.

Table 10.1 Selection of ADR methods for dispute settlement

Type of dispute	Proposed question
Describe the nature of the dispute in your current project (if any)	From this lists of ADR Method, please select (One) Best ADR method to settle this dispute Arbitration/Mediation/Adjudication/Dispute Review Board/Expert Determination

10.4.4 Proposed Methodology: Future Quantitative Studies

To test the conceptual framework shown in Fig. 10.4, 10.2 separate phases of studies have been proposed. The first phase of the study can be carried out to investigate the formation of intentions (decision making process). Based on the prompted actual dispute scenario, the decision makers/ADR users could be first asked to make a choice from a list of ADR method to settle the dispute (Table 10.1).

After making a proper selection on ADR method, respondents can be further prompted to evaluate the constructs with reference to the selected ADR method. Such evaluation can be carried out using a 5 or 7 point scales (Table 10.2).

Accordingly, the second phase of the study (longitudinal) can be undertaken to investigate actual ADR use behaviour. The results of this phase can be used to investigate **Hypothesis 1 ($\mathbf{H_1}$)**, on whether or not intention to use ADR has any significant positive relationship with actual ADR use. To achieve this, respondents could be re-contacted to provide their self-report on the actual ADR method used (Table 10.3).

Table 10.2 Proposed evaluations in phase 1

Model construct	Proposed example question
Intention	"I intend/will/plan to use this ADR method to settle this project dispute"
Attitude	"Is it good/wise/desirable to use this ADR method?"
Subjective norm	"Do other people expect/think that I should use this ADR method?"
Perceived behavioural control	"Am I capable of using this ADR method?"
Coercive pressures	"Do regulatory agencies/professional bodies/associations in Malaysia require and mandate the use of this ADR method in this project?"
Normative pressures	"Do regulatory agencies/professional bodies/associations encourage the value of this ADR method in this project?"
Mimetic Pressures	"Do other people use this ADR method as well?"

Table 10.3 Proposed evaluations in phase 2

Model construct	Proposed question
Actual ADR Use	"This ADR method has been used to settle the project dispute"

10.5 Conclusion

This paper proposes a conceptual framework in explaining the influences of macro conditions on micro decision making process on ADR use. Drawing on both **Theory of Planned Behaviour** and **Institutional Theory**, this paper demonstrates how individual's decision making process in ADR follows a consistent fashion in formulating beliefs. These cognitive beliefs serve as cognitive foundations for users' careful deliberation in ADR use. Macro conditions such as **institutional isomorphism** (derived from isomorphic institutional theory) systematically influence individual's intention to use ADR. This paper postulates that institutional pressures such as coercive, normative, and mimetic pressures exert influence on individual's intention through subjective norm, while mimetic pressures influence intention through descriptive norm. Future quantitative studies can be undertaken to investigate the underlying hypothesis. If this framework is established, it could offer practical premise for public policies and how ***micro phenomena*** (for example, lack of preference for the use of ADR), and ***macro phenomena*** (such as low rates of ADR use) can be improved by attentively focusing on user's decision making process. Investigations in decision making process offers practical premise for public policies and useful reflections that is beneficial for future ADR use interventions.

References

Ajzen I (1985) From intentions to actions: a theory of planned behavior. In: Kuhl J, Beckman J (eds.) Action-control: from cognition to behavior. Springer, Heidelberg, Germany, pp 11–39

Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–291

Ajzen I, Fishbein M (2000) Attitudes and the attitude-behavior relation: reasoned and automatic processes. Eur Rev Soc Psychol 11(1):1–33

Ajzen I, Madden TJ (1986) Prediction of goal-directed behavior: attitudes, intentions, and perceived behavioral control. J Exp Soc Psychol 22(5):453–474

Sheeran P et al (2005) Implementation intentions and health behaviour. Bibliothek der Universität Konstanz

Li L et al (2014) Key strategies for improving public transportation based on planned behavior theory: case study in Shanghai, China. J Urban Plann Dev, 0(0), 04014019

Liefbroer AC et al (2015) Reproductive decision-making in a macro-micro perspective: a conceptual framework. In: Philipov D, Liefbroer AC, Klobas JE (eds) Reproductive decision-making in a macro-micro perspective. Springer, Amsterdam, pp 1–16

Ameer Ali NAN (2010) Mediation in the Malaysian construction industry. In: Brooker P, Wilkinson S (eds) Mediation in the construction industry: an international review edn. Spon Press, USA and Canada, pp 82–107

Cao D, Li H, Guangbin W (2014) Impacts of isomorphic pressures on BIM adoption in construction projects. J Constr Eng Manag 140(40):04014056
Cheung SO, Yiu TW (2006) Are construction disputes inevitable? IEEE Trans Eng Manage 53 (3):456–470
Chong HY, Mohamad Zin R (2012) Selection of dispute resolution methods: factor analysis approach. Eng, Constr Architectural Manag 19(4):428–443
Chong HY, Mohamad-Zin R (2009) The behaviour of dispute resolution methods in Malaysian construction industry. Proceedings of the 2009 IEEM, 8–11 Dec 2009. 643–647
Coleman JS (1987) Microfoundations and macrosocial behavior. In: Alexander JC et al (eds) The micro-macro link. University of California Press, Berkeley, CA, pp 153–173
Coleman JS (1990) Foundations of social theory. Belknap Press of Harvard University Press, Cambridge, MA
DiMaggio PJP, Walter W (1983) The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. Am Sociol Rev 48(2):147–160
Doll J, Ajzen I (1992) Accessibility and stability of predictors in the theory of planned behavior. J Pers Soc Psychol 63:754–765
Fife-Schaw C, Sheeran P, Norman P (2007) Simulating behaviour change interventions based on the theory of planned behaviour: Impacts on intention and action. Br J Soc Psychol 46(Pt 1):43–68
Fishbein M, Ajzen I (2010) Predicting and changing behavior: the reasoned action approach. Psychology Press-Taylor and Francis Group, New York
Forward SE (2009) The theory of planned behaviour: the role of descriptive norms and past behaviour in the prediction of drivers' intentions to violate. Transp Res Part F: Traffic Psychol Behav 12(3):198–207
Hrubes D, Ajzen I, Daigle J (2001) Predicting hunting intentions and behavior: an application of the theory of planned behavior. Leisure Sci 23(3):165–178
Klobas JE, Ajzen I (2015) Making the decision to have a child. In: Philipov DD, Liefbroer ACAC, Klobas JEJE (eds) Reproductive decision-making in a macro-micro perspective. Springer, Amsterdam
Lee CK, Yiu TW, Cheung SO (2016) Selection and use of Alternative Dispute Resolution (ADR) in construction projects—past and future research. Int J Project Manage 34:494–507
Liang H et al (2007) Assimilation of enterprise systems: the effect of institutional pressures and the mediating rule of top management. MIS Q 31(1):59–87
Little D (2012) Explanatory autonomy and Coleman's Boat. Theoria 74:137–151
Raub W, Buskens V, Van Assen MALM (2011) Micro-macro links and microfoundations in sociology. J Math Sociol 25(1–3):1–25
Rivis A, Sheeran P (2003) Descriptive norms as an additional predictor in the theory of planned behaviour: a meta-analysis. Curr Psychol: Dev, Learn, Pers, Soc 22(3):218–233
Taylor S, Todd PA (1995) Understanding information technology usage: a test of competing models. Inf Syst Res 6(2):144–176
Teo HH, Wei KK, Benbasat I (2003) Predicting intention to adopt interorganizational linkages: an institutional perspective. MIS Q 27(1):19–49
Triandis HC (1980) Values, attitudes and interpersonal behavior. In: Howe H, Page M (eds) Nebraska symposium on motivation, vol 27. University of Nebraska Press, Lincoln, NE, pp 195–259

Chapter 11
A Preliminary Study on the Effects of HSR on Station Area

Guo Liu and Kunhui Ye

11.1 Introduction

Since the first high-speed railway (HSR) passenger service was launched in Japan with trains running at 210 km/h during the 1960s, the second railway age is coming (Banister and Hall 1993; Givoni 2006). By virtue of the advantages of fast, safety, on time, and environment friendly, HSR was paid much attention on in this age. By the end of 2015, HSR has been extended over 30,000 km across the globe (International Union of Railways, UIC).

With the increasing proliferation of HSR, the effects brought by HSR on urban area are emerging. For instance, the operation of HSR is deemed to play a catalyst role in station and its surrounding zones by cultivating new development and forming into economic pole (Loukaitou-Sideris et al. 2012; Pol 2008). These effects are important elements which reshape and drive the evolution of urban space (Liu et al. 2015), arising concerns of scholars throughout the world (Givoni 2006; Wang and Lin 2011). Many researchers claimed that the effects of HSR on station and its vicinity, where passengers arrive at and leave from, direct and significant, and thus cannot be undervalued (Hou et al. 2016; Pol 2008; Yin et al. 2015). Scholars, such as Bertolini (1996, 1999), have developed a node-place model to explain the development of this area, which laid a foundation for the effect analysis.

In practice, local governments have tried to make the urban area around HSR station to be a catalyst for boosting urban development (Pol 2008). For instance, many Chinese authorities orientate HSR stations and their environs as urban

G. Liu (✉)
School of Construction Management and Real Estate, Chongqing University, Chongqing, China
e-mail: lgjycqu@163.com

K. Ye
International Research Center for Sustainable Built Environment, Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_11

(sub) centers or new economic development districts in order to cultivate urban development. In this sense, HSR station area is a valuable part in the achievement of urban sustainable development (Reusser et al. 2008). However, a majority of governments merely focus on economic poles of HSR station areas and ignore the interaction among economic effect, social effect and environmental effect, which is not conducive for the catalyst role of station area.

The complex effects are essential for the evolution of station areas. For instance, the combined economic effects (e.g., house value), transport effects (e.g., time reduction), and environmental effects (e.g., noise and crime) sustain the development of HSR station and its surrounding (Geng et al. 2015). Therefore, it is very important to explore the multiple effects to facilitate and manage this urban area towards sustainability. However, previous studies always explored partial impact, which is not conducive for the systematic understanding for these effects of HSR, and also makes against the management and development of urban area around a HSR station. A comprehensive analysis of the impacts of HSR on station area will boost the usefulness of the HSR and the sustainability of urban space (Martínez et al. 2016). Moreover, these effects are complex and various in different culture and districts. Bearing these in mind, the aim of this study is to preliminarily identify the multiple effects brought by HSR on station area in Chinese context to shed some light on the practice for local authorities to promote a catalyst of station area.

11.2 The Development of HSR in China

HSR is a typical passenger rail transport with faster speed than traditional ones. According to the European Union, the speed of a HSR should be at least 200 km/h for a upgraded track and 250 km/h for a new track (Verma et al. 2013). The development of HSR can be traced back to the year of 1964 when the first HSR routine in the world, *Tokaido Shinkansen*, was constructed to connect Tokyo and Osaka. In 1981, the first European HSR (TGV), linking Pairs and Lyon, was built in France (UIC). Currently, 16 countries and/or regions, such as China, Germany, Sweden, Italy, and Russia, have constructed and operated their HSR (National Railway Administration of the People's Republic of China, NRAPRC). According to UIC, over 30,000 km of HSR have been reached in 2015, forming into a huge HSR network.

About 40 years later, the first Chinese HSR, *Shenyang-Qinhuangdao,* was conducted into operation in 2003 with the speed of 200 km/h. Nevertheless, the first newly-built HSR line (Beijing-Tianjin) with a maximum speed of 350 km/h came into operation in 2008, and this symbolizes that China entry into the period of 'rapid HSR development'. After a decade of development, the total length of HSR in China has been over 19,000 km, ranking first in the world (NRAPRC).

With the soaring development of HSR, lots of stations appear. The development of a HSR station and its surrounding area is directly affected by HSR network (Hou et al. 2016; Pol 2008). HSR network provides the nurishment, such as people, materials, capital and information and so on, for the growth of station areas (Oosten 2000). To identify these effects to some degree can help instruct the development of urban areas based on HSR stations.

11.3 Effects of HSR on Urban Development

Since the 19st century, railway systems have been found can play a vital role in shaping urban space by increasing or decreasing the development of the urban area they pass by Loukaitou-Sideris et al. (2012). At the dawn of the 21st, this phenomenon is strengthened with the evolution of high-speed railway in the second rail age (Banister and Hall 1993). For instance, HSR can promote the regional cooperation and labor division, thus leading to regional integration (Verma et al. 2013). The issue of important role of HSR in urban development has been raised since the birth of HSR.

Many studies were conducted to explore the roles of HSR at different urban level. First, at the regional level, Zhang et al. (2014) put forward that HSR influence regional economic growth, industrial structure and improve the regional cooperation. Second, at the city level, the impact of HSR on the improvement of accessibility, the optimization of urban spatial structure, locational advantage, and the inflows of production elements were demonstrated (Lu et al. 2016; Murayama 1994; Zhang et al. 2014). Third, at the station level, HSR network can ascend the value of neighboring houses and lands (Zhuang and Zhao 2014), and lead to electromagnetic radiation and noise pollution (Geng et al. 2015).

In appreciating the multi-dimensional effects of HSR, the effects brought by HSR on station and its surrounding area are significant (Hou et al. 2016; Wang 2011). This arguments can be sustained by the dual characters of station area (Bertolini 1996). On one side, stations are important nodes in the HSR network and make good accessibility for the station areas, thus stimulating a large volume of passengers (Nuworsoo and Deakin 2009). On the other side, with the increasing travelers in the station, consumption, entertainments, and house and other activities are usually constructed in the adjacent areas to take advantage of the accessibility, consequently forming into urban places (Bertolini 1996; Wang et al. 2012). In sum, the effects of HSR make station and its vicinity have potential to develop into activity poles.

11.4 Methods

To examine the effects of HSR on urban area around a HSR station, three main research methods are adopted: literature review, interview, and online survey. First, a set of initial effects of HSR on station areas were derived by using the techniques of literature review, as listed in Table 11.1.

Table 11.1 Effects of HSR identified by literature review

Abr.	Effects	Reference
OC	Condition of outward connectivity among cities	(Shen et al. 2014; Willigers 2008)
IC	Condition of inward connectivity in urban	(Hou et al. 2012)
DTC	Degree of traffic congestion	(Geng et al. 2015; Loukaitou-Sideris et al. 2012)
SPF	Service level of public facilities (transportation)	(Nuworsoo and Deakin 2009; Yang and Sun 2014)
TT	The transport time toward other places	(Vickerman 2015; Willigers 2008)
TC	The transport cost toward other places	(Gargiulo and Ciutiis 2010)
PV	Passengers volume	(Tian 2014; Vickerman 2015)
PS	Passengers structure (e.g., kinds of jobs)	(Hong and Yao 2016; Lu et al. 2016)
CD	Cultural diversity of inhabitants	(Hiroshi 1994; Yang and Sun 2014)
PPR	Population of permanent residents	(Zhuang and Zhao 2014)
CR	Crime rate	(Geng et al. 2015)
SE	Structure of employment	(Bollinger and Ihlanfeldt 1997)
RE	Rate of Employment	(Hiroshi 1994; Schuetz 2014)
FI	Family income	(Loukaitou-Sideris et al. 2012)
GR	Government revenue	(Zhuang and Zhao 2014)
ILD	Intensity of land development	(Loukaitou-Sideris et al. 2012)
SLI	Structure and layout of industries	(Nuworsoo and Deakin 2009; Lu et al. 2016)
VRE	Values of real estate (e.g., house and land)	(Gargiulo and Ciutiis 2010; Diao et al. 2016)
ER	Electromagnetic radiation	(Geng et al. 2015)
NP	Noise pollution	(Bertolini et al. 2005; Geng et al. 2015)

Second, online survey and interview (six senior professionals from Jilin, Shandong, Jiangsu, Jiangxi, Guangzhou and Tianjin) were conducted to supplement the effects. In this stage, the influence of light pollution (LP) and Life cycle of building (LCB) brought by HSR was added. After these steps, the primary effect factors were gathered, forming into a factor set. Last, these effect indicators were further commented and suggested by four professionals from Beijing and Chongqing. Finally, the preliminary effect set of HSR were achieved. The effects of HSR and its source are illustrated in Table 11.2.

Table 11.2 Preliminary effects of HSR and their source

Code	Abr.	Literature	Expert interview	Online survey
1	OC	√	√	√
2	IC	√	√	√
3	DTC	√		
4	SPF	√		√
5	TT	√		√
6	TC	√		√
7	PV	√	√	√
8	PS	√		√
9	CD	√		√
10	PPR	√		√
11	CR	√		
12	SE	√		
13	RE	√		√
14	FI	√		√
15	GR	√		
16	ILD	√	√	
17	SLI	√	√	√
18	VRE	√	√	√
19	ER	√		√
20	NP	√		√
21	LCB (Life cycle of building)			√
22	LP (Light pollution)			√

11.5 Findings and Discussion

From Table 11.2, it can be found that there are multiple effects accompanied with the evolution of HSR on station areas. The results were concluded based on previous research, thus echoing to and further supplementing these studies (Geng et al. 2015; Loukaitou-Sideris et al. 2012).

The station is the direct physical carrier of the effects brought by HSR network (Wang 2011). On one side, the station has an essential primary function of interconnecting many urban spaces, playing a node role in the HSR network; on the other side, by virtue of the effects, its surrounding areas are identified as an place of local dimension, sustaining a multiple and complex functions (e.g., facilitating commercial use of real estate, providing public space) (Bertolini 1996; Zemp et al. 2011).

For the feature of node, apart from the node in HSR network, the operation of HSR stimulates the construction of other traffic facilities, such as bus, taxi and subway (Trip 2008), enabling the station links other multiple traffic modes. Thus, the effects of HSR on other transport development are significant and important. For the other feature of place, the urban area around HSR station can cover economy,

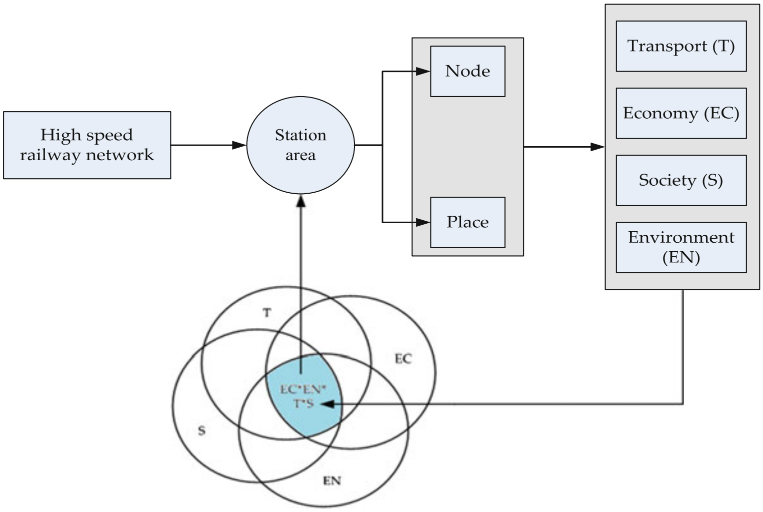


Fig. 11.1 The effects model of HSR on station area

society and environment based on the urban sustainability (Hassan and Lee 2015). On the basis of the node-place model (Bertolini 1996, 1999), it therefore can be induced that these effects of HSR can be categorized into four sub-systems, namely transport, economy, society, and environment (Fig. 11.1), consistent with prior studies (Givoni 2006; Zhang and Cao 2007).

The four sub-systems are independent on one another (Zemp et al. 2011). For instance, Bertolini (1996) found that, with fast flow of people, coupled with materials, capital, and information, the interaction between society and economy has obtained much impetus. Likewise, Geng et al. (2015) has proved that HSR can bring in transport advantage by lowering traffic cost and time, which can subsequently increase the real estate prices in surrounding areas in economy. This implies that both of these effects and their interaction underscore the development of HSR station area (Fig. 11.1).

These interactive relationships suggest that the effects of HSR on urban area based on station are combined results among the above-mentioned four sub-systems forces. Further, due to the limited land in station area and the evolution of HSR network, dynamic balance though the interaction of four sub-systems is very important. Therefore, the achievement of dynamic balance among these sub-systems is a key factor to pursuit the catalyst role of station area for urban development. It can be implied that merely highlighting the effects from the perspective of economy by many local governments is incomplete because this depends on many factors, such as transport or society. This finding provides a systematic understanding of development process of station area, and shed light on the achievement of the catalyst role of a HSR station area.

11.6 Conclusions

The rapid development of HSR across the world has generated significant effects on urban areas, especially the zones around the HSR station. These effects stimulate the development of a HSR station and its vicinity, and enable a station area to be a vital role in the achievement of sustainable urban development. It is necessary to comprehensively understand these effects of HSR in order to play a catalyst role of station area sustainability. Two main findings are derived, the effects of HSR can be divided into transport, economy, society and environment; there are interactions between these effects, and dynamic balance among them underscores the development of a station and its surrounding. The findings outline the combined effects of HSR and their dynamic balance, providing a systematic thinking for the evolution of station areas and laying a preliminary exploration for the future study. It also shed some light on the practice for local authorities to promote a catalyst of station areas towards urban sustainability.

References

Banister D, Hall P (1993) The second railway age. Built Environ 19(3–4):156–162

Bertolini L (1996) Nodes and places: complexities of railway station redevelopment. Eur Plan Stud 4(3):331–345

Bertolini L (1999) Spatial development patterns and public transport: the application of an analytical model in the Netherlands. Plan Pract Res 14(2):199–210

Bertolini L, le Clercq F, Kapoen L (2005) Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. Transp Policy 12(3):207–220

Bollinger CR, Ihlanfeldt KR (1997) The impact of rapid rail transit on economic development: the case of Atlanta's MARTA. J Urban Econ 42(2):185–194

Gargiulo C, Ciutiis F (2010) Urban transformation and property value variation. The role of HS stations. TeMA: Territorio Mobilit e Ambiente 3:65–84

Diao M, Zhu Y, Zhu J (2016) Intra-city access to inter-city transport nodes: the implications of high-speed-rail station locations for the urban development of Chinese cities. Urban Stud

Geng B, Bao H, Liang Y (2015) A study of the effect of a high-speed rail station on spatial variations in housing price based on the hedonic model. Habitat Int 49:333–339

Givoni M (2006) Development and impact of the modern high-speed train: a review. Transp Rev 26(5):593–611

Hassan AM, Lee H (2015) Toward the sustainable development of urban areas: an overview of global trends in trials and policies. Land Use Policy 48:199–212

Hiroshi O (1994) Features and economic and social effects of the Shinkansen. Japan Railway & Transport Review

Hong S, Yao C (2016) High-speed rail station and urban spatial evolution: review and introspection. Urban Plan Int 31(2):84–89

Hou X, Zhang W, Lv G, Hu Z (2012) Study on the influence of regional development around station of HST-taking Beijing south station as an example. Urban Stud 19(1):41–46

Hou X, Zhang W, Qiao B, Li W (2016) Development of high-speed train station: a comparison between Tianjin and the Randstad (Netherlands). J Beijing Jiaotong Univ (1):42–48

Liu Z, Yang H, Yao H (2015) Overseas study progress of high speed rail's influences on regional and urban spatial development. Urban Dev Stud 22(4):14–20

Loukaitou-Sideris A, Cuff D, Higgins T, Linovski O (2012) Impact of high speed rail stations on local development: a delphi survey. Built Environ 38(1):51–70

Lu Y, Yu B, Han Y (2016) Procedia engineering economic radiation effect of high-speed rail based on structure of passenger flow: a case study of Wuhan city. Resour Environ Yangtze Basin 25 (1):39–47

Martínez HS, Moyano A, Coronado JM, Garmendia M (2016) Catchment areas of high-speed rail stations: a model based on spatial analysis using ridership surveys. EJTIR 16(2):364–384

Murayama Y (1994) The impact of railways on accessibility in the Japanese urban system. J Transp Geogr 2(2):87–100

Nuworsoo C, Deakin E (2009) Transforming high-speed rail stations to major activity hubs: lessons for California. Paper presented at the 88th annual meeting of the Transportation Research Board

Oosten WJ (2000) Railway stations and a geography of networks. Paper presented at the 6th Annual Congress of the Netherlands Research School for Transport, Infrastructure and Logistics, Hague

Pol P (2008) HST stations and urban dynamics: experiences from four European cities. In: Bruinsma F, Pels E, Priemus H, Rietveld P, Wee B (eds) Railway development: impacts on urban dynamics. PhysicaVerlag, (pp 59–77)

Reusser DE, Loukopoulos P, Stauffacher M, Scholz RW (2008) Classifying railway stations for sustainable transitions—balancing node and place functions. J Transp Geogr 16(3):191–202

Schuetz J (2014) Do rail transit stations encourage neighbourhood retail activity? Urban Stud 52 (14):2699–2723

Shen Y, Silva JDE, Martinez LM (2014) Assessing high-speed rail's impacts on land cover change in large urban areas based on spatial mixed logit methods: a case study of Madrid Atocha railway station from 1990 to 2006. J Transp Geogr 41:184–196

Tian C (2014) A study on promotion of urbanization by intercity railway through TOD pattern: take Wuhan city circle for example. Urban Dev Stud 21(5):20–25

Trip J (2008) What makes a city: urban quality in Euralille, Amsterdam South Axis and Rotterdam Central. In: Bruinsma F, Pels E, Priemus H, Rietveld P, Wee B (eds) Railway development: impacts on urban dynamics. PhysicaVerlag, (pp 79–99)

Verma A, Sudhira HS, Rathi S, King R, Dash N (2013) Sustainable urbanization using high speed rail (HSR) in Karnataka, India. Res Transp Econ 38(1):67–77

Vickerman R (2015) High-speed rail and regional development: the case of intermediate stations. J Transp Geogr 42:157–165. doi:10.1016/j.jtrangeo.2014.06.008

Wang J (2011) Urban and regional impacts of high-speed railways: a preamble. Urban Plan Int 26 (6):1–5

Wang JX, Lin CH (2011) High-speed rail and its impacts on the urban spatial dynamics in China: the background and analytical framework. Urban Plan Int 26(1):16–23

Wang L, Cao YH, Yao SM (2012) Review and evaluation of high-speed railways impaction urban space. Resour Environ Yangtze Basin 21(9):1073–1079

Willigers J (2008) The impact of high-speed railway developments on office locations: a scenario study approach. In: Bruinsma F, Pels E, Priemus H, Rietveld P, Wee B (eds) Railway development: impacts on urban dynamics. PhysicaVerlag, (pp. 237–264)

Yang D, Sun N (2014) Exploring tran-scalar and multi-factor impacts of Dalian high-speed railway station on the surrounding area development. Urban Plan Forum (5):86–91

Yin M, Bertolini L, Duan J (2015) The effects of the high-speed railway on urban development: international experience and potential implications for China. Prog Plan 98:1–52

Zemp S, Stauffacher M, Lang DJ, Scholz RW (2011) Generic functions of railway stations: a conceptual basis for the development of common system understanding and assessment criteria. Transp Policy 18(2):446–455

Zhang K, Cao X (2007) A review on the research of the relationship between railway station and the Neighborhood circumstance. Hum Geogr (6):6–9 + 84

Zhang M, Wu Q, Wu D, Zhao L, Liu X (2014) Analysis of the influence on regional economic development of high-speed railway. J Chem Pharm Res 6(8):243–254

Zhuang X, Zhao S (2014) Effects of land and building usage on population, land price and passengers in station areas: a case study in Fukuoka, Japan. Front Architectural Res 3(2): 199–212

Chapter 12
A System Dynamics Framework of Drivers and Constraints to Enhancing Productivity of the Hong Kong Construction Industry

A.A. Javed, Zhan W and W. Pan

12.1 Introduction

The Hong Kong construction industry has performed well in terms of gross value during the past few years. In 2014, the gross value of construction work performed by main contractors increased by 13% Year on Year to HK$199.7 billion (US $25.6 billion). In Quarter 2 of 2015, gross value went up by 15% to HK $55.2 billion (US$7.1 billion). At present, public sector works projects and public housing projects account for about half of the total volume of local construction activities (Hong Kong Trade Development Council 2015). Construction productivity in Hong Kong has lagged behind compared to in many other developed countries. Construction cost in Hong Kong is also relatively high (Pan et al. 2016), so the industry must improve its efficiency and productivity substantially to stay competitive (Construction Industry Review Committee 2001). Construction productivity plays an important role to the economic growth of Hong Kong's economy. Productivity can be defined in a variety of ways depending upon the work being performed. It is defined as the ratio of product output to input resources (Haas et al. 1999; Maloney 1990). Output expressed in terms of physical units and input as man-hours required to producing the output. The industry average project productivity can be used to assess a project's productivity performance and the builder can set improvement targets for future projects. However, construction productivity in Hong Kong has been declining over the years, highlighting an urgent need for investigation and improvement.

Several studies have been carried out to determine the effects of different factors on labour productivity. For instance, Nasirzadeh and Nojedehi (2013) presented a system dynamics (SD) based approach to model labour productivity using cause and effect feedback loops. However, few investigated the effects of drivers and

A.A. Javed (✉) · Z. W · W. Pan
Department of Civil Engineering, The University of Hong Kong, Pok Fu Lam, Hong Kong
e-mail: aajaved@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_12

constraints on overall construction productivity covering the industry, project and activity levels in a systems manner. This paper aims to develop a SD framework of drivers and constraints to enhancing construction productivity at industry, project and activity level. The paper first explains the SD approach and the research methodology. It then examines the wide-ranging drivers and constraints to enhancing construction productivity through a literature review and reports results from semi-structured interviews with 30 industry leaders of Hong Kong construction. The examination is made in five aspects, namely, policy formation; regulatory requirements; planning and design; project management and administration; and site construction. The inter-related structure of the drivers and constraints to construction productivity is modelled using the SD approach.

12.2 Systems Dynamics Approach to Examining Drivers and Constraints

The SD methodology, proposed by Forrester (1961), is an objective-oriented simulation methodology enabling us to model complex systems considering all the influencing factors (Khanzadi et al. 2012). SD has been widely used in the public and private sectors for policy analysis and design. A dynamic system is a system in which the variables interact to simulate changes over time (Mawdesley and Al-Jibouri 2009). SD modelling is useful for managing and simulation of processes with two major characteristics: (1) they involve changes overtime; and (2) they allow feedback (Richardson and Pugh 1981). SD models provide more strategic insights and understanding about the effectiveness of different managerial policies (Rodrigues 1994). Different researchers have applied SD to study construction productivity for developing causal loop diagrams, flow diagrams, and governing equations. For example, Moselhi et al. (2005) investigated the impact of change orders on construction productivity and recommended a new neural network model for quantifying this impact. Similarly, Pan proposed a fuzzy model for assessing the impact of rain on productivity of the operations and project completion (Pan 2005). Hanna et al. (2005) developed crew schedule productivity models to analyse the impacts of overtime on construction labour productivity. Ibbs et al. (2007) presented causal linkages to capture the interactions of changes, disruptions, productivity losses and the responsible parties. Other researchers have used dialectical approach for understanding the interdependence of the elements of a system. For example, Pan and Ning (2014) applied dialectical approach for understanding the complex interdependence of sustainable buildings.

In this paper, the SD approach is used to understand three aspects (i.e. industry, project and activity or trade level) and address the institutional and socio-technical complexity of the many interactive factors affecting construction productivity. Any fragmented identification of such factors would introduce theoretically flawed assumptions and therefore would not effectively tackle the fundamental issues with productivity, hence failing to lead to robust strategies and action plans. For example, the drivers and constraints in the areas of policy formulation and regulatory requirements seem to be more focused at the industry level, those factors in the areas of planning and design, project management and administration seem to be more focused at the project level, and those factors in the area of site construction seem to be more focused at the site construction or trade level. However, actually all such factors interact and interplay across the three levels to affect construction productivity, not necessarily in a positive manner but in a negative manner if not managed well.

12.3 Methodology

The drivers and constraints to construction productivity were first identified through a comprehensive literature review and then verified through semi-structured interviews with 30 informed professionals in the Hong Kong construction industry. These interviewees represented different stakeholder groups including clients, government departments, contractors, architects and consultants. All of the interviewees held senior management positions. Almost all of them possessed more than 20 years of working experience and were involved in one or more particular construction projects.

The interviews were audio-recorded with permission of the interviewees and then transcribed. The notes taken of the interviews and transcripts were analysed using QSR Nvivo 10 analytical software (QSR International 2015) to yield meaningful themes and insights. The interview data were coded using constant comparative method aided by QSR Nvivo 10 software. Interview data of common key themes were initially coded together as the same category. Later, open coding; axial codes were constructed to determine the clear and distinct categories in five aspects: (a) policy formation; (b) regulatory requirements; (c) planning and design; (d) project management and administration and (e) site construction levels. At the end, 35 drivers and 36 constraints were identified as most important and significant respectively. The qualitative model of construction productivity is constructed using Vensim simulation software (Ventana Systems 2016), more specifically at three levels (industry, project and activity) and in five aspects (policy formulation, regulatory requirements, planning and design, project management and administration, and site construction). A SD framework of construction productivity is developed with the interrelationships between the identified drivers and constraints examined.

12.4 Key Drivers Identified Through Literature Review

Construction productivity is influenced by many drivers and constraints which have complex relationships with each other. The key drivers were identified through a comprehensive literature review.

- ***Policy formation***: Earlier researchers world-wide have studied the drivers and constraints of productivity at different levels. For example, Koehn and Brown suggested that effective management (proper planning, realistic scheduling, adequate coordination, and suitable control), labor (availability, level of skilled craftsmen, and use of equipment), government role (regulations, social characteristics, environmental rules, climate, and political ramifications), contracts (fixed price, unit cost, and cost plus fixed fee, design and build etc.), owner characteristics, and financing are key drivers of productivity growth (Koehn and Brown 1986).
- ***Regulatory requirements***: Hesapro Partners (2013) has found that health and safety measures have impact on the health and safety performance of the workplaces and also on the productivity performance. Previous literature pointed out that implementation of health, safety and environment (HSE) regulations has linear connection with productivity. Because if there will be less accidents as a result there will be less absenteeism and productivity will decline due to disruption on site which will lead to a delay in progress (Zhi et al. 2003).
- ***Planning and design***: Ballard (2000) suggested Last Planner System (LPS) as an effective tool for planning, scheduling. Sanvido study identified four primary ways of increasing productivity through effective management which include: (1) planning; (2) resource supply and control; (3) supply of information and feedback; and (4) selection of the right people to control certain functions (Sanvido 1988).
- ***Project management and administration***: Clarity of project scope and requirements, drawings and specification, and meeting the legal, aesthetic and functional requirements (Arditi and Gunaydin 1997) and efficient specifications and design practices are prerequisite for high process quality of a project (Arditi and Mochtar 2000). There should be incentive for good performance and equal pay on projects can retain skilled workers (Dai et al. 2009).
- ***Site construction***: Rivas et al. have identified several productivity factors affecting projects in the Chilean construction industry. Their findings indicate that critical areas affecting construction productivity were related to shortage of materials, tools, equipment, truck unavailability, rework, and workers' motivational dynamics (Rivas et al. 2010). Chau and Lai (1994) have suggested that use of precast components (standard prefabricated components) can also save labour cost and can improve productivity.

12.5 Main Constraints Identified Through Literature Review

Many constraints have been reported to enhancing construction productivity. According to the (Construction Industry Review Committee 2001), a number of factors can affect the efficiency and productivity of local construction industry, which include segregated delivery processes, non-value-adding multi-layered sub-contracting, prevalence of labour intensive in situ construction methods, too many small organisations in the industry without the requisite capabilities, and relatively low investment in the use of new technologies.

- ***Policy formation***: At policy formation level, shortage of construction workers, ageing workforce and lack of young workers (Koehn and Brown 1986; Chan et al. 2016) are important factors affecting the productivity. Koehn and Brown pointed out that impeding environmental sustainable construction and plethora tendering procedure as key constraints (Koehn and Brown 1986). Slow local authorities' approval (Kadir et al. 2005) and corruption (Parham and Economics 2008) were identified key constraints to enhancing construction productivity.
- ***Regulatory requirements***: Borcherding et al. (1980) study employing questionnaires and interviews with over 600 craftsmen and foremen from five nuclear power plant construction projects indicated 20–25 lost man-hours per-week per-man due to engineering lead time. The U.S. Department of Energy (DOE) findings revealed that strict quality assurance and quality control (QA/QC) tolerances, complex design and frequent change orders were present on many nuclear power plant projects.
- ***Planning and design***: Maloney (1990) found that poor planning and execution and poor quality performance resulted in increased reworks, which have significant cost and schedule implications. Rojas and Aramvareekul (2003) identified adverse working conditions and scope changes will influence productivity.
- ***Project management and administration***: Koehn and Brown (1986) found that union agreements, restrictive work practices, absenteeism, turnover, delays, contract modifications and design changes are key hindrance. Rojas and Aramvareekul (2003) classified factors into different categories, including management systems and strategies, scheduling, manpower management, experience and motivation, industry environment, and external conditions.
- ***Site construction***: Borcherding and Garner's DOE studied over 1300 craftsmen and foreman from eleven power plant projects and a nuclear processing facility found an average 23.14 lost manhours per week. These lost manhours were due to delays in resulting from (1) material unavailability; (2) tool unavailability; (3) work redone; (4) overcrowded work area; (5) inspection delays; (6) foreman incompetence; (7) crew interference; (8) craft turnover and absenteeism; and (9) foreman changes (Borcherding and Garner 1981).

12.6 Drivers and Constraints Verified Through Stakeholder Interviews

The conceptual productivity drivers and constraints are structured using the SD approach in Figs. 12.1 and 12.2. The identified drivers and constraints are, although not all-inclusive, fairly well cover the majority of circumstances at industry, project and site levels. Different factors affecting construction productivity are rarely independent of the others; some factors may be the results of the same cause, or one factor may trigger the occurrence of others.

12.6.1 Main Drivers to Enhancing Construction Productivity

Figure 12.1 depicts the inter-relationships between different drivers. Some drivers are influencing other drivers. For example, certainty and continuity of construction work and attractive salaries, job security, career prospects and a good working environment will attract more young workers. Various drivers, however, would enhance the productivity at industry level which includes investment on skills training, attracting young workers, and incentive for using prefabrication and modularisation. To be productive, efficient and competitive, the government can play a leading role by promoting innovation. Electronic submission of design is also an important driver for

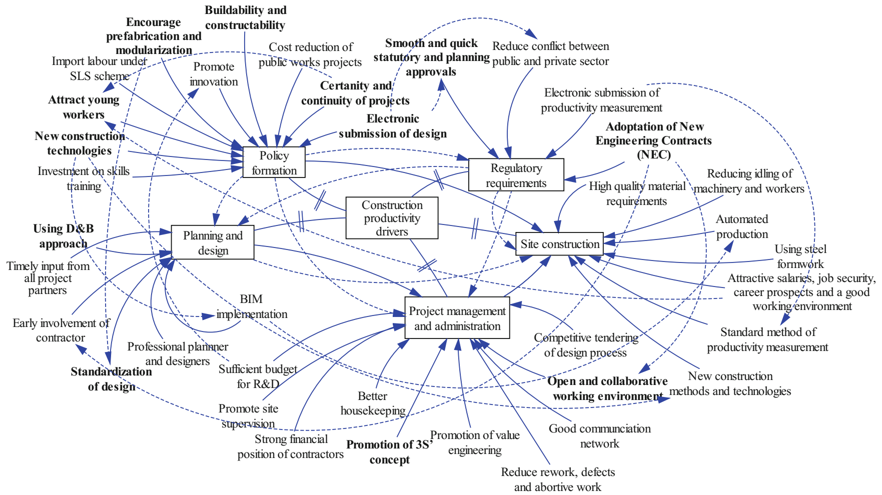


Fig. 12.1 Key drivers for enhancing construction productivity. *Note* Doted arrows represent direct influence on other factors and bold text represents important factors

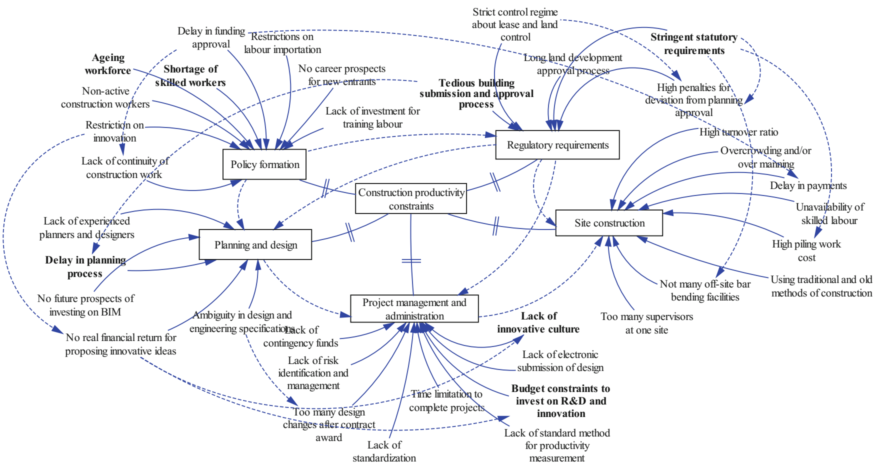


Fig. 12.2 Main constraints to enhancing construction productivity. *Note* Doted arrows represent direct influence on other factors and bold text represents important factors

reducing lengthy planning approval process. The industry must need to adopt new construction technologies and must have sufficient skilled labour force on site. To meet the current demand of skilled labour shortage, the government should import skilled labour under Supplementary Labour Scheme (SLS) scheme. However, SLS scheme may have some pros and cons. For example, labour unions may raise their voices against labour importation. Imported workers may be paid less than local workers. Local workers may lose their job and their bargaining power might be weakened. The construction industry of Hong Kong is often perceived as volatile which requires stability and medium to long-term commitment of public works projects. By doing so the government will not only be able to attract young workers but also it will be helpful for consultants and contractors to plan their human resources and long-term investment in R&D.

Some of the drivers are interdependent and interlinked to each other. Other drivers include smooth and quick statutory and planning approval process which can be achieved by reducing conflict between government departments and private developers. Further, similar to neighbouring city Singapore, the Hong Kong government should promote buildability and constructability assessment methods. Buildability and constructability assessment will provide a chance for the client and contractors to review their plans, specifications, and contracts to determine whether the design is feasible using existing technology and resources.

The government should formulate medium to long-term plans to move the construction industry for adopting Building Information Modelling (BIM) software programs. Electronic submission of BIM format for architectural, structural and mechanical and electrical (M&E) plans for building works should be made mandatory. The public sector should also take a lead for using risk sharing and collaborative New Engineering Contracts (NEC). NEC contracts will encourage early involvement of contractors and other project stakeholders. Furthermore, in Hong Kong there is no standard productivity measurement method so if the government will introduce electronic submission of productivity data it will help monitor the progress of the whole construction productivity. For example, Building and Construction Authority (BCA) of Singapore collects construction productivity data of building projects with gross floor area of 5000 m^2 or more on monthly basis using the Electronic Productivity Submission System (ePSS) (Infocomm Development Authority of Singapore 2015).

Drivers identified at project level include close coordination between project participants at the outset of a project, standardisation of design, using design and build (D&B) approach, promoting research and development. Development Bureau has introduced 3S concept at design stage of a construction project to enhancing the construction productivity. This 3S concept includes (1) standardisation, (2) simplification and (3) single integrated element. D&B contracting method is advantageous because it reduces the cost and time of the project by not issuing contract documents for competitive bids and eliminating the evaluation of multiple bids. It also provides a single point of coordination for projects. Key drivers identified at activity level are promoting new construction technologies and robots, quality of craftsmanship, attracting young workers by offering attractive salaries, job security and career prospects, providing safe and good working environment, and promoting automated production methods at construction sites. Some of the drivers are interdependent and also influenced by others.

12.6.2 Main Constraints to Influencing Construction Productivity

Figure 12.2 shows inter-connected relationships between different constraints at policy formation, regulatory requirements, planning and design, project management and administration as well as site construction level. Some constraints are directly and indirectly affecting others. For example, delay in funding approval by the Legislative Council of Hong Kong (LegCo.), has affected continuity of major public works projects and ultimately work progress has been affected. For example, MTR Express Rail Link (XRL) project has been delayed due to different factors including labour shortage, difficult ground conditions and delay in funding approval. Construction productivity can be negatively influenced by a variety of variables, such as government regulations, the state of the economy, the unique practices of each firm, management style, and the attitudes of workers. Figure 12.2 shows list of constraints affecting construction productivity negatively at industry level including ageing workforce, shortage of skilled labour force, restriction on innovation, lack of continuity of construction work, stringent statutory requirements, delay in funding approval, long waiting time for planning approval, strict control regime and tedious building submission and approval process.

Both public and private sector have different views on some constraints. For example, from private developer point of view statutory requirements and approval process are perceived as key constraints and these will impact productivity and efficiency. However, public sector viewed these factors important for enforcement of health, safety and environment requirements.

The constraints identified at project level are that Hong Kong has no standard method for productivity measurement. There is no standard platform for BIM software and public and private sector is unwilling to invest on BIM technology and staff training due to volatile construction sector. In Hong Kong, not much budget is allocated for R&D to improving productivity of construction industry. The industry is lacking experienced planners and designers. Recently more focused is on paper work rather than physical supervision. Idling of machines and workers also hamper the progress of work. Frequent design and schedule changes from the client will result rework, defects and abortive work. In addition, main constraints identified at activity level are relying on old techniques and delay in payment, unskilled workers, higher turnover ratio, overcrowding and over manning. If workers at construction jobsite are not properly trained to perform their assigned work task, it is probable that efficiency and productivity will be impacted. If the retention rate of workers is low, it is unlikely that it will achieve good productivity, simply because of the additional time required for new workers to train and master their work tasks. Some of the constraints are interdependent and also interlinked to each other. One constraint may negatively influence others.

12.7 Conclusions

This paper has developed a SD framework of drivers and constraints to enhancing construction productivity. The framework categories the wide-ranging drivers and constraints and also highlights the interrelations between them. The research delineates the fact that the SD approach using inter-related structure is a powerful tool for modelling drivers and constraints to enhancing the productivity of construction projects. The framework enables the in-depth study of the many influencing factors and the inter-linked relations between the drivers and constraints. The results indicate that site and project level productivity is influenced by industry level policy and regulatory requirements factors. These factors require more urgent attention from relevant government departments in order to improve productivity. Future research should take the SD framework further to develop a simulation model of construction productivity using cause-and-effect feedback loops. In that way the relationships between different factors will be quantified in real-life project contexts.

Acknowledgements This publication was made possible by the research funding from the Construction Industry Council (CIC), Hong Kong. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the CIC, Hong Kong.

References

Arditi D, Gunaydin HM (1997) Total quality management in the construction process. Int J Project Manage 15(4):235–243

Arditi D, Mochtar K (2000) Trends in productivity improvement in the US construction industry. Constr Manage Econ 18(1):15–27

Ballard G (2000) The last planner system of production control. Ph.D. thesis, Department of Civil Engineering, University of Birmingham, Birmingham, p 198

Borcherding JD, Garner DF (1981) Work force motivation and productivity on large jobs. J Constr Div 107(3):443–453

Borcherding JD, Samelson NM, Sebastian SM (1980) Improving motivation and productivity on large projects. J Constr Div 106(1):73–89

Chan APC, Javed AA, Lyu S, Hon CKH, Wong FKW (2016) Strategies for improving safety and health of ethnic minority construction workers. J Constr Eng Manage 05016007

Chau KW, Lai LWC (1994) A comparison between growth in labour productivity in the construction industry and the economy. Constr Manage Econ 12(2):183–185

Construction Industry Review Committee (2001) Construct for excellence—report of the construction industry review committee. Hong Kong Special Administrative Region

Dai J, Goodrum PM, Maloney WF, Srinivasan C (2009) Latent structures of the factors affecting construction labor productivity. J Constr Eng Manage 135(5):397–406

Forrester J (1961) Industrial dynamics. MIT Press, Cambridge, MA

Haas CT, Borcherding JD, Allmon E, Goodrum PM (1999) US construction labor productivity trends, 1970–1998. Center for Construction Industry Studies, Report No. 7. The University of Texas at Austin

Hanna AS, Craig ST, Kenneth TS (2005) Impact of extended overtime on construction labor productivity. J Constr Eng Manage 131(6):734–739

Hesapro Partners (2013) The link between productivity and health and safety at work. Background Research Paper. http://bit.ly/1sIhumS, 10 July 2016

Hong Kong Trade Development Council (2015) Building and construction industry in Hong Kong. Hong Kong. http://bit.ly/1q37hjj, 27 June 2016

Ibbs W, Nguyen LD, Lee S (2007) Quantified impacts of project change. J Prof Issues Eng Educ Pract 133(1):45–52

Infocomm Development Authority of Singapore (2015) Enhanced iSprint–piloting new sector solutions–specifications for construction sector. https://goo.gl/2m14zb, 12 Aug 2016

Kadir AMR, Lee WP, Jaafar MS, Sapuan SM, Ali AAA (2005) Factors affecting construction labour productivity for Malaysian residential projects. Struct Surv 23(1):42–54

Khanzadi M, Nasirzadeh F, Alipour M (2012) Integrating system dynamics and fuzzy logic modeling to determine concession period in BOT projects. Autom Constr 22:368–376

Koehn E, Brown G (1986) International labor productivity factors. J Constr Eng Manage 112 (2):299–302

Maloney WF (1990) Framework for analysis of performance. J Constr Eng Manage 116(3): 399–415

Mawdesley MJ, Al-Jibouri S (2009) Modelling construction project productivity using systems dynamics approach. Int J Prod Perform Manage 59(1):18–36

Moselhi O, Assem I, El-Rayes K (2005) Change orders impact on labor productivity. J Constr Eng Manage 131(3):354–359

Nasirzadeh F, Nojedehi P (2013) Dynamic modeling of labor productivity in construction projects. Int J Project Manage 31(6):903–911
Pan N (2005) Assessment of productivity and duration of highway construction activities subject to impact of rain. Expert Syst Appl 28(2):313–326
Pan W, Ning Y (2014) Dialectics of sustainable building: evidence from empirical studies 1987–2013. Build Environ 82:666–674
Pan W, Zhan, W, Zhao X, Wang J, Lam JC (2016) Cost paradigms of future building. In: IET 2016 symposium on cost management for mega projects. The Institution of Engineering and Technology, Hong Kong, 6 May 2016
Parham D, Economics D (2008) Definition, importance and determinants of productivity. http://goo.gl/sXnaax, 19 Feb 2016
QSR International (2015) NVivo 10 for windows. QSR International Pty Ltd. Australia. http://goo.gl/7r4KQR, 14 May 2015
Richardson GP, Pugh III AI (1981) Introduction to system dynamics modeling with DYNAMO. Productivity Press Inc
Rivas RA, Borcherding JD, González V, Alarcón LF (2010) Analysis of factors influencing productivity using craftsmen questionnaires: case study in a Chilean construction company. J Constr Eng Manage 137(4):312–320
Rodrigues A (1994) The role of system dynamics in project management: a comparative analysis with traditional models. In: Conference proceedings the 12th international conference of the system dynamics society Stirling, Scotland, 214
Rojas EM, Aramvareekul P (2003) Is construction labor productivity really declining? J Constr Eng Manage 129(1):41–46
Sanvido VE (1988) Conceptual construction process model. J Constr Eng Manage 114(2):294–310
Ventana Systems (2016) Vensim PLE software. Ventana Systems Inc. http://vensim.com/, 23 June 2016
Zhi M, Hua GB, Wang SQ, Ofori G (2003) Total factor productivity growth accounting in the construction industry of Singapore. Constr Manage Econ 21(7):707–718

Chapter 13
A Whole Life Cycle Group Decision-Making Framework for Sustainability Evaluation of Major Infrastructure Projects

B. Xue and H. Xu

13.1 Introduction

Currently, in the accelerative stage of urbanization in China, the urban population is expected to increase by 310 million in the year 2030, reaching to 70% in urbanization rate (United Nations Development Programme 2013). Among those factors facilitating urbanization process, the level of major infrastructure development is one of the most significant driving forces (Wu and Sun 2010). However, there lie some problems of construction management decision-making of major infrastructure projects (MIPs) in the current urbanization progress of developing countries: lack of long-term perspective during planning stage; insufficient account for demand variation; and low-level adaptability during MIPs' whole life cycle (WLC), especially in feasibility research stage. In allusion to these hot problems, many research scholars have made great efforts to deal with them. To be precise, the representative scholars, Shen et al. (2011), established key assessment indicators to evaluate infrastructure from the perspective of sustainable development. Furthermore, based on the WLC theory, Meng et al. (2015) divided construction process into four stages, i.e., decision-making stage, planning stage, construction stage, and operation stage to dynamically analyze and identify the key influence indicators of infrastructure sustainability in the context of Chinese urbanization. In addition, Liu et al. (2014a, b, c) developed some substantial group decision-making

B. Xue (✉)
Department of Architecture and Civil Engineering, College of Science and Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR, China
e-mail: xuebin527@gmail.com
URL: https://www.researchgate.net/profile/Bin_Xue11

H. Xu
School of Construction Management and Real Estate, Chongqing University, Chongqing, China
e-mail: changsha2006916@163.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_13

(GDM) models in construction projects both by empirical study and quantitative study to improve scientificity and objectivity of GDM process. However, decision-making of construction projects is a complex systematic project involving diversified decision-makers and multi-layered purposes (Liu et al. 2014c). Therefore, the root causes of the issues above mentioned are the lack of consideration of sustainability dimension in the decision-making process of MIPs management, the static and divisional attitudes toward infrastructure appraisal hold by decision-makers, and the shortage of systematic deliberation on sustainability impacts during the WLC decision-making process of infrastructure management. Nevertheless, large-group public participation, as a bottom-up democratic decision-making model based on public interests, could dissolve decision-making conflict, as well as defend social stabilization. It is being commonly accepted by practitioners and scholars that large-group public participation based decision-making mechanism for real-timely sustainability evaluation should be boosted and perfected during the process of quickening transparency, scientificity, and democratization of MIPs (Cole 1981; Xi 1988; Lu 2009; Liu et al. 2014b, c).

Decision-making of MIPs under large-group public participation is essentially a typical question of multi-layers, multi-stakeholders, multi-attributes, complex large-group, and dynamic interactive decisions under uncertain circumstances, which is generally divided into four stages: decision-making of project intention, optimization of project objectives, identification of key indicators, and planning of project programs, with their objectives being various as well as internally connected. Decision-makers will showcase the characteristics of large scale and sheer complexity, which directly influences decision-making effects through conflict differences upon the preference of decisions due to their diversified backgrounds, knowledge, and information resources (Lei et al. 2011a). However, one of the most efficient ways to defuse the conflicts is to make dynamic interactive decisions, by which specific sustainable schemes can be improved continuously to meet the needs of stakeholders to the largest extent and fulfill the WLC real-time evaluation of MIPs sustainability. Furthermore, dynamic interactive decision-making requires integration of construction project information during its WLC for real-time sustainability evaluation, which creates a new orientation and a great platform for integrating GDM modeling with WLC evaluation technology (i.e., provides a new insight of evaluation, simulation, and monitoring of buildings with multi-level interfaces) in sustainability study. Therefore, the research scope of this study is to develop an operational Sustainability Breakdown Structure (SBS) framework and a conceptual Dynamic Interactive Coordination based GDM (DIC-GDM) framework for real-timely integrating GDM information and MIPs sustainability evaluation.

13.2 Literature Review

Among the research efforts related to MIPs sustainability evaluation by means of GDM models and WLC technology, three aspects, including infrastructure sustainability, GDM models in construction projects, and life-cycle assessment for construction projects, are attracting the most attention from scholars.

13.2.1 Infrastructure Sustainability

Infrastructure sustainability provides a sustained and effective system for urban economic, social, and ecological development throughout the WLC of MIPs and has the property of maintaining long-term infrastructure functional value based on its safety, validity, and durability as project life and urbanization process go on Meng et al. (2015). Research scholars are now discerning key sustainability influencing factors regarding the sustainability evaluation of infrastructure mainly by means of literature review, field research, and expert interviews to establish sustainable decision indicator systems. Dae-Hyun et al. (2009) supposed that influencing factors affecting infrastructure sustainability include construction materials, construction technologies, project management, land and space utilization, environment pollution, social value and culture protection, economic efficiency and benefits, etc.; others like Shen et al. (2011) set up indicator systems of infrastructure sustainability evaluation based on 20 key indicators from three aspects, i.e., economy, society, and environment. However, Ugwu and Haupt (2007) hold the view that the factors affecting infrastructure sustainability should be categorized into 6 aspects, which are economy, environment, society, resources utilization, health and safety, and project management. In allusion to two-phase evaluation, Shovini and Edwin (2005) designed two groups of evaluation indicators, i.e., mandatory filtration indicator and discriminate indicator. Apart from those, some other scholars established decision-making indicator systems with regard to aspects like project waste management (Hee et al. 2009), project delivery (Rodolfo and Leidy 2013; Liu et al. 2015), project social impact (Lipika et al. 2011), project environmental influences (Zhou and William 2011; John et al. 2012), etc.

Although large amounts of scholars made eminent contributions to exploring decision-making indicator systems of infrastructure sustainability that are the basis and reference of this study, the sustainability management and decision-making mechanism for MIPs were excessively macroscopic, lack of operability, and yet did not form a unified mature dynamic interactive decision-making factor set for WLC real-timely sustainability evaluation.

13.2.2 Group Decision-Making Models in Construction Projects

In the research area of GDM in construction projects, scholars launched preliminary discussions on the basis of the importance, approach, legal status, and procedure of public participation, which only concentrated on the planning stage. Amado et al. (2010) had discussed the ways by which the citizens could take part in urban scheming decision-making and put forward the significance of public participation in the process of sustainable urban planning. In fact, the sustainability decision-making for MIPs under public participation is essentially a complex GDM problem. Recently, with the development of global democratization and internet technology, the decision-makers' structures and decision-making surroundings have become more and more complicated. As a result, complex GDM is now a hotspot in research circles. In the study of GDM methods, scholars' researches covered aggregation of decision-makers, decision-making information integration and so forth (Herrera and Martinez 2000; Herrera et al. 2005, 2008; Chen 2009), the outcomes of which are mainly applied in fields like major construction projects (Liu et al. 2014a) and natural disaster management (Xu 2011). Furthermore, in the decision-making mechanism of infrastructure sustainability under large-group public participation, conflicts among decision-makers were proved as a common problem (Palomares et al. 2014), whose effective solution, as a result, will be critical. Apart from these, according to dynamic interactive decision-making for resolving conflicts, researches have been conducting on the basis of reasons, measurement models, coordination or negotiation strategies, and decision-making methods of conflicts (Lang et al. 2005; Liu et al. 2014b, c). Getting access to relevant research achievements and selectively referring to the research area of major projects decision-making will definitely lay the foundation for the innovation of dynamic interactive decision-making of infrastructure sustainability evaluation under large-group public participation.

While the significance of decision-making under public participation in construction projects and the dominant characteristics of large scale and crucial collision of decision-makers have been realized by scholars, exploiting the decision-making methodology systems to solve conflicts problem is not only the foundation for scientific decision-makings in MIPs but the trend of GDM theory and technique innovation. Therefore, based on the infrastructure sustainability decision-making factor sets being established in this study, it will become one of the most urgent academic issues of dynamic interactive decision-making methodology systems to analyze characteristics of GDM processes and develop dynamic interactive coordination measurement model, information integration model, as well as decision-making model for real-timely evaluating WLC sustainability of MIPs.

13.2.3 *Life-Cycle Assessment (LCA) for Construction Projects*

LCA is a cradle-to-grave research methodology for systematically analyzing and evaluating environmental performance of products, projects, or processes over their WLC, including raw material extraction, manufacturing, transportation, use, and end-of-life disposal and recycling (Cabeza et al. 2014). Currently, as for the studies of LCA application in construction projects' sustainability evaluation, areas like energy consumption, carbon emissions, and environmental impacts during their WLC are being conducted (Cabeza et al. 2013; Rincón et al. 2013).

From the perspective of analyzing energy consumption and carbon emissions by LCA, Ramesh et al. (2010) and Cabeza et al. (2013, 2014) conducted a research review of LCA application in buildings respectively, which summarized that buildings' life cycle energy demand can be reduced by the reduction of operating energy through the use of passive and active technologies and that low energy buildings perform better than self-sufficient (zero operating energy) buildings in the WLC context. More importantly, these two studies also concluded that most of the case studies available are conducted in developed or cold countries, leaving the building energy analysis with LCA for developing or non-cold countries needing to be evaluated and compared in the future. Besides, Hernandez and Kenny (2010) defined a new LCA model, namely life cycle zero energy buildings (LC-ZEB) for analyzing embodied energy of building components together with energy consumption in operation, as well as proposed the net energy ratio (NER) as a factor to aid in building design with a WLC perspective. In addition, Rossi et al. (2012) developed an LCA model for residential buildings located in three different European towns that focused on the structure and materials of the buildings to evaluate their embodied energy, embodied carbon, and yearly energy consumption.

From the perspective of evaluating environmental impacts by LCA, Khasreen et al. (2009) conducted a research review of LCA and environmental impacts for buildings and identified the future study areas as the whole process of construction, the relative weighting of different environmental impacts, and the applications in developing countries. Besides, Bribián et al. (2011), Van den Heede and De Belie (2012), and Rincón et al. (2013) analyzed the environmental impacts (embodied energy and energy consumption) of building materials, which deepened the knowledge of energy and environmental specifications of building materials through assessing their possibilities for improvement and indicating guidelines for materials selection in the eco-design of new buildings and rehabilitation of existing buildings. Furthermore, Cuéllar-Franca and Azapagic (2012) presented a full LCA model for the three most common types of house in the UK, i.e., detached, semi-detached, and terraced and highlighted the significance of decision-makings in the design and construction stages as they determine the impacts in the use and end-of-life stages of buildings.

Although the LCA studies in energy consumptions and carbon emissions of buildings tend to be mature, most of the recent studies mainly focus on a certain or several stages in the buildings' WLC, without much attempts to take major construction projects like infrastructures into consideration and to integrate LCA with other methodologies such as GDM models to simulate and evaluate infrastructure's WLC (i.e., building material production, building construction, building renovation, building operation, and building demolition) sustainability, so as to explore standardized building construction ideas and patterns with lower sustainability or environmental impacts, which is one of the key scientific issues that will be tackled in this study.

As a consequence, an integration of a systematic GDM factor set with dynamic interactive coordination GDM framework is the theoretical and practical need for sustainability evaluation of MIPs. The abovementioned comprehensive literature review, objectively, provides a substantial basis for developing the sustainability evaluation system of MIPs.

13.3 Sustainability Breakdown Structure Framework

Taking the multi-attributes characteristics of GDM procedure as the starting point, the MIPs sustainability has been outlined with the research idea of definition and breakdown of sustainability concept. Based on the research findings of Meng et al. (2015), we have divided the infrastructure sustainability into internal efficiency and external efficiency from the perspective of project system theory. To be specific, the internal efficiency is measured by three dimensions, i.e., buildability, maintainability, and long-term adaptability; the external efficiency is measured by two dimensions, i.e., social utility and environmental implication. Therefore, the Sustainability Breakdown Structure (SBS) framework with the two-level dimensions of infrastructure sustainability is shown in Fig. 13.1.

Furthermore, after classifying, revising, combining, and breaking down the GDM sustainability dimensions based on MIPs' WLC, the influencing mechanism among GDM sustainability dimensions is going to be explored by the established PLS (Partial Least Squares) path framework, which is illustrated in Fig. 13.1. As a result, the interactive relationships (including positive and negative impacts), influence properties, influence extents, and influence paths among the two-level dimensions can be properly identified. Based on the WLC theory, the dynamic weights can be determined by the path analysis of the PLS framework according to the paths coefficients during the various stages of MIPs. Ultimately, key measurable factors of GDM sustainability evaluation can be identified in accordance with the principle of "retaining the large and releasing the small" to optimize the initial dimension set (Liu et al. 2014a, c).

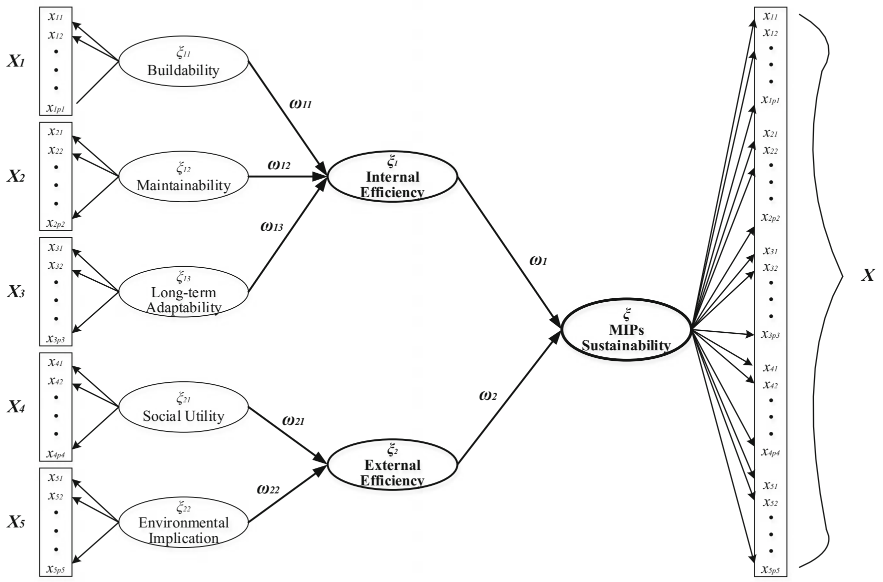


Fig. 13.1 The SBS and PLS path analysis framework. *Notes* $X_1 = (x_{11}, x_{12},\ldots, x_{1p1})$ is the measurable factor set of buildability (ξ_{11}); $X_2 = (x_{21}, x_{22},\ldots, x_{2p2})$ is the measurable factor set of maintainability (ξ_{12}); $X_3 = (x_{31}, x_{32},\ldots, x_{3p3})$ is the measurable factor set of long-term adaptability (ξ_{13}); $X_4 = (x_{41}, x_{42},\ldots, x_{4p4})$ is the measurable factor set of social utility (ξ_{21}); $X_5 = (x_{51}, x_{52},\ldots, x_{5p5})$ is the measurable factor set of environmental implication (ξ_{22}). (ω_{11}, ω_{12}, ω_{13}) is the weight vector of internal efficiency (ξ_1); (ω_{21}, ω_{22}) is the weight vector of external efficiency (ξ_2); (ω_1, ω_2) is the weight vector of MIPs sustainability (ξ)

13.4 Dynamic Interactive Coordination Based Group Decision-Making Framework

Based on the SBS framework and from a public participation perspective, a conceptual Dynamic Interactive Coordination based GDM (DIC-GDM) framework has been established for determining group decision-makers' and GDM attributes' evaluation weights, as well as for integrating GDM information of MIPs sustainability evaluation.

13.4.1 Coordination Mechanism Design of Dynamic Interactive GDM

To begin with, the empirical decision-making questionnaire survey, including multi-attribute SBS decision-making framework of MIPs sustainability, can be designed for collecting data. Furthermore, the constructive suggestions for sustainability decision-making scenarios based on public participation by means of text mining technology can be identified. In addition, based on the quantitative and qualitative methods, the dynamic interactive coordination strategies is going to be designed and conducted to realize the organic combination and maximum coupling of GDM measurement and GDM coordination.

13.4.2 Measurement Model Development of Dynamic Interactive GDM

To start with, a visual clustering model based on the SBS framework and its relative algorithms of multi-attribute GDM under linguistic environment can be developed and designed based on social network technology to analyze the aggregation structure of preferences among different decision-making groups. Moreover, a dynamic interactive coordination measurement model is going to be established under linguistic environment via the application of Euclidean Distance Model to calculate each decision maker's preference vector within every aggregation structure and the overall decision-making preference vector among all the aggregation structures.

13.4.3 DIC-GDM Development Under Public Participation

First of all, a coordination bi-level programming model (Lei et al. 2011a, b) with interactive multi-attributes of the SBS framework under public participation and its relative resolution algorithms to work out consistent or compromising satisfactory solutions among different decision-making groups can be developed. Moreover, an information integration model of DIC-GDM with SBS multi-attributes based on relative entropy theory to effectively coordinate the conflicts of interests or suggestions among various decision-makers is then going to be established. Besides, a fuzzy coordination rating model based on fuzzy logic theory (Tan et al. 2011) to explore fitting interval of coordination between satisfactory solutions under minimum conflicts and DIC-GDM information for MIPs during their WLC (i.e., MP stage, MT stage, C stage, R stage, O stage, D stage, and WT stage) can be developed, which will guarantee high coordination degree of dynamic interactive GDM under public participation for real-timely evaluating MIPs' WLC sustainability.

Consequently, based on the LCA study idea, this study has initially developed a conceptual framework of DIC-GDM for MIPs sustainability evaluation, which is shown in Fig. 13.2.

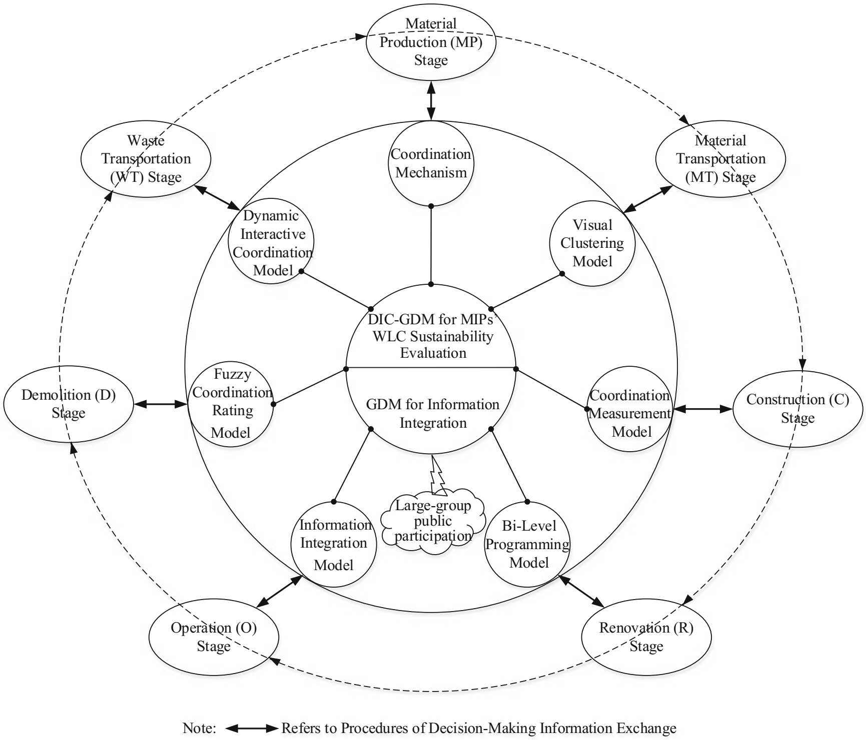


Fig. 13.2 The DIC-GDM framework

13.5 Sustainability Evaluation of Major Infrastructure Projects

Based on the established SBS framework and DIC-GDM framework, this study has developed an integrated procedure for MIPs' WLC sustainability evaluation under public participation. To be precise, the SBS framework, assisted by the two-level dimensions criteria that identified from the PLS path analysis framework, and the DIC-GDM framework, assisted by the multi-attribute GDM information integration procedure, can be integrated with each other via real MIP cases, simultaneously guided by means of WLC monitoring and simulation procedures. Furthermore, the GDM and evaluation data from group decision-makers under public participation is collected from data sources of WLC monitoring and simulation procedures (i.e., MP stage, MT stage, C stage, R stage, O stage, D stage, and WT stage) based on the LCA method. Besides, the public decision-making and evaluation data is going to be flowed into a GDM and evaluation information database to properly integrate SBS framework with DIC-GDM framework for MIPs sustainability evaluation. As

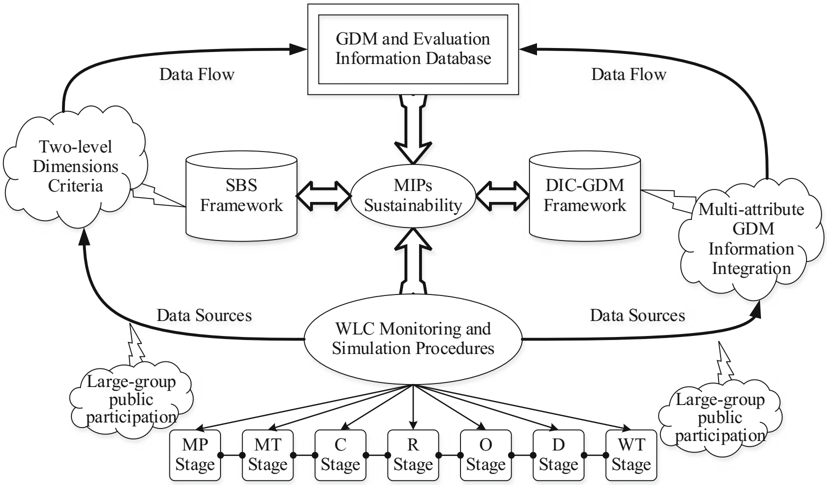


Fig. 13.3 The integrated procedure for MIPs' WLC sustainability evaluation

a result, the integrated MIPs' WLC sustainability evaluation procedure is illustrated in Fig. 13.3.

13.6 Conclusions and Further Research

This study proposes the research idea of establishing SBS framework and internal influencing mechanism to identify sustainability decision-making and evaluation factors for MIPs. More importantly, from a research design pattern angle, this study develops the large-group public participation based DIC-GDM framework for real-timely evaluating MIPs' WLC sustainability.

From the perspective of methodological and theoretical value, the introduced SBS framework (the research strategy of the establishment of GDM factors and exploration of influencing mechanism) provides a new insight of taxonomy in defining the concept of MIP sustainability. Furthermore, the proposed DIC-GDM framework (the research strategy of measurement of dynamic interactive coordination and integration of GDM information) will innovatively and organically consolidate GDM evaluation for MIPs' WLC sustainability to realize the creativity of research methodology at a mechanism level and a modeling level. From the perspective of practical value, the integrated evaluation procedure for MIPs' WLC sustainability under all-around and all-dimensional large-group public participation will achieve the information integration and optimization from public and policy decision-makers, as well as realize the principle of openness, fairness, impartiality in GDM and real-timely evaluation. All in all, the study on integrating SBS framework with DIC-GDM framework for real-timely evaluating MIPs' WLC sustainability from the perspective of public participation is not only valuable in theoretical methodology innovation of combining GDM theory with classification theory, but also certainly valuable in practical MIP sustainable development and success in the long run.

Prospectively, quantitative and qualitative modeling development of GDM under public participation to enrich the DIC-GDM framework should be made in further efforts. In addition, feedback, optimization, and supervision mechanisms should be designed to normalize and optimize the integrated evaluation procedure for MIPs' WLC sustainability in future studies.

References

Amado MP, Santos CV, Moura EB (2010) Public participation in sustainable urban planning. Int J Soc Sci 5(2):102–108

Bribián IZ, Capilla AV, Usón AA (2011) Life cycle assessment of building materials: comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. Build Environ 46(5):1133–1140

Cabeza LF, Barreneche C, Miró L, Morera JM, Bartolí E, Fernández AI (2013) Low carbon and low embodied energy materials in buildings: a review. Renew Sustain Energy Rev 23:536–542

Cabeza LF, Rincón L, Vilariño V, Pérez G, Castell A (2014) Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. Renew Sustain Energy Rev 29:394–416

Chen XH (2009) Methods and application of complex large group decision-making. Science Press, Beijing

Cole RL (1981) Participation in community service organizations. J Community Act 1:53–60

Cuéllar-Franca RM, Azapagic A (2012) Environmental impacts of the UK residential sector: life cycle assessment of houses. Build Environ 54:86–99

Dae-Hyun K, Samuel TA, Edward KJ (2009) Development of a sustainability assessment model for underground infrastructure projects. Can J Civ Eng 36:765–776

Hee S, Jeehye K, Ju-Yeoun H (2009) Identifying and assessing influence factors on improving waste management performance for building construction project. J Constr Eng Manage 135 (7):647–656

Hernandez P, Kenny P (2010) From net energy to zero energy buildings: defining life cycle zero energy buildings (LC-ZEB). Energy Build 42(6):815–821

Herrera F, Martinez L (2000) A 2-tuple fuzzy linguistic representation model for computing with words. IEEE Trans Fuzzy Syst 8(6):746–752

Herrera F, Martinez L, Sanchez PJ (2005) Managing non-homogeneous information in group decision-making. Eur J Oper Res 166(1):115–132

Herrera F, Herrera-Viedma E, Martinez L (2008) A fuzzy linguistic methodology to deal with unbalance linguistic term sets. IEEE Trans Fuzzy Syst 16(2):354–370

John M, Usha I, Patricia M, Anthony M (2012) A strategic project appraisal framework for ecologically sustainable urban infrastructure. Environ Impact Assess Rev 33(1):55–65

Khasreen MM, Banfill PF, Menzies GF (2009) Life-cycle assessment and the environmental impact of buildings: a review. Sustainability 1(3):674–701

Lang CHG, Xi YM, Bi PCH (2005) Study on conflict in group decision making process. Forecasting 24(5):1–8

Lei LC, Zhou J, He J (2011a) Complex analysis and process study of decision-making in major construction projects. Project Manage Technol 9(1):18–22

Lei LC, Zhou J, Li M (2011b) Study on interactive multi-attribute group decision making method for large-scale projects based on relative entropy. China Soft Sci 2:166–175

Lipika S, Sinen K, David R (2011) Project delivery metrics for sustainable high-performance buildings. J Constr Eng Manage 137(12):1043–1051

Liu BS, Huo TF, Liao PC, Gong J, Xue B (2014a) A group decision-making model for contractor selection in large construction projects based on two-stage partial least squares (PLS) path modelling. Group Decis Negot 24(5):855–883

Liu BS, Shen YH, Chen XH, Chen Y, Sun H (2014b) PLS path modelling based methods for the complex multi-attribute large-group decision making problem under interval-valued intuitionistic fuzzy environment. Appl Math Model 38(17):4512–4527

Liu BS, Shen YH, Chen XH, Chen Y, Wang XQ (2014c) A partial binary tree DEA-DA cyclic classification model for decision makers in complex multi-attribute large-group interval-valued intuitionistic fuzzy decision-making problems. Inf Fusion 18:119–130

Liu BS, Huo TF, Shen QP, Yang ZY, Meng JN, Xue B (2015) Which owner characteristics are key factors affecting project delivery system decision making? Empirical analysis based on the rough set theory. J Manage Eng 31(4):05014018

Lu GY (2009) Establishment of decision-making misplay and decision-making mechanism in major projects. Forum Sci Technol China 4:3–35

Meng JN, Xue B, Liu BS, Fang N (2015) Relationships between top managers' leadership and infrastructure sustainability—a Chinese urbanization perspective. Eng Constr Architectural Manage 22(6):692–714

Palomares I, Martinez L, Herrera F (2014) A consensus model to detect and manage non-cooperative behaviours in large group decision making. IEEE Trans Fuzzy Syst 22 (3):516–530

Ramesh T, Prakash R, Shukla KK (2010) Life cycle energy analysis of buildings: an overview. Energy Build 42(10):1592–1600

Rincón L, Castell A, Pérez G, Solé C, Boer D, Cabeza LF (2013) Evaluation of the environmental impact of experimental buildings with different constructive systems using material flow analysis and life cycle assessment. Appl Energy 109:544–552

Rodolfo V, Leidy EK (2013) Social sustainability considerations during planning and design: framework of processes for construction projects. J Constr Eng Manage 139(1):80–89

Rossi B, Marique AF, Glaumann M, Reiter S (2012) Life-cycle assessment of residential buildings in three different European locations, basic tool. Build Environ 51:395–401

Shen L, Wu Y, Zhang X (2011) Key assessment indicators for the sustainability of infrastructure projects. J Constr Eng Manage 137(6):441–451

Shovini D, Edwin KL (2005) Indicators and framework for assessing sustainable infrastructure. Can J Civ Eng 32:30–44

Tan YT, Shen LY, Langston C (2011) A fuzzy approach for assessing contractors' competitiveness. Eng Constr Architectural Manage 18(3):234–247

Ugwu OO, Haupt TC (2007) Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective. Build Environ 42:665–680

United Nations Development Programme (2013) China human development report: sustainable and livable cities. China Translation & Publishing Corporation, Beijing

Van den Heede P, De Belie N (2012) Environmental impact and life cycle assessment (LCA) of traditional and 'green' concretes: literature review and theoretical calculations. Cement Concr Compos 34(4):431–442

Wu LC, Sun PY (2010) China's infrastructure development's impact on China's urbanization process. China Popul Resour Environ 20(8):121–125

Xi YM (1988) Decision-making of large-scale projects. Guiyang People Press, Guiyang

Xu XH (2011) Complex large group decision making models and application for extraordinarily serious natural disasters. Science Press, Beijing

Zhou K, William RS (2011) EIA application in China's expressway infrastructure: clarifying the decision-making hierarchy. J Environ Manage 92(6):1471–1483

Chapter 14
Adaptive Reuse of Inner-City Buildings: Methods for Minimising Waste and Stimulating the Economy

N. Udawatta, Zillante George, A. Elmualim, R. Rameezdeen and J. Zuo

14.1 Introduction

As a result of rapid improvements and restructuring of the economy, number of aged and obsolete buildings in the world has been increased in the recent past (Tan et al. 2014). Similarly, commercial and operating performance of buildings tend to decline over the lifespan (Bullen and Love 2010). Petersdorff et al. (2006) stated that other than natural depreciation of buildings, the building's effectiveness is affected by the dynamic market demands. As highlighted by Government of South Australia (2013), buildings face physical, functional, technological and economic obsolescence with their age. Thus, in order to use built stocks sustainably, it is necessary to optimise the use of buildings by considering their residual life expectancy (Bullen and Love 2010). Furthermore, to reduce environmental degradation and problems associated with resource depletion, it is necessary to identify the appropriate methods of dealing with ageing building stocks in cities (Eames et al. 2014). Researchers identified a narrow focus on demolition and redevelopment of buildings and the absence of focus on urban regeneration activities as main problems associated with urban renewal activities (Yung et al. 2014). As pointed out by Wilkinson and Remoy (2011), there are social issues associated with structurally vacant buildings. Thus, Eames et al. (2014) pointed out the importance of collectiveness of urban retrofitting activities to provide substantial amount of social, economic and environmental benefits. Thus, in this research, an

N. Udawatta
School of Architecture and Built Environment, Deakin University, Geelong, Australia

Z. George · J. Zuo (✉)
School of Architecture and Built Environment, University of Adelaide, Adelaide, Australia
e-mail: jian.zuo@adelaide.edu.au

A. Elmualim · R. Rameezdeen
School of Natural and Built Environments, University of South Australia, Adelaide, Australia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_14

extensive literature review together with cost analysis were undertaken to identify benefits and barriers for adaptive reuse of buildings in the Central Business District CBD) of Adelaide.

14.2 Common Strategies of Dealing with Vacant Buildings

Bullen and Love (2010) highlighted that developers and owners/managers have different focuses on building's performance, i.e. short term investment vs. long term operational performance. Building owners often tend to follow four possible strategies in relation to vacant office buildings such as: consolidate; renovate; demolish and rebuild; and convert to new a function (Remøy and van der Voordt 2014).

As consolidation is often not economical and there are high risks associated with redevelopment, conversion to new use was identified as less disruptive and beneficial in terms of financial and social aspects (Remøy and van der Voordt 2014). According to the study conducted by Kohler and Yang (2007), refurbishment of buildings was identified as an economical method than demolition. Highfield (2000) observed that if a building is structurally stable and in high quality, better to refurbish. However, Kohler and Yang (2007) pointed out that ability to renovate a building is limited when it has shortcomings related to the performance. In such situations the renovation cost, could be higher than new construction. Furthermore, Bruce et al. (2015) pointed often it is not convenient to demolish a building in CBD due to its proximity to other buildings and sharing of common footing with them. Bullen and Love (2010) pointed out that even though there is a notion that buildings are demolished due to their lower value, the value is set by the market instead of externalities. Furthermore, Itard and Klunder (2007) stated that both physical and economical capital are destroyed due to demolition of buildings.

However, some researchers pointed out that if a buildings' life can be optimised by adaptive reuse, decision to demolish it can be premature (Ellison et al. 2007). Bullen and Love (2010) pointed out that buildings should only be demolished if those cannot be converted due to technical or physical incapability. Measurements of the building and structure play an important role in the conversion (Remøy and van der Voordt 2014). Tan et al. (2014) highlighted the benefits of changing the use of a building by retaining the structure and fabric compared to extracting materials subsequent to deconstruction. The following section explains the factors affecting the decision to reuse buildings.

14.3 Factors Affecting the Decision of Reusing Buildings

Bullen and Love (2010) identified a number of factors, which affect the decision to reuse rather than demolition, that includes: ability to attract tenants, investment returns, meeting employee needs, marketability, maintenance and repair costs, operating costs, productivity levels, employee retention rates and market value. According to Remøy and van der Voordt (2014), opportunities and risks associated with building conversions in Netherlands are influenced by a number of issues such as financial, functional and engineering. Itard and Klunder (2007) stated that longevity of buildings can be affected by adverse impacts on environment and technical problems associated with renovation and refurbishment of buildings. Thus, Franco et al. (2015) pointed out the importance of finding the compatibility of conservation and innovation of building in refurbishment. Table 14.1 summarises the key factors that affect the decision to reuse buildings.

Table 14.1 Factors affecting the decision to reuse buildings

Factor	Sub-factor	Country	Relevant studies
Legal	New function fits the zoning plan	Netherlands	Remøy and van der Voordt (2014)
	Conversion preferred by the neighbours	Netherlands	Remøy and van der Voordt (2014)
	Measures fit with building code requirements	Netherlands	Remøy and van der Voordt (2014)
Financial	Low purchasing price	Netherlands	Remøy and van der Voordt (2014)
	Pre-selling implies lower financing costs	Netherlands	Remøy and van der Voordt (2014)
	Commercial activities in the plinth	Netherlands	Remøy and van der Voordt (2014)
	Investment returns	Perth, Australia	Bullen and Love (2010)
	Maintenance and repair costs	Perth, Australia	Bullen and Love (2010)
	Operating costs	Perth, Australia	Bullen and Love (2010)
	Market value	Perth, Australia	Bullen and Love (2010)
Technical	Reuse of large parts of the existing building, e.g. facade and construction	Netherlands	Remøy and van der Voordt (2014)
	Strong floors; possible to add extra weight	Netherlands	Remøy and van der Voordt (2014)
	Strong foundation; vertical extension possible	Netherlands	Remøy and van der Voordt (2014)

(continued)

Table 14.1 (continued)

Factor	Sub-factor	Country	Relevant studies
Functional	Sufficient parking places	Netherlands	Remøy and van der Voordt (2014)
	Existing floor plan is easily adapted	Netherlands	Remøy and van der Voordt (2014)
	Extra 'leftover space' not available in new developments	Netherlands	Remøy and van der Voordt (2014)
	Meeting employee needs	Perth, Australia	Bullen and Love (2010)
	Marketability	Perth, Australia	Bullen and Love (2010)
	Productivity levels	Perth, Australia	Bullen and Love (2010)
	Employee retention rates	Perth, Australia	Bullen and Love (2010)
Cultural-historical	Historical value, strong architectural appearance	Netherlands	Remøy and van der Voordt (2014)
	Positive impact on the surrounding area	Netherlands	Remøy and van der Voordt (2014)

14.4 Adaptive Reuse of Buildings

A common definition of adaptive reuse of buildings is "a process that changes a disused or ineffective item into a new item that can be used for a different purpose" (Department of Environment and Heritage 2004). According to Department of Environment and Heritage (2004), during the process of adaptive reuse, it is necessary to protect the heritage value of buildings. There are economic, technical, spatial, environmental and social advantages of adaptive reuse of buildings. Similarly, there are technical, economic, environmental and legal disadvantages of adapting buildings (Douglas 2006). Thus, Bullen and Love (2010) identified four main criteria that should be considered in adaptive reuse decision-making process, that includes environmental, economic, social and governance related factors. Yung et al. (2014) stated that mostly social and economic factors affect the decision of adaptive reuse of buildings in Hong Kong. Yung et al. (2014) highlighted the importance of maintaining the balance between economic performance and social performance during the process of adaptive reuse of buildings.

14.4.1 Different Approaches and Key Attributes Associated with of Adaptive Reuse of Buildings

The property market is comprised of four general sectors such as: residential, commercial, office and industrial (Tan et al. 2014). One of the important drivers for converting office buildings into some other function is mostly driven by structural vacancy in buildings (Remøy and van der Voordt 2014). Remøy and van der Voordt (2014) pointed out that converting vacant office buildings to housing as an effective method of adaptive reuse of vacant office buildings. Supporting this, Tan et al. (2014) highlighted that by converting unused office buildings to residential buildings bring people back and revitalize the inner city. This method was successfully used for inner city redevelopment in both London and Toronto (Remøy and van der Voordt 2014). Similar approaches were applied for excess office buildings in New York and Tokyo (Remøy and van der Voordt 2014). According to Remøy and van der Voordt (2014), environmental consciousness is the main driver for adaptation and conversion of buildings in Australia. As highlighted by Wilkinson et al. (2009) and Wilkinson and Remoy (2011), there are number of attributes associated with adaptive reuse of buildings such as: age, condition, envelope, structure, building services, internal layout, location, heritage, size, accessibility, parking and character/aesthetics.

14.4.2 Benefits and Barriers of Adaptive Reuse of Buildings

Table 14.2 highlights the benefits of adaptive reuse of buildings, which were identified from the literature.

Table 14.2 Benefits of adaptive reuse of buildings

Benefits of adaptive reuse of buildings	Relevant studies
Promote sustainable construction	Conejos, et al. (2015)
Address issues related to climate change	Conejos, et al. (2015)
Lower material, transport and energy consumption	Bullen and Love (2011)
Reduced resource consumption	Bullen and Love (2011); Tan et al. (2014)
Less material waste	Bullen and Love (2011); Tan et al. (2014)
Rising energy costs	Bullen and Love (2011)
Building functionality	Bullen and Love (2011)
Less disruption	Bullen and Love (2011)
Reduce negative impact of poor buildings	Bullen and Love (2011)
Changing work patterns	Bullen and Love (Bullen and Love 2011)
Requirement for multiple use	Bullen and Love (2011)
Financial incentives	Bullen and Love (2011)

Conejos et al. (2015) stated that adaptive reuse of buildings promote environmental sustainability while addressing issues related to climate change. Similarly, adaptive reuse of buildings provide more sustainable solutions for reuse of buildings for property stakeholders by reducing waste generation and resource consumption due to construction activities (Tan et al. 2014). Furthermore, Ferretti et al. (2014) stated that reuse of historical buildings are challenging due to presence of different actors and different values such as historical, cultural, economic, and artistic. Similarly, Yung et al. (2014) identified clashes between heritage values and economic viability in the decision of adaptive reuse of buildings. Conejos et al. (2015) pointed out that the concept of sustainability is generally focused on energy and resource consumption than potentials of adaptive reuse of buildings. Similarly, uncertainty associated with financial feasibility in adaptive reuse and limited knowledge on risks and opportunities associated with this conversion process act as barriers to convert office buildings to housing in Netherlands (Remøy and van der Voordt 2014). A summary of barriers to adaptive reuse of buildings is shown in Table 14.3.

Table 14.3 Barriers to adaptive reuse of buildings

Barriers to adaptive reuse of buildings	Relevant studies
Condition of external fabric and finishes	Bullen and Love (2011)
Maintenance costs	Bullen and Love (2011)
Higher rental in reuse buildings	Bullen and Love (2011)
Building regulations/planning restrictions	Bullen and Love (2011)
Complexity	Bullen and Love (2011)
Lack of skilled tradesmen	Bullen and Love (2011)
Building layout (e.g. space efficiencies)	Bullen and Love (2011)
Health and safety requirements	Bullen and Love (2011)
Commercial risk and uncertainty	Bullen and Love (2011)
Low quality construction	Bullen and Love (2011)
Uncertainty associated with financial feasibility in adaptive reuse	Remøy and van der Voordt (2014)
Risks and opportunities associated with this conversion process	Remøy and van der Voordt (2014)
High land costs	Porter (2012: 21)
Opposition from neighbourhood	Porter (2012: 21)
Complex zoning and approval processes	Porter (2012: 21)
Inflexible zoning restrictions and regulations	Porter (2012: 21)
The need to design new projects to fit into existing neighbourhoods	Porter (2012: 21)
The high cost of deck parking (for high-density projects)	Porter (2012: 21)
Lack of popular and market support for and knowledge of higher-density and mixed use	Porter (2012: 21)

Thus, Siu (2014) identified the importance of collecting information related to building design and constraints; number of occupants and their characteristics; nature of activities undertaken in the building; and materials of construction of the building.

In the Australian context, CBDs attracts most of the office buildings due to radial nature of public transport and road systems (Colliers International 2015). However, as a result of the trend of converting commercial zones to residential zones, the growth of office developments in Australia has been in decline (Colliers International 2015). According to a study conducted by Adelaide City Council and Jones Lang LaSalle (2007), Adelaide central business district was experiencing its largest construction cycle in last two decades and it has been created a domino effect on developers and land owners to reconsider their landholding options. According to Snoswell (2014), Adelaide office market comprises 1.383 million sqm of stock and four main office generating sectors in Adelaide are public administration; professional services; finance and insurance; and education and training. According to Colliers International (2015), SA government owns largest share in office building stocks in Adelaide CBD. The top drivers of tenant demand includes: availability of green spaces; less car parking spaces; flexible spaces; data driven designs; precinct amenity; and centralisation of tenants (Colliers International 2015).

14.4.3 Cost Implications of Adaptive Reuse of Buildings

As discussed by Bullen and Love (2010), adaptive reuse is not an economical option when the building structure requires extensive strengthening works. Similarly, Mackay et al. (2009) cited in Remøy and van der Voordt (2014) found that when converting office buildings to housing, major costs are associated with façade alterations (27% of the total building cost), interior walls (17% of the total building cost) and contractor costs (15% of the total building cost). According to Remøy and van der Voordt (2014), it was found that conversion costs are lower than demolition and new-build costs in Netherlands. However, they identified that conversion costs can be increased due to technical risks. Furthermore, Young (2014) pointed out that reusing of building cost 4% less than new construction. As shown in Table 14.4, cost of recycle/regeneration of buildings is higher than the cost of new construction in Adelaide.

Table 14.4 Indicative cost per square meter for Adelaide ($)[a] (Rawlinsons 2015)

Description	Major refurbish cost	Recycle/ regenerate cost	New construction cost (shell and core)	New construction cost (finished floor)
High rise fully serviced office buildings, 7–20 storey, standard finishes and facilities, air-conditioning, medium speed lifts, fire sprinklers	2690–2940	3325–3625	2915–3140	3125–3370
High rise fully serviced office buildings, 21–35 storey, standard finishes and facilities, air-conditioning, medium speed lifts, fire sprinklers	3545–3795	4380–4680	3660–3945	3885–4190

[a]Costs are average prices as at December 2014 within the Adelaide metropolitan area. It includes allowances for preliminaries and Builders profit and overheads. It excludes external services outside 3.0 m from the outside face of the building, external works other than those immediately adjacent to the building, loose or special equipment, furniture, furnishings, legal and professional fees, and GST

14.4.4 Acts, Regulations and Standards Related to Adaptive Reuse of Buildings

According to regulation requirements, the entire building should comply with current legislation requirements if half of the building is changed (Government of South Australia 2013). However, it was highlighted the use of terms such as: “as far as is reasonable” or “as far as is reasonably practicable” when it comes to compliance of existing buildings with legislation (Government of South Australia 2013). Remøy and van der Voordt (2014) pointed out that financial feasibility of converting buildings into some other function can be reduced by legal aspects associated with the conversion process. Section 53A of Development Act 1993 provides requirement to up-grade building in certain cases (Development Act 1993). As per Development Act (1993), building construction includes the following activities:

- “to build, rebuild, erect or re-erect the building;
- to repair the building;
- to make alterations to the building;
- to enlarge or extend the building;
- to underpin the building;
- to place or relocate the building on land.”

According to the Development Regulations (2008), development plan is not required for internal building works undertaken “other than in a historic conservation zone/area, a flood management zone/area, a river Murray zone, or the area of the corporation of the city of Adelaide", where total floor area will be same and no "significant alteration to the external appearance of the building". Even though the National Construction Code (NCC)/the Building Code of Australia (BCA) is designed to provide performance requirements for both new or existing buildings (Board 2014), restrictions associated with use of BCA/NCC in existing buildings were identified by some researchers. For example, Bullen and Love (Bullen and Love 2010) highlighted that construction practitioners consider modifications and reconfigurations of buildings are difficult due to requirements of maintaining occupational health and safety standards to fulfil environmental performances described in the BCA. Government of South Australia (2013) highlighted that even though the main focus of NCC is providing performance guidelines for new building works, it is necessary to use those guidelines as a benchmark for existing buildings despite practical issues of achieving that. There are some planning restraints, which limit the adaptation of buildings, in terms of level of fire resistance and availability of means of escape in buildings (Douglas 2006). Similarly, Siu (2014) identified tensions between conservation professionals and government officials in adaptive reuse of buildings in Honk Kong. According to Siu (2014), these tensions occur as a result of conservation professionals focusing more on international best practices while the government officials on fire safety codes. However, Siu (2014) highlighted that to some extent, the importance of compromising requirements of fire codes in adaptive reuse of buildings was identified by government officials and conservation professionals in Hong Kong.

In order to overcome legal impediments, International Existing Building Code was developed in United States of America. This Code encourages upgrade and improvements of existing buildings as well as adaptive reuse by provision of minimum regulations in relation to prescriptive and performance related provisions in use of existing buildings (International Existing Building Code 2012). City of Melbourne strategic plan 1985 (City of Melbourne 1991) provides guidelines for building surveyors to determine the extent of compliance with existing regulations and building code for alterations to existing buildings. Similarly, City of Melbourne (1991) provides guidelines for designers to comply with acceptable level of fire safety in adaptive reuse of buildings. However, there is a lack of focus on dealing with existing building stocks in South Australia. These arguments were supported by the findings of the ARC Linkage Project "Re-considering Sustainable Building and Design—A Cultural Change Approach" and the following two recommendations were made at the end of the project.

- Recommendation 9—The researchers recommend that government incentives be introduced to encourage innovative reuse of existing building stock, including exemptions to some existing national construction code requirements which currently render reuse prohibitive.
- Recommendation 10—The researchers recommend that government develop an alternative building code exclusively for existing buildings.

Essential fire safety items in buildings include “fire hose reels, fire extinguishers and suppression systems, occupant warning systems and fire barriers such as fire doors” (Government of South Australia 2013). According to the Australian Building Codes Board (2014), in case of multiple classification of a building, the classification, which requires the most fire-resisting has to be applied to all other storeys of a particular building. Thus, this can limit the flexibility of using mixed type of construction in adaptive reuse of buildings. As mentioned in the Government of South Australia (2013), the following provisions are applied for earthquake resistance in buildings.

- Strengthening Existing Buildings for Earthquakes (PO45), DPTI Building Management
- Critical Infrastructure and the Earthquake Hazard (G139), DPTI Building Management
- Earthquake Hazard Risk Mitigation in Government Leasing (G137), DPTI Building Management
- Treasury Circular 314 Seismic Assessment and Earthquake Mitigation Works for Existing Government Buildings.

Wilkinson and Remoy (2011) stated that number of elevators and facilities influence the decision of adaptive reuse of buildings. Section 53A of Development Act (1993), provides requirements of upgrading safety in buildings. Similarly, according to the Australian Building Codes Board (2014), there are certain requirements for disability access including lift installation and sanitary facilities. Also there are number of provisions and regulations related to hazardous substances such as asbestos, mercury vapour, Polychlorinated Biphenyls (PCBs) and synthetic mineral fibres (SMFs) in existing buildings (Government of South Australia 2013).

14.5 Conclusions

In this research it was identified that buildings experience physical, functional, technological and economic obsolescence with age. However, the life of a building can be increased by adaptive reuse and decision to demolish a building can be a premature decision. Adaptive reuse of a building is defined as “a process that changes a disused or ineffective item into a new item that can be used for a different purpose”. There are significant social, economic and environmental benefits associated with adaptive reuse of buildings. Key factors to be considered for the reuse of buildings include: attractiveness to tenants, return on investments, ongoing operation costs, and market values. Similarly, it is necessary to identify key attributes related to adaptive reuse of buildings in Adelaide CBD. There are some restrictions associated with using National Construction Code and other legislation in adaptive reuse of existing buildings especially in relation to fire and safety requirements, earthquake resistance, hazardous substances, disability access and environmental protection. Even though there are some clauses use in current legislation and standards to provide flexibility in using them in existing buildings (for example "as far as is reasonable' or 'as far as is reasonably practicable"), still there are practical problems associated with using these legislation and standards in adaptive reuse of buildings. Thus, it is important to have a separate building code for existing buildings to enable effective implementation of adaptive reuse of buildings.

References

Adelaide City Council and Jones Lang LaSalle (2007). Building refurbishment guide. Adelaide City Council

Board Australian Building Codes (2014) National Construction Code Series. In: Series National Construction Code (ed) Australian. Canberra, Building Codes Board

Bruce T, Zuo J, Rameezdeen R, Pullen S (2015) Factors influencing the retrofitting of existing office buildings using Adelaide, South Australia as a case study. Struct Survey 33(2):150–166

Bullen PA, Love PE (2010) The rhetoric of adaptive reuse or reality of demolition: views from the field. Cities 27(4):215–224

Bullen PA, Love P (2011) A new future for the past: a model for adaptive reuse decision-making. Built Environ Project Asset Manag 1(1):32–44

City of Melbourne (1991) Guidelines for dispensations. Melbourne

Colliers International (2015) Who will rule our CBDs? Ownership changing the realm of office

Conejos S, Langston C, Smith J (2015) Enhancing sustainability through designing for adaptive reuse from the outset: a comparison of adaptSTAR and Adaptive Reuse Potential (ARP) models. Facilities 33(9/10):531–552

Department of Environment and Heritage (2004) Adaptive reuse. Commonwealth of Australia, Canberra

Development Act (1993) South Australia, Australia

Development Regulations (2008) South Australia, Australia

Douglas J (2006) Building adaptation, 2nd edn. Routledge, Oxford

Eames M, Dixon T, Lannon S, Hunt M, De Laurentis C, Marvin S, Hodson M, Guthrie P, Georgiadou MC (2014) Retrofit 2050: critical challenges for urban transitions. Cardiff University

Ellison L, Sayce S, Smith J (2007) Socially responsible property investment: quantifying the relationship between sustainability and investment property worth. J Prop Res 24(3):191–219

Ferretti V, Bottero M, Mondini G (2014) Decision making and cultural heritage: an application of the Multi-Attribute Value Theory for the reuse of historical buildings. J Cult Herit 15(6): 644–655

Franco G, Magrini A, Cartesegna M, Guerrini M (2015) Towards a systematic approach for energy refurbishment of historical buildings. The case study of Albergo dei Poveri in Genoa, Italy. Energy Build 95:153–159

Government of South Australia (2013) Managing building compliance obligations (existing buildings): A guide for Government of South Australia Agencies. Government of South Australia, SA

Highfield D (2000) Refurbishment and upgrading of buildings. FN Spon, London

International Existing Building Code (2012). International Code Council, Inc., U.S.A

Itard L, Klunder G (2007) Comparing environmental impacts of renovated housing stock with new construction. Build Res Inf 35(3):252–267

Kohler N, Yang W (2007) Long-term management of building stocks. Build Res Inf 35(4): 351–362

Petersdorff C, Boermans T, Harnisch J (2006) Mitigation of CO_2 emissions from the EU-15 building stock. beyond the EU directive on the energy performance of buildings. Environ Sci Pollut Res 13(5):350–358

Porter DR (2012) Managing growth in America's communities. Island Press

Rawlinsons (2015) Australian construction handbook. Rawlhouse Publications Perth, Australia

Remøy H, van der Voordt T (2014) Adaptive reuse of office buildings into housing: opportunities and risks. Build Res Inf 42(3):381–390

Siu WMP (2014) The fire engineering approach in the adaptive reuse of a historical building: the case of revitalising the former Tai O police station as the Tai O heritage hotel. The University of Hong Kong, Hong Kong

Snoswell D (2014) Adelaide CBD office market—the investment proposition. Jones Lang LaSalle

Tan Y, Shen LY, Langston C (2014) A fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong. Int J Strateg Prop Manag 18(1):66–76

Wilkinson SJ, Remoy HT (2011) Sustainability and within use office building adaptations: a comparison of Dutch and Australian practices. In PRRES 2011: proceedings of the 17th Pacific Rim Real Estate Society annual conference. Pacific Rim Real Estate Society, pp 1–11

Wilkinson SJ, James K, Reed R (2009) Using building adaptation to deliver sustainability in Australia. Structural Survey 27(1):46–61

Young RA (2014) Historic preservation and adaptive use: a significant opportunity for sustainability. In: ARCC conference repository

Yung EH, Langston C, Chan EH (2014) Adaptive reuse of traditional Chinese shophouses in government-led urban renewal projects in Hong Kong. Cities 39:87–98

Chapter 15
An AHP-ANP Integrated Framework of Evaluating Innovative Business Models for Sustainable Building

X. Zhao, L. Chen, W. Pan and Q. Lu

15.1 Introduction

It has been widely recognized that the construction industry has significant impact on economy, environment and society. There are growing political imperatives to deliver sustainable buildings (SB). Although the definition of SB depends on the time, domain and social context, SB is generally referred to the structure and practices that are environmentally responsible and resource-efficient throughout a building's life cycle stages (Berardi 2013). Despite the substantial body of literature addressing sustainable technologies (Copiello 2015), building owners and design teams commonly cite the comparable higher upfront costs of sustainable strategies as a major barrier to realizing high performance in building projects. Innovative business models are able to act as 'market device' to overcome this barrier and finally transform the SB marketplace (Zhao et al. 2016). Research on business model innovation has explored the innovative components of business model and the role of innovation in organizational entities through case study of demonstration projects and abductive reasoning and coding based on grounded theory, e.g. (Rajala et al. 2016). Research studies have also applied multi-criteria decision making tools to evaluate the performance of business model. For instance, Xu and Chan (2013) and Xu et al. (2015). employed a case study and an Analytic Network Process (ANP) approach to examine the effect of Energy Performance Contract as an innovative mechanism on building energy efficiency retrofitting.

However, discussion on the performance of innovative business model for SB is incomplete without considering the characteristics of SB. Moreover, existent

X. Zhao · L. Chen (✉) · W. Pan · Q. Lu
Department of Civil Engineering, The University of Hong Kong, Hong Kong, China
e-mail: dragoncl@hku.hk

X. Zhao
e-mail: xjzhao@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_15

business model evaluation procedures typically lack the interdisciplinary integration of economic performance with environmental and social features, and seldom investigate the interdependencies among performance criteria. Hence, this paper focuses on this research gap and aims to develop a systematic performance evaluation network for innovative business models of SB using AHP-ANP integrated approach, to ascertain the weights of selected criteria, indicators and possible interdependencies among them. The paper is organized as follows: Sect. 15.2 reviews the indicators assessing the performance of innovative business models for SB, and introduces ANP and AHP approach used in analytical network. Section 15.3 describes the research methodology. Section 15.4 develops the proposed systematic performance evaluation network for innovative business models of SB. Finally, Sect. 15.5 discusses and concludes the research findings.

15.2 Literature Review

15.2.1 Business Model Innovation and Performance Evaluation

While an increasing number of studies have explored the elements and process of conducting business model innovation within recent years, there is still a lack of research on the performance of innovative business model. In general, two types of impacts have been examined in the research of the performance of innovative business model: short-term economic performance and long-term non-economic performance. Short-term economic performance is one of the dimensions that most business model studies have focused on. A series of measures have been established to evaluate firms' profits and costs in providing products and services for customers with the innovative core earning logics in business models such as revenue growth, profitability, market capitalisation, and equity growth (Baden-Fuller and Morgan 2010). For the aspect of long-term performance, non-economic performance measures have been covered in the previous studies, such as the resilience in challenging markets and the ability to provide social value to stakeholders. Chiu et al. (2015). incorporate market acceptance, interconnectedness, diversity, environmental friendliness, and raw material usage in the evaluation framework of business model for product service system. Girotra and Netessine (2013) argued that business models' performance function can be defined with three factors: profits, growth, or sustainability. The effect of innovative business model has been linked with competitive advantage (Saaty 1996), the transferability to new markets (Sánchez and Ricart 2010), and the firms' agility and adaptability to respond to changes/disruptions (Feller et al. 2008). The performance indicators identified above suggests that innovative business model lead to both short-term and long-term business performance. While short-term performance indicators link to financial benefits and cost of SB projects, long-term indicators reflect the non-economic corporate strategic benefits, source of competitive advantage, investment risk, firm reputation, environmental and social performance.

15.2.2 AHP and ANP Approach

AHP and ANP are two related decision-making methods initially proposed by Saaty (Saaty 1980; 1996; 2006). AHP is a framework of logic and problem resolved by organizing decision makers' judgement into a hierarchy of forces that influences decision results. The pair-wise comparison method is adopted in AHP to assign weights to the elements at the criteria and sub-criteria levels for assessing the bottom level finally (Wong et al. 2008). ANP (Saaty 1996) extends AHP to solve problems with dependence and feedback, allowing for complex interrelationships among decision elements by replacing the hierarchy in AHP with a network.

Designing performance evaluation network for innovative business model of SB may involve interdependences and conflicts among elements. Therefore, ANP is used to solve problems that can be structured into network-like decision models, while the AHP approach is adopted to address hierarchical decision problems. The process of ANP comprises the following three steps (Xu and Chan 2013; Xu et al. 2015; Saaty 1996): (i) model construction: a problem is decomposed into a network in which nodes corresponds to clusters; (ii) pairwise comparison and local priorities: the five-point Likert scale is used to determine the relative importance of elements using pairwise comparisons where the elements are compared pairwisely with respect to their impacts on other elements; (iii) supermatrix formation and final priorities: the local priority vectors are entered into the appropriate columns of a supermatrix, which is a partitioned matrix where each segment represents a relationship between two levels or clusters.

$$W = \begin{array}{c c} & \begin{array}{c c c c} K_1 & K_2 & \cdots & K_N \\ k_{11}\cdots k_{1n_1} & k_{21}\cdots k_{2n_2} & \cdots & k_{N1}\cdots k_{Nn_N} \end{array} \\ \begin{array}{c c} K_1 & \begin{array}{c} k_{11} \\ \vdots \\ k_{1n_1} \end{array} \\ K_2 & \begin{array}{c} k_{21} \\ \vdots \\ k_{2n_2} \end{array} \\ \vdots & \vdots \\ K_N & \begin{array}{c} k_{N1} \\ \vdots \\ k_{Nn_N} \end{array} \end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix} \end{array} \tag{15.1}$$

where K_i is the cluster decomposed in ANP model and k_{in} is the elements involved in K_i. W_{ij} represents the relationship between K_i and K_j. Each column of W_{ij} is the local priority vector obtained from the corresponding pairwise comparison, determining the importance of elements in K_i to elements in K_i The weighted supermatrix can be obtained by multiplying all the elements in a component of the unweighted supermatrix by the corresponding weight matrix of clusters. Finally, the limit supermatrix can be obtained by raising the weighted supermatrix to powers until the column of numbers is the same for every column using Eq. (15.2).

$$W' = \lim(1/N)\sum_{k=1}^{N} W^k \tag{15.2}$$

where W' is the limit supermatrix, W. the weighted supermatrix, N indicates the sequence, and k is the exponent determined by iteration. The priorities of elements can be found in the corresponding columns in the limit supermatrix. The final priorities can be ultimately obtained from the corresponding columns in the limit supermatrix.

15.3 Methodology and Model Development

15.3.1 Methodology

To establish the systematic performance evaluation network for innovative business model of SB, a AHP-ANP integrated approach has been employed. It comprises of three steps, namely, criteria selection, AHP structure development, and ANP structure development (Fig. 15.1).

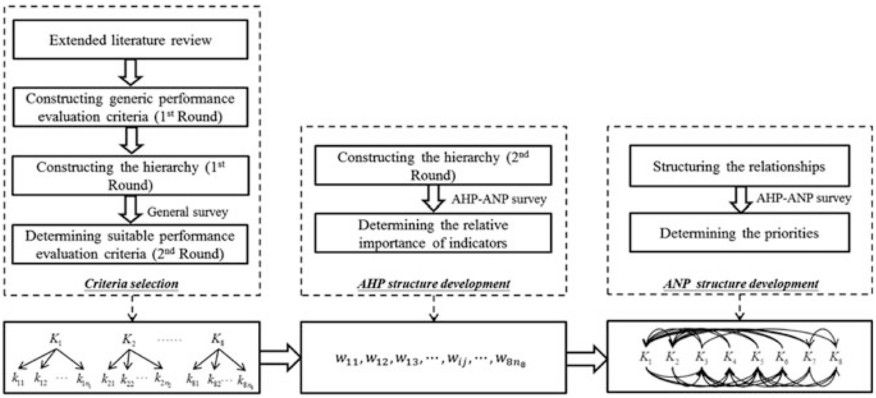


Fig. 15.1 Procedures of the systematic performance evaluation network

15.3.2 Criteria Selection and Survey Instruments

This research derived key performance criteria and indicators from a comprehensive literature review (for example, Chiu et al. 2015; Mills and Rosenfeld 1996; Chen and Pan 2016), and constructed the analytical framework for appraising the performance of innovative business model for SB. A pilot study was first undertaken to test the potential response, suitability and comprehensibility of the questionnaire. Five academic researchers with rich experience in the SB area were selected to assess whether the proposed indicators sufficiently represented the characteristics of the business model performance for SB project. Eight key performance criteria and their corresponding indicators were included in the proposed evaluation framework after the minor amendment based on the received comments.

A questionnaire-based survey was conducted subsequently to validate the developed model. The survey was designed to collect the general views from industry practitioners to determine the relevance of the indicators for performance criteria in measuring the business model performance regarding SB projects. Post and online survey tool were used to invite oversea professionals who have rich experience in sustainable building investment and development. Until late June 2016, a total of 185 questionnaires were sent out and distributed, and 34 questionnaire surveys were returned, given the response rate of 18.4%. Three returned questionnaires were removed due to incomplete or inappropriate responds. The demographic data of the survey respondents is detailed in Figs. 15.2 and 15.3. The mean scores and t-tests were employed to identify 'suitable' indicators (Wong et al. 2008). t-value higher than t_c (2.042) and the mean scores higher than 3 indicates the significance of the indicators. Finally, 33 key performance indicators were extracted under the eight key criteria.

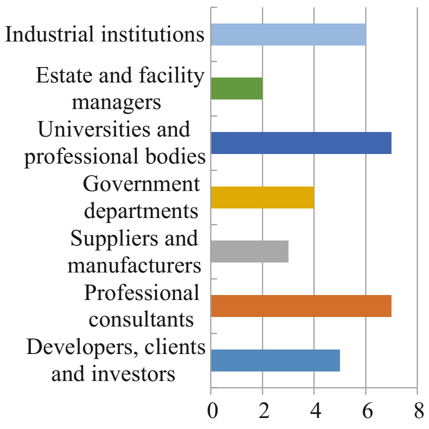


Fig. 15.2 Nature of work of survey respondents

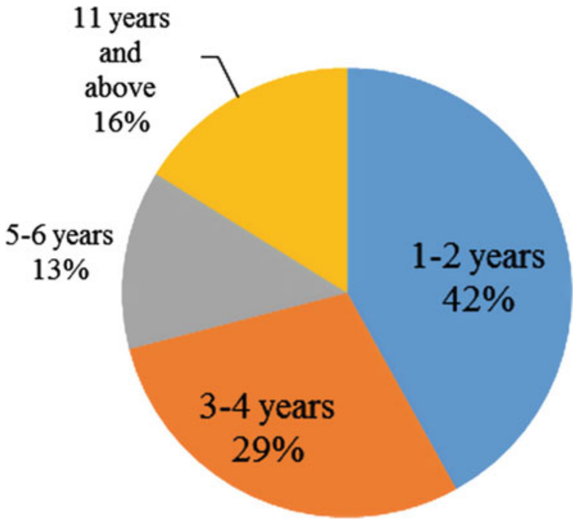


Fig. 15.3 Year of experience in the area of SB

15.3.3 AHP Structure Development

Based on the refined performance evaluation framework, eight comparison matrices pairwise were structured to compare key performance indicators with respect to their impacts on the higher-level performance criteria. The weighted geometric mean method was used to aggregate individual judgement matrices to obtain a collective judgement matrix. All the relevant data of the pairwise comparison matrices were summarized and calculated in the final result.

15.3.4 ANP Structure Development

(i) Model construction. In order to construct the network where key performance criteria can interact with each other, the interdependencies among different criteria need to be determined. A focus group discussion comprising of six experts was thus conducted to format the relation matrix to avoid decision-maker bias. The ANP model can be constructed based on the structured relationships among key performance criteria of innovative business model for SB (as shown in Fig. 15.4), revealing the interdependencies among them.

(ii) Pairwise comparison and local priorities. A total of 12 pairwise comparison matrices were made with respect to the impact on the given criterion among criteria under their performance aspects. All the results derived from pairwise comparison matrices were also summarized and calculated in the final result with results derived from AHP model. Following that, comparisons between

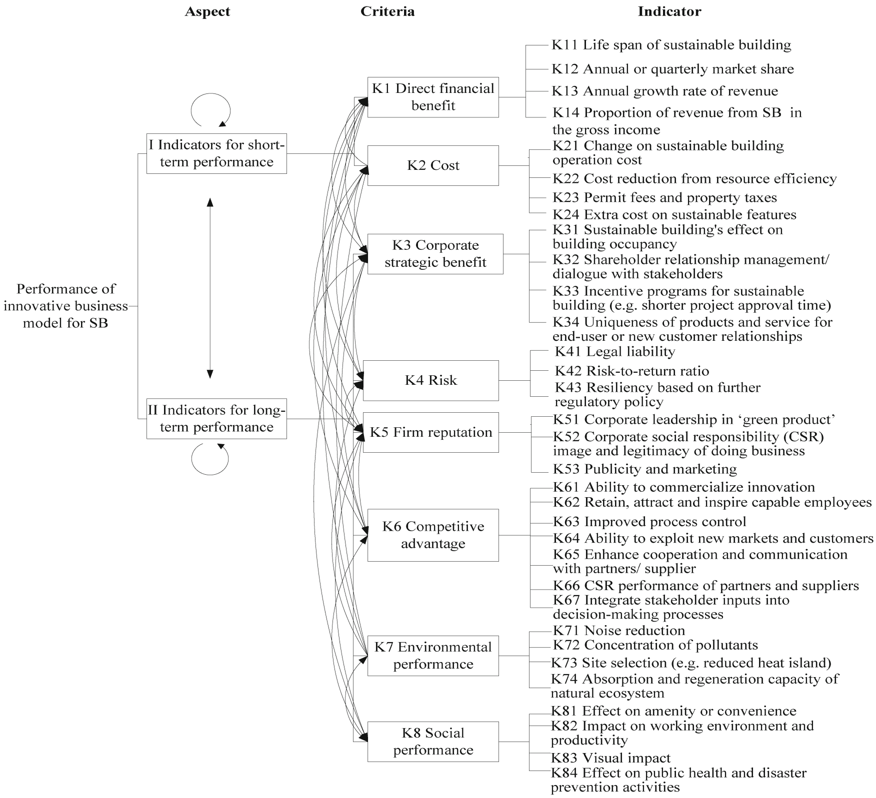


Fig. 15.4 Performance evaluation network for innovative business model of SB

Table 15.1 Final weights of indicators

K1 (0.1175)	K2 (0.1911)	K3 (0.1583)	K4 (0.1191)	K5 (0.0815)	K6 (0.0683)	K7 (0.1238)	K8 (0.1401)
k11 (0.0276) k12 (0.0308) k13 (0.0373) k14 (0.0218)	k21 (0.0501) k22 (0.0618) k23 (0.0384) k24 (0.0408)	k31 (0.0333) k32 (0.0552) k33 (0.0401) k34 (0.0297)	k41 (0.0382) k42 (0.0428) k43 (0.0381)	k51 (0.0265) k52 (0.0251) k53 (0.0299)	k61 (0.0143) k62 (0.0133) k63 (0.0077) k64 (0.0111) k65 (0.0059) k66 (0.0068) k67 (0.0092)	k71 (0.0340) k72 (0.0293) k73 (0.0348) k74 (0.0257)	k81 (0.0446) k82 (0.0355) k83 (0.0240) k84 (0.0360)

long-term and short-term performance aspects were also carried out with respect to one aspect as sub-criteria underlying performance criteria, which aims to identify the weight matrix.

(iii) Supermatrix formation and final priorities. The third step of ANP calculation relates to the formation of a limit supermatrix. This is a process by raising the entire weighted supermatrix to a limiting power until convergence in terms of a limes (Saaty 1996; Wong et al. 2008; Wolfslehner et al. 2005). The average priority weights can be obtained using Eq. (15.2). A programme based on MATLAB was developed and adopted to calculate the limit supermatrix which was obtained when N = 35. The final priorities can be obtained accordingly via the relative importance of key performance criteria and indicators. Table 15.1 summarizes the final weights of each indicator.

15.4 Results and Analyses

Table 15.1 shows the final weights of the eight key performance criteria and the priorities of indicators under each key performance criteria. K2 (cost) and K3 (corporate strategic benefits) constitute around one third of the total weights and are the top two most important performance criteria in evaluating the innovative business model of SB. Design teams and building owners commonly cite the incremental first costs of sustainable strategies as a significant barrier to realizing widespread market adoption of SB. It is suggested that companies put more emphasis on designed and constructing SB cost-effectively, and pursuing the long-term strategic benefits brought about by SB projects.

Besides the direct cost and indirect benefits, the K8 (social performance, 0.1401) and K7 (environmental performance, 0.1238) were given a higher priority in measuring the performance of business model for SB. Companies become more concerned with the long-term strategic implications of environmental and social challenges to maintain competitiveness and create business value. For the four remaining criteria, K6 (Risk, 0.1191) and K1 (Direct financial benefit, 01175), ranked 5th and 6th, have a similar weight. Climate change, scarcity of raw materials, demographic change, or a change in the market participants' preferences can lead to new risks. Preserving the property value and seeking profits from the sales and renting of SB are sub-objectives that can be attributed to the short-term performance of innovative business model. The characteristics of SB, such as energy and resource efficiency, flexibility and resilience, can help to reduce such risks. Moreover, while the development and marketing of SB can improve the firm's public image (K5) and competitive position, and widen the range of products offered in the market (K6), these two criteria were given a comparable low priority in measuring the business performance of SB, which are together only accountable for about one seventh of the total weight.

The Short-term performance is measured by K1 (Direct financial benefits) and K2 (Cost), while the Long-term performance measured by the remaining six criteria. The weight of Long-term performance is 0.6914, which is much higher than the Short-term performance. Most investors and developers hold the notion that higher capital cost incurs when they invest in SB, while the visible market value and financial benefits of SB are not directly visible. Companies willing to invest on SB rely on the positive impact of SB such as risk reduction, increasingly rated social and environmental impacts.

Key performance indicators k22 (Cost reduction from resources efficiency, 0.0618) in the project delivery stages, k32 (Shareholder relationship management/dialogue with stakeholders, 0.0552) and k21 (savings in SB's operation cost, 0.0501) have the top three orders of significance level (0.3231) in evaluating the performance of business model of SB. It is worth mentioning that k24 is ranked comparatively low although the higher upfront cost is commonly cited as a significant barrier in delivering SB, which implies that significant improvements in sustainable performance can be achieved at a very little additional cost.

15.5 Conclusions

This paper has presented an AHP-ANP integrated approach to measure the interrelations between key performance criteria of innovative business model, and developed a systematic performance evaluation network of appraising innovative business models for SB. Two performance aspects, eight key criteria and 33 key indicators have been identified for evaluating the innovative business models of SB based on a comprehensive literature review and a questionnaire-based survey. The eight key performance criteria were found to be: direct financial benefit, cost, corporate strategic benefit, risk, firm reputation, competitive advantage, environmental, and social performance. The final 33 indicators were weighted and the relationships among the eight key performance criteria were also uncovered. The top five key performance indicators were found to be: cost reduction form resource efficiency, change on operation cost of SB, shareholder relationship management/dialogue with stakeholder, effect on amenity or convenience, and risk-to-return ratio, demonstrating that cost-effectiveness of SB, corporate strategic benefits and environmental and social performance are highly prioritized in evaluating the performance of innovative business model for SB. The results should help developers, designers and contractors to understand the innovative business models' effect in addressing challenges associated with SB delivery, and provide developers a valuable reference for business model selection. Future research should apply the established performance evaluation network to evaluate and prioritize business model alternatives derived from multiple real-life cases for verification. The performance evaluation network of innovative business model for different building types should also be explored in other urban contexts.

References

Baden-Fuller C, Morgan MS (2010) Business models as models. Long Range Plan 43(2–3): 156–171

Berardi U (2013) Stakeholders' influence on the adoption of energy-saving technologies in Italian homes. Energy Policy 60:520–530

Chen L, Pan W (2016) BIM-aided variable fuzzy multi-criteria decision making of low-carbon building measures selection. Sustainable Cities and Society (in press)

Chiu MC, Kuo MY, Kuo TC (2015) A systematic methodology to develop business model of a product service system. Int J Ind Eng 22(3):369–381

Copiello S (2015) Achieving affordable housing through energy efficiency strategy. Energy Policy 85:288–298

Feller J, Finnegan P, Hayes J (2008) Delivering the 'whole product': business model impacts and agility challenges in a network of open source firms. J Database Manag 19(2):95–108

Girotra K, Netessine S (2013) OM forum-business model innovation for sustainability. Manuf Serv Oper Manag 15(4):537–544

Mills E, Rosenfeld A (1996) Consumer non-energy benefits as a motivation for making energy-efficiency improvements. Energy 21(7–8):707–720

Rajala R, Westerlund M, Lampikoski T (2016) Environmental sustainability in industrial manufacturing: re-examining the greening of Interface's business model. J Clean Prod 115: 52–61

Saaty TL (1980) The analytic hierarchy process. Mc Graw-Hill

Saaty TL (1996) The analytic network process: decision making with dependence and feedbacks. RWS Publications, Pittsburgh, PA

Saaty TL (2006) Rank from comparisons and from ratings in the analytic hierarchy/network process. Eur J Oper Res 168:557–570

Sánchez P, Ricart JE (2010) Business model innovation and sources of value creation in low-income markets. Eur Manag Rev 7(3):138–154

Wolfslehner B, Vacik H, Lexer MJ (2005) Application of the analytic network process in multi-criteria analysis of sustainable forest management. For Ecol Manag 207(1–2):157–170

Wong J, Li H, Lai J (2008) Evaluating the system intelligence of the intelligent building systems: Part 1: Development of key intelligent indicators and conceptual analytical framework. Autom Constr 17(3):284–302

Xu P, Chan EH (2013) ANP model for sustainable Building Energy Efficiency Retrofit (BEER) using Energy Performance Contracting (EPC) for hotel buildings in China. Habitat Int 37: 104–112

Xu P, Chan EH, Visscher HJ, Zhang X, Wu Z (2015) Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: analytic Network Process (ANP) approach. J Clean Prod 107:378–388

Zhao X, Pan W, Lu W (2016) Business model innovation for delivering zero carbon buildings. Sustainable Cities and Society (in press)

Chapter 16
An AHP-GIS Based Model of C&D Waste Landfill Site Selection: A Triangulation of Critical Factors

Zhikun Ding, Menglian Zhu, Yifei Wang and Jiasong Zhu

16.1 Introduction

With the rapid growth of Chinese economy, the amount of construction and demolition (C&D) waste also increase at a high speed. According to the "Annual report on the comprehensive utilization of resources in China (2014)," the production of construction waste in China is about 10 million tons in 2013 and the demolition waste in the construction waste is about 740 million tons. The amount of construction waste in China has accounted for 30–40% of the total urban waste (Ding et al. 2015). C&D waste generated has become a huge challenge for sustainable urban development because it will consume the limited landfill and lead to water pollution, energy consumption and emissions of harmful gases (Ding et al. 2016). Therefore, effective C&D waste management will be the focus of sustainable development in the future (Ding et al. 2016). Most C&D waste without any treatment was transported to the suburbs or rural areas and was processed by random stacking or landfill.

Traditional site selection methods include graphical method, fuzzy comprehensive evaluation and gray clustering method. In contrast, applying GIS and analytic hierarchy process (AHP) can effectively solve the landfill sitting problem. For example, Şehnaz Şener integrated GIS with AHP analysis to achieve multiple criteria decision-making in landfill sitting studies. The AHP is employed to estimate the weight of each criterion which will be assigned to a specified level so as to draw maps in GIS (Şener et al. 2010). Gorsevski presents a GIS-based multi-criteria

Z. Ding (✉) · M. Zhu · Y. Wang
Department of Construction Management And Real Estate, College of Civil Engineering, Shenzhen University, Shenzhen, Guangdong Province, People's Republic of China
e-mail: ddzk@szu.edu.cn

Z. Ding · J. Zhu
Smart City Research Institute of Shenzhen University, Shenzhen, Guangdong Province, People's Republic of China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_16

decision analysis approach which combined AHP and ordered weighted average (OWA) techniques for evaluating the suitability of targeted landfill site (Gorsevski et al. 2012).

A normative landfill site selection process requires consideration of extensive criteria to determine the best available disposal locations, and unreasonable sitting will bring many problems (i.e., odor, dust, garbage, noise, pests and visual intrusion) and adverse long-term effects (i.e., pollution of the local environment through contamination of groundwater and aquifers) (Gorsevski et al. 2012). The landfill site selection is a difficult and complex process because social, environmental and technical factors are involved (Şener et al. 2010). Landfill site selection affects different aspects in the economic, the ecological, and the environmental regions (Morton et al. 2003; Goorah et al. 2009; Kouznetsova et al. 2007). The consideration of the environmental factor should be more sensitive than economic factor. Because the greatest impact on the natural resources of the environment is leachate generated from landfills. The economic factor is also important because of the financial restrictions (Gorsevski et al. 2012; Morton et al. 2003; Wang et al. 2009; Uyan 2014). This study comprehensively considers the environmental, social, and economic factors, especially in environmental factors to consider the ecological control line. Considering the three critical factors screens out the best suitable landfill area for consideration.

16.2 Background Information

Shenzhen, located in the southern province of Guangdong and adjoining Hong Kong, is the first special economic zone in China. The total land area of Shenzhen is 1996.85 km^2 and the total population in 2014 is 10,778,900. There are six administrative regions and four new developing areas under the jurisdiction of Shenzhen as shown in Fig. 16.1: Futian district, Luohu district, Nanshan district, Yantian district, Baoan district, Longgang district, Guangming new district, Longhua new district, Pingshan new district, and Dapeng new district. The three largest construction wastes landfill sites in Shenzhen are Tang Lang mountain landfill site (mainly for the construction waste), Longgang landfill site, and Baoan landfill site. Landfill sites in Longgang and Baoan District received only a small part of the construction waste and most construction waste is simply disposed (Lu et al. 2006). In recent years, with the expansion of the scale of construction in Shenzhen City, construction waste production has increased every year and the demand for landfill increases. According to statistics, the area of Shenzhen building is 900 km^2 in 2015, the building construction waste not only to the environment bring serious negative effect, and takes a lot of landfill. Therefore, reasonable selection of landfill is an urgent need to solve a major problem.

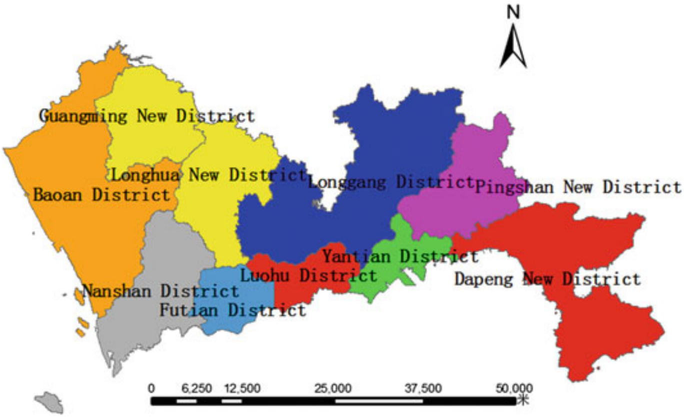


Fig. 16.1 Geographical regions of Shenzhen

16.3 Location Analyses

16.3.1 Site Selection Factors and Indicators

Site selection factors are determined by three experts in the field of construction waste. The critical factors cover three aspects: environment, society, and economics which are rarely considered simultaneously in the literature. Detailed indicators for each factor are identified as:

(1) Environmental factors: Rivers; Ecological control zone; Distance from airport; Agricultural land; Special land;
(2) Social factors: Natural scenery; Cultural Tourist; Urban settlements; Rural settlements;
(3) Economic factors: Distance from the centre of the construction waste generated; Transportation costs; Land prices.

Finally, the weights are calculated by AHP. The logic of this study is shown in Fig. 16.2.

16.3.2 The Determination of Weights

The Analytic Hierarchy Process (AHP) is a theory of measurement through pair-wise comparisons and relies on the judgments of experts to derive priority scales. AHP is also a multi-objective qualitative and quantitative triangulated decision analysis method (Saaty 2008). To make a decision in an organized way to generate priorities, we need to establish analytic hierarchy model as shown in Fig. 16.3.

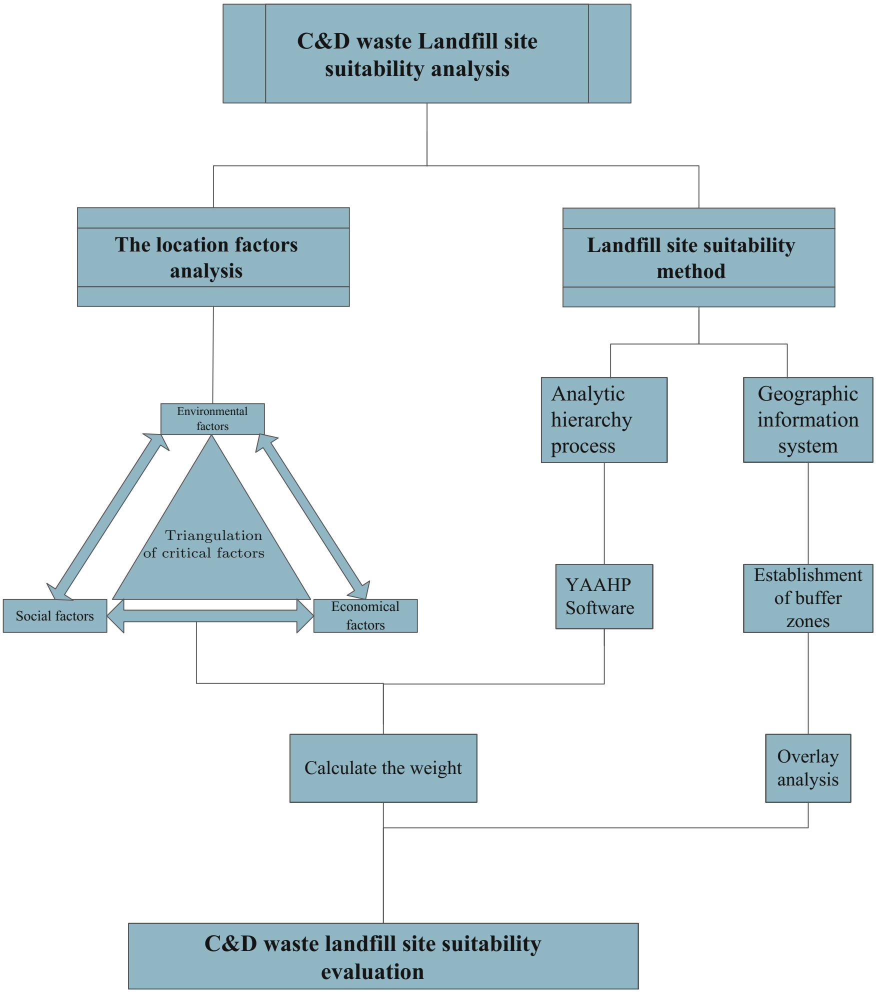


Fig. 16.2 The overall research logic

The weight values in this study are calculated using the AHP software YAAHP. YAAHP enables the hierarchical model building process very convenient and users could focus on the decision-making problem by leaving the model data collection and analysis to the software. YAAHP provides convenient judgment matrix data input, weight calculation, sensitivity analysis and other functions. It is flexible and easy to use by saving complex matrix calculation steps and time. Hence, YAAHP is adopted in the study.

Firstly, the hierarchical model is plotted in YAAHP as shown in Fig. 16.3. After the model establishment, the judgment matrix is input. After the data matrix input, consistency is verified by YAAHP. The final output weights are shown in

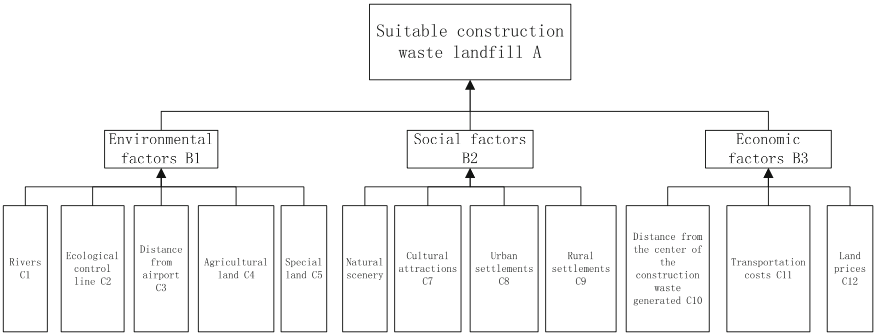


Fig. 16.3 The hierarchical structure model

Table 16.1. It can be seen that the ecological control lines and urban settlements are the first two most important indicators.

16.3.3 GIS Analysis

GIS data can be updated in real time, more adapted to the changes in the real world situation. GIS plays a vital role in landfill site selection and it has been increasingly used as an important spatial decision support system for evaluating landfill locations (Uyan 2014).

According to the "Landfill Pollution Control Standard" (GB 16889—2008), landfill sitting should be consistent with regional environmental planning, environmental sanitation, construction planning and local urban planning. The related GIS data in this study were collected from the Shenzhen Planning and Land Commission departments.

16.3.3.1 The Buffer Generation

A buffer is an area defined by the bounding region determined by a set of points at a specified maximum distance along the segment of all nodes of the object. The buffer in GIS is a zone around a map feature of the unit of distance or time of the measurement and a buffer is useful for proximity analysis. (Sommer and Wade 2006) Creating a buffer can be a very time-consuming operation both manually and by computer, especially when the objects to be buffered are complex (Scholten and Lepper 1995).

(1) The surface water: Shenzhen is characterized by a number of widely distributed short rivers. According to China's solid waste landfill site selection requirements, the distance between a landfill and surface waters should not be less than

Table 16.1 Criteria weights

Goal A	Hierarchy B	Weight B	Hierarchy C	Weight C
Suitable construction waste landfill	B1Environmental factors	0.6141	C1 Rivers	0.1387
			C2 Ecological control line	0.2802
			C3 Distance from airport	0.0653
			C4 Agricultural land	0.0585
			C5 Special land	0.0714
	B2Social factors	0.2897	C6 Nature Spot	0.0313
			C7 Cultural attractions	0.0251
			C8 Urban settlements	0.1421
			C9 Rural settlements	0.0912
	B3Economic factors	0.0962	C10 Distance from the center of the construction waste generated	0.0221
			C11 Transportation costs	0.0624
			C12 Land prices	0.0117

150 m. Therefore, a 150 m buffer zone was scored as 1, a 500 m buffer zone scored as 2, a 1 km buffer zone scored as 3, a 1.5 km buffer zone scores as 4, and the buffer zone greater than 2 km scores as 5, fractional with increasing distance increased (Fig. 16.4a). The score increased progressively as distance increased from the buffer zone (Wang et al. 2009).

(2) Ecological control line: Basic ecological control line is to protect the basic ecological security of the city, to maintain the ecological system, according to the relevant laws and regulations, combined with the actual situation of the city to delineate the scope of the ecological protection. (Cui 2012). It is not suitable for regional landfill within the range of ecological control lines which scored as 1 (Fig. 16.4b).

Ecological control lines cover the following areas (Yang and Huang 2014):

(1) Nature reserve, basic farmland protection areas, water source protection areas, forest parks, country parks and other scenic tourist resort;
(2) Slope greater than 25% of the mountain, Forest and More than 50 m above sea level in the highlands;
(3) Main rivers, reservoirs, wetlands and coastal eco-conservation value land;
(4) Maintenance of ecological corridors and Isolated green space;
(5) Other areas that need ecological control.

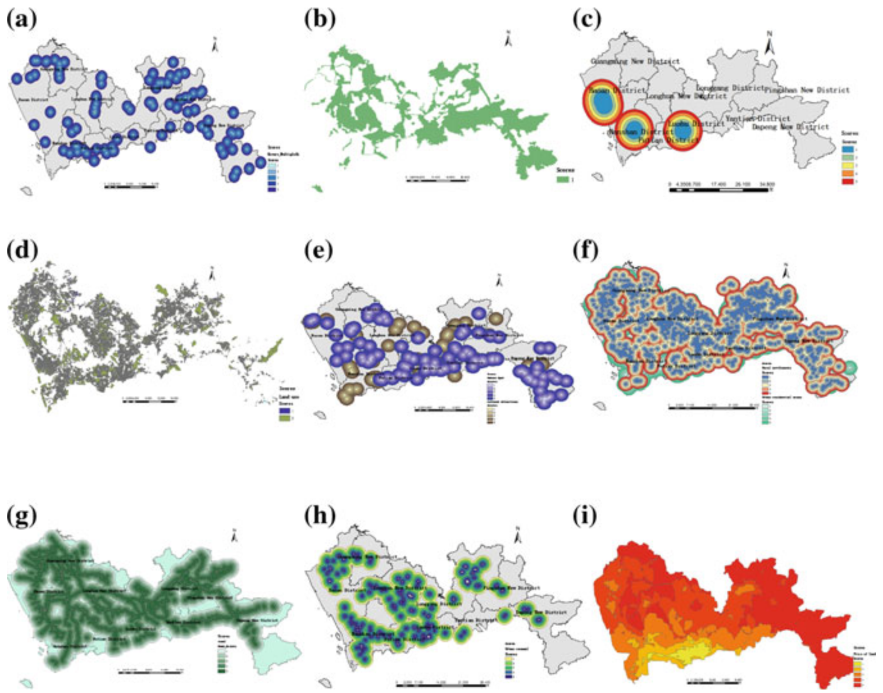


Fig. 16.4 The hierarchical structure GIS model

(3) Distance from airfields: According to China's solid waste landfill sitting requirements, the distance from the airport landfill should be 3000 m or more. For the sake of safety, the distance to the airport should be above 3 km. (Bagchi 1994; Kontos et al. 2003). A 3 km buffer zone was scored as1, a 4 km buffer zone scored as 2, a 5 km buffer zone scored as 3, a 6 km buffer zone scored as 4, and the buffer zone greater than 6 km scores as 5 (Fig. 16.4c).
(4) Land use: According to the solid waste landfill sitting requirements, landfill site should not be located at the urban industrial and agricultural development zone, agricultural protection zone and the other special protection areas. Therefore, the agricultural land, school sites and special land were scored as 1. It is not suitable for the landfill area and other areas were scored as 5 (Fig. 16.4d).
(5) Natural and cultural scenic spots: In Shenzhen, the distance between the natural scenic spot and the human scenic spot should be separated from each other as far as possible. Hence,the 500 m buffer zone was scored as 1, a 1 km buffer zone scored as 2, a 1.5 km buffer scored as 3, a 2 km buffer zone scored as 4, and the buffer zone greater than 2 km scores as 5 (Fig. 16.4e).
(6) Urban settlements: The standard such as "Life Landfill Pollution Control Standards "(GB16889—1997) requires that the landfill field should be more than 500 m away from residential area as minimum. The selection of the sanitary landfill site is 500 m and the safe landfill site is 800 m. Landfill distance from towns, rural settlements should be as far as possible. So the 500 m buffer was scored as 1, a 1 km buffer was scored as 2, a 1.5 km buffer was scored as 3, a 2 km buffer was recorded as 4 and the 2 km more was scored as 5 (Fig. 16.4f).
(7) Transportation costs: Transportation costs were related with the distance between highways and the C&D waste generation sites. With the increase of urban population and the rapid development of urban renewal, a large number of old buildings will be demolished and a lot of C&D waste will be produced (Ding et al. 2016). C&D waste is mostly solid waste and generally produced in the process of construction, maintenance of old buildings or demolition. The closer the highways to the C&D waste generated the shorter the transport distance and the less transport costs. The 500 m buffer was scored as 5, each increased 500 m to establish a buffer as shown in Fig. 16.4g, h.
(8) Price of land: According to the latest land price released by Shenzhen Urban Planning and Land Resources Committee, Shenzhen benchmark land prices will be divided into five grades. The lower land prices, the lower economic costs. The highest land price was scored as 1, the minimum price of land scored as 5, as shown in Fig. 16.4i.

Through the factor analysis, according to the expert scoring method of the influence factor weight value based on the comprehensive evaluation model, using ArcGIS field calculator, joint 12 factors data set of weighted superposition and get comprehensive suitability evaluation results (Figure 16.5).

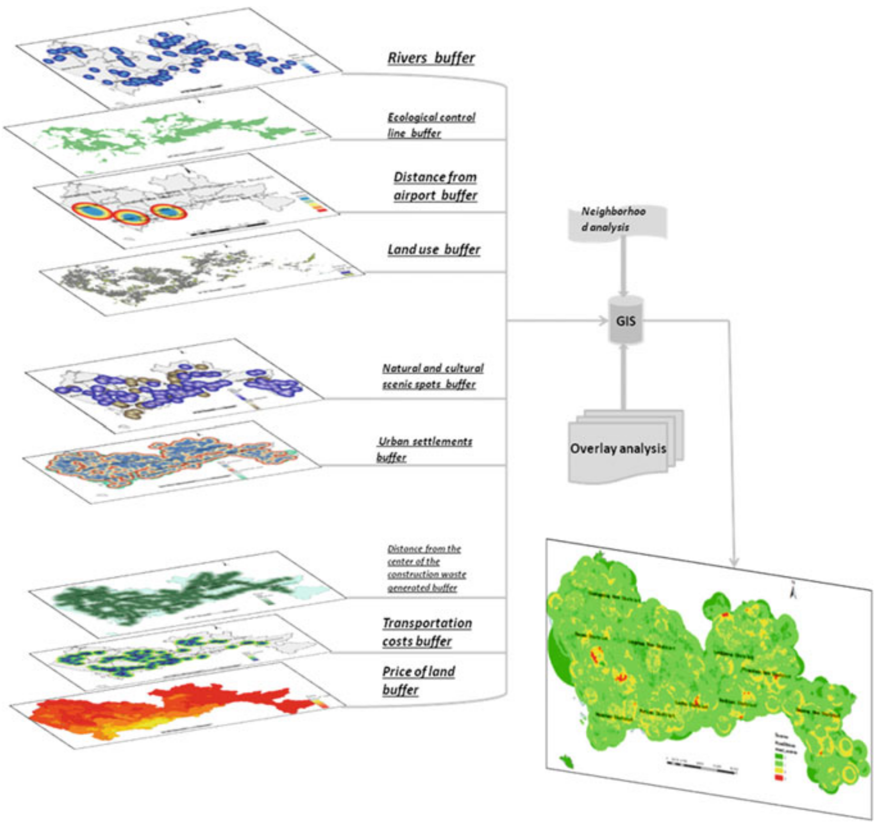


Fig. 16.5 Final suitability map

Table 16.2 Comprehensive evaluation result

Appropriate level	Area (m^2)	Proportion (%)
Most suitable	9661896.83	0.38
Suitable	485710007.50	19.09
Not suitable	2049161170.59	80.53

16.3.4 The Location Result Analysis

The evaluation of the results show in Table 16.2 and the Fig. 16.6 shows that the most suitable region covers 9661896.83 m^2, 0.38% of the total area. The areas are mainly concentrated in the central of Bao'an District and in the northern of Nanshan District. There are scattered suitable sites in Luohu, Longgang, Pingshan and other regions. According to the analysis result, the suitable area of the landfill is 485710007.50 m^2, 19.09% of the total area as show in Fig. 16.7. The distribution is pretty scattered. The unsuitable area is 2049161170.59 m^2 accounting for 80.53% of the total area.

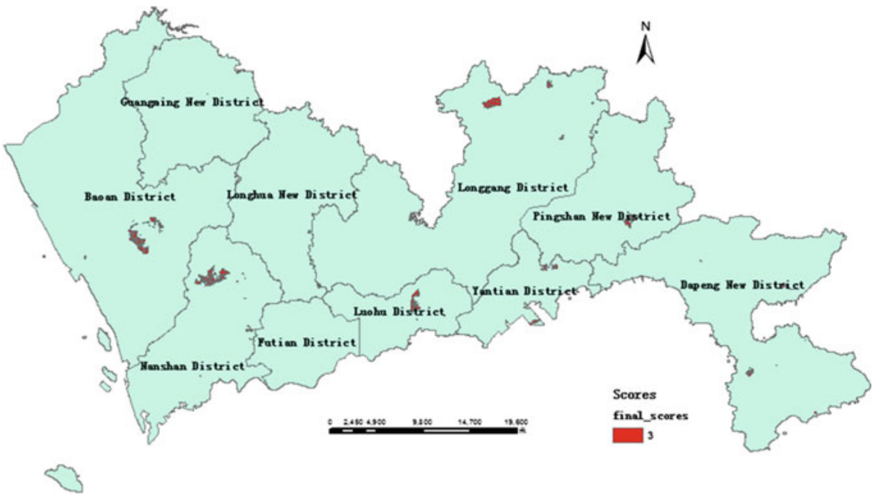


Fig. 16.6 The most suitable area

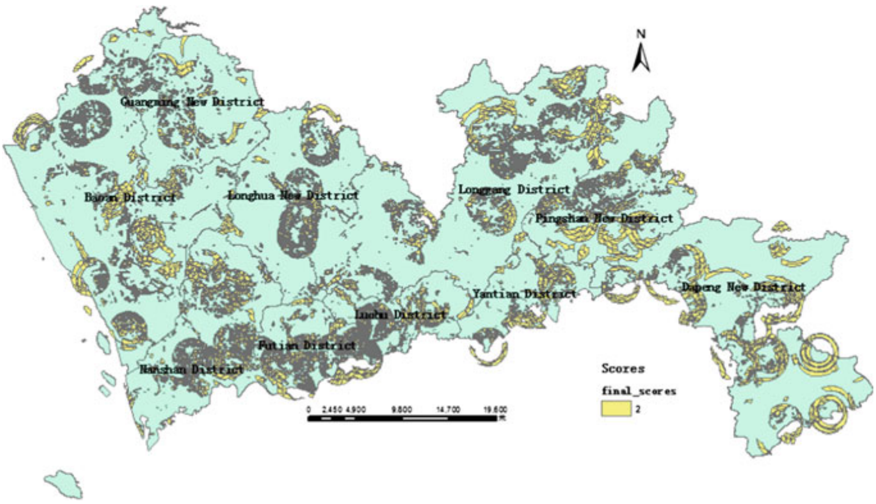


Fig. 16.7 Suitable area

16.4 Conclusion

Although it is very difficult and expensive to include environmental, social, and economical parameters, studies for selecting the sites for C&D waste landfill should be performed for every city in China. The three critical factors constraints address the issue more comprehensively, especially the environmental factors covered by the ecological line of control and the selected region is more favorable to ecological environmental benefits. This paper applied the GIS technology and AHP for the C&D waste landfill site selection. The GIS technology can get the analysis result quickly and AHP provides a comprehensive analysis of the weight value for GIS. The results provide a reliable scientific basis for the site location decisions in the future.

However, some limitations in this research should be clarified. There are many factors affecting the site selection yet to be considered in the model. Moreover, the calculation of the weights depended heavily on the experts' opinions. These limitations should be addressed in the future research.

Acknowledgements This research is conducted with the support of the National Science Foundation for Young Scholars of China (Grant No. 71202101); Social Science Research Support Grant(No.17QNFC34), Shenzhen University; Scientific Planning Research Grant (No. 2009-K4-17, No. 2011-K6-24), Ministry of Housing and Urban-Rural Development of P.R. C.

References

Bagchi A (1994) Design, Construction, and Monitoring of Sanitary Landfill. React Kinet Catal Lett 19(3–4):297–301

Cui QY (2012) The basic ecological line city delimit the scope of research (In Chinese). J Environ Manag Coll China 22(03):23–26

Ding ZK, Wang YF, Wang HT et al (2015) A comparison study of C&D waste management in Shenzhen and Hong Kong: a SWOT perspective. Springer, Berlin Heidelberg, pp 157–168

Ding ZK, Wang YF, Zou PXW (2016a) An agent based environmental impact assessment of building demolition waste management: conventional versus green management. J Clean Prod 133:1136–1153

Ding ZK, Yi GZ, Tam VWY et al (2016b) A system dynamics-based environmental performance simulation of construction waste reduction management in China. Waste Manag 51:130–141

Ding ZK, Wang YF, Wu JC (2016) CAS and ABM-based demolition waste management research in the AEC industry. 3(1):18–23

Goorah SS, Esmyot ML, Boojhawon R (2009) The health impact of nonhazardous solid waste disposal in a community: the case of the Mare Chicose landfill in mauritius. J Environ Health 72(1):48–54

Gorsevski PV, Donevska KR, Mitrovski CD et al (2012) Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. Waste Manag 32(2):287–296

Kontos TD, Komilis DP, Halvadakis CR (2003) Siting MSW landfills on Lesvos island with a GIS-based methodology. Waste Manag Res J Int Solid Wastes Public Cleansing Assoc Iswa 21(3):262–277

Kouznetsova M, Huang X, MA J et al (2007) Increased rate of hospitalization for diabetes and residential proximity of hazardous waste sites. Environ Health Perspect 115(1):75–79

Lu XM, Tang SJ, Guo P (2006) Study on the Countermeasures of construction waste disposal in Shenzhen City (In Chinese). Sichuan Build Mater 32(4):81–82

Morton B, Pervin OK, S Ranji RR et al (2003) Evaluating environmental impacts of solid waste management alternatives, Biocycle 44(10):52–56

Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1(1):83–98

Scholten HJ, Lepper MJC (1995) An introduction to geographical information systems. The added value of geographical information systems in public and environmental health, pp 53–70

Şener Ş, Şener E, Nas B et al (2010) Combining AHP with GIS for landfill site selection: a case study in the Lake Beyşehir catchment area (Konya, Turkey). Waste Manag 30(11):2037–2046

Sommer S, Wade T (2006) A to Z GIS: an illustrated dictionary of geographic information systems. Esri Press 23(3):263–264

Uyan M (2014) MSW landfill site selection by combining AHP with GIS for Konya, Turkey. Environ Earth Sci 71(4):1629–1639

Wang GQ, Li Q, Li GX, Chen LJ (2009) Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. J Environ Manag 90(8):2414–2421

Yang J, Huang AB (2014) The basic ecological line management practice in shenzhen city (In Chinese). Environ Impact Assess 04:22–24

Chapter 17
An Alternative Model for Regional Sustainability Evaluation: A Case Study of Chongqing

C.Y. Shuai, Y.T. Tan and L.D. Jiao

17.1 Introduction

Sustainable development is firstly defined as "… ***meeting the needs of present without compromising the ability of future generations to meet their own needs***" (Brundtland Commission, and Brundtland Commission 1987). Since then, the principle of sustainable development has been universally encompassed in various sectors. With the worldwide promotion of sustainable development programs, it is thereby considered significant to realize the sustainable development performance in pursuit of effective sustainable development, since plenty of financial and material resources have been invested (Shen et al. 2016).

In line with these requirements, studies have introduced amount of models and tools to assess the sustainability performance (Shen et al. 2015a, b; Zhou et al. 2015; Lu et al. 2016; Lu et al. 2015; Shen et al. 2017a, b; Chen and Lu 2017; Jiao et al. 2016). Among them, fuzzy logic theory is widely used to evaluate sustainability performance (Azadi et al. 2015; Escrig-Olmedo et al. 2015; Zhao and Li 2016; Cavallaro 2015; Carnero 2015). The study by Andriantiatsaholiniaina et al. (2004) asserted that sustainability assessment requires both hard and soft criteria rather than only using simple hard criteria. Phillis and Andriantiatsaholiniaina

C.Y. Shuai (✉) · L.D. Jiao
School of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: 1391843874@qq.com

L.D. Jiao
e-mail: 396732441@qq.com

Y.T. Tan
Department of Building & Real Estate, The Hong Kong Polytechnic University, Hong Kong, China
e-mail: bstan@polyu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_17

(2001) emphasized that fuzzy logic system seems to be a natural technical tool to assess sustainability.

Nevertheless, the disadvantage of fuzzy logic is also clear. As Singh et al. (Singh et al. 2012) argued that the in the traditional fuzzy logic application, membership function and fuzzy rules are established by the trial and error process. For complex system such as sustainable development, it required a significant time to find out the correct membership function and rules to obtain a reliable solution. The generalization capability of the fuzzy logic is very poor because it uses the heuristic algorithms for defuzzification, rule evolution and antecedent processing. The research by Buragohain and Mahanta (2008) and Naderloo et al. (2012) both criticized that the use of pre-defined membership functions and fuzzy rules highly depends on experts' knowledge, which may not reflect a real-world situation.

Therefore, with the aim of overcoming this disadvantage, induction of fuzzy membership functions and fuzzy rules from training samples has been studied. In combining the advantages of ANNs and fuzzy logic theory, adaptive neural fuzzy interference system (ANFIS) was introduced by Jang (1993). The aim of this research is innovatively introduced the ANFIS method to assess the regional sustainability performance.

17.2 The ANFIS Method

ANFIS is a neuro-fuzzy approach, which can be used to build an input-output relationship with the reference of training samples. The membership function parameters were computed by the ANFIS modeling to track the known experimental input-output data. Generally, the hybrid training algorithm integrating gradient method and the least-squares estimate are applied in ANFIS to modify the initial parameters and the mathematical relationship between input and output. The details of the gradient method and the least-squares estimate method of ANFIS can be found in the study of Jang (1993).

17.3 The Application of ANFIS

In order to evaluate the nation sustainability performance by using ANFIS, six steps are integrated in the process, which is exhibited by a flow chart as shown in Fig. 17.1.

As shown in Fig. 17.1, the first step is to select the indicators for measuring sustainability performance. Secondly, sample data sets for training and checking ANFIS need to be collected. Thirdly, membership functions of each input need to be determined. After determining the membership functions of each input, the fourth step is to establish the Fuzzy interference system (FIS). Fifthly, we need to train the established FIS by applying the collected training sample data sets. The

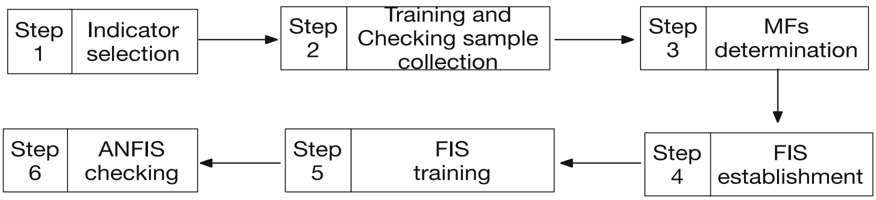


Fig. 17.1 Procedure for assessing urban sustainability by using ANFIS

last step is to check accuracy of the after training ANFIS by applying the checking data sets.

17.3.1 Indicators for Measuring Regional Sustainability Performance

Before establishing the ANFIS model to evaluate the sustainability performance. A comprehensive and operable indicator system is important. Table 17.1 presents the indicator system for measuring regional sustainability performance, which is collected from the pervious results from the Prof. Shen's research group.

Table 17.1 Indicator system for measuring regional sustainability performance

	Indicator
Social	So1-Mileage transportation system per capital
	So2-Number of high school and college students per 10,000 population
	So3-Number of health care facilities per 10,000 population
	So4-Number of poverty population per 10,000 population
	So5-Number of patents per 10,000 population
Environment	En1-Population growth
	En2-Green area per capita
	En3-Proportion of green area in built-up areas
	En4-SO2 emissions
	En5-NO2 emissions
	En6-PM10 particles concentration
	En7-Quality of noise environment
Economic	Ec1-GDP Per Capita
	Ec2-Social labor productivity
	Ec3-Total Retail Sales of Consumer Goods
	Ec4-Disposable annual income of urban households per capita
	Ec5-Savings deposit of urban and rural residents
	Ec6-Proportion of unemployment in industry

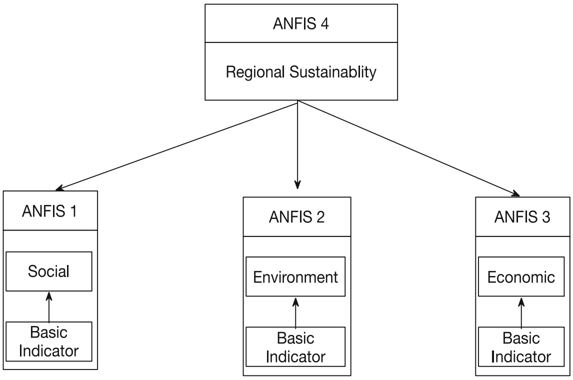


Fig. 17.2 Assessment framework of sustainability performance

As shown in Table 17.1, there are two levels to assess the overall regional sustainability performance. Based on the ANFIS principle, the hierarchical structure of ANFIS model is graphically shown as follows.

As shown in Fig. 17.2, there are also two levels of ANFIS. For example, ANFIS 1 has five basic indicators including So1, So2, So3, So4 and So5. The normalized values of these five basic indicators are the inputs, and the value of SOCIAL is the output. The output of basic ANFIS 1 is the input of ANFIS 4 in the first level.

17.3.2 Training and Checking Sample Collection

The training and checking samples are also collected from the evaluation results from the Prof. Shen's research group. The sustainability performance of 38 different the regions in Chongqing over the period 2007–2011 is assessed in their study. Whilst, in this study, the data from 2007–2010, with the 38 * 4 = 152 groups, are used as the training samples, and the data of 2011, with the 38 groups, as the checking sample. The data of 2010 and 2011 are used as validating samples.

As shown in Fig. 17.3, the symbols "o" and "+" denote the training and checking samples respectively. The vertical axis represents the normalized value of Social, which range from 0 to 1, and the horizontal axis represents the groups of dataset, which indicates there are nearly 150 groups of training data and 40 groups of checking data.

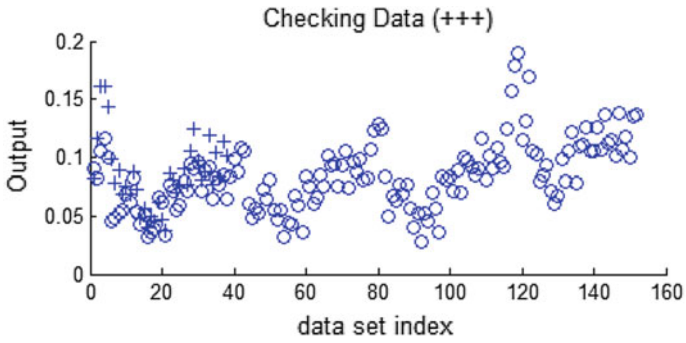


Fig. 17.3 Training and checking samples of ANFIS 1

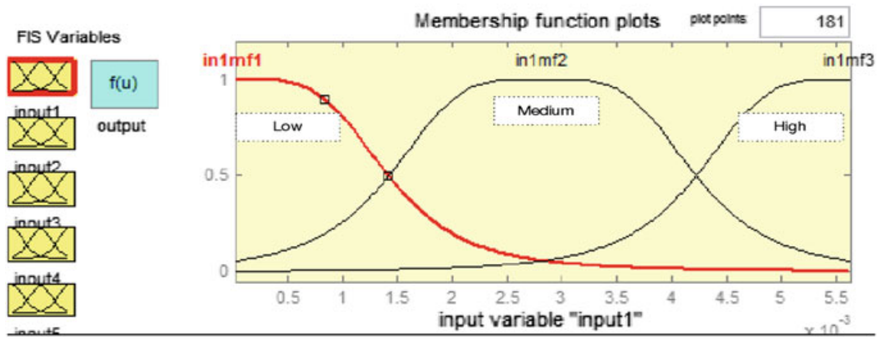


Fig. 17.4 Initial membership functions of input 1

17.3.3 Membership Function Determination

In this study, the bell-shaped membership functions are applied, and each input has three fuzzy sets, namely, Low, Medium and High. Take ANFIS 1 as an example, the membership functions of basic indicator So1 are shown in Fig. 17.4.

As shown in Fig. 17.4, the vertical axis represents the membership degree of each fuzzy set, which ranges from 0 to 1, and the horizontal axis represents the normalized value of input variable.

17.3.4 The Establishment of FIS

After determining the MFs of each variable, the next step is to establish the fuzzy interference system. Figure 17.5 presents the FIS structure of ANFIS 1, which is implemented using the fuzzy logic toolbox of MATLAB software package.

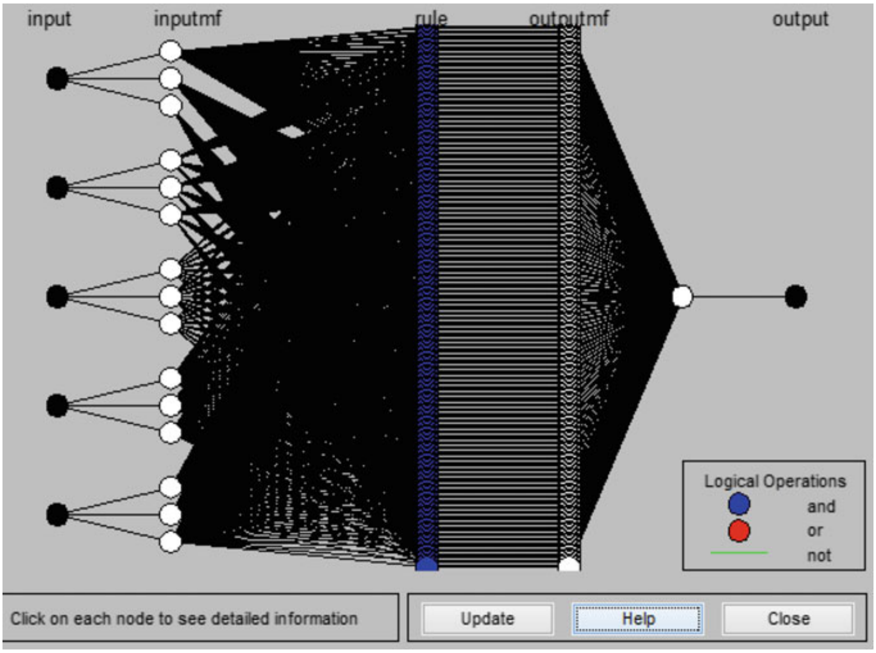


Fig. 17.5 FIS structure of ANFIS 1 in MATLAB

As shown in Fig. 17.6, there are five input variables and each variable has three fuzzy sets with overall 243 if-then fuzzy rules in ANFIS 1.

17.3.5 Training Process of FIS

In this part, the established FIS will be trained using training samples collected previously. Figure 17.7 demonstrates the training process of FIS.

As shown in Fig. 17.6, the initial epochs are set as 30 in this study, and the error are decreasing up to 3 epochs for training which suggests the 3 epochs is appropriate for training the model. Meanwhile, the error of this ANFIS is only 0.0007 indicating the trained ANFIS is accurate enough (Singh et al. 2012; Jang 1993; Tan et al. 2017).

Fig. 17.6 Training process

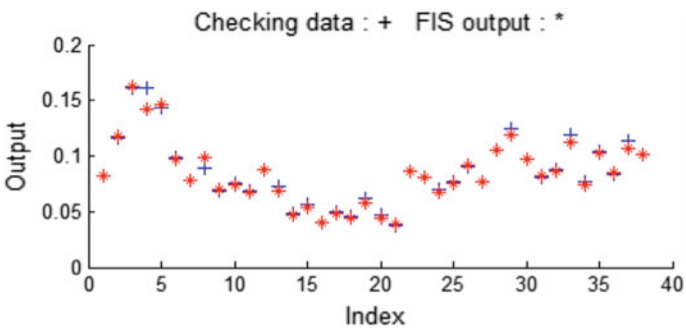


Fig. 17.7 Comparison between training, checking data and the ANFIS

17.3.6 Checking Process of ANFIS

After training the established ANFIS, the next step is to check the trained ANFIS model. Take ANFIS 1 as an example. Figure 17.7 presents the output comparison between checking data and the ANFIS model.

As shown in Fig. 17.7, "+" denote the checking data respectively, "*" denotes the value from ANFIS model. Most of the checking data are fit with value derived from ANFIS model, which suggest the ANFIS is effective to assess the value of PRKNOW by adopting the normalized value of three basic indicators.

17.4 Discussion

By applying the six steps as mentioned in last section, the rest of 3 ANFIS models can be easily established with the same principle, the maximum error belongs to ANFIS 6 with the acceptable error of 3.67 * 10 − 3, which indicates all the 4 ANFIS is effective and accurate (Phillis and Andriantiatsaholiniaina 2001).

After training and checking, the overall sustainability performances of 38 regions in Chongqing are re-assessed by ANFIS method using the data of years 2013. Table 17.2 presents the original and new value.

As shown in Table 17.2, the error of ANFIS of overall regional sustainability performance is less than 1.73%, which indicates ANFIS is an alternative approach for regional sustainability assessment.

Table 17.2 Regional sustainability rankings by SHEN and ANFIS

Region	SHEN	ANFIS	Error (%)	Region	SHEN	ANFIS	Error (%)
Yuzhong	0.4733	0.472	0.27	Tongnan	0.3449	0.345	0.02
Dadukou	0.4057	0.405	0.17	Rongchang	0.3814	0.383	0.42
Jiangbei	0.5503	0.548	0.41	Wanzhou	0.4046	0.407	0.59
Shapingba	0.477	0.469	1.67	Liangping	0.3925	0.393	0.13
Jiulongpo	0.5089	0.502	1.35	Chengkou	0.3776	0.379	0.37
Nanan	0.4825	0.481	0.31	Fengdu	0.3774	0.377	0.11
Beibei	0.4753	0.476	0.14	Dianjiang	0.3793	0.379	0.08
Yubei	0.5798	0.579	0.13	Zhong	0.3592	0.359	0.06
Banan	0.4466	0.445	0.35	Kai	0.3375	0.339	0.44
Fuling	0.4004	0.403	0.64	Yunyang	0.3809	0.382	0.28
Qijiang	0.3353	0.338	0.81	Fengjie	0.3477	0.348	0.09
Dazu	0.3857	0.379	1.73	Wushan	0.3905	0.392	0.38
Changshou	0.3911	0.394	0.74	Wuxi	0.3427	0.343	0.09
Jiangjin	0.3882	0.388	0.52	Qianjiang	0.4471	0.448	0.2
Hechuan	0.3574	0.357	0.11	Wulong	0.3878	0.389	0.31
Yongchuan	0.3836	0.384	0.1	ShiZhutujia	0.3635	0.365	0.41
Nanchuan	0.3358	0.337	0.35	Xiushantujia	0.3812	0.384	0.73
Bishan	0.4031	0.405	0.47	Youyangtujia	0.3961	0.399	0.73
Tongliang	0.4482	0.449	0.17	Pengshuimiaozu	0.356	0.356	0

17.5 Conclusion

In order to evaluate the sustainability performance, an effective method is necessary. In this paper, we innovatively introduce the adaptive neuro-fuzzy interference system (ANFIS) for regional sustainability performance assessment. The robust validation process reveals that the ANFIS method is effective and accurate to evaluate the regional sustainability performance. The results of this research add value to the development of methodology for further studies on the sustainability performance.

Acknowledgements This research is supported by a grant from the Research Grants Council of Hong Kong Special Administrative Region, China (Project No. F-PP2F). This paper is also funded by the National Social Science Foundation of China (Grant No. 15BJY038 and 15AZD025).

References

Andriantiatsaholiniaina LA, Kouikoglou VS, Phillis YA (2004) Evaluating strategies for sustainable development: fuzzy logic reasoning and sensitivity analysis. Ecol Econ 48 (2):149–172

Azadi M, Jafarian M, Mirhedayatian SM, Saen RF (2015) A novel fuzzy data envelopment analysis for measuring corporate sustainability performance. Int J Prod Qual Manag 16(3):312–324

Brundtland Commission, & Brundtland Commission.(1987) Our common future

Buragohain M, Mahanta C (2008) A novel approach for ANFIS modelling based on full factorial design. Appl Soft Comput 8(1):609–625

Carnero MC (2015) Assessment of environmental sustainability in health care organizations. Sustainability 7(7):8270–8291

Cavallaro F (2015) A Takagi-Sugeno Fuzzy Inference System for developing a sustainability index of biomass. Sustainability 7(9):12359–12371

Chen X, Lu W (2017) Identifying factors influencing demolition waste generation in Hong Kong. J Clean Prod 141:799–811

Escrig-Olmedo E, Fernández-Izquierdo MÁ, Muñoz-Torres MJ, Rivera-Lirio JM (2015) Fuzzy Topsis for an integrative sustainability performance assessment: a proposal for wearing apparel industry. In Scientific Methods for the Treatment of Uncertainty in Social Sciences (pp 31–39). Springer International Publishing

Jang JS (1993) ANFIS: adaptive-network-based fuzzy inference system. IEEE Trans Syst, Man, Cybern 23(3):665–685

Jiao L, Shen L, Shuai C, He B (2016) A novel approach for assessing the performance of sustainable urbanization based on structural equation modeling: a China case study. Sustainability 8(9):910

Lu W, Chen X, Peng Y, Shen L (2015) Benchmarking construction waste management performance using big data. Resour Conserv Recycl 105:49–58

Lu W, Chen X, Ho DC, Wang H (2016) Analysis of the construction waste management performance in Hong Kong: the public and private sectors compared using big data. J Clean Prod 112:521–531

Naderloo L, Alimardani R, Omid M, Sarmadian F, Javadikia P, Torabi MY, Alimardani F (2012) Application of ANFIS to predict crop yield based on different energy inputs. Measurement 45 (6):1406–1413

Phillis YA, Andriantiatsaholiniaina LA (2001) Sustainability: an ill-defined concept and its assessment using fuzzy logic. Ecol Econ 37(3):435–456

Shen L, Jiao L, He B, Li L (2015a) Evaluation on the utility efficiency of metro infrastructure projects in China from sustainable development perspective. Int J Project Manage 33(3):528–536

Shen L, Zhou J, Skitmore M, Xia B (2015b) Application of a hybrid Entropy–McKinsey Matrix method in evaluating sustainable urbanization: a China case study. Cities 42:186–194

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017a) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Shen L, Yan H, Zhang X, Shuai C (2017) Experience mining based innovative method for promoting urban sustainability. J Clean Prod

Singh R, Kainthola A, Singh TN (2012) Estimation of elastic constant of rocks using an ANFIS approach. Appl Soft Comput 12(1):40–45

Tan Y, Shuai C, Jiao L, Shen L (2017) An adaptive neuro-fuzzy inference system (ANFIS) approach for measuring country sustainability performance. Environ Impact Assess Rev 65:29–40

Zhao H, Li N (2016) Performance evaluation for sustainability of strong smart grid by using stochastic AHP and Fuzzy TOPSIS methods. Sustainability 8(2):129

Zhou J, Zhang X, Shen L (2015) Urbanization bubble: four quadrants measurement model. Cities 46:8–15

Chapter 18
An Empirical Analysis of the Effect of Prefabrication on Fostering Sustainable Construction

Peter S.P. Wong, Michael Phillip Kanellopoulos and Luke Edmonson

18.1 Introduction

The advancement of building information modelling and volumetric preassembly technologies has unleashed the potential of a more extensive use of prefabrication in construction projects (Pan et al. 2012). Over the years, prefabrication associated businesses have extended its scope from precast concrete panels to a wide range of components like bathrooms, kitchen pods, as well as other composite modular units (Jaillon and Poon 2014). By using more radical approaches, completely finished modular buildings can be factory made and, once complete, transported to site for installation on a developed substructure (Lu 2007).

Interestingly, in recent years, scholars often described prefabrication as an effective means to attain sustainable construction (Osmani et al. 2006). An industry review conducted by Hampson and Brandon (2004) identified prefabrication as one of the major themes for the Australian construction industry to attain sustainable practice. Zhai et al. (2013) advocated off-site production in the construction process as the viable means of enhancing the level of sustainability. Industry review reports from the Department of Trade and Industry in the United Kingdom and the Building and Construction Authority in Singapore also described prefabrication as a vital approach to achieve sustainable construction (BCA 2011; UKDTI 2001). Furthermore, such beliefs may be developed on some evidence that prefabrication helps reduce on-site construction wastes and enables greater use of low embodied-carbon materials in manufactured building components or units (Jaillon and Poon 2014; Osmani et al. 2006).

However, other studies have argued that the more extensive use of prefabrication may not necessarily be initiated by a goal of achieving sustainable construction.

P.S.P. Wong (✉) · M.P. Kanellopoulos · L. Edmonson
School of Property Construction and Project Management,
RMIT University, Melbourne, Australia
e-mail: peterspwong@rmit.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_18

Blismas et al. (2007) conducted a cross comparison case study between traditional construction and offsite construction. The results reveal that the real benefits prefabrication brought to the projects are labour and material cost reduction. Nadim and Goulding (2010) argued that uptake of prefabrication may be due to various reasons such as optimising integration between planning and design, reducing reliance of labours, improving site safety and improving end-product quality control. The mix findings reported in previous studies make it interesting to investigate the roles played by prefabrication in fostering sustainable construction. The study reported in this paper aims to investigate the effect of prefabrication on fostering sustainable construction. This study helps demonstrate how achievements in sustainable construction in projects can be evaluated. The associated findings of this study help clarify the reasoning behind greater adoption of prefabrication. Furthermore, the results would help gain insights into devising pragmatic measures to foster sustainable construction in projects.

This paper commences with a background review of the sustainable construction. Measures of evaluating the achievements in fostering sustainable construction are identified. This is followed by a description of the research methodologies, with the research findings then discussed. Finally, concluding remarks and recommendations are made.

18.2 Evaluation of Sustainable Construction

Sustainable construction has been defined in different contexts. Miller et al. (2015) defines sustainable construction as a "development that appropriately and equally benefits economic and social considerations, while concurrently minimising related environmental impacts". In board terms, sustainable construction is described as an attempt to combine growing concerns about a range of environmental issues and socio-economic issues. Bourdeau (1999) interprets sustainable construction in terms of the physical factors involved such as land, materials, water and energy in conjunction with the building cycle starting from the procurement of raw materials to the deconstruction of buildings. Biswas (2014) described sustainable construction as measures that reduce excessive energy consumptions of buildings at initial and operational stages. Ding (2007) argues that the interpretation of sustainable construction varies depending on the parties involved. For instance, a building owner may view sustainable construction from an economical viewpoint where as an occupant may be more interested in the in-door quality and safety impacts of buildings. From the literature above, it appears that the definitions of sustainable construction became fragmented to reflect on different stakeholders' perspectives. This study comes back to the fundamentals and adopts the general principles proposed by Kibert (1994) that defines sustainable construction as "the creation and responsible maintenance of a healthy built environment, based on ecological principles, and by means of an efficient use of resources".

Very few studies attempted to evaluate the effect of sustainable construction in projects. Chen et al. (2010) identified 16 economic criteria, 8 social criteria, and 9 environmental criteria to evaluate sustainable performance of concrete buildings. However, these criteria merely facilitate selection of more sustainable construction methods. Hong et al. (2015) conducted a systematic review on sustainable construction management strategies. In their studies sustainable construction is evaluated by tracking the building's dynamic energy performance at monitoring, diagnosing, and retrofitting phases. However, the proposed concepts are not applicable to evaluate the effectiveness of prefabrication in achieving sustainable construction. Ametepey et al. (2015) developed a 6-dimensional framework to identify barriers of sustainable construction: Financial, Political, Management/Leadership, Technical, Socio-cultural, Knowledge/Awareness. They suggested that the success of sustainable construction can be evaluated by the extent of the barriers being removed in projects. Nevertheless, the proposed evaluators did not directly focus on construction project operations. The above review timely reminds the importance to develop measures to evaluate effectiveness of sustainable construction that are project specific. In this aspect, the Green Construction Board (2015) of the United Kingdom conducted a comprehensive review and developed a set of project specific measures to evaluate the effectiveness of sustainable construction in five aspects: Waste; Water, Carbon, Materials and Biodiversity (Green Construction Board 2015). This study adopts the measures suggested by the Green Construction Board (2015) and evaluates the effect of prefabrication on achieving sustainable construction in the above-mentioned five aspects. Table 18.1 presents the measures of evaluating the effect of prefabrication on sustainable construction.

Table 18.1 Measures of evaluating the effect of prefabrication on sustainable construction (adopted from Green Construction Board 2015)

Aspects	Implementing prefabrication in your project is effective to achieve the following goals
	Respective operational statements
Waste	Waste minimisation during the design and construction phase of the project (WS1)
	Enable greener designs to be established that create less waste (WS2)
	Limit the amount of packaging used to protect material (WS3)
	Allow for the recycling of previously used materials to thus avoid landfill (WS4)
Water	Allow for water targets to be set to minimise water usage both during the construction and operation of the project (WT1)
	Reduce mains water consumption through the life of the project (WT2)
	Allow for water usage to be tracked during the construction phase (WT3)
	Prevent water pollution at construction and operational stages of the building life cycle (WT4)

(continued)

Table 18.1 (continued)

Aspects	Implementing prefabrication in your project is effective to achieve the following goals
Carbon	Allow for carbon targets to be set to monitor effective performance (CB1)
	Reduce carbon emissions in the design process by taking into account the whole life of the project (CB2)
	Allow for carbon emissions to be cut during the construction and manufacturing stage (CB3)
	Enable carbon saving by giving occupants the ability to cut their carbon usage (CB4)
Materials	Allow for new and more environmentally friendly materials to enter the market (MT1)
	Enable material to go further through more effective designs and resource efficiency (MT2)
	Have a low environmental impact whilst improving the performance of the project (MT3)
	Allow for the responsible sourcing of materials (MT4)
Biodiversity	Provide better results when paired with sites of low ecological and agricultural value (BV1)
	Enable the assessment and monitoring of natural habitat (BV2)
	Incorporate features such as green roofs and walls that are able to protect the environment (BV3)
	Benefit from consultations of specialists who can develop long term management plans that meet the needs for people and wildlife (BV4)

18.3 The Research Methodologies

To accomplish the research objectives, a questionnaire survey was performed for data collection. The questionnaire designed for this study consists of two parts. Part 1 includes questions designed to solicit the respondents' demographic information. Part 2 of the questionnaire consists of the 20 operational statements enlisted in Table 18.1 to evaluate the effectiveness of prefabrication on achieving sustainable construction.

Respondents were asked to assess the degree of agreement of the statements by using a five-point likert scale (from 1: "Strongly Disagree", 3: "Neutral" to 5: "Strongly Agree"). Respondents targeted for this study are directors, project managers and professional grade staff from consultants, main contractors and sub-contractors which are listed in the latest edition of builders' directories and the official web pages of the professional institutes. A list of 200 target respondents, with 100 work in contractor firms and the rest work in the developers/consultants firms, were identified on random basis. The target respondents were invited to participate in the survey via either an online platform supported by Qualtrics or hardcopies delivered by our research team. To avoid disruption to selected hard-copies recipients, the research team initially sought permission via telephone before visiting the respective companies in person. In order to secure the reliability of the received responses, respondents were asked to provide information on their experiences in construction projects with prefabrication work. If the respondents replied that they had no relevant experience, their returned questionnaires were discarded. This study had successfully gone through the ethics clearance which standards are outlined in the National Ethics Application Form (NEAF). The proposed data collection method and the sample questionnaire are approved by the ethics clearance committee of the authors' institution.

Concerning data analysis, firstly the mean scores of the respondents' degree of agreement on the effectiveness of prefabrication on achieving sustainable construction were compared. Furthermore, it is mindful that company type may affect the respondents' perceptive views of the effect of prefabrication on sustainable construction. In this regard, an analyses of variance (ANOVA) was conducted to identify if a significant difference in views are found between company types. Mean scores among groups are considered as significantly different when $\rho < 0.05$ in F-tests.

18.4 The Sample Profile

A total of 200 questionnaires were dispatched. 58 respondents with relevant experience in prefabrication projects returned the questionnaires with 2 replies excluded due to being incomplete. 56 valid responses were used (refer to Table 18.2). This sample size is comparable with questionnaire surveys of this kind (Tang et al. 2012). As a pilot study that focused on the perceptive views on practitioners in greater Melbourne region, the sample size of this survey is considered acceptable. Notwithstanding, this data characteristic should be considered when interpreting the findings and it also points to further research using a larger sample size to validate the current results.

Among the respondents' backgrounds, 85% of the respondents have had more than 5 years' experience in their respective field. It should be noted that over 15% of our respondents have more than 20 years of project management experience. The creditability of the respondents is indicative of their service to the industry thus their responses are considered reflective to the industry's views.

Table 18.2 Questionnaires sent and received

Sample group	Questionnaires sent (No.)	Valid samples received (No.)
Developers/consultants	100	21
Contractors/sub-contractors	100	35
Total	200	56

Table 18.3 Respondents' perceptive views about the effectiveness of prefabrication on fostering sustainable construction—compared by company types

	Developers/ consultants		Contractors		Overall		ANOVA	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F-value	Sig.
Waste								
WS1	3.52	0.95	3.66	1.01	3.62	0.98	0.25	0.62
WS2	3.53	0.95	3.09	1.16	3.25	1.10	1.92	0.17
WS3	2.90	1.00	3.26	1.14	3.14	1.10	1.43	0.24
WS4	3.83	0.68	3.00	1.09	3.17	1.04	9.75	0.00*
Water								
WT1	2.64	0.93	2.44	1.15	2.51	1.07	0.40	0.53
WT2	2.64	0.96	2.43	1.22	2.50	1.13	0.44	0.51
WT3	3.00	0.88	2.44	1.11	2.64	1.06	3.57	0.07
WT4	2.96	0.83	2.50	1.06	2.70	1.02	3.91	0.05*
Carbon								
CB1	3.10	0.70	2.40	2.40	1.11	1.06	7.12	0.01*
CB2	2.53	1.60	2.32	2.32	1.66	1.64	5.82	0.02*
CB3	2.14	1.29	1.90	1.90	1.36	1.34	3.86	0.06
CB4	2.00	1.47	2.22	1.60	2.15	1.56	4.27	0.04*
Materials								
MT1	2.77	1.57	2.54	1.71	2.60	1.66	5.19	0.03*
MT2	3.37	1.96	3.45	2.00	3.33	1.99	1.29	0.26
MT3	3.16	1.55	3.26	1.77	3.23	1.70	1.22	0.28
MT4	2.95	0.97	2.94	1.11	2.94	1.05	0.00	0.99
Biodiversity								
BV1	2.24	0.69	2.16	1.03	2.18	0.97	1.28	0.27
BV2	2.22	0.81	2.01	1.07	2.08	0.98	0.60	0.44
BV3	2.14	0.83	2.08	0.98	2.12	0.98	1.22	0.29
BV4	2.46	0.87	1.91	1.13	2.11	1.07	3.40	0.07

Note *significantly different mean scores between groups at $\rho < 0.05$

18.5 Findings and Discussions

Participants were asked whether they agreed with the 20 operational statements listed in Table 18.1 to describe the effectiveness of prefabrication on achieving sustainable construction. The scale intervals are interpreted as from 1 "Strongly Disagree" to 5 "Strongly Agree". The results are presented in Table 18.3.

As Table 18.3 indicates, the mean scores for all questions under Water, Carbon and Biodiversity categories are lower than 3 out of the 5-point likert scale. This indicates that respondents generally disagree with the utilisation of prefabrication as being effective in achieving sustainable construction. The result does not seem to align with the a similar study conducted by Khalfan et al. (2014) who adopted a qualitative case study approach and reported that prefabrication may bring whole lifecycle benefits to projects, then extend to foster sustainable construction. The contradictory results may be linked to the fact that the cited previous study merely focused on few cases relevant to rail infrastructure projects in Australia. Moreover, findings discussed in other countries appear to show that saving on-site construction time, reducing defect, as well as reducing the reliance of on-site labours are the major drivers of prefabrications (Blismas et al. 2006; Pan et al. 2012).

However, regardless whether these factors outweigh those statements listed in Table 18.1 as the drivers of going prefabrication. There appears to be some mixed views about the role played by prefabrication in foster sustainable construction. The result of a systematic review conducted by Zhai et al. (2013) indicate the positive effect of prefabrication on fostering sustainable construction in terms of reducing construction wastes. Similar result was also reported by Jaillon et al. (2009). In their case study conducted in Hong Kong, buildings with prefabricated components created in average of 52% less on-site construction wastes than the conventional buildings. The above reported findings generally align with the outcomes of this survey. Refer to Table 18.3, all questions related to 'Waste' were rated above 3 out of the 5-point likert scale. In relation to 'Materials', it is worth noting that respondents generally agree with the following two statements:

'MT2—Enable material to go further through more effective designs and resource efficiency' (Mean = 3.33, Standard deviation (S.D.) = 1.99);
'MT3—Have a low environmental impact whilst improving the performance of the project' (Mean = 3.23, Standard deviation (S.D.) = 1.79);

Mean scores of the other two statements under 'Materials' slightly exceed the mid-point of the five point scale. Similar results (mean scores ranged from 2.4 and 2.6) are also found from some statements under other categories. This suggest that respondents might perceive some statements as neutral in regards to the effectiveness of fostering sustainable construction. However, such result pattern provides little information for management actions. Moreover, previous construction management research studies indicate that respondents from the developers and consultants firms might engender different perceptive views than those who work in the contractors' firms. In this regard, Analysis of Variance (ANOVA) was conducted to identify whether significant differences in views appeared among respondents grouped by company type.

As displayed in Table 18.3, at the 95% confidence level (i.e. at $\rho < 0.05$ level), group differences in mean scores of 14 out of the 20 operational statements are not significantly different. However, the ANOVA results also reveal that in some areas, as far company type is concerned, the respondents may posed different views.

Under the category of 'Waste', significant difference of means is found in WS4—'Allow for the recycling of previously used materials to thus avoid landfill' (with an F value of 9.75 at sig. level 0.003). The result indicates that the respondents who work as Developers/Consultants strongly agree that prefabrication allows for the recycling materials to thus avoid landfill as compared to the respondents who work as Contractors. The disparity may be explained by the fact that the contractors being onsite and producing/seeing the amount of waste that is inherently produce. Contractors generally have better onsite experience and knowledge of what materials have to go to landfill and what can be reused correctly.

Another statement where significant mean scores difference is found is WT4—'Prevent water pollution at the construction and operational stages of the building life cycle' (with an F value of 3.91 at sig. level 0.05) under the category of 'Water'. When construction work is completed, the building will be handed over to the developers. Beyond that point, the buildings will enter to the operational stage of the building life cycle. It becomes much harder to pinpoint improper construction process as a major reason for contaminated water supply. In this regard, as the owners of the buildings, the developers are believed to be more mindful about the design faults possibly caused by the use of prefabrication in preventing water contamination.

The result obtained from both groups of respondents in relation to 'Carbon' is quite interesting as there were 3 statements that produced significantly different mean scores. They are CB1 "Allow for carbon targets to be set to monitor effective performance" (with F value of 7.12 at sig. level 0.01) CB2 "Reduce carbon emissions in the design process by taking into account the whole life of the project" (with an F value of 5.82 at sig. level 0.02) and CB4 "Enable carbon saving by giving occupants the ability to cut their carbon usage" (with F value of 4.27 at sig. level 0.04).

What made these results quite intriguing is that the respondents who work in the developer/consultant firms agreed more with the statements CB1 and CB2 regarding prefabrications ability to reduce carbon emissions than those who work as contractors. It is observed that in recent years developers are becoming more enthusiastic in obtaining green star ratings for their projects. The perception of green Star ratings amongst the general public has in some sense brought the construction practitioners to attend to carbon reduction. However, the mean scores of these statements reflect that the respondents do not have high regard for seeing prefabrication as a way to reduce carbon emissions. The higher means found from the designers/consultant group are coherent with those of some critics who have mentioned that developers perceived Green Star ratings as a marketing tool under an assumption of reduced utilities and better design. In fact, they may not be genuine in seeking low carbon solutions for the sake of the environment (Wong et al. 2013).

Under the category of 'Materials', MT1—'Allow for new and more environmentally friendly materials to enter the market' (With an F value of 5.19 at sig. level 0.03). The ANOVA results indicate that the Developers/Consultants agree more to the statement then those who work as contractors. This may due to the facts that developers and his consultants have the decisive power on the materials to be used in the construction projects. Despite the fact that Design and Build projects are very popular in Australia that to certain extent empowers the contractors to choose what materials to be used in the prefabrication components, their design ideas typically need approval by the developers. Collectively bound by the project-based collaboration mechanism, contractors are merely project executers who have neither a contractual right nor a responsibility to challenge the decisions made by the developers or their in-house professionals. Unless being initialised by the developers, contractors may not proactively suggest new or more environmentally friendly materials to be used in manufacturing prefabrication components (Wong and Zapatis 2013).

18.6 The Concluding Remarks

Prefabrication has become a popular construction alternative. This has caught the eye of some scholars about what has caused the greater reliance of prefabrication in the construction projects. Prefabrication has also been advocated as a more effective approach in reducing construction time, on-site labours and enhancing on-site safety. Previous studies have made progress towards the understanding of role of prefabrication in fostering sustainable construction. Nevertheless, research contributions from these studies are scattered in regards to not assessing all aspects of sustainable construction. The study reported in this paper evaluates the effects of prefabrication on sustainable construction in five aspects proposed by the UK Green Construction Board: Water, Waster, Carbon, Materials and Biodiversity.

The results of this study reflect that prefabrication may be effective in fostering sustainable construction in terms of reducing construction wastes and using more environmental friendly materials to manufacture prefabricated components. However, the ANOVA results further reveals that actions like reducing construction waste may not necessarily be motivated by a goal to achieve sustainable construction. The real intention to adopt prefabrication might not be associated with the fulfilment of social responsibilities. This study advances our understanding by evaluating the effect of sustainable construction from a different perspective. The findings of this study aptly remind us that there is no quick fix for fostering sustainable construction. Going prefabrication can be part of the solutions for achieving sustainable construction if the true motives of the actions match with its goal.

The findings in this paper should be taken within the context of several limitations. First, the results are paper are drawn from a pilot study that was conducted in the greater Melbourne region in Australia. The findings should be read in the light of this geographical context. Secondly, the 56 valid responses used in this study are considered reasonable, although a larger number is preferred. Using greater sample size for analyses and collecting data from other countries can therefore be considered for further studies.

References

Ametepeya O, Aigbavboab C, Ansahb K (2015) Barriers to successful implementation of sustainable construction in the Ghanaian construction industry. Procedia Manufact 3:1682–1689

Biswas WK (2014) Carbon footprint and embodied energy consumption assessment of building construction works in Western Australia. Int J Sustain Built Environ 3(2):179–186

Blismas N (2007) Offsite manufacture in Australia: current state and future directions. Cooperative Research Centre for Construction Innovation, Brisbane, Australia

Blismas N, Pasquire C, Gibb A (2006) Benefit evaluation for off-site production in construction. Constr Manage Econ 24(2):121–130

Bourdeau L (1999) Sustainable development and the future of construction: a comparison of visions from various countries. Build Res Inf 27(6):355–367

Building and Cosntruction Authority (BCA) (2011) Prefabricate and drywall it up with PIP. Built Smart 11(6):7–11

Chen Y, Okudan GE, Riley DR (2010) Sustainable performance criteria for construction method selection in concrete buildings. Autom Constr 19(2):235–244

Ding GKC (2007) Sustainable construction—the role of environmental assessment tools. J Environ Manage 86(3):451–464

Green Construction Board (2015) 20 steps to greening our industry. The Green Construction Board, United Kingdom. Available at: http://www.greenconstructionboard.org/images/gcbtoptips.pdf

Hampson K, Brandon P (2004) Construction 2020: a vision for Australia's property and construction industry. Cooperative Research Centre for Construction Innovation, Brisbane

Hong T, Koo C, Kim J, Lee M, Jeong K (2015) A review on sustainable construction management strategies for monitoring, diagnosing, and retrofitting the building's dynamic energy performance: focused on the operation and maintenance phase. Appl Energy 155:671–707

Jaillon L, Poon CS (2014) Life cycle design and prefabrication in buildings: a review and case studies in Hong Kong. Autom Constr 39:195–202

Jaillon L, Poon CS, Chiang YH (2009) Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Manage 29(1):309–320

Khalfan M, Noor M, Maqsood T, Alshanbri, N, Rahmani F, Sagoo A (2014) Perceptions towards sustainable construction amongst construction contractors in state of Victoria, Australia. In: Georgiev DV, Park C, Arias CC, Chen D (eds) Proceedings of the 2014 international conference on business, marketing and management (ICBMM 2014), Hong Kong, 8–10 Nov 2014, pp 181–188

Kibert C (1994) Establishing principles and a model for sustainable construction. In: Proceedings of the first international conference on sustainable construction, Tampa, Florida, 6–9 Nov 1994

Lu N (2007) Investigation of designers and general contractors perceptions of off site construction techniques in the United States construction industry. Ph.D. Dissertation, Graduate School of Clemson University. Available at http://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=1081&context=all_dissertations

Miller D, Doh JH, Mulvey M (2015) Concrete slab comparison and embodied energy optimisation for alternate design and construction techniques. Constr Build Mater 80:329–338

Nadim W, Goulding JS (2010) Offsite production in the UK: the way forward? A UK construction industry perspective. Constr Innov 10(2):181–202

Osmani M, Glass J, Price A (2006) Architect and contractor attitudes to waste minimisation. Waste Resour Manage 2(1):65–72

Pan W, Gibb AGF, Dainty ARJ (2012) Strategies for integrating the use of off-site production technologies in house building. J Constr Eng Manage 138(11):1331–1340

Tang LCM, Atkinson B, Zou RR (2012) An entropybased SWOT evaluation process of critical success factors for international market entry: a case study of a medium-sized consulting company. Constr Manage Econ 30(10):821–834

UK Department of Trade and Industry (UKDTI) (2001) Current practice and potential uses of prefabrication. In: Waskett P (ed) Department of Trade and Industry, London

Wong PSP, Zapantis J (2013) Driving adoption of carbon reduction strategies in the construction projects—the moderating role of organizational culture. Build Environ 66:120–130

Wong PSP, Ng TST, Shahidi M (2013) Towards understanding the contractor's response to carbon reduction policies—an organisational culture perspective. Int J Project Manage 31(7): 1042–1056

Zhai Z, Reed R, Mills A (2013) Increasing the level of sustainability via off-site production—a study of the residential construction sector in China. In: Proceedings of the 19th annual Pacific-RIM real estate society conference, Melbourne Australia, 13–16 Jan 2013, pp 1–13

Chapter 19
An Empirical Investigation of Construction and Demolition Waste Management in China's Pearl River Delta

J.K. Liu, Y.S. Pang, D. Wang and J.W. Zhou

19.1 Introduction

As one of the main departments formed by fixed capital and the pillar industries in China' s national economic system, the construction industry has been developing fast. According to statistics, the nationwide newly-completed construction area in 2004 achieved 4.231 billion m^2, and it is increasing year by year. It is expected that China will have another construction area of 30 billion m^2 as of 2020. The construction waste produced by such a big number of construction projects will be shocking (Lu 2006).Taking the economically-advanced Pearl River Delta as an example, the area of constructions is increasing stably and it achieved 3.450123 billion m^2 in 2014, as shown in Fig. 19.1. According to rough statistics, 500–600 tons of construction wastes are produced in the process of constructing an construction area of 10,000 m^2 (Lu 2006). Calculated in this way, the construction wastes achieved in recent years will achieve 100 million tons, if the construction of a large area of urban villages is added in.

Since the reform and opening up policy was introduced, China's economy has been developing fast. However, the life of China's architectures isn't increasing and its average age is only around 30 years (Zhou 2011; Liu 2013). The architectures with a short life are waiting to be torn down, which generate a large amount of construction wastes every year. Moreover, added with those produced by newly-completed architectures, the overall amount of China's architectures has accounted for 30–40% of all urban wastes (Li et al. 2015). The piling of wastes takes up tens of thousands of hectares' land and the phenomenon that wastes surround the city is becoming increasingly serious. Most construction wastes haven't received any treatment and are directly transported by the construction units to the suburbs or

J.K. Liu (✉) · Y.S. Pang · D. Wang · J.W. Zhou
Department of Construction Management, School of Business Administration,
Guangzhou University, Guangzhou, China
e-mail: ljkgowell@163.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_19

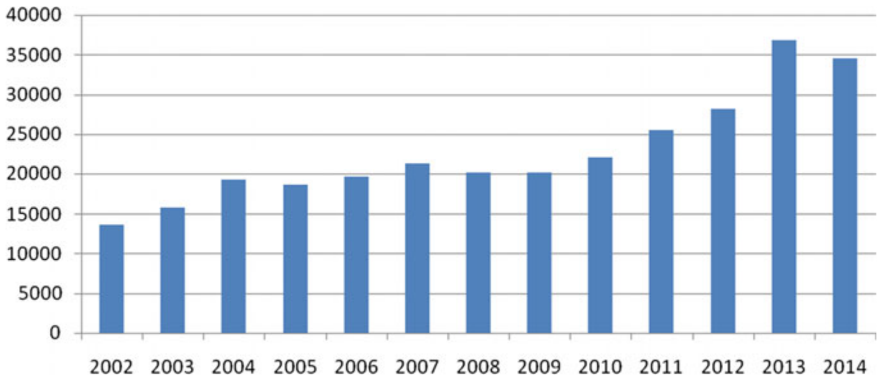


Fig. 19.1 The floor space of buildings under construction by construction enterprises of the pear river delta between 2002 and 2014 (10,000 sq.m) (Guangdong Provincial Statistics Bureau 2015)

the countryside. They are stacked in the open air or are simply processed such as being land-filled, which occupies valuable land, consumes high transportation fees and leads to a great waste of resources. Meanwhile, the dispersion, dust and rising debris produced in the process of transportation and stacking cause serious environmental pollution. If we don't pay high attention to or manage the generation and treatment of construction wastes, it will not only bring unfavorable influences to the implementation of the country's policies, such as energy-conservation, development of resources and low-carbon circular economy, but will also create obstacles to the sustainable development of China's construction industry.

This paper is aimed at researching on the problem of construction wastes in China's Pearl River Delta so as to analyze and find out key factors, as well as adopt relevant policies. The research conclusions of this research can provide reference for stakeholders to formulate effective strategies of managing construction wastes. Meanwhile, in the context of fast economic development, it also has certain reference to how to decrease the bad influences on the environment that are caused by construction wastes produced in construction activities.

19.2 Literature Review

In recent years, with the development of China's construction industry, a large amount of construction wastes are produced in the process of building and demolition. Chinese scholars also notice the seriousness of the generation of construction wastes on the environment and resources, so they also have carried out a large number of researches on the construction wastes in various regions of China (Li et al. 2010, 2013; Wang et al. 2010). However, many researches are not meticulous and comprehensive analyses are rare (Zhang et al. 2005; Osmani et al. 2008; Jaillon et al. 2009; Cha et al. 2009), seen from Table 19.1.

Table 19.1 Generalizations and differentiations of different opinions of various scholar (Li et al. 2010, 2013; Wang et al. 2010; Zhang et al. 2005; Osmani et al. 2008; Jaillon et al. 2009; Cha et al. 2009; Beguma et al. 2007; Agamuthu 2008; Lu and Tam 2013)

Scholar	Case study	Opinions
Zhang et al. (2005)	USA	According to the researches on America, paying attention to the minimization of construction wastes in the process of constructing residential buildings will greatly promote the production, safety and quality of residential buildings
Tam (2008)	Hong Kong	Through questionnaire research and structural interview, the author pointed out the " construction waste management plan" can effectively achieve the reusing of on-site architectural materials and the generation of construction wastes
Osmani et al. (2008)	UK	According to researches on UK, 1/3 of construction wastes are determined by architects' design and model selections
Jaillon et al. (2009)	Hong Kong	Through researches, the authors pointed out: Widely using standardized pre-made components in construction projects can effectively reduce the production of construction wastes
Cha et al. (2009)	South Korea	The authors identified 59 waste management influence factors in Korea and established the tool of assessing the construction waste management level on the basis of these influence factors, and used it for constantly measuring the levels of managing construction wastes in projects
Li et al. (2010)	Shenzhen, China	Through the research on 25 newly-constructed projects, the authors pointed out that the scrape ratio is the smallest among industrial construction wastes; moreover, the authors also designed the construction waste minimization measures list to be adopted on the construction site through on-site research and interviews
Wang et al. (2010)	Shenzhen, China	By investigating the construction site of the construction projects and the face-to-face interview of personnel in the industry, the authors affirmed the six key factors that influence the treatment of construction wastes on the construction site, which include: (1) manpower; (2) market of recycling materials; (3) classification of architectural resources; (4) good on-site management; (5) space for construction; (6) equipment for classifying construction wastes
Lu et al. (2011)	Shenzhen, China	By researching on the construction waste generation ratio of construction projects in Shenzhen, the authors analyzed the main reasons for producing construction wastes and proposed solutions of controlling from the root, such as adopting high-quality production personnel, replacing the currently widely-used wooden templates with metal templates and formulate an encouragement plan to promote decreasing construction wastes

The methods and results of controlling the minimization of construction wastes adopted by the above scholar provide important reference to subsequent researches. However, as construction projects are greatly influenced by the national condition, regional characteristics, structural forms and construction techniques, these conclusions are relatively scattered, while their experience and results can hardly be applied directly (Beguma et al. 2007; Agamuthu 2008; Lu and Tam 2013). Meanwhile, the domestic researches on construction projects' control from the root and the classification treatment after wastes are produced are not mature. Therefore, this paper adopts the method of questionnaire research, takes the Pearl River Delta as its research subjects and analyzes the situation of architectural products produced in the construction of China's construction projects and relevant reasons for them. It also analyzes the measures of managing each architectural waste, trying to find out the effective method of minimizing China's construction wastes.

19.3 Research Methods

This research adopts the research questionnaire method and the thought patterns of designing questionnaires is to analyze the problems that exist in the current situation of producing and recycling construction wastes in China, analyze the reason targeting at problems and eventually try to solve problems through researches on strategies. The questions of the questionnaire can be divided into four parts: The first part is about the researched subject's working background; the second part is about the situation of wastes produced in construction projects and the recycling of wastes produced when architectures are torn down and find out the problems that need to be focused and strictly controlled. The third part is the research analysis carried to further realize reasons targeted at problems. The fourth part is based on researching problems and their reasons, carry out strategy research and try to find out effective measures of minimizing construction wastes.

To accurately get to know the situation of wastes produced in the process of architectural construction, this questionnaire takes the technicians and supervision engineers of construction companies, the engineering managers of estate companies and the management personnel of the construction department of the government as its research subjects. They have high qualities, rich experience and strong professional knowledge. They are the technical and management cadres of construction project management. Their realization can reflect the real problems in a more faithful way. The research time for this questionnaire is from June 2015 to December 2015. 200 questionnaires have been handed out and 160 valid ones are recycled, with an effective efficiency of 80%. The application software SPSS19.0 calculates Cronbach's α coefficient to analyze the credit of the questionnaire's contents. The credit value $\alpha = 0.7675 > 0.70$, meaning that the questionnaires have a good structural credit.

19.4 Data Analysis

19.4.1 Composition of Interviewed Personnel

Among the 160 recycled valid questionnaires, the interviewed personnel have rich experience of participating in construction projects and most of them are directly engaged in China's architectural constructions and technical management. Seen from the nature of the company, the interviewed personnel are mostly from state-owned enterprises and private-owned enterprises, which respectively account for 31.7 and 51% of the total amount. In terms of the occupational distribution, the proportions of project engineers and supervision engineers are very big, which respectively account for 43.3 and 20.2% of the total amount. Seen from the occupational natures of their units, interviewed personnel from construction companies, supervision companies and the first-line and second-line estate companies account for 79.8% of all interviewed people. Seen from the qualifications of the company, relevant construction enterprises that have first-line or above qualifications account for 74% of all, while engineers with five years' or over five years' experience in the architectural industry account for 81.7% of all samples.

19.4.2 Production of Wastes in the Construction Process

The waste rate of architectural materials refer to the proportion of the amount of turning a certain kind of architectural material into wastes to the overall amount of this material. The amount is mainly calculated by volume. The sub-projects of architectures in their construction process mainly include: the basic project, the project of main structures, the decoration project and temporarily-built project. The item projects mainly include: the concrete project, the template projects, the steel project, the project of steel structures, the piling project, the pouring pole project, the brick-laying project and the scaffold project. 100 questionnaires that include complete contents of this part are selected, so as to analyze the distribution of each sub-project's and item project's waste rates in the waste rate range.

(1) Aspect of sub-projects

As shown in Fig. 19.2: The questionnaires of the basic project are mostly concentrated in the waste ratio interval [$\leq 3\%$], which account for 62% of all questionnaires. Questionnaires of the decoration project are mostly concentrated in the waste ratio interval [$\geq 5\%$], accounting for 60.2% of all questionnaires; the questionnaires of the temporarily-built project and the main structure project are the second most concentrated, which respectively account for 45 and 36% of all questionnaires. A part of researchers even think that the waste ratios of the decoration project and the temporarily-built project both exceed 10%, which account for 22.4 and 14% of all questionnaires.

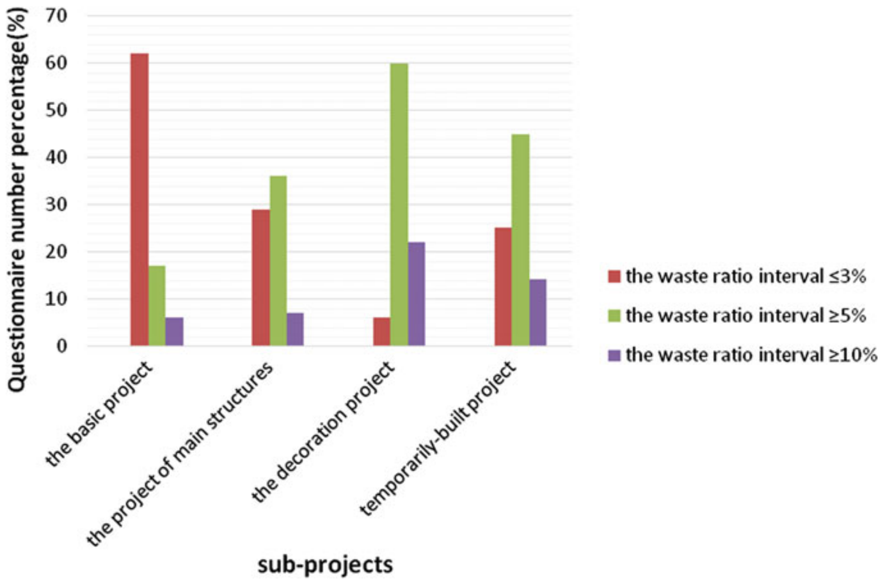


Fig. 19.2 Bar chart of questionnaires concerning each sub-project in the waste ratio interval

According to the above data: In each sub-project, the waste rate of the decoration project is the highest and its waste rate universally exceeds 5%. Due to its complex construction techniques, the decoration project has a low efficiency of using materials and many architectural wastes are generated, such as mortar, broken bricks, plastics, wrapping paper and ceramic tiles. In the construction process, it is needed to exercise focus control. The temporarily-built project has the second highest waste rate. In the temporarily-built project, most wastes are the enclosure materials of the construction site and the construction wastes produced by the hardening of the site and roads. Adopting reasonable construction and organization designs in projects and reasonably planning temporary sites and roads to make them components of eternal sites and roads can effectively reduce the generation of wastes. The project of main structures can be divided into the template project, the steel or iron structural project, the reinforce project and the masonry project. The relevant contents of them will be analyzed in the following item projects, so there are not introduced here. However, the basic project has a good control over the waste rate because its technical conditions are mature and its construction techniques are simple.

(2) Aspect about item projects

The distribution of questionnaires concerning each item project is shown in Fig. 19.3. Seen from the bar chart, the interviewed personnel think the waste rates of the steel structural project, the steel project, the scaffolding project and the piling project in item projects are all within 3%, which respectively account for 77, 66, 65

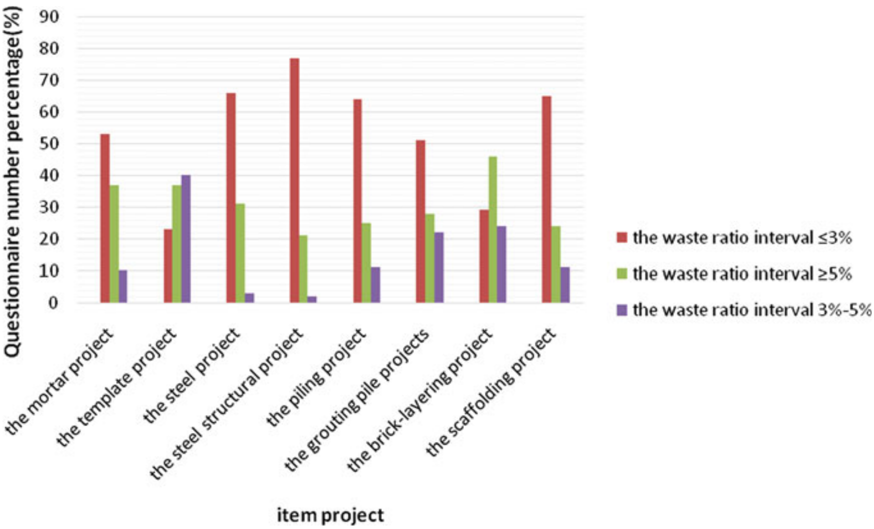


Fig. 19.3 The bar chart of the questionnaires concerning each item project in each waste ratio range

and 64%; the waste rates of the mortar project and the grouting pile projects are within 3%, which respectively account for 52.5 and 51% of all questionnaires; for the brick-layering project and the template project, the interviewed personnel universally think their waste rates exceed 3%, which account for 71 and 77% of all questionnaires. Even many interviewed personnel think their waste rates exceed 5%, which account for 40 and 24.2% of all questionnaires.

According to the above data, the waste rate of the template project in item projects is the highest, followed by the brick-layering project, both of which need to be controlled with emphasis. In the template project, wooden templates are most frequently used. As the bakelite plate will easily transform after being exposed in rain or sunshine and workers have poor consciousness of reasonably using materials, the rate of recycling wooden plates is low and the waste rate is high. So adopting new template materials and new techniques can effectively lower the generation of wastes in the template project. According to practice: In the reinforcing project and the grouting pile project, strengthening on-site management, recycling and reusing the cement and, as well as selecting regular mortars can effectively decrease the times of cutting bricks in the process of brick-layering. The wastes of the reinforcing project and the grouting pile project can't be neglected as well, which need to have strengthened on-site management, so as to decrease their rates of wastes. However, the waste rates of the steel structure project, the steel project, the scaffold project and the piling projects are small, which are within a reasonable range.

19.4.3 The Situations of Recycling Construction Wastes

In the process of tearing down architectures, the produced broken bricks, bricks, concrete, steel, debris, wood and glass account for over 80% of all wastes. 99 questionnaires containing complete contents are selected, so as to analyze the research results. In the questionnaire samples, the distributions of the recycling and reusing rate of broken bricks, bricks, concrete, steel, debris, wood and glass are shown in Fig. 19.4.

The recycling rate means the proportion of recycled or reused amount of construction wastes to the overall amount of construction wastes produced in the process of tearing down construction wastes. Seen from Fig. 19.4, the situation of recycling waste steel is the best and the distribution of questionnaire samples is within the recycling interval [>50%], accounting for 76.8% of all questionnaire samples; the second best situation of recycling is wood, whose questionnaire sample distribution is within the waste rate interval of [>50%], accounting for 67.7% of all samples; those whose recycling situations are bad include: broken bricks, debris and wasted concrete produced in the process of demolition, and their sample distributions are within the recycling interval [<35%], which account for 51.6, 64.6 and 74.7% of all samples; however, the recycling situation of broken glass is the worst and its sample distribution is located within the recycling rate interval [<20%], accounting for 50.5% of all samples; some construction sites even offer no treatment at all.

In the demolition process, waste steel are usually sent to waste recycling centers after being selected, separated by punching and gathered. In this process, although some labor or transportation costs may be consumed, the recycled steel can be

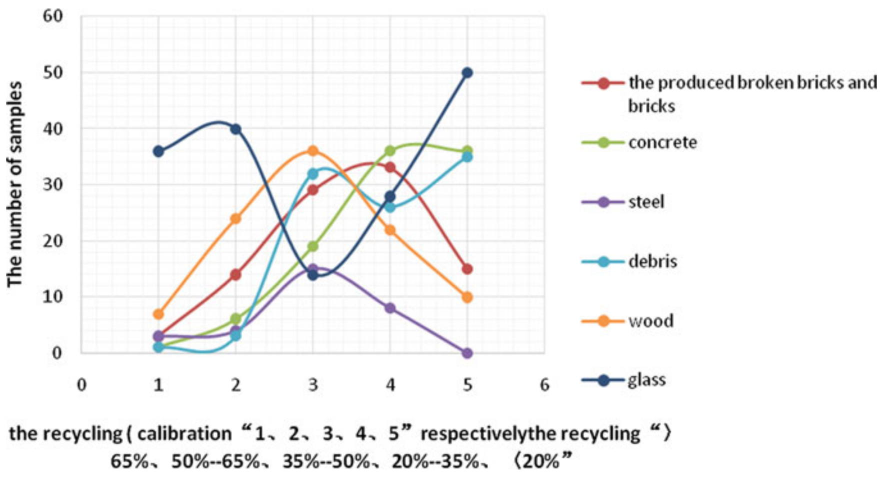


Fig. 19.4 The smooth line and scatter-plot figure of questionnaire samples' concerning the recycling rate of each architectural waste in the range

manufactured into steel materials with various specifications after being reprocessed in iron and steel factories, which have certain substantial economic benefits and thus have a good recycling rate. Though adopting humans in the demolition of walls and houses can generate a large amount of bricks and roof tiles which are architectural materials that can be used repeatedly, this process will consume a large amount of labor and machines, influence the construction time and have bad economic benefits. Therefore, people actually tend to use large-scale machines to pull down or explode them. Influenced by technical conditions, the large amount of broken bricks and debris are mostly used to refill the construction site or act as road base. As the technical conditions are not mature and relevant policies and regulations are not sound in China, a lot of costs may be consumed in the links of separating, transporting and broken processing, which cause the regenerated concrete to lose its competitiveness in the market compared with common concrete. In the process of demolition, the broken glass is basically not processed. This is because the awareness of classifying construction wastes in the industry is weak and there lacks advanced separation techniques currently. It's difficult to separate broken glass with other construction wastes. Currently, broken bricks, debris, waste concrete and broken glass are usually used in re-landfill directly or transported to be stacked in the suburbs. Thus, the rates of recycling and reusing wastes are very low.

19.4.4 Analysis of the Current Situation of Construction Wastes and Relevant Reasons

To further get to know the relevant reasons for the current situation of construction wastes in China's Pearl River Delta, this questionnaire lists 14 influence factors (represented as W1–W14). Seen from the perspective of engineers related to the construction industry, this paper assesses the influence performances of these factors and find out key influence factors among them, so as to provide a basis for us to carry out the in-depth analysis of measures. We select 93 questionnaires with complete contents from the questionnaires that research on the reasonableness. The contents of the questionnaires and the feedback from their results are shown in Table 19.2. For the opinions for the current situation of construction wastes and the reasons for them, we adopt the five-scale selection.

To simplify our influence factor assessment model, make the assessment results more direct and easier to be calculated, we adopt the scoring method. We determine that "much-agreed" has the highest score, namely 5′; "much-disagreed" has the lowest score, namely 1′; the others are 4′, 3′ and 2′. Through using relevant maths formulas, we obtain the average score of each influence factor W1–W14 AVi, the standard difference SDi and the average score of influence factors. The rank of influence factors is shown in Fig. 19.2 (Avi means the average score of the influence factor and SDi means the standard difference of influence factors W1).

Table 19.2 Research scale of the current situation of construction wastes and relevant reasons (%)

Influence factors of construction wastes	Much-agreed (%)	Agreed (%)	Normal (%)	Disagreed (%)	Much-disagreed (%)
The problem of treating construction wastes is not important and there is no need to change the originally designed construction means (W1)	3.2	8.6	3.2	33.4	51.6
The recycled and reused architectural materials are a little more expensive than original materials (within 10%) and people are willing to use recycled materials (W2)	6.5	50.5	16.1	23.7	3.2
The classification of architectural materials will take too much time (W3)	2.2	42.8	16.5	35.2	3.3
The management of construction wastes conflicts with economic benefits (W4)	4.3	35.5	10.8	36.5	12.9
The construction site lacks management plans for construction wastes (W5)	28.0	54.8	8.6	6.5	2.1
Many construction wastes are produced because of the backward transmission of information on the specifications and types of architectural materials and components on the site (W6)	9.8	40.2	20.7	23.9	5.4
In the process of transporting and installing architectural materials or semi-products, the protection is inadequate and architectural products are produced (W7)	6.5	50.0	16.3	21.8	5.4
The on-site construction management level is too low, which causes a waste of materials (W8)	22.0	54.9	6.6	14.3	2.2
The on-site management personnel have inadequate understanding of waste management and their initiative for treatment is not high (W9)	20.4	62.4	7.5	9.7	0.0
The government doesn't provide adequate policies, technologies or capital support for treating construction wastes (W10)	58.1	36.6	2.1	1.1	2.1
The responsibility boundary for treating construction wastes is not clear (W11)	15.0	61.3	14.0	6.5	3.2
The behaviors of not classifying and abandoning construction wastes should be punished more seriously (W12)	30.1	60.2	5.4	4.3	0.0
Many incomplete contents or errors exist in contracts, which causes the production of may construction wastes (W13)	5.4	40.9	19.3	24.7	9.7
The designed drawing is not complete and the design will result in the production of more construction wastes (W14)	11.8	41.9	22.6	19.4	4.3

Seen from Table 19.3, among the top 5 of the 14 influence factors, W10 gets the highest score, which is 4.473′. Researchers universally think "the government offers inadequate policies, technologies and capital for treating construction wastes" is the most important reason why the recycling rate of construction wastes in China's Pearl River Delta is low. The other four are respectively W12, W5, W9 and W8, whose scores are 4.161, 4.0, 3.935 and 3.802, namely, "the construction site lacks management plan for construction wastes" and "the on-site construction management level is low, which causes a waste of materials" results in "many construction wastes are produced on the site". Meanwhile, "the on-site management personnel have inadequate understanding of waste management and their initiative for treatment is low". Besides, "the punishments for not classifying construction wastes and discarding wastes are not enough", which leads to a low rate of recycling construction wastes. We can see that the lowest value of influence factors is W1 and its score is only 1.785, which means the researched persons universally realize the negative influences cause by construction wastes, while current designed construction means can't effectively lower the production of construction wastes.

The research of Tom (2008) and Lu et al. (2013) on Hong Kong's "construction waste management plan" shows: "The government's inadequate encouragement for managing construction wastes" is the biggest obstacle to Hong Kong's construction wastes (Tam 2008; Lu and Yuan 2013). It means though there are differences between Hong Kong and the Chinese mainland's current situation of construction wastes, the management of construction wastes of both can't be separated with the government' financial support.

Table 19.3 The assessment form of the influence factors of construction sites

Influence factor	AVi	SDi	Rank
W1	1.785	1.066	14
W2	3.333	1.010	8
W3	3.055	0.998	12
W4	2.817	1.173	13
W5	4.000	0.904	3
W6	3.250	1.090	10
W7	3.304	1.051	9
W8	3.802	1.009	5
W9	3.935	0.688	4
W10	4.473	0.785	1
W11	3.785	0.890	6
W12	4.161	0.709	2
W13	3.075	1.120	11
W14	3.376	1.058	7

19.5 Countermeasures and Suggestions

In the following research work, we try to propose effective countermeasures for minimizing construction wastes in China's Pearl River Delta through analyzing the countermeasures of questionnaires. In this part of questionnaire research, 104 valid questionnaires have been obtained in all and the relevant contents and results represented through questionnaires are shown in Table 19.4. Through referring to a large amount of materials and following up relevant project cases, we select 13 factors that influence measures for analysis and try to find out the key countermeasures that suit China's national conditions. These 13 factors that influence countermeasures adopt the 5-scale selection according to their contributions to minimizing construction wastes.

To simplify the analysis and evaluation model, the scoring method is also adopted. It is determined that "Very important" is 5′ and others decrease in a succession, and "ineffective" is 1′. It is obtained that the average score of the influence factor for each measure W1–W13 is AVi and the standard difference is SDi. According to the average score, the ranks of influence factors are shown in Table 19.4 (Avi means the average score of the factor than influences measures Wi and SDi means the standard difference of the factor that influence measures Wi).

Seen from the results of assessing factors that influence the measurements for various construction wastes in Table 19.5, the key countermeasures whose scores rank the first fifth are: W5, W13, W8, W12 and W6, while their average scores are respectively: 4.231, 4.173, 4.115, 3.962 and 3.933. We can see that the key average scores of the countermeasures W5, W13 and W8 are all over 4′, which means the engineers participating in research universally think: "In the construction process, adopting new techniques can effective decrease the generation of construction wastes; "The government completes should improve relevant policies and regulations, increase the supervision of construction wastes, as well as increase punishments on relevant units and enterprises that fail to meet standards"; "The government provides subsidiaries to promote the repeated using or recycling of construction wastes of different categories" can all promote the minimization of construction wastes of China. It also shows the application of new technology, the government's restriction of policies and regulations on architectural units, and their economic support and subsidiary to resource regeneration units play an important role in the development of minimizing China's construction wastes. Meanwhile, "providing technical support and providing raw materials to other factories after classifying construction wastes: "carrying out education or training about minimizing construction wastes on construction technical personnel and workers" are also measures of minimizing construction wastes, which are affirmed by architectural construction technicians. This means improving construction workers' awareness of minimization through turning technical support into valuable things and enhancing the education are the inevitable paths for achieving the minimization of architectural raw materials. Besides, W9 has the lowest score, which is 3.067′. It is because when considering saving costs in projects, construction units can have

Table 19.4 Research form of analyzing the measures for minimizing construction wastes

Measures for minimizing construction wastes	Very important (%)	Important (%)	Normal (%)	Not significant (%)	Ineffective (%)
Purchase construction materials that can be fixed and are suitable for re-installation and durable (W1)	27.9	47.1	15.4	6.7	2.9
When purchasing construction materials, they select the ones whose packing materials can be used repeatedly (W2)	23.1	40.4	20.2	14.4	1.9
Use non-toxic or low-toxic construction products (W3)	37.5	29.8	19.2	11.6	1.9
Change the existing construction techniques and processes (W4)	14.4	42.3	29.8	9.6	3.9
In the construction process, adopt the new technology that can effectively reduce the generation of construction wastes (W5)	33.7	56.7	8.6	1.0	0.0
Carry out education or training on construction technicians and workers (W6)	28.9	44.2	19.2	6.7	1.0
Provide awards to units or individuals which do well in minimizing construction wastes (W7)	26.9	42.3	23.1	6.7	1.0
The government provides subsidiaries and promote the repeated utilization or recycling of construction wastes of different categories (W8)	34.6	48.1	12.5	3.8	1.0
Control the amount of purchased construction raw materials, which should be appropriate (W9)	10.6	22.1	40.4	17.3	9.6
In the process of carrying out constructions, use construction materials with reliable qualities (W10)	21.2	36.5	26.0	12.5	3.8
In the industrialization, increasing the proportion of pre-made products especially can effectively reduce construction materials (W11)	22.1	32.7	32.7	9.6	2.9
Provide technical support and provide raw materials for other factories after classifying construction wastes (W12)	26.9	48.1	19.2	5.8	0.0
The government should complete relevant policies and regulations, strengthen the supervision over construction wastes and increase the punishments on relevant units and enterprises which fail to meet requirements (W13)	34.6	49.0	15.4	1.0	0.0

Table 19.5 Evaluation form of factors that influence the minimizing each architectural waste

Influence factor	Average score (AV_i)	SDi	Rank
W1	3.904	0.976	6
W2	3.683	1.040	9
W3	3.894	1.091	7
W4	3.538	0.980	12
W5	4.231	0.639	1
W6	3.933	0.912	5
W7	3.875	0.917	8
W8	4.115	0.836	3
W9	3.067	1.094	13
W10	3.587	1.071	11
W11	3.615	1.022	10
W12	3.962	0.831	4
W13	4.173	0.713	2

good control over the amount of architectural materials. Therefore, "using repairable and durable architectural materials that are suitable for being installed" can achieve the minimization of construction wastes to the greatest extent; while "providing education and technical training on construction wastes" has a small contribution to achieving the minimization of construction wastes. This means that there are differences in the countermeasures for management construction wastes under different conditions.

19.6 Conclusion and Discussion

This paper is based on the questionnaire research and selects the construction waste management in China's Pearl River Delta as its research subject. Through the analysis of the research's results and seen from the process of architectural constructions, the ratio of wastes produced in the basic project of sub-project is small, while the ratios of wastes in the decoration project and the temporarily-built project are big; in the item projects, the ratios of wastes in the steel project, the steel structure project, the piling project and the scaffolding project are all small, while the ratios of wastes in the masonry project and the template project are big; in the process of tearing down architectures, the construction waste steel and wood are well-recycled, while the recycling situations of concrete, debris and broken glass are normally bad.

In the analysis of the reason for these problems, the author finds out five key reasons, which are: "The government provides inadequate policies, technology and capital for treating construction wastes", "the construction site lacks plan for managing construction wastes", "the management level of the on-site construction is low and leads to the waste of materials", "on-site management personnel have inadequate knowledge of waste management and have low initiative for treating them" and "there are inadequate efforts of punishing behaviors of not classifying, abandoning and staking construction wastes". In the strategic analysis targeting at reasons, we propose five key countermeasures. They are: (**a**) In the process of constructing, adopt new technology and technique to lower the generation of construction wastes; (**b**) The government improves relevant policies and legal regulations to strengthen the efforts of supervising construction wastes and increase the punishments on relevant units and enterprises that fail to meet requirements; (**c**) The government offers subsidiary to promote the repeated use of recycling of different kinds of construction wastes; (**d**) Provide technical support and offer raw materials to other factories after classifying construction wastes; (**e**) Carry out education or training on the construction personnel and workers about architectural waste minimization.

The above researches are aimed at providing reference to relevant construction management departments. Governments need to formulate complete policies and legal regulation systems, so as to strengthen the management of construction wastes. Meanwhile, the support from policies, economic and technology can provide big encouragements to relevant industries. The management of construction wastes is a process of complete life cycles, which is accompanied with the planning, designing, constructing, delivering, using, maintaining and scraping. In the process, the government needs to supervise, leads and encourage functions. Relevant construction units need to deepen their knowledge and select reasonable plans in the phases of planning and designing so as to avoid vanity and non-applicability; In the construction phase, adopt good architectural materials, advanced technological techniques, strengthen on-site management and select construction teams with good technologies and a strong environmental-awareness consciousness, so as to reduce the production of construction wastes. Meanwhile, strengthen the treatment of scrapped architectures, adopt advanced technology to turn wastes into valuable thing, so as to recycle construction wastes to the largest extent and improve the rate of recycling construction wastes.

Acknowledgements This study is supported by the Young Innovative talents development program of Guangdong Education Department (No. 2014WQNCX073) and research project of universities owned by the municipal government of Guangzhou (No. 1201431441). The research was supported by the National Natural Science Foundation of China (NSFC) (project no.: 71501052).

References

Agamuthu P (2008) Challenges in sustainable management of construction and demolition waste. Waste Manage Res 26:491–492

Beguma RA, Siwar C, Pereira JJ, Jaafar AH (2007) Implementation of waste management and minimisation in the construction industry of Malaysia. Resour Conserv Recycl 51:190–202

Cha HS, Kim J, Han JY (2009) Identifying and assessing influence factors on improving waste management performance for building construction projects. J Constr Eng Manage 6:647–656

Guangdong Provincial Statistics Bureau (2015) Guangdong statistics yearbook. China Statistics Press, Beijing, China

Jaillon L, Poon CS, Chiang YH (2009) Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Manage 29:309–320

Li JR, Ding ZK, Mi XM, Wang JY, Zhu JL (2010) Investigation on the on-site construction waste reduction measures. J Constr Eng Manage 24(3):332–335

Li JR, Ding ZK, Mi XM, Wang JY (2013) A model for estimating construction waste generation index for building project in China. Resour Conserv Recycl 74:20–26

Li JR, Tam VWY, Zuo J, Zhu JL (2015) Designers' attitude and behaviour towards construction waste minimization by design: a study in Shenzhen, China. Resour Conserv Recycl 105:29–35

Liu JK (2013) Research on cost compensation model for construction and demolition waste management. South China University of Technology, Ghuangzhou [in Chinese]

Lu KA (2006) Status quo and comprehensive utilization of refuse produced from construction and removal of buildings in China. Constr Technol 28(5):44–45 [in Chinese]

Lu WS, Tam VWY (2013) Construction waste management policies and their effectiveness in Hong Kong: a longitudinal review. Renew Sustain Energy Rev 23:214–223

Lu WS, Yuan H (2013) Investigating waste reduction potential in the upstream processes of offshore prefabrication construction. Renew Sustain Energy Rev 28:804–810

Lu WS, Yuan HP, Li JR, Hao JJL, Mi XM, Ding ZK (2011) An empirical investigation of construction and demolition waste generation rates in Shenzhen city, South China. Waste Manage 31(4):680–687

Osmani M, Glass J, Price ADF (2008) Architects' perspectives on construction waste reduction by design. Waste Manage 28:1147–1158

Tam VWY (2008) On the effectiveness in implementing a waste-management-plan method in construction. Waste Manage 28:1072–1080

Wang JY, Yuan HP, Kang XP, Lu WS (2010) Exploring critical success factors for waste management in construction projects of China. Resour Conserv Recycl 54:931–936

Zhang J, Eastham DL, Bernold LE (2005) Waste-based management in residential construction. J Constr Eng Manage 131:423–430

Zhou JW (2011) Survey Analysis and Countermeasures of C&D Waste Problem in South China. Master thesis of South China University of Technology, Guangzhou, China [in Chinese]

Chapter 20
An Intelligent Decision Support System for Improving Information Integrity in Procuring Infrastructures in Hong Kong

L. Chen and W. Pan

20.1 Introduction

Hong Kong has gone through great development of infrastructure projects, including Hong Kong Airport Core Programme launched in 1989 and Ten Major Infrastructure Projects Programmes launched in 2008, which definitely brings about significant economic benefits and improves our living environment. The government of the HKSAR has projected that public expenditures on capital works, including major rail, road, land port, and environmental projects, reached HK$70.8 billion for fiscal year 2014–15 (Lo et al. 2006; Financial Secretary 2014). However, cost and time overruns have always been reported on major infrastructure projects, and there is even an increase in the number of construction and infrastructure projects experiencing extensive delays leading to exceeding the initial time and cost budget (Ramanathan et al. 2012), seriously hindering the productivity improvement in the construction industry of Hong Kong (Kumaraswamy and Chan 1998).

Although the major instances of infrastructure projects overruns usually take place in the construction phase, some principal and common causes of such overruns are existed in the pre-construction phase. Chan and Kumaraswamy (1997) firstly regarded the low speed and inefficiency of decision making involving all project teams was one of the principal causes of delays in Hong Kong construction projects. More specifically, Ramanathan et al. (2012) figured out that extensive delays were more evident in the traditional type of contracts in which the contract was awarded to the lowest bidder, and this procurement strategy adopted by majority of public works projects needed to be improved. Park and Papadopoulou (2012) revealed furtherly that contract involved in the procurement process was the main cause of cost overrun, including contract awarded to lowest bidder, inappropriate procurement route, and inaccurate estimates in contract. Assaf and

L. Chen (✉) · W. Pan
Department of Civil Engineering, The University of Hong Kong, Hong Kong, China
e-mail: dragoncl@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_20

Al-Hejji (2006), and Lo et al. (2006) also agreed that the type of project bidding and award (i.e., negotiation, lowest bidder) was the significant cause of construction delay in Hong Kong.

Inappropriate and inefficient decision making in the procurement process has already been commonly regarded as one of the most essential and frequent factors contributing to the cost and time overruns, frequently existed in the infrastructure projects in Hong Kong. Although the government of Hong Kong has made great efforts in tender evaluation methods to improve the decision efficiency and validity in the public works infrastructure procurement process (DEVB 2014), the essential decision information loss (i.e., vagueness and scarcity), is always impeding the improvement of validity and efficiency of decision making involved in the infrastructure tender evaluations (Kilic and Kaya 2015). It is necessary to address the issues about information loss by refining the government's tender evaluation methods to improve decision validity and efficiency and avoid time and cost overruns.

Although researchers have suggested fuzzy theories based methods to address the issues related to the uncertainty and decision invalidity, these methods have seldom been made explicit in infrastructure procurement process. The aim of this paper is to develop an intelligent decision support system (IDSS) for improving decision information integrity for in procuring infrastructures in Hong Kong. A systems approach based model to identify the main causes of decision information loss will be firstly constructed. Based on that, an IDSS using perceptual computing and fuzzy theories will be newly developed for the infrastructure projects tender evaluation process in Hong Kong to minimize overruns at the very beginning stage and to be incorporated into a forecasting model for Hong Kong infrastructure projects.

20.2 Literature Review

20.2.1 Decision Information Loss in Tender Evaluation Process

Owing to the larger scope and increasing complexity in infrastructure projects, the tender evaluation is becoming a crucial decision to ensure the success of a construction project. Infrastructure tender evaluation decisions are often based on multiple and conflicting criteria or data that are subject to different levels and types of uncertainty and incorporate engineering judgements and expert opinions (Kabir et al. 2014). In Hong Kong, the government's tender evaluation methods for public works enacted in 2014 specify a wide range of criteria in addition to the tender price, centring on the tenderer's experience, past performance and technical resources, and technical proposals and design (DEVB 2014). The criteria on technical proposals include traditional considerations for method statement, logistics, quality assurance and health, safety and welfare, and also newly introduced attributes such as innovation and creativity proposal, environmental management, use of low-carbon products and processes, and productivity enhancement. These new attributes, while encouraging competition in quality, innovation, productivity and sustainability, challenge the use of existing tender evaluation methods due to their associated uncertain or insufficient performance data that lead to the decision information loss ultimately.

In order to improve the efficiency and validity of decisions, the main reasons for and key stages of decision information loss should be revealed and analyzed. Kumianingsih et al. (2015) introduced two types of information loss in investment decision making, namely risk and ambiguity. Yue (2013) focused on the decision information loss in the aggregation phase and proposed an avoiding information loss approach to group decision making in the context of supplier selection. Hsu and Lambrecht (2007) introduced asymmetric and incomplete information resulted from competitive environment in real options. Using the filtering theory, Bernardo and Chowdhry (2002) and Decamps et al. (2005). have investigated models in which a firm has incomplete information about the value of its own decision criteria during the investment decision process. Almost all stages of decision making process (i.e., tender evaluation) can lose essential information when there are no appropriate methods adopted. Therefore, not only specific stages of decision process need be concerned, but the whole decision process should be analyzed systematically.

20.2.2 Type-2 Fuzzy Sets and Fuzzy Integral Used in Decision Making

Let a set Z be fixed, a fuzzy set F in Z is given by Zadeh as follows (Zadeh 1965)

$$F = \{ < z, \mu_F(z) > | z \in Z \tag{20.1}$$

It is used to solve problems with subjective, vague and imprecise information. And type-2 fuzzy set (T2FS) was firstly introduced by Zadeh as an extension of the concept of an ordinary fuzzy set (henceforth called a type-1 fuzzy set). Such sets are fuzzy sets whose membership grades themselves are type-1 fuzzy sets; they are very useful in circumstances where it is difficult to determine an exact membership function for a fuzzy set; hence, they are useful for incorporating linguistic uncertainties, e.g., the words that are used in linguistic knowledge can mean different things to different people. A T2FS, denoted $\tilde{A}$, is characterized by a type-2 membership function $\mu_{\tilde{A}}(x, u)$, where $x \in X, u \in J_x \subseteq [0, 1]$, i.e.,

$$\tilde{A} = \{((x, u), \mu_{\tilde{A}}(x, u)) | \forall x \in X, \forall u \in J_x \subseteq [0, 1]\} \quad (20.2)$$

in which $0 \leq \mu_{\tilde{A}}(x, u) \leq 1$. And $\tilde{A}$ can also be expressed as

$$\tilde{A} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{A}}(x, u)/(x, u), \quad J_x \subseteq [0, 1] \quad (20.3)$$

where $\int\int$ denotes union over all admissible x and u. For discrete universes of discourse $\int$ is replaced by $\sum$. Uncertainty in the primary memberships of a T2FS, $\tilde{A}$, consists of a bounded region that we call the footprint of uncertainty (FOU), which is the union of all primary memberships.

The adoption of T2FS enables convenient modeling of problem where the meanings of criteria are not clear and the evaluators do not hold the same opinions, to remove the noise of evaluation and obtain more effective results (Kilic and Kaya 2015). Meanwhile, the use of non-additive fuzzy integrals can solve the interdependencies among criteria to improve the decision accuracy.

Sugeno proposed the concept of fuzzy integrals in 1974 in Japan (Sugeno 1974). The distinguishing feature of a fuzzy integral is that it is able to represent a certain kind of interaction between criteria, ranging from redundancy (negative interaction) to synergy (positive interaction). This innovative technique is without any doubt the most useful method to deal with interacting criteria problem in the field of multi-criteria decision making (MCDM).

Let us denote by $X = \{x_1, \ldots, x_n\}$ the set of criteria, and by $P(X)$ the power set of X, the Sugeno integral of a function $f : X \rightarrow [0, 1]$ with respect to μ is defined by:

$$S_\mu(f(x_1), \ldots, f(x_n)) := \bigvee_{i=1}^{n} (f(x_{(i)} \wedge \mu(A_i)) \quad (20.4)$$

where $\bullet_{(i)}$ indicates that the indices have been permuted so that $0 \leq f(x_{(1)}) \leq \cdots \leq f(x_{(n)}) \leq 1$, and $A_{(i)} = \{x_{(1)}, \ldots, x_{(n)}\}$.

Another definition was proposed by Murofushi and Sugeno in 1991, using a concept introduced by Choquet in capacity theory (Murofushi and Sugeno 1992). Let μ be a fuzzy measure on X. The Choquet integral of a function $f : X \rightarrow [0, 1]$ with respect to μ is defined by:

$$C_\mu(f(x_1), \ldots, f(x_n)) := \sum_{i=1}^{n} (f(x_{(i)}) - f(x_{(i-1)}))\mu(A_{(i)}) \quad (20.5)$$

with the same notations as above, and $f(x_{(0)}) = 0$.

Sugeno and Choquet integrals are essentially different in nature, since the former is based on non-linear operators (min and max), and the latter on usually linear operators.

20.2.3 Perceptual Computing Aiding in Making Subjective Judgments

Zadeh (1996), the founder of computing with words and fuzzy logic, firstly coined phrase "computing with words (CWW)", which is essential for MCDM under linguistic uncertainties.

> CWW is a methodology in which the objects of computation are words and propositions drawn from a natural language." It is "inspired by the remarkable human capability to perform a wide variety of physical and mental tasks without any measurements and any computations.

It is thus proposed that computers would be activated by words, which would be converted into a mathematical representation using fuzzy sets (FSs), and that these FSs would be mapped by a CWW engine into some other FS, after which the latter would be converted back into a word (Mendel and Wu 2010). A specific architecture has been proposed by Mendel for making subjective judgments by CWW, as shown in Fig. 20.1 (Mendel 2002).

It can be also called a perceptual computer or Per-C for short. The Per-C consists of three components: encoder, CWW engine, and decoder. The encoder transforms linguistic perceptions into FSs that activate a CWW engine, which performs operations on the inputted FSs. The decoder maps the output of the CWW engine into a recommendation with words and data.

20.3 Systems Approach to Revealing Decision Information Loss

As discussed before, despite the increasing emphases on the information integrity during the decision process, the systems approach is seldom made explicit. This knowledge gap is significant as researchers have increasingly realized that information loss can happen in the whole decision process (Kilic and Kaya 2015; Kabir et al. 2014; Kumianingsih et al. 2015; Yue 2013; Hsu and Lambrecht 2007; Bernardo and Chowdhry 2002; Decamps et al. 2005; Lee et al. 2016) and definitely affect the

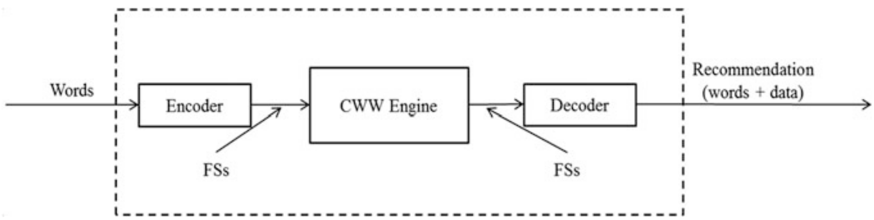


Fig. 20.1 Specific architecture for CWW-the perceptual computer

decision results (Ramanathan et al. 2012; Kumaraswamy and Chan 1998; Park and Papadopoulou 2012; Chan and Kumaraswamy 1997; Assaf and Al-Hejji 2006). Reflected in this paradigm shift of decision analysis research is the systems approach to addressing issues improving information integrity. This proposed framework attempts to bridge this knowledge gap firstly, which argues for the integration of MCDM model, systems approach and initial research (Kilic and Kaya 2015; Kabir et al. 2014; Kumianingsih et al. 2015; Yue 2013; Hsu and Lambrecht 2007; Bernardo and Chowdhry 2002; Decamps et al. 2005; Lee et al. 2016) to examine the decision information loss in the whole tender evaluation process from a systems perspective.

Based on the extensive literature review, the reasons for information loss can be divided into three types, namely scarcity, vagueness and risk. Scarcity means that insufficient information is provided or delivered with some data or information missing, while vagueness reveals the uncertainty and ambiguity involved. Risk can be regarded as the potential threat that may lead to decision inefficiency and invalidity. According to the research of Hsu and Lambrecht (2007), Bernardo and Chowdhry (2002), and Decamps et al. (2005), there exists information loss at the beginning of tender evaluation process on account of the incomplete and vague information provided by tenderers and tenderees. After that, in the process of decision making, Kilic and Kaya (2015), Kabir et al. (2014), Kumianingsih et al. (2015), and Yue (2013) pointed out that the vagueness and scarcity existed in the criteria and aggregation stage could also reduce the information integrity. And the outputs always just focus on the ranking of tenderers rather than the potential risks existed in tender documents, resulting in the information loss finally (Kumianingsih et al. 2015; Lee et al. 2016).

The information loss is co-existent with the external environment and MCDM procedure. The information loss procedure can thus be regarded as complex systems, which cover the external environment that could produce noise to increase the vagueness and scarcity and decrease the possibility of risk exposure, and MCDM procedure to conduct tender evaluation (Fig. 20.2).

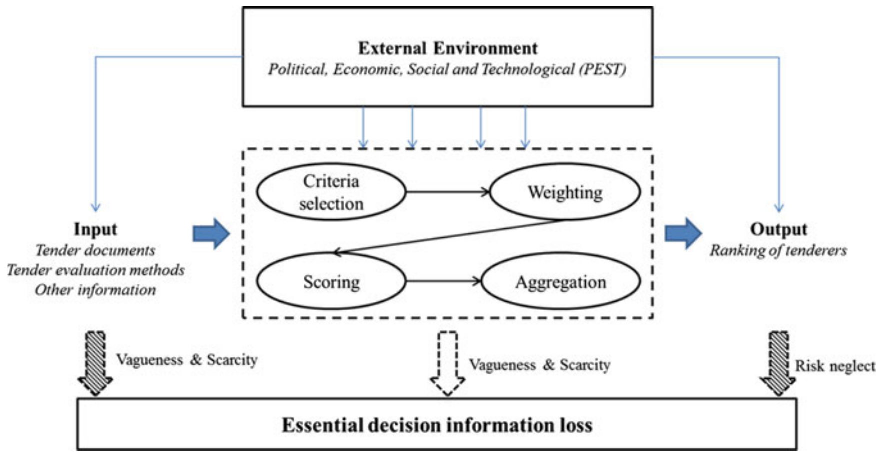


Fig. 20.2 A conceptual model of decision information loss procedure

20.4 IDSS for Improving Decision Information Integrity

An IDSS has been newly developed on the basis of typical MCDM process, considering consistency, transparency, practicality and auditability, as suggested by Dodgson et al. (2000). For IDSS, considering the information loss problems demonstrated in Fig. 20.2, the newly developed methods will mainly focus on the improvement of weighting, marking, and scoring stages (Fig. 20.3).

Firstly, using Eq. (20.2), weights of criteria can be expressed in linguistic words or interval data that are furtherly transformed into generalized T2FSs (as shown in Fig. 20.3). Via fuzzy rating or fuzzy analytic hierarchy process (AHP) method, the weights can thus be obtained. Then we will develop the tender marking schemes by combining the use of Per-C and T2FS theory, which is similar to the weighting stage. As shown in Fig. 20.3, using rating method, linguistic words or interval data are also transformed into generalized T2FSs, which however are the performance values or marks under evaluation rather than the relative importance at the weighting stage. Finally, we will develop the method of integrating weights and marks for the generation of tender evaluation overall scores by using the fuzzy integrals method (Eq. 20.4 or 20.5). The use of fuzzy integrals method should eliminate the effects of double-counting or interdependency among the decision criteria, which may not be guaranteed during the process of identification and weighting of criteria but are actually taken for granted in the traditional additive aggregative model. By using the fuzzy integral, we will be able to represent a certain type of interaction among criteria with the aid of structural modelling, such as the system dynamics model (SDM) and interpretive structural modelling

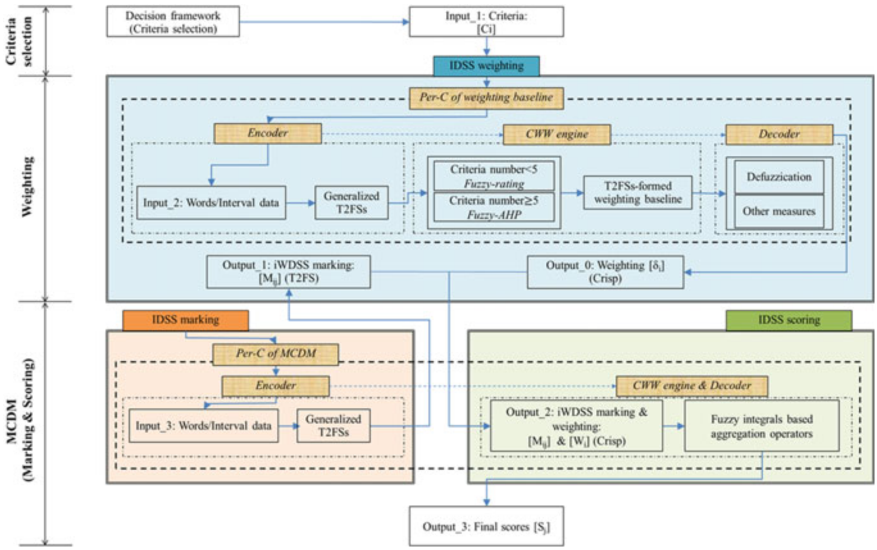


Fig. 20.3 Development of IDSS

(ISM) ranging from redundancy (negative interaction) to synergy (positive interaction) when criteria are interdependent. Necessary iterations and modifications in the process of scoring can be engaged.

This IDSS can definitely reduce the information loss through the adoption of T2FS and Per-C based MCDM process. The use of T2FS can eliminate the noise from the external environment and ambiguity from decision makers, accommodating the uncertain and missing data and providing more freedom for subjective judgments. Fuzzy integral can improve the decision accuracy via eliminating the effects of double-counting or interdependency among decision criteria. Meanwhile, the use of Per-C mechanism and MCDM is appropriate to address the complex information and aid people in making subjective judgements under uncertainty.

20.5 Conclusions

This paper has examined the decision information loss in tender evaluation process by regarding information loss procedure as a complex system within their regulatory, social and technological contexts. Three reasons for information loss have been identified in this system at different stages, namely vagueness, scarcity and risk neglect, which can be furtherly attributed to the noise from the external environment and ambiguity from decision makers. In order to address issues about information loss, an IDSS on the basis of the typical MCDM process using Per-C and T2FS has been developed. In cases where the meanings and values of information are not clear or missing, this model enables convenient modeling of targeted problems, and provides more comprehensive and sufficient information. This system will greatly improve the decision information integrity, furtherly to improve the decision validity and efficiency, not only specific to infrastructure procurement, but also other complex decision problems under uncertainty.

Acknowledgements This research was supported by a grant from The University of Hong Kong Seed Funding Programme for Basic Research (Project No.: 201411159141).

References

Assaf SA, Al-Hejji S (2006) Causes of delay in large construction projects. Int J Project Manag 24:349–357

Bernardo A, Chowdhry B (2002) Resources real options and corporate strategy. J Financ Econ 63:211–234

Chan DWM, Kumaraswamy MM (1997) A comparative study of causes of time overruns in Hong Kong construction projects. Int J Project Manag 15(1):55–63

Decamps J, Mariotti T, Villeneuve S (2005) Investment timing under incomplete information. Math Oper Res 30:472–500

DEVB (2014) Tender Evaluation Methods for Works Contracts, Technical Circular (Works) No. 4/2014, Development Bureau (DEVB), HKSAR

Dodgson J, Spackman M, Pearman A, Phillips L (2000) Multi-criteria analysis: a manual. DETR, London

Financial Secretary (2014) The 2014-15 budget. The HKSAR Government, Hong Kong

Hsu Y, Lambrecht B (2007) Preemptive patenting under uncertainty and asymmetric information. Ann Oper Res 151:5–28

Kabir G, Sadiq R, Tesfamariam S (2014) A review of multi-criteria decision-making methods for infrastructure management. Struct Infrastruct Eng 10(9):1176–1210

Kilic M, Kaya I (2015) Investment project evaluation by a decision making methodology based on type-2 fuzzy sets. Appl Soft Comput 27:399–410

Kumaraswamy MM, Chan DWM (1998) Contributors to construction delays. Constr Manag Econ 16(1):17–29

Kumianingsih YA, Sim SKY, Chee MWL, Mullette-Gillman OA (2015) Aging and loss decision making: increased risk aversion and decreased use of maximizing information, with correlated rationality and value maximization. Front Hum Neurosci 9:280–291

Lee J-H, Son JK, Yi JS (2016) Text analytics on construction tender documents for project-oriented risk mining. In: Proceedings of the CIB world building congress 2016, Finland, Tampere

Lo TY, Fung IWH, Tung KCF (2006) Construction delays in Hong Kong civil engineering projects. J Constr Eng Manag 132(6):636–649

Mendel JM (2002) An architecture for making judgments using computing with words. Int J Appl Math Comput Sci 12(3):325–335

Mendel JM, Wu DR (2010) Perceptual computing: aiding people in making subjective judgments. IEEE press series on computational intelligence. Wiley, Piscataway, New Jersey

Murofushi T, Sugeno M (1992) A theory of fuzzy measures: representation, the Choquet integral and null sets. J Math Anal Appl 159(2):532–549

Park Y, Papadopoulou TC (2012) Causes of cost overruns in transport infrastructure projects in Asia their significance and relationship with project size. Built Environ Project Asset Manag 2 (2):195–216

Ramanathan C, Narayanan SP, B Idrus A (2012) Construction delays causing risks on time and cost—a critical review. Australasian J Constr Econ Build 12(1):37–57

Sugeno M (1974) Theory of fuzzy integrals and its application, Ph.D. thesis, Tokyo Institute of Technology, Tokyo, Japan

Yue Z (2013) An avoiding information loss approach to group decision making. Appl Math Model 37:112–126

Zadeh LA (1965) Fuzzy sets. Inf Control 8(3):338–353

Zadeh LA (1996) Fuzzy logic = computing with words. IEEE Trans Fuzzy Syst 4(103–111):1996

Chapter 21
An Investigation of Waste Reduction Measures Employed in Construction Industry: Case of Shenzhen

Y. Gao, J.Y. Wang, H.Y. Wu and X.X. Xu

21.1 Introduction

The large-scale construction activities occurred in China over the past decades have produced a vast amount of construction and demolition waste (CDW), which adversely affects human health and sustainable development. According to statistics, the annual construction waste accounts for about 40% of the total municipal waste in China (Li 2007), more than 200 million tons and of which 100 million tons are generated from new buildings (Huang and Xu 2011). A large number of CDW not only consumes a lot of raw materials (it contains toxic substances that endanger human health and the surrounding environment), but also causes huge economic losses (Wang et al. 2015).

One of the best way to reduce the impact of waste on the environment is to avoid producing waste (Yuan and Shen 2011). Over the past 20 years, experts have made a multitude of beneficial researches and proposed some measures to reduce CDW generation and minimize their social and environmental impacts. Tam (2008) researched the effectiveness of the implementation of the existing waste management plan method in Hong Kong and proposed that waste separation is a useful method for on-site reuse of materials (Tam 2008). Jaillon et al. (2009) stated that the use of prefabricated components is the major measure to encourage waste reduction. In addition, Li et al. (2015) stated that the majority of designer's attitude toward construction waste minimization is positive but their behavior is hindered by their low perceived behavior control and technology specifications, legislation as well as efficient cooperation among stakeholders, designer experience in design works are the main factors affecting the designer's performance. Zhu and Li (2011) pointed out that it is the lack of awareness of waste reduction education and technical training, as well as incentives from the owners who are vital to support to

Y. Gao · J.Y. Wang (✉) · H.Y. Wu · X.X. Xu
School of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: wangjy@szu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_21

CDW reduction that hinder construction workers from actively carrying out reduction. Other researchers focused on causes influencing CDW management on site, e.g. Yuan and Shen (2011) and Wang et al. (2010). Both studies have identified several critical success factors for the CDW management.

Although researches on CDW management has been widely conducted and proposed various measures to reduce CDW generation, little attention has been paid to the assessment of those measures effectiveness, which are imperative to promote the effective CDW management. The aim of this research is to investigate waste reduction measures employed in construction industry exploring critical factors for effectively CDW minimization.

21.2 Research Methodology

This study applies research methodologies involving literature review, questionnaire survey and interviews. First, the review of literature was undertaken for identifying a full set of selected waste reduction measures. Besides, a questionnaire survey is designed to investigate each measures application employed by design and construction stage in Shenzhen. Based on the survey data, individual structured interviews were arranged with professionals in the industry, intending for reinforcing the data collection and gathering further comments.

21.2.1 Key Measures in Construction Waste Minimization Identification

Based on the literature review, 24 key measures recommended regularly in terms of CDW reduction measures were identified. For the adequacy and comprehensiveness of these measures, five professionals were invited for a preliminary survey. These professionals were carefully selected with abundant experience in the construction industry, two from design department, two from construction companies and one from government department, which ensures the identification of a list of measures. After removing some repeat measures, 21 key measures were determined finally, 8 of them during the design stage and 13 regarding the construction stage. The results were tabulated in Table 21.1 along with their source.

21.2.2 Questionnaire Survey

A questionnaire, consisting of two parts, was developed based on the CDW reduction measures listed in Table 21.1 to investigate critical CDW measures both

Table 21.1 CDW reduction measures

No.	Measures	Sources
Design stage		
D1	Modular design	Tam (2008,) Jaillon et al. (2009), Li et al. (2015), Hong et al. (2011)
D2	Fewer design modification	Li et al. (2015), Hong et al. (2011)
D3	Select green building materials	Tam (2008), Li et al. (2015), Poon et al. (2002)
D4	Optimize design to improve durability	Li et al. (2015)
D5	Design for disassemble	Li et al. (2015), Hong et al. (2011)
D6	Education and technical training for reducing waste awareness of designer	Tam (2008), Li et al. (2015), Zhu and Li (2011)
D7	Economic incentive	Tam (2008), Li et al. (2015), Zhu and Li (2011), Coffey (1999)
D8	Enterprise have waste reduction culture	Tam (2008), Li et al. (2015)
Construction stage		
C1	Make waste manage plan before construction	Tam (2008), Shen et al. (2006)
C2	Relevant personnel have responsible for the implementation and supervision of waste manage plan	Wang et al. (2010)
C3	On-site sorting	Yuan and Shen (2011), Tam (2008), Wang et al. (2010)
C4	Fixed waste storage space	Tam (2008), Wang et al. (2010), Shen et al. (2004)
C5	Green supervision practice	Tam (2008), Wang et al. (2010)
C6	Use prefabricated components	Tam (2008), Jaillon et al. (2009), Wang et al. (2010)
C7	Use advanced technology, such as Gunite	Wang et al. (2010)
C8	Purchase materials rationally	Tam (2008), Wang et al. (2010)
C9	Use of recycled materials, such as metal scaffolding, metal formworks.	Tam (2008), Wang et al. (2010), Poon et al. (2002), Wu et al. (2016)
C10	Education and technical training for reducing waste awareness of construction personnel	Zhu and Li (2011), Wang et al. (2010), Shen et al. (2006)
C11	Economic incentive	Tam (2008), Zhu and Li (2011), Wang et al. (2010)
C12	Enterprise have waste reduction culture	Tam (2008), Wang et al. (2010), Shen et al. (2006)
C13	Waste landfill charging fee	Tam (2008)

in design stage and construction stage. The questionnaire was designed and administered to 100 professionals in the construction industry, who were all from Grade 1 design and contraction companies in Shenzhen and the whole process lasted around two month. There were 72 respondents with a response rate of 72%, which was considered satisfactory according to Moser and Kalton (1971), Moser and Kalton (1971). The majority of respondents were experienced designers, engineers and managers.

In the questionnaire, the respondents were requested to mark an appropriate level measured on a 5-point Likert scale, from the lowest to the highest level (1–5) reflecting the importance of the variables in each question. At the end of the questionnaire, a question "whether you are willing to have in-depth interviews?" was provided. If promised, the respondent was required to leave the information.

21.2.3 Data Calculation

The mean of each variable was calculated by the following Eq. (21.1) to evaluate the importance, which has been widely adopted to identify the relative importance of variables by calculating their importance index values (Tam 2008).

$$u_i = \frac{\sum_{j=1}^{5} N_{ij} S_j}{\sum_{j=1}^{5} N_{ij}} \tag{21.1}$$

where u_i is the mean importance rating of i variable, and S_j represents the level of each variable to CDW (S1 = 1, S2 = 2, … S5 = 5), and N_{ij} represents the number of respondents who chose the jth level (Sj) for the ith variable. After calculating the mean score of each variable, the results are ranked which can be seen in Tables 21.2 and 21.3.

21.2.4 Structure Interviews

Having ranked critical measures, in-depth interviews were conducted by professionals mainly to gather further interpretation and elaboration to the collected data. In the questionnaire, 12 respondents showed their interests in accepting further interview and 6 experienced respondents were selected. Among them, three were from design companies and others were from construction companies. The face-to-face

Table 21.2 Measures and their importance index values in design stage

Ranking	Measures	Importance index values
1	D5 Design for disassemble	2.79
2	D6 Education and technical training for reducing waste awareness of designer	2.76
3	D2 Fewer design modification	2.64
4	D1 Modular design	2.60
5	D7 Economic incentive	2.58
6	D3 Select green building materials	2.54

Table 21.3 Measures and their importance index values in construction stage

Ranking	Measures	Importance index values
1	C9 Use of recycled materials, such as metal scaffolding, metal formworks.	4.01
2	C4 Fixed waste storage space	3.74
3	C3 On-site sorting	3.67
4	C8 Purchase materials rationally	3.51
5	C7 Use advanced technology, such as Gunite	3.43
6	C1 Make waste manage plan before construction	3.40
7	C6 Use prefabricated components	3.36
8	C2 Relevant personnel have responsible for the implementation and supervision of waste manage plan	3.26

interviews were conducted, each lasted about 40 min. The major aim of the interviews was to interpret the ranking and explain the reasons.

21.3 Results and Discussion

The composition of the survey respondents were 46% designer and 54% constructor. Based on the survey results, the analysis results are divided into two parts to calculate the mean, and the variables are ranked according to the results shown in Tables 21.2 and 21.3. Results showed that critical measures together with the views of professionals in the in-depth interviews are discussed in the following section. There are five critical measures affect construction waste reduction at design stage and eight measures at construction stage.

21.3.1 Design Stage

In the design stage, results showed the rank use of 6 measures recommended regularly. "Design for disassemble" received the highest mean importance rating of 2.79, this result indicates that the designer pay increasingly attention to the disassemble design, it is an important means to reduce waste generation from the source to achieve the final efficient recycling of materials. What is more, "Education and technical training for reducing waste awareness of designer" received the second mean importance rating of 2.76, but "Economic incentive" (D7) received lower rating, that means the design company has less economic incentive. Previous studies have suggested that special reward programs are effective (Coffey 1999). However the respondents expressed that although their company has some education and technical training for reducing waste with green environmental protection culture, the designers have less willingness to design adopt low waste measures proactively. Hence, it is necessary to enhance incentive schemes to motivate designer and improve their environmental design performance. “Fewer design modification” (D2) received the third mean importance rating of 2.64, it is known that design modifications take place when the building is almost finished, and may result in part of the structure being taken apart and generate enormous waste. The respondents stated that due to the use of 3D simulations and the consideration of the modifications that may occur in advance at the construction stage, and the timely communication among stakeholders, the design modification have changed better. The fourth mean importance rating is “Modular design” (D1). Several researches found that Modular construction accelerates construction, improves quality, and reduces resources and waste (Hong et al. 2011). However, the application in construction industry in Shenzhen is still at the initial stage, this might be due to the low acceptance dwellings built with prefabricated systems and immature markets. The last mean importance rating is “Select green building materials” (D3) due to the high expensive.

21.3.2 Construction Stage

Firstly, from the ranking, it is not surprising to see that “use of recycled materials, such as metal scaffolding, metal formworks” received the highest mean importance rating (4.01), which is perceived as the most important factor for affecting the effective implementation of CDW reduction in Chinese construction industry. The interviewees described that timber formwork is commonly used in the past because of its versatility and ease of handling. However, due to its short service life and low recovery rate, metal formworks took place in the construction of cast in situ concrete structures because of its durable, recyclable as scrap and reusable on other sites for other projects (Poon et al. 2002).

The followed ranking is “fixed waste storage area” and “on-site sorting”. Respondents said that although the space for waste storage is not big enough in Shenzhen, contractors were willing to find usable site space to storage waste easily and conduct simple on-site sorting of construction waste. Therefore, it is beneficial for recycling and reusing some useful materials. To some extent, any valuable materials and formworks will be restored. Well on-site sorting of construction waste revealed that the management of on-site is improved, which confirmed previous studies that management has been extensively investigated and highlighted in on-site CDW reduction (Yuan and Shen 2011; Shen et al. 2004). All interviewees agreed that management played a key role in promoting the effectiveness of on-site sorting of construction waste and it needs the joint efforts of both managerial staffs and operatives.

"Purchase materials rationally" and "use advanced technology, such as Gunite" are ranked in the fourth and fifth place respectively. According to respondents, the purchase of materials are in accordance with the standards specified in the contract and the rest will be recycled. However, due to the weakness of supply chain management and low informationization degree, effect is not significant. The use of advanced technology such as Gunite instead of artificial smear not only decreased the waste of materials but enhanced the concrete strength and durability.

Previous studies stated that making a waste management plan before construction start (C1) could decrease the waste generation (Wang et al. 2010), but the survey shows that the rating of this measure is lower, this to some extent differs from the findings. The reason for the difference is probably that environment is generally of lower priority compared with other project objectives, namely cost, quality, duration and safety in the Chinese construction industry (Shen et al. 2006). Making a waste management is only formalism and few people are going to perform and supervise. As a result, C2 got lower score than C1.

The "use prefabricated components" is in the seventh place with mean importance rating of 3.36. The interviewees described the current construction activities in Shenzhen as industrialization trend, and the use of prefabricated components could improve noise, dust, muddy run-offs and reduce amount of waste, but it might be more complex because of the setting up of fabrication yard and transportation, workers" training and problems in connecting components, as a consequence, the use of prefabricated components in Shenzhen is uncommon but it would have a good tendency from now on.

21.4 Conclusion

This paper carries out a questionnaire survey and conducted structured interviews among the construction industry in order to investigate waste reduction measures and explore critical factors for effectively CDW minimization. The results show that the best use of the CDW reduction measure in design stage is "Design for disassemble", and in construction stage is "use of recycled materials, such as metal scaffolding, metal formworks". In addition, other critical measures application in Shenzhen construction industry were analyzed. These critical measures not only provide designers and project managers with a useful set of criteria for effective design strategies to reduce construction waste, but also serve as valuable references for the government to formulate related construction waste minimization regulations.

Acknowledgement This work was supported by the Technology Research and Development Program of Shenzhen (grant number JCYJ20160520173631894).

References

Coffey M (1999) Cost-effective systems for solid waste management. Waterlines 17:23–24
Hong SG, Cho BH, Chung KS, Moon JH (2011) Behavior of framed modular building system with double skin steel panels. J Constr Steel Res 67:936–946
Huang XS, Xu X (2011) Legal regulation perspective of eco-efficiency construction waste reduction and utilization. Urban Dev Stud 9:90–94
Jaillon L, Poon CS, Chiang YH (2009) Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Manag 29(1):309–320
Li P (2007) Comprehensive utilization of construction waste vigorously develop the circular economy. SAR Pract Theory 6:84–91
Li JR, Tam VWY, Zuo J, Zhu JL (2015) Designers' attitude and behaviour towards construction waste minimization by design: a study in Shenzhen, China. Resour Conserv Recycl 105:29–35
Moser CA, Kalton G (1971) Survey methods in social investigation. Heinemann Educational, London
Poon CS, Jaillon L, Hong H (2002) A guide for minimizing construction and demolition waste at the design stage. The Hong Kong Polytechnic University, Department of Civil and Structural Engineering
Shen LY, Tam VWY, Tam CM, Drew D (2004) Mapping approach for examining waste management on construction sites. Constr Eng Manag 130(4):472–481
Shen LY, Yao H, Alan G (2006) Improving environmental performance by means of empowerment of contractors. Manag Environ Q Int J 17(3):242–257
Tam VWY (2008) On the effectiveness in implementing a waste-management-plan method in construction. Waste Manag 28(6):1072–1080
Wang JY, Yuan HP, Kang XP, Lu WS (2010) Critical success factors for on-site sorting of construction waste: a China study 54:931–936
Wang JY, Li ZD, Tam VW (2015) Identifying best design strategies for construction waste minimization. J Clean Prod 92:237–240
Wu H, Duan H, Zheng L, Wang J, Niu Y, Zhang G (2016) Demolition waste generation and recycling potentials in a rapidly developing flagship megacity of South China: Prospective scenarios and implications. Constr Build Mater 113:1007–1016
Yuan HP, Shen LY (2011) Trend of the research on construction and demolition waste management. Waste Manag 31:670–679
Zhu JL, Li JR (2011) Construction workers construction waste reduction behavior influencing factors analysis—case of Shenzhen City Project. Manag Technol 25(6):633–637

Chapter 22
An Optimization-Based Semantic Building Model Generation Method with a Pilot Case of a Demolished Construction

F. Xue, K. Chen, D. Liu, Y. Niu and W.S. Lu

22.1 Introduction

Building information modeling (BIM) involves physical as well as functional characteristics of constructions and their components. BIM has been developed to facilitate construction management along the whole life-cycle (Lu et al. 2014) through as-required, as-designed, as-planned, as-built (or "as-is"), as-altered, and as-demolished BIM models. The as-built BIM model can provide critical building information about construction quality assessment, construction automation, energy consumption, green gas emissions, facility management, retrofitting planning, and renovation recommendation (Woo et al. 2010; Lu et al. 2012; Niu et al. 2015; Kalyan et al. 2016). However, BIM was very recently adopted widely in architectural, engineering and construction (AEC) industrial practice. For example, the adoption of BIM expanded from 17% in 2007 to over 70% in 2012 in North America (Bernstein et al. 2012). As a result, there is a large gap between the need and the availability of as-built BIM for many existing constructions. Thanks to the new technologies such as laser scanning, 3D photogrammetry and videogrammetry, the as-built BIM model now can be generated from point cloud and multiple images (Volk et al. 2014). These new methods are much easier and more vivid than manual reconstruction. However, most of the available techniques that generate 3D models from point cloud and photogrammetry do not offer exploitable topological and semantic contents for BIM models (Gimenez et al. 2016).

F. Xue (✉)
KB714, ILab, Faculty of Architecture, The University of Hong Kong, Pok Fu Lam, Hong Kong SAR
e-mail: xuef@hku.hk

K. Chen · D. Liu · Y. Niu · W.S. Lu (✉)
Department of Real Estate and Construction, The University of Hong Kong, Pok Fu Lam, Hong Kong SAR
e-mail: wilsonlu@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_22

In this paper, we present an Optimization-based Model Generation (OMG) method with an orientation of organizing semantic BIM components to fulfill the task of automated BIM generation. The remainder of this paper is organized with the following sections, related works, a general framework of the OMG method, a pilot case of a demolished building, and conclusions.

22.2 Related Works

A typical scan-to-BIM process is a semi-automated method which reply on both software (such as IMAGINiT "Scan to BIM" and CapturingReality) and BIM professionals to pre-process (register, merge/stitch, clean, decimate) data, to recognize (semantic labels), and to create/adjust BIM models (Volk et al. 2014; Barazzetti 2016). Researchers also presented automated means in two categories in general to facilitate the reconstruction process. One category is "data-driven". An early example was that Baltsavias et al. represented (Baltsavias et al. 2001) 3D blocks and roofs of buildings of University of Melbourne campus out from 2D IKONOS® satellite images. Most of automation functions of the available software on the market also belong to the "data-driven" category. The other category is "model-driven", such as a series of typical operations of pose adjustment by principle component analysis (PCA), silhouette extraction and merger, size adjustment, and position matching (Liu et al. 2016). OMG is a model-driven method, yet with an optimization-based model generation mechanism.

Semantic BIM information, such as construction geometry and architectural design, has always been, implicitly or explicitly, included in the literature (Volk et al. 2014; Barazzetti 2016). The mainstream methodology of existed research on semantic BIM was based on object recognition such as identifying component geometry or labeling semantic properties from input images or point cloud first (Volk et al. 2014; Gimenez et al. 2016; Barazzetti 2016; Baltsavias et al. 2001; Liu et al. 2016; Perez-Perez et al. 2016). Heuristic rules from human experts and automated knowledge discovery tools, such as support vector machines (Perez-Perez et al. 2016) and deep machine learning neural networks (Patraucean 2016), were generally involved in BIM object recognition. However, the supporting technologies of object recognition are still in development. The data requirement is usually high and the performance varies case by case. For instance, Perez-Perez et al. (2016) reported the best precision was between 79–92%, along with 2–31% labeled as "unrecognized", in automated labeling point cloud segmentations on average.

OMG, in contrast, does not involve object recognition process. In the framework of OMG, the BIM model is an entirety, and the target measure is another one. The objective of OMG is to pursue the best matching level between the two entireties as a systematic way of generating models. Off-the-peg BIM components and their semantic information are compiled for attaching, modifying, or removing objects during model generation in OMG.

22.3 OMG: A Semantic-Oriented Model Generation Framework

22.3.1 The General Framework of OMG

In general, OMG requires two inputs, i.e. a target measure such as matching a point cloud or image set and a set of (usually excessive) semantic BIM component libraries, as shown in Fig. 22.1. Typical semantic BIM data include geometric properties, surface pattern, architecture style, typical functions, typical supporting structures, material and thermodynamic properties, mechanical properties. The final output of OMG is a semantic BIM model. The first phase in OMG is the transformation of the target measure to a fitness function. Then a solver or algorithm, denoted as the dotted box in Fig. 22.1, will try to optimize the fitness function in the second phase. The last phase is output the fittest model with necessary inverse transformation.

In OMG, the task of building model generation is equivalent to the determination a set of parameters for each component. The parameter set may include a non-negative number of instances, geometric information (position, scaling, and rotation) of each instance, and connection/joint and topological relations to other component instances. The model generation task can hence be rewritten to

$$\text{optimize} f(x), \quad x = (x_1, \ldots, x_n) \in \Re^n,$$

where x denotes all parameters of all components in this research, n is the number of parameters. The fitness function f is defined as the matching level between an arbitrary model and the target measure. Hard constraints can also be introduced from semantic requirements and domain knowledge, such as the available technologies at the construction time, consistency to the architectural style, and instability of the structure. Hence, the task of building model generation can be extended to:

$$\begin{array}{rl} \text{optimize} & f(x), \\ \text{subject to} & C(x) \le 0, \end{array}$$

where C means a function set representing the hard constraints.

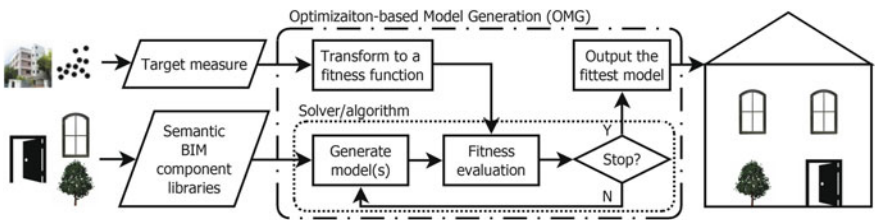


Fig. 22.1 A general framework of optimization-based model generation (OMG)

22.3.2 Typical Fitness Functions and Solvers

One of the most well-known functions f is the mean square error (MSE) which is defined as

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(\hat{Y}_i - Y_i\right)^2$$

where Y is the vector of target values (e.g., coordinates of a laser point) and $\hat{Y} = g(x)$ is the vector of model values (e.g., coordinates of the nearest point on the model surface). For instance, the MSE can measure Euclidean distance and difference of color between a model and a point cloud (or images). Competitive alternatives can also be found in some domains. For example, in the similarity test of 2D images, Wang et al. (2004) presented the structural similarity (SSIM) index which integrated structure, luminance, and contrast measurements of 2D images. SSIM outperformed MSE in a few international image processing competitions.

The fitness function f is usually very sophisticated (derivative-free) and sometimes "opaque". Therefore, many powerful solvers, such as IBM CPLEX™ and Gurobi Optimization™, cannot be directly adopted in OMG. In the literature of derivative-free optimization (Conn et al. 2009) (also known as black-box optimization, automatic parameter tuning, and model selection) and several international competitions,[1] many well-known computational algorithms such as genetic algorithm (GA) were found with acceptable performances. Furthermore, surrogate methods, which adjust estimations of variables consistently, could find much more satisfied results, especially for the "expensive" functions which cost much effort (time and cost) to calculate. One typical surrogate method is the covariance matrix adaptation with evolution strategy (CMA-ES) proposed by Hansen and Ostermeier (2001). Solvers with surrogate methods such as CMA-ES are therefore recommended, whereas universal algorithms like GA can also be good candidates for "cheap" functions.

[1]See Ruhr-University Bochum, Germany: Black Box Optimization Competition, http://bbcomp.ini.rub.de/; See also Missouri University of Science and Technology, USA: Combinatorial Black-Box Optimization Competition, http://web.mst.edu/~tauritzd/CBBOC/.

22.4 A Pilot Case

22.4.1 The Target Measure, Component Libraries and Supporting Software

The School of Tropical Medicine and School of Pathology, The University of Hong Kong (HKU) used to occupy a baroque-style two-storey architecture, as shown in Fig. 22.2. The building was built on the main campus of HKU in 1919, later refurbished with an additional floor, and demolished in campus development decades ago. In this pilot test, this building is employed to describe the process of OMG.

The task was set to reconstruct the BIM model of the front side of the building due to limited data from the target 2D image. More specifically, apparent components with width and height greater than 1 m, including trees, front facade, the door and the windows should be included in the 3D model. Groups of components, as listed in Table 22.1, were collected from shared models of 3D Warehouse of SketchUp with a keyword filter "baroque". Some semantic attributes such as type, material, surface glued to, typical size and typical locations were manually added to SketchUp dictionaries of components.

The pilot test was implemented on SketchUp API (application programming interface, version 2016 PRO Ruby). The components were automatically adjusted with Ruby (version 2.0.0p648) scripts in SketchUp and then projected to 2D images (in 640 $\times$ 360 resolution). The similarities between projected images and the target image were measured by the SSIM function (Wang et al. 2004). Scientific packages of OpenCV (Open source computer vision library, version 2.4.13) and ruby-opencv (version 0.0.17) were employed to facilitate the measurement. A C++ implementation[2] of CMA-ES and its Ruby wrapper were adapted as the solver in OMG. Google Earth™ (version 7.1.5.1557) was used to present the resulting model. Stanford Protégé (version 5.0) was used to represent the semantic links in the resulting model.

22.4.2 Transformation and the Solving Procedure

Seven components, as shown in Table 22.1, were gathered for model generation. The numbers of component instances were set to 1 door portico, 1 tree, 2 walls, and 9 windows to simplify the pilot task. For each component instance, there were six real parameters, i.e., position and scaling on the three axes. The rotation parameters were omitted in this case due to the front face of the target building. According to estimation about the place where the photo was taken, the camera of SketchUp was

[2]CMA-ESpp, see: https://github.com/AlexanderFabisch/CMA-ESpp.

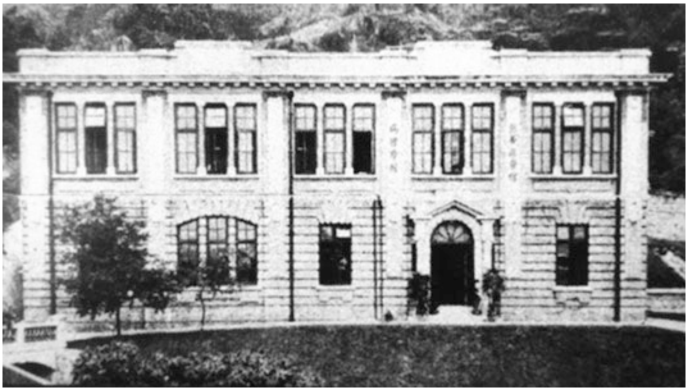


Fig. 22.2 A demolished building of The School of Tropical Medicine and School of Pathology, The University of Hong Kong (640 × 360 pixels; *Source* Exit A of MTR HKU railway station, photographed by an Android mobile phone in July 2016)

Table 22.1 A list of components extracted from shared models in SkechUp™ 3D warehouse for the pilot case

Library name	Component name	Original model from 3D warehouse (Contributor ID)	Attached semantic labels
Door	Door portico	Door (3) classical ottoman osmanli colonial (Mohamed EL Shahed); blenheim orangery and function rooms (Richard)	Typical size; Glued to: wall
Tree	Oak tree	Downy oak (KangaroOz 3D)	Location: ground; Glued to: open space
	Palm tree	Royal palm tree (Yoshi productions)	Location: ground; Glued to: open space
Wall	With h-sliding	Salm palace (3dolomouc)	Typical size; Location: ground
	Smooth surface	Salm palace (3dolomouc)	Location: 1/F and above; Glued to: wall
Window	Three-section	French window (Architect)	Typical size; Glued to: wall
	Traditional	Mahogany framed window (Ben)	Typical size; Glued to: wall

located to (0, 850, 157.5) heading to (0, 0, 157.5) (unit in inch). The ground was defined as the horizontal plane $z = 0$. The semantic relations of location and glued to were required as hard constraints. So the fitness function f is the dissimilarity between a projected image and Fig. 22.2 to:

$$\begin{array}{ll} \text{minimize} & f = \text{dissimilarity} = 1 - \text{SSIM} \\ \text{subject to} & \text{Semantic constraints of location, size and glued - to} \end{array}$$

The model was generated increasingly by attaching one component each time, where ground components preceded facade instances. 200 trials of parameters were allowed for the CMA-ES solver in attaching a new component instance concerning f. The incremental generation procedure stopped when no new instance could lead to a reduction of f. The component instances were then fine-tuned by CMA-ES for an additional 2000 trials before termination.

22.4.3 The Pilot Run and the Result Model

The pilot run was conducted on an Intel® i5-6500 CPU (3.20 GHz) computer. The CMA-ES solver spent 1 h 3 min and 42.4 s (3822.4 s) to optimize f in 4800 trials in total, as shown in Fig. 22.3. After 400 trials from the beginning, the G/F wall and the door portico were attached to the model. Then a palm tree was attached yet was quickly replaced by an oak tree, because the attachment of the palm tree contributed an $f = 0.8603$ but the new oak tree conflicted with it in location and had a better $f = 0.8392$. The incremental generation phase stopped at the 2800th trial. After 2000 trials of the fine-tuning phase, the final model achieved a fitness $f = 0.7772$ by slightly changes of the door portico and a few windows automatically. The result of OMG was saved as a SketchUp file in 2.06 MB.

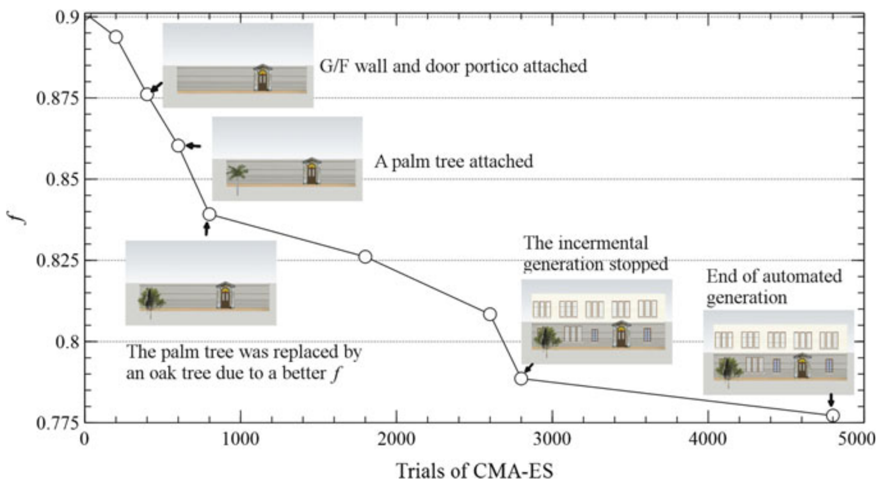


Fig. 22.3 The automated optimization process of OMG with annotated SketchUp™ models in the pilot run (Incremental generation phase: 1–2800; fine-tuning phase: 2801–4800)

(a) Auto-generated front face in SketchUp (b) Manually completed building model (c) Illustrated on Google Earth

Fig. 22.4 The resulting model of OMG

Some components in the resulting model, such as a three-section window glued to the G/F wall shown in Fig. 22.4a, did not satisfy axial rules of baroque architecture. So the authors made a few manual amendments to the auto-generated front face of the building. The model of the whole building, as shown in Fig. 22.4b, was estimated based on a survey map of HKU (1969–1976) and manually completed with the replicas of the auto-generated facade. An illustration of the building model, as shown in Fig. 22.4c, described its historical location near today's Exit A2 of the HKU station and the Kadoorie Biological Science Building, HKU.

The semantic relations between the components were inherited during the model generation. The relations could also be exported as queryable ontology format such as the Web Ontology Language (OWL). The Ontology software like Protégé can then provide search and reasoning functions for the components and their relations in the generated model illustrated in Fig. 22.4a. Figure 22.5 shows an example of the search result of term "Traditional". The "Traditional" window component and all the three instances are shown with "is-a" connections in Fig. 22.5. The relations of "location" and "glued to" are presented as dashed links between component classes.

22.4.4 Discussions

This case was a preliminary test of the feasibility of OMG. So some minor details such as decorative cornice and front door plants were excluded in this pilot test. The whole process of OMG used a couple of hours more than the approximate 1 h spent by CMA-ES solver in this pilot. It was because the preparation of component libraries and post-optimization procedures brought extra time cost into the OMG process. Object recognition of the target image was not involved. However, the components were placed in the correct locations mostly and hence implicitly identified the objects with semantic labels and relations. For example, a window

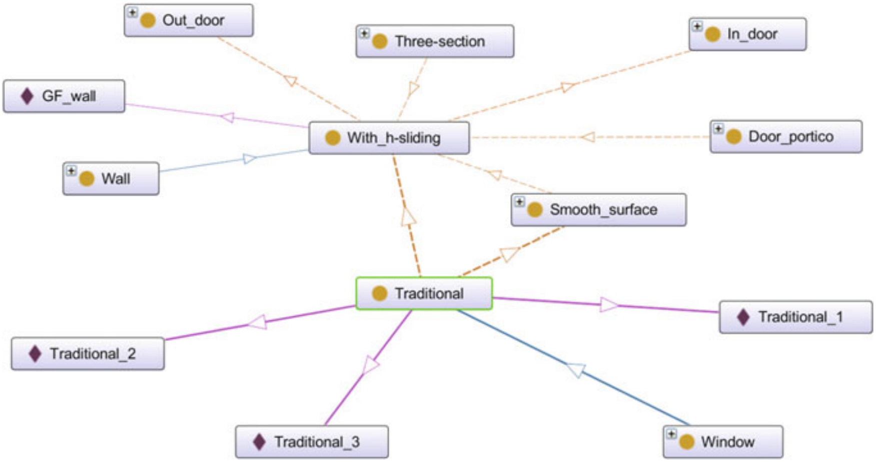


Fig. 22.5 The semantic links in the auto-generated model illustrated in Stanford Protégé (circle denotes a component class and a diamond stands for an instance/object)

which was difficult to recognize visually was placed accurately behind the tree in the model. One limitation of this pilot was that the numbers of component instances were set to constants to simplify the task, although they can be a part of parameters to be determined according to the general OMG framework.

In comparison to typical scan-to-BIM process, OMG has several advantages. First, the automation level is elevated to a higher level. A saving of cost could also be expected from equipment, data gathering, and manpower. In OMG, BIM professionals need to be involved only in the early stages such as pre-process, component selection and definition, and definitions of fitness functions and constraints. Furthermore, the data requirement of OMG is also much more relaxed than that of scan-to-BIM (usually tens of millions of pixels). It is because many details can be inherited from components if defined. Other features of OMG include semantic data to meet BIM requirements, low requirement on measurement, relationship discovery for components, reusable component libraries, and scalability to new environments.

Disadvantages of OMG, nevertheless, can also be found. The first was the accuracy and availability of component libraries. Thanks to the antique building modelers over the world, most of the major components in this pilot case were extracted from shared models directly. Yet those components, such as the trees, did not perfectly match the target measure in fact. Another one was the quality of the model. The finite trials of computer program certainly cannot compare with BIM professionals' knowledge, experience, and insights in model generation.

22.5 Conclusion

This study presented a new semantic-oriented as-built BIM generation method named optimization-based model generation (OMG). In OMG, building model generation is regarded as an assembly of components from semantic BIM component libraries. The assembly of components is considered as a derivative-free function to fit target point cloud or images with respect to semantic constraints. Some computerized optimization algorithms can automatically find the best arrangements of component parameters and hence the corresponding 3D models. The result of OMG is a BIM model with geometric, topological and semantic data. A pilot case of a demolished building at HKU campus validated the main process of OMG.

This study is expected to enrich the research of automated BIM generation with an alternative framework to object recognition in point cloud and images. The findings of the pilot case were preliminary. Further research is needed to validate the transformation of the fitness function for other targets like point cloud, other advanced mathematical programming algorithms, and the effects of using semantic data as soft constraints.

Acknowledgements The authors would like to express their gratitude to Mr. Pak Kei Hon at Estates Office, The University of Hong Kong for supporting documents of the pilot building.

References

Baltsavias E, Pateraki M, Zhang L (2001) Radiometric and geometric evaluation of IKONOS GEO images and their use for 3D building modelling. In: Proceedings of joint ISPRS workshop on high resolution mapping from space 2001, Hannover, Germany, pp 19–21 September (on CD-ROM)

Barazzetti L (2016) Parametric as-built model generation of complex shapes from point clouds. Adv Eng Inform 30(3):298–311

Bernstein HM, Jones SA, Russo MA, Laquidara-Carr D, Taylor W, Ramos J, Healy M, Lorenz A, Fujishima H, Fitch E, Buckley B (2012) The business value of BIM in North America: multi-year trend analysis and user ratings (2007–2012). McGraw-Hill, Bedford, MA, USA

Conn AR, Scheinberg K, Vicente LN (2009) Introduction to derivative-free optimization, vol. 8. SIAM

Gimenez L, Robert S, Suard F, Zreik K (2016) Automatic reconstruction of 3D building models from scanned 2D floor plans. Autom Constr 63:48–56

Hansen N, Ostermeier A (2001) Completely derandomized self-adaptation in evolution strategies. Evol Comput 9(2):159–195

Kalyan TS, Zadeh PA, Staub-French S, Froese TM (2016) Construction quality assessment using 3D as-built models generated with project tango. Proc Eng 145:1416–1423

Liu T, Zhao D, Pan M (2016) An approach to 3D model fusion in GIS systems and its application in a future ECDIS. Comput Geosci 89:12–20

Lu W, Peng Y, Shen Q, Li H (2012) Generic model for measuring benefits of BIM as a learning tool in construction tasks. J Constr Eng Manag 139(2):195–203

Lu W, Fung A, Peng Y, Liang C, Rowlinson S (2014) Cost-benefit analysis of building information modeling implementation in building projects through demystification of time-effort distribution curves. Build Environ 82:317–327

Niu Y, Lu W, Chen K, Huang GG, Anumba C (2015). Smart construction objects. J Comput Civ Eng, ASCE: 04015070

Patraucean V (2016) Deep machine learning: key to the future of BIM? Cambridge: University of Cambridge, 14 Mar 2016, http://www-smartinfrastructure.eng.cam.ac.uk/news/viorica-patraucean-featured-in-infrastructure-intelligence. Accessed 15 July 2016

Perez-Perez Y, Golparvar-Fard M, El-Rayes K (2016) Semantic and geometric labeling for enhanced 3D point cloud segmentation. In: Construction research congress 2016, San Juan, Puerto Rico: ASCE, pp 2542–2552

Volk R, Stengel J, Schultmann F (2014) Building Information Modeling (BIM) for existing buildings—literature review and future needs. Autom Constr 38:109–127

Wang Z, Bovik AC, Sheikh HR, Simoncelli EP (2004) Image quality assessment: from error visibility to structural similarity. IEEE Trans Image Process 13(4):600–612

Woo J, Wilsmann J, Kang D (2010) Use of as-built building information modeling. In: Construction research congress 2010, Banff, Alberta, Canada: ASCE, pp 538–547

Chapter 23
Analysis and Optimization of Key Index of Public Investment Building Project's Performance Evaluation Based on Project Governance

Y.S. Wang, F.f. Liu, W.Z. He, Y. Zhang, H.Y. Li and J.F. Li

23.1 Introduction

Performance evaluations of domestic government investment projects have been focused on building new index systems. Since 2004, the central government has issued several policies and papers about performance evaluations of government investment projects. These policies include a common index system framework for evaluating budgets, and a budget performance management work plan (2012–2015). Analysing the efficiency, effects, rationality, etc., of the existing system implementation processes, will help in related fields on a practical level.

23.2 Performance Evaluations of Public Investment Projects Based on Project Governance Methods

23.2.1 Research Status on Performance Evaluations of Public Investment Projects

An efficient performance measurement system is essential for a government organization to control, monitor, and improve the quality of its services.

Y.S. Wang (✉) · F.f.Liu · W.Z. He · Y. Zhang · H.Y. Li
School of Civil Engineering and Transportation, South China
University of Technology, Guangzhou, China
e-mail: yswang@scut.edu.cn

J.F. Li
School of Civil Engineering and Transportation, South China University
of Technology, Architectural Design and Research Institute of Guangdong Province,
Guangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_23

Jerry et al. (2008), Michail et al. (2001), and Mladen et al. (2013) proposed a new management model framework that evaluates the performance of government investment projects by using a balanced scorecard structure and the European Foundation for Quality Management (EFQM) Excellence Model to balance and improve the quality of public services. Gao (2009) and Wu et al. (2009) use frontier theory, public administration, and multiple principal agents to analyse formation mechanisms in the performance of public projects. The researchers also proposed a corresponding index system. Yang (2012) used the 5E principle to perfect a performance evaluation system for public investment projects by using a system, index, and method. Hu (2012) applied evidence theory and fuzzy mathematics to the performance evaluation of large public projects.

However, according to correlation research, index definitions, integration, and modifications to key indexes have problems resulting from changes to policies, targets, and benchmarks.

Yeung et al. (2008) defined each key index accurately, and provided objective evaluation results based on quantitative evidence. This was accomplished by conducting five structured face-to-face interviews and two rounds of a Delphi questionnaire survey in Hong Kong. Jin et al. (2007), Amaka (2011) and Hwang et al. (2015) used contrastive analysis to research a performance evaluation system for the construction industry in China, Nigeria, and Singapore. In addition, this method provides a key performance index and an iterative framework for performance evaluation. Bai (2010) established a project performance management system for an agent's construction project. This system was based on a process performance evaluation. Min (2013) presented an index framework for the performance evaluation of a government investment project that contains 49 common indexes with regard to time and goals.

In order to resolve disputes and provide incentives, many researchers have investigated factors that affect project performance in the past.

Jin et al. (2007) found that relational risks have a negative influence on project performance. Lia et al. (2012) investigated the problems between transaction costs and project performance. They found that project performance is stronger if the uncertainties in the transaction environment are minimized, transaction costs are kept low, and if owners and contractors are sensitive to transaction-related issues. Brooks et al. (2008) and Guilherme et al. (2014) researched the relationships between a port project's governance methods, models, and performance. The researchers used a literature review and case studies. Du (2009). regarded project governance as the basic reason for improvements in the performance of public project management. Du used a Structure-Conduct-Performance model and a structural equation model, and demonstrated the governance providing positive influences for performance of public project management.

23.2.2 Theoretical Basis of Project Performance Evaluation Based on Project Governance Method

(1) New public management theory

Since the 1960s, western capitalist countries have experienced revolutions in government and social institutions. Along with this process came many new types of government management modes. Collectively, these are called new public management theories (Mei 2006).

Government departments should pay more attention to the allocation of administrative resources, and optimize relationships dealing with financial input-output expenditures. Therefore, new public management theory views the division of administrative resources to be based on real requirements, expected effects, and emergency (Fig. 23.1).

(2) Law-based administration theory

The state council published suggestions for enhancing legislation dealing with government buildings in 2010. These policies required all levels of government to build an administrative performance evaluation system scientifically. In the modern world, legislation is defined as the operation and functions of all organizations or institutions, which must follow basic rules such as fairness, justice, and morality. These basic rules show the highest respect for individuals in society (Walkker 2003).

Under the trend of era condition of building a law-based country or government, strengthening law-based administration has gradually become a key point for all

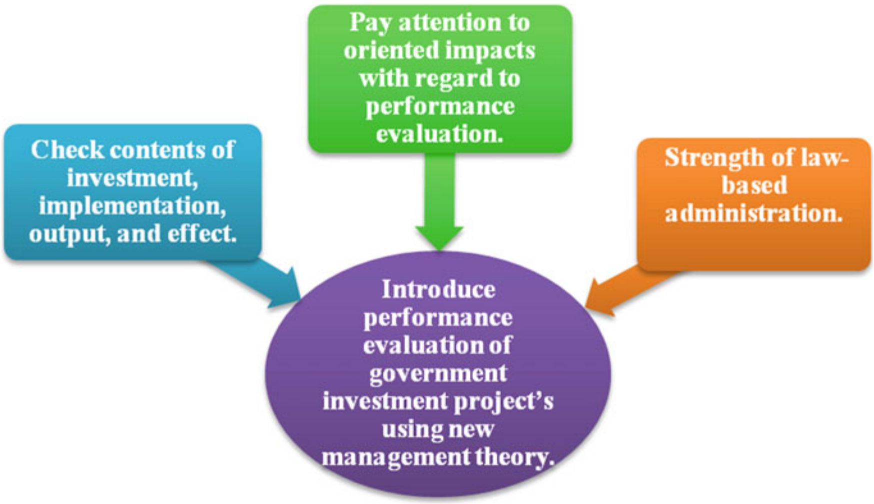


Fig. 23.1 Reference chart for new management theory

levels of government in China. For example, Guangdong province published a building index system of a law-based government.

23.3 Analysis of a Government Investment Project's Performance Evaluation Index System

This article examines the performance evaluation index system (referred to as a case index system) for a government investment project in 2014 and 2015. The infrastructure, negotiation meetings, and other categories will be choice the relative performance evaluation system by considering a representative and sufficient sample. Meanwhile, the author compiled a system of 23 indexes (referred to as a 'sample index system') related to the performance evaluations of recent government investment projects at home and abroad. Then, this article analyses and evaluates the advantages and disadvantages of the proposed index system.

23.3.1 Analysis of the Success of the System

(1) Hierarchy and quantity of index system

The number of three-level index of the three-level system in the case index system is counted. Then, the three-level index data group's coefficient of variation, $CV = 0.23 < 1$, is calculated. It shows that the data group's distribution is small and representative to a certain degree.

In addition, the author averages approximately 30–40 min on each project. This time includes reading the project materials, scoring, and filling in the evaluation comments. During this period, the author can stay focused on this task in order to ensure the effectiveness and efficiency of the evaluation.

(2) Supplement and additional content of the index system

The performance evaluation index system has a specific definition and marking standard for each three-level index. At the end of the evaluation column, a description is set up for marking. If the expert deducts points for this item, he must briefly explain his/her reason in the evaluation column.

(3) Establishment of unique index and plus index

The establishment of a unique index helps to enhance the evaluated project's relevance and accuracy, and focuses on the differences between projects. In addition, the total score for the evaluation system is 110 points, among which 10 points are pluses. Setting up a plus index is helpful in enhancing a project's performance, and encourages the sound development of the investment project.

23.3.2 Analysis of Deficiencies in the System

(1) The ratio of quantity and qualitative index is irrational

The ratio of the qualitative index occupies almost 64–73% of the case evaluation system, while the quantity index is nearly 27–36%. In all sample systems, the number of qualitative indexes that occupy 20.1–30% of all system indexes is as high as 39%. The expectation is 33%, and the CV is 0.29 (<1). The data group is weak variation, the dispersion degree is minimal, and own representation. However, the qualitative index of the case index system is over 33%, which exceeds the interval ranges of all statistical sample data. This article recognizes that the ratio of quantity to the qualitative index is irrational (Table 23.1).

(2) Part of the index definition is irrational, and the indexes' quantity degree is insufficient

For example, the realization rate for expenses (shown as bold content in the explanation column in Table 23.2) is mainly used to measure the effectiveness of capital expenses. Budgetary appropriations that are not used in this project will be considered when making calculations. When all budgetary appropriations are used for this item, this index not exist errors. This index will not reflect real situations if parts of the budgetary appropriations cannot be used for projects because of several reasons.

(3) Key information in index system is insufficient

For example, an implementation procedure is a unique index about project tendering and bidding. (This is shown as the bold content of the score criterion in Table 23.2.) If a project is not based on tendering and bidding, this item takes off no more than 5 points. The weight ratio only is 4.5%. In other words, it cannot significantly influence the results. According to legal liability in bidding law, a project-building contract that fails to include tendering and bidding is an ineffective contract. The performance evaluation should get a 0 when these conditions occur.

23.4 Optimization of a Government Investment Project's Performance Evaluation System

The contrastive analyses of the case index system and sample index system shown in Table 23.3, 23.4 and 23.5. The amend indexes come from case shown as bold italics in the Table 23.3–23.5.

Table 23.1 Calculation of coefficient of variation for number of three-level indexes in case index system

E	σ	$CV = \frac{\sigma}{E}$
30.23	7.07	0.23

Table 23.2 Common indexes of index system

First-level index	Second-level index	Third-level index	Index explanation	Score criteria
Preliminary work (7 points) ***Project establishment*** ***(17 points)***	Project establishment (7 points) ***Sufficiency of project establishment*** ***(10 points)***	Feasibility of project establishment (2 points)	Have project proposals been submitted, and has a feasibility study been carried out?	When fund reaches between 300,000 and 3,000,000, project proposals need to be submitted When fund is over 3,000,000, feasibility study needs to be submitted If units cannot provide these materials, the score of this item is 0
		Completeness of establishing procedures (1 point)	Have projects provided documents that meet relative requirements?	If projects provide documents that meet relative requirements, this item will get 1 point Otherwise, score different points according to different situations
Preliminary work (7 points) ***Project establishment*** ***(17 points)***	Project establishment (7 points) ↓ ***Sufficiency of project establishment*** ***(10 points)***	Fund established process (4 points)	Have projects declare funds according to the process? Have projects passed a performance budget review?	Projects that declare funds according to the process and pass a performance budget review score 4 points Otherwise, score different points according to different situations
		Normativity of establishing approval process ***(3 points)***	***Has an approval process been established? Is the procedure complete, and does it meet relative requirements?***	***Total accordance will get 3 points*** ***Accordance will get 2 points*** ***Less accordance will get 1 point*** ***Nonconformity gets 0***
	Scientificity of performance goal ***(3 points)***	***Feasibility of performance goal*** ***Sufficiency of basis for reasoning*** ***(3 points)***	***Are the projects' performance goals evident and feasible? Is the performance goal consistent with project investment goals?***	***Total accordance will get 3 points*** ***Accordance will get 2 points*** ***Less accordance will get 1 point*** ***Nonconformity gets 0***
	Level of detail of performance goal ***(4 points)***	***Details of investment goal*** ***(1 point)***	***Are the performance goals defined precisely in the project's establishing materials?*** ***Is the content of the performance goal specific, measurable, and quantitative?***	***If all indexes satisfy requirements listed at left, 1 point will be given for this item*** ***If indexes partially satisfy requirements, this item will get 0.5*** ***If no indexes satisfy requirements, this item will get 0***
		Details of quality goal ***(1 point)***		
		Details of time goal ***(1 point)***		
		Details of effective goal ***(1 point)***		

(continued)

Table 23.2 (continued)

First-level index	Second-level index	Third-level index	Index explanation	Score criteria
Fund management (17 + 2 points)	Budget control and executive condition (9 + 1 points)	Budget outlay scheme (3 points)	Does the project reframe its implementation plan according to budget approval? Is the expenditure structure detailed and rational?	If units reframe project implementation plans, and the expenditure structure is detailed and rational at one month after agreeing to a project's budget approval, this item will receive 3 points Otherwise, score different points by different situations.
		Rationality of budget declaration (2 points)	Is the project's budget declaration rational?	If actual spending amount is completely consistent with budget approval amount, this item will get 2 points If actual spending amounts deviate from budget approval amounts by more than 30%, this item will take off 1 point If actual spending amounts deviate from budget approval amounts by more than 50%, this item will get 0
		Control of budget spending (4 points)	Are project spending expenses based on actual needs expenditures and maintained within the budget indexes? ***Ratio of real investment that is over budget = (real investment that is over budget ÷ investment of approved budget) × 100%***	If project expenses are according to the actual need and is maintained within the budget indexes, this item will get 4 points Otherwise, score different points by different situations If project rationality save spending high as 10%, this item will add another 1 point ***According to the ratio of real investment that is over budget (X), the score is defined as follows:*** ***$X \leq -10\%$, get 5 points;*** ***$-10\% < X \leq 0$, get 4 points;*** ***$0 < X \leq 5\%$, get 3 points; $5\% < X \leq 10\%$, get 2 points; $10\% < X \leq 15\%$, get 1 point; $15\% < X$, get 0***

(continued)

Table 23.2 (continued)

First-level index	Second-level index	Third-level index	Index explanation	Score criteria
Fund management (17 + 2 points)	Consistency of capital expenses (5 points)	Expenses are consistent with budget approval (5 points)	Expenses are consistent with project budget approval, establishing scheme, and contract stipulations	If expenses totally conform to the project, this item will get 5 points Otherwise, score different points by different situations ***If expenses are totally conformed to the project, this item will get 5 points; partially conformed to the project will get 3 points; less conformed to the project will get 1 points; any discrepancy will get 0***
	Effectiveness of capital expenses (3 + 1 points)	Realization rate for expenses (3 points) ***Effectiveness of spending (3 points)***	**Real amount paid/real appropriation × 100%** ***Real amount paid that is used for projects/real appropriation × 100%***	Realization rate for expenses that is up to 90% will receive 3 points between 80% and 89% will receive 2.5 points between 70% and 79% will receive 2 points between 60% and 69% will receive 1.5 points, and less than 59% will get 0 If projects have matching funds and are completed in time, this item will add another 1 point
Implementation and organization (14 + 1 points)	Project implementation (14 + 1 points)	Fundamental guarantee (3 points)	Is the guarantee of support conditions by regime, information, site, equipment, and staff of the project undertaking unit sufficient?	If the support conditions of regime, information, site, equipment, and staff of project are adequately protected, this item will get 3 points If the protection is not sufficient, it will get 1 point or 2 points If there is no protection, it will get 0
Implementation and organization (14 + 1 points)	Project implementation (14 + 1 points)	Execution rate of regime (3 points)	Was the project implementation process executed by implementation plan and regulatory framework in proposal stage? ***Quantity of Executing regulatory framework and project management method ÷ total***	If implementation plan and regulatory framework are executed effectively, this item will receive 3 points Otherwise, score different points by different situations

(continued)

Table 23.2 (continued)

First-level index	Second-level index	Third-level index	Index explanation	Score criteria
			quantity of regulatory framework and project management method) × 100%	***According to the result of execution rate of regime (X), score as follows:*** ***X = 100%, get 3 points;*** ***80% ≤ X < 100%, get 2 points;*** ***60% ≤ X < 80%, get 1 point;*** ***X < 60%, get 0***
		Implementation procedure (5 points)	Is the project implementation process standardize? Whether projects tendering, adjustment, change, and acceptance check are base on the corresponding formalities?	**If project implementation is standardized and project tendering, adjustments changes, and acceptance check are base on the corresponding formalities, this item will get 5 points** **Otherwise, score different points by different situations**
		Implementation scheduling (3 + 1 points)	Does the project operate according to implemented scheduling and ensure quality? ***[(Real working days − booking days) ÷ booking days] × 100%***	If projects operate according to implementation scheduling and ensure quality, this item will get 3 points Otherwise, score different points by different situations If projects win the recognition of higher-level units, another 1 point will be added ***The result of implementation scheduling is X: X ≤ 0, get 3 points;*** ***< X ≤ 10%, get 2 points;*** ***10% < X ≤ 20%, get 1 point;*** ***20% < X, get 0 points. If project wins leader's recognition, another 1 point will be added to this item***
Supervision management (12 points)	Spending compliance (4 points)	Financial accounting standardization (4 points)	Does the financial accounting and approval meet standards? Are there any issues with regard to the misuse and retaining of funds? Is there an excessive spending situation?	If financial accounting and approval meet standards, Projects have no problems with regard to the misuse and retaining of funds

(continued)

Table 23.2 (continued)

First-level index	Second-level index	Third-level index	Index explanation	Score criteria
				If projects do not have excessive spending situations, this item will get 4 points Otherwise, score different points by different situations
	Spending Rationality (4 points)	Fund spending Rationality (4 points)	Is it necessary to spend on all items of the project? Is the ratio of spending rational? Are cost controls considered?	If all factors are more rational, this item will get 4 points If all factors are rational, this item will get 2–3 points If all factors are less rational, this item will get 1 point If all factors are not rational, this item will get 0 points
	Supervision (4 points)	Tracking supervision (4 points)	Have the program directors followed the control measures of project quality inspection/follow/acceptance? Do program directors have financial checks and monitoring mechanisms, and are there materials for examination and supervision?	If this item satisfies the following requirements, it will get 4 points: First, program directors fulfil responsibilities of daily examination and supervision; Second, these people are equipped with financial checking and monitoring mechanisms Third, they have materials for examination and supervision Otherwise, score different points by different situations

Table 23.3 Unique indexes of infrastructure

First-level Index	Second-level index	Index definition and score criteria
Infrastructure (40 + 7 points)	Building projects get through acceptance and review (8 points)	Building projects get through acceptance and review of experts or departments ***Building projects, once they get through acceptance and review of experts or departments, get 8 points; several get through acceptance and review, get 4 points; not get through, get 0***
	Timeliness (7 points)	Are projects finished on time? ***[(Project's actual construction period − project's expected period) ÷ project's actual construction period] × 100%. X as the result of timeliness: X ≤ 0, get 7 points; 0 X ≤ 5%, get 6 points; 5% < X ≤ 10%, get 5 points; 10% < X ≤ 15%, get 4 points; 15% < X ≤ 20%, get 3 points; 20% < X ≤ 25%, get 2 points; 25% < X ≤ 30%, get 1 point; 30% < X, get 0***
	Situations of engineering change (7 points)	There are no or few engineering changes, and formalities are standard and intact ***Investment plus or minus of project design changing occupying project total investment is X: 0 ≤ X < 2.5%, get 7 points; 2.5% ≤ X < 5%, get 5 points; 5% ≤ X < 7.5%, get 3 points; 7.5% ≤ X < 10%, get 1 point; 10% ≤ X, get 0***
	Total cost control of building projects (10 points)	Basing on tender contract and settlement amount control total cost (no added cost, get 8 points; passing under 5%, get 7 points; under 10%, get 6 points; under 15%, get 5 points; and so on)
	Utilization rate of infrastructure (8 points)	Service condition of infrastructure
	Bonus index (maximum is 7 points)	Building projects win honor from departments of regions and cities

23.4.1 Suggestions to Amend the Common Index

For example, this article introduces a concept-over-budget ratio of real investment according to budget spending controls. The computational formula is 'over budget ratio of real investment = (over budget of real investment ÷ approved investment budget of project) × 100%'. Then, according to relative establishment ways of reference, the scoring criteria are amended as follows: According to the ratio of real

Table 23.4 Unique indexes of negotiation meeting

First-level index	Second-level index	Index explanation and score criteria
Negotiation meeting (40 + 7 points)	Discuss status with enterprises (6 points)	Meeting project status with enterprise through negotiation ***More than 3 projects that discuss over 5 times, get 6 points; more than 2 projects, get 4 points; one project, get 2 points; projects with lower than 5 discussions, get 0***
	Introduce intention to negotiate enterprise (6 points)	Enterprise signs letter of intent through negotiation ***Signing letter of intent to introduce over 6 enterprises get 6 points*** ***5 letters of intent get 5 points and so on. Not signing letter of intent, get 0***
	Review situation of negotiated enterprise (6 points)	Review situation of enterprise after negotiation meeting ***If there at least two enterprise reviews after negotiation, this item will get 6 points; one time will get 3 points. Not enterprise review gets 0***
	Immigration of negotiated enterprise (9 points)	Immigration of enterprise through negotiation meeting ***Introduced enterprises transact more than 3 business licenses will get 9 points, 2 business licenses will get 6 points, 1 business license gets 3 points, no business license gets 0***
	Management situation of introduced enterprise (6 points)	Enterprise's management situation in estate after being introduced ***Introduced enterprises pay taxes on estate get 6 points, but not paying taxes gets 0***
	Effectiveness of other aspects (7 points)	Successfully introduce world top 500 enterprises/world-famous enterprises/investment projects of famous domestic enterprises, score 7/5/3 points, respectively
	Bonus index (limit is 7 points)	Introducing listed company or high-tech enterprise/scientific institutes/chambers of commerce at province level

investment over budget (X), the score is defined as follows: $X \leq -10\%$, get 5 points; $-10\% < X \leq 0$, get 4 points; $0 < X \leq 5\%$, get 3 points; $5\% < X \leq 10\%$, get 2 points; $10\% < X \leq 15\%$, get 1 point; $15\% < X$, get 0.

23.4.2 Suggestions to Amend the Unique Index

Suggestions to amend the unique index focus on the index-defined quantification and score criterion quantification.

Table 23.5 Unique indexes of others

First level index	Second-level index	Index definition and score criteria
Other projects (40 + 7 points)	Accomplishment degree of output (20 points)	Real completion rate = (real output amount/plan output amount) × 100%, to reflect and assess degree of realization of quantities of objectives of project output. Finished at least 95% of objective gets 18–20 points; Finished 90–94% of objective gets 15–18 points; Finished 80–89% of objective gets 10–14 points; Finished 70–79% of objective gets 5–9 points; Finished 60–69% of objective gets 1–4 points; Finished under 60% of objective gets 0
	Timeliness of output (10 points)	Is the output content finished during the implementation period of project or in a reasonable time? Is the project output time misleading? ***[(actual construction period − expected period)] ÷ the actual construction period] × 100%. Modify scoring criteria as follows, with the result of timeliness defined as X: X ≤ 0, get 7 points; 0 < X ≤ 5%, get 6 points; 5% < X ≤ 10%, get 5 points; 10% < X ≤ 15%, get 4 points; 15% < X ≤ 20%, get 3 points; 20% < X ≤ 25%, get 2 points; 25% < X ≤ 30%, get 1 point; 30% < X, get 0***
	Effects of project (10 points)	Economic effect: project brings direct or indirect effects or saves costs of national economic and regional economic development ***Economic effect: when project is established, XX enterprises or factories will be introduced directly or indirectly, contributing XX value for this region***
		Social effect: project implementation influences social development, environmental protection, and labour employment ***Social effect: when project is established, XX electricity sale (k W· h/year) will be increased, increasing XX electricity supply in local region***
		Another measurable evaluation effect: whether project implementation reaches intended target with sustainable development effects or other expected effects? ***Another measurable evaluation effect: the number of complaints from environmental problems from project building is lower than XX (once/year)***
		Satisfaction of public or service objective: extent of satisfaction with implementation effects that comes from departments, groups, or individuals ***Satisfaction of public or of service object: Satisfaction of questionnaire survey that comes from project users and nearby communities reaches XX%***
	Bonus index (maximum is 7 points)	If four effect contents that comes from effect of project reaching performance goals, project will add 7 points

For example, in an infrastructure, the index 'building projects get through acceptance and review' has a relative weighted score (8 points), while the score criteria do not have a grade reference for the quantitative hierarchy. There are several common situations that occur in the project acceptance and review phase: passing acceptance and review, passing acceptance and review after one or more rectifications, and never passing acceptance and review. To achieve feasibility and operability with regard to index scoring, the index will be quantified to improve the evaluation's objectivity and scientific basis.

23.5 Conclusion and Expectations

The problems of the performance index for a government investment project are obtained through a constrictive analysis. The problems are as follows: qualitative index is too many, the quantitative degree of the score criteria is insufficient, and key indexes that contain compliance and output situations are deficient. Therefore, a project governance method is used to optimize the ratio of quantity over qualitative characteristics, weight structure, etc. Improvements to the rationality and operability of the performance index for government investment projects are reflected in the following: a more detailed index definition, more specific score criteria, and a more rational weight of the key index. The key indexes in the common index contain the following: sufficiency of project establishment, budget controls and executive conditions, and project implementation. Building projects get through acceptance and review and total cost control of building projects will be as key index in infrastructure. Key index of Negotiation meeting contains immigration of negotiated enterprise and Management situation of introduced enterprise. Accomplishment degree of output will be as key index in other projects.

In the future, it will be feasible to analyse the similarities and differences of performance evaluation systems for government investment projects that are adopted by all levels of government in China. A transverse comparison will help to analyse the advantages and disadvantages of performance evaluation systems for investment projects sponsored by local Chinese governments. The goal is to build a performance evaluation system for government investment projects that has uniform standards. Using a project case demonstration, an index system with more effective content will be created.

References

Amaka O (2011) The critical success factors influencing project performance in Nigeria. Inter J Manag Sci Eng Manag 6(5):343–349

Bai JF (2010) Research on evaluation of agent construction project process performance and improvement of management performance[D]. Tianjing: Project Management, Tianjing University

Brooks MR, Pallis AA (2008) Assessing port governance models: process and performance components. Marit Policy Manag Flagship J Int Shipping Port Res 35(4):411–432

Du YL (2009) Research on the improvement of public project management performance based on project governance: positive study on enterprise agent construction project[D]. Project Management, Tianjing University, Tianjing

Gao XZ (2009) Research on public projects performance evaluation system and performance realization mechanism[D]. Tianjing: Technology Economics and Management, Tianjing university

Guilherme BBV, Francisco JKN, Fernando GA (2014) Governance, governance models and port performance: a systematic review. Transp Rev 34(5):645–662

Hu F (2012) Research on performance assessment system of large-scale public project[D]. Hu nan: Management Science and Technology, Hunan University

Hwang BG, Zhao XB (2015) Review of global performance measurement and benchmarking initiatives. Int J Constr Manag 15(4):265–275

Jerry CTW, HT Tsai, MH Shih, HH Fu (2008) Government performance evaluation using a balanced scorecard with a fuzzy linguistic scale. Serv Indus J 30(3):449–462

Jin XH, Doloi H, Gao SY (2007) Relationship-based determinants of building project performance in China. Constr Manag Econ 25(3):297–304

Li HM, David A, Wang ZF (2012) Transaction-related issues and construction project performance. Constr Manag Econ 30(2):151–164

Mei Z (2006) The new public management theory and its significance. Adm Tribune, 1:5–8

Michail K, Rachel C, Ghassan A (2001) Performance management in construction: a conceptual framework. Constr Manag Econ 19(1):85–95

Min R (2013) The study on the evaluation index of government investment project performance auditing[D]. Project Management, Huazhong University of Science and Technology, Wuhan

Mladen V, Mladen R (2013) The balanced scorecard and EFQM working together in a performance management framework in construction industry. J Civ Eng Manag 19(5): 683–695

Walkker DM (2003) The Oxford companion to law[M]. Translated by Li Shuangyuan. Beijing: Law Press, pp 990–991

Wu JN, Zhang L, Yan B, Liu J (2009) Design research on public project performance evaluation index system—basing on multidimensional framework of factors application. Proj Manag Technol 04:13–17

Yang XC (2012) Research on public investment project performance evaluation[D]. Chengdu: Taxation, Southwestern University of Finance and Economics

Yeung JFY, Chan APC, Chan DWM (2008) Establishing quantitative indicators for measuring the partnering performance of construction projects in Hong Kong. Constr Manag Econ 26 (3):277–301

Chapter 24
Analysis on the Influencing Factors of Building Energy Consumption—A Southwest China Case Study

Z.N. Zhao, H.M. Zhang, Y.F. Ding and L.Y. Shen

24.1 Introduction

With the advent of the 21st century, the Chinese government has transferred its national development policy from rapid-economic increase to harmonious development between human and nature. During the World Climate Conference in Copenhagen,based on United Nations Framework Convention on Climate Change, the Premier Wen Jiabao on behalf of China committed to the world that we would reduce 40–45% of carbon dioxide emissions per unit of GDP by 2020 compared with 2005.

As a responsible developing country, in order to achieve the goal, China attached great importance to reduce energy consumption in every sector. Building, industry and transportation are the major sectors responsible for energy consumption. According to the developed countries, with continuous development of industrial technology and improvement of people living standard, the energy consumption in industrial production has declined while the energy consumption in buildings and consumer traffic continue to rise (Wu et al. 2017). It was estimated by Tsinghua University Buildings Energy Conservation Research Center that the current total energy consumption in building construction in China accounts for nearly 20% of total national energy consumption (TUBECRC 2014; Shen et al. 2017). High consumption, high ratio to the total value,and long-term growth trend are main characteristics of energy consumption in building area. However, building sector has great potential and low abatement cost for saving energy, which is considered

Z.N. Zhao (✉) · H.M. Zhang · Y.F. Ding · L.Y. Shen
School of Construction Management & Real Estate,
Chongqing University, Shapingba Qu, China
e-mail: zhaozongnan@hotmail.com

Z.N. Zhao · H.M. Zhang · L.Y. Shen
International Research Centre for Sustainable Built Environment,
Chongqing University, Shapingba Qu, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_24

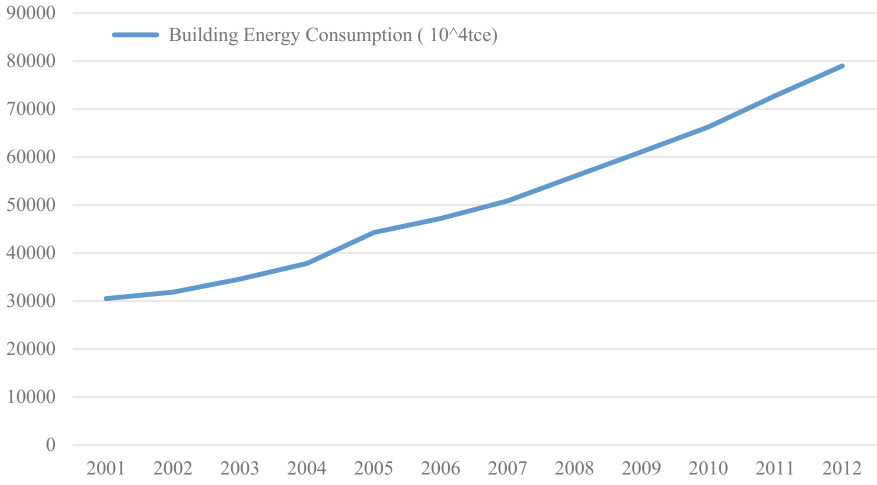


Fig. 24.1 Buildings energy consumption in China

as a key to inhibit energy consumption growth (Cai 2011). Meanwhile as building have longer life cycle, they have a long-term impact on the energy consumption. If it is not conducive to the energy efficiency and low-carbon emission in the new construction or renovation buildings, the inferior performance of these buildings will hinder the progress of the country towards low carbon development.

In the building sector in China, especially in Southwest region, the energy consumption maintains a rapid growth. From the Fig. 24.1, it can be seen that the energy consumption of the buildings in China in 2012 is 2.59 times of that in 2001. Energy consumption is mainly from using petroleum, diesel and other fuel consumption. In order to reduce the consumption, we should not only consider the consumption composition, but also the main influence factors on the energy consumption in building sector (Shuai et al. 2017). In the following discussion, factors related to buildings energy consumption are from the perspectives of population, economy and technology in Southwest China.

24.2 Research on Methods

In order to describe the methods used in this paper, several definitions need to be addressed.

24.2.1 Building Energy Consumption

Building energy consumption usually refers to the energy required to maintain the functions of residential building, mainly including air conditioning, electric appliances, lighting, cooking and hot water (Cai 2011). In China, there is no specific database about building energy consumption, but only as a link in the distribution of energy consumption between all section. At present, a majority of scholars agree with the view that the energy consumption in building mainly include tertiary industry and residential fields, which make up by two parts: public building energy consumption and residential building energy consumption. Therefore, building energy consumption can be expressed by the formula (24.1)

$$Y = Y_1 + Y_2 \tag{24.1}$$

Y Building energy consumption
Y_1 Public building energy consumption
Y_2 Residential building energy consumption

This study considers public energy consumption on 7 energy sources in tertiary industry including coal, gasoline, kerosene, diesel, liquefied petroleum (LPG) gas, natural gas and Electric from, while residential building energy consumption is on 5 sources including coal, kerosene, LPG Gas, natural gas and electric.

24.2.2 The Study Scope—Southwest China

Southwest China is one of seven Chinese traditional geographical divisions, the north by Northwest region and the east by South Coast region. It includes four provinces—Sichuan, Yunnan, Guizhou & Tibet—and a municipality—Chongqing. Based on national the policy of "The development of the western region in China", the region of Southwest China got rapid development in economics that the Per capita GDP has come to 5300 US$ in 2014, nearly 2 times of 2008. Because of less developed in education, technology, service, and culture areas than that in Eastern China,Southwest region still have problems of high energy input and low economic output. In addition, the difference among 4 provinces and 1 municipality is also obviously. However, without the energy consumption data in Tibet, this paper chooses Southwest China except Tibet as the research scope.

24.2.3 STIPRAT Model

The theory IPAT is a widely accepted theory that analyses human activity's impact on the environment (Signor et al. 2001), but it can only reflect the proportional influence among variables. To avoid this insufficiency, STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model is adapted from IPAT to be a random form, which can be expressed as (Li and Yuan 2014)

$$I = aP^{b}A^{c}T^{d}e \tag{24.2}$$

I	Environmental impact
P	Population factor
A	Affluence factor
T	Technology factor
a	Model coefficient
b/c/d	Coefficient of *P/A/T*
e	Random error term

Comparing with the IPAT, STIRPAT considered the disproportional influence between factors. From another point of view, IPAT model is a special form of STIRPAT mode, i.e., when $a = b = c = d = e = 1$ in the STIRPAT. As a multiple nonlinear model, STIRPAT in formula (24.2) can be transferred to linear formula as

$$LnI = Lna + bLnP + cLnA + dLnT + Lne \tag{24.3}$$

I	Environmental impact
P	Population factor
A	Affluence factor
T	Technology factor
a	Model coefficient
b/c/d	Coefficient of *P/A/T*
e	Random error term

In the formula (24.3), *LnI* is a dependent variable, while *LnP, LnA,* and *LnT* are independent variables, and *Lna* is a constant term, with *Lne* an error term. Therefore, we can utilize (3) to do multiple linear fitting process analysis. According to the concept of elasticity coefficient, when 1% change occur on factor of *P/A/T*, it will cause the variation of the dependent variable *I* in *b%/c%/d%* degree. As can be seen from above, STIRPAT model not only allows each coefficient as a parameter to estimate, but also allows various factors for proper decomposition. So, it was widely used in the environment influence analysis. This paper chooses formula (24.3) as the research foundation.

24.3 Analysis on Energy Consumption Influencing Factors for Urban Buildings

24.3.1 Analysis of Influencing Factors

There are many factors influencing building energy consumption that STIPRAT theory divided them into 3 groups: Group 1 is population factors such as population sizes, distribution of urban and rural population (urbanization ratio), age distribution structure; Group 2 is affluence factors including GDP, the tertiary industry GDP, CPI (Consumer Price Index), RPI (Retail Price Index), construction output; and Group 3 is technology factors such as patent numbers, energy saving technologies,university laboratory. Considering the data availability and effectiveness, this analysis choose the factors that most directly relevant with building energy consumption, including population size ($x_1/10^4$), urbanization ratio (x_2/%), Per Capita Value-added of Tertiary Industry at Constant Prices (VTP) ($x_3/10^4$ yuan, 2000 year base), CPI (x_4/2000 year base), RPI (x_5/2000 year base), and patent number (x_6).

There are two typical factors from population perspective, namely, population size and urbanization ratio.

With the size of the population continues to expand, the demand for energy resources will grow consistently, and the resulting environmental pressures will be intensified. Southeast China has a large amount of population, nearly 200 million, which is about 1/7 of the total China population (Shen et al. 2016). Pérez et al.'s study shows that carbon dioxide emissions have does association with population size (Pérez-Lombard et al. 2008). So, the population size is an impact factor to energy consumption research.

Urbanization is a historical stage during the progress of human civilization and social development. Urbanization has multiple effects on building energy consumption. On one hand, following the advance of urbanization and urban extensive construction, total urban construction grows rapidly. On the other hand, urbanization will promote development of tertiary industry, resulting in the growth of energy consumption in public buildings (Liu 2009).

There are mainly three factors affecting energy consumption from affluence perspective, namely, VTP (Per Capita Value-added of Tertiary Industry at Constant Prices), CPI (Consumer Price Index), and RPI (Retail Price Index).

The economic activity in tertiary industry generates energy consumption in the building sector (Zhang and Cheng 2009). According to the general principles of international energy statistics, tertiary industry related energy consumption can equal to the public building energy consumption. The rapid development of tertiary industry is bound to results in the growth of public building energy consumption. As population and economic inflation factors in examining tertiary industry must be excluded in using STPRAT mode, we use "Per Capita Value-added of Tertiary Industry at Constant Prices" as a factor under affluence perspectives in this paper.

CPI is to reflect changes in the living-related consumer goods and the level of services price of important macroeconomic indicators, it is also an important indicator of macroeconomic analysis. CPI is used to understand the basic situation of the country about the price changes, the analysis of the impact of price changes on the social and economic standards for residents (Asafu-Adjaye 2000). The changes of directly lead to rapid growth in energy consumption in buildings.

RPI is an index to reflect the change in retail prices of goods during a given period by a relative number and trend of changes. It indicates the purchasing behavior of consumers both in urban and rural areas. Retail price changes directly affect the expenditures of residents and the revenue of national government, i.e. the balance between market supply and demand. Therefore, the retail reflects the residential living standard. The growth of RPI directly drives the increase of energy consumption.

The typical energy consumption for technology perspective is patent number.

Technological advance represents the change of the way of energy consumption way. But there are few number of index to reflect the change of technological progress except patent. Increase in the number of patent represents the strong basis of science and technology. The more patents we have the more choices we will have to improve energy efficiency. There are three types of patent in China: invention patent, utility model patent and design patents. As there is little relation between design patent and energy consumption, this paper refers the patent number factor as the sum of invention patent and utility model patent.

24.3.2 Formula Analyzing the Impact Coefficients of Individual Factors

In the analysis of the impact of the factors affecting building energy consumption, the STPRAT theory its adopted. In using the model the impact coefficients of individual factors will be analyzed though using the following formula (York et al. 2003):

$$Lny = a + bLnx_1 + cLnx_2 + dLnx_3 + eLnx_4 + fLnx_5 + gLnx_6 \qquad (24.4)$$

y	Building energy consumption
x_1	Population size
x_2	Urbanization ratio
x_3	VTP (per capita value-added of tertiary industry at constant prices)
x_4	CPI (Consumer Price Index)
x_5	RPI (Retail Price Index)
x_6	Patent number
a	Model coefficient
$b/c/d/e/f/g$	Coefficient of factors

In the formula (24.4), the independent variables (Lnx_1, Lnx_2, Lnx_3, Lnx_4, Lnx_5, Lnx_6) and the dependent variable (Lny) are in linear form, and the regression coefficients (b, c, d, e, f, g) correspond to the degree of influence of the six variables.

24.4 Research Data

24.4.1 Data of Building Energy Consumption

As mentioned above, the building energy consumption, which consist of public building energy consumption and residential building energy consumption, must be calculated from published database. The data from Chongqing are used as example to conduct the analysis.

The data of energy consumption for both public and residential building employed in our analysis are based on the China Energy Statistical Yearbook. The data are about the consumption of coal, gasoline, kerosene, diesel, LPG Gas, natural gas and electricity in Chongqing for the period of 2004–2014. These data need to be converted into standards coal according to the "General Principles for Calculation of Total Production Energy Consumption". The public building energy consumption of Chongqing was shown in Table 24.1, while residential in Table 24.2.

The building energy consumption of Chongqing is abstained by adding up the values of the energy consumption of public and residential buildings which are presented in Tables 24.1 and 24.2. The results of the calculation on the total energy consumption in Chongqing are shown in Table 24.3.

After the calculated of Tables 24.1 and 24.2, adding up the in standards coal type, displayed in row 5 of Table 24.3.

Table 24.1 The public building energy consumption of Chongqing

Year	Coal (10^4 t)	Gasoline (10^4 t)	Kerosene (10^4 t)	Diesel (10^4 t)	LPG gas (10^4 t)	Natural gas (10^8 cu.m^3)	Electricity (10^8 kW h)	Standards coal (10^4 tce)
2004	1.85	14.58	0.01	3.62	0.00	0.30	14.63	55.25
2005	1.85	15.24	0.10	3.62	0.00	0.32	33.44	53.71
2006	2.24	15.67	0.10	3.71	3.00	2.57	44.55	42.08
2007	2.24	15.67	0.10	3.71	3.30	2.57	49.70	63.31
2008	15.20	17.07	0.10	3.72	3.32	2.67	54.30	131.99
2009	77.84	17.07	0.10	3.72	4.41	2.62	62.31	206.31
2010	86.16	19.92	0.00	4.71	5.45	3.31	75.26	221.35
2011	98.17	22.64	0.00	10.00	6.21	3.79	72.10	243.22
2012	104.70	30.00	0.00	6.04	7.51	4.22	96.98	311.89
2013	113.04	33.29	0.00	7.46	7.78	4.29	119.21	361.42
2014	49.04	37.13	0.00	9.23	9.54	4.29	126.44	370.97

Table 24.2 The residential building energy consumption of Chongqing

Year	Coal (10^4 t)	Kerosene (10^4 t)	LPG gas (10^4 t)	Natural gas (10^8 cu.m^3)	Electricity (10^8 kW h)	Standards coal (10^4 tce)
2004	171.77	1.93	0.00	6.50	53.56	407.80
2005	155.00	1.93	0.00	8.00	60.90	441.61
2006	155.00	1.90	4.21	8.00	76.47	502.76
2007	150.00	1.90	4.26	8.00	74.99	487.84
2008	172.34	2.14	4.40	8.05	84.99	532.35
2009	173.02	2.14	4.69	8.10	94.41	559.12
2010	195.23	2.24	5.49	8.20	98.57	576.32
2011	196.37	2.46	6.25	10.12	119.27	667.44
2012	194.09	2.62	7.00	20.55	123.42	814.58
2013	90.98	2.57	7.25	15.77	140.68	729.03
2014	48.08	3.27	9.06	20.11	136.54	747.35

Table 24.3 The building energy consumption of Southwest China

Year	Southwest China (10^4 tce)	Sichuang (10^4 tce)	Yunnan (10^4 tce)	Guizhou (10^4 tce)	Chongqing (10^4 tce)
2004	4083.94	1716.52	544.55	1351.76	471.12
2005	4267.58	1605.76	710.36	1377.86	573.60
2006	4250.58	1552.43	692.41	1296.67	709.07
2007	4583.31	1833.73	692.05	1348.33	709.19
2008	5141.48	1997.66	778.45	1589.80	775.57
2009	5667.88	2152.09	936.15	1708.62	871.01
2010	6119.76	2332.94	969.80	1879.28	937.74
2011	6744.38	2660.69	1048.49	1996.79	1038.41
2012	7581.17	2891.60	1196.63	2222.73	1270.22
2013	7786.21	2622.33	1238.77	2664.20	1260.92
2014	8436.49	2831.89	1461.10	2885.38	1258.12

The similar calculations on the total building energy consumption for other four provinces in Southwest China are conducted, and the results are also shown in Table 24.3.

The same as Chongqing, the data of building energy consumption of Southwest China and provinces are listed in Table 24.3.

24.4.2 *Data of Influencing Factors*

The data about the values of the six independent influencing factors for the five provinces in Southwest region are obtained based on China Statistical Yearbook both directly and indirectly. In using SPTRAT model, the data about population size (x_1), urbanization ratio (x_2), VTP (x_3), CPI (x_4), RPI(x_5), patent number (x_6) for Southwest China and provinces are collected and shown in Table 24.4.

Table 24.4 Data of influencing factors

	Year	Population size ($x_1/10^4$)	Urbanization ratio (x_2/%)	VTP ($x_3/10^4$ yuan, 2000 year base)	CPI (x_4/2000 year base)	RPI (x_5/2000 year base)	Patent number (x_6)
Southwest China	2004	19,202	31.2	0.194	107.1	101.9	5163
	2005	19,190	32.8	0.200	108.6	102.3	5731
	2006	19,150	33.9	0.206	110.8	103.6	7595
	2007	19,089	35.1	0.216	117.3	108.4	10,440
	2008	19,116	36.7	0.228	124.1	114.7	12,552
	2009	19,152	37.9	0.230	124.0	113.9	15,635
	2010	19,010	39.6	0.241	128.1	117.2	27,830
	2011	19,069	41.4	0.262	134.7	122.9	32,121
	2012	19,164	43.3	0.277	138.2	125.2	48,530
	2013	19,266	44.6	0.297	142.0	127.6	58,605
	2014	19,353	46.1	0.305	144.8	128.8	61,063
Sichuan	2004	8090	31.1	0.206	108.6	104.0	2405
	2005	8212	33.0	0.207	110.4	104.6	2561
	2006	8169	34.3	0.213	113.0	106.4	3320
	2007	8127	35.6	0.222	119.6	112.0	4848
	2008	8138	37.4	0.233	125.8	118.0	6381
	2009	8185	38.7	0.235	126.8	118.1	8157
	2010	8045	40.2	0.251	130.8	121.6	14,928
	2011	8050	41.8	0.263	137.7	127.2	15,803
	2012	8076	43.5	0.276	141.2	129.3	24,125
	2013	8107	44.9	0.290	145.1	131.5	29,296
	2014	8140	46.3	0.305	147.5	132.3	29,742
Yunnan	2004	4287	24.9	0.172	99.1	98.4	775
	2005	4333	26.0	0.170	98.9	96.5	605
	2006	4376	26.6	0.171	100.1	96.4	700
	2007	4415	28.1	0.176	106.1	101.0	821
	2008	4450	29.5	0.181	107.6	101.1	869
	2009	4483	30.5	0.186	109.6	101.9	1044
	2010	4514	31.6	0.200	116.1	106.4	1385
	2011	4543	33.0	0.210	122.7	112.8	1421
	2012	4571	34.0	0.210	123.2	113.0	1814
	2013	4602	34.7	0.215	127.8	117.0	2678
	2014	4631	36.8	0.244	134.0	123.0	3223

(continued)

Table 24.4 (continued)

	Year	Population size ($x_1/10^4$)	Urbanization ratio (x_2/%)	VTP ($x_3/10^4$ yuan, 2000 year base)	CPI (x_4/2000 year base)	RPI (x_5/2000 year base)	Patent number (x_6)
Guizhou	2004	3799	24.0	0.096	101.8	98.4	399
	2005	3837	24.3	0.098	100.8	97.7	381
	2006	3870	24.8	0.103	102.0	97.7	434
	2007	3904	26.3	0.108	106.1	100.8	543
	2008	3730	26.9	0.118	107.1	102.1	695
	2009	3690	27.5	0.125	109.0	103.1	1050
	2010	3632	28.2	0.139	115.9	107.4	1353
	2011	3596	29.1	0.153	124.7	115.1	1453
	2012	3537	29.9	0.157	123.1	112.4	1556
	2013	3479	33.8	0.164	126.7	115.7	2377
	2014	3469	35.0	0.181	133.1	122.1	2481
Chongqing	2004	2793	43.5	0.310	105.7	98.8	1394
	2005	2798	45.2	0.323	106.5	97.5	1606
	2006	2808	46.7	0.326	109.1	99.1	2181
	2007	2816	48.3	0.321	114.2	102.7	2854
	2008	2839	50.0	0.336	120.6	107.9	3297
	2009	2859	51.6	0.336	118.7	105.0	4108
	2010	2885	53.0	0.345	122.5	106.7	7847
	2011	2919	55.0	0.387	129.0	111.8	10,614
	2012	2945	57.0	0.425	132.3	113.5	15,858
	2013	2970	58.3	0.498	135.9	115.6	18,983
	2014	2991	59.6	0.503	138.3	116.6	18,206

24.5 Multiple Linear Regression Analysis

By using the data in Tables 24.3 and 24.4, the calculations of the formula (4) can be conducted by results of calculations are:

$$a = -25.623$$
$$b = 2.810$$
$$c = 0.419$$
$$d = 0.272$$
$$e = 0.414$$
$$f = 0.580$$
$$g = 0.069$$

Therefore, the regression formula (24.4) in Southwest China can be written as:

$$Lny = -25.623 + 2.810Lnx_1 + 0.419Lnx_2 + 0.272Lnx_3 + 0.415Lnx_4 + 0.580Lnx_5 + 0.069Lnx_6 \quad (24.5)$$

The significance level of the six factors are determined by the values of parameters Beta(unstandardized coefficient), which are *5.2, 20.5, 16.1, 16.8, 19.3, 23.7%* respectively x_1, x_2, x_3, x_4, x_5, and x_6.

Calculations are conducted for all five provinces, and the results are shown in Table 24.5.

In the Ridge regression model results, from the year 2004 to 2014, the degree (row Beta) of factors' influences about building energy consumption can be put in order as patent number (x_6/23.7%), urbanization ratio (x_2/20%), RPI (x_5/19.3%), CPI (x_4/16.8%), VTP (x_3/16.1%), population size (x_1/5.2%), In this period, the elasticity coefficient of every independence variable are 2.810,0.419,0.272,0.415, 0.580 and 0.069.

24.6 Discussion

Based on the above analysis, this research found that, in southwest China, all the six factors from the three perspectives (Population, Affluence, and Technology) can affect energy consumption; Among those factors, the patent number, followed by the urbanization ratio, has the highest influence on building energy consumption; The factors in the affluence perspective (i.e., VTP/CPI/RPI) have impact to certain extent. The population size has little impact on building energy consumption.

In referring to the perspective of population, the urbanization ratio has greater influence on building energy consumption than that from the population size in southwest China. The average influence degree of urbanization is around 0.2, almost 4 times that of the population size. As for Chongqing and Guizhou in particular, the influence degree of urbanization exceeds 0.25. As shown in Table 24.5, the analysis results on the coefficients of population size factors are invalid in Sichuan and Yunnan due to the irregular change of the population size in those two provinces, and therefore, the model cannot produce reasonable results.

When it comes to the affluence perspective, CPI and RPI have greater influence than the on building energy consumption value of VTP, indicating that consumers' behavior can have larger impact than the tertiary industry. In other words, consumers' behavior can directly influence energy consumption. In addition, the influence of CPI and RPI vary in different provinces. CPI has a greater influence than RPI in Chongqing, while the opposite was observed in the other provinces. Considering Chongqing is the only municipalities in southwest China, its regional planning may be different from that in other four provinces.

Table 24.5 Multiple linear regression

		B[a] (unstandardized coefficient)	Beta[a] (unstandardized coefficient)
Southwest China	*x1*	2.81011804	0.05209761
	x2	0.41936956	0.20573684
	x3	0.27155851	0.16097249
	x4	0.4145038	0.16847208
	x5	0.57953074	0.19314477
	x6	0.06862558	0.23765788
	Constant	−25.62251548	0
Sichuan	*x1*	–[b]	–
	x2	0.13131996	0.074774677
	x3	0.258938972	0.15470514
	x4	0.421144469	0.200946577
	x5	0.700235985	0.278345568
	x6	0.057043697	0.238006732
	Constant	1.658139174	0
Yunnan	*x1*	–[b]	–
	x2	0.508869483	0.311611194
	x3	0.041332827	0.038109308
	x4	0.420228977	0.18949663
	x5	0.582646138	0.208504343
	x6	0.04756939	0.158217406
	Constant	0.681635844	0
Guizhou	*x1*	1.181965667	0.109218839
	x2	0.318699148	0.165573215
	x3	0.310442278	0.15650578
	x4	0.261922841	0.110666023
	x5	0.474695332	0.164079107
	x6	0.100800734	0.257582177
	Constant	−8.08801826	0
Chongqing	*x1*	1.78761474	0.10713954
	x2	0.70137037	0.25998678
	x3	0.04780242	0.02314171
	x4	0.79621054	0.22593316
	x5	0.76065663	0.12941478
	x6	0.07615153	0.22352557
	Constant	−18.23124514	0

[a]Row B is the unstandardized regression coefficient, and row Beta is standardized regression coefficient

[b]Because of the negative regression coefficients got from the SPSS 23.0, which don't fit for the economic significance test, the research abnegates variable population size (x_1) and just calculate the influence of rest factors

Furthermore, from technology perspective, the increase in the patent number should indicate technological development, but the analysis results shown an increase of the energy consumption increases. This result may be attributed to the method used for defining the calculation in this research. In the traditional IPAT model, technology factors often play a denominator role in the formula; however, this research shows that the influence of technology on building energy consumption cannot be ignored.

When comparing the results in each province against the whole region of southwest China, the authors found that Yunnan has the closest results to average value of the whole region, where patent number is the most significant factor and the population is the least. On this basis, the authors assert that Yunnan can be used as a representative to research the building energy consumption of Southwest China.

24.7 Conclusion

The results from this study shows that the patent number is the most significant factor to the building energy consumption. In addition, the three factors under the affluence perspective can also have great influence to building energy consumption. It can be observed CPI and RPI play important roles on energy consumption than VTP in affluence perspective. However, the population perspective has little effect on building energy consumption because of the rapid population growth. As to population perspectives, the factor of urbanization ratio is obviously more influential to energy consumption than population size. The finding from this study will help further research investigate the changing trend of building energy consumption.

Acknowledgements This research was supported by a grant from the Project of National Social Science Foundation of China (No. 15BJY038).

References

Asafu-Adjaye J (2000) The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Econ 22(6):615–625

Cai W (2011) Analyzing impact factors of building energy consumption: modeling and empirical study. Chongqing University

Li G, Yuan Y (2014) Impact of regional development on carbon emission: empirical evidence across countries. Chin Geogra Sci 24(5):499–510

Liu Y (2009) Exploring the relationship between urbanization and energy consumption in China using ARDL (autoregressive distributed lag) and FDM (factor decomposition model). Energy 34(11):1846–1854

Pérez-Lombard L, Ortiz J, Pout C (2008) A review on buildings energy consumption information. Energy Build 40(3):394–398

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Signor R, Westphal FS, Lamberts R (2001, August). Regression analysis of electric energy consumption and architectural variables of conditioned commercial buildings in 14 Brazilian cities. In: Seventh international IBPSA conference, Rio de Janeiro, Brazil, pp 1373–1379

TUBECRC (2014) 2014 Annual report on China energy building energy efficiency. Architecture and Building Press, Beijing

Wu Y, Chen J, Song X, Shen L (2017) Relationship between the energy consumption for urban residential buildings and residents' living standards—a case study of the four municipalities in China. In: Proceedings of the 20th international symposium on advancement of construction management and real estate, Singapore: Springer, pp 1229–1238

York R, Rosa EA, Dietz T (2003) STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. Ecol Econ 46(3):351–365

Zhang XP, Cheng XM (2009) Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 68(10):2706–2712

Chapter 25
Analysis on the Influencing Factors of Multidimensional LMDI Energy Consumption—A Case Study of Chongqing

H.M. Zhang, Z.N. Zhao, L.Y. Shen, W.W. Wen and M. Chen

25.1 Introduction

Energy is the most basic driving force for the development of economic growth and social development, and it is the foundation of human survival (Su et al. 2006). The sustainable development of society can not be separated from the healthy development of energy resources. Since the Reform and Opening-up, the Chinese economic development has made a great achievement. In 2014, China's total economic output exceeded 10 trillion U.S. dollars, ranking second in the world. In the same year, China was the world's largest consumer of energy resources, her energy consumption accounting for 23% of global consumption, and 61% of the global net growth (BP 2015).

In China, coal consumption has been the center of the energy consumption structure. In the past years, China has been promoting Green Road. Development by using renewable energy such as nuclear power, wind power, solar power. However, the share of fossil fuels in energy consumption was still up to 88.8%. Fossil energy is non-renewable resource (Ma and Li 2014). At the same time, the use of these fossil fuels produces a large amount of sulfur dioxide, nitrogen oxides,

H.M. Zhang (✉) · Z.N. Zhao · L.Y. Shen
School of Construction Management & Real Estate,
Chongqing University, Chongqing Shi, China
e-mail: 20140313044@cqu.edu.cn

H.M. Zhang · Z.N. Zhao · L.Y. Shen
International Research Centre for Sustainable Built Environment,
Chongqing University, Chongqing Shi, China

W.W. Wen
School of Electronic Engineering, Qingdao Huanghai College, Qingdao, China

M. Chen
School of Educational Science, Chongqing Normal University, Chongqing Shi, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_25

carbon dioxide, soot and other pollutants, which cause environmental pollution (Li et al. 2015; Shen et al. 2016, 2017).

During the "Twelfth Five-Year Plan" period, China's energy consumption increased from 34.8 million tons of standard coal to 43.0 billion tons of standard coal, an average annual growth rate of 4.7%. In order to ensure China's energy security, release the pressure on resource demands and the environment, the outline of Chinese 13th Five-Year Plan for economic and social development planned in 2016 "total energy consumption would be controlled in the 5 billion tons of standard coal".

At present, the task of saving energy and reducing energy consumption is still arduous, so how to effectively save energy? Only the correct factors analysis on energy consumption growth can help identify right measures for the total energy consumption and enhancing the efficiency of saving energy to achieve the target of energy consumption control.

Domestic study on energy consumption began in 1980s, and they focused on the relationship between energy consumption and economic growth on the initial stage. Currently, the study has been shifted to the analysis on the factors affecting the energy consumption in order to develop effective measures for energy-saving and emission reduction (Yang and Cheng 2016). Xiaotian Wang used IPAT (Impacts of Population, Affluence and Technology) model to find influencing factors for energy consumption in Henan Province, and the study revealed that economic development was the main factor contributing to the growth of total energy consumption, and technical progress played the important in energy saving (Wang et al. 2016). Wenxian Jiao used STIRPAT (Stochastic Impacts Population and Affluence and Technology) model to analyze energy consumption in Gansu Province, and the result showed that increasing affluence and urbanization progress leaded to increase of energy consumption (Jiao 2012).

LMDI (Logarithmic Mean Divisia Index) model is classical model to analyze energy consumption influencing factors. It can not only find what factors work on energy consumption, but also reflect the degree and direction of the various influencing factors for the energy consumption. In using the model in early stage, there are three main factors: output effect, structural effect and energy intensity effect (Zhao et al. 2013; Li et al. 2012; Su 2016; Ma and Cui 2012; Shuai et al. 2017; Wang and Li 2012; Yue 2010). In further development, scholars begin to consider the impacts of other factors on energy consumption. For examples, Wang Yanqiu selected four factors: energy structure, industrial structure, per capita GDP and population size to calculate the impact of various factors on China's energy consumption growth (Yanqiu et al. 2014). Teng Fei choosed five factors: economic scale, energy consumption of per unit output, per capita energy consumption, population density and energy space support to analyze the impacts in 32 mega cities during 1996 and 2010 (Tengfei et al. 2013). Zhou Guofu selected six aspects, including energy consumption structure, non-industrial energy intensity, proportion of GDP, capital productivity, average capital of labor and employment (Zhou and Zhao 2012). Yan Fashan choosed seven aspects, consisting of the energy structure, energy intensity, industrial structure, average productivity of capital, capital stock, per capita income of residents, residents scale (Yan and Wu 2011).

The application of LMDI model in the above researches mainly focuses on the impact of technological progress, industrial structure, energy consumption structure, energy intensity on energy consumption. But, there are still two aspects worthy to further explore: (1) The urbanization on energy consumption, urbanization rate is an important factor which has not been reflected in existing LMDI model. In fact, many scholars' studies show that urbanization rate has a great impact on energy consumption. Wen and Tao (2015) pointed out that the urbanization as a way of intensive development, has the aggregation effect and scale effect on improvement of energy efficiency and promotion of efficient energy utilization technology, in a certain extent, its growth can reduce energy consumption; On the other hand, Hongwu (2013) believed that the energy consumption in urban area was significantly greater than that in rural area. At present, whether the impact of urbanization rate on energy consumption is positive or negative is not yet conclusive (Yeh 2012). (2) The past studies mainly focused on studying energy consumption factors from sectoral perspectives or the type of energy consumption, few studies have analyzed the energy consumption factors from the industry perspective. China is in the process of industrial restructure adjustment, so it is very important to analyze the impact on energy consumption from the industrial perspective.

Chongqing is the economic center of the West of China, and its GDP growth rate has been ranked first among all the provinces in the country for 2 consecutive years. At the same time, Chongqing's high-speed economic development has led to the rapid growth of energy consumption. In 2014, Chongqing's energy consumption growth rate was 6.1%, while the national average energy consumption growth rate was 2.6%. High economic growth accompanied by the high energy consumption in Chongqing is an indisputable fact, and the economic growth model which heavily depends on energy consumption is considered to have a long-term negative impact on the cities sustainable development. In addition, a large number of pollutants produced by energy consumption is also the main cause of poorly environmental quality in Chongqing (Rui and Li 2013). Based on this, in 2016, Chongqing municipal government's "National Economic and Social Development of The 13th Five-Year Plan" clearly put forward "proper control total energy consumption" in the following five years.

Through adding the two factors of urbanization rate and industrial structure, this paper updates the LMDI energy consumption influencing factor analysis method. A multidimensional LMDI model is proposed, including five factors: urbanization rate, industrial structure, economic growth, technological progress and scale of the population. The influence degree of these factors on the energy consumption in Chongqing will be analyzed, according to the data collected from 1997 to 2013. The research result can be helpful for decision-maker when formulating the policy about reducing energy consumption. The research result can also provide references for the study of energy consumption in other regions of China.

25.2 Multi Dimensional Decomposition Model for Energy Consumption

The factor decomposition model can be divided into many types, and whether having residual error is the primary condition to determine the decomposition model is scientific or not (Chen 2003). At present, it is widely believed that the logarithmic mean divisia index (LMDI) model is a scientific decomposition model with zero residual error, which has the advantages of simple calculation, mature theory and wide application.

In applying the LMDI model, the following formula will be constructed based on the principle of Kaya identity.

$$E_{\mathrm{t}} = \sum_{i=1}^{3} E_{it} = \sum_{i=1}^{3} \frac{E_{it}}{g_{it}} \times \frac{g_{it}}{g_t} \times \frac{g_t}{p_t'} \times \frac{p_t{}'}{p_t} \times p_t \tag{25.1}$$

E_t energy consumption in the year of t
E_{it} energy consumption of the industry i in the year of t
g_{it} GDP of the industry i in the year of t
g_t total GDP in the year of t
p_t' urban residential population in the year of t
p_t the total population in the year of t.

Secondly, in order to facilitate the calculation, the following expressions are introduced:

$$\frac{E_{it}}{g_{it}} = e_{it}, \frac{g_{it}}{g_t} = s_{it}, \frac{g_t}{p_t'} = a_t, \quad \frac{p_t{}'}{p_t} = u_t,$$

Accordingly, formula (25.1) can be rewritten as

$$E_{\mathrm{t}} = \sum_{i=1}^{3} e_{it} \times s_{it} \times a_t \times u_t \times p_t \tag{25.2}$$

e_{it} denotes the energy intensity of the industry i in the year of t, representing the technical progress factor; s_{it} denotes the proportion of the GDP of industrial i to the total industry GDP in the year of t, representing the industrial structure factor; a_t denotes per capita GDP of urban residential population, representing economic growth factor; u_t is the urbanization rate in the year t, representing urbanization factor; and p_t represents the total population in the year of t, representing the population scale factor.

Formula (25.2) reveals that energy consumption in the year of t is influenced by the technical progress factor (e_{it}), the industrial structure factor (s_{it}), economic growth factors (a_t), urbanization (u_t), and scale of population factor (p_t). In other words, the change of energy consumption is due to the effects of five different factors: e_{it}, s_{it}, a_t, u_t, p_t.

The difference of energy consumption between the year of t (target year) and the year of 0 (base year) is the total effect ΔE:

$$\begin{aligned}\Delta E_t = E_t - E_0 &= \sum_{i=1}^{3} e_{it} \times s_{it} \times a_t \times u_t \times p_t - \sum_{i=1}^{3} e_{i0} \times s_{i0} \times a_0 \times u_0 \times p_0 \\ &= \Delta E_t^e + \Delta E_t^s + \Delta E_t^a + \Delta E_t^u + \Delta E_t^p\end{aligned} \tag{25.3}$$

$\Delta E_t^e, \Delta E_{\mathrm{t}}^s, \Delta E_t^a, \Delta E_{\mathrm{t}}^u, \Delta E_{\mathrm{t}}^p$ denotes the contribution of technological progress, industrial structure, economic growth, urbanization, and population scale on energy consumption growth in the period of 0 to t.

According to the decomposition method of the LMDI, the expressions in formula (25.3) are defined as follows:

$$\Delta E_t^e = \sum_{i=1}^{3} \frac{E_{it} - E_{i0}}{\ln E_{it} - \ln E_{i0}} \times \ln \frac{e_{it}}{e_{i0}}, \tag{25.4}$$

$$\Delta E_t^s = \sum_{i=1}^{3} \frac{E_{it} - E_{i0}}{\ln E_{it} - \ln E_{i0}} \times \ln \frac{s_{it}}{s_{i0}}, \tag{25.5}$$

$$\Delta E_t^a = \frac{E_t - E_0}{\ln E_t - \ln E_0} \times \ln \frac{a_t}{a_0}, \tag{25.6}$$

$$\Delta E_t^u = \frac{E_t - E_0}{\ln E_t - \ln E_0} \times \ln \frac{u_t}{u_0}, \tag{25.7}$$

$$\Delta E_t^p = \frac{E_t - E_0}{\ln E_t - \ln E_0} \times \ln \frac{p_t}{p_0} \tag{25.8}$$

In order to determine the contribution of these five factors on energy consumption, the following parameter will be evaluated:

$$\eta_t^e = \frac{\Delta E_t^e}{\Delta E_t}, \tag{25.9}$$

$$\eta_t^s = \frac{\Delta E_t^s}{\Delta E_t}, \tag{25.10}$$

$$\eta_t^a = \frac{\Delta E_t^a}{\Delta E_t}, \tag{25.11}$$

$$\eta_t^u = \frac{\Delta E_t^u}{\Delta E_t}, \tag{25.12}$$

$$\eta_t^p = \frac{\Delta E_t^p}{\Delta E_t}; \tag{25.13}$$

25.3 Data Collection and Processing

According to “Chongqing Statistical Yearbook”, energy consumption consists of three aspect: terminal energy consumption, energy consumption on input-output during processing and conversion stage, and the amount of loss. Chongqing’s terminal energy consumption includes two major categories: productive energy consumption and living energy consumption. The chosen object of the research is the terminal energy consumption of the productive energy consumption in Chongqing, mainly considering the following three reasons: (1) the living energy consumption has no corresponding GDP value of life, the energy consumption for living is not involved in the study; (2) energy consumption is examined from the perspective of industrial structure. This is important as industrial structure is under reform in Chongqing; (3) The energy consumption on production is much larger than that for living. In fact, energy consumption on production accounts for 90% of terminal energy consumption. This can be seen in Fig. 25.1. The change trend of productive energy consumption determines the change trend of energy

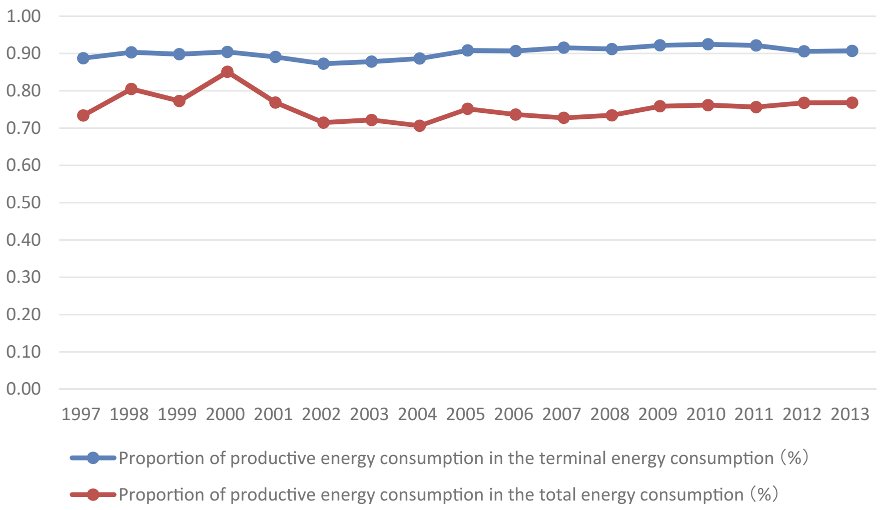


Fig. 25.1 Productive energy consumption from 1997 to 2013

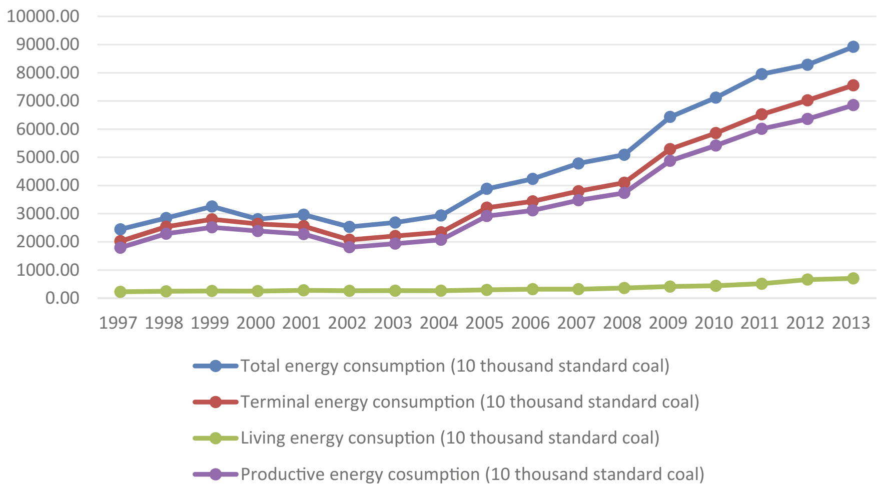


Fig. 25.2 Changing trend of productive energy consumption and the other types of energy consumption from 1997 to 2013

consumption. This can be seen in Fig. 25.2. So, this study investigates the influencing factors of productive energy consumption.

In the paper, original data are collected from "Chongqing Statistical Yearbook" in the period of 1998–2014. In order to eliminate the impact of the price, the GDP of the year from 1998 to 2013 have been converted to the comparable date based on the price of year 1997. The data about energy consumption of three industries are selected from the comprehensive energy balance table in the Yearbook for 1998–2014. Among the three industries, energy consumption of first industry includes five departments, including agriculture, forestry, animal husbandry, fishery, and water conservancy industry. Energy consumption of second industry is composed by industry and construction industry. The third industry's energy consumption consists of transportation, storage and postal, wholesale, retail, accommodation, catering industry, and other industries. The raw data of the relevant variables to be used in the LMDI model are shown in Table 25.1.

25.4 Analysis on Effects of the Influencing Factors on Energy Consumption in Chongqing

In recent years, Chongqing has achieved rapid development. With the growth of economy and the increase of consumption level, the contradiction between energy supply and demand is increasing. Similarly, the pressure to save energy and protect ecological environment is increasing. However, industrialization will still play the leading role for economic and social development for Chongqing in the following

Table 25.1 .

t	E_{1t} (unit: 10,000 tons of standard coal)	E_{2t} (unit: 10,000 tons of standard coal)	E_{3t} (unit: 10,000 tons of standard coal)	g_{1t} (unit: 100 million RMB)	g_{2t} (unit: 100 million RMB)	g_{3t} (unit: 100 million RMB)	g_t (unit: 100 million RMB)	p'_t (unit: 10,000 people)	p_t (unit: 10,000 people)
1997	145.87	1543.94	105.00	307.21	650.40	552.14	1509.75	890.74	2873.36
1998	179.10	1973.16	138.74	313.66	697.23	629.44	1640.33	935.86	2870.75
1999	184.14	2211.36	119.69	314.92	771.14	677.28	1763.33	981.11	2860.37
2000	180.03	2042.33	163.81	319.32	854.42	738.91	1912.65	1013.88	2848.82
2001	181.32	1926.92	168.87	326.35	958.66	805.41	2090.42	1058.12	2829.21
2002	190.86	1445.33	173.42	340.06	1095.74	877.09	2312.89	1123.12	2814.83
2003	190.76	1574.03	173.77	355.02	1277.64	956.03	2588.69	1174.55	2803.19
2004	163.93	1558.81	351.27	372.06	1493.56	1049.72	2915.34	1215.42	2793.32
2005	194.79	2324.42	397.30	388.80	1692.20	1176.74	3257.74	1265.95	2798.00
2006	217.33	2429.90	469.99	367.42	1981.57	1332.07	3681.06	1311.29	2808.00
2007	222.74	2698.04	556.81	402.32	2395.72	1493.25	4291.29	1361.35	2816.00
2008	224.21	2888.79	624.61	429.68	2831.74	1675.42	4936.84	1419.09	2839.00
2009	228.73	3983.74	664.70	453.31	3338.62	1901.61	5693.54	1474.92	2859.00
2010	258.43	4359.64	800.39	480.97	4096.48	2137.41	6714.86	1529.55	2884.62
2011	279.02	4862.23	869.91	505.50	4989.52	2368.25	7863.26	1605.96	2919.00
2012	310.30	5010.62	1038.45	532.29	5767.88	2652.44	8952.60	1678.11	2945.00
2013	325.61	5371.50	1153.37	557.30	6540.78	2978.68	10,076.77	1732.76	2970.00

Note The data in the table are collected from Chongqing Statistical Yearbook during the period of 1998 to 2014, and GDP values for the first, second and third industry have been converted to the equivalent value in price of 1997 five years. There is no doubt that Chongqing will face more challenges. Consequently, it is necessary to quantitatively analyze the influencing factors on energy consumption in Chongqing in order to provide references for studying measures to control energy consumption.

The proposed LMDI model is used in this paper to analyze energy consumption factors for Chongqing. In the period of 1997–2013, the annual effects of the five factors on energy consumption are calculated, including the effects of economic growth, technical progress, urbanization, industrial structure, and the scale of population. This can be seen in Table 25.2 and Fig. 25.3. Based on the above analysis results of the factor's taking 1997 as the base year, cumulative effects can be obtained by adding the effects for individual years, which can be seen in Table 25.3 and Fig. 25.4. At the same time, the cumulative contribution of each factor to the change of energy consumption during the 16 year from 1998 to 2013 is calculated, and this can be seen in Fig. 25.5. Among the five types of effects, economic growth effect is due to the change of energy consumption influenced by growth of per capita income of urban resident population. Technical progress effect is because of the change brought by the decrease of energy consumption per unit output value. Urbanization effect is the change due to the increase of urbanization rate. Industrial effect is the change due to industrial restructure. And population scale effect is the results of the change of the the total population.

As shown in Table 25.2 and Fig. 25.3, the annual effects of factors on energy consumption are fluctuant. Nevertheless, the general trend is that the technical

Table 25.2 The annual effects of five factors on energy consumption from 1998 to 2013 for Chongqing

t	$\Delta E_t^e(t)$	$\Delta E_t^s(t)$	$\Delta E_t^a(t)$	$\Delta E_t^u(t)$	$\Delta E_t^p(t)$	$\Delta E_t(t)$
1998	355.30	−27.74	68.18	102.30	−1.85	496.20
1999	3.45	47.16	60.24	122.07	−8.70	224.23
2000	−361.80	33.76	118.66	91.14	−9.91	−128.15
2001	−355.72	39.49	107.62	114.99	−16.10	−109.73
2002	−713.57	40.58	84.47	131.64	−10.37	−467.25
2003	−125.94	43.87	127.16	91.62	−7.76	128.95
2004	−141.02	39.32	169.73	75.16	−7.07	136.11
2005	552.65	15.68	173.77	94.74	4.14	840.99
2006	−216.48	48.83	262.30	98.46	10.76	203.87
2007	−204.28	59.42	381.86	110.97	9.37	357.34
2008	−289.50	44.20	355.56	124.74	29.33	264.33
2009	484.80	44.70	445.42	134.88	30.06	1139.86
2010	−411.33	104.15	661.50	137.68	45.88	537.88
2011	−414.68	105.95	623.10	211.49	67.65	593.51
2012	−490.41	36.53	530.54	220.87	54.83	352.36
2013	−303.02	13.22	569.35	148.88	55.81	484.24

Unit 10,000 tons of standard coal

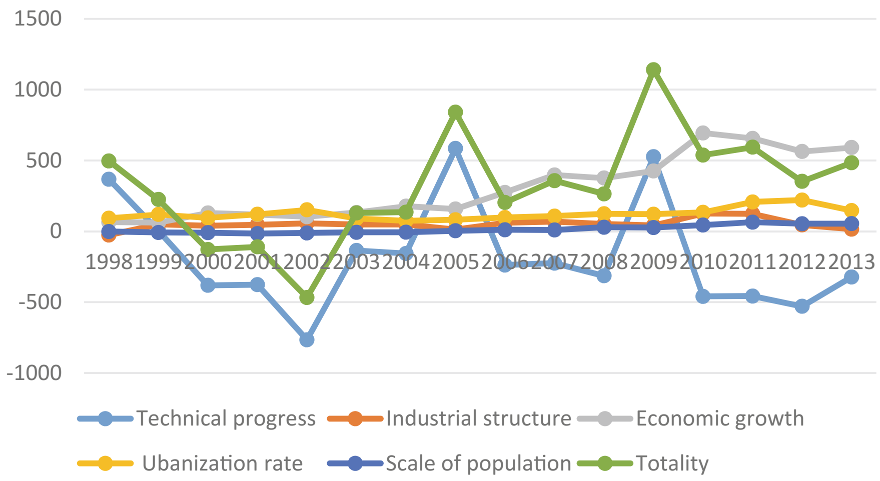


Fig. 25.3 Annual effects of factors on energy consumption for Chongqing from 1998 to 2013

Table 25.3 Cumulative effects of five factors on energy consumption from 1998 to 2013 for Chongqing

t	$\Delta E_t^e(t)$	$\Delta E_t^s(t)$	$\Delta E_t^a(t)$	$\Delta E_t^u(t)$	$\Delta E_t^p(t)$	$\Delta E_t(t)$
1998	355.30	−27.74	68.18	102.30	−1.85	496.20
1999	358.75	19.42	128.42	224.37	−10.55	720.42
2000	−3.05	53.18	247.09	315.51	−20.46	592.28
2001	−358.77	92.67	354.71	430.50	−36.56	482.55
2002	−1072.33	133.25	439.17	562.14	−46.93	15.30
2003	−1198.27	177.13	566.33	653.76	−54.69	144.26
2004	−1339.29	216.45	736.06	728.92	−61.77	280.37
2005	−786.64	232.12	909.83	823.66	−57.63	1121.35
2006	−1003.12	280.95	1172.13	922.12	−46.87	1325.22
2007	−1207.40	340.37	1553.99	1033.09	−37.50	1682.56
2008	−1496.90	384.57	1909.55	1157.83	−8.16	1946.89
2009	−1012.09	429.27	2354.97	1292.71	21.90	3086.75
2010	−1423.43	533.41	3016.47	1430.39	67.78	3624.64
2011	−1838.11	639.37	3639.58	1641.89	135.43	4218.15
2012	−2328.51	675.89	4170.11	1862.75	190.26	4570.51
2013	−2631.54	689.12	4739.46	2011.63	246.07	5054.74

Unit 10,000 tons of standard coal

growth has positive effect on the decrease of energy consumption for most of the years surveyed, and that of the remaining factors have positive contribution the increase of energy consumption for most of the years surveyed. The above fact has been apparently evidenced by Table 25.3 and Fig. 25.4. From the perspective of cumulative effects, the technological growth is the only factor which plays a role

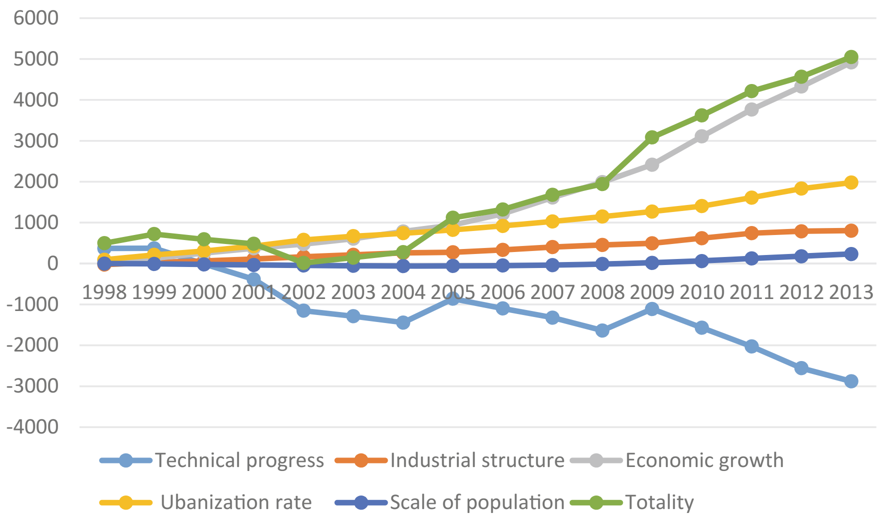


Fig. 25.4 Cumulative effects of factors on energy consumption for Chongqing from 1997 to 2013

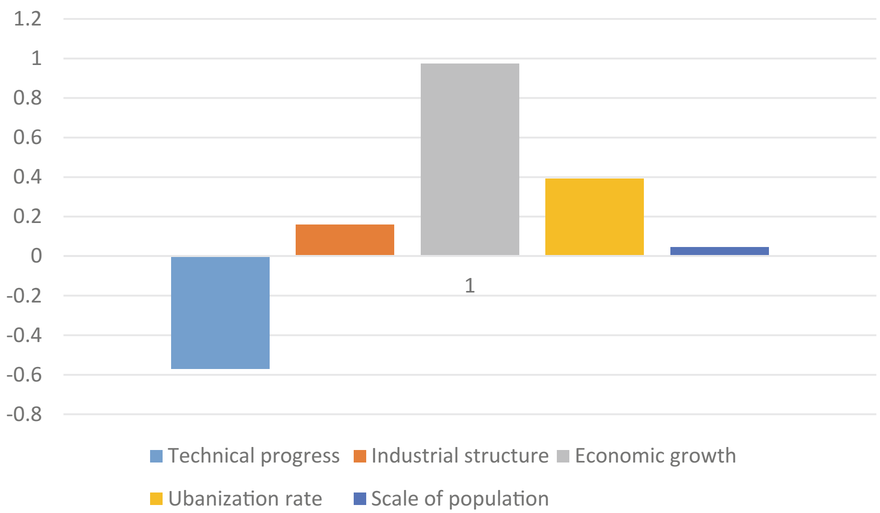


Fig. 25.5 Cumulative effects of factors on energy consumption for Chongqing by the year of 2013

restraining the growth of energy consumption. In contrast to this, economic growth, industrial restructure, urbanization, and the scale of population all play roles leading to the growth of energy consumption. It can be seen that the orientation of the effects from different factors are different. On the other hand, the significance of the effects from different factors are also different. As shown in Fig. 25.5, significance degree of economic growth is the largest, followed by urbanization, and industrial structure. Surprisingly, the scale of population has the least effect.

25.5 Discussion

25.5.1 Economic Growth

During the survey period (1997–2013), the effect of economic growth on energy consumption has been positive, and it is the main factor for the growth of energy consumption. From 1997 to 2002, the annual effect of economic growth is smaller than that of urbanization. After 2003, the annual effect of economic growth on energy consumption had been the biggest. The effect of economic growth reached the summit 693.91 ten thousand tons of standard coal up to 2010. In the subsequent 3 years, the effect of economic growth converted to a downward trend.

As mentioned above, the per capita GDP of urban residential population denotes the economic growth. In other words, the growth of per capita GDP of urban residential population is the main driving factor for the growth of energy consumption. With the national economic growth and social development, the per capita GDP will further improve, thus resulting in the growth of energy consumption is inevitable. Therefore, how to ensure increasing per capita GDP and reduce at the same time the energy consumption becomes an important research issue.

It is necessary to reduce the economic growth's dependence on energy consumption, not by promoting the quantity of per capita GDP, but by promoting the quality. Therefore, improving the quality of economic growth has become an urgent need for energy saving and consumption reduction (Yeh 2012).

25.5.2 Technical Progress

During the sample period, the effect of technical progress on energy consumption is fluctuant. The change trend is downward from 1998 to 2002. And the value fell of the effect to the minimum in the following 10 years. After that, it gradually rebounded, and rose to the maximum value in 2005. From 2006 to 2013, the trend is downward. This is contributed by continuously improving energy efficiency in Chongqing in recent years. In 2005, the intensity of energy consumption is 0.86 tons of standard coal/ten thousand yuan, and it decreased to 0.68 tons of standard coal/ten thousand yuan in 2013.

Some studies have shown that "in any country in accelerating period of industrialization development period, the energy intensity showed a rising trend"

(Choi and Ang 1997). Based on this, it can be predicted that Chongqing's energy intensity will remain a high-level trend of energy consumption in a certain period of time. So, improving technic is the key for reducing energy consumption.

25.5.3 Urbanization Rate

The effect of urbanization rate on energy consumption has been positive. Urbanization rate of Chongqing rose from 32.6% in 1998 to 58.3% in 2013, with an average growth of 1.71%. However, energy consumption due to the growth of urbanization rate increased from 92.55 ten thousand tons of standard coal in 1998 to 146.32 ten thousand tons of standard coal in 2013, with an average annual growth of 3.87%. By comparison, the increase of energy consumption is significantly higher than that of urbanization rate. Although some studies have shown that in the process of urbanization of China, the impact of urbanization rate on energy consumption is a inverted U shape relationship, this relationship is not significant in Chongqing (Feng et al. 2012). It can be predicted that the urbanization rate of Chongqing is in a period of rapid growth, thus the effect of urbanization rate on the increase of energy consumption will remain for the coming future years.

25.5.4 Industrial Structure

The effect of industrial structure on energy consumption during the sample period is relatively stable, expect for 1998. Between 1999 and 2013, there are three inverted U shape curves about the effects of industrial structure, respectively, the peak appeared in 2002, 2007 and 2010, and the trough appeared in 2005, 2009 and 2013. This verifies the conclusion of the study by Liang Zhaohui that "the growth of energy consumption in China has been derived by urbanization and industrialization since 1996" (Liu et al. 2015). Liu Jianghua believes that "the increase of proportion of the third industry will play a positive role in the decrease of energy consumption" (Liang 2010). Based on this study, the effect of industrial structure on energy consumption of Chongqing will decrease in the coming years as proportion of the third industry has been increasing in this city.

25.5.5 Scale of Population

During the sample period, the effect of the scale of population on energy consumption changes from negative to positive. Before 2004, the effect is negative, and the value is very small. After 2005, the effect is positive, and the value is increasing. In contrast to effects brought by the other factors, the value is still relatively small.

This is also echoed by the conclusion from Guo Wen (Dong and Xu 2015) that “the contribution of changes in the scale of the population on regional energy consumption is close to 0 in the western region, and this value is significantly smaller than that in the eastern region”. Taking it into account that China implements substantial liberalization of the family planning policy in 2016, it is considered that the effect of the scale of the population on the increase of energy consumption will grow by certain degree in Chongqing.

25.6 Conclusions and Policy Recommendations

Through the above comprehensive analysis, we can see that energy consumption in Chongqing is mainly contributed by economic growth, followed by technical progress, urbanization rate, the industrial structure and scale of population. Effect of economic growth on energy consumption will be the main factors for a long period of time. However, as the economic development is irreplaceable, it is not realistic by relying on the sacrifice of economic growth for lower energy consumption. The effect of technical progress to reduce energy consumption should be pursued as well. The present situation is that the reduction of energy consumption brought by technological progress cannot offset the increase of energy consumption caused by the economic growth. The positive effect of urbanization on energy consumption growth lies in the transformation of the mode of production, life style, and the release of consumer demand. The positive effect of economic structure on energy consumption growth in the city is due to that second industry accounts for high. However, the effect of industrial structure adjustment brings the growth of energy consumption. The effect of population growth on the total energy consumption is relatively small, and it can not be an effective means to control the total amount of energy consumption.

It is believed that Chongqing is still in the rising period of total energy consumption. The city’s major strategies at present stage vigorously developing the economy, improving the living standards of residents, speeding up the process of urbanization. Nevertheless, these schemes contribute to the growth of energy consumption in order to realize Chongqing 13th Five-Years plan on “reasonable control goal of total energy consumption, this paper argues the following two aspects”.

Firstly, continue to seek for energy efficiency in order to reduce energy consumption. On the one hand, to strengthen the technical exchanges and cooperation between the East and the central region, to promote energy conservation and consumption reduction technology diffusion and spillover. Energy consumption in western region such as Chongqing should focus on improving the technical efficiency and industrial structure adjustment, promoting the formation of the intensive mode of economic growth. Furthermore, the government should continue to implement and strengthen energy-saving emission reduction policies, in order to promote green GDP instead of pure digital GDP.

Secondly, continue to fully take advantage of industrial structure adjustment for reducing energy consumption growth. The second industry is the main body of energy consumption, and this study should be given more attention by upgrading the internal structure of the second industry, upgrading the industrial level, giving priority to the development of advanced manufacturing industry, developing new production services and life services. There should plans to eliminate the high energy consumption and high pollution industry to speed up the economic structure adjustment for the aim of energy saving, and reduce excessive dependence on energy consumption in the economic development through industrial structure optimization.

The further study will be conducted to ensure that data are from longer period. The study provides useful references for examination ennergy consumption practice in other major cities.

Acknowledgements This research was supported by a grant from the Project of National Social Science Foundation of China (No. 15BJY038).

References

Ang BW, Liu FL, Chen EP (2003) Perfect decomposition techniques in energy and environmental ANG analysis. Energy Policy 31:1561–1566

BP (2015) World energy statistics yearbook

Choi BW, Ang KH (1997) Decomposition of aggregate energy and gas intensities emission for industry: a refined Divisia index method. Energy J 18:59–73

Dong M, Xu D (2015) Research on the rebound effect of energy consumption in the west of China based on the decomposition of technological progress. China Sci Technol Forum 10:115–119

Fang WS, Miller SM, Yeh CC (2012) The effect of ESCOs on energy Fang use. Energy Policy 51:558–568

Fu F, Ma L, Li L, Ni W (2012) China energy dynamic growth mechanism and energy-saving connotation. China Popul Resour Environ 08:96–101

Huang R, Wang L (2013) Model based on the STIRPAT model of the energy consumption of carbon emission factors in Chongqing. J Environ Sci 33(2):602–608

Jiao CX (2012) The environmental impact analysis of Gansu Province based on STIRPAT model: a case study of energy consumption in 1991-2009. Resour Environ Yangtze River Basin 21 (1):105–110

Li Z, Wang S, Yao Y (2012) Analysis of the three factors of energy consumption effect—a case study of Shanxi province. Econ Transit 01:47–51

Li S, Cao W, Lu B (2015) Study on the optimization of China's energy consumption structure under the constraint of low carbon target. J Shanxi Univ (Philosophy and Social Sciences) 04:108–115

Liang L (2010) Study on the influence factors of energy consumption at different stages of urbanization. J Shanghai Univ Finan Econ 05:89–96

Liu J, Shao S, Jiang X (2015) The impact of urbanization on energy consumption: how far is it from the world level? Based on the comparative study of domestic and international data. Finan Res 02:111–122

Ma X, Li Q (2014) The analysis of the regional difference of energy consumption in China and its influencing factors. Ind Technol Econ 10:114–124

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Identifying key impact factors on carbon emission: Evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Su XG (2016) The decomposition analysis of China's industrial energy consumption. Mod Manage Sci 06:48–50

Su Y, Hair Y, Jing De Z et al (2006) The new energy and renewable energy Conspectus. Chemical Industry Press, Beijing, pp 1–25

Tengfei Z, Yi L, Liang JF (2013) Influence factors of large cities in China the change of energy consumption decomposition and its regional differences. Resour Sci 02:240–249

Wang L, Li J (2012) Study on the decomposition of China's energy consumption factor based on LMDI resource development and market 07:604–607

Wang Y, Yang X, Zhu Z (2014) MRCI and LMD I and II of China's energy consumption based on change analysis. Ecol Econ 05:22–25

Wang X, Jiao literature, Chen X, Zhang Z (2016) The characteristics of energy consumption and its influencing factors in Henan province. Reg Res Dev 01:144–149

Wen Guo, Tao Sun (2015) The impact of urbanization on China's regional energy consumption and residents' living energy consumption. China Environ Sci 10:3166–3176

Xiaowei Ma, Xiaoling Cui (2012) The influence factors of terminal energy consumption and carbon emission change in Beijing city. J Beijing Inst Technol (SOCIAL SCIENCE EDITION) 05:1–5

Yan F, Wu R (2011) Shanghai terminal energy consumption change pattern and driving factors research—based on LMDI decomposition of Shanghai city and the eastern, central and western area comparative analysis. World Econ Forum 02:52–68

Yang H, Cheng Y (2016) Analysis of the factors affecting the energy consumption of Yunnan Province based on the STIRPAT model. Eco Econ 03:87–91

Yue T (2010) Long long hair. Based on LMDI Jiangsu Province's total energy consumption growth effect analysis. Resour Sci 07:1266–1271

Zhang H, Ke Y, Wang B (2013) City of differences on the effects on CO_2 emission. China Population Resour Environ 23(3):152–157

Zhao T, Hong G, Zhang H (2013) The decoupling relationship between industrial development and energy consumption of the ring in Bohai province and the forecast of energy consumption level. Mod Finan Econ (Tianjin University of Finance Economics Journal) 06:79–89

Zhou G, Zhao H (2012) Analysis of the influence factors of energy consumption—based on the method of industry decomposition and region decomposition. Mod Finan Econ (Tianjin University of Finance Economics Journal) 10:87–94

Chapter 26
Application of Building Information Modeling (BIM) in Site Management—Material and Progress Control

A. Nadeem, A.K.D. Wong, G. Akhanova, S. Azhar and S.N. Wong

26.1 Introduction

Site management plays an important role during the whole construction period of a project. It includes, among other things, progress control, building services design and site layout planning. In a traditional way, all the drawings of above aspects are drawn in 2D on paper with software such as AutoCAD. However, for some aspects relating to time and coordination, it is hard to present these aspects on the paper. In addition, it is difficult to understand the real situation with a 2D drawing only. Although the drawings may provide different views of the structure, it requires imagination which is not easy for all clients or stakeholders to understand. Moreover, if a number of sub-contractors work at the same location, there will be a risk of clashes as they submit their drawings individually. For example, water pipes and electrical wires are required to install on the same part of the roof.

In recent years, invention of new technologies breaks the framework of dimensions. Building Information Modeling (BIM) is an innovative technology which is beneficial to site management in terms of time and coordination. For example, a common database enables different contractors to share their drawings by submitting them onto the same platform. Nevertheless, according to Smart Market Report published by McGraw Hill Construction (2008), contractors are the lightest users of BIM while architects are the heaviest users. Therefore, more

A. Nadeem (✉) · G. Akhanova
Department of Civil Engineering, Nazarbayev University, Astana, Kazakhstan
e-mail: abid.nadeem@nu.edu.kz

A.K.D. Wong · S.N. Wong
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China

S. Azhar
McWhorter School of Building Science, Auburn University, Alabama, USA

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_26

research should be carried out to raise attention from companies in the construction industry.

The aim of this chapter is to investigate the application of BIM to site management in terms of material and progress control. To achieve this aim, the components of site management are first identified. Then the use of BIM in site management is illustrated and the limitations for adopting BIM in site management are identified.

26.2 Literature Review

26.2.1 Building Information Modeling

BIM is a technology that provides a platform, where many parties can get involved, for sharing information and analysis of the building or facility in terms of time, cost and quality (Conocer et al. 2009; Rosenberg 2006; NIBS 2007). The information to be shared in the database not just includes the physical appearance, but also the details of each component of the building. Scottsdale (2009) comments that "BIM represents an evolution from traditional 2D design to a dynamic 3D model build around a database of a project's physical and functional characteristics". It means that instead of relying on traditional paper-based 2D design, BIM provides a model constructed from a database containing all the relevant information of the project for discussion.

Moreover, in the Guide for ASHRAE members, Conocer et al. (2009) state that BIM can create a precise model and hence improve productivity, lower construction cost and enhance construction quality. It is because accurate material quantity, scheduling and process control can be derived from information contained in the building model automatically. So, there is increase in productivity and reduction in construction cost as a result of reduction in wastage of time and material. In addition, one of the key findings shown in the SmartMarket report (McGraw Hill Construction 2008) is that 82% of BIM experts believe in the improvement of productivity by adopting BIM. On the other hand, with the help of visualization feature of BIM, clashes and conflicts can be detected and observed from the model. Thus, immediate remedies or changes can be made to have a better construction quality.

26.2.2 Site Management

For traditional site planning, Chau et al. (2005) comment that when planning for resource allocation and site layout, planners rely on their experience, intuition, imagination and judgment with the help of 2D drawings and general schedules, such as bar chart. However, all this information is paper-based. Site planning is required for better site management on time, cost and quality. It is the organizational process of creating and maintaining a plan; and the psychological process of thinking about the activities required to create a desired goal. According to Rodriguez and Walter (1998), objectives of construction site management are as follow:

(i) Support the construction job personnel through efficient material transportation
(ii) Provide flexible work space
(iii) Use available site space effectively
(iv) Reduce capital investment
(v) Provide labour safety and job satisfaction
(vi) Reduce construction time
(vii) Facilitate the construction process
(viii) Reduce "energy consumed" in the construction operation.

In summary, these categories can be grouped into three parts, which are material and progress control (iv, vi), site layout planning (i, ii, iii, vii, viii) and site safety (v). This chapter addresses material and progress control issues of site management.

26.2.3 Material Control

Material cost is one of the major expenditures in a construction project. In current practice, the material quantity is calculated by on-site quantity surveyor (QS) from drawings and bills of quantities manually. Materials are usually ordered throughout the construction period as there may not be enough storage areas for all materials. In case there are changes made to the design, then QS needs to adjust the quantity. However, the drawings on site may not be up-to-date and so there is either overestimate or underestimate of material quantity. Both will lead to increase in material cost.

Nevertheless, accuracy could be improved by adopting BIM technology. There are many different kinds of software to be used for quantification and estimation, such as Automated Estimator (Drogemuller and Tucker 2009), Exactal, Innovaya (Eastman et al. 2008) and Autodesk Quantity Takeoff. The sources of these quantity takeoff tools are the data from various BIM tools, for example, Autodesk Revit, AutoCAD. The special feature of quantity takeoff tools is to link up design data and the 3D model. Quantity and cost are automatically generated from the tools after inputting the unit rate for material and labour.

26.2.4 Progress Control

Since changes to the design do occur, the construction manager has to spend time on reviewing the updated drawings and renewing schedule, which highly relies on the interpretation of drawings by the manager. When there is a mistake in interpretation, it will affect the schedule and may lead to a delay. Thus, BIM is introduced to improve the efficiency with the use of shared database and enhance the accuracy through visualization of a 4D model (Hardin 2009). A 4D model is created by 4D tools or software like Autodesk NavisWorks. The main idea of these tools is integration of BIM model and construction schedule to produce a 4D model (i.e. 3D geometrical model + time).

With the visualization of the end results, the construction manager is able to check whether the sequence is correct and to optimize the construction sequence (Ashcraft 2008). Visualization helps communication between team members so that everyone understands the work in an easier way than just referring to the bar chart. Meanwhile, contractor can check the feasibility of the working schedule through 4D simulations. If there are conflicts or changes of design, adjustments to the schedule can be made immediately before the activity starts.

Koohang et al. (2008) comment that BIM is helping the industry to transform from a paper-based process to an integrated and interoperable way of performance as the shared database encourages more interaction and communication between parties, as well as knowledge capture and management. Regarding the construction process, the database provides information or knowledge for the construction sequence adopted in previous projects for the same task. So they have an idea of how the work is carried out and may either follow the same process or create a new sequence by making adjustment. This is particularly useful for complex task and special building design or structure as they do not have much experience in tackling the problems of these specialties.

26.3 Case Studies

In this section, two case studies are used to show how BIM is applied in different areas of site management in real practice for material and progress control.

26.3.1 Case 1: One Island East

The One Island East (OIE) is a 70 storey office building completed in Hong Kong at about $300 million. In OIE, BIM was implemented throughout the whole development process, including both design and construction phases. With the use of specialized BIM software, the accuracy of material quantity increased as the bills of quantities (BQ) was kept up-to-date before and after tender. The quantity takeoff was automatically generated from Digital Project (DP) software. Construction time could be reviewed in the same table as well. So the on-site QS would know how many materials were required at what time and hence the QS could figure out the reorder point to ensure that materials were ready before construction.

Furthermore, BIM helped in reducing material wastage through counter-checking of the quantity in the model and manual calculations to ensure that there was not a great difference between them. It benefited in the calculation of concrete amount as Grade 60 and 100 concrete were used for outriggers, in which they had very limited experience in using these two high strength concrete. So they were not sure how much of it should be ordered.

Alongside with the construction schedule, BIM helped to reduce part of the construction time. Construction sequences could be visualized in the 4D model so that it allowed contractor to identify problems and resolve them before construction commenced. In this case, BIM was used for planning the erection sequence of outriggers which was complicated. The outrigger zone occupied about four floors, which were non-typical floors. As they had not tackled with such complex situation before, they allowed more time for contingency in case there was error in construction planning.

With the implementation of BIM for clashes identification, about HK $19.9 million, which is about 7% of $300 million, and 254 m^3 of materials were saved. Moreover, it shortened the construction period of the outrigger installation activity by about 20 days. Therefore, lower construction cost was achieved in this case.

26.3.2 Case 2: The Camino Medical Office Building

The Camino Medical Office Building (MOB) project was composed of a main medical building and a parking structure in San Francisco in the US at a cost of $96 million. In this case, BIM was helpful in reducing construction period by 6 months. The project manager decided to adopt a lean approach together with an integrated BIM model.

Camino MOB is different from the previous case, OIE. It allowed not only contractor to design the model, but also allowed subcontractor to provide an input to the model. In fact, every major party were able to add constructability knowledge into the model so as to enhance collaboration and clashes identification within the 3D model. Weekly meetings were also held for sharing information and resolving conflicts found in the model. Therefore, less rework was performed due to reduction in conflicts between installations of precast components.

Besides that, in order to avoid delay due to late delivery of materials, a detailed schedule was produced to show the construction process of each part of the project through visualization of the 3D model. Hence, it would be easy to identify what kinds of materials were required for the completion of tasks and when detailed design was required. Since the most updated quantity would be used for material ordering and sufficient lead time had to be provided for material delivery, detailed design should be produced just before purchasing material. Meanwhile, just-in-time delivery method was applied to this project so that the construction process could run continuously and keep on track.

The lean approach and BIM model helped increase the productivity by 10–30% for a couple of reasons, including less rework and safer working environment. At the same time, there was a total reduction in construction schedule for 6 months comparing to traditional design-bid-build method and it led to a great success of the project.

26.4 Findings of Case Studies and Interviews

26.4.1 Case Study Findings

The case studies have shown how BIM was applied in real practice in terms of site management for materials and progress. At the same time, interviews were conducted with three consultant and three contractor representatives for how BIM is applied on site management and their comments on implementation of BIM, including limitations, from various perspectives. The summary of findings from the case studies is presented in Table 26.1.

Table 26.1 Summary of BIM application in two cases

	Case 1: One island East, (Hong Kong, China)	Case 2: Camino medical, Office building project (San Francisco, US)
BIM scope	➢ Utilize BIM throughout the project life cycle (both design and construction phase)	➢ Reduce overall project duration
BIM participants	➢ Owner ➢ Consultant ➢ Architect ➢ Contractor ➢ Quantity Surveyor	➢ Owner ➢ Contractor ➢ Subcontractor ➢ Architect
Application in material and progress control	➢ Focus on accurate material quantity ➢ Check the construction schedule to work out the material reorder point ➢ Optimize construction sequence	➢ Able to know when detailed design is required for material ordering ➢ Keep on tracking the construction schedule to ensure materials delivered on time and reduce conflicts through visualization
Observed benefits	➢ Reduction in construction cost by HK$19.9 million ➢ Reduced construction time of outrigger installation by 20 days ➢ Reduce 254 m^3 of materials	➢ Reduced construction period by 6 months

26.4.2 *Interview Findings*

26.4.2.1 Material Control

For material management, BIM is capable to calculate the accurate quantity of materials by material quantity takeoff from the BIM model, which is one of the BIM usages in the One Island East (OIE) case. However, there is no software which can calculate the amount of materials to be reduced with the implementation of BIM. Instead, all interviewees agreed that it helps to reduce risk of material waste. It is because in most cases, wastage is caused by mistakes, such as wrong calculation of material quantities so that excess materials are wasted and this can be coped with BIM.

26.4.2.2 Progress Control

On the other hand, the consultants suggested that theoretically, if the 3D model is accurate enough, prefabrication can be used as the main construction method because delivering fully arranged components is more preferable than piece by piece because of quality and time. Since the precast element is automatically manufactured in the factory, this helps in controlling the quality of the material and reducing material waste. Therefore, there will be less in situ procedures and hence risk of mistakes as well as rework is lowered.

The visualization of 3D or 4D model helps people understand the real situation. Concerning optimization of construction sequence, interviewees agreed that theoretically, BIM is able to provide "the most optimized situation" that it can guarantee the project to be completed on time if everything is exactly the same as those in the model. However, the technologies used at this moment cannot attain this optimized situation because there must be some changes or something missing during construction so that the project cannot complete on time. Instead, the model just helps planner to optimize the sequence, but not automatically.

26.4.2.3 Limitations of BIM Application for Material and Progress Control

From the point of view of contractor, interviewee mentioned that, sometimes BIM model is different from SMM (Standard Method of Measurement) as BIM has its own measurement method in the software. For example, the dimensions in BIM are always using "mm" as the unit. However, in SMM, it uses "m" as the standard unit. Also, the calculation of area may not be the same. Therefore, when using the quantity provided in the model, it should be taken care of the unit as well as how it is calculated. Otherwise, errors will easily appear in the calculation.

Human attitude towards BIM technology is an obstacle to BIM implementation, which is so-called “black art of planning” by one of the interviewees. He explained that people sometimes do not trust the findings generated from the model. Instead, they prefer do it themselves. For example, some quantity surveyors do not rely on the material quantity calculated from the model and they use their own calculations. Thus, BIM may not be very useful in this case.

26.5 Conclusions

As conditions on a construction site are complex, it is hard to understand the site relying on 2D drawings only, not to mention the site management. Building Information Modeling (BIM) has great potential helping in the interpretation, communication and coordination among involved parties, such as developers, quantity surveyors and contractors. The findings of the case studies and interviews in this chapter show that BIM is useful for material and progress control components of site management, including quantity takeoff, construction sequence optimization and provision of knowledge database. This encourages interaction between parties because an informative BIM model cannot be produced by just one party. It requires various kinds of data to be input into the model to make it as perfect as possible.

References

Ashcraft HW (2008) Building information modeling: a framework for collaboration. Constr Law 28(3). American Bar Association

Chau KW, Anson M Saram DDD (2005) 4D dynamic construction management and visualization software: 2. Site trial. Autom Constr 14(4):525–536

Conocer D, Crawley D, Hagan S, et al (2009) An introduction to building information modeling: a guide for ASHRAE members. American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc

Drogemuller R, Tucker S (2009) Automating the extraction of quantities. CSIRO Division of Manufacturing & Infrastructure Technology, Australia

Eastman C, Tecicholz P, Sacks R, Liston K (2008) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers, and contractors. Wiley, Hoboken, New Jersey

Hardin B (2009) BIM and construction management: proven tools, methods, and workflows, 1st edn. Wiley Publishing Inc., Indianapolis, Indiana

Koohang A, Harman K, Britz J (2008) Knowledge management: research & application. Informing Science Press, Santa Rosa, California, USA

McGraw Hill Construction (2008) SmartMarket report on building information modeling: transforming design and construction to achieve greater industry productivity. McGraw Hill Construction Limited

NIBS (National Institute of Building Sciences) (2007) National building information modeling standard version 1.0—Part 1: overview, principles, and methodologies. National Institute of Building Sciences, Facility Information Council. 27 Dec 2007

Rodriquez R, Walter E (1998) Quantitative techniques for construction site layout planning. U.M.I, Ann Arbor, Mich

Rosenberg TL (2006) Building information modeling. Roetzel & Andress

Scottdale AZ (2009) Press release: BIM goes "5D", dramatically reducing construction costs. Available at: http://goo.gl/vU1pQv

Chapter 27
Application of SWOT Analysis in Turkish Construction Industry

Z. Işık, H. Aladağ, G. Demirdöğen and Ç. Aygün

27.1 Introduction

Construction companies competing in national and international markets have to seek and implement the ways of gaining competitive advantage in order to survive and improve success as well as coping with the rivals and sustaining the competition. The complex and dynamic environment of the construction industry cause the construction companies to be more sensitive to both internal and external factors. Therefore, strategic management has become an indispensable tool for the construction companies to provide success and continuous improvement. In respect to this situation, many researchers suggested that construction companies should conduct strategic planning and select correct long-term strategies in order to reduce or benefit the impact of uncertainties (Kazaz et al. 2014). Besides, it is brought forward that there is a significant shift in the industry context and construction firms must adapt their strategies to remain viable in deference to the shifting context (Blair 2009). The shifting context is the main impetus driving construction enterprises to revisit their current strategy and develop strategies by taking consideration of a high degree of future uncertainty. Notably, Strengths-Weaknesses-Opportunities and Threats (SWOT) analysis, which is commonly used for the analysis of internal and external environment of the organization in order to identify specific opportunities and threats, became one of the most popular tools for strategic planning (Lu 2010).

The construction industry is an important contributor to the growth of any national economy (Öcal et al. 2007) and this situation is also valid for Turkey.

Z. Işık (✉) · H. Aladağ · G. Demirdöğen
Department of Civil Engineering, Yıldız Technical University, Istanbul, Turkey
e-mail: zeynep@yildiz.edu.tr

Ç. Aygün
Denay Construction, Istanbul, Turkey

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_27

In despite of contributing national economy, the Turkish construction industry is vulnerable to the economic and political changes resulting from increasing globalization and domestic risks such as political crisis, inflation, current budget deficit, stagnancy, underemployment and etc. Turkish Contractors Association (2015). On the other hand, significant investments in energy, urban regeneration and public private partnership projects (PPPs) are carried out as a solution towards assuring sustainable performance of construction industry in order to create potentials for foreign investors (Turkish Contractors Association 2015). At this point, considering the future growth of the Turkish construction industry and the obstacles that can directly affect the performance of the industry, a well-established SWOT analysis of Turkish construction industry will help construction companies to position themselves in Turkish construction industry and to highlight their current strategic management practice for strategizing in a most correct way.

In this study, with the aim of identifying the internal and external factors in terms of their significance on the Turkish construction industry; the strengths and weakness of Turkish construction industry with the opportunities and threats in national and international markets were examined based on a comprehensive literature review. Then, comparison of SWOT analysis of the Turkish construction industry with the strategies of two leading Turkish construction companies was made.

27.2 Current Situation of Turkish Construction Industry

Turkish construction companies play an important role in both international and domestic markets and there are many factors that can directly affect the performance of the construction industry. In this context for construction companies aiming to develop future actions in Turkish construction industry, internal and external environment analysis should have been done in order to obtain sustainable competitive advantage by taking advantages of changes in these environments. Thus, it can be concluded that the construction companies should increase their performance by defining correct strategies regarding with the factors affecting internal and external environment. In this context, current situation of Turkish construction in domestic and international markets are explained below.

27.2.1 Current Situation of Turkish Construction Industry in Domestic Market

The construction industry hold a position as an important contributor to the growth of national economy (Öcal et al. 2007). In this context, it is generally argued that the correlation between economic performance and construction industry can be monitored in growth rates. The growth rate of construction industry has shown a parallel and fluctuant tendency with the growth rate of gross domestic product since 1999. In this context, the years of 2008 and 2009 can be described as trough for Turkish construction industry while there is a rapid growth in 2010 and 2011, a recession in 2012 and then a moderate growth in 2013. However, it is registered that the growth in economy and industry fall into a decline in 2014 and 2015 (TMB 2016).

Real estate and infrastructure projects take an important place in the Turkish construction industry. In 2015 the government has launched a number of large-scale infrastructure projects, including a third bridge over the Bosphorus strait and a third airport in Istanbul, which will further underpin the industry's growth. The list of future projects includes two nuclear power plants in Mersin and Sinop, pipelines construction and an artificial waterway called Canal Istanbul (EMIS 2014). Likewise, in 2016, it is expected that the infrastructural investment will continue with harbor, metro and highway projects (TMB 2016) taken into account of the government's focus on the development of physical and social infrastructure in the country.

Turkey is the 3rd most attractive real estate investment destination among emerging countries (The Association of Real Estate Investment Companies 2013) and in real estate sector it is predicted that there will be a growth of 20% in terms of urban regeneration and new housing projects in terms of government prevention such as the urban development reform and the reciprocity law, and allowing foreigners to buy real estate in the country. It is also stated that construction of the 3th Bridge and 3th Airport that are the agenda topics for Turkish construction industry will trigger the housing demand in Turkey (The Association of Real Estate Investment Companies 2013).

Additionally, it is highlighted that urban regeneration is one of the important impetus behind the real estate industry considering the new demand that has emerged with the reinforcement of buildings against earthquakes and transforming technically insufficient buildings into qualified ones (The Association of Real Estate Investment Companies 2012). It is expected that 6.5 million housing renewal projects will be regenerated with the implementation of the "Law on the Regeneration of Areas under Disaster Risk" (The Association of Real Estate Investment Companies 2013). This regulation will lead the market to attract both local and foreign demand and will also create a financial activity worth approximately $400 billion (The Association of Real Estate Investment Companies 2013). This impact is not limited to construction industry, but also it affects to related industries such as construction material industry (Deloitte 2013).

In the light of the information presented above, it can be concluded that big investments in industrial sectors like energy, infrastructure and urban regeneration are considered to be a strategic activity to improve the performance of the construction industry (Turkish Contractors Association 2011).

27.2.2 Current Situation of Turkish Construction Industry in International Market

According to the data of Economy of Ministry, between 1972 and 2015, Turkish contracting companies undertook 8662 projects in 107 countries with a total amount of 322 billion USD. Specifically, in 2015, Turkish construction companies undertook 156 projects which total amount is nearly 19.4 billion USD, meanwhile it was seen that there was a downfall of 28.4% in the project size compared to 2014. The top five countries in which Turkish construction companies perform can be listed as Russia (26%), Kuwait (22.5%), Turkmenistan (16.3%), Algeria (10.8%) and Saudi Arabia (5.3%) (TMB 2016).

On the other hand, the situation in international market can be examined by analyzing the revenues of the "Top 250 contractors of 2015" list of the Engineering News Record (ENR). In this list it is seen that; the total revenue of 43 Turkish contractors (37,547.6 billion $) is considerably lower than the revenue of the chart-topping company (46,081.1 billion $) (ENR 2015). Even though, Turkish contractors' historical peak in taking new jobs with a total worth of 26.1 billion dollars in 2012 (Turkish Contractors Association 2013), results of ENR's "Top 250 contractors of 2015" list indicates that Turkish contractors do not have enough power to compete abroad yet. Therefore, Turkish contractors need to increase the number and the size of their projects, as well as their corporate performance so that they can increase their competitiveness in order to benefit from business opportunities in the global economy (Aladağ and Işık 2016).

27.3 SWOT Analysis of Turkish Construction Industry

SWOT is a tool for analyzing internal and external environments in order to attain a systematic understanding of a strategic management situation. In turn, it encourages strategists to adopt a strategy that can best cope with the situation. The philosophy behind the SWOT analysis is that the strategies an organization adopts should match the external environmental threats and opportunities with the organization's internal weaknesses and especially its strengths. This thinking has widely been accepted as a fundamental principle underlying modern strategic management (Beer et al. 2005) and used as a basis against which to judge future courses of action. A SWOT analysis consists of two steps: (a) Evaluating both internal factors by identifying the strengths (something a company is good at doing or a characteristic that gives it an important capability) and weaknesses of a firm (something a company lacks or does poorly in comparison to others, or is a condition that puts it at a disadvantage), and external factors by identifying opportunities and threats introduced by the market and (b) Examining the interaction of internal and external factors to develop solutions or strategies (Pearce and Robinson 2003).

By appraising its strengths, weaknesses, opportunities, and threats, the organization can identify and forecast the prospective situation and also develop future actions.

In this study, with the aim of establishing SWOT analysis of Turkish construction industry, various number of studies about SWOT analyses in Turkish construction industry are examined based on a comprehensive literature review considering strategic management practices, international competitiveness and characteristic of the Turkish construction industry (BMI 2010; TMB 2011; Ertem and Yilmaz 2014; Emlak Konut 2014; INTES 2014; Ozorhon and Demirkesen 2014; Kazaz and Ulubeyli 2009). In this context, the combined finding of these studies is presented in Table 27.1.

Table 27.1 SWOT Analysis of the Turkish Construction Industry

Internal factors	
Strengths	**Weakness**
S1 Planning and reviewing future strategies systematically	W1 Having a shortage of mission statements and objectives
S2 Attaching great importance to technological improvement	W2 Neglecting qualitative criteria in choosing investments
S3 Analyzing potential competitors in the construction sector	W3 Perceiving long-term planning as unnecessary
S4 Giving close attention to human resource input to enhance its quality	W4 Making no responsibility allocation in strategy development
S5 Specializing in different project types	W5 Lacking a strategic management culture
S6 Establishing more joint venture companies	W6 Not trusting lower-level personnel,
S7 Reliability in the sector	W7 Lacking economic and political environment evaluation
S8 Low costs	W8 Rarely applying the strategy diversification
S9 Large source of employment	W9 Incomplete perception of quality management
S10 Experienced and competitive in domestic and international markets	W10 High turnover rates
S11 Good client relations and high customer satisfaction	W11 Lack of supportive organizational structure and culture
S12 The risk taking attitude	W12 Lack of engineering design expertise
S13 Strong sub-sectors (steel and cement)	W13 Insufficient number of qualified construction workers
S14 Housing demands	W14 The informal rate in the industry
S15 The insurance system	W15 Shrinking business volume
S16 Work quality	W16 Lack of control in the construction process
S17 Rapid progress and development in the industry	W17 Lack of data on the sector
S18 Cost and flexibility-oriented activities	W18 Low supervised contracting system
S19 The ability work fast and mobilization	W19 High bureaucracy
S20 Geographical proximity and logistic advantages to the countries with high investment potential	W20 High labor costs
S21 The cultural and ethnic with Central Asian and South Caucasus neighbors has led to the strong presence of Turkish construction companies in the region for many years	W21 Weak finance structure of the construction companies
	W22 Government support

(continued)

Table 27.1 (continued)

Internal factors	
Strengths	Weakness
S22 Increasing demand for urban renewal projects S23 Increasing demand for housing by foreign investors in terms of reciprocity law S24 Increased of planned construction and qualification in terms of new construction and housing standards	W23 The extremely low price offer reducing profit margins and the presence of large companies in the system remaining weak W24 A low level of labor training W25 Uninsured workers W26 Tax regulations W27 Difficulties in finding credit and high interest rates W28 Low institutionalization
External factors	
Opportunities	Threads
O1 Receiving progress payments on time in construction investments from the private sector O2 Availability of some neighboring countries that need Turkey's expertise and investments in construction O3 The need for built environment as a developing country O4 Support of government for domestic and international projects O5 Mutual trade agreements with host countries O6 The geographical and cultural proximity to host countries O7 Young population O8 High growth rate in population O9 Economic growth and development O10 Foreign investment O11 Housing purchasing desire is increasing O12 Turkey's position as a transit country for energy from the Caspian Sea to Europe O13 Benefits of the transition to EU membership	T1 Political and economic variability in Turkey T2 Problems in project finance T3 Difficulty in getting construction loans, construction permits, and compliance with environmental regulations T4 A low level of labor training T5 Earthquakes, natural disasters, and wars T6 Incompatibility of Turkish building materials with international specifications T7 Rapid increase of land prices T8 Tax regulations T9 Increased floor area ratio caused by the urban renewal projects T10 Increased prices creating risk of "bubble" perception T11 The difficulty of competitive foreign investors with strong capital strength

27.4 Comparative SWOT Analysis with the Leading Turkish Construction Companies

As one of the highly competitive industry; The SWOT analysis also can utilize in company wise because any change in the environment may affect firms positively or negatively. Therefore, every firm should have specific strategies to cope with or take advantage of these changes. In following, according to the ENR Top 250 International Contractors List in 2015, two major Turkish construction companies were selected and examined in order to find out how these companies form their strategies in deference to the SWOT analyses of Turkish construction industry.

27.4.1 Company A

The company, although operating in five different sectors, gains the majority of its revenues from construction contracts and energy projects. According to the ENR Top 250 International Contractors List in 2015, Company A was ranked 65th. In regional terms, out of a total US$ 1.4 billion in revenues, US$ 914 million was gained from projects in Turkey. This was followed by sales in the Russian Federation, Kazakhstan and Ukraine, reaching a total value of US$ 405.5 million (Turkish Contractors Association 2013). The firm has a particular expertise in Russia and Commonwealth of Independent States markets, having completed 130 projects in these regions, including hospitals, industrial plants and oil and gas projects and contributed the majority of the revenues from these projects. In this case it can be stated that as the biggest electricity producer in Turkey's private sector, Company A used its "experience in international markets" as a strength in order to dominate the market in these region that has a high investment potential with a "geographical proximity and logistic advantages" as mentioned as an opportunity in SWOT analysis. In 2007, a new law passed that broadens the Build-Operate-Transfer (BOT) model to include a wider range of projects, thereby aiming to increase the eligibility of foreign companies to enter construction projects in Turkey. This might impact Company A's domination in the private sector, so that entering new markets in other countries and improving the diversity of in the construction industry was a proper strategy for Company A in order to reduce the vulnerability to fluctuations.

Company A has also a strong partner in US-based construction company. The two have formed joint ventures for projects in Albania, Romania, Russia and Kazakhstan. These projects paved the way for major contracts to expand, upgrade and develop the Tengiz and the Korolev Oil Fields on the eastern shores of the Caspian Sea. Company A and its joint venture partner provided integrated engineering, construction, project management and procurement expertise. Thus, by partnering with a strong firm that is among the global leaders in infrastructure and construction sector, Company A reduced the possible impacts of "lack of engineering design expertise", "lack of control in the construction process" and "lack of qualified construction workers" that were brought forward as one of the most important weakness of the Turkish construction industry. Also, considering the high investment amount of these projects, Company A had the opportunity to have a more stable funds in order to sustain project finance by eliminating the thread of "problems in project finance" in terms of the difficulty of competitive foreign investors with strong capital strength with this alliance.

In 2015, Company A also completed its works on the Erbil Combined Cycle Power Plant Project, which became the first synchronized combined cycle power plant in Iraq and in the same year, started the construction of a gas-fired combined cycle power plant with a 1500 MW capacity to provide electricity in Baghdad. This situation shows that, Company A used the opportunity of "the availability of the need Turkey's expertise and investments in neighboring construction industry" in order to position in a geography which might open up a new market for itself. However, it is predicted that the decreasing energy prices and risks based on Russian's unstable economy will affect the feasibility of some important projects and will increase competition globally. Taken into account of these changing dynamics and potential investments in South Amerika and Sub-Saharan Africa, Company A might consider to change its route towards these new markets as a strategic positioning in order to increase competitive advantage in international market.

Today, Company A is both the developer and the owner of many prestigious projects in Moscow that feature Intelligent Building technologies with efficient layouts and interior premises fitted-out in accordance with international standards and automated engineering and safety control systems. Company A is carrying out the maintenance and administrative management of all these buildings with professional teams located on-site. Considering the threat of "low level of labor training" and "insufficient number of qualified workers" in the implementation of new and innovative technologies required for these kind of projects, it was Company A's unwavering belief that its "engineering know-how" and "highly skilled workforce" were one of its most significant competitive advantages.

With a well-defined mission statement to design, build and deliver safe, high-quality and cost-effective construction projects on schedule while providing quality employment and career growth opportunities, Company A constitutes its vision to be one of the best and innovative engineering and construction companies serving globally. Unlike the majority of the other construction companies in Turkey, the weakness of "the shortage of long-term strategic planning in the industry" was reversed to a strength by defining clear mission statements and objectives in order to position the company correctly.

27.4.2 Company B

Company B is one of the most diversified construction companies in Turkey and also has been active over a wide geography from UAE, Saudi Arabia, Libya, Algeria, Morocco and Qatar to Georgia, Poland, Russia, Turkmenistan, Uzbekistan, Iraq and Afghanistan. The activity areas of Company B mainly focus on the residential, infrastructural and industrial projects. According to the ENR Top 250 International Contractors List in 2015, Company B was ranked 139th. Their international revenue is 450 $M, in total is 1.151 $M with domestic value (Turkish Contractors Association 2013).

In the light of the data related to current situation of the Turkish construction industry in order to provide the sustainability of the construction industry, big investments in industrial sectors like energy, infrastructure and urban regeneration are considered as a strategic activity by policy-makers with the considerable impact they have on the construction industry in Turkey (Turkish Contractors Association, Turkish Construction Industry-Vision of 2023). Also the big amount of capital investment of BOT projects in the transportation industry creates a potential to draw the attention of the international investors to Turkey. In this context, in addition to their business development activities for expanding the range of their activities abroad, in 2013 serious domestic activities were also progressed and major industrial complexes and infrastructure investments of Turkey had been added to references including Gebze-Izmir Motorway, Istanbul Metro Construction, Marmaray Bosphorus immersed tube tunnel crossing and Ilısu dam project in order to get a share in the domestic market. Marmaray Bosphorus immersed tube tunnel crossing for rail project was one of the major infrastructure investments of Turkey and had been executed by the Turkish-Japanese joint venture. Similarly, Gebze-Izmir motorway project was the biggest infrastructure investment of Turkey realized under BOT scheme. This tending shows that Company B used the opportunities of the need and the support of government for built environment of Turkey as a focus strategy in order to enhance its competitive advantage as a long term effort.

27.5 Conclusion

In this study, with the aim of identifying the internal and external factors in terms of their significance on the Turkish construction industry; the strengths and weaknesses of Turkish construction industry with the opportunities and threats in national and international markets were examined based on a comprehensive literature review. The result of the study constitutes that Turkish construction companies keep going to use construction industry's opportunities and strengths in both international and domestic construction industry with the help of their expertise, qualified workers, geographic position, strong financial position and building technologies. The SWOT analysis of the Turkish construction industry depicted from literature was comparatively discussed and found that the Company A benefits from its organizational structure, international background, experience, geographical proximity, cost effectiveness, high quality and innovativeness against to international rivals. In domestic construction industry, infrastructure and urban transformation projects present promising future to construction companies and foreign direct investment in spite of political stability, management problems and shrinking in the industry. In this context, review of the company B also provided insights into infrastructural projects held in Turkey. Moreover, tendency of company B to partnership with international companies and having technical competency for complex projects bring the company into the forefront in domestic market.

The research opens up to future developments such as comparison of Turkish construction industry with developed nations (England, USA etc.). Therefore, difference between developing countries and developed countries can be clearly revealed.

References

Aladağ H, Işık Z (2016) Sustainable key performance indicators for urban regeneration projects. Sigma J Eng Nat Sci 34(1):1–13

Beer M, Voelpel SC, Leibold M, Tekie EB (2005) Strategic management as organizational learning. Long Range Plan 38(5):445–465

Blair B (2009) Strategy in the eye of the storm. FMI Corporation, Raleigh, North Carolina

BMI (2010) Turkey infrastructure report. Retrieved from: http://www.perpustakaan.kemenkeu.go.id/FOLDERJURNAL/turkey%20infra%20report.pdf. Accessed 29 July 2016]

Deloitte (2013) Infrastructure industry Turkey. Retrieved from: http://www.invest.gov.tr/en-US/infocenter/publications/Documents/INFRASTRUCTURE.INDUSTRY.pdf. Accessed 29 July 2016

EMIS (2014) Construction sector Turkey. Retrieved from: https://www.emis.com/sites/default/files/EMIS%20Insight%20-%20Turkey%20Construction%20Sector%20Report.pdf. Accessed 29 July 2016

Emlak Konut GYO (2014) Gayrimenkul ve Konut Sektörüne Bakış. Retrieved from: http://www.emlakkonut.com.tr/_Assets/Upload/Status/EKGYO_01a.pdf. Accessed 29 July 2016

ENR (2015) Top 250 international contractors. Retrieved from: http://www.enr.com/toplists/2015_Top_250_International_Contractors1. Accessed 29 July 2016

Ertem C, Yilmaz L (2014) Türkiye Konut Sektörü, SDE. Retrieved from: http://www.sde.org.tr/userfiles/file/T%C3%BCrkiye%20Konut%20Sekt%C3%B6r%C3%BC%20Geli%C5%9Fmeler%20%E2%80%93%20Beklentiler%20Raporu.pdf. Accessed 29 July 2016

INTES (2014) İnşaat sektörü raporu. Retrieved from: http://www.intes.org.tr/content/MArt-2014.pdf. Accessed 29 July 2016

Kazaz A, Ulubeyli S (2009) Strategic management practices in Turkish construction firms. J Manage Eng 25(4):185–194

Kazaz A, Er B, Ozdemir BE (2014) A fuzzy model to determine construction firm strategies. KSCE J Civil Eng 18(7):1934–1944

Lu W (2010) Improved SWOT approach for conducting strategic planning in the construction industry. J Constr Eng Manage 136(12):1317–1328

Öcal ME, Oral EL, Erdis E, Vural G (2007) Industry financial ratios—application of factor analysis in Turkish construction industry. Build Environ 42(1):385–392

Ozorhon B, Demirkesen S (2014) International competitiveness of the Turkish contractors. In: 11th international congress on advances in civil engineering, 21–25 October, Istanbul

Pearce JA, Robinson RB (2003) Strategic management: formulation, implementation, and control, 8th edn. McGraw-Hill/Irwin, Boston

The Association of Real Estate Investment Companies (2012) 2023 vision for the real estate market. Retrieved from: http://www.gyoder.org.tr/PDFs/Publishings/Gayrimenkul%20Sektorunun2023Vizyonu.pdf. Accessed 29 July 2016

The Association of Real Estate Investment Companies (2013) Vision 2023 the next decade of real estate in Turkey. Retrieved from: http://www.gyoder.org.tr/PDFs/PagePDFs/MIPIMinvestorguide2013.pdf. Accessed 29 July 2016

TMB (2011) İnşaat sektörü 2023 vi̇zyonu. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/TMB_insaat_sektoru_2023_vizyonu.pdf. Accessed 29 July 2016]

Turkish Contractors Association (2011) Turkish construction industry-vision of 2023. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/TMB_insaat_sektoru_2023_vizyonu.pdf. Accessed July 29, 2016

Turkish Contractors Association (2013) Analysis of Turkish construction industry—January 2013. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/tmb_bulten_ocak2013.pdf. Accessed 29 July 2016

Turkish Contractors Association (2015) Analysis of Turkish construction industry—January 2015. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/tmb_bulten_ocak2015.pdf. Accessed 29 July 2016

Turkish Contractors Association (2016) Turkish construction industry-vision of 2023. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/TMB_insaat_sektoru_2023_vizyonu.pdf. Accessed 29 July 2016

Türkiye Müteahhitler Birliği (TMB) (2016) İnşaat Sektörü Analizi. Retrieved from: http://www.tmb.org.tr/arastirma_yayinlar/tmb_bulten_ocak2016.pdf. Accessed 29 July 2016

Chapter 28
Assessment of Energy Efficiency for Retrofit Versus Reconstruction Projects by Building Information Modeling

G. Demirdöğen and Z. Isık

28.1 Introduction

According to Buildings and Climate Change-Summary for Decision-makers report, "buildings are responsible for more than 40% of global energy use and one third of greenhouse gas emissions, both in developed and developing countries". This leads the authorities to taking measure against to environmental determination in the world. When construction industry was distinguished into its fields, the residential sector is not only responsible 27% energy consumption, but also it has an impact on 17% carbon dioxide emission. However this disruptive impact is not only limited with these values because demand for more energy or natural resources is growing every year (Nejat et al. 2015).

In the literature, carbon dioxide emission and energy consumption in construction industry have been intensively investigated. These studies shows variety. Energy efficiency precautions' impact on carbon dioxide emission or their relationship can be given as an example (Hens et al. 2001). Additionally, balance between energy and environmental benefits, energy retrofit actions, retrofit options, related technologies, and retrofit strategies are another studies that investigated in the literature (Ardente et al. 2011; Chidiac et al. 2011; Ma et al. 2012).

"Physical obsolescence, economic obsolescence, functional obsolescence, technological obsolescence, social obsolescence and legal obsolescence" play an important role in future of existing buildings (Langston et al. 2008). These obsolescence push owners to make a choice between retrofit, and reconstruction in their existing projects. In this study, "physical obsolescence" was considered. In this context, retrofitted and reconstruction projects were handled together. In retrofit project, before making retrofitting, structural condition was analyzed. Generally, if the analyzed building necessitates retrofitting, the last decision is determined by

G. Demirdöğen (✉) · Z. Isık
Department of Civil Engineering, Yildiz Technical University, Istanbul, Turkey
e-mail: gokhand@yildiz.edu.tr

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_28

owner side. In this situation, there are two options. In first option, after a possible earthquake exposes to the building, that building becomes unusable. This is not allow owner side to make a decisions because of regulations. However in second option, owners' preferences such as financial earnings from reconstructed building are the main factors that specify future of the existing building. Additionally, this process does not consider environmental concerns. This study aimed to make a comparison between reconstruction and retrofit project by considering environmental concerns. In many studies, embedded energy and carbon emission were presented as a consequence of reconstruction projects' hazardous impact on environment (Langston et al. 2008). However this study considered retrofitting project related to structural concern contrary to equivalent studies that consider retrofitting project as an energy (Dong et al. 2005).

28.2 Research Methodology

In this study, an experimental research was performed. In this context, a school reinforcement project was chosen as a sample. Chosen project's structure elements were presented in Fig. 28.1. Structural elements of reconstruction project were thought having the same size with Structural elements' dimensions of old projects due to the lack of reconstruction project. However some improvements in rebar and concrete were considered.

The project of structure reinforcement presented in Fig. 28.2. As a result of evaluation of existing structure in terms of reinforcement, nine shear wall, seven column jacketing to every floor and foundation reinforcement were performed.

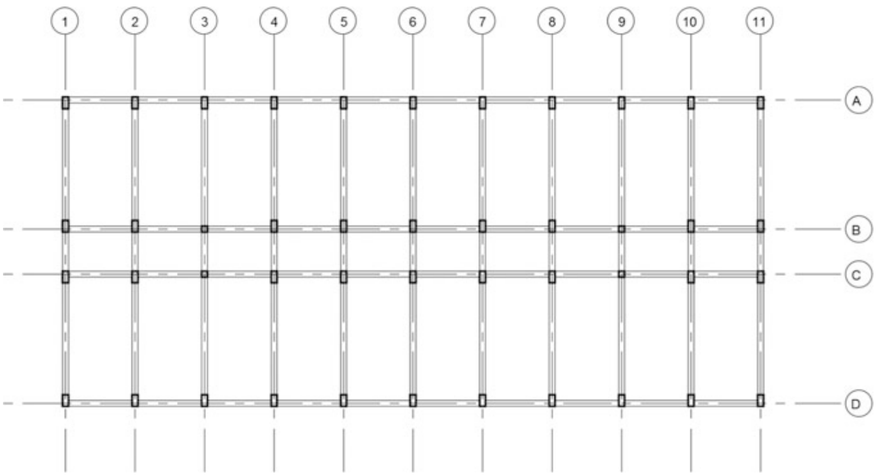


Fig. 28.1 Reconstruction plan

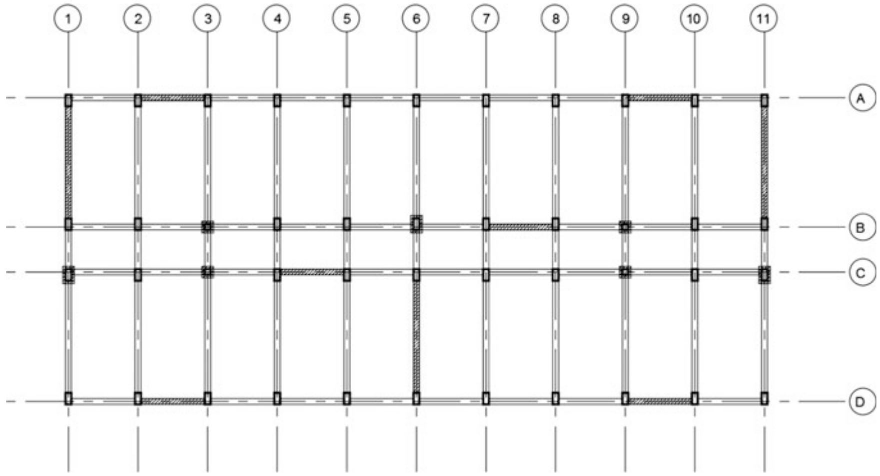


Fig. 28.2 Structure reinforcement plan

Chosen sample project was modelled in BIM for both reconstruction and retrofit project. Therefore, outcomes of these projects enabled to make an environmental comparison between reconstruction and retrofit projects. In order to measure environmental impact, material quantity takeoff of two projects were calculated via BIM software. Measured material quantity takeoff was converted to weight as kg unit and these were multiplied by coefficients of carbon dioxide emission and embedded energy for per kg. Therefore, outcomes of numerical calculation enabled to make comparison between two projects due to conversion to the same unit. However, some assumptions were made. These assumptions were explained within the next section.

28.2.1 Assumptions in Models

When the study was being performed, some assumptions were made in both modelling of retrofit project and modeling of reconstruction project.

Considered parameters for reconstruction project were presented in below premises:

- Structural elements (columns, beams, foundations, and rebar).
- Foundation of reconstruction project was presumed as raft foundation.
- In order to lack of architectural project, assumptions are made in designs of internal structure such as walls, rooms etc.
- In reconstruction project, one lunchroom, one cafeteria, two resting room, one teacher's lounge, one library, one store, two toilets, and upstairs considered on basement floor.

- In reconstruction project, eleven classrooms, two manager offices, two toilets, two labs, and one teacher's lounge were designed on ground, first, and second floor.
- In model, wood roof was considered.
- In design, foundation insulation did not consider.
- In design, insulation of building was designed by considering rough-cast, rigid insulation, netting, plaster and paint. However, damp-proofing added into insulation of ground floor.
- In design, cement finish of floor considered.
- Interior design walls were designed by considering rough cast, finish plaster and paint.
- Mechanical and electrical design did not consider in design.
- Suspended floor was designed on the ceiling.
- Windows and doors were added into design. However, windows were only considered when quantity takeoffs was calculated.

Considered parameters for retrofit project were presented below premises:

- Structural elements (shear wall, columns jacketing, foundation additions and their rebar).
- In structure reinforcement model, reconstruction of ground floor and cement finish added due to necessity of foundation reinforcement, column jacketing and shear wall.
- Foundation of reconstruction project was presumed as strip foundation.
- In order to lack of architectural project, assumptions are made in designs of internal structure such as walls, rooms etc.
- In project, one lunchroom, one cafeteria, one resting room, one teacher's lounge, one library, one store, two toilets, and upstairs considered in basement.
- In project, seven classrooms, one manager office, two toilets, one lab, and one teacher's lounge were designed in ground, first, and second floor due to the shear wall constraints. Contrary to made on ground and first floor, lab is not designed on second floor.
- In design, roof was designed as wood. And roof system of the existing structure reconstructed.
- In design, foundation insulation did not consider.
- In order to enable equality of heat insulation in both projects, insulation reconstructed. In design, insulation of building was designed by considering rough-cast, rigid insulation, netting, plaster and paint. However, damp-proofing added into insulation of ground floor.
- All brick walls reconstructed.
- Interior design walls were designed by considering rough cast, finish plaster and paint.
- Mechanical and electrical design did not consider in the design.
- Suspended floor was designed on the ceiling.

- Windows and doors were added into design. However, windows were only considered within quantity takeoffs. The design had less windows than previous design.

28.3 Discussion

In this study, twenty-one building materials were taken into consideration. These materials' quantity takeoffs were calculated through BIM software. The results of quantity takeoffs were multiplied with corresponding carbon efficient and embedded energy coefficients. In this section, these materials that show variety according to the comparison results will be discussed under subtitles. Before comparison is made, sum of carbon emission and embedded energy for both reconstruction and retrofit project was summarized in Fig. 28.3. According to results, while embedded energy for reconstruction project was found 10,063,847.52 MJ, embedded energy for retrofit project was gauged as 5,130,441.28 MJ. Carbon emission parameter was measured as 824,344.40 $kgCO_2$ for reconstruction project. The same emission parameter was found half and half approximately.

In this section, amounts of $kgCO_2$ and MJ will be compared under related subsections. In this context, comparison for projects will be presented specific to amount difference.

28.3.1 Comparison of Projects for Paint

Paint interior and exterior were calculated together. As a result of calculation, while 3,790.86 $kgCO_2$ released to air for reconstruction project, 4,007.25 $kgCO_2$ released to air for structure reinforcement project. While embedded energy for paint was calculated as 108,151.12 MJ in reconstruction project, embedded energy for paint was calculated as 114,324.55 MJ in structure reinforcement project. These differences can be originated from new additions into shear walls.

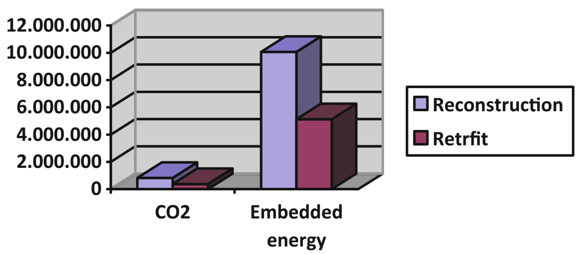


Fig. 28.3 Comparison of projects

28.3.2 Comparison of Projects for Ceramic

Environmental impacts of ceramics were calculated as same value as in both projects. However, some difference was observed in quantity takeoff of ceramic due to number of rooms. In reconstruction project, 4,564.67 $kgCO_2$ released to air. In another project, this value corresponded to 5038 $kgCO_2$. Embedded energy for paint in both reconstruction and structure reinforcement projects are 68,955.56 and 76,333.33 MJ respectively.

28.3.3 Comparison of Projects for Concrete

Concrete volume in both project showed huge variety when two projects were compared. Accordingly, while this value for reconstruction project were calculated as 300,296.9 $kgCO_2$, it was calculated 72,635.37 $kgCO_2$ for structure reinforcement. Embedded energy was found 2,148,466 and 519,667.72 MJ respectively. They presented in Fig. 28.4. The reason of this difference was that the volume of concrete in retrofit project is too low when compared with reconstruction project.

28.3.4 Comparison of Projects for Exterior and Interior Plaster

Environmental damage that was caused by utilization of plaster in both interior and exterior side was measured as 5,736.19 $kgCO_2$ and 86,042.88 MJ for reconstruction project and 6,162.24 $kgCO_2$ and 92,433.6 MJ for structure reinforcement project respectively. The reason of different amount is that some window was filled with concrete due to additional shear walls to retrofitted building.

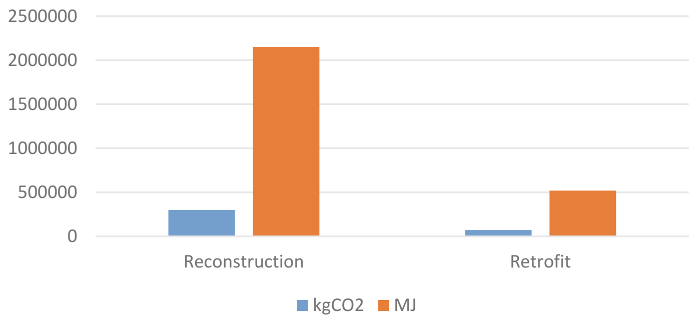


Fig. 28.4 Evaluation of environmental impact of cement

28.3.5 Comparison of Projects for Exterior and Interior Rough-Cast

Results of quantity takeoff of rough cast showed that structure reinforcement cause more rough-cast material utilization. Values of carbon dioxide and embedded energy were calculated as 27,836.83 $kgCO_2$ and 183,665.66 MJ for reconstruction project. In other project, these values were calculated as 29,886.86 $kgCO_2$ and 1,979.68 MJ.

28.3.6 Comparison of Projects for Rigid Insulation

Rigid insulation showed variety according to shear walls in structure reinforcement project. However, these differences are not too many. Values of carbon dioxide and embedded energy were calculated as 2,459.85 $kgCO_2$ and 59,512.5 MJ for reconstruction project. In other project, these values were calculated as 2,606.33$kgCO_2$ and 63,056.25 MJ.

28.3.7 Comparison of Projects for Cement Finish

Cement finish values in structure reinforcement project showed significant difference in comparison with reconstruction project. In this context, values of carbon dioxide and embedded energy were calculated as 32,562.67 $kgCO_2$ and 214,846.5 MJ for reconstruction project. In other project, these values were calculated as 8,767.25 $kgCO_2$ and 57,845.76 MJ (see Fig. 28.5).

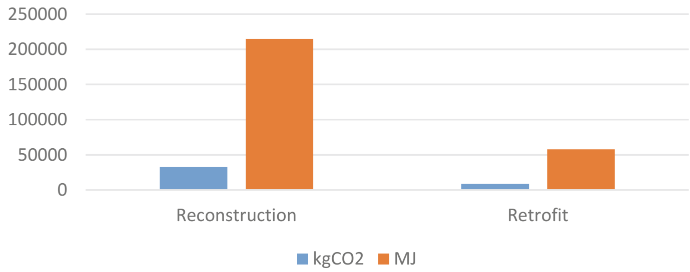


Fig. 28.5 Evaluation of environmental impact of cement finish

Fig. 28.6 Evaluation of environmental impact of rebar

28.3.8 Comparison of Projects for Rebar

Rebar utilization is one of explanation of huge environmental impact of reconstruction project. Environmental damage that is caused by rebar is 284,539.4 $kgCO_2$ and 4,174,629 MJ for reconstruction project and 94,790.57 $kgCO_2$ and 1,390,723 MJ for structure reinforcement project respectively (see Fig. 28.6).

28.4 Conclusion

In this study, comparison between embedded energy and CO_2 of materials in reconstruction project and retrofit project was performed. In this context, a school project was chosen and it was modeled by making assumptions in BIM software. The study shows that although all materials except columns, beams, walls, floorings and windows renewed, reconstruction project has more impact on environment in terms of embedded energy and CO_2 emission. Proportion of CO_2 emission of two projects was calculated as 0.45 when sum of CO_2 emission of retrofit was divided by sum of CO_2 emission of reconstruction. Another important finding was proportion of embedded energy. Proportion of embedded energy of two projects was calculated as 0.51 when sum of embedded energy of structure reinforcement was divided by sum of embedded energy of reconstruction. These values were found very close to each other. This closeness can be tested with another studies in order to see whether they have direct relationship or not. As a result of the study, reconstruction activities such as urban transformation activities give two times damages to environment and money and static analysis-based assessment of existing structure are insufficient in terms of environmental issues. Therefore, environmental impact of reconstruction projects must be evaluated and some constraints must be regulated by governments.

References

Ardente F, Beccali M, Cellura M, Mistretta M (2011) Energy and environmental benefits in public buildings as a result of retrofit actions. Renew Sustain Energy Rev 15(1):460–470

Chidiac SE, Catania EJC, Morofsky E, Foo S (2011) Effectiveness of single and multiple energy retrofit measures on the energy consumption of office buildings. Energy 36(8):5037–5052

Dong B, Kennedy C, Pressnail K (2005) Comparing life cycle implications of building retrofit and replacement options. Can J Civ Eng 32(6):1051–1063

Hens H, Verbeeck G, Verdonck B (2001) Impact of energy efficiency measures on the CO_2 emissions in the residential sector, a large scale analysis. Energy Build 33(3):275–281

Langston C, Wong FK, Hui EC, Shen LY (2008) Strategic assessment of building adaptive reuse opportunities in Hong Kong. Build Environ 43(10):1709–1718

Ma Z, Cooper P, Daly D, Ledo L (2012) Existing building retrofits: methodology and state-of-the-art. Energy Build 55:889–902

Nejat P, Jomehzadeh F, Taheri MM, Gohari M, Majid MZA (2015) A global review of energy consumption, CO_2 emissions and policy in the residential sector (with an overview of the top ten CO_2 emitting countries). Renew Sustain Energy Rev 43:843–862

Chapter 29
Barriers to and Enablers for Lessons Learned Practices in International Infrastructure Development Projects—A Case Study

Tiendung Le, Eric Too and Viet Anh Tran

29.1 Introduction

Activities in generating, sharing, managing and using lessons learned (called lessons learned practices) enable organizations to create know-how, stay competitive and develop their own work force. Organizations involved in international infrastructure development projects have unique challenges because all of the projects have stakeholders from different countries of varying levels of development and management maturity. Of these organizations, organizations in recipient countries (mostly government agencies) tend to be least equipped to generate, share, manage and use lessons learned. This fact poses serious challenges to the effectiveness of international infrastructure development projects as these projects depend on human resources of all parties to be implemented. The least effective one among these organizations will determine the level of effectiveness of projects and the amount of lessons learned generated, shared, managed, and used. In other words, the strength of a chain is only as much as the weakest link.

While most organizational stakeholders (e.g., international development banks, independent consultants) are sophisticated in lessons learned practices, little is researched on and understood of how governments agencies manage lessons learned and how to help them do so more effectively. This paper reports on the preliminary results of a research project investigating the practices of generating, sharing, managing and using lessons learned in international development projects, in particular what are the barriers to and enablers for the effectiveness of lessons learned. The research uses a government agency in Vietnam as the case study. The agency oversees international development projects in the infrastructure sector.

T. Le (✉) · E. Too · V.A. Tran
School of Property, Construction and Project Management, RMIT University, Victoria, Australia
e-mail: tiendung.le@rmit.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_29

For the confidentiality purposes, further detail on the nature of the infrastructure, the name of the agency as well as the ministry will be withheld.

29.2 Literature Review

There is significant research on how organizations generate, share, manage and use lessons learned and knowledge. However, lessons learned practices in development projects tend to focus on the organization's level, i.e., from the organization's perspectives. In a study that investigated empirically critical success factors for World Bank projects, Ika et al. (2012) reviewed a number of studies on critical success factors for international development projects (Kwak 2001; Khan et al. 2003; Vickland and Nieuwenhujis 2005; Struyk 2007; Khang and Moe 2008; Diallo and Thuillier 2005). None of these studies mention lessons learned practices at the individual level. This tendency leaves out great opportunities to improve government agencies' capability of increasing directly and indirectly the probability of process success.

Caldas et al. (2009) suggest 'capturing, sharing, and utilizing the combined knowledge of the current workforce is essential so the industry and organizations avoid losing their vital, valuable asset—corporate knowledge.' These lessons learned practices and their effectiveness are highly influenced by how individuals behave, learn and share their knowledge. The common practices, however, have a different focus. For example, when there was a lack of participation in irrigation management in a project, a panel of experts would be consulted to develop recommendations for government and for use in future projects (ADB 2012); these lessons learned would act as a tool for assisting and reviewing organizational strategies rather than a mechanism for development of individual skills in the government agency.

Lessons learned practices for individuals in international development projects face with numerous barriers, which can be defined as a factor whose presence would negatively impact the effectiveness of lessons learned. Barriers to lessons learned practices have been identified and discussed in a number of studies. For example, Hong et al. (2011) mention the linguistic background and capability as a barrier to how people share lessons and experience. Distrust in experienced experts could hinder a person's ability to make full use of shared knowledge (Barson et al. 2000). The ability to communicate and distribute effectively knowledge may prevent lessons learned to be shared among those concerned (Wiewiora et al. 2009; Chroneer and Backlund 2015). Another important factor in limiting lessons learned practices is motivation. People may not have motivation, both to learn and to share (Bartsch et al. 2013).

In parallels to barriers are enablers, which can be defined as a factor whose presence would positively impact the effectiveness of lessons learned. Enablers can be of different types, for example, people, system or tool. Maqsood (2006) and Chroneer and Backlund (2015) cite ICT systems as an enabling factor for people to store and share lessons learned. A fair reward system may do *esprit de corps* a favor and people would be more willing to share lessons learned (Yang and Wu 2008; Wang and Hou 2015).

Some factors or the lack of them could form a pair of a barrier and an enabler. For example, while lack of trust could be a barrier, having trust would enable the sharing practices because it would reduce the fear of losing competitive value (Renzl 2008). One of the participants in this study said it squarely “if you are close to me, I will share with you everything; otherwise, I won’t tell you even a word.”

The nature of international development projects seems to further complicate the lessons learned practices because of the diversity of the stakeholders, their motivations, their interests, and management maturity levels. It is critical for the effectiveness of international development projects to understand and develop appropriate strategies for improving lessons learned practices both at the strategic level and at the individual level. While the former tends to have significant visibility and attention, the latter lacks substantial research efforts. This research project is an attempt to shed some light on the subject.

29.3 Research Methods

The research team chose to use the case study method to perform in-depth exploration of the current practices in lessons learned at a government agency in Vietnam. While this method may limit the representativeness of the findings, it would allow for a holistic, comprehensive study of a single organization. It would, hopefully, provide some insight into the complex nature of how barriers hinder and enablers promote lessons learned in international development projects.

The research started with reviewing relevant literature on lessons learned, especially in the contexts relevant to international development projects. The literature review was followed by the review of project documents available in the agency to understand the current practices of all aspects of managing lessons learned. These reviews helped the research team design an appropriate approach to interviewing the practitioners within the agency. A semi-structured interview guide was developed and piloted with two practitioners. After the pilot interviews, only wording of the guide was adjusted and the guide was considered final. The results from these two interviews were considered appropriate to be included in data analysis. Another 30 practitioners were requested for interview; 23 of them agreed and were interviewed making the total number of interviewees 25. The interviewees had from one to 18 years’ experience and an average of more than 9 years’ experience. Most of them were middle level professionals in the organization.

Results from these initial steps were used to identify and categorize the barriers and enablers. As a result, twenty-two barriers and 21 enablers were identified.

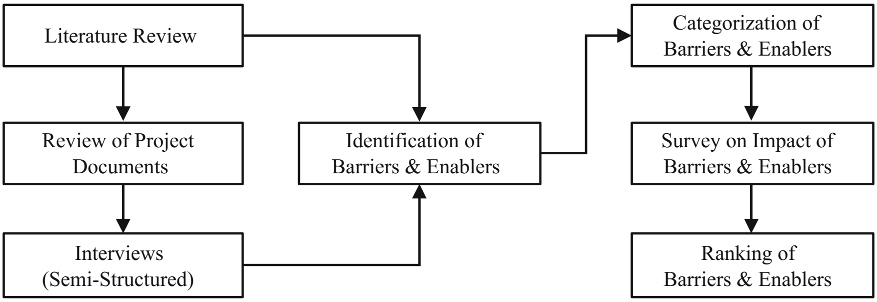


Fig. 29.1 Research process

These barriers and enablers are not necessarily equal in terms of impact to the effectiveness of lessons learned and need to be ranked relatively. A survey was designed and sent to 70 practitioners for ranking. They were asked to assess the impact of the barriers and enablers to the effectiveness of lessons learned practices on a 7-point Likert scale. After 2 weeks, forty-five of them answered and returned the survey, all of which were valid for data analysis. Out of the 45 participants, twenty-six of them had more than five years' working experience, nineteen with five years' experience or less. The average years of experience was seven. The participants in the survey include junior, middle and senior level professionals in the agency.

The research team used the data from the survey to perform data analysis to rank the barriers and enablers. The preliminary research results are discussed further in the following section. While research instrument development and data analysis were performed in English, communication (including interviews and survey) with the practitioners was conducted in Vietnamese. Figure 29.1 shows the main steps of the research process.

While technically speaking, this research uses a case study approach, both survey and interview were used as the data collection methods that allow for more in-depth understanding of the practices within the agency. This in-depth understanding, rather than representativeness of the data and findings, is expected to be the main strength of this study.

29.4 Results

This section provides further detail on how the barriers and enablers were identified, categorized, ranked relatively in terms of impact. It also discusses the research results and the future research steps.

29.4.1 *Identification and Categorization of Barriers and Enablers*

In this study, lessons learned are investigated using individual perspective and perceptions. In other words, it studies how people, as individuals, view lessons learned. While there were a number of ways to categorize the 22 barriers and 21 enablers, the research team decided to group them into three main categories of individual, organizational, and inter-organizational. At the individual level, the barriers and enablers are further divided into 'receiver' and 'giver' sub-categories. At the organizational level, they are divided into 'systemic' and 'cultural' sub-categories. No further division is needed at the inter-organizational level. The categorization of the factors allows for better understanding of where the barriers and enablers originate from and it would be helpful for devising strategies to cope with the barriers and to promote the enablers. The list of the factors, the categories, and the sub-categories can be found in Table 29.1.

Table 29.1 Barriers and enablers to lessons learned (LL) in international development projects

Individual	Barrier	Enabler
Receiver	B1. Language barrier B2. Underestimating the value of LL B3. Lack of trust in givers B4. Lack of background and skills B5. Lack of motivation B6. Lack of self-confidence about experience and knowledge	E1. Good relationship with givers E2. Effective work habits E3. Intrinsic motivation to learn
Giver	B7. Perceived competitiveness of LL B8. Fear of exposure of strengths and weaknesses B9. Ineffectiveness in sharing LL B10. Demotivation when LL not being applied B11. Lack of time for sharing	E4. Positive attitude towards sharing E5. Desire for better personal relationships E6. Sharing as opportunity for learning E7. Perceived responsibility to share
Organizational	Barrier	Enabler
Systemic	B12. Lack of effective information management system B13. Lack of effective physical storage system B14. Lack of instructions and processes	E8. Reward system for sharing E9. Internal competition E10. Job rotation E11. Formalizing LL in internal documents E12. Management's support E13. Use of technology in communication

(continued)

Table 29.1 (continued)

Individual	Barrier	Enabler
Cultural	B15. Indirect communication habit B16. Perceived individual possession of LL B17. Blaming habits B18. Fear of being different	E14. Altruism for organization E15. Sharing as formal responsibility E16. Perceived moral obligations
Inter-organizational	Barrier	Enabler
	B19. Differences in policies and procedures among entities (including donors) B20. Inter-organizational political context B21. Fear of legal actions B22. Lack of motivation for innovation	E17. Support from donor's staff E18. Support from external consultants E19. Inter-organizational workshop E20. Funding for training E21. Increasing competition for funding

Table 29.2 Top five barriers

Barrier	Category–sub-category	Mean	SD
B12. Lack of effective information management system	Organizational–Systemic	4.67	1.88
B14. Lack of instructions and processes	Organizational–Systemic	4.16	2.02
B4. Lack of background and skills	Individual–Receiver	4.16	1.86
B7. Perceived competitiveness of LL	Individual–Giver	4.13	1.82
B2. Underestimating the value of LL	Individual–Receiver	4.11	1.97

29.4.2 Ranking of Barriers and Enablers

While most of the barriers and enablers were identified using the 25 face-to-face interviews of the practitioners, they vary in terms of impact to the effectiveness of lessons learned practices. The results from survey of the 45 participants show interesting results. The top five barriers, their sub-categories, categories and mean scores are presented in Table 29.2. The most impactful barriers were perceived to be those of the Systemic sub-category in the Organizational category, in particular 'B12. Lack of information management system' and 'B14. Lack of instructions and processes.' Two of the top five barriers relate to the receiver's capabilities and attitudes ('B4. Lack of background and skills' and 'B2. Underestimating the value of lessons learned.').

The top five enablers, their sub-categories, categories and mean score are presented in Table 29.3. Four of the top five enablers are at the individual level (two of

Table 29.3 Top five enablers

Enabler	Category–Sub-category	Mean	SD
E14. Altruism for organization	Organizational–Cultural	5.76	1.33
E2. Effective work habits	Individual–Receiver	5.71	1.50
E4. Positive attitude towards sharing	Individual–Giver	5.69	1.26
E3. Intrinsic motivation to learn	Individual–Receiver	5.60	1.47
E6. Sharing as opportunity for learning	Individual–Giver	5.38	1.50

them relate to receivers, two relate to givers). Interestingly, the only non-individual (also the most impactful) factor in the top five enablers belongs to the Cultural sub-category (Organizational) but can be reasonably interpreted as an individual one. The factor (E14. Altruism for organization) illustrates the interest in and the evaluation of the positive influence one's sharing knowledge has to the organization (Wang and Hou 2015). This result shows that while the most impactful barriers to lessons learned tend to be of both the organization and the individual, the most impactful enablers for lessons learned seem to be more related to individuals.

It should also be interesting to note that while the standard deviations of the top barriers are in the neighborhood of 2.00, the standard deviations of the top enablers are around 1.50. The participants seem to be in more agreement in terms of impact of the enablers than that of the barriers. It may suggest that barriers' impact is more influenced by individual experience or perception while enablers' impact is more shared among the organization's members. It should be reminded that all the participants were of the same organization.

Another point of note is that the mean scores of the top enablers are relatively higher than those of the barriers. This result could reflect the belief that the participants perceive more impact from the positive aspects than impact from the negative aspects. This result may have implication when developing strategies to improve the effectiveness of lessons learned. However, it may also suggest that the participants were willing to talk more about the enablers than about the barriers.

The researchers used five years' experience as a cut-off point to test out how level of experience might have certain impact on people's perceptions of the top barriers and enablers. There were 26 participants with more than five years' experience (called 'experienced'), nineteen with five years' experience or less (called 'less experienced'). The results show that there are negligible differences between these two groups for all top barriers. However, there are significant differences between them when it comes to enablers, as shown in Fig. 29.2. Except for 'E6. Sharing as opportunity for learning,' in all other four enablers, the experienced participants saw more impact of the enablers to the effectiveness of lessons learned.

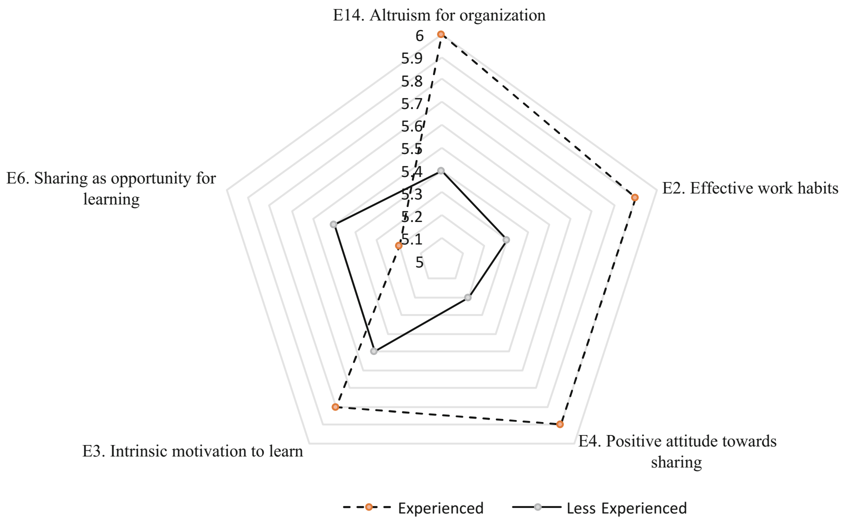


Fig. 29.2 Perceptions on impacts of top five enablers: experienced versus less experienced

29.4.3 Next Steps

The preliminary analysis of the data collected shows interesting insight into how people view the impact of barriers to and enablers for lessons learned effective. More in-depth statistical analysis would probably offer more detail on the different categories and different groups of people. Based on the further data analysis, the research team should be able to develop a conceptual model for effective lessons learned in international development projects.

Further analysis would also allow the researchers to develop and validate effective strategies for coping with the barriers (to minimize their impact) and for promoting enablers (to maximize their impact). It is expected that these next steps would further improve the contribution of the study to our knowledge on lessons learned practices, especially in international development projects.

29.5 Conclusion

This paper reports on the initial results of a research into the practices of generating, sharing, managing and using lessons learned in international development projects. It presents the lists of 22 barriers to and 21 enablers for effective lessons learned practices. These factors were identified, refined and categorized with input mainly from interviews of 25 practitioners. The factors were suspected to have different potential impacts on lessons learned practices and were ranked relatively using data collected from a survey of 45 practitioners. The most interesting result is probably that the participants tend to perceive more (positive) impact of the enablers than (negative) impact of the barriers. This finding is believed to provide insight into developing strategies and conceptual model for lessons learned practices, which will be performed in a later stage of the research.

References

ADB (2012). Learning lessons: participatory irrigation management. ADB, Accessed 03 Mar 2016

Barson RJ, Foster G, Struck T, Ratchev S, Pawar K, Weber F, Wunram M (2000) Inter-and intra-organisational barriers to sharing knowledge in the extended supply-chain. In: Proceedings of the eBusiness and eWork, pp 18–20

Bartsch V, Ebers M, Maurer I (2013) Learning in project-based organizations: the role of project teams' social capital for overcoming barriers to learning. Int J Proj Manage 31(2):239–251

Caldas CH, Gibson GE Jr, Weerasooriya R, Yohe AM (2009) Identification of effective management practices and technologies for lessons learned programs in the construction industry. J Constr Eng Manage 135(6):531–539

Chroneer D, Backlund F (2015) A holistic view on learning in project-based organizations. Proj Manage J 46(3):61–74

Diallo A, Thuillier D (2005) The success of international development projects, trust and communication: an African perspective. Int J Proj Manage 23(3):237–252

Hong D, Suh E, Koo C (2011) Developing strategies for overcoming barriers to knowledge sharing based on conversational knowledge management: a case study of a financial company. Expert Syst Appl 38(12):14417–14427

Ika LA, Diallo A, Thuillier D (2012) Critical success factors for World Bank projects: an empirical investigation. Int J Project Manage 30(1):105–116

Khan ZA, Thornton N, Frazer M (2003) Experience of a financial reforms project in Bangladesh. Publ Adm Dev 20:33–42

Khang DB, Moe TL (2008) Success criteria and factors for international development projects: a life-cycle-based framework. Proj Manage J 39(1):72–84

Kwak YH (2001) Risk management in international development projects. In: Proceedings of the 32nd project management institute annual seminars and symposium (PMI2001), Nashville, USA, 1st–10th Nov, Philadelphia, PA

Maqsood T (2006) The role of knowledge management in supporting innovation and learning in construction. School of Business Information Technology, RMIT University

Renzl B (2008) Trust in management and knowledge sharing: the mediating effects of fear and knowledge documentation. Omega 36(2):206–220

Struyk RJ (2007) Factors in successful program implementation in Russia during the transition: pilot programs as a guide. Publ Adm Dev 27:63–83

Vickland S, Nieuwenhujis I (2005) Critical success factors for modernizing public financial management information systems in Bosnia and Hergzegovina. Publ Adm Dev 25(2):95–103

Wang W, Hou Y (2015) Motivations of employees' knowledge sharing behaviors: a self-determination perspective. Inf Organ 25(1):1–26

Wiewiora A, Trigunarsyah B, Murphy D, Liang C (2009) Barriers to effective knowledge transfer in project-based organisations. In: Proceedings of the 2009 international conference on global innovation in construction, 13–16 Sept 2009, Holywell Park, Loughborough University

Yang H, Wu TCT (2008) Knowledge sharing in an organization. Technol Forecast Soc Chang 75(8):1128–1156

Chapter 30
Benchmarking Innovation Potentials in Large Projects by Public Private Partnerships

Cut Sarah Febrina and Palaneeswaran Ekambaram

30.1 Introduction

Large construction projects often fail due to the challenging environment they have. Those challenges, if they occur, might have negative impacts to project performance. Innovation is deemed as a key requirement for sustainable survival of organizations, especially in a dynamic and challenging environment (Gambatese and Hallowell 2011a; Engineers Australia 2012). Thus, the challenging environment of large projects should be dealt by implementing new approaches or innovative solutions as innovative solutions can enhance project performance with respect to cost, schedule, quality and safety along with improving competitiveness and market share (Slaughter 1998).

Moreover, if innovation is considered as the way to enhance project performance in large construction projects, an imperative point to be highlighted would be the procurement methods used, as choosing the appropriate procurement method is the way to create a conducive environment for innovation. Specifically, public private partnership (PPP) arrangement is recognized as a suitable procurement method for delivering large and complex projects (Infrastructure Partnership Australia 2008). PPP is an integrated procurement method which provides significant opportunities for innovation as requirements for extensive collaboration between government and one or more private parties including funding, delivering, and operating of long term project lifecycle period. Furthermore, to maximise the innovation potential in PPP projects first we need to identify the positive factors that influence innovation in construction projects then synchronise what factors specifically belong to PPP environment. In the literature of construction innovation, these positive factors that can cause, encourage, or stimulate innovation to happen are called enabler, driver,

C.S. Febrina (✉) · P. Ekambaram
Faculty of Science, Engineering and Technology, Swinburne University of Technology, Melbourne, Australia
e-mail: cfebrina@swin.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_30

and stimulant of innovation. These three words (i.e. enabler, driver, and stimulant) are used interchangeably in the literature of construction innovation. The innovation potential in PPP projects is showed by the presence of those positive factors of innovation. What then found to be crucial too is to separate the factors that can cause innovation and the factors that can be used as tools, resources, and strategies that encourage innovation. This paper uses the term 'driver' for the factors that cause and motivate innovation and the term 'enabler' for the strategies, tools, or resources of innovation. This is important to separate these two terms as they have fundamentally different essence; the driver of innovation is the motivation to innovate that comes before employing the enablers (tools, strategies, and resources) of innovation. Identifying these two sets of innovation positive factors is vital to confirm and maximise the innovation potential in PPP projects.

30.2 Research Method

First of all, it needs to be mentioned that as a project-based and fragmented industry, much of the innovation in construction is co-developed at the project level and therefore remains hidden (NESTA 2006; Barrett et al. 2007). Thus, this paper studies the positive factors of innovation at project level to understand it thoroughly as many factors coming from the project itself.

A literature review and six interviews have been done to find the positive factors of innovation in construction projects generally and PPP projects specifically, which are the attributes of innovation potentials. The literature study includes journal database such as; ASCE, Emerald Insight, Elsevier ScienceDirect and EBSCOhost, using a number of keywords; enabler, driver, stimulant, innovation, PPP, and construction. As for the interviews, four respondents are working for construction companies in Australia; Lend Lease, Engineering Co, PCL construction, and Brookfield Multiplex, one respondent is working for Aquasure (the consortium of Victorian Desalination Project), and one for Road and Maritime Services New South Wales. The respondents are experienced engineers.

In the next sections, this paper will firstly review the drivers and enablers of innovation (as the attributes of innovation potential) from the literature of construction innovation and compare the view to the respondents' answers. The driver of innovation refers to the factors that cause and motivate innovation to happen and the enabler of innovation refers to the arrangement, strategies, and resources that encourage innovation. At the end, the drivers and enablers of construction innovation will be synchronised with the characteristics of PPP arrangement.

30.3 Drivers and Enablers of Innovation as the Attributes of Innovation Potential

All previous researchers in construction innovation reviewed have been using the term ‘driver’ and ‘enabler’ of innovation interchangeably as the factors that influence innovation positively, except Ozorhon et al. (2010) who have started to distinguish the two terms. Although they do not mention explicitly the difference influence these two terms having towards innovation. As mentioned before, this paper uses the term drivers of innovation as the factors that cause and motivate innovation to happen so innovation will not be introduced or considered to be implemented without these factors, while enablers of innovation are the factors that can empower or facilitate innovation. Innovation will still be introduced with the drivers only without the enablers but it cannot be implemented and cannot have benefits without the enablers thus it will not be a ‘real’ innovation as The UK’s Department of Trade and Industry (2007) defines innovation as the successful exploitation of new idea, successful exploitation means that the new idea/knowledge needs to be implemented and create a benefit or value. The same view by Ozorhon et al. (2010) that a new idea/knowledge implemented needs to improve the value of products, processes, or services to be called an innovation. The presence of drivers and enablers of innovation will indicate the potential of the innovation to be introduced, implemented, and having the benefits.

Another point that needs to be highlighted that as a project-based industry, construction industry is partly manufacturing and partly servicing then there will be opportunities for technological and non-technological innovation to occur in this industry. As Anderson and Schaan (2001) affirms that looking from construction industry perspective, innovation can be broadly classified as either ‘Organisational innovation’ or ‘Technical innovation’. Organisational innovation is dealing primarily with people and the organisation of work and may result by the introduction of changes to the organisational structure and introduction of advanced management techniques. The drivers and enablers of innovation listed in this paper has not been clustered based on the types of innovation (i.e. technical and organisational innovation). However, the drivers and enablers listed in this paper will be used in a more in-depth study, the study will include clustering the innovation drivers and enablers based on innovation types using an online survey (Fig. 30.1).

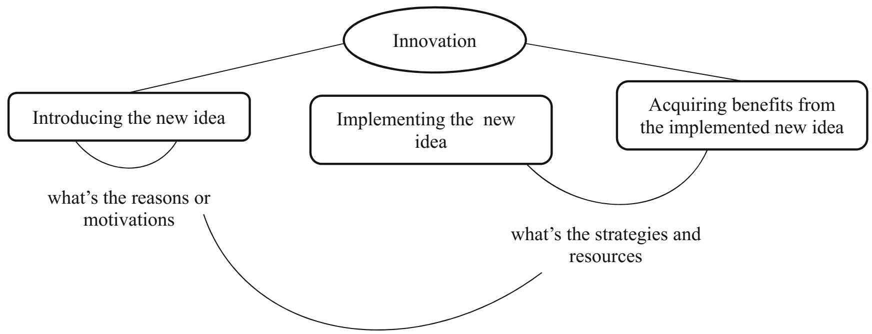


Fig. 30.1 How innovation potential is predicted

30.3.1 Drivers of Innovation in Construction Projects

Innovation can be a primary solution to enhance project performance. However, innovation has to have a primary reason or a motivation first then it can be considered as a solution to enhance project performance. The drivers of innovation have been obtained from the literature of construction innovation and from the respondents' answers. As mentioned a few times before, the drivers and enablers have been mixed and provided as the same term in the literature and even from the respondents' answers. They have been distinguished now by the sense of taking the factors that motivate and cause innovation to happen as the drivers of innovation and the factors that empower or stimulate innovation as the enablers of innovation. This section will discuss about the drivers of innovation in construction projects.

- Client's requirements for innovation: innovation is more likely to happen when there is a demand from the client or when the client is interested in implementing innovation in the project (Ling 2003; Blayse and Manley 2004; Bossink 2004; Ling et al. 2007). Client's requirements have been cited a lot as the reason of introducing innovation (Eaton et al. 2006; Gambetese and Hallowell 2011a, b).
- Competition between bidders: the survival of organisations in an intense climate depends on their creativity and innovation as competitive forces encourages experimentation and drive the innovation process (Eaton et al. 2006; Russell et al. 2006). Two respondents, from Brookfield Multiplex and Aquasure, have the same view that when the teams are bidding for a project, they will strive to find a new way to do it to produce a better outcome for the client and beat their competitors, it especially happens for PPP projects.
- Potential for project performance improvement; cost, time, quality, and safety: the potential for project performance improvement will also drive innovation. Innovation solutions are expected to enhance project performance with respect

to cost, schedule, quality and safety along with improving competitiveness and market share (Slaughter 1998; Ling 2003). Ling et al. (2007) includes the potential to enhance project quality specifically can foster innovation.

- Demand for green benefits and environmental sustainability: nowadays there is even greater demand to comply with green benefits and environmental sustainability. Organisations are developing and using technological capabilities to become innovative in sustainable construction as innovative design and construction processes can help mitigate or even avoid some environmental risks (Bossink 2004; Russell et al. 2006; Ozorhon et al. 2010). Environmental penalty is now included in some procurement contracts and it is a motivation for innovation (Rangel and Galende 2010). A respondent from Engineering Co. says that non-commercial targets like safety and sustainability can foster innovation.
- Regulator's requirements for innovation: beside client, government also plays a big role in driving and enabling innovation. As the regulator, government can increase its role by establishing regulations or rules that demands or stimulates innovation, such as increasing tax incentives for innovative companies, demand for complying with the environmental sustainability, subsidising materials and applications for companies that are willing to be innovative in sustainability, and developing performance-based regulations (Dulaimi et al. 2002; Blayse and Manley 2004; Bossink 2004; Russell et al. 2006; Ozorhon et al. 2010). Specifically in PPP projects, as a client government has a key role in driving and stimulating innovation (Eaton et al. 2006).
- End-user's requirements: infrastructure as the end-products will commonly be used by the civilians and when they are engaged and asked to convey their needs, creative ideas might occur. It specifically could happen in PPP projects. End-user's requirement could be a motivation to innovate (Dikmen et al. 2005; Ozorhon et al. 2010; Russell et al. 2006).
- Technical challenges or complexities: project complexity implies a high level of technical sophistication in the design and related construction processes; it also implies stringent technical and performance requirements (Russell et al. 2006). A more complex project is a more challenging project, innovation comes to solve technical problems and challenges that arise in project execution at the construction site (Eaton et al. 2006; Ling et al. 2007; Pellicer et al. 2012). A respondent from Aquasure says that if there are new challenges in the project then innovation might occur to answer them.
- Uncertain tasks: beside complexity, uncertainty also a characteristic of large construction projects. Feasible innovation is conceived by client and other key project participants to overcome the uncertainties (Nam and Tatum 1997; Russell et al. 2006). A respondent from Engineering Co reveals that high level of technical risk and uncertainty can be a reason for the team to create innovative solutions to overcome the problems.

30.3.2 Enablers of Innovation in Construction Projects

This paper uses the term enablers as the strategies and resources that can encourage, empower, and facilitate innovation. The enablers of innovation have been obtained from the literature of construction innovation and from the respondents and have been distinguished with the drivers of innovation. The enablers of innovation are grouped into two clusters; arrangement and strategies for innovation and resources for innovation.

1. **Arrangement and strategies for innovation**

NESTA (2006) and Barrett et al. (2007) claims that as a project-based and fragmented industry, much of the innovation in construction is co-developed at the project level and therefore remains hidden. Thus, to study innovation in construction industry thoroughly it should be done at project level. Studying what can encourage innovation to happen needs to be done at project level too, as many factors that can affect innovation coming from the project itself. Different project would have different arrangement and strategies (e.g. contract, stakeholders' arrangement, duration), where those arrangement and strategies will form the characteristics of the project. In arranging the project, whether the contract type, the stakeholders' relationships, the scope and activities, etc, one should consider what arrangement and strategies they choose to boost innovation and in the end has benefits to project performance.

- Integrated project delivery arrangement: when one team is responsible for all project stages, this team will have more flexibility in designing solutions and applying innovation. The integration of design and build will give the project team a design freedom to employ innovative solutions (Dulaimi et al. 2002; Bossink 2004; Blayse and Manley 2004; Leiringer 2006; Rangel and Galende 2010; Gambetese and Hallowell 2011a). Integrate or bring together specialists as one team in all phases of a project's life cycle or the integration across the project supply chain will encourage innovation (Russell et al. 2006; Barlow and Köberle-Gaiser 2009; Gambetese and Hallowell 2011b). The same insight by a respondent from Engineering Co that early engagement with the contractors in the concept design phase will enable innovation to occur, similar statement from Brookfield Multiplex's respondent that in PPP projects, any inclusion in the design phase that achieves improvement is seen as innovation.
- Long term project life cycle: financial and reputational incentive to focus on long-term asset management stimulates innovative thinking in design and construction (Barlow and Köberle-Gaiser 2009). The establishment of long term relationship is a driver of innovation in construction industry (Bossink 2004). Long-term commitment forces the actors concerned to look at tried and tested solutions, i.e. existing methods and technology and might lead to the achievement of technological innovation (Leiringer 2006).

- Appropriate risks transfer/allocation, risks transferred to the party who can best manage them: specifically, in PPP projects, a greater degree of risk transferred to the private sector as the party that is assumed having more capabilities in managing the risks or the risks are allocated to the party that can best manage it, thus most likely the party will create new solutions to overcome the risks (Blayse and Manley 2004; Leiringer 2006; Russell et al. 2006; Rangel and Galende 2010).
- Mechanisms for pain and gain share: these days, some contracts have included the agreement to share losses and rewards (profit and incentives). Bossink (2004) points that mechanisms for sharing financial risks and benefits will encourage innovation. More equitable pain and gain share will enhance performance and stimulate innovation as it reduces the fear to innovate (Ghassan et al. 2010).
- Collaboration of skills and expertise: in the purpose to coordinate an innovation effort in a project, cooperation must be increased among organisations involved (Dulaimi et al. 2002). Organisations integrate their project experiences into continuous business processes to limit the loss of tacit knowledge between projects, the knowledge that is needed to create new ideas (Blayse and Manley 2004). Programs promoting collaborative working can drive innovation (Bossink 2004; Leiringer 2006; Ozorhon et al. 2010; Gambetese and Hallowell 2011b; Barlow and Köberle-Gaiser 2009).
- Performance-based contracting: the less stringent the performance requirements are, the potentially greater the incentive for innovation will be (Russell et al. 2006). Strengthening of performance-based regulations and standards through the formulation of simple enforcement strategies will stimulate innovation (Blayse and Manley 2004). A prescriptive client defined scope and specifications can hinder innovation, a statement from Engineering Co respondent. A respondent from Aquasure also gives his view that to encourage innovation it is better to invite proposals with a fairly open specification. A performance brief challenges the bid teams to come up with an innovative solution in a way not thought of before (Brookfield Multiplex respondent).
- Performance metrics for innovation: a metric needs to be developed to indicate innovation performance against the project outcomes, this kind of metric will promote innovation (Russell et al. 2006; Barlow and Köberle-Gaiser 2009). Ozorhon et al. (2010) suggests that to improve innovation in construction industry, a more appropriate metric is required to measure the technological and non-technological innovation potential and its impacts to different project outcomes (which includes not only basic outcomes such as profit and quality but also health, safety, and environmental outcomes).
- Mechanisms to track and monitor innovation: a separate group should be established to coordinate and monitor innovation activities, it can ensure a successful innovation and promote innovation (Ling 2003; Ling et al. 2007). Similar view from Yitmen (2011) that innovation should be coordinated by a specific unit.

- Potential for repetition for the innovation; in current project or future projects: when there is a possibility of the same activity happens in the project or in another projects, an innovation solution will worth the effort because this solution will be used repeatedly. A greater range of potential design solutions are needed for projects that maximize repetition of factors (Russell et al. 2006). Gambatese and Hallowell (2011b) argues that innovative changes will be encouraged when the innovations are disseminated and used on subsequent projects.
- No blame culture: no blame culture includes trust between the project team members and openness to new ideas so people will not be afraid to be innovative. Trust and help for each other in the project team as an innovation stimulant in PPP projects (Eaton et al. 2006; Ozorhon et al. 2010). According to a respondent from PCL Construction, for innovation to truly occur, employees and team members must have a level of trust with their surrounding team mates in order to feel safe stepping forward with new ideas. Openness to new ideas is one of organisational attributes that is conducive to innovation (Blayse and Manley 2004; Eaton et al. 2006; Manley and McFallan 2006). PCL construction respondent states that having a culture that is open to change and embraces the idea of doing things differently can positively affect innovation.
- Flexible communication structure: flexible communication is the key to knowledge sharing as knowledge needs to be distributed to allow people to use it and create solutions. Blayse and Manley (2004) express that to improve communication and learning which lead to innovation outcomes, a more innovative procurement method will be chosen that might include partnering. Lateral communication structure is more flexible because communication will not be hindered by hierarchy (Bossink 2004). Flexible communication within the firm and among the project team will enable the successful diffusion of innovation to another projects (Dikmen et al. 2005; Gambatese and Hallowell 2011a, b). Eaton et al. (2006) and Barlow and Köberle-Gaiser (2009) state that it happens especially in PPP projects.
- Knowledge management system: losing knowledge can lead to missing opportunity to innovate. Knowledge must be obtained, recorded, and shared so people can use it to improve the system. Managing the knowledge exchange is an important strategy to facilitate the development of new knowledge that can be used to innovate (Bossink 2004; Dikmen et al. 2005; Ozorhon et al. 2010; Yitmen 2011). Improving knowledge flows by developing closer relationships with the parties involved and research institutes will integrate the project experiences and encourage innovation (Dulaimi et al. 2002; Blayse and Manley 2004). Lessons learned should be captured so it can be used to innovate in the project and subsequent projects (Gambetese and Hallowell 2011b).
- Intellectual property protection arrangement for innovation: the original innovation needs to be protected as it is an important asset or property, it requires resources and efforts to be implemented. An original innovation is an intellectual property (IP) of the innovator and it can be protected by law. Companies use their intellectual properties as strategic resources that can be managed to create a

competitive advantage, and when they have that kind of arrangement they will be motivated to innovate and create more intellectual properties (Yitmen 2011). Protecting the organisation's intellectual property is a strategy or arrangement that would encourage innovation (Manley and McFallan 2006).

- Reward and recognition for innovators: rewarding individual creativity motivates people to be creative, create new ideas and solutions and removes the fear of expressing thoughts and ideas. Having a reward system to recognise creative individuals or innovators allows innovative ideas to be created (Dulaimi et al. 2002; Dikmen et al. 2005; Gambetese and Hallowell 2011b). Eaton et al. (2006) asserts that reward and recognition for creative works stimulates innovation in PPP projects. A respondent from Lend Lease also asserts that creating a conducive environment for innovation could include providing incentives/benefits to individuals.
- Government regulations that encourage innovation (e.g. tax incentives, subsidies for innovation): as the regulator, government can increase its role by establishing regulations or rules that can stimulate innovation (Dulaimi et al. 2002; Blayse and Manley 2004; Bossink 2004; Russell et al. 2006; Ozorhon et al. 2010). As the client of PPP projects, government has a key role in stimulating innovation in those projects (Eaton et al. 2006). Creating a conducive environment which could include incentives/benefits to the company, client and individuals will encourage innovations (Lend Lease respondent). Engineering Co respondent has the same view and says that both monetary and non-monetary incentives are enablers of innovation.

2. **Resources for innovation**

Developing and implementing new ideas in the form of new product, process, or organisational method, require resources, beside the substantial human resource, it will need skills and experience, time, fund, applications, materials, and facilities to innovate.

- Client's experience in innovation: clients that are experienced and have a history in innovation will have more support in innovation, they will stimulate innovation in the projects (Nam and Tatum 1997; Barlow 2000; Blayse and Manley 2004). As a respondent from RMS New South Wales also states that support from client in the form of availability of experienced staffs will enables innovation. So client can both drive and enable innovation in construction projects.
- Presence of innovation champions: innovations need champions because ideas are carried by people, and ideas are the rallying point around which collective action mobilizes (Blayse and Manley 2004). Innovation champions act as individual enablers of innovation in organizations and projects (Bossink 2004; Dikmen et al. 2005; Gambetese and Hallowell 2011a). The project team in PPP

projects must be constituted to have a structure that can create an environment in which innovation can come from several champions: owners (who can embrace new ideas), designers, and contractors (Russell et al. 2006). Gambetese and Hallowell (2011b) found a strong relationship between innovation champions and project innovation in their case study projects.

- Presence of innovation leaders: leadership is an essential skill for accomplishing any organisation goals and it is no difference when the focus is innovation. Innovation leaders function as initiators and managers of the innovation processes in organizations and projects (Bossink 2004). According to Blayse and Manley (2004), client leadership is one of the strategies to get innovation outcomes. A respondent from RMS NSW states that leadership from project management team can drive people to be innovative.
- Time available for creativity and innovation: the project team can create innovative ideas when they are given the time allowance by the owner or the upper management (Gambatese and Hallowell 2011b). A 'slack' time in the staffs' workloads would give them a chance to develop new ideas (Dulaimi et al. 2002). A respondent from RMS New South Wales agrees that time is one of innovation important resources.
- Fund available for innovation: having financial resource is really important for the development of a new idea, adequate fund is needed for the project team to have courage in implementing an innovation (Bossink 2004; Dikmen et al. 2005; Ozorhon et al. 2010). When the client and upper management provide a specific budget for innovation, it will be an objective of the project team to innovate (Gambetese and Hallowell 2011b). Lend Lease respondent says that a PPP project commonly has a budget to accommodate innovation so there is more opportunity for innovation to happen in PPP projects than in other projects procured by traditional methods. Eaton et al. (2006) has a similar view.
- Facilities, applications, and materials for innovation: government agencies are clients of public infrastructures who commonly are concerned about sustainability which then will require innovation. To let innovation happens, the authorities would have a budget prepared for subsidising the sustainable applications, materials, and facilities (Bossink 2004; Yitmen 2011). Eaton et al. (2006) asserts that access to appropriate materials and facilities for innovation is an innovation stimulant that could be found in PPP projects.
- Research and development investment: Dulaimi et al. (2002) asserts that to enable innovation, construction companies need to invest more in R&D, they agree that increasing R&D volume means increasing the innovation level of the company. Dikmen et al. (2005), Manley and McFallan (2006), and Gambetese and Hallowell (2011b) have the same view that investing more in R&D will increase innovation opportunity (Fig. 30.2).

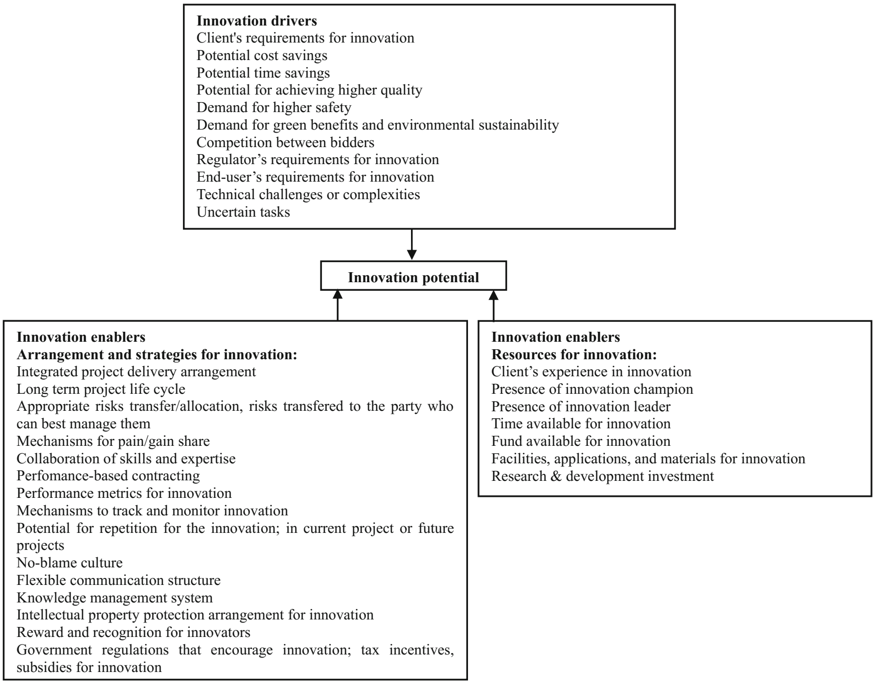


Fig. 30.2 Innovation potential as the presence of innovation drivers and enablers

30.4 Innovation Potentials in PPP Projects

As mentioned before that Public Private Partnership (PPP) is an integrated procurement method which allows private sector to be more flexible in designing solutions. The features of PPP method eliminate some ultimate innovation barriers. Previous researchers have identified the factors that can hinder the presence of innovation in construction industry. The most frequent factors mentioned are:

1. temporary or one-off nature of construction projects (Blayse and Manley 2004; Dikmen et al. 2005; Ozorhon et al. 2010)
2. fragmented nature of construction business (Dikmen et al. 2005; Ozorhon et al. 2010)
3. stringent requirements; scope and specifications (Russell et al. 2006; Pellicer et al. 2012)
4. lack of communication (Blayse and Manley 2004; Gambatese and Hallowell 2011b)
5. unavailable financial resources (Dikmen et al. 2005; Ozorhon et al. 2010)
6. conservatism, fear of change (Ozorhon et al. 2010; Gambatese and Hallowell 2011b)

Respondents of the interview support the finding from the literature of the top innovation barriers. The respondent from Lend Lease states that temporary and fragmented nature of construction projects can hinder innovation as it blocks the knowledge flow. Over specify or prescriptive project scope and specifications can also hinder innovation happening in the project, said respondent from Aquasure and Engineering Co. Lack of communication and transparency and fear of change are also barriers of innovation mentioned by a respondent from PCL construction and Road and Maritime Services New South Wales. Another ultimate barrier is the absence of innovation investment which is clearly will hold back any innovative ideas, this is an opinion from Lend Lease and Road and Maritime Services New South Wales respondents. Those six barriers could be removed by PPP method as PPP forms a long term contract between the public and private party to not only build/construct the facility but also design, finance, operate, and maintain it. PPP creates an environment where the parties can be working collaboratively with a performance-based specification where private party will be able to give innovative solutions. Moreover, that kind of environment will allow PPP to have some characteristics or criteria that can create potentials for innovation. Most of the drivers and enablers of construction innovation that were mentioned frequently in the literature and also mentioned by the respondents in the email interview, can be found in the environment of PPP projects. Thus, not only eliminating the innovation barriers, PPP projects' environment gives opportunities for innovative service delivery, that means PPP projects have great innovation potentials. Table 30.1 shows the characteristics or criteria of PPP projects (National PPP Guidelines, Infrastructure Australia 2008) and how they are fitting with the drivers and enablers of construction innovation.

Table 30.1 Drivers and enablers of innovation in PPP environment

No.	PPP projects criteria[a]	Innovation potential	
		Drivers of construction innovation	Enablers of construction innovation
1.	Managing complexity	Technical challenges or complexities	
2.	Focusing more on outcome and quality of the project	Potential for achieving higher quality Demand for green benefits and environmental sustainability	Performance-based contracting arrangement No-blame culture
3.	Whole of life asset management is achievable, strong financial support		Fund available for innovation Facilities, applications, and materials for innovation R&D investment

(continued)

Table 30.1 (continued)

No.	PPP projects criteria[a]	Innovation potential	
		Drivers of construction innovation	Enablers of construction innovation
4.	Strong market interests; attracting a sufficient number of private parties	Competition between bidders	
5.	Opportunity for risk transfer		Appropriate risks transfer/allocation, risks transferred to the party who can best manage them
6.	Bundling of contracts; integration of design, construction, operation, and maintenance over the life of an asset in a single project package		Integrated project delivery Collaboration of skills and expertise Long term project life cycle
7.	Competitive process	Competition between bidders	
8.	Innovation demand	Client's requirements Regulator's requirements End-user's requirements	Reward and recognition for innovation Tax incentives for innovation Fund available innovation
9.	Non-core services like accommodation availability and information technology outputs	End-user's requirements Demand for non-commercial targets like safety and sustainability	

[a]Paraphrased from the National PPP Guidelines, Infrastructure Australia (2008)

30.5 Conclusions

Innovation potentials in construction projects can be predicted by the presence of the drivers and enablers of innovation. It has been studied that PPP projects have better performance than traditional contracting projects, one of the main reason is because innovation potential in PPP projects is higher, as innovation is a solution to enhance performance. Another important point is that PPP environment eliminates the ultimate barriers of innovation such as; temporary and fragmented nature of construction projects, lack of communication, unavailable financial resources, stringent requirements, and conservatism.

Furthermore, the drivers and enablers of innovation that create innovation potential such as; client's requirements, end-user's involvement and requirements, regulator's requirements, potential for achieving higher quality, integrated project delivery, performance-based contracting, reward and recognition for innovation, competition between project bidders, no blame culture, tax incentives for innovation, and some others can be potentially found in the PPP projects environment because that kind of environment is intentionally created for the PPP projects to bring the best for the project and also to form an environment conducive for innovation. Moreover, as innovation is one of the winning factors in the bidding stage of PPP projects, thus most likely PPP project will be more innovative than other projects procured by traditional methods.

Another point that needs to be highlighted that government acts as the client of PPP projects and it is common that government demands innovation and often it is not just for the commercial targets but also for non-commercial target such as environmental sustainability and safety. It is likely to happen since the projects are infrastructure projects that are built for the community for the people to use. PPP projects would have more resource for innovation, in the form of time and fund to innovate as well as subsidies for innovative materials and applications.

Therefore, a further research is needed to dig up more about innovation in PPP projects and using those projects as model projects to develop an innovation framework, a guidance for the practitioners in construction industry to have successful innovation. The basic framework of innovation potential from this paper can have a part in the innovation framework which would show the relationships between the related factors of innovation and project performance. As the innovation happening in construction projects will be both technical and organisational, that more detailed innovation framework will also show the relationships of those two innovation types.

References

Anderson F, Schaan S (2001) Innovation, advanced technologies and practices in the construction and related industries: national estimates survey of innovation, advanced technologies and practices in the construction and related industries, 1999. Working Paper 880017MIE, National Research Council/Statistics Canada, Canada

Barlow J (2000) Innovation and learning in complex offshore construction projects. Res Policy 29 (7–8):973–989

Barlow J, Köberle-Gaiser M (2009) Delivering innovation in hospital construction: contracts and collaboration in the UK's private finance initiative hospitals program. Calif Manage Rev 51 (2):126–143

Barrett P, Abbott C, Ruddock L, Sexton M (2007) Hidden innovation in construction and property sectors. RICS Research Paper Series 7(20), RICS, London

Blayse AM, Manley K (2004) Key influences on construction innovation. Constr Innov 4(3):143–154

Bossink BAG (2004) Managing drivers of innovation in construction networks. J Constr Eng Manage 130(3):337–345

Dikmen I, Birgonul MT, Artuk SU (2005) Integrated framework to investigate value innovations. J Manage Eng 21(2):81–90

DTI (Department of Trade and Industry) (2007) Innovation in Services. Department of Trade and Industry, London
Dulaimi MF, Ling FY, Ofori G, De Silva N (2002) Enhancing integration and innovation in construction. Build Res Inf 30(4):237–247
Eaton D, Akbiyikli R, Dickinson M (2006) An evaluation of the stimulants and impediments to innovation within PFI/PPP projects. Constr Innov 6(2):63–77
Engineers Australia (2012) Innovation in engineering report
Gambatese JA, Hallowell M (2011a) Enabling and measuring innovation in the construction industry. Constr Manage Econ 29(6):553–567
Gambatese JA, Hallowell M (2011b) Factors that influence the development and diffusion of technical innovations in the construction industry. Constr Manage Econ 29(5):507–517
Ghassan A, Beliz O, Carl A (2010) Facilitating innovation in construction: directions and implications for research and policy. Constr Innovation 10(4):374–394
Infrastructure Australia (2008) National public private partnership guidelines
Leiringer R (2006) Technological innovation in PPPs: incentives, opportunities and actions. Constr Manage Econ 24(3):301–308
Ling FYY (2003) Managing the implementation of construction innovations. Constr Manag Econ 21(6):635–649
Ling FYY, Hartmann A, Kumaraswamy M, Dulaimi M (2007) Influences on innovation benefits during implementation: client's perspective. J Constr Eng Manage 133(4):306–315
Manley K, McFallan S (2006) Exploring the drivers of firm-level innovation in the construction industry. Constr Manage Econ 24(9):911–920
Nam CH, Tatum CB (1997) Leaders and champions for construction innovation. Constr Manage Econ 15(3):259–270
NESTA (National Endowment for Science, Technology and the Arts) (2006) The innovation gap —why policy needs to reflect the reality of innovation in the UK. NESTA, London
Ozorhon B, Abbott C, Aouad G, Powell J (2010) Innovation in construction a project life cycle approach. SCRI Research Report
Pellicer E, Correa CL, Yepes V, Alarcón LF (2012) Organizational improvement through standardization of the innovation process in construction firms. Eng Manage J 24(2):40–53
Rangel T, Galende J (2010) Innovation in public-private partnerships (PPPs): the Spanish case of highway concessions. Publ Money Manage 30(1):49–54
Russell AD, Tawiah P, De Zoysa S (2006) Project innovation—a function of procurement mode? Can J Civ Eng 33(12):1519–1537
Slaughter ES (1998) Models of construction innovation. J Constr Eng Manage 124(3):226
Yitmen I (2011) Intellectual capital: a competitive asset for driving innovation in engineering design firms. Eng Manage J 23(2):3–16

Chapter 31
Benefits of Using Constructability, Operability, and Maintainability in Infrastructure Projects: A Meta-Synthesis

S. Jadidoleslami, E. Saghatforoush, N. Kordestani Ghaleenoe and C. Preece

31.1 Introduction

All over the world, governments invest high amounts in infrastructure sections to develop their countries (Trigunarsyah and Skitmore 2010). High volume of investment in this section and relatively long period of time for construction and existing problems in the field of managing this category of projects need attention of most officials (Taleqani 2011).

Infrastructure projects can be large scale projects or national development plans which are implemented for comprehensive economic and social development of the country; and regardless of geographical location, the extent of their impact has been trans-provincial and trans-regional; and also the domain of enjoying them has been national and the general public benefit from their results. Considering huge financial and human resources as well as equipment cooperating for their construction, necessarily their fund is provided from national resources (Nouri 2005).

Infrastructure projects underlie progress and are the center of activities and services of societies to improve social, economic and nations' productivity development (Trigunarsyah and Skitmore 2010). According to definition, infrastructure is as an organizational structure and physical equipment necessary for the operation of a society or organization (Oxford advanced learners dictionary of current English 2000). Among issues that has been considered constantly during last decades in most countries, and has been the focus of policy makers and managers, is focus on infrastructure actions. In such policy makings, less attention has been paid to pre

S. Jadidoleslami · E. Saghatforoush (✉) · N. Kordestani Ghaleenoe
Department of Project and Construction Management,
Mehralborz Institute of Higher Education, Tehran, Iran
e-mail: e.saghatforoush@mehralborz.ac.ir

C. Preece
Centre on Sustainable Built Environment,
Abu Dhabi University, Abu Dhabi, United Arab Emirates

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_31

and post stages of the infrastructure programs, and usually managing infrastructure projects is done without considering basic assumption of holistic view (Alikhah 2010).

In each project, there are some stakeholders with different roles, desires, and aims. Therefore, in order to satisfy them and also to satisfy their demands, senior managers should interact and communicate with stakeholders throughout the Project Life Cycle (PLC) (Davis 2013). This interaction indicates constructability, operability, and maintainability (COM) concepts, which are able to reduce concerns of project owners and resulted into project success (Wells 1986; Kordestani et al. 2015).

Constructability means integrating construction knowledge and experience in early project phases to achieve general objectives of the project in all stages of planning, designing, logistics, and execution (Trigunarsyah and Skitmore 2010; Yustisia 2014); operability is another similar concept that refers to utilization and operational capability of a system that performs its expected jobs (Uwohali-Incorporated 1996); and finally maintainability is defined as the ability of maintaining or ease of sustaining (Trigunarsyah and Skitmore 2010).

Now available performance in managing infrastructure projects, has resulted into separation of various phases of the project from each other in the process of doing it from beginning to the end (Kordestani et al. 2016; Jadidoleslami et al. 2015). Also this issue caused lack of integration of objectives and performance of working stakeholders in each project; which in most cases is considered as the origin of failure (Saghatforoush 2014). Integrating various phases of the project will cause realization of the main objective of infrastructure projects' owners, i.e. project success; while some literature refer to lack of coordination or procrastination and laziness in the necessity of paying attention to integration of phases of conducting project (Heising 2012). Therefore, identifying benefits of using these concepts and importance of applying them in projects is necessary; through which a lot of problems and duplications can be reduced. According to the necessity of understanding these concepts, the next section investigates them.

31.2 Concepts of Constructability, Operability and Maintainability of Infrastructure Projects

Constructability is a project management technique for improving construction process from beginning to the end using early decision makings during pre-construction phase. This technique will cause reduction or prevention of occurring errors, delays and also overflow costs through identifying available barriers in early project definition and design.

Constructability is optimal utilization of construction experience and knowledge in planning, design, supplies and appropriate implementation in order to achieve the overall objectives of the project (Constructability A Primer 1986). So far constructability has been used consciously or unconsciously in various projects and also has been discussed and analyzed by various researchers and organizations frequently, as optimal utilization of construction knowledge and experience in stages of conceptual planning, descriptive engineering and construction in order to achieve the overall objectives of the project (Saghatforoush et al. 2011). From beginning to the end of building projects, there are phases composed of defining objectives and tasks, planning, design, construction, operation and maintenance. These phases can be summarized into two basic steps of pre-construction and post-construction (Thabet 2000). On the other hand, in addition to the concept of constructability that is effective in success and integration of various steps of the project, two other concepts of operability and maintainability also influence this process (Jadidoleslami et al. 2016).

Operability and maintainability mean transferring knowledge of post-construction stage to initial planning, design and even construction. These two concepts are so close and similar to each other. Operability is defined through (Trigunarsyah and Skitmore 2010) ease of operation. This concept has been introduced as one of powerful techniques for enhancing the integration in the infrastructure projects. Because of the feature of uniqueness in the world knowledge, it is required that each country evaluate every single concept specifically (Saghatforoush et al. 2011). Maintainability in infrastructure projects, for the first time proposed by US military services organization in 1954 (Thabet 2000), which in order to reduce costs and job hardness, should be considered in design and implementation (Chew et al. 2004). Maintainability is ease of maintaining products which is considered to reduce defects and/or identify the reasons of their occurrence, discovering new needs, easier maintenance in future, and compliance with changes of environment conditions (Shen et al. 1998).

Maintainability is defined as design features that are related to ease accuracy, safety, and economy in performance of repair and maintenance actions (Blanchard et al. 1995; Dhillon 1999). Maintainability states actions taken in the process of phase development, design, and installation of produced products, which results in proper maintenance of tools, equipment, and reduction of the required skill level. Optimal Maintainability of design features includes access, reliability, ease of repair and maintaining and performance of all of system components, which reduces costs and increases profit and value of PLC (Dunston and Williamson 1999). This concept, through transferring experiences of maintenance step to initial stages, tries to integrate them to minimize duplications and problems (Saghatforoush 2012). The process of doing research for realization of defined goals requires to identify methodology of this project and its processes, which is presented in the next section.

31.3 Methodology

In this study, in order to achieve benefits of using COM concepts in infrastructure projects, the qualitative method of meta-synthesis has been used. Meta-synthesis method is integrating researches conducted before in terms of common points and differences among them. This method finally concludes by presenting a comprehensive description of the issue researched. This method, in order to make a final achievement and to create new metaphors in research field, tries to collect main cases and translate the results. The desired scope in this method is qualitative studies, interpretation and integrating the results of these interpretations which helps the researcher in understanding the issue (Shirpak et al. 2010; Yahyapour and Shami Zanjani 2012; Vadadhir 2011).

In meta-synthesis, the researcher investigates data and edits the results precisely and conceptually, and then unifies qualitative results which are related to each other (Azkia and Tavakoli 2006). The researcher investigates similar texts systematically (Zimmer 2006), and by searching selected studies, extracts codes that represent a comprehensive concept of the desired phenomenon (Dixon-Woods et al. 2005). Data obtained from meta-synthesis method, are analyzed in this research by the Nvivo software. Using this software is recommended when there are a lot of data in the literature proposed by various experts in this field (Zolfagharian and Latifi 2011). In this software, there is a system for fast coding through pattern and descriptive analysis, which helps receiving main ideas of collected texts (Bazeley and Richards 2000). In this study, in order to get the answer of the proposed question, seven fold steps of meta-synthesis method introduced by Russo and Sandlovski 2006 has been used (see Fig. 31.1).

31.4 Data Analysis

In this study, as mentioned previously, in order to classify benefits of using the COM concepts, meta-synthesis method has been used. In this section, executive steps of this method will be presented along with the findings resulted.

Step One: Setting Research Questions

The first section of meta-synthesis method focuses on specifying research questions considering previous studies and the researcher interests where he is to answer them (Paterson and Thorne 2003). In this study, the aim is identifying benefits of utilizing constructability, maintainability, and operability concepts which are to realize research objectives based on "what" question types (Azkia and Tavakoli 2006). In this research, the document analysis method as the secondary data analysis is also used. Researcher identifies and specifies appropriate literature that should be entered the meta-synthesis process and those that exit from it, by considering certain criteria (Zanganeh 2004).

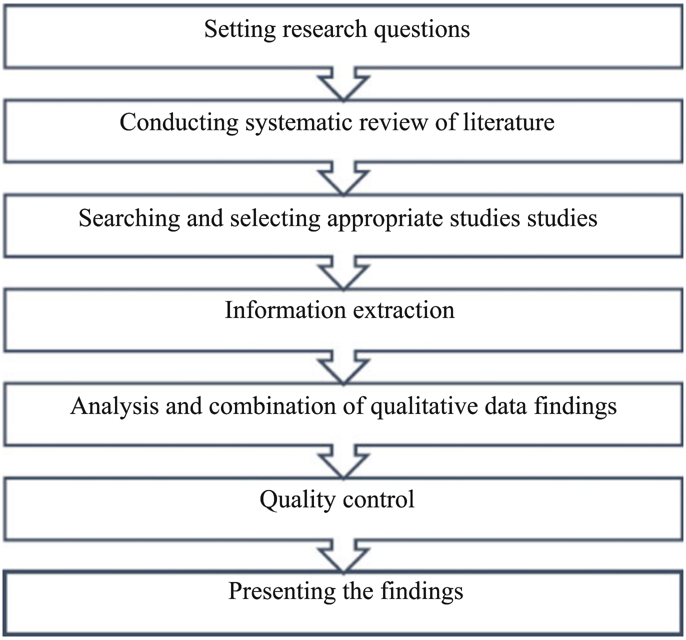


Fig. 31.1 Meta-synthesis steps (Azkia and Tavakoli 2006)

Table 31.1 Keywords

English
Maintainability
Constructability or buildability
Operability
Benefits or Incomes or profits

Step Two: Conducting Systematic Review of Literature
In the second step, the researcher searches and stores sources in reliable scientific bases, based on desired keywords and in compliance with research objectives. These defined keywords will be reviewed and evaluated repeatedly during research process (Dabaq Kashani 2011). Keywords are presented in the Table 31.1.

Step Three: Searching and Selecting Appropriate Studies
At the stage of literature search, it is required to determine whether found sources are compatible with research questions or not. In order to achieve this, it is required that all found articles be evaluated and at each stage, a number of them which are not related to the aim of the research, be eliminated. Thus it is required that the researchers pay well attention to this process and evaluate found sources in the last stage of every single step during meta-synthesis. Found sources are evaluated many times and at each stage, some sources are excluded from the research process, and

in this way, the number of them will decrease. In meta-synthesis method, acceptance or non-acceptance criteria are used for selecting appropriate studies and excluding unrelated ones (Briggs 2006).

One of important parts of conducting this process is determining criteria for accepting studies at the following steps of meta-synthesis, along with specifying factors for excluding unrelated ones in this process (Weed ME, Sports tourism research 2000). Defined acceptance criteria for selecting studies are as follows:

- Language of the articles: English and other
- Methodology: qualitative, quantitative-qualitative (synthetic)
- Type of studies: published articles in reliable scientific journals or conferences

At this step, in order to accelerate and facilitate evaluation process of found sources, in the content investigation section, Critical Appraisal Skills Program (CASP) has been used. This model tool has ten factors, which act like a check list and help the researcher to evaluate accuracy, reliability, and importance of the above studies. The aim of this stage is eliminating sources that their data doesn't have appropriate quality, based on researcher's view while the researcher evaluates and criticizes them through giving them quantitative scores (Najafi et al. 2013). Questions of the mentioned tool includes: 1—research objectives; 2—logic of method; 3—research plan; 4—sampling method; 5—data collection; 6—reflectivity; 7—moral considerations; 8—accuracy of data analysis; 9—clear articulation of findings; 10—research value (Dixon-Woods et al. 2005). At this stage, it is required that the researcher study full text of the articles and be aware of their content (Dabaq Kashani 2011). After conclusion of this stage, final number of articles for entering meta-synthesis process is determined (Dabaq Kashani 2011), which in this study is 63. In this process that is based on 50 score scale, each article that has score lower than good (lower than 31) will be excluded. Then, in the step four of information extraction, the descriptive analysis is implemented using the NVIVO software. This is an accurate investigation to achieve meta-synthesis findings.

In the Fig. 31.2, the brief summary of the step three is illustrated.

Step Four: Information Extraction

34 selected articles from the previous step are to be used in the step four. Table 31.2 codes the extracted benefits along with name and year of publication of the article.

Step Five: Analysis and Combination of Qualitative Data

At this step, after classifying the codes identified from the previous step, they are offered in the frame of barriers according to pattern analysis in the NVIVO software. These findings are finally presented in the categories of PLC phases in the step seven.

Step Six: Quality Control

During meta-synthesis method, researcher was to select resources from reliable databases, and did not study those resources without academic merits. Also, to achieve that, the CASP technique was used. At coding extracted data section, obtained codes are reviewed and studied repeatedly, and if an error find, it was

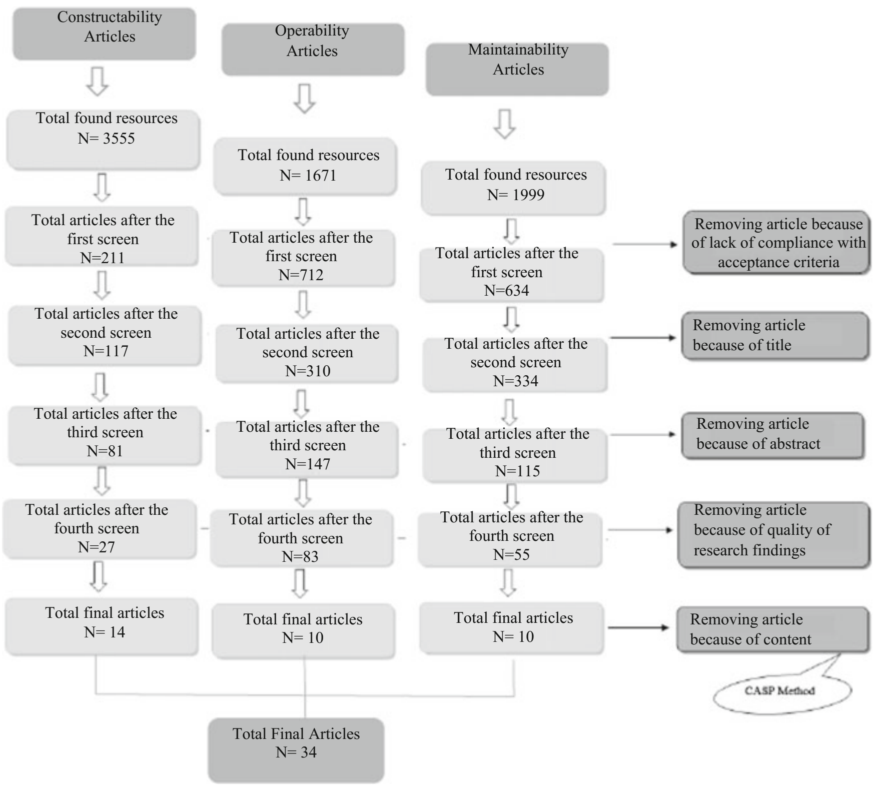


Fig. 31.2 Brief summary of the meta-synthesis step three

corrected. In this way, the mentioned cases can guarantee quality of findings of this research to an acceptable level. This is briefly illustrated in the Fig. 31.3 as a framework of controlling meta-synthesis quality.

Step Seven: Presenting the Findings

While the nature of projects is different in terms of content of the desired job, yet there are some similarities independent of content among projects. In most projects, the phases of doing them include four to five stages. Stages of doing project, is a set of continuous and sometimes overlapping phases in the project, which their name and number is determined by control and managerial needs of the involved organizations, nature of the project, and its application areas.

In most cases, project management processes are grouped rationally in 5 process groups, which these phases represent main stages and major steps in implementing the project from beginning to the end. In the Fig. 31.4, benefits of descriptive analysis, which were identified at the first stage and were coded by the pattern coding technique are presented considering its implementation in successive phases of PLC, i.e. phase zero—justification plan, phase one—preliminary design, phase

Table 31.2 Benefits of using COM

	Title	Year	Benefits
1	Tennessee Department of Transportation Construction Division (2016)	2016	Integration of knowledge and experience, to minimize the potential changes, Improve the quality, Increased coordination, reduction of costs, Using new ideas, The availability of information, reduction of construction time, Fixing The project Returns, Increased safety and To minimize the risks
2	Zidane et al. (2015)	2015	The use of new technology, reducing delivery time, improve planning, mitigation and errors, improve quality management, integration and synchronization of design and manufacturing, improve relationships, increase customer satisfaction, improve information management, dealing with uncertainty, increase satisfaction of stakeholders, sharing information
3	Allen (1993)	2015	Reduction of project risks, Integration between knowledge and manufacturing experience In the planning and design phase, Create a framework to facilitate entry of construction among project stakeholders, Increase the value of the executive phase input, Increase opportunities, reduction of cost, reduction of working hours, reduction of changes, Improve cooperation, Early identify real challenges, Improving the experiences of previous projects, Create a comprehensive vision for the client project, Solve problems before project implementation
4	Sødal et al. (2014)	2014	Improve cost estimates, Improve planning, reduction of management errors, Increase accountability, Improve teamwork, Increase efficiency, reduction of the gap between designers and builders, Increased innovation, reduction of cost, reduction of time, Enhance the quality, Informed decisions about the design, reduction of cost of change, To minimize errors, Improve the quality of outputs, Improve the exchange of information, reduction of disputes, reduction of delays, Improving risk management, reduction of costs risk, Increasing mutual respect and trust, Integration of knowledge and experience, Effective analysis of project feasibility
5	Alinaitwe et al. (2014)	2014	Improve communication, Increased coordination, Improve planning, use of update technology, reduction of disputes, reduction of changes, Save money and time, Improve employee engagement, reduction of delays, Increased safety, Improved organization and management
6	Pulaski and Horman (2005)	2014	Ease of maintenance, increasing the value of project finance, increased collaboration and teamwork, facilitating decision-making process, share information, share ideas, enhance quality, reduce project time, project team integration activities, documentation, information, increase opportunities for long time, create better relationships
7	Ivory et al. (2001)	2014	Effective use of labor and materials and capital, Improve scheduling, reduction of errors, reduction of conflicts and disputes, Optimize quality, improve process management, Raising awareness of standard operating procedures, improved documentation, information, reduction of costs, reduction of changes, Increased coordination, Improving risk management, Facilitate control and management
8	Smith and Principal (2006)	2013	Early detection of problems, Focus on Value Engineering as a normal output of the process, reduction of Changes and reworks, reduction of time limits, increasing discipline, a significant increase interdisciplinary coordination, Enhance the quality, Improve the design process
9	Baiden and Price (2011)	2013	Utilizing the knowledge and experience of maintenance in early stages, Increase customer satisfaction and end-users, Improve cooperation between staff, Make better decisions, reduction of Potential problems later in the project, Utilizing feedback from people to reduce errors and defects, Increase the attractiveness for client, Improved responsiveness to user needs, Facilitate control and management, Improved responsiveness to personnel, Better preservation project, Increase the

(continued)

Table 31.2 (continued)

	Title	Year	Benefits
			financial value of the project, Emphasizing the total project cost, Identify design flaws before they occur, Improving maintenance practices, Encourage more sustainable projects, Supporting performance, Provide greater flexibility to make needed changes
10	Hillman Willis and Willis (1995)	2013	Reduce maintenance costs, more precise planning, the use of support services, reduce costs, improve access, reduce changes, improve decision making, increase performance, reduce interference, the use of new technologies, improvement of the maintenance operation strategies, increase satisfaction of stakeholders, improved planning, to avoid mistakes, improve documentation, enhance immunity, reduce costs
11	Yik et al. (2010)	2010	Increase reliability, improve quality, increase customer satisfaction, enhance engineering services, improved awareness, increased safety, sustainable development, improve communications, the availability of information
12	Karim and Magnusson (2008)	2010	Reduction of project risks, Reduce project life cycle costs, Reduce maintenance time, reduction of disputes, Raising the scientific level of design, Reduce downtime, Create backup system, Ease of Maintenance, reduction of Maintenance personnel, Increased ease of access, Simplicity, Testable design of projects
13	Pitt (1994)	2009	Reduce waste, improve decision making, reduce risk, improve documentation, access to high-quality delivery of projects, reduce costs, increase efficiency, reduce time, reduce overall project changes and annexes of the contract, increase teamwork
14	Karim (2010)	2008	Improve methods and techniques to reduce maintenance costs by reducing intervention time and efficient tool, the exchange of knowledge among those involved in the project, improving cultural problems, coordination between the various stages of the project more, increase stakeholder awareness, increase motivation more for the various stages, the emphasis on life cycle costs of the 15project, the creation of evaluation process with clear ins16tructions, create the database, share information, reduce problems and rework, facilitate the process of achieving the project objectives, increase quality, reduce costs final project
15	Dunston et al. (2007)	2007	Improving communication between operational units, especially the design and construction, upgrade policies and methods of teamwork, team improved relations with contractors, improving quality, avoidance of large claims, saving time and cost of construction, reduced costs, improving communication between operational units, reduce claims, increase discipline, increases safety, reduces design time, minimize problems and changes, due to maintenance issues
16	Markeset et al. (2013)	2006	Reduction of project challenges, Integration of knowledge building, Limitations balancing environmental projects to achieve project goals, Facilitate construction, Enhance the quality, reduction of problems and reworks, Increased safety, Storage funds, Improving industrial relations, Increase teamwork, Client satisfaction, Good relationships among stakeholders
17	De Silva et al. (2004)	2006	The integration of the different stages of the project and the disappearance of boundaries between groups, Facilitating the realization of the objectives predetermined, The integrity of the rules and principles of the various phases of the project, reduction of costs& problems& reworks
18	Meng (2013)	2005	Taking advantage of the knowledge construction, pre-project documentation, better integration projects to achieve predetermined objectives efficiently, increase quality
19	Makarand et al. (2004)	2004	reduce cost, better performance, emphasizing the project life cycle costs, taking advantage of the knowledge and experience designers maintenance phase

(continued)

Table 31.2 (continued)

	Title	Year	Benefits
20	Meier and Russell (2000)	2004	Documenting Information, reduction of changes and reworks, The use of new technology, improved planning, reduction of errors, Improving quality management, integration and synchronization of design and construction, increased customer satisfaction, Improving information management, dealing with uncertainty, increase satisfaction of stakeholders, improving the decision-making process, Reducing delivery time, improve collaboration, reduce project risks, reducing project life cycle costs, reduced maintenance time, Increased financial value to client projects
21	Hines et al. (2001)	2001	Enhance the quality of engineering output, reduction of Errors, Fixed a problem related to lack of information, reduction of Rework, reduction of Delays, reduction of Construction costs, reduction of Project Risks, Improving Productivity, Availability of skilled labor, Clear scope of work, Improve planning, Increase the integrity of the building, , reduction of Changes, Rapid assessment of the consequences of deviations, Direct connection between Design and Engineering and Supply and delivery, Effective use of the workforce, Increase the reliability of things right, maximize of the opportunities, Improve access to the site, Increased safety, Saving labor costs
22	Dunston et al. (2001)	2001	Achieving high quality in the delivery of projects, cost reduction, mitigation and contract extensions, increase team collaboration, reducing overall project time, reduce the need for monitoring, increased cooperation between the operational units, Increasing coordination, more effective use of experiences and expertise, to create a reliable knowledge base, the realization of a wide range of potential benefits, documentation, information, recognition of quality-driven processes, increase design flexibility, experience and build effective cooperation, facilitating efficiency culture of teamwork, enhance the satisfaction of stakeholders, improving the design, use of standard Czech and updated lists to document and increase productivity, to share information, facilitating communication, reducing the cost of communications
23	Radtke and Russell (1993)	2001	Reduction of reworks, Increased safety projects in the implementation phase, increased quality, storage resources, early detection of problems, integration and information technology, greater cooperation between the various stages of project
24	Allen (1993)	2001	Sharing knowledge and experience with each other, increasing communication between the various stages of project, document information, reducing the problems and risks, achieving the goals of the project, reducing the cost and time of the project, supervision over the project and increase accountability
25	Naderpajouh et al. (2015)	2000	To minimize changes, reduction of disputes, reduction of costs and delays, Increased cooperation
26	Ogburn et al. (2014)	2000	Increased cooperation and integration, Enhance communication among project stakeholders, Transfer of knowledge and experience, Reducing the difficulties and challenges, Utilizing the experiences of previous projects, Documenting information
27	Wong et al. (2005)	2000	Sharing knowledge, improve building performance, reduce maintenance, reduce changes during the design phase, mitigation guidelines related to maintenance, reduce rework on the run, efficient latest projects, the importance of maintenance in the early stages, reduce maintenance costs
28	Dunston and Williamson (1999)	1999	Reduce project costs, increase awareness of drug and material design and implementation and maintenance, coordination between the systems and work processes, improve communication between the various stages, reducing rework and modifications during the project, early identification of challenges, the increased commitment stakeholders, raising the level of responsibility of the various stages of the project, using the experiences of previous projects, documentation of data.

(continued)

Table 31.2 (continued)

	Title	Year	Benefits
29	Anderson et al. (2000)	1995	Improving quality management, quality of output, reduction of costs, Increased coordination, To minimize rework, increase customer satisfaction, reduction of errors, Improve communication, reduce the inclination time, improve the quality of engineering, Improve planning, increase productivity, enhance safety, reduce distortions in the design phase, improving the decision-making process
30	Anderson et al. (2000)	1998	Improve safety management, reduction of technical and human errors, abuse control policy, improve performance management, improve information processing, designed to achieve more accurate results, reduce risk, optimize the use of technology to improve the planning, preparation of documentation feedback, improve communication
31	Kartam (1996)	1996	Better planning, lower financial costs, the effective transfer of experiences, increase output quality, improve coordination, team building, enhancing communication, improving documentation, development planning and integrated design, increase profits and productivity, improve effective communication, available the necessary knowledge, reducing the cost of rework, reducing the gap between engineering and execution, integration of knowledge and manufacturing experience, increase safety, improve discipline, there is value engineering as a normal byproduct of this process, the possibility of providing feedback on project results, increase innovation, the availability of information, creation of knowledge-based systems interact effectively, to develop strategies to document and share information, plan realistic, the use of new technologies, increase quality, systematic management databases, dynamic communication, the use of technology
32	Duggan and Blayden (2001)	1994	Effectively increase safety, improve management, increase accountability of staff, reduce risk, anticipate problems, improve quality, reduce waste, reduce costs, reduce delays
33	Ling et al. (2014)	1993	Reducing the total cost of the project, revealing hidden opportunities for employers, reducing duplication in projects, employing lessons learned in previous projects, the creation of the database, using the experiences and knowledge building, replacing the cost of construction, supervision further, reduction of contractual problems, the key people in one place for the project, commit latest project owner, increased support from senior management, to facilitate the achievement of project objectives, project collaboration more people, create a profile to select team members, accepting ideas new, prioritize goals, optimization of the construction process
34	Kennedy and Kirwan (1998)	1993	Reduction of costs, utilizing the knowledge and experience maintenance at an early stage, improve the quality of engineering, Providing documentation feedback, improve communication, setting clear priorities, improve safety, enhance the technical performance, improved access to information.

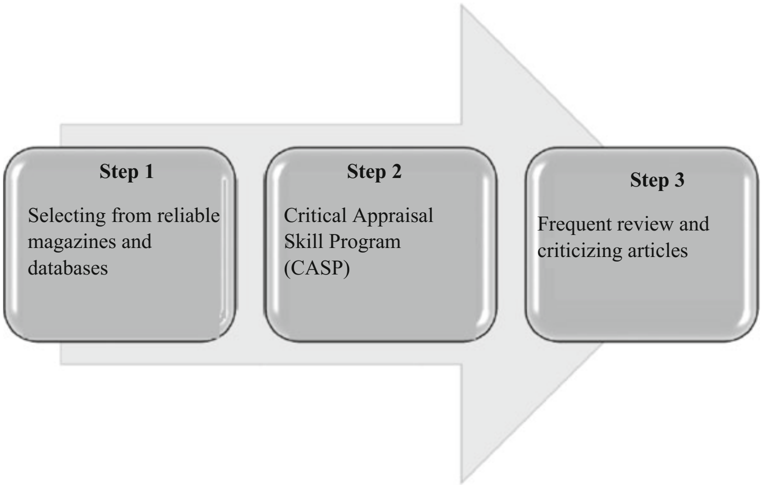


Fig. 31.3 Framework of controlling meta-synthesis quality

two—in-depth design, phase three—implementation of the contract, and phase four—operation.

It should be noted that phases two to four, i.e. in-depth design, implementation of the contract and operation are in one cycle; this is because of the nature of interdependence of these phases from each other, and this dependency made researchers of this study to classify COM benefits in the framework of phases of PLC. As sometimes it is necessary to modify project program in terms of the obtained experiences during early implementation, or through changes arising during project, and corrected results send for implementation again.

Some of the benefits of implementing COM concepts, in addition to belonging to a specific phase, can be obtained in other phases of conducting the project too (see Fig. 31.4); because due to continuity and dependency of phases of doing project to each other, surely implementation of each of these three concepts of COM can have common benefits for them. Therefore, these benefits should be noted in terms of the extent of the influence and also their additional performance.

31.5 Discussions and Conclusions

Lack of attention to the effects of the initial planning and design decisions on final phases of the project are very significant in its performance and final success. Therefore, any ignorance can have severe negative influences on achieving the project objectives. On the other hand, any stage of the project is important for existence of various stakeholders and different interests and expectations. While to

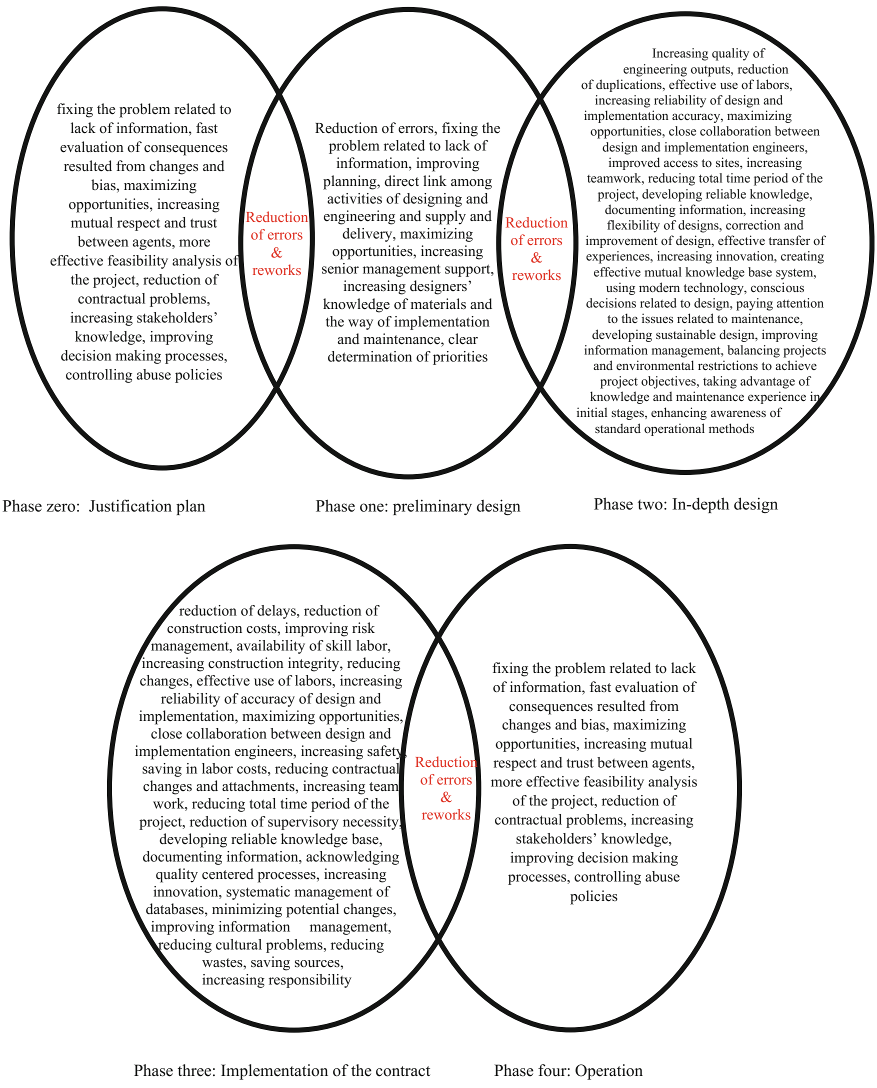


Fig. 31.4 Benefits chain of using COM along the PLC

realize project success, it is necessary that knowledge and experience of different stages integrate with each other, in order to decrease problems.

In this study, by using meta-synthesis method, benefits of using three COM concepts are extracted and explained from available sources. They were coded and classified in different phases of PLC. A large portion of these benefits are focused on two stages of design and implementation, which somehow indicates importance of performance in these stages. Most of estimations and predictions at the beginning stages of the project aren't accurate and realistic; thus the effect of COM performers' view in determining qualitative and executive specifications is so significant at the beginning of the project. Gradually with the progress of the project by obtaining more accurate basics and deduction of time interval between prediction and implementation, COM performers' views (which are more of dos and don'ts mode) have to be decreased and according to the conditions of the project and tangible facts, project features and its stages are explained and determined. It is evident that if there is least conflict between planning and its implementation, achieving project success would be more probable. This case shows necessity of paying attention to the benefits of applying COM concepts in various phases of the PLC.

In addition to the numerous benefits in two stages of design and implementation, we observed repetition of some of benefits on all or several stages of the project. This case confirms necessity of applying each of the COM concepts to enhance project performance and realization of its objectives at different stages; and therefore, it is very important in understanding and utilizing them in project final success. Theoretically, this study helps recognizing the role of implementing COM concepts in the progress of objectives and success of an infrastructure project in different phases, and the extent of the effect of each of these concepts on different stages of PLC is specified, and in terms of applying, it also helps managers to increase efficiency and productivity of the project and improve their performance by using these concepts and strategies and their utilization.

References

Alikhah F (2010) Social impact assessment: at the Qazvin-Rasht highway. In: 10rd Scientific conference of University of Guilan

Alinaitwe H, Nyamutale W, Tindiwensi D (2014) Design phase constructability improvement strategies for highway projects in Uganda. J Constr Dev Countries 19(1):127–140

Allen D (1993) What is building maintenance? Facilities 11(3):7–12

Anderson SD, Fisher DJ, Rahman SP (2000) Integration constructability into project development: a process approach

Anderson SD, Fisher DJ, Rahman SP (2000) Integrating constructability tools into constructability review process. J Constr Eng Manageent

Azkia M, Tavakoli M (2006) Meta-analysis of studies on job satisfaction in educational organizations. J Soc Sci. Iran. No. 27:26-1

Baiden BK, Price DF (2011) The effect of integration on project delivery team effectiveness. Int J Project Manage 29:129–136

Bazeley P, Richards L (2000) NVivo qualitative project book. Sage, London

Blanchard BS, Verma DC, Peterson EL (1995) Maintainability: a key to effective serviceability and maintenance management. Wiley, New York, US

Briggs J (2006) Cochrane qualitative research methods group. The Cochrane Collaboration, URL: http://www.joannabriggs.eduau/cqrmg/role.html

Chew MYL, Tan SS, Kang KH (2004) Building maintainability—review of state of the art. J Archit Eng 10:3(80):80–87. doi:10.1061/(ASCE)1076-0431

Constructability A Primer. Publication 3-1. Austin, T.C.I.I.C.T.F., July 1986

Dabaq Kashani Z (2011) Identify the critical success factors for implementation within the framework of business management in Iranian organizations. Alzahra University thesis, Faculty of Social and Economic Sciences
Davis K (2013) Different stakeholder groups and their perceptions of project success. Int J Project Manage
De Silva N, Dulaimi MF, Ling FYY, Ofori G (2004) Improving the maintainability of building in Singapore. Build Environ
Dhillon BS (1999) Engineering maintainability. Gulf Publishing Company, Houston, Texas
Dixon-Woods M, Agarwal S, Jones D, Young B, Sutton A (2005) Synthesising qualitative and quantitative evidence: a review of possible methods. J Health Serv Res Policy
Duggan M, Blayden R (2001) Venture maintainability : a pass to project success. J Qual Maint Eng
Dunston PS, Williamson CE (1999) Incorporating maintainability in constructability review process. J Manage Eng
Dunston PS, McManus JF, Gambatese JA (2001) Cost/benefits of constructability reviews. National Cooperative Highway Research Program
Dunston PS, Gambatese JA, McManus JF (2007) A cost and benefit model for constructability review implementation. ASCE
Heising W (2012) The integration of ideation and project portfolio management a key factor for sustainable success. Int J Project Manage 30:582–595
Hillman Willis T, Willis WD (1995) A quality performance management system for industrial construction engineering projects. Int J Qual Reliab Manage 13(9), 1996:38–48
Hines JA, Kokkinos A, Fedock DS (2001) Benefit of SCR design for constructability. POWER-GEN International, Dec 11–130, Las Vegas, Nevada, U.S.A
Ivory CJ, Thwaited A, Vaughan R (2001) Design for maintainability: the innovation process in long term engineering projects. Paper presented at the future of innovation studies, Eindhoven, Netherland
Jadidoleslami S, Saghat Foroush E, Heravi Torbati A, Athari Nikooravan H (2015) Assessing barriers to the implementation of the concept of constructability in the construction industry. In: 3rd International congress on civil engineering, Architecture and Urban Development, Shahid Beheshti University, Tehran, Iran
Jadidoleslami S, Saghat Foroush E, Heravi Torbati A, Athari Nikooravan H (2016) Provide solutions to increase constructability based on principles of constructability of the construction industry. In: 3rd National & 1st international conference on applied researches in civil engineering, Architecture and Urban Planning, KHAJEH NASIREDDIN TOOSI University, Tehran, Iran
Karim H (2010) Evaluation of attempts for efficient road maintenance knowledge compilation. Dept of Highway Engineering, Swedish Royal Institute of Technology, Dalarna University, 781 88 Borlange, Sweden
Karim H, Magnusson R (2008) Road design for future maintenance problems and possibilities. J Trans Eng
Kartam NA (1996) Making effective use of construction lessons project learned life cycle. J Constr Eng Manage
Kennedy R, Kirwan B (1998) Development of a hazard and operability-based method for identifying safety management vulnerabilities in high risk systems. Elsevier Science Ltd. All rights reserved
Kordestani N, Saghatforoush E, Athari Nikooravan H (2015) Identification and assessment of the entrance barriers of maintenance contractors to the preliminary studies, design and construction in infrastructure projects. In: 3rd International congress on civil engineering, Architecture and Urban Development, Shahid Beheshti University, Tehran, Iran

Kordestani N, Saghat Foroush E, Athari Nikooravan H (2016) Assessment & identify the solutions to enhance maintenance contractors participation in the design and construction implementation stages of infrastructure projects. In: 3rd National & 1st international conference on applied researches in civil engineering, Architecture and Urban Planning, KHAJEH NASIREDDIN TOOSI University, Tehran, Iran

Ling FYY, Toh BGY, Kumaraswamy M, Wong K (2014) Strategies for integrating design and construction and operations and maintenance supply chains in Singapore. Struct Surv 32 (2):158–182

Makarand (Mark) H, Halpin DW, Hong T (2004) Constructability, maintainability, and operability of fiber reinforced polymer (FRP) bridge deck panels

Markeset T, Moreno-Trejo J, Kumar R (2013) Maintenance of subsea petroleum production systems: a case study. J Qual Maint Eng

Meier JR, Russell JS (2000) Model process for implementing maintainability. J Constr Eng Manage, Nov/Dec

Meng X (2013) Involvement of facilities management specialists in building design: United Kingdom experience. J Performance Constr Facil, Sept/Oct

Naderpajouh N, Oh EH, Hastak M, Gokhale S (2015) Integration of the construction knowledge and expertise in front-end planning. J Constr Eng Manage

Najafi F et al (2013) Meta-synthesis of qualitative research in nursing: a case study. J Res Health Sci Iran

Nouri FMS (2005) Standardization of processes and technical knowledge engineering department managing large projects as EPC. In: 2nd International project management conference, Tehran, Mar 2005

Ogburn ML, Islam PE, El-adaway H (2014) Buildability, constructability, operability, and environmental checklist: potential role in reducing conflicts, claims, and disputes. ASCE

Oxford advanced learners dictionary of current English, 2000

Paterson BL, Thorne S (2003) The potential of metasynthesis for nursing care effectiveness research. Can J Nurs Res 35:39–43

Pitt MJ (1994) Hazard and operability studies: a tool for management analysis. Facilities 12(13), 1994:5–8, MCB University Press

Pulaski MH, Horman MJ (2005) Organizing constructability knowledge for design. J Constr Eng Manage 131(8)

Radtke MW, Russell JS (1993) Project-level model process for implementing constructability. J Constr Eng Manage 119(4)

Saghatforoush E (2012) Extending of constructability concept to include operation and maintenance issues. In: 1st International construction and business management symposium. Kuala Lampur, Malaysia

Saghatforoush E (2014) Extension of construction to include operation and maintenance for infrastructure project. Queensland University of Technology

Saghatforoush E, Trigunarsyah B, Too E, Heravitorbati A (2011) Effectiveness of constructability concept in the provision of infrastructure assets. In: 1st International postgraduate conference on engineering, Designing and Developing the Built Environment for Sustainable Wellbeing, Brisbane QLD 4000, Australia

Shen Q, Lo KK, Wang Q (1998) Priority setting in maintenance management: a modified multi-attribute approach using analytic hierarchy process. Constr Manage Econ 16:693–702

Shirpak K et al (2010) Meta-synthesis of qualitative research in the health sciences. Iran J Epidemiol 6(1):51–57

Smith JG, Principal (2006) Construction analysis and planning. LLC

Sødal AH, Lædre O, Svalestuen F, Lohne J (2014) Early contractor involvement: advantage and disadvantage for the design team. J Design Manage

Taleqani S (2011) Improve the implementation of road projects on BOT method using risk management. Master's thesis. Iran University of Science and Technology

Tennessee Department of Transportation Construction Division (2016) Constructability review procedures manual

Thabet W (2000) Design/Construction integration thru virtual construction for improved constructability
Trigunarsyah B, Skitmore M (2010) The key to successful implementation: project management of sustainable infrastructure provision
Uwohali-Incorporated (1996) Operability in systems concepts and designs: survey, assessment, and implementation. NASA, Huntsville, FL
Vadadhir A (2011) The results of meta-synthesis of qualitative analysis and cultural studies: reality or illusion
Weed ME, Sports tourism research 2000–2004 (2006) A systematic review of knowledge and a meta-evaluation of methods. J Sport Tourism 11(1):5–30
Wells J (1986) The construction industry in developing countries: alternative strategies for development. Croom Helm Ltd., London, UK
Wong FWH, Lam PTI, Chan EHW, Shen LY (2005) A study of measures to constructability. Int J Qual Reliab Manage 24(6)
Yahyapour S, Shami Zanjani M (2012) The conceptual framework knowledge management benefits of using meta-synthesis
Yik FWH, Lai JHK, Chau CK, Lee WL, Chan KT (2010) Operation and maintenance the perception of Hong Kong's general public about building service. J Facil Manage 8(2)
Yustisia H (2014) The evaluation of constructability towards construction safety. Case study: Kelok-9 Bridge project, West Sumatera
Zanganeh M (2004) Providing a framework of strategic purchasing portfolio using the methodology of meta-synthesis. Master's thesis, Tehran University, School of Management
Zidane YJ-T, Stordal KB, Johnsen A, Van Raalte S (2015) Barriers and challenges in employing of concurrent engineering within the Norwegian construction projects. Proc Econ Finance 494–501
Zimmer L (2006) Qualitative meta-synthesis: a question of dialoguing with texts. J Adv Nurs 53 (3):311–318
Zolfagharian M, Latifi M (2011) Grounded theory with Nvivo8 proper task of promoting Imam Sadeq

Chapter 32
Big Data in Urban Planning Practices: Shaping Our Cities with Data

Ruiqu Ma, Patrick T.I. Lam and C.K. Leung

32.1 Introduction

The promises of smart cities respond to the desire for improving life efficiency and quality. With the development of smart cities, various fields such as energy supply, transport management and natural disaster prevention have been transformed into intelligent and integrated systems where an enormous volume of data about the urban environment and its inhabitants is collected and processed from various sources including sensors, smartphones, computers, GPS (Global Positioning System), and information network. Consequently, the development of smart cities leads to an exponential increase in data capture and transfer (Hashem et al. 2016). Since the core task of the smart city development is to utilize the right information at the right place for making decisions efficiently at the city level (Rathore et al. 2016), the effective application of big data becomes essential for the successful development of smart cities.

The purpose of this study is to identify the approaches of utilizing big data for the urban planners and designers during the delivery and implementation processes by reviewing and summarizing case studies globally. The paper is structured as follows: firstly, it presents the definitions and characteristics of big data, and introduces the current applications of big data in smart cities. Secondly, another section analyzes the present advancement and applications of big data in the domains of urban planning and design, with emphasis on how big data is used by planners to understand people's behaviors and needs through passive data acqui-

R. Ma · P.T.I. Lam (✉)
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong SAR, People's Republic of China
e-mail: tsun.ip.lam@polyu.edu.hk

C.K. Leung
Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, People's Republic of China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_32

sition and active public participation. This paper ends with revealing five problems and challenges that need to be overcome for enjoying better advantages of big data in the future.

32.2 Definitions and Characteristics of Big Data

The big data concept has become widespread since 2011 and been evolving rapidly (Gandomi and Haider 2015). Numerous definitions of big data have been proposed by various organizations, such as:

> *Big data is a term that describes large volumes of high velocity, complex and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management, and analysis of the information.*
>
> TechAmerica Foundation's Federal Big Data Commission, 2012.
>
> *Data, coming from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records, and cell phone GPS signals to name a few.*
>
> IBM, 2013.

Despite the multifarious definitions, Volume, Variety, and Velocity as proposed by Laney (2001) form the common framework to describe big data. Afterwards, Veracity (by IBM), Variability and Complexity (by SAS company), Value (by Oracle company), and etc. have emerged to enrich the descriptions of big data and demonstrate its characteristics from different perspectives. Certainly, the characteristics of big data (e.g. massive, dynamic, varied) empower cities to obtain valuable insights from a considerable volume of data (Hashem et al. 2016; Kitchin 2013).

32.3 Applications of Big Data in the Smart City

The use of big data in smart cities enables efficient data generation, storage and processing, thus enhancing various services (Hashem et al. 2016), including traffic management, waste management and power supply, etc. For instance, in Songdo, South Korea, cameras and sensors are installed to monitor and regulate traffic in real time. Once a traffic jam is detected, the traffic lights controlled by the central system will react automatically, and the information will be shared among drivers via smartphones and traffic signs (Castaignède 2015). In Barcelona, internet-connected sensors and wireless links are embedded in many trash containers to monitor how full these bins are. Then dynamic routes and visiting frequencies of trash collection vehicles are suggested according to the timely information of bin capacities (Datoo 2014). In the field of power supply, the analytics of smart grid data (e.g. utilization habits of users, energy consumption data) can help decision making in terms of the electricity supply level, prediction of power demand in the future, and setting strategic objectives (Al Nuaimi et al. 2015). Certainly big data has so far been mainly utilized by city government for operational purposes to save money and improve services due to its great potentials for providing enhanced insight and improving decision-making for lots of tasks (ARUP and RIBA 2013). However, it has been used rather infrequently by urban planners and designers to-date (ARUP and RIBA 2013).

In the field of urban planning and design, professionals have been working with data about the environment and people for a period of time. Most data sources they used are fairly static and slowly-updated (e.g. census data) instead of dynamic. However, big data with great volumes and speed, could significantly benefit the domain of urban planning by better meeting people's needs, providing greater ability to experiment and transparency (ARUP and RIBA 2013; Manyika et al. 2011). In a study of ARUP and RIBA (2013), there are several ways for designers and planners to use data to improve their work based on their experience from architecture and other industries. Those approaches include using data to better match user needs, modelling urban environment, analyzing big data to improve policy delivery and planning, etc. In another study by Sawhney (2015), major scenarios under which big data can be deployed were identified, such as modelling the construction processes during the design stage, well understanding and capturing end-users' requirements, creating data-driven participatory processes at the construction and maintenance stage for regulators, etc. It can be found that these approaches and scenarios build upon the design process as well as attempts to seek alternative ways of generating and utilizing city data to create better places.

32.4 Applications of Big Data for Understanding Users' Behaviors and Needs

Among the attempts to explore better ways of forming and delivering urban planning and design, the idea of understanding users' behavior patterns and needs could help create spaces that are better attuned to people who use them, and it embodies the notion of human-orientation which currently has become a significant principle of city development (Chai et al. 2014). This idea could be realized effectively with the application of big data by collecting and analyzing public space-time information which provides solid evidence for decision-making in urban planning. It is learnt from case studies that there are mainly two approaches to understand users' behaviors and needs via obtaining public space-time information. They are passive data acquisition, and active public participation respectively. The passive data acquisition keeps track on massive information including positioning coordinates, communication modes, commuting patterns, etc. drawn from physical devices such as GPS, sensors, phone cards, banking cards, transport cards and so on that are maintained or issued by authorized departments. On the contrary, the active data acquisition needs civic engagement such as communication, discussion and report in urban planning process between planners and the public.

32.4.1 Passive Data Acquisition

The wide availability of digital tracking technologies (e.g. GPS) makes it possible to collect spatial and temporal data accurately and consistently (Shoval and Isaacson 2007). The data collected by tracking technologies describes the space-time movement of city dwellers and helps analyze human behavior pattern, thus potentially augmenting practices in the field of urban planning (Shoval 2008). For instance, personal location data derived from GPS and mobile phones has already been used to forecast future transit needs and congestion in Singapore and the Netherlands (Manyika et al. 2011). Not being limited to traffic planning, tracking technologies could aid urban planning in other aspects, such as using visitors' spatial and temporal information to exploit better regulation of the tourist flows in places of attractions (Shoval and Isaacson 2007; Kellner and Egger 2016).

Besides GPS, sensors positioned in the built environment also help gather public data to boost urban planning. An example of this is the project of Array of Things in Chicago which utilizes sensors and networks to gather real-time data on the city's environment, and inhabitants' activities for research and public use. The big data collected allows planners to proactively take actions that will make Chicago healthier and more livable. Another example is the 24-h pedestrian counting system in the City of Melbourne, Australia, which measures pedestrian movements by sensors installed around the city. The data collected enables planners develop a better understanding of how people go about in the city, whereby planners can manage the way people live and plan for future needs. In addition, the data in citizen cards such as public transport cards and phone cards could also offer urban planners useful information about the regular living patterns of the public at a city level.

Passive data acquisition contributes to urban planning through providing massive volumes of data efficiently. It helps planners understand how the city is inhabited in terms of different variables such as time, location, people and events, according to which planners can make appropriate plans for city development and also address common city problems such as congestion and pedestrian safety.

32.4.2 Civic Engagement

In the era of big data, with the improvement of data collection, dissemination and processing, it becomes easier and more efficient to have communication and discussion about urban planning among experts and the public via multiple media. Therefore, the way of making decision in urban planning and design switches from expert dominance to public participation (Yu et al. 2014). Various cases of civic engagement project in urban planning can be found worldwide.

In London, a web service called "Fix My Street" was launched in 2007, which helps people report and discuss local problems (e.g. malicious graffiti, fly tipping, broken paving slabs and failed street lightings) with their local councils directly by locating the problems on a map of the area and entering details (ARUP 2011). Similarly, a platform called "City Sourced" in the USA allows citizens to upload media such as photos, videos, or audio recordings directly from their devices to report problems with their location information. After a submission is made, the feedback about the actions taken by the local municipality would be offered to the reporters. In China, an on-line platform was established by a research group in 2013 for public discussion on the renewal project of Zhonggulou area in Beijing. Citizens can submit their comments with photos targeting at individual buildings or compounds. Various data and research outcomes are also available on that platform for people to check and learn more about the renewal process.

The practices of active public participation could better support planning decisions, and generate good social effects and increase the public acceptance of urban planning initiatives (Hao et al. 2015). The approach of allowing active public participation reflects the notion of human-orientation, helps communicate with users about their opinions and needs, and deliver feedback to help people make sense of spaces. Additionally, platforms for collecting big data such as smartphone applications and interactive websites serve as the primary interfaces through which public could let their voice be heard, thereby facilitating civic engagement in urban planning.

32.4.3 Complementary Effects of Passive and Active Acquisition

Both passive data acquisition and active public participation contribute to the domain of urban planning by helping planners understand people's behaviors and needs. What differentiate them are the volumes of data obtained and the degree to which personalized contribution is included. The volumes of data collected via passive data acquisition are more enormous than that for the data gathered via active public participation, but without individual and personalized information such as activity purposes and people's levels of satisfaction. Therefore, it will be effective to apply passive data acquisition to obtain the public's behavior patterns, whilst utilize active public participation to learn more about ideas and expectations from people. Hence, their complementary adoption by urban planners would be more beneficial than separate uses.

32.5 Challenges of Big Data Application in Urban Planning Practices

Although big data has great potential in urban planning applications, there still exist various kinds of problems in urban planning practices, including poor data quality, data analytics, privacy leakage, "digital divide" syndrome, and information security.

32.5.1 Data Quality

Challenge of the big data application in urban planning practices can be posed by poor data quality such as lack of structure and consistency, as well as heterogeneity, and disparity issues. This problem is especially so when massive data is captured in different sectors and stored in distinctive databases without any unified format (Lee et al. 2013). Thus data uncertainty and questions of trustworthiness may arise, causing negative impact on inferences drawn from the analysis of existing data. Necessary measures of data quality management should be taken from both technological and non-technological aspects, such as unifying data standards and promoting cooperation among different departments.

32.5.2 Data Analytics

"Big data analytics" has been defined as technologies (e.g., database and data mining tools) and techniques (e.g., analytical methods) that can be used to analyze large-scale and complex data for various applications (Kwon et al. 2014), such as uncovering market trends, the pattern and preference of customers. Effective big data analytics bring benefits to smart city applications, since useful information may be extracted from the oceans of data (Al Nuaimi et al. 2015). The application of big data analytics, however, still stays in the initial stage, with traditional data mining and analytic platforms being challenged in terms of the of data storage and processing efficiency (Hashem et al. 2016). Once the big data analytics are enhanced, the quality and effectiveness of corporate decision making will be boosted subsequently (Kwon et al. 2014).

32.5.3 Individual Privacy

Privacy leakage will be nearly inevitable due to the routine collection and storage of a huge amount of personal data (Porter 2014). Numerous sensors haven been installed in many cities worldwide to collect large volumes of data such as parking vacancies, street density and refuse levels. Privacy protection needs to be addressed when public data is collected and used. Possible solutions can be formulated partly by establishing ethical standards on how public data may be used, and partly by avoiding the inclusion of personalized information in the data collected. Furthermore, the right of people to opt out of the data collection process should be respected and maintained (ARUP and RIBA 2013).

32.5.4 Digital-Divide

When electronic devices and information technologies provide opportunities for helping people participate in urban planning process, a problem still remains as to how to include as many different social groups as possible in civic urban planning. Some social groups, such as the aged, and people with a low education level and poor information technology skills and literacy may suffer from digital-divide. Digital-divide triggers social inequality and imbalance, bringing negative effects to the whole society (Van Dijk and Hacker 2003). Therefore, measures such as providing digital education for disadvantaged groups and increasing network coverage and accessibility need to be taken. Additional solutions based on social and psychological aspects deserve more attention from designers and planners.

32.5.5 Information Security of Systems

When massive volumes of data are being collected and disseminated across the Internet via publicly accessible media such as Wi-Fi, Bluetooth, and ZigBee, the data are subject to abuse causing issues to their confidentiality, integrity, and authenticity. The information network infrastructure may also be subject to abuse and attacks causing issues in their availability. Previous works have studied the possible security issues in a systematic way (Cilliers and Flowerday 2014; Ferraz and Ferraz 2014). Measures to address these information security issues should be taken right from the start when a smart city is being planned ("Security by Design").

32.6 Conclusions

Big data enriches our experiences and knowledge of how cities perform, and well supports social interactions as well as decision-makings (Batty 2013). Among various applications of big data in smart cities, utilizing big data in the domain of urban planning contributes to a deep and evidence-based understanding of citizen's behaviors and needs, thus enhancing the analysis and decision-makings of planners. In this study it is proposed that the two main approaches of obtaining urban big data (i.e. passive data acquisition and active public participation) focus on different aspects in terms of data volume obtained and whether personalized contributions are included, both approaches can well support planning decisions. In particular, active civic participation could achieve good social effects and improve the public acceptance of planning decisions. Therefore, these two approaches could be applied respectively in different situations or used together to achieve integrated objectives.

Besides analyzing big data applications in the field of urban planning, this study sheds some light for a further study of potential and existing pitfalls in the application of big data and development of smart cities. It identifies five challenges that need to be met to take better advantage of big data, including data quality, data analytics, privacy, digital-divide, and information security. In order to meet these challenges, suitable measures should be taken from both technological as well as non-technological aspects. In addition, better coordination among various society stakeholders including government departments and the industry (including smart device manufacturers) is necessary to overcome difficulties and achieve a promising smart future.

References

Al Nuaimi E, Al Neyadi H, Mohamed N, Al-Jaroodi J (2015) Applications of big data to smart cities. J Internet Serv Appl 6(1):1–15

ARUP (2011) The smart solution for cities. Retrieved from http://www.arup.com/homepage_c40_urbanlife. Accessed 5 June 2016

ARUP and RIBA (2013) Designing with data: shaping our future cities. Retrieved from https://www.architecture.com/Files/RIBAHoldings/PolicyAndInternationalRelations/Policy/Designingwithdata/Designingwithdatashapingourfuturecities.pdf. Accessed 5 June 2016

Batty M (2013) Big data, smart cities and city planning. Dialogues Hum Geogr 3(3):274–279

Castaignède F (Director and Writer) (2015) Cities of tomorrow: new cities [Documentary]. ZED, France

Chai Y, Shen Y, Chen Z (2014) Towards smarter cities: human-oriented urban planning and management based on space-time behavior research. Urban Plann Int (6):31–37

Cilliers L, Flowerday S (2014) Information security in a public safety, participatory crowdsourcing smart city project. Proc World Congr Internet Sec 36–41

Datoo S (2014) Smart cities: are you willing to trade privacy for efficiency? Retrieved from https://www.theguardian.com/news/2014/apr/04/if-smart-cities-dont-think-about-privacy-citizens-will-refuse-to-accept-change-says-cisco-chief. Accessed 8 Aug 2016

Ferraz FS, Ferraz CAG (2014) Smart city security issues: depicting information security issues in the role of a urban environment. In: Proceedings 2014 IEEE/ACM 7th international conference on utility and cloud computing, pp 842–847

Gandomi A, Haider M (2015) Beyond the hype: big data concepts, methods, and analytics. Int J Inf Manage 35(2):137–144

Hao J, Zhu J, Zhong R (2015) The rise of big data on urban studies and planning practices in China: review and open research issues. J Urban Manage 4(2):92–124

Hashem IAT, Chang V, Anuar NB, Adewole K, Yaqoob I, Gani A, Ahmed E, Chiroma H (2016) The role of big data in smart city. Int J Inf Manage 36(5):748–758

Kellner L, Egger R (2016) Tracking tourist spatial-temporal behavior in urban places, a methodological overview and GPS case study. Inf Commun Technol Tourism 2016. Springer, Berlin, pp 481–494

Kitchin R (2013) Big data and human geography opportunities, challenges and risks. Dialogues Hum Geogr 3(3):262–267

Kwon O, Lee N, Shin B (2014) Data quality management, data usage experience and acquisition intention of big data analytics. Int J Inf Manage 34(3):387–394

Laney D (2001) 3-D data management: controlling data volume, velocity and variety. Appl Deliv Strat. Retrieved from http://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf. Accessed 28 May 2016

Lee C-H, Birch D, Wu C, Silva D, Tsinalis O, Li Y, Yan S, Ghanem M, Guo Y (2013, 6–9 Oct) Building a generic platform for big sensor data application. Paper presented at the 2013 IEEE International Conference on Big Data, Silicon Valley, CA

Manyika J, Chui M, Brown B, Bughin J, Dobbs R, Roxburgh C, Byers AH (2011) Big data: the next frontier for innovation, competition, and productivity. Retrieved from https://zh.scribd.com/doc/296129743/MGI-Big-Data-Full-Report. Accessed 7 June 2016

Porter C (2014) Little privacy in the age of big data. Retrieved from https://www.theguardian.com/technology/2014/jun/20/little-privacy-in-the-age-of-big-data. Accessed 6 June 2016

Rathore MM, Ahmad A, Paul A, Rho S (2016) Urban planning and building smart cities based on the Internet of Things using Big Data analytics. Comput Netw 101:63–80

Sawhney A (2015) Embracing big data in the built environment. Retrieved from http://www.rics.org/hk/about-rics/responsible-business/rics-futures/discussions/embracing-big-data-in-the-built-environment/. Accessed 4 June 2016

Shoval N (2008) Tracking technologies and urban analysis. Cities 25(1):21–28

Shoval N, Isaacson M (2007) Tracking tourists in the digital age. Ann Tourism Res 34(1):141–159

Van Dijk J, Hacker K (2003) The digital divide as a complex and dynamic phenomenon. Inf Soc 19(4):315–326

Yu Y, Zongcai W, Haijun W (2014) Urban planning response for big data development. Planners 8:001

Chapter 33
Board of Director's Role in Preventing Corporate Misconduct in the Construction Industry

C.J. Lee, R. Wang, S.C. Hsu and C.Y. Lee

33.1 Introduction

Over the last few decades, the corporate scandals such as Enron and Volkswagen have led to a concern with the lack of oversight of management. The increasing demands for transparency and accountability have placed the boards of directors at the center of the corporate governance debate (Kiel and Nicholson 2003; Ingley and Van Der Walt 2005). Most scholars (Fama and Jensen 1983; Pearce and Zahra 1991) believe that corporate boards have a fiduciary duty to shareholders to monitor management in their effort to maximize shareholder wealth. However, board of directors' increasing involvement has raised the questions of board effectiveness and what the appropriate composition of boards should be.

Corporate board composition and its influence on firm performance is one of the most discussed issues in the organization theory, economics, and management literature (Fama and Jensen 1983; Herman 1981; Mizruchi 1983), yet there are relatively less studies on the effects of board composition in preventing firms' unethical acts or misconducts. The relation between the board composition and occurrences of corporate misconduct is particularly important in the construction industry because the construction industry remains a prominently high-risk sector

R. Wang · S.C. Hsu (✉)
Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong, China
e-mail: mark.hsu@polyu.edu.hk

C.Y. Lee
Department of Management and Information Technology, Southern Taiwan University, Tainan City, Taiwan

C.J. Lee
Institute of Human Resource Management, National Sun Yat-Sen University, Kaohsiung, Taiwan

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_33

(Le et al. 2014). Unethical or illegal business practices in construction industry often lead to fatal injuries to workers and residents.

When the magnitude-6.4 earthquake struck southern Taiwan in 2016, the Wei-guan Golden Dragon Building crumbled and fell. At least 63 people were killed and more than 50 others are missing. The investigation report indicates that the design of the construction did not match calculations made in its blueprints. Comparing to the building's structural calculation books, at least half of the main beam joints were missing. Indeed, poor construction practices by contractors were widely blamed for the collapse of many building and cause increasing numbers of deaths worldwide. Therefore, it is important for business owners and stakeholders have a responsibility to identify situations where corporate misconduct has a greater likelihood of occurring.

On the theoretical front, the fundamental concepts in corporate governance start with the agency theory. The agency theorists (Fama and Jensen 1983; Young et al. 2000) suggest that board should oversee management's actions owing to the agency problem. Agency problems arise when principals (shareholders) hire and authorize agents (managers) to act on their behalf. A manager working in his/her own self interest tend to maximize his/her wealth at the expense of the stockholders. For example, managers may choose to pursue short-term gains that maximize their compensation while sacrifice firms' long-term profit. Therefore, boards of directors are crucial safeguards against opportunism on the part of top management thus rein in corporate misconduct. However, under some circumstances, board of directors may have limited influences on decision-making. CEOs and top management team may dominate boards (D'Aveni and Kesner 1993; Mallette and Fowler 1992; Stiles 2001) because directors have been selected by management or lack knowledge of the workings of the corporation.

In pursuit of enhanced board monitoring power, board reform advocates have called for changes including reduced board size, more independent directors, separation of CEO and chairman and larger equity holdings by directors (Kesner and Johnson 1990). While scholars and business practitioners have acknowledged the importance of adequate board control (Baysinger and Hoskisson 1990; Jensen and Zajac 2004), the empirical evidence on the link between board composition and corporate effectiveness has been far from conclusive (Johnson et al. 1996; Zahra and Pearce 1989). In response to the recent calls for more inquiries into the wrongful behaviors in businesses, this study intends to conduct an empirical analysis to identify the factors determining board effectiveness in preventing misconduct.

Literature in corporate governance give some form of meaning and provide several solid perspectives on governance, but fall short in directors' power of monitoring distorted behavior. Hence, it is important to consider the influences a director has in order to grasp a better understanding of governance mechanism. The board of directors are well known as an initiating force in CEO dismissals (Friedman and Singh 1989) and this initiative in poorly performing firms are often received positive feedback from stock market (Borokhovich et al. 1996; Weisbach 1988). Interestingly, though, compared with its role in affecting firm performance, the directors' role in influencing corporate conducts has been studied less often. Overall, this study attempts to answer the following question: do corporate boards matters in preventing corporate misconduct?

33.2 Literature Review

In nearly all modern governance research, the overwhelmingly dominant theoretical perspective is the agency theory (Jensen and Meckling 1976; Dalton et al. 1998). Jensen and Meckling (1976) provided the convincing rationale for how firms are able to survive and prosper despite the self-interested proclivities of managers. Corporate governance are conceptualized as deterrents to managerial self-interests. While managers are self-interested and do not bear the full wealth effects of their decisions, the board of directors are presumed to carry out the monitoring function on behalf of a shareholder to minimize costs that result from the separation of ownership and control (Fama and Jensen 1983).

Board of directors' monitoring role is an important component of corporate governance. However, barriers to monitoring can lead to governance failure, in which internal control mechanisms were short-circuited by conflicts of interest. Such as information, communication, and incentive problems can increase the difficulty to monitoring. Hirshleifer and Thakor (1994) suggest that noisy information, incentive alignment, and external disciplining mechanisms can interact to influence the board effectiveness.

John and Senbet (1998) argue that the board effectiveness in monitoring is determined by its size and independence. Bacon (1993) suggests that large boards may be too unruly for effective decision-making. Jensen (1993) argues that smaller boards play a controlling function whereas larger boards are easier for CEO or top management teams to control. In contrast, Chaganti et al. (1985) suggest that large boards are valuable for the breadth of their services. They found that firms filing for bankruptcy have smaller boards than non-failed firms, indicating that larger boards are more effective in preventing corporate failure. These diverging arguments point to the necessity of conducting further investigation on whether board size significantly affects the likelihood of corporate misconducts.

Previous studies indicate that firms' board independence can be positively related to the percentage of outside directors sitting on a board. The underlying logic of this argument is that outside directors make better monitors. Raheja (2005) indicates that insiders are the key source of firm-specific information for the board. However, insiders also have distorted objectives due to private benefits and lack of independence from the managers. On the contrary, outsiders provide more independent monitoring, but at the same time, are less informed about the firm's information, constraints and opportunities. In other words, while corporate boards are encouraged to comprise directors who are free from any relationship that would interfere their independent judgment as a director, boards also suffer from insufficient information to exert their will. As the result, they are not able to affect important decisions and stop companies to act illegally. This dilemma gives us the motivation to further investigate the relationship between board independence and corporate misconduct.

33.3 Methods

33.3.1 Sample and Data

The sample for this study consisted of 45 construction companies in Taiwan and the related information we collected was generated from the Corporate Social Responsibility (CSR) database provided by Taiwan Economic Journal (TEJ) database which collects information from the firms' annual reports, press release, and other public records. To lower the interference of random factors, we calculated the average of each index for three consecutive years, resulting in 450 company-year observations from 2005 to 2014.

33.3.2 Measures

Corporate misconduct (CM). As a proxy of corporate misconduct in the construction industry, the variable is measured by the total number of events in which firms were found guilty in litigated cases in the focal year. The disclosure of fines and penalties of construction companies spanning from 2002 to 2013 is generated from CSR database provided by Taiwan Economic Journal (TEJ) database which collects information from the firms' annual reports, press release, and other public records.

Board size (BS). As the independent variable, board size is measured by the number of directors of a board. The total number of directors is included because the absolute size director group can affect its impact on board decisions.

Board independence (BI). The proportion of outside directors (i.e., nonmanagement members) on boards is applied to measure board independence which indicates the relative impact of outsiders on board decisions (Dalton et al. 1998).

Control Variables. There are two sets of control variables: firm characteristics and corporate governance structures. We measure firm size as the natural logarithmic transformation of *total assets* (TA) and a *number of employees* (NoE). Each firm's *return on asset* (ROA) during the study period serves as the performance measures. For board-related variables, we first control *the number of female directors* (NFD). Besides, directors' tenure is also included in our model. The average number (AoT), and the variation (TV) of years directors served on the firm's board are used as proxies for director's tenure.

33.3.3 Analysis

According to the above statements, we could build our full model as follow:

$$CM_{it} = \alpha_1 \times Ln(NoE_{it}) + \alpha_2 \times Ln(TA_{it}) + \alpha_3 \times ROA_{it} + \alpha_4 \times NFD_{it} + \alpha_5 \times AoT_{it} + \alpha_6 \times TV_{it} + \alpha_7 \times Ln(BS_{it}) + \alpha_8 \times BI_{it} + \beta_i + \lambda_t + \varepsilon_{it} \quad (33.1)$$

where, $\alpha_1 \sim \alpha_8$ represent the coefficients of all the variables except the dependent variable; β_i represent the effects of individual direction; λ_t represent the effects of time direction; ε_{it} represent the effect of random factors. We take the natural log of board size, the number of employees and total assets to eliminate heteroscedasticity problem and to reduce their absolute value so that the coefficients wouldn't be too low.

In the process of regression analysis, we follow Fich and Shivdasani (2006), taking advantage of fixed effects for both individual direction and time direction. The reason is that the fixed effect regression could be robustly even though some variables about firms were omitted which may result in biased evaluation for OSL regression analysis.

33.4 Results

Table 33.1 reports the descriptive statistics of all variables. In our sample, there are about nine directors in boards in average. The minimum number of directors is 1, and the maximum is 27. The average number of misconduct in this study is 0.2610, and the maximum is 7.

The third column of Table 33.2 present the coefficients of the independent variable and the control ones. The results indicate that the coefficient of board size is positive and significant at 1% level, which means the larger the board is, the more

Table 33.1 Descriptive statistics

	Count	Minimum	Maximum	Mean	Std. Deviation
NoE	450	6.0000	1136.0000	142.6240	189.2559
TA	450	31,436.0000	95,162,556.0000	9,222,588.2426	12,131,019.5483
ROA	450	−67.5400	42.5300	4.3073	10.2447
NFD	450	0.0000	7.0000	2.0110	1.4670
AoT	450	0.0000	17.7500	5.6748	4.0961
TV	450	0.0000	190.7400	27.2035	36.6557
BS	450	1.0000	27.0000	8.9960	2.8513
BI	450	0.0000	4.0000	0.5960	1.0515
CM	450	0.0000	7.0000	0.2610	0.7132

Table 33.2 Impact of board size on firms' misconduct performance

Variables	Model 1	Model 2
C	−1.216518* (−1.808627)	−2.204183*** (−2.895834)
Ln(NoE)	0.109411** (2.153163)	0.060732 (1.132373)
Ln(TA)	0.070823 (1.560051)	0.080384* (1.777959)
ROA	−0.010020** (−2.547796)	−0.010107** (−2.584200)
NFD	0.020433 (0.640156)	−0.007660 (−0.229963)
AoT	−0.001039 (−0.067330)	0.001366 (0.088812)
TV	−0.001397 (−0.679826)	−0.001208 (−0.591338)
Ln(BS)		0.508077*** (2.729922)
BI		−0.164736 (−0.339404)
R-squared	0.325096	0.337887
Durbin-Watson stat	0.838153	0.847511
F-statistic (for model)	3.184068***	3.245941***

Note ***, ** and * indicates $p < 0.01$, $p < 0.05$ and $p < 0.1$ respectively

likely the firm misconduct is to happen. The coefficient of board independence is negative but insignificant, indicating that independent directors may not be an effective mechanism to constrain misconduct.

We also noted that ROA, one of the control variables, have a negative impact on misconduct performance at 5% level of significance in Model 2, meaning the better the firm performs, the less likely the firm is to misconduct. This finding indicates that pressure to engage in illegal acts may be associated with firm performance. The coefficient of NoE is positive and significant at 5% level in Model 1, but it is insignificant in Model 2.

33.5 Discussion and Conclusion

Much of the research on boards has examined board composition (Barnhart et al. 1994; Bathala and Rao 1995; Boyd 1990; Daily and Dalton 1994; Daily and Schwenk 1996; Gales and Kesner 1994; Pearce and Zahra 1992). However, most of the works have focused on the performance effect of corporate board regardless of the role in preventing firms' irresponsible or illegal behavior.

The central question addressed by this study is whether board directors can monitor corporate misconduct in the construction industry. That is, the authors are intended to guide firms facing decisions to select directors and owners seeking advice on how to help directors to fulfill their duties. By using the data of 45 construction companies in Taiwan from 2005 to 2014, strong evidence indicates that larger board size may lead to more illegal acts. Surprisingly, our empirical result suggests that the proportion of outside directors may not be a rightful tool to constrain unethical or illegal firm behavior.

This paper has some limitations. First, we obtained data from a single industry. Although focusing on single industry allowed us to explore context-specific phenomenon, it limited the generalizability of our findings to other empirical settings. Future research may consider to extend and apply our research to other contexts. Second, owing to a vast number of explanatory factors, proposed framework of corporate governance can be flawed as each researcher is forming his/her scope and concerns. Third, this study focused board composition but took no consideration of the characteristics (e.g., age, education background and managerial experience) of every director. Board members' human and social capital gained through managerial, industrial and board experiences may play an important role in board governance.

References

Bacon J (1993) Corporate boards and corporate governance. Conference Board

Barnhart SW, Marr MW, Rosenstein S (1994) Firm performance and board composition: some new evidence. Manage Decis Econ 15(4):329–340

Bathala CT, Rao RP (1995) The determinants of board composition: an agency theory perspective. Manage Decis Econ 16(1):59–69

Baysinger B, Hoskisson RE (1990) The composition of boards of directors and strategic control: effects on corporate strategy. Acad Manage Rev 15(1):72–87

Borokhovich KA, Parrino R, Trapani T (1996) Outside directors and CEO selection. J Financ Quant Anal 31(3):337–355

Boyd B (1990) Corporate linkages and organizational environment: a test of the resource dependence model. Strateg Manage J 11(6):419–430

Chaganti RS, Mahajan V, Sharma S (1985) Corporate board size, composition and corporate failures in retailing industry. J Manage Stud 22(4):400–417

Daily CM, Dalton DR (1994) Bankruptcy and corporate governance: the impact of board composition and structure. Acad Manage J 37(6):1603–1617

Daily CM, Schwenk C (1996) Chief executive officers, top management teams, and boards of directors: congruent or countervailing forces? J Manage 22(2):185–208

Dalton DR, Daily CM, Ellstrand AE, Johnson JL (1998) Meta-analytic reviews of board composition, leadership structure, and financial performance. Strateg Manage J 19(3):269–290

D'Aveni RA, Kesner IF (1993) Top managerial prestige, power and tender offer response: a study of elite social networks and target firm cooperation during takeovers. Organ Sci 4(2):123–151

Fama EF, Jensen MC (1983) Separation of ownership and control. J Law Econ 26(2):301–325

Fich EM, Shivdasani A (2006) Are busy boards effective monitors? J Finance 61(2):689–724

Friedman SD, Singh H (1989) CEO succession and stockholder reaction: the influence of organizational context and event content. Acad Manage J 32(4):718–744

Gales LM, Kesner IF (1994) An analysis of board of director size and composition in bankrupt organizations. J Bus Res 30(3):271–282
Herman ES (1981) Corporate control, corporate power, vol 98. Cambridge University Press, Cambridge, p 1
Hirshleifer D, Thakor AV (1994) Managerial performance, boards of directors and takeover bidding. J Corp Finance 1(1):63–90
Ingley C, Van Der Walt N (2005) Do board processes influence director and board performance? Statutory Perform Implications. Corp Governance Int Rev 13(5):632–653
Jensen MC (1993) The modern industrial revolution, exit, and the failure of internal control systems. J Finance 48(3):831–880
Jensen MC, Meckling WH (1976) Theory of the firm: managerial behavior, agency costs and ownership structure. J Financ Econ 3(4):305–360
Jensen M, Zajac EJ (2004) Corporate elites and corporate strategy: how demographic preferences and structural position shape the scope of the firm. Strateg Manage J 25(6):507–524
John K, Senbet LW (1998) Corporate governance and board effectiveness. J Bank Finance 22 (4):371–403
Johnson JL, Daily CM, Ellstrand AE (1996) Boards of directors: a review and research agenda. J Manage 22(3):409–438
Kesner IF, Johnson RB (1990) An investigation of the relationship between board composition and stockholder suits. Strateg Manage J 11(4):327–336
Kiel GC, Nicholson GJ (2003) Board composition and corporate performance: how the Australian experience informs contrasting theories of corporate governance. Corp Governance Int Rev 11 (3):189–205
Le Y, Shan M, Chan AP, Hu Y (2014) Overview of corruption research in construction. J Manage Eng 30(4):02514001
Mallette P, Fowler KL (1992) Effects of board composition and stock ownership on the adoption of "poison pills". Acad Manage J 35(5):1010–1035
Mizruchi MS (1983) Who controls whom? An examination of the relation between management and boards of directors in large American corporations. Acad Manage Rev 8(3):426–435
Pearce JA, Zahra SA (1991) The relative power of CEOs and boards of directors: associations with corporate performance. Strateg Manage J 12(2):135–153
Pearce JA, Zahra SA (1992) Board composition from a strategic contingency perspective. J Manage Stud 29(4):411–438
Raheja CG (2005) Determinants of board size and composition: a theory of corporate boards. J Financ Quant Anal 40(2):283–306
Stiles P (2001) The impact of the board on strategy: an empirical examination. J Manage Stud 38 (5):627–650
Weisbach MS (1988) Outside directors and CEO turnover. J Financ Econ 20:431–460
Young GJ, Stedham Y, Beekun RI (2000) Boards of directors and the adoption of a CEO performance evaluation process: agency—and institutional—theory perspectives. J Manage Stud 37(2):277–296
Zahra SA, Pearce JA (1989) Boards of directors and corporate financial performance: a review and integrative model. J Manage 15(2):291–334

Chapter 34
Bridging Knowledge Gap Between Green and Non-green Facilities Management in Singapore

Yujie Lu and Ngiam Min Li Joyce

34.1 Introduction

Many studies over the years have identified and illustrated the importance of green buildings, and how energy savings can be achieved. Yet few addressed the need for proper green facilities management after the building construction phase. Facilities represent a large part of green building's assets and proper green facilities management is required, but many fail to realize that the road to a sustainable future does not end by just having green infrastructures. A truly sustainable building comprises of the efforts of both people and infrastructure, and it is the job of the facilities manager to continue creating a green environment that encourages productivity, is safe, pleasing to clients and customers, and efficient (Inc, N.D).

To undertake green building management, a facilities manager should have the necessary green skills and knowledge to ensure that proper operation and maintenance is conducted. As defined in the national Green Skills Agreement (GSA) endorsed by the Council of Australian Governments (COAG), green skills are the skills, knowledge, values and attitudes needed in the workforce to develop and support sustainable social, economic and environmental outcomes in business, industry and the community (McDonald et al. 2012).

Globally, the greening process of the building sector is held back by skill shortages, and the introduction of skills-led strategies can drive green building movement forward (ILO 2011). Similarly, in local context, not every facilities manager in the industry possesses the skills set necessary to maintain green buildings and facilities, a setback termed as green skills or knowledge gap.

Therefore, the specific objectives of this paper are to (1) identify the presence of green knowledge and skills gap between non-green and green building

Y. Lu (✉) · N.M.L. Joyce
Department of Building, School of Design and Environment,
National University of Singapore, Singapore, Singapore
e-mail: luy@nus.edu.sg

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_34

management, (2) investigate the reasons for the presence of green skills and knowledge gap, and (3) propose possible considerations that could effectively bridge the green skills and knowledge gap.

34.1.1 Presence of Green Knowledge Gap

Green facilities management, also known as sustainable facilities management (SFM), embodies a similar concept, taking note of the fact that green buildings have different processes and assets than of a non-green building. There are no singularly agreed upon definition for green facilities management, but an assessment of other descriptions from a variety of sources reveals several similarities. Using the list of definitions and explanations, we can define green facilities management as a multi-disciplinary profession that (1) integrates human factors, sustainable facilities, along with green processes and technology aspects of a building; (2) enhances green operations and maintenance management, while optimizing user productivity; and (3) maximizes total green building potential in terms of improving energy efficiency, environmental quality, reducing water consumption, and other benefits.

Several studies have shown that green buildings are underperforming during the O&M stage, especially in terms of energy performance. Green Mark designs do not always lead to sustainable buildings, and the right green facilities management practices have to be in place, hand-in-hand, to maximize total green building potential. Elmualim et al. (2010) investigated facilities managers' experiences in the United Kingdom in regards to the implementation of SFM policies and practices. The study was conducted among 251 facilities managers, and results identified time constraints, lack of knowledge, and lack of senior management commitment as the three main hurdles to the SFM practice there. The research paper thus establishes and emphases the lack of knowledge and skills within the facilities management industry to effectively manage facilities from a sustainable perspective (Elmualim et al. 2010). This reiterates the fact that while facilities managers are responsible for sustainable operations in green buildings, they are not yet equipped with adequate green knowledge and skills to conduct SFM.

Furthermore, in a report issued by the American Society for Training & Development (ASTD), it was noted that the green industry is experiencing challenges finding skilled green workers. A total of 86% of architecture/engineering firms and 91% of general contractors reported that skilled green employees were difficult to hire (ASTD 2012). With a growing green market that requires specialized green skills, it is proposed that additional trainings and certifications needs to be provided for educated workers to hone on their existing skills set (ASTD 2012). Therefore, both factors—lack of knowledge and lack of training tools—are interlinked and should be addressed together to ensure that green skills gap can be properly handled.

Additionally, the research also identified managerial issues such as maintenance management problem, as one of the factors resulting in green buildings operations and maintenance problems. These managerial issues include improper maintenance planning and management, and wrong maintenance policies. Green buildings require careful operation and maintenance management plans to enhance their productivity performance (Lim 2013), and adequate green knowledge and skills are essential in ensuring that every characteristic of green buildings are integrated into the O&M phase. Hence, without the necessary set of green skills, it will lead to improper maintenance practices or plans that are costing organizations more money and time. This not only applies to newly constructed green buildings, but also buildings with retrofitted green facilities and systems.

The presence of green knowledge gap is a problem that needs to be solved, requiring commitment not only major organisations, but also individuals, and warrants the need to identify possible measures to bridge the gap. The building industry can be divided into two categories—the “software” and “hardware”. The concept of “software” speaks to the management aspects of green buildings and the knowledge and skills set of facilities managers in Singapore. On the other hand, “hardware” stems from green building development and projects, as well as green architectural features and technologies found in green buildings.

Since the launch of the Green Mark Scheme, BCA Academy has provided a range of green certification courses to deliver quality training for the green advancement of the building industry (BCA, N.D). The problem is, however, since it is not compulsory to sign up for these courses, facilities managers might be less willing to attend the courses for green skills upgrading, with factors attributing to time and cost. There is currently close to 2300 Green Mark building projects in Singapore as of 1 May 2015 (BCA, N.D), and the demand for green professionals is rapidly increasing. What happens if and when demand outstrips supply? Therefore, both “software” and “hardware” tie in together and relate to whether the speed of training and cultivation of green facilities management professionals can catch up the speed of green building development.

34.1.2 Research Methodology

For this study, literature reviews on non-green and green facilities management, for both overseas and local context, were carried out first. The purpose of the reviews is to explore the differences between non-green and green facilities management and to identify trends and issues encountered in the shift from conventional to green buildings. The concept of skills and knowledge gaps will also be covered, so as to understand how many facilities managers of the industry are actually equipped with the right green knowledge and skills set to manage green buildings. Based on the literature review, research gaps in existing green facilities management methods were identified and the presence of green skills gap was established, forming the research basis.

Upon gathering the necessary information from literature review, a suitable research design was developed, including a three-fold survey questionnaire designed for local facilities managers as well as interviews. First, based on the existing studies and with reference to the study conducted by Mohammad et al. (2014), seven main barriers were proposed to impede the development of green facility management and they include: (1) Inadequate experience, training and/or knowledge; (2) Improper maintenance planning/management; (3) Design problems; (4) Lack of understanding and cooperation from stakeholders; (5) Lack of expertise by service providers; (6) Financial constraints; and (7) Cultural practices. Followed by the survey, respondents were required to choose 5 factors out of 7 given factors, and to rank them using a five-point scale (5 = most impactful to 1 = least impactful) according to their impact on green building maintenance difficulties. Second, the consequence of inadequate facility management knowledge has been tested regarding (1) early system failure; (2) lack of green building potentials; and (3) underperforming green buildings. Third, we also tested the perceived importance of green knowledge and skills sets and investigated effective ways to improve the inadequacy knowledge.

Once a response result was attained, survey results were analyzed via descriptive statistics and statistics test—one sample t-test. In addition to quantitative data collection and analysis, qualitative interview method will be used to understand industry trends and practices from experienced individuals' point of view, drawing relevant findings to resolve research objectives. The use of both qualitative and quantitative data will generate optimal research findings and guarantee a more thorough and comprehensive research. At the output stage, research findings will be utilized and applied to local facilities management industry. The results can also be used in both theoretical and practical means to introduce more and better initiatives to bridge green skills gap.

34.1.3 Survey and Interview Results

A total of 280 electronic mails were sent out to selected organizations from the private and public sectors in the area of facility management in Singapore, including operational division of large real estate developers, professional companies registered for facility management services, and consulting firms that provide design and engineering services to facilities. The survey was implemented from July to October 2015 and a total of 121 responses were obtained. Out of 121 survey responses, 31 were incomplete and hence excluding from the sample, and 90 result were retained for the analysis. A total of 32.1% response rate was obtained out of 280 electronic mails sent to participating organizations.

A large proportion of respondents (47.8%) have more than 10 years of experience in traditional facilities management and none had less than 1 year or no experience. Comparatively, the proportion of respondents that possess more than 10 years of experience in green facilities management is smaller (10%), and majority (41.1%) fell under the category of 5–10 years of experience. This section elaborates results of the survey and interviews.

34.1.4 Establishing the Presence of Green Skills Gap

After data analyses, among the 7 factors, "inadequate experience, training and/or knowledge" is identified as the most critical problem in green facilities maintenance, with a mean of 4.20. This further supports the fourth research hypothesis, as well as the overall research question that the local facilities management industry faces the problem of green skills gap. The presence of such green skills gap is thus primarily attributed to inadequate experience, training and/or knowledge. Additionally, it was previously established in the literature review that green buildings require careful operation and maintenance management plans to enhance their productivity performance (Lim 2013). As such, facilities managers should possess sufficient green skills and knowledge so as to ensure that green buildings can perform up to their potential during the O&M phase.

Following which, with a mean of 3.45, "improper maintenance planning/management" is identified as the second most common factor in terms of green building maintenance difficulties. One possible explanation behind this result is that maintenance planning and management is related to the extent of experience, training and/or knowledge one has. Without the necessary green experience, training and/or knowledge, a facilities manager will not be able to effectively conduct maintenance planning and management for green buildings.

Though 88 respondents selected this factor for ranking, "improper maintenance planning/management" still has a lower overall mean as compared to "inadequate experience, training and/or knowledge". This shows that while a greater proportion of respondents feel that improper maintenance planning will result in green building maintenance difficulties, the factor is comparatively less significant than the lack of knowledge to them.

In third, fourth and fifth place respectively are factors such as design problems (i.e. disregard for maintainability aspect in design), lack of understanding and cooperation from tenants and/or other stakeholders' cooperation, and lack of expertise by service providers (i.e. outsourced contractors) to maintain green facilities. At the design stage, maintainability in conventional and green buildings was often disregarded, resulting in maintenance issues later on during the operation stage. With architectural features such as light shelves, solar panels and vertical greenery, it is ever more important to ensure that maintainability issues are taken into account during the design stage of green buildings.

It is crucial to note that green technologies and systems are usually sourced from specialized companies. Without the right expertise, effective maintenance could not be carried out. These supply-side companies possess teams with the necessary technological knowledge and specialized green skills to support these systems, and are best maintained by them. While it is not a must for the client-side facilities management team to possess green technological skills, it is vital that they understand these green technologies and facilities, which will in turn allow them to look out for system failure signs and plan for maintenance effectively (Table 34.1).

Table 34.1 Identification of factors resulting in green building maintenance difficulties (N = 88)

Factors	Number of respondents	Overall		Experience of respondents							
				Traditional FM				Green FM			
				≤ 10 years		>10 years		≤ 5 years		>5 years	
		μ	*p*-value	μ	*p*-value	μ	*p*-value	μ	*p*-value	μ	*p*-value
Inadequate experience, training and/or knowledge	80	4.20	0.000	4.43	0.000	3.95	0.000	4.02	0.000	4.37	0.000
Improper maintenance planning/management	88	3.45	0.000	3.41	0.000	3.50	0.000	1.57	0.000	1.78	0.000
Design problems (i.e. disregard for maintainability aspect in design)	70	2.42	0.000	2.59	0.000	2.24	0.000	2.60	0.000	2.26	0.000
Lack of understanding and cooperation from tenants and/or other stakeholders' cooperation	70	1.684	0.000	1.46	0.000	1.93	0.000	1.57	0.000	1.78	0.000
Lack of expertise by service providers (i.e. outsourced contractors) to maintain green facilities	74	1.59	0.000	1.74	0.000	1.43	0.000	1.76	0.000	1.43	0.000
Financial constraints (i.e. insufficient budget allocation)	52	1.30	0.000	1.09	0.000	1.52	0.000	1.38	0.000	1.22	0.000
Cultural practices (i.e. occupants culture thwarting maintenance)	18	0.36	0.000	0.30	0.000	0.43	0.000	0.36	0.000	0.37	0.000

34.1.5 Consequence of Inadequate Knowledge

With an increasing amount of green buildings, there is a need for facilities managers to upgrade their knowledge, as well as increase the demand for green training and certification courses. A total of 77 survey respondents agree/strongly agree that green buildings, should be managed by certified facilities management professionals. Out of 77 of them, 63.3 and 22.2% of them agree and strongly agree to that statement respectively.

Similarly, majority of the respondents (95.5%) agree/strongly agree that facilities manager(s) of green buildings require higher technological knowledge than those managing non-green buildings. With the need for higher technological and green knowledge, as well as green skills set, it is thus important for facilities managers to attend green certification courses. With the necessary knowledge and certifications, facilities managers will be better equipped in handling green facilities.

More specifically, out of the 90 collected responses, a total of 82 facilities management professionals (91.1%) agree/strongly agree that inadequate green knowledge and skills set can lead to early system failures. This observation can be attributed to the fact that a lack of green knowledge and skills set can affect the way facilities managers handle green technologies and systems, and potentially impede the success of green buildings. The above statements are further supported by statistical results, as shown in Table 34.2, where the p-value (0.000/2 = 0.000) is smaller than the predetermined significance level (0.000 < 0.05), the null hypothesis for the fifth research hypothesis is rejected. Likewise, the statistical results also indicate that a lack of green knowledge and skills set to manage green facilities can minimise total green building potential and its performance during the O&M stage.

As mentioned earlier in the report, green buildings typically consists of various advanced building technologies such as EMS and expansive rectilinear roof—a distinctive feature found in Singapore Changi Terminal 3—which can help buildings save energy. Some of these green building technologies incur a sizeable upfront cost, and it is imperative for facilities managers to properly operate and maintain these technologies in order to maximise the life cycle of these technologies and systems. These results thus highlight the importance of equipping the facilities management team with the right green knowledge and skills set, as early systems failures can not only cause cost inefficiency, but also affect green building potential.

Table 34.2 Statistical test for the consequence of inadequate green facility knowledge

	t	df	Sig. (2-tailed)	Mean difference	95% CI* (lower)	95% CI (upper)
Early systems failure	18.316	89	0.000	1.167	1.04	1.29
Discount total green building potential	24.325	89	0.000	1.289	1.18	1.39
Under-performing green buildings at the O&M stage	22.552	89	0.000	1.333	1.22	1.45

*CI is confidence level

34.1.6 Green Skills Training

The respondents were also asked to indicate their preferred method of training in order to investigate the most suitable training method for facilities management professionals. Using this result, institutions offering green certification courses will be able to alter their course design principles according to the needs and preferences of facilities management professionals. Facilities managers prefer to attend classroom or instructor-led trainings as compared to other training methods. A majority of 67 respondents (74.4%) favour classroom or instructor-led trainings, whereby individuals attend courses taught by experienced instructors. 16 respondents (17.7%) prefer to attend computer-based training/online or e-learning, an observation that could be explained due to time constraints, and such e-learning platforms offer great convenience to full-time working adults. Comparatively, hands-on training and self-learning are the least popular training methods, with only 5 and 2 respondents (5.7 and 2.2%) selecting those options. With hands-on training, facilities managers often have to learn based on experience and/or rely on their mentors' knowledge. Such a method takes time and relies on the assumption that the knowledge imparted by the mentors is accurate and up-to-date. As such, this could explain why most facilities managers do not prefer to undergo hands-on training and self-learning.

We also designed the survey questionnaire so as to understand the manner course fees of green certification programs affect individuals' willingness to undergo green certifications and trainings. Ultimately, the cost to be incurred by facilities managers is a key variable, which will affect an individual's willingness to attend green certification courses. The results showed that all 90 respondents (100%) are willing to undergo green training and certification courses if their company was to subsidize the course fees incurred. On the other hand, only 59 respondents (66%) are willing to go for green training and certification courses if the course fees are not subsidized. This corresponds to a 44% decrease in willingness to attend green certification courses between subsidized and non-subsidized course fees. The observation could be explained by the high course fees required to be paid in order for individuals to attend green certification courses. If the company does not subsidize the course fees, this will result in a consequent lack in individuals' willingness to sign up for green certification courses, an important point that needs to be considered when recommending suggestions to bridge green skills gap.

In addition, respondents were required to indicate an affordable course fee range for green certification courses if they were not subsidized. In contrast to a fee of S $1120 for a typical Green Mark Facility Manager (GMFM) certification course under the BCA Academy, majority of the respondents (94%) are unwilling to pay more than $1000 per course if the course fees are not subsidized. The result shows that a total of 59 respondents consider a fee of $200–$500 per course affordable, and only 5 were willing to pay more than $1000 per course. The result highlights the need for additional incentives from government or organizations in order to encourage individuals to take up green certification courses.

34.2 Conclusion and Recommendations

This research study was undertaken to investigate the presence of green skills gap in the local facilities management industry, and ultimately, propose plausible solutions that can help to bridge the gap. It was found that the key factors are often interrelated, and ultimately boils down to the lack of green knowledge and skills set. The lack of knowledge on the benefits of attending green certification courses, as well as the lack of willingness to sign up for said courses without company funding are drivers behind the limited demand for green certification courses among facilities management professionals. As such, few truly understood how green buildings operate differently from non-green buildings, and how they should be maintained, which in turn leads to a failure to realise green building potential. When total green building potential is not realised, it results in a vicious cycle, deterring potential energy savings and other environmental benefits.

In order to overcome these problems and encourage more facilities management professionals to sign up for green certification courses, 4 plausible solutions can be proposed. They are (1) two-pronged approach—increasing individual's awareness of the benefits accrued in attending green certification courses and widening the skills funding or subsidies coverage for individuals; (2) increase the extent of subsidies coverage to trainings and certification courses offered by other institutions and associations; (3) implement and reinforce regulations that call for the early involvement of green certified facilities managers in early project stage; and (4) introduce the use of shared network among facilities managers. Through the proposed solutions, local facilities managers may be keener and more willing to sign up for green certification courses, which will drive the demand for these courses. Having said, with a better understanding of the differences between non-green and green buildings, as well as a greater awareness of green building operations and technologies, sustainable results can be yield from green buildings.

Ultimately, it is important to note that while facilities managers need not possess a whole lot of technical knowledge in order to manage green buildings. Instead, green technologies and systems are usually maintained and repaired by specialised service providers, who possess the necessary technical skills set to do so. However, in order to adequately perform the role of a facilities manager in Singapore, one would need to understand the Green Mark scheme, regulations, green buildings, trends, green technologies and systems, as well as be able to identify system breakdown signs. With these necessary knowledge and skills set, a facilities manager will then be able to generate a good maintenance plan and adequately manage green facilities.

Despite successfully achieving all research objectives set out in this paper, there are limitations to this study, which may result in any anomaly present, one of which is the study's sample size. Considering that there are around 900 certified facilities management professionals in Singapore, and a large pool of uncertified facilities managers, a sample size of 90 may be considered limited. Therefore, one should be cautioned against using the results to generalise all facilities managers in the industry. Lastly, data collection and findings from this study were interpreted in the context of Singapore, as such; results in other countries may differ. Future studies are recommended to provide a more in-depth analysis illustrating the reasons and impacts of green skills gap in various countries, and to compare the results among countries of different context and industry maturity.

Acknowledgements This study is supported by the National University of Singapore (R-296-000-151-133). However, all arguments only represent but not the sponsor.

References

ASTD (2012) Bridging the skills gap. Retrieved from American Society for Training & Development: http://nist.gov/mep/upload/Bridging-the-Skills-Gap_2012.pdf

Elmualim A, Shockley D, Valle R, Ludlow G, Shah S (2010) Barriers and commitment of facilities management profession to the sustainability agenda. Build Environ 45(1):58–64

ILO (2011) Skills and occupational needs in green building. Retrieved from International Labour Office: http://www.ilo.org/wcmsp5/groups/public/—ed_emp/—ifp_skills/documents/publication/wcms_166822.pdf

Inc. (N.D). Facility management. Retrieved from Incorporation: http://www.inc.com/encyclopedia/facility-management.html

Lim C (2013) Green buildings need careful management to perform. Retrieved from Eco-Business: http://www.eco-business.com/news/green-buildings-need-careful-management-perform/

McDonald G, Condon L, Riordan M (2012) The Australian Green Skills Agreement: policy and industry context, institutional response and green skills delivery. Retrieved from TAFE Directors Australia: http://www.tda.edu.au/cb_pages/files/APEC%20Australia%20TDA%20Green%20Skills%20Agreement%202012.pdf

Mohammad IS, Zainol NN, Abdullah S, Woon NB, Ramli NA (2014) Critical factors that lead to green building operations and maintenance problems in malaysia. Theor Empirical Res Urban Manag 9(2):68

Chapter 35
Bridging the Cyber and Physical Systems for Better Construction: A Case Study of Construction Machinery Monitoring and Utilization

D.D. Liu, W.S. Lu, Y.H. Niu, F. Xue and K. Chen

35.1 Introduction

With the rapid development of Building Information Modeling (BIM), virtual models have been increasingly used in construction projects (Wilkins and Barrett 2000). While the potentials of BIM and virtual models have been explored and realized mostly in the design and tendering stage, the value of the model seems to diminish once the construction stage commence. This is due to that as-built construction may deviate from the models while the models remain static. If the updated information in the ongoing building process cannot be synchronized with the virtual models in real-time, the virtual models are risk of being 'blind and deaf', functioning only for visualization (Chen et al. 2015). This situation has given rise to the application of cyber-physical system (CPS) in the construction industry.

The research study CPS has been strongly supported by the US National Science Foundation, encompassing systems where physical and virtual component are deeply intertwined by internet (The National Science Foundation 2016). In a cyber-physical system, the component-based system can respond to the dynamic and real-time changes to facilitate controlling and monitoring (Tang et al. 2010). To apply the CPS approach in construction, Akanmu et al. (2013) further refined its definitions as 'a tight integration and coordination between virtual models and physical construction/constructed facility so as to enable bi-directional coordination'. The concept of bridging BIM and building (BBB) proposed by Chen at el (2015). Also address similar needs to connect information contained in BIM with as-built situation in the physical building processes.

While research studies of CPS in construction are growing, most of the research focuses are confined to using CPS for building components and materials. As

D.D. Liu (✉) · W.S. Lu · Y.H. Niu · F. Xue · K. Chen
Department of Real Estate and Construction, The University of Hong Kong, Hong Kong, China
e-mail: liudd@connect.hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_35

Akanmu et al. (2013) suggested, engineered materials such as pump size, bulk materials such as lighting fixture, and prefabricated materials can be monitored by CPS when changes happen. Yuan et al. (2016) further explored the applications of CPS for monitoring temporary structure, showing the potentials of CPS for on-site safety monitoring. However, for construction projects where numerous machines are involved, the CPS has the potentials to be applied for machine monitoring so as to facilitate safety management and resource utilization. The primary aim of this study is to propose a cyber-physical system for machine monitoring and utilization. Tower crane is selected as a typical example of on-site construction machines for case study in this research. The remainder of the paper comprises four sections. Section 35.2 introduces the system architecture of the CPS. The pilot lab test and the preliminary results are presented in Sect. 35.3. Section 35.4 discusses the prospects and future research areas presented by the CPS, and conclusions are drawn in this section as well.

35.2 The System Architecture

The system architecture demonstrates the cyber-physical coordination between the tower crane and its ‘cyber twin’ in the web-based platform (WBP), as shown in the Fig. 35.1. For the tower crane in the construction site, a smart core comprising the sensing and communicating modules will be deployed on both the crane cab and the main jib. It collects the motion data of the tower crane and filters the collected data. For the virtual model of the tower crane with the surrounding environment, it will be established and presented in the WBP, which can be accessed through any types of computers or mobile devices. Live data extracted from the movement of the tower crane will be processed in the WBP, so as to create synchronized animation on the 3D model. The WBP can also display the live chart plotted based on the live data.

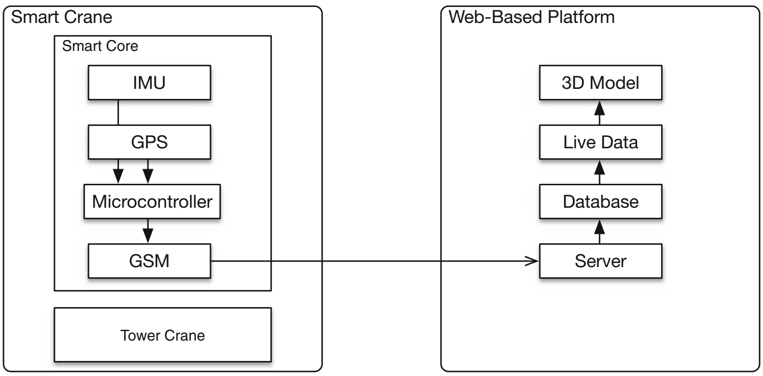


Fig. 35.1 The system architecture diagram

35.2.1 The Development of the Smart Core

The smart core consists of the inertial measurement unit (IMU), global positioning system (GPS), microcontroller, and the global system for mobile communication (GSM) module. The inertial measurement unit (IMU) is a printed circuit board (PCB) that measures the static/dynamic acceleration, angular velocity, and the strength of the magnetic field (Won et al. 2010). Some advanced IMU could also measure the barometric pressure and the temperature. Generally, the IMU is using the combination of 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer, sometimes also the barometer and thermometer. The IMU was originally developed for the rockets in early 1900s (Minor and Rowe 1998). Later, the IMU is being used to help with the human spaceflight (Hoag 1963). Nowadays, the IMU is commonly used in the devices that are expected to acquire the precision of the position. For example, it is used for exact position tracking of the smart phones, many types of robots, and the guided missiles.

In this study, a 11 degree of freedom (DOF) IMU module is adopted from the *Adafruit Industries*. This IMU module contains the three functional modules, which are LSM303DLHC, L3GD20 and BMP180. The LSM303DLHC is a 2-in-1 3-axis accelerometer and 3-axis magnetometer made by the *ST Microelectronics*. It could sense up to ±16 g acceleration and detect up to ±8.1 gauss magnetic field strength. The L3GD20 is the 3-axis gyroscope made by the *ST Microelectronics*. It could sense up to ±2000 dps angular velocity and will not be affected by the gravity. The BMP180 integrates a 2-in-1 barometric pressure sensor and the temperature sensor, which is developed by *Bosch*. It could sense the barometric pressure in the range of 300–1100 hPa and detect the temperature with ±2° accuracy in the range of −40 to 85°. In this study, the movement data is mainly reply on the magnetometer. The headings detected by the magnetometer implies the rotation angles of the crane jib. Data from the accelerometer will be fused by the microcontroller to calibrate the measurement when the IMU is tilted.

The global positioning system (GPS), also known as the global navigation satellite system (GNSS), is a system that provides the absolute geographical locations and coordinated universal time (UTC) through the satellites. The GPS was originally developed by U.S. Department of Defense (DoD) for military use in late 1900s (The National Aeronautics and Space Administration (NASA) 2012). Later, Ronald Reagan, the president of United State, has issued the directive that the U.S. would provide the GPS to the worldwide for free (Pellerin 2006). Nowadays, the GPS is widely used for the application that requires the information of real-time location. In this study, an *Adafruit FONA 808* breakout board is adopted, which is made of the SIM808 cellular module with integrated GPS. It can not only get the GPS coordinates from the satellites but also transfer the coordinates via cellular network. Considering that the accuracy of GPS is not precise enough to trace out the movement of the tower crane and the power consumption of the whole module, the time interval for acquiring GPS coordinates is set to 10 s to help calibrate the measurements from the IMU.

35.2.2 The Development of the Web-Based Platform

To actively monitor the operation of the tower crane, a 3D model of the tower crane is created in the WBP with the site as the background. This user interface is developed based on a web graphics library (WebGL) engine Cesium and Microsoft Bing Map, as shown in the Fig. 35.2, where the 3D tower crane model is made by the SketchUp with the slewing unit and the tower unit individually. The slewing unit of the 'cyber twin' will mimic the motion and rotate at the same angle as the physical tower crane simultaneously, based on the live data sent back from the smart core.

The real-time monitoring enabled by the CPS has significant safety implications for on-site management, especially in providing early warning to avoid potential hazards. For the operation of tower crane, there are danger zones on site where the movement of jib should not bypass. The danger zones can be highlighted in the WBP. When the tower crane is approaching the danger zone from either direction, a notification box will pop up at the top middle of the user interface to make an alert.

The seamless dataset acquired by the CPS can also be used to analyze machine utilization. The live data visualization is presented at the bottom right corner. Currently, the live data visualization is conducted with the python script as the plug-in for the WBP. There are several useful built-in data analysis tools in Matplotlib, so that the user could analyze the data while the system is running. All data will be stored in the cloud database, which can be used for tracing out the movement of the tower crane along with the coordinated universal time (UTC). A timeline toolbar is placed at the bottom of the user interface. The user could click the specific time to see the location of the main jib or he could play the whole movement of the tower crane throughout the day.

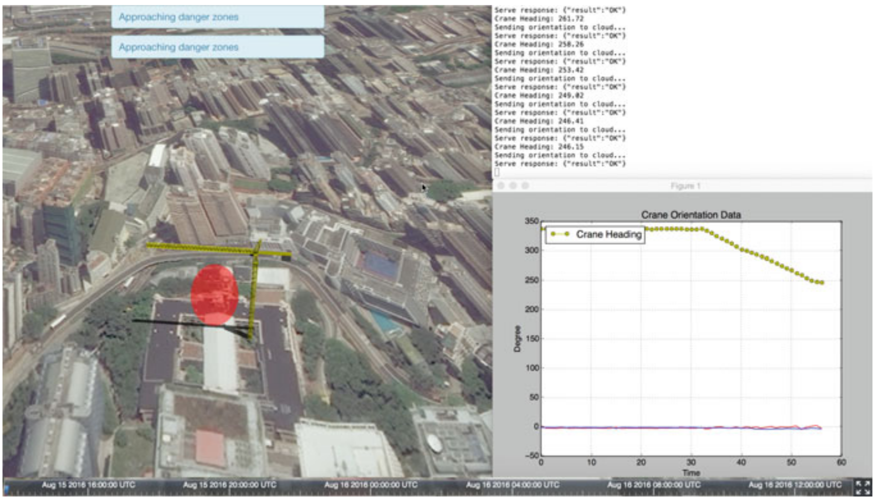


Fig. 35.2 The web-based platform

35.3 Pilot Lab Testing and Preliminary Results

The CPS has been tested in the lab by using LEGO® as the physical tower crane model. The pilot aims to test the capability of the system for real-time monitoring and tracing out the movement of the tower crane. Three tasks have been carried out in the lab pilot test, shown as the system flow in Fig. 35.3. The first task is to test the functionality and the data accuracy of the smart core. The second task is to test the stability of the data transmission. The third task is to validate the location checking algorithm. This algorithm is designed for checking whether the tower

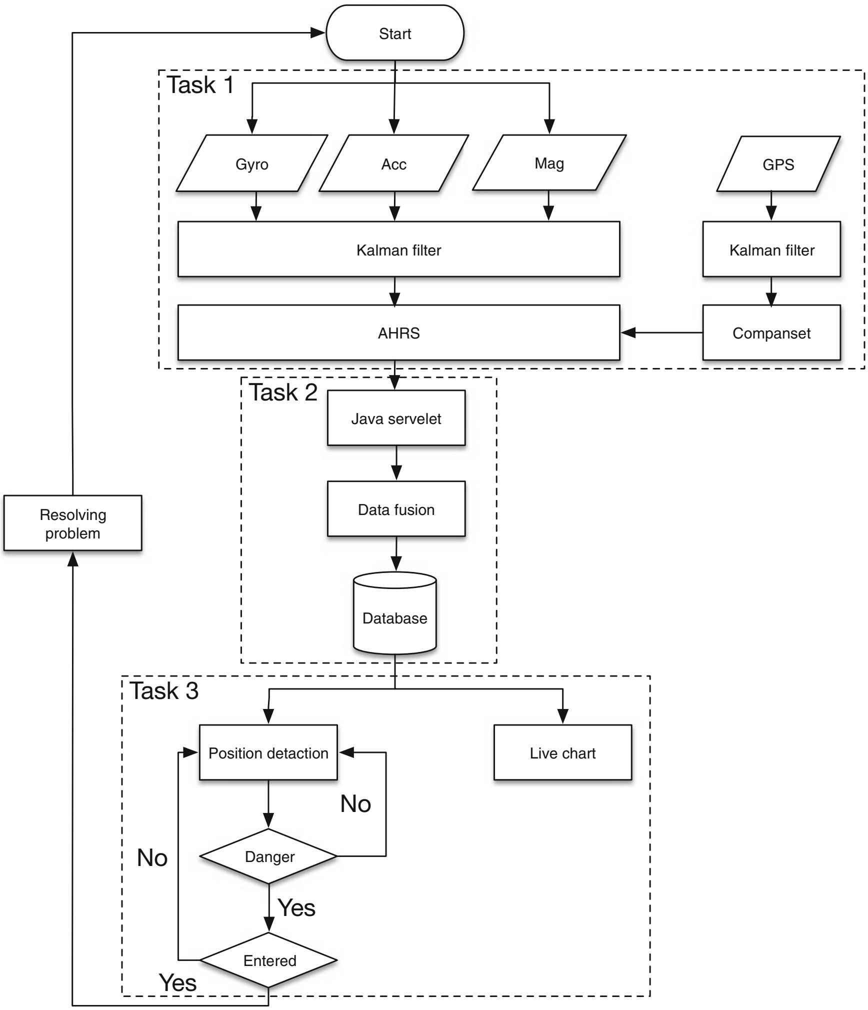


Fig. 35.3 The system flow

crane is approaching or have entered the danger zone. Moreover, the live chart for data visualization will be tested as well. Since the lab test is conducted using the LEGO® tower crane, the GPS data is excluded in this lab testing.

The smart core is attached to the main jib of a LEGO® tower crane. A servo motor controls the LEGO® tower crane to move in different patterns with different speeds. There is a protractor, which is placed at the bottom of the LEGO® tower crane in parallel, to measure the actual rotation angles. In order to test the accuracy of data sensed by the smart core, the rotation angles sent back by the smart core are compared against the actual rotation angles obtained by the protractor. The degree of difference is measured by using the root mean squared error (RMSE) as shown in Eq. (35.1). In the lab test, data from the gyroscope, accelerometer and the magnetometer are fused through the Kalman filter. The value of RMSE is 1.76°, indicating measured data is deviated from the actual angles about 1.76° on average, which good enough for tracing out the movement of the tower crane. The low RMSE value also indicated that the attitude and heading reference system (AHRS) algorithm and the Kalman filter worked properly.

$$RMSE = \sqrt{\frac{1}{n}\sum\nolimits_{i=1}^{n}\left(Actual_i - Measured_i\right)^2} \tag{35.1}$$

Since this system is developed for operation throughout the working hour of the tower crane, the stability of the data transmission on both smart core and WBP are vitally important. This test for data transmission has been done for 23 h, during which the data is uploaded via the hypertext transfer protocol (HTTP) link every second and stored in the database. Theoretically, there are 82,800 sets of data will be stored in the database, while 82,190 sets of which are actually received. Nevertheless, the overall plotting pattern is rarely affected by the data lose. As for the task 3, the location checking algorithm is being checked by two steps. The first step is to manually control the 3D tower crane to approach and enter the danger zone. It is confirmed that the location checking algorithm is working properly under the manual mode, by checking popping up of the notification boxes.

35.4 Discussion and Conclusion

To explore the potentials of using cyber-physical system (CPS) for on-site machine monitoring and facility utilization, this study proposes a CPS that could actively link the virtual model of machines to the physical machines on construction site that are in operation. System architecture and necessary techniques to set up the system are presented in this study. To test the applicability of the CPS, the tower crane is selected as an example of construction machines to be tested in a lab pilot.

The preliminary results suggest that the real-time data captured by the smart core could enable the virtual model to mimic the movement of the physical tower crane in a relatively precise manner. Data from three types of sensors are fused while the angle detection are highly relying on the headings provided by the magnetometer. Therefore, compared to previous studies on tower crane monitoring, the CPS proposed in this study provide a more stable and accurate data string for reconstructing the animation in the virtual model. Meanwhile, the webpage-based WPS supports multi-party and mobile access, enhancing the interoperability of the system for various users involved. Besides, the rarely lost data set captured and stored by the CPS could be further used to analyze the operation time and patterns of the tower crane, so as to facilitate resources utilization. Further studies are expected to test and deploy the CPS on construction site, so as to identify the practical constraints and potential benefit for the further research on CPS.

References

Akanmu A, Anumba C, Messner J (2013) Scenarios for cyber-physical systems integration in construction, vol 18, pp 240–260

Chen K, Lu W, Peng Y, Rowlinson S, Huang GQ (2015) Bridging BIM and building: from a literature review to an integrated conceptual framework. Int J Project Manage 33(6):1405–1416

Hoag D (1963) Apollo guidance and navigation: considerations of apollo IMU gimbal lock. MIT Instrumentation Laboratory, Canbridge, pp 1–64

Minor RR, Rowe DW (1998, April) Utilization of GPS/MEMS-IMU for measurement of dynamics for range testing of missiles and rockets. In Position Location and Navigation Symposium, IEEE 1998 (pp 602–607). IEEE

Pellerin C (2006, February 3) United States Updates Global Positioning System Technology. Retrieved from http://iipdigital.usembassy.gov/st/english/article/2006/02/20060203125928lcnirellep0.5061609.html#axzz4HItYa8po

Tang LA, Yu X, Kim S, Han J, Hung CC, Peng WC (2010, December) Tru-alarm: trustworthiness analysis of sensor networks in cyber-physical systems. In 2010 IEEE International Conference on Data Mining (pp 1079–1084). IEEE

The National Aeronautics and Space Administration (NASA) (2012, October 28) Global Positioning System History. Retrieved from http://www.nasa.gov/directorates/heo/scan/communications/policy/GPS_History.html

The National Science Foundation (2016, March 4) Cyber-Physical System (CPS). Retrieved from https://www.nsf.gov/pubs/2016/nsf16549/nsf16549.htm

Wilkins B, Barrett J (2000) The virtual construction site: a web-based teaching/learning environment in construction technology. Autom Constr 10(1):169–179

Won SHP, Melek WW, Golnaraghi F (2010) A Kalman/particle filter-based position and orientation estimation method using a position sensor/inertial measurement unit hybrid system. IEEE Trans Industr Electron 57(5):1787–1798

Yuan X, Anumba CJ, Parfitt MK (2016) Cyber-physical systems for temporary structure monitoring. Autom Constr 66:1–14

Chapter 36
Building Information Modeling (BIM) in Architecture, Engineering and Construction (AEC) Industry: A Case Study in Malaysia

N.F. Azmi, C.S. Chai and L.W. Chin

36.1 Introduction

The growing demand of AEC (Architect, Engineer and Construction) sector has prompted the Malaysian construction for the last few decades. The stakeholders in construction team are always in demand due to the successful delivery process in budgetary cost, limited manpower, tight schedule and issue of waste, which majority is initiated due to the fragmented nature of AEC industry (Man and Machine 2014).

The AEC industry always seeks for alternatives to adopt techniques to reduce the project cost, project delivery period and effective waste management to enhance the productivity and quality (Azhar et al. 2008). One of the techniques is Building Information Modeling (BIM). BIM had been introduced to solve problems in the industry. BIM is suitable to support the simulation of a construction project in a virtual environment, with abundant associating advantages through the use of proper software package (Grilo and Jardim-Goncalves 2010a, b). The information related to the design such as location, climate, and materials of the building can be uploaded into the database (Liu et al. 2015). Besides that, during the design process, BIM gives an advantage to the designers and the time scale of design works will be shortened.

BIM is a digital representation of physical and functional characteristics of a facility (BIM Standard 2016). BIM is a shared of knowledge resource of infor-

N.F. Azmi (✉) · C.S. Chai · L.W. Chin
Department of Structure and Materials, Faculty of Civil Engineering,
Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
e-mail: faira_90@yahoo.com

C.S. Chai
e-mail: cschai@utm.my

L.W. Chin
e-mail: liwei5494@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_36

mation for a facility which forming a reliable basis for decisions-making during its life cycle, which is from the earliest conception to demolition. However, there is limited application of BIM in Malaysia due to the cost implications. The cost of BIM platform software and training triggered the additional expenses to the practitioners (Sebastian 2011).

Despite the initial cost issue, quality and production are still the priority for project even though the adoption of BIM is lower in developing countries. Medium enterprises are still affording ICT investment while most of the small enterprises find its adoption as an encumbrance. However, BIM can result in quality enhancement other than time reduction and delay avoidance. The project cost will be lowered as effective clash detection, routine maintenance and proper manpower management can significantly overcome the problems in AEC industry (Abu Hamra 2015). As such, this paper aims to evaluate the BIM adoption challenges in AEC sectors. The BIM implementation challenges will be identified through the categorisation of BIM drivers. The significances of study are to increase AEC performance in BIM-related field and help the practitioners to appreciate the interrelationship of BIM-AEC in the construction industry.

36.2 Building Information Modeling: An Overview

BIM can be defined as tools, process and technologies that are simplified by digital, building's documentation inclusive of its performance, planning, construction and operation that are able to be used by a computer. There are researchers defined BIM as a combination of processes delivery, communication and analysis of the building models to form the entire projects of the lifecycle (CIDB 2003; Jeong et al. 2009).

BIM is a platform that represents the digital characteristic and physical object-oriented that eases visualisation and ensures effective communication; as abundant data can be incorporated within. The outcomes gathered from the available information will precipitate the decision-making process (Aound et al. 2004). The process of development to stimulate the planning, design, construction and operation of the facility can be greatly done through utilisation of BIM.

36.2.1 BIM Drivers

There are three components of BIM drivers, which are Culture Case, Technology Case and Business Case that are interrelated among the stakeholders (Davies and Harty 2011). Ultimately, the vision for BIM integration addresses the cost benefits of BIM implementation in the industry. Figure 36.1 shows the integration of BIM among culture, business and technology cases.

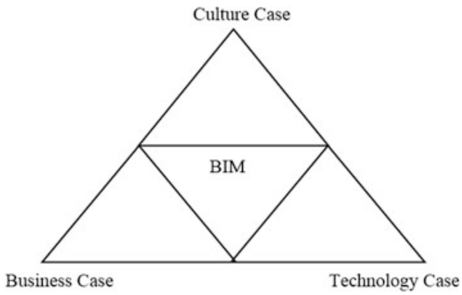


Fig. 36.1 The case BIM is incomplete without people case (Deutsch, 2011)

36.2.1.1 Business Case

Business case is related to 'Return on Investment' (ROI) in the long period with the proposal related to the responsibilities of ownership, insurances, or standard of procedure from culture firm. To introduce BIM in a company, the software and trainings are the major challenges to the practitioners (Deutsch 2011; Bernstein and Pittman 2004). The practitioners involved are consultants (due to design disciplines), contractors (due to constructions) and project managers (due to planning in management). The design disciplines view BIM as a connection to CAD which is more advantageous than before. Contractors and project managers view BIM as an intelligent software related to cost, planning as well as data extraction from CAD (Gu and London 2010).

Along the long run, BIM vendors should audit the BIM application after implementation and to verify the software is user friendly to the beginner. Majority designers who possess CAD background will consider BIM as a visualisation and able to monitor from the software only (Gu and London 2010; Deutsch 2011). The contractors and project managers which are familiar with the Document Management System (DMS) background probably consider BIM as featured software that are important for visualisation and navigation. In conclusion, BIM social affects the ROI to become higher and should be made much effective in future.

36.2.1.2 Technology Case

BIM in technology case is referring to technology integration which contains the software ability that is involving in managing data base software and interoperability (Gray et al. 2013). BIM adoption necessitates changes to the current work practice. A BIM development model required collaboration and communication between practitioners. An alternative way to approach the BIM development can be made easier if big data model is considered.

Experience from the DBMS (Database Management System) was useful for data organisation and management. However, the common practice is the needs to develop one's data management practices to suit in practitioners and project requirements. In fact, the elements should be incorporated with others to maximize BIM benefits (Gu and London 2010).

36.2.1.3 Culture Case

BIM is incomplete without the cultural case. Personal initiative, mutual respect and trust are an example of human cultural factors. Other than that, human nature, owner suspend auto-ship, comfort with work progress, productivity, effect of technology on design, works behaviour, preference, and legacy also related to the human factor. All of these impact the efficiency of BIM efforts (Deutsch 2011).

Previous studies tend to focus on technology factor rather than user behaviour. The problems related to communication, collaboration, human issues and process issues with humanity problem are interrelated (Deutsch 2011). Thus, strong team bonding and commitment to job scope are highly recommended in BIM environment. This can be achieved through systematic BIM adoption training and top management integrity to promote organizational working environment.

As BIM adoption in Malaysia is still at minimal level, it is essential to reveal the challenges of BIM implementation in the industry. The following section discusses the challenges of BIM in Malaysia.

36.2.2 The Implementation Challenges Malaysia

The BIM implementation challenges are categorised to business, technology and culture as shown in Table 36.1. The categorization is done according to the BIM drivers as per discussed in previous section. Each component in the category is carefully examined in terms of definition, characteristics and factors related. It is achievable through critical literature review.

The components of business are cost and market demand. Cost is being defined as a strategy of recording and analysing all important costs that related with equipment in a building or manufacturing facility (Fitchett 2003). While, the latter, market demand is referring to the demand and supply chain (Wheelwright 2010). There are four (4) factors categorized in cost component, meanwhile two (2) are categorized in market demand component.

Interoperability and software are categorized in technology. The interoperability is the ability of two or more networks, frameworks, gadgets, application, or components to trade in and utilisation of data security (Markovic et al. 2013). In the meantime, software is a sequence of abstract program statements that describe computations to be performed by a machine (Councill and Heineman 2001). From the literature, there were three (3) factors categorized in interoperability and six (6) factors in software component.

The culture components are knowledge/skill and stakeholder. Knowledge is known as the gathering of information following with the skills that gained through

Table 36.1 Categorization of BIM implementation challenges

BIM implementation challenges	Category	Components	Code	Factors	Sources
	Business	Cost (BC)	BC 1	High initial cost in BIM	Bryde et al. (2013)
			BC 2	Extra cost implication	Bryde et al. (2013)
			BC 3	The cost is expensive	Eastman et al. (2011), Barlish and Sullivan (2012)
			BC 4	Cost implication to hardware is high	Mohd and Ahmad Latiffi (2013)
		Market Demand (BM)	BM 1	Unsupportive BIM environment	Jiang (2011)
			BM 2	Limited choices of software	Zakaria et al. (2013)
	Technology	Interoperability (TI)	TI 1	BIM simulation helps in construction process	Azhar (2011)
			TI 2	Malaysia is limited to BIM exposure	Gu and London (2010)
			TI 3	Low BIM implementation level due to lack of awareness.	Zakaria et al. (2013)
		Software (TS)	TS 1	The software of BIM is hard to find in Malaysia	Azhar (2011)
			TS 2	Properties missing in file conversion	Kiviniemi et al. (2008)
			TS 3	Unstandardized BIM platform	Barlish and Sullivan (2012)
			TS 4	Multiple BIM definition	Bryde et al. (2013)
			TS 5	Simulation helps in project life cycle	
			TS 6	Unstandardized file format	Abanda et al. (2015)
	Culture	Knowledge/Skill (CK)	CK 1	Limited BIM trainer	Deutsch (2011)
			CK 2	Training should provided to all parties	Arayici et al. (2011)
			CK 3	Do not alert of technology change	Gu and London (2010)
			CK 4	Lack of experience in BIM	Gu and London (2010)
			CK 5	Time constraints to attend the training	Mohd and Ahmad Latiffi (2013)
			CK 6	Lack of professional skills	Arayici et al. (2011)
		Stakeholders (CS)	CS 1	Reluctant to change	Deutsch (2011)
			CS 2	Commitment to implement BIM	Porwal and Hewage (2013)
			CS 3	Difficult to understand BIM model	Arayici et al. (2011)
			CS 4	No enhancement from authority	Eastman et al. (2011)
			CS 5	Limited BIM awareness campaign	Zakaria et al. (2013), CIDB (2003)
			CS 6	No confidence in BIM	Lam and Wong (2011)

experience and learning (Steel 2007). From the definition, it is found that there are six (6) factors can be categorized in component "knowledge". Lastly, the interpretation of stakeholder is a group of people that gathered together to accomplish something and are responsible for survival and make it a success (Freeman 2010). In order words, this component is related to human behaviour in BIM implementation. Six (6) factors were classified in this component.

Most of companies indicated that BIM is a challenge in practice due to familiarity of conventional 2D presentation (Tse et al. 2005). Through a systematic categorization of BIM implementation, practitioners are able to identify their weaknesses in each component. Improvement plan can be initiation accordingly. The categorization of BIM implementation challenges is illustrated in Table 36.1.

36.2.3 BIM Implementation in the Malaysian AEC

In conjunction to the Malaysian agenda in the 12 National Key Economic Areas (NKEAs) to enhance business growth in the AEC industry, new technologies are aggressively embraced in order to remain competitive in the current market. BIM is one of the new emerging technologies to be deployed in the design, construction and project management to facilitate the exchange and interoperability of information in digital format. Despite the advantages derived from this paradigm, local construction industry is reluctant to implement the technology in its service delivery.

Although BIM has been in the market for a number of years, it has not been adopted industry wide to its full capacity. The technology, process and organizational investments required to implement BIM are costly, and adopting BIM requires substantial changes to how the industry traditionally designs and builds projects. As the AEC implements BIM, decision makers and end users are able to benchmark and understand the value of BIM for their organizations and projects.

36.3 Research Methodology

The questionnaires are distributed to government representative, developers, civil engineer, contractors, education professional and architects. Quantitative approach is selected in this study. Questionnaire with five-point Likert Scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) is designed. The questionnaire is separated into three parts. Part A is meant to collect general information of the respondent, Part B is important to gather information on BIM implementation challenges and Part C is used to examine the integration relationship among the BIM drivers in AEC. The questionnaires were distributed through by-hand and via e-mail to 120 respondents.

There were 32 variables (challenges factors) identified from critical literature review. Descriptive analysis is used to analyze the demographic information of respondents. Next, Principle Component Analysis (PCA) is utilized to examine the BIM implementation challenges from the data collected. The data analysis results are discussed in following section.

36.4 Data Analysis and Discussion

120 questionnaires were sent, 60 of questionnaire were returned, 45 were valid, indicating 37.5% of response rate. As recommended by Frohlich (2002), the average response rate for questionnaire survey is ranging from 30 to 40%. Therefore, the response rate for this study is at acceptance range.

Figure 36.2 shows the background of respondents. There were 21% contractors, 43% engineers and 36% architects answered the questionnaire. The respondents were medium executive and above in which working experience is 5 years and above. The respondents experience in BIM and AEC is essential to determine the reliability of the data collected.

36.4.1 Principle Component Analysis (PCA)

The reliability and sampling adequacy is important to determine the data competency. The reliability of the data set is determined through Cronbach's Alpha coefficient. Meanwhile Kaiser-Meyer-Olkin and Bartlett's Test (KMO) is used to determine sampling adequacy. It is found that Cronbach's Alpha coefficient for this study is recorded 0.966, indicated that the data collected is reliable. Kaiser-Meyer-Olkin (KMO) and Bartlett's Test is recorded 0.691, the data is found significant in sampling adequacy (Tabachnick et al. 2001).

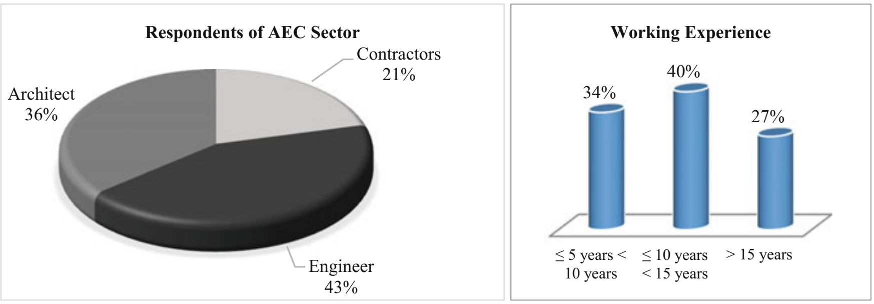


Fig. 36.2 Background of respondents

The Principal Component Analysis (PCA) is conducted to analyse the collected data. Comparisons are made across factor loadings of AEC. The highest factor loading in each component (highlighted italic in Table 36.2) is selected as the BIM implementation challenges factor. From the Table 36.2, there were seven (7) factors selected in the architect category. The seven factors covered five (5) components, namely cost, market demand, interoperability, knowledge and stakeholders. It is found that lack of professional skills (factor loading 0.973) is the major factor contributing to BIM implementation challenges in architect firm.

However, in the engineer category, it is found that the highest factor loading falls in software component, recorded 0.929 in "properties missing in file conversion". This is mainly due to different BIM platform is used among architect and engineer, the model conversion leads to missing properties which might jeopardise the structural analysis. There are various software available in the market, include Archi CAD, Bentley system AECOSim, Revit Building and Revit Structure, Tekla Structures, Digital Project (CATIA-based), Structure Works (Solidworks-based) and other that lead to that situation (Lee et al. 2006). Thus, standardization of BIM platform is important to synchronize the model created.

For the contractor category, there were twelve (12) factors contributed to BIM implementation challenges. The most contributing factor is interoperability, BIM simulation helps in construction process (TI1). The result is reasonably true as the contractor required simulation model to clarify on clash detection, structural detailing and others. The simulation model is able to reduce the corresponding time in request for information (RFI) procedure.

From the PCA, the factor loading is rearranged in each component. The new categorisation of BIM implementation challenges is shown in Fig. 36.3.

Figure 36.4 illustrated the framework in explaining the BIM implementation challenges between architect, engineer and contractor. It is found that cost, knowledge and stakeholder are proper subset of AEC. This indicated that the fundamental challenges of BIM implementation is greatly rely on monetary influence, availability of professional trainers and investors intention. Therefore, focuses should be emphasized in these 3 criterions in enhancing the BIM implementation in AEC industry Malaysia. Also, business model based on cost, knowledge and stakeholder should be encouraged in order to maximize the BIM benefits.

The main idea of the study is to identify the major challenges of BIM implementation in AEC industry, however it also served the purpose to enhance the AEC performance through BIM implementation by mitigating the challenges factors. BIM brought the revolution of construction engineering from analogue decision to digital decision in 21st century. Furthermore, BIM is predicted to be continues enhancing the industry in predictive digital decision and artificial intelligence decision in the future.

Table 36.2 Principal component analysis BIM implementation challenges in Malaysia

		Code	Challenges	Architect	Engineer	Contractor
Business	Cost	BC 1	High initial cost in BIM	0.624	0.724	*0.876*
		BC 2	Extra cost implication	0.797		*0.838*
		BC 3	The cost is expensive	0.651	*0.864*	0.759
		BC 4	Cost implication to hardware is high	*0.745*	0.708	0.707
	Market demand	BM 1	Unsupportive BIM environment	*0.826*		0.783
		BM 2	Limited choices of software	*0.787*	0.712	0.779
Technology	Interoperability (I)	TI 1	BIM simulation helps in construction process	0.857	0.650	*0.931*
		TI 2	Malaysia is limited to BIM exposure	0.718	0.727	*0.841*
		TI 3	Low BIM implementation level due to lack of awareness.	*0.750*	0.640	0.672
	Software	TS 1	The software of BIM is hard to find in Malaysia	0.724	*0.862*	0.672
		TS 2	Properties missing in file conversion	0.864	*0.929*	0.957
		TS 3	Unstandardized BIM platform	0.654	*0.719*	0.649
		TS 4	Multiple BIM definition	0.707		*0.874*
		TS 5	Simulation helps in project life cycle		0.832	*0.859*
		TS 6	Unstandardized file format			*0.798*
Culture	Knowledge/skill	CK 1	Limited BIM trainer		*0.859*	0.764
		CK 2	Training should provided to all parties	0.607	0.601	*0.681*
		CK 3	Do not alert of technology change	0.645	0.728	*0.902*
		CK 4	Lack of experience in BIM	*0.828*	0.733	0.800
		CK 5	Time constraints to attend the training			*0.638*
		CK 6	Lack of professional skills	*0.973*	0.970	0.776
	Stakeholder	CS 1	Reluctant to change	0.697		*0.920*
		CS 2	Commitment to implement BIM	0.752	0.839	*0.860*
		CS 3	Difficult to understand BIM model	*0.817*	0.687	0.621
		CS 4	No enhancement from authority		*0.881*	0.817
		CS 5	Limited BIM awareness campaign		*0.777*	0.659
		CS 6	No confidence in BIM	0.657	*0.863*	0.826

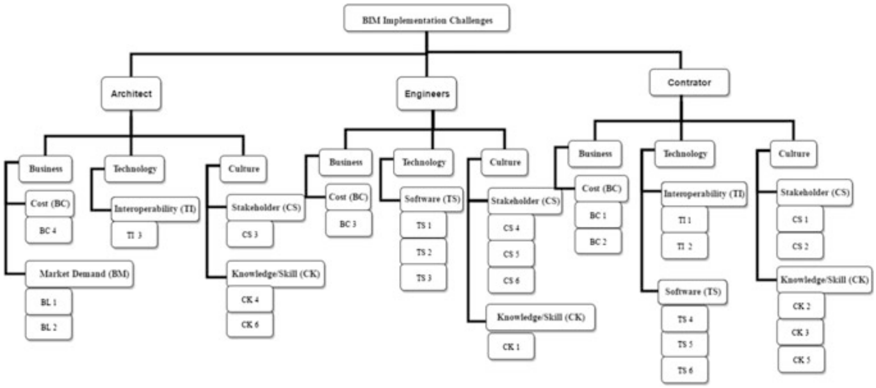
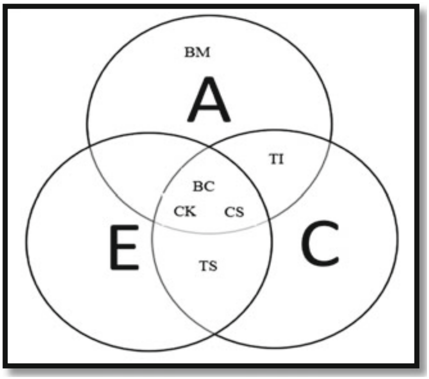


Fig. 36.3 The categorisation of BIM implementation challenges



Legend		
1	Architect	A
2	Engineer	E
3	Contractor	C
4	Market and Demand	BC
5	Cost	BM
6	Knowledge	CK
7	Stakeholder	CS
8	Interoperability	TI
9	Software	TS

Fig. 36.4 The AEC-BIM implementation challenges framework

36.5 Conclusion

The study had identified the major challenges of BIM implementation of AEC in Malaysia. The BIM framework reveals that cost, knowledge and stakeholders are key factors to drive the BIM adoption. This study is significant to raise awareness among practitioners in mitigating possible challenges during BIM adoption. Also, it acts as a precaution guideline to new BIM user/investor in the industry.

Many researchers had identified that the BIM implementation level in Malaysia AEC is still at minimal level due to several challenges. However, some initiatives are taken by the authority to improve the situation through tax relief scheme, financial bridging opportunities and others. Moreover, Construction Industry Development Board Malaysia had invested RM1.5mil lately for BIM awareness programme to enhance BIM adoption in the country. After all, government's role is still crucial to drive a transformation towards new technology implementation.

Acknowledgements This research was supported by PAS grant, vote no: Q. J130000.2722.02K11. The authors appreciated the colleagues from UTM (Universiti Teknologi Malaysia) who provided insight and expertise that greatly assisted the research.

References

Abanda F, Vidalakis C, Oti A, Tah J (2015) A critical analysis of Building Information Modelling systems used in construction projects. Adv Eng Softw 90:183–201

AbuHamra LA (2015) An investigation into Building Information Modeling (BIM) application in Architecture, Engineering and Construction (AEC) Industry in Gaza Strip Master thesis, Construction Project Management, Civil Engineering, Islamic University of Gaza (IUG), Gaza strip, Palestine (Sept 2, 2015). http://library.iugaza.edu.ps/thesis/116796.pdf

Arayici Y, Coates P, Koskela L, Kagioglou M, Usher C, O'Reilly K (2011) BIM adoption and implementation for architectural practices. Struct Surv 29(1):7–25

Aound G, Lee A, Wu S (2004) The utilisation of building information models in nD modelling: a study of data interfacing and adoption barriers

Azhar S, Hein M, Sketo B (2008) Building Information Modeling (BIM): benefits. Risks Chall

Azhar S (2011) Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadersh Manag Eng 11(3):241–252

Barlish K, Sullivan K (2012) How to measure the benefits of BIM—a case study approach. Autom Constr 24:149–159

BIM Standard (2016) https://www.nationalbimstandard, 24 April 2016

Bryde D, Broquetas M, Volm JM (2013) The project benefits of building information modelling (BIM). Int J Project Manag 31(7):971–980

Bernstein PG, Pittman JH (2004) Barriers to the adoption of building information modeling in the building industry. Autodesk Build Solut

CIDB (2003). *Malaysia Conctruction Industry Master Plan*. CIDB

Councill B, Heineman GT (2001) Definition of a software component and its elements. Compon Based Softw Eng Putt Pieces Together, pp 5–19

Davies R, Harty C (2011) Building Information Modelling as innovation journey: BIM experiences on a major UK healthcare infrastructure project. In 6th Nordic conference on construction economics and organisation–shaping the construction/society nexus, pp 233–245

Deutsch R (2011) BIM and integrated design: strategies for architectural practice. Wiley, NY

Eastman C, Eastman CM, Teicholz P, Sacks R, Liston K (2011) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors. Wiley, NY

Frohlich MT (2002) Techniques for improving response rates in OM survey research. J Oper Manag 20(1):53–62

Fitchett D (2003) The true cost of downtime, E-book. Bussiness Industrial Network

Freeman F (2010) Strategic management. Cambridge University Press, United Stated of America

Gu N, London K (2010) Understanding and facilitating BIM adoption in the AEC industry. Autom Constr 19(8):988–999

Gray M, Gray J, Teo M, Chi S, Cheung YKF (2013) Building Information Modelling: an international survey

Grilo A, Jardim-Goncalves R (2010a) Building information modeling and collaborative working environments. Autom Constr 19(5):521

Grilo A, Jardim-Goncalves R (2010b) Value proposition on interoperability of BIM and collaborative working environments. Autom Constr 19(5):522–530
Jiang X (2011 Jan) Developments in cost estimating and scheduling in BIM technology. Mast Abstr Int 50(2)
Jeong YS, Eastman CM, Sacks R, Kaner I (2009) Benchmark tests for BIM data exchanges of precast concrete. Autom Constr 18(4):469–484
Kiviniemi A, Tarandi V, Karlshøj J, Bell H, Karud OJ, (2008) Review of the development and implementation of IF Compatible BIM. http://erhvervsstyrelsen.dk/file/9498/ReviewoftheDevelopmentandImplementationofIFCcompatibleBIM.pdf, 23 April 2016
Lam PT, Wong FW (2011) A comparative study of buildability perspectives between clients, consultants and contractors. Constr Innov 11(3):305–320
Lee G, Sacks R, Eastman CM (2006) Specifying parametric building object behavior (BOB) for a building information modeling system. Autom Constr 15(6):758–776
Liu S, Meng X, Tam C (2015) Building information modeling based building design optimization for sustainability. Energy Build 105:139–153
Mohd S, Ahmad Latiffi A (2013) Building Information Modeling (BIM) application in construction planning
Markovic DS, Zivkovic D, Branovic I, Popovic R, Cvetkovic D (2013) Smart power grid and cloud computing. Renew Sustain Energy Rev 24:566–577
Man and Machine (2014) BIM uncovered—collaborate effectively and deliver better design, https://www.theengineer.co.uk/supplier-network/product/white-paper-bim-uncovered-collaborate-effectively-and-deliver-better-design/, 20 March 2016
Porwal A, Hewage KN (2013) Building Information Modeling (BIM) partnering framework for public construction projects. Autom Constr 31:204–214
Steel M (2007) Oxford wordpower dictionary 7th impression. Oxford Fajar Sdn. Bhd, Selangor
Sebastian R (2011) Changing roles of the clients, architects and contractors through BIM. Eng Constr Archit Manag 18(2):176–187
Tse TK, Wong KA, Wong KF (2005) The utilization of building information models in nD modelling: a study of data interfacing and adoption barriers. ITcon 10(Special Issue From 3D to nD modelling):85–110
Tabachnick BG, Fidell LS, Osterlind SJ (2001) Using multivariate statistics
Wheelwright SC (2010) Managing new product and process development: text cases. Simon and Schuster
Zakaria Z, Mohamed Ali N, Tarmizi Haron A, Marshall-Ponting AJ, Abd Hamid Z (2013) Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A QUALITATIVE approach. Int J Res Eng Technol 2(8):384–395

Chapter 37
Carbon Emission Modelling for Construction Logistics Process Through Activity-Based Method

Y. Fang, Z.D. Ma and Y.Z. Luo

37.1 Introduction

Greenhouse gas emissions have been proved to be the culprit for global warming, especially carbon emissions contribute greatly to climate change (Gaussin et al. 2013; Jing et al. 2014). It is about 82.9% of total greenhouse gas emissions (Todd et al. 2001). By 2020, the building sector will be responsible up to 31% of the CO_2 emissions in the world. IPCC (International Panel on Climate Change) proposes this share is projected to be up to 52% by 2050. Many attentions focus on the design of energy efficient building and the selection of low carbon construction materials (Sharrard et al. 2008). However, the carbon emissions during construction stage cannot be ignored.

Although several researchers have assumed that the carbon emission during the construction stage are negligible, others have indicated that the environmental impacts associated with construction are underestimated (Hendrickson et al. 1998; Junnila and Horvath 2003; Guggemos and Horvath 2005). Except the works done on site, the supply and storing of building materials and components to site is especially filled with gas pollution, which can have a significant effect on levels of carbon emission during construction stage. Building materials often require large storage capacity, but quite often construction sites in urban areas are limited. At the same time, materials being kept on site are prone to damage from bad weather and/or movement of people, plant and equipment. Damaged materials will have to be re-ordered, thus lead to more carbon emission. The construction industry should play a more proactive attention in controlling the carbon emission during materials logistics process. More strict logistics method should be found in order to control and cut down the carbon emissions during construction stage.

Y. Fang (✉) · Z.D. Ma · Y.Z. Luo
Department of Civil and Transportation Engineering, Guangdong University of Technology, No. 100 Wai Huan Xi Road, Guangzhou, China
e-mail: carolynfang@gdut.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_37

Because construction schedule is always separated into many process, the process is complex and has many participants. The calculation of carbon emissions during construction stage is not an easy thing. The divergence and limitation exist both on the research range and the calculation method. Especially, although many researchers realised the important contribution of construction logistics process to carbon emissions, there has no exact agreement on what kinds of logistic actions should be considered when calculating the carbon emission of construction stage. This research will build a methodology of finding the source of carbon emissions during construction logistics process based on construction supply chain theory. The logistic actions which should be included in construction stage will be decided with activity-based method.

37.2 Construction Logistics Process

It is important to give a clear range of construction logistics process because the carbon emission during production stage should be considered by manufactory industry. The carbon emission from construction activities and logistics process are the reduction object of construction industry. There are many different advices on the research range of carbon emissions during construction stage. The focus of controversy is whether the material logistics process should be considered during construction stage (Guggemos and Horvath 2006; Guggemos 2003; Cole 1999). Some researchers think the transportation of materials is part of construction stage and the construction industry is highly dependent on imported materials, and the energy used in transportation could take up around 20% of the industry's total (Smith et al. 2003). But for the materials storage process, the researchers didn't give their attention (Guggemos 2003; Guggemos and Horvath 2006; Bribian 2009). There are also researchers think both the logistics process and the material production process are individual process and should be calculated separately (Cole 1999; Smith et al. 2003; Lin and Liu 2015).

All in all, although some researchers realized the importance of materials logistics process, they pay little attention on the materials storage and loading processes, which occur after the materials left manufacturer's warehouse and which are also accompany with carbon emissions. Furthermore, most researchers agreed that neither materials production nor the raw materials logistics process should be included in construction stage because the carbon emission during these processes are the focus of manufactory industry.

The discrepancy on the research range of carbon emission during construction stage hindered people from revealing the rules of carbon emissions in the construction industry. It becomes an obstacle on the study of this area. According to Fang and Ng (2011), logistics process during construction stage comprises planning, organization, coordination, and control of the materials flow from their leaving the manufactory warehouse to their incorporation into the finished building. Based on previous studies, the construction logistics process in this research starts

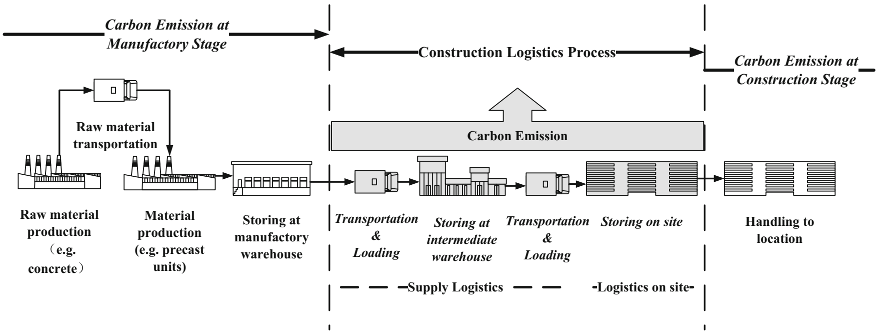


Fig. 37.1 Research range of construction logistics process

from materials leaving manufactory, through uploading, transportation, unloading and storing at construction site/intermediate warehouse, ends at the materials leaving storing area to exact location at construction site (Fig. 37.1).

37.3 Research Method

It is overwhelmingly agreed that there are basically two epistemic approaches to modelling domestic energy consumption and the resulting CO_2 emissions (Oladokun and Odesola 2015). According to the IEA (1998), these approaches are either top-down approach or bottom-up approach. There are also some researchers developed calculation paradigm based on both top-down and bottom-up approaches in order to get a more robust models (Kelly 2011; Kavgic et al. 2010)

However, researchers found that the top-down approach is lack of flexibility and accuracy when considering the current and future technology, and can only be used as a guide for the development of macro policy decision (MIT 1997). Kelly (2011) also believes that this approach does not give a reasonable consideration of the dynamic changes in the environment, social and economic direction. It is not conducive to the accuracy of energy consumption and carbon emissions estimating (Hitchcock 1993). For the bottom-up approach, the technical limitations can also be found: (1) the research method based on the operation process is still not accurate enough; (2) the bottom-up approach cannot give a dynamic simulation for the calculation problem of energy consumption and carbon emission which has the characters of complexity and multi factor dependence; and (3) The effects of human management behavior on energy consumption and carbon emissions are not considered.

Although the calculation methods for carbon emissions have a strong advantage in energy consumption analysis of buildings, except to design and materials production process, they often have no way to supervise the Contractor's environmental performance during logistics and construction process on the supply chain

(Shen et al. 2005; Veys 2008). In order to reveal the possible sources of carbon emission during construction logistics process and overcome inaccuracy problem of bottom-up approach, the calculation in this research will based on an activity based research method for detail process analysis and emission factor approach (a bottom-up approach) for activities' carbon emission calculation.

Activity based method has been employed to analyze the financial information (Damme and van der Zon 1999) or help quantify the productivity of resources (Ng et al. 2009) so as to establish the most suitable strategy for improving the logistics of materials handling in a construction project. This method is always used in logistics process analysis and can help to identify those logistics activities that could affect the outsourcing decisions (Maltz and Ellram 1997). As numerous factors can drive up logistics carbon emission substantially, which may offset the benefits of low carbon design and materials. Executing a logistics process involves a number of distinctive activities, and an activity may discharge CO_2 directly or indirectly through the consumption of fuel or electricity. Activity based method uses a single element (i.e. activity) to model a general construction process, the activities are the basic element in the model. The activity attributes are the type and consumption quantity of carbon emission source for the activity.

The emission factor approach can be used then to carbon emission calculation. It is a method to calculate the value of carbon emissions according to the amount of average gas emission for per unit of production under the normal economic and technical management conditions (Leif et al. 2010). Emission factor method has been used in some researches on carbon emissions during the construction stage (Kua and Wong 2012; Rossi 2012; Chen and Zhu 2008; Li et al. 2010). However, due to the variety of building processes, the use of emission factor method requires an accurate basis of the active data sources and reasonable emission coefficient of activities. Although generally this method is based on process, when combined with activity based method, an activity based carbon emission analysis can be developed.

37.4 Analysis of Construction Logistics Carbon Emission

37.4.1 Calculation Rule

The calculation rule of carbon emission during construction logistics process is built as Fig. 37.2. The rule includes calculation models for electricity carbon emission factor, fossil carbon emission factor, materials carbon emission factor, and total carbon consumption. As the materials carbon emission factor is always included during manufacturing process. This paper will only consider the fossil and

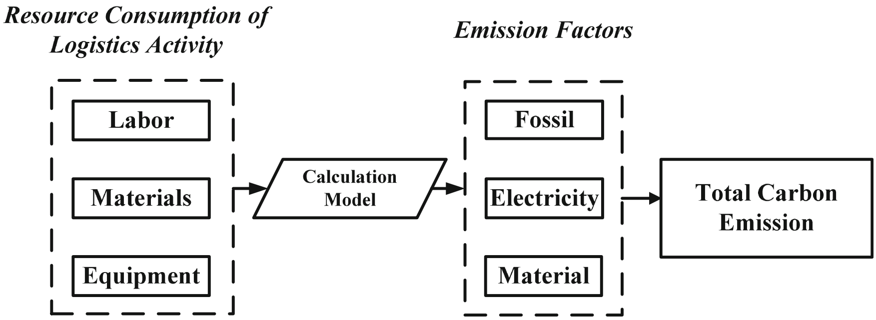


Fig. 37.2 Calculation rule for carbon emission

electricity carbon emission factors during construction logistics process. The basic calculation method is as following steps and the detail analysis process according to the rule is described then.

(1) Based on the real time observation for activity tracing, the activities and related resource consumptions (labors, materials and equipment) during logistics process are found;
(2) The electricity and fossil consumptions of resources are converted according to calculation models for electricity carbon emission factor and fossil carbon emission factor;
(3) Then total carbon emission of construction logistics process are calculated according to calculation models for total carbon consumption.

37.4.2 Activity Tracing

According to the China's quota formation theory, the construction logistics process can be separated into different procedures and the procedures can further be separated into activities. On site observation is used for activity tracing and decomposition work. Activity tracing is to determine the research boundary of carbon emissions in the construction logistics process, including time and space boundaries and boundary element. It is important for accurately defining the types of carbon source during construction logistics process. In this study the time boundary starts from materials leaving manufactory warehouse and ends at the point of their leaving on site storage area. The space boundary is from manufactory warehouse to construction storage space.

37.4.3 Identifying the Source, Type and Quantity of Carbon Emission Factor

Source identification of carbon emission is important to accurately determine the carbon emissions amount during the process under research. The work includes the analysis of carbon source, types of emission factor (*EF*) and the quantity consumed during the procedures or activities found above. In this study the main sources of carbon emission come from the consumption of fossil and electricity materials. The extra carbon emission because of labor's working compare to average standard can be neglected.

37.4.4 Calculation Model for Carbon Emission

The consumption amount of carbon emission source can be achieved by on site observation. The calculation model to achieve the exact carbon emission amount is based on the research by Wang and Ma (2016).

$$EF_{Electricity} = \frac{CE_P + CE_{PQ}}{E_P + E_{PQ}} \tag{37.1}$$

Equation 37.1 is calculation model for carbon emission factor of electricity, where $EF_{Electricity}$ represents the carbon emission amount for unit electricity consumption in city *P*, i.e. carbon emission factor of electricity. CE_P is the carbon emission amount because of power generation in city *P*. CE_{PQ} is the carbon emission amount because of electricity transportation from city *Q* to city *P*. E_P denotes the total electricity amount by power generation in city *P*. E_{PQ} is the total electricity amount transporting from city *Q* to city *P*.

$$EF_{Fossil} = CC_m \times OR_m \times MF_m \times \beta \times \frac{44}{12} \tag{37.2}$$

Equation 37.2 is calculation model for carbon emission factor of fossil, where EF_{Fossil} represents the carbon emission for per unit consumption of fuel *m*, i.e. carbon emission factor of fossil. OR_m denotes the carbon oxidation rate when burning fuel *m* (%). CC_m is the carbon amount of unit calorific value (kJ/kg). MF_m signifies the marker factor of fuel *m* which published by related energy department for reference. β is coal content for unit calorific value. When carbon is oxide into CO_2, the molecular weight will change from 12 to 44. According to "Guide for compilation of greenhouse gas bill" and "General rule for the calculation of comprehensive energy consumption" in China, the carbon emission values for different energy consumption can be calculated.

$$E_{CO_2} = \sum\nolimits_{i=1}^{n} EF_i \times q_i \tag{37.3}$$

Equation 37.3 is calculation model for total carbon emission, where E_{CO_2} is the total carbon emission during the process. EF_i represents carbon emission factor i and q_i is the consumption amount of that kind of factor during the process.

37.5 Case Study

The project chosen for this study is a residential Project in Hong Kong, which uses pre-cast reinforced concrete component extensively for all the non-structural components. 76 blocks are required for each typical floor, giving a total of about 10,400 blocks for the whole project. The façade and lost form are used most frequently, accounting for over 90% of the precast units.

To simplify to problem, it is assumed that the materials is delivered to the construction site directly, i.e. intermediate warehouse is not considered. Three procedures are included in construction logistics process. They are transportation, loading and storing on site. The transportation procedure and loading procedure are further separated into activities (Fig. 37.3).

The common sources and types of carbon emission for every logistics activity are shown as Table 37.1. The fossil materials consumed during logistics process are mainly liquid fuel (e.g. gasoline) when truck uploading, unloading and delivering materials. The electricity consumption occurs during storing procedure. The total electricity needed during storing can be achieved by storing duration of materials and electricity consumed per day. If the storing space is outdoor, the electricity consumption approximates to zero.

According to the site visit, the resources and duration for logistics activity are collected. The consumption quantity of carbon emission sources can be found based on the collected data. According to Eq. 37.2, the carbon emission factor of gasoline is 2.925 kgCO_2/kg (i.e. $EF_{gasoline}$ = 2.925 kgCO_2/kg). The total carbon emission during construction logistics process is **400.64 kg** for 10 facade to be loading and delivery to construction site (Table 37.2). As 70 blocks are required for each typical floor, giving a total of about 10,400 blocks needed to be transported to the construction site, the carbon emission during logistics process for the whole project will be about **416,662.74 kg**. This result can be compared with the total carbon emission quantity during construction stage and help to find the exact percentage of carbon emission during construction logistics process for future research.

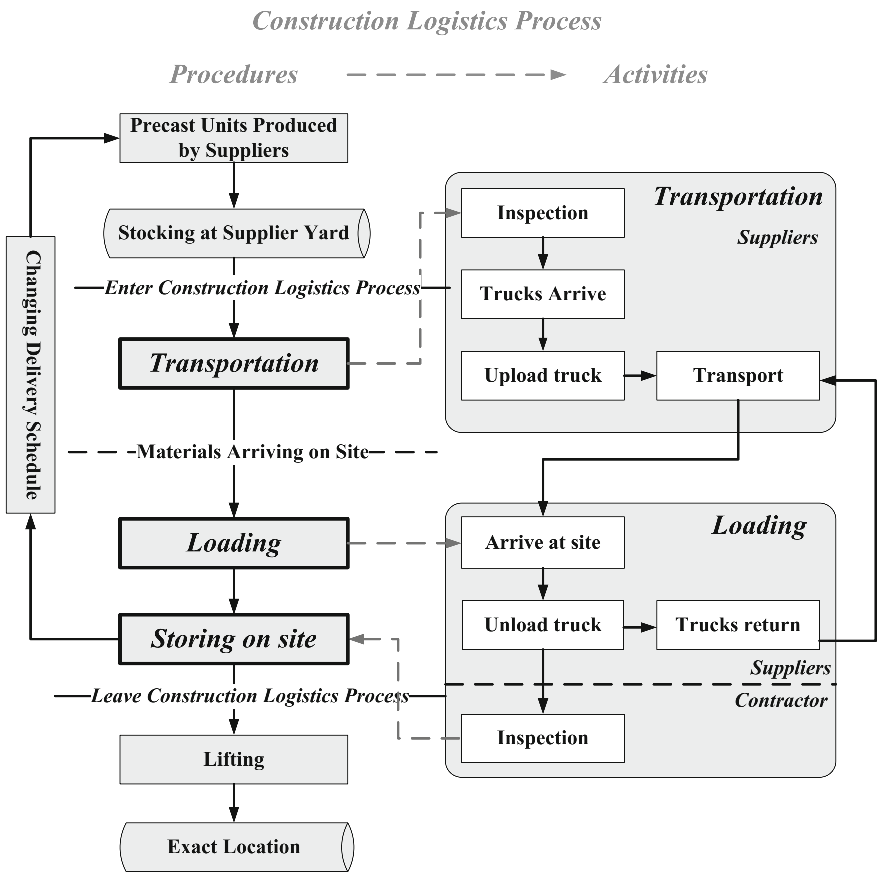


Fig. 37.3 Procedures and activities during construction logistics process

Table 37.1 Carbon emission attribute of logistics activity

Procedure	Activity	Source of *CE*	Type of *EF*	Consumption
Transportation	Inspection	Human activity	*None*	*None*
	Truck Arriving	*None*	*None*	*None*
	Uploading	Crane	Fossil (liquid fuel)	Oil consumption per hour × Working Time (h)
	Transportation	Trucks	Fossil (liquid fuel)	Fuel consumption per hundred kilometers × Distance

(continued)

Table 37.1 (continued)

Procedure	Activity	Source of *CE*	Type of *EF*	Consumption
Loading	Arriving at site	*None*	*None*	*None*
	Unloading	Crane	Fossil (liquid fuel)	Oil consumption per hour × Working Time (h)
	Inspection	Human activity	*None*	*None*
	Truck return	Trucks	Fossil (liquid fuel)	Fuel consumption per hundred kilometers × Distance
Storing	Inventory	Human activity	*None*	*None*
		Inventory facilities	Electricity	Storing duration × Electricity consumed per day

Table 37.2 Carbon emission for construction logistics process

Activity Name	Source of *CE*	Type of *EF*	Consumption
Uploading procedure			
Upload crane truck	Crane Truck, Labour (1)	Oil	2.91 kg/h × 8.5 min/60 min = 0.31 kg
Upload truck	Crane Truck, Truck (4), Labour (5)	Oil	2.91 kg/h × 8 min/60 min × 4 = 1.55 kg
Transportation procedure			
Transport	Crane Truck, Truck (4), Labour (5)	Oil	23.9 L/100 km × 75 km × 0.84 kg/L × 5 = 75.29 kg
Unloading procedure			
Unload crane truck	Crane Truck, Labour (1)	Oil	2.91 kg/h × 6.5 min/60 min = 0.32 kg
Unload truck	Crane Truck, Truck (4), Labour (5)	Oil	2.91 kg/h × 6.3 min/60 min × 4 = 1.22 kg
Truck return	Crane Truck, Truck (4), Labour (5)	Oil	18.5 L/100 km × 75 km × 0.84 kg/L × 5=58.28 kg

(continued)

Table 37.2 (continued)

Activity Name	Source of *CE*	Type of *EF*	Consumption
Storing procedure			
Storing	Labour (2)	–	–
Total consumption		Oil	136.97 kg
		$EF_{gasoline}$	2.925 $kgCO_2/kg$
Total carbon emission			2.925 $kgCO_2/kg \times$ 136.97 kg = **400.64 kg**

37.6 Conclusion

There are two most important problems during the study of carbon emission at the construction logistics process. One is defining the exact activities which should be included in the logistics process. The second is finding the method to calculate the carbon emission of those activities. Although a large amount of literature exists discussing the carbon emission method during the building operation stage. Limitations made this method cannot been used to construction stage or logistics process directly. This research is an initial step towards an integrated construction logistics modeling and carbon emission measurement. Based on the activity based method and emission factor approach, the carbon emission of each construction logistics activity can be analyzed in detail and the relationship between the sources consumption and its carbon emission quantity can also be established. The carbon emission model for construction logistics process in the paper is based on the just-in-time concept where no off-site warehouse exists. The outcomes of this initial study lay an important foundation for further research. As the contractor plays a key role in balancing the construction schedule, transportation mode, and inventory strategy (IBM 2008). The management behaviour of the contractor will have a lot of influence on the carbon emission in the construction process. Further research will focus on developing a more robust dynamic model to meet the requirements of considering the human behaviour effect on the carbon emission during logistics process.

Acknowledgements The authors would like to acknowledge The National Natural Science Foundation of China for supporting this study (Grant No.: 51608132).

References

Bribian US (2009) Life cycle assessment in buildings: state of the art and simplified LCA methodology as a complement for building certification. Build Environ 44(12):2510–2520

Chen Y, Zhu Y (2008) Analysis of environmental impacts in the construction stage of concrete frame buildings. Department of Construction Management, Tsinghua University, China

Cole RJ (1999) Energy and greenhouse gas emissions associated with the construction of alternative structural systems. Build Environ 34(3):335–348
Damme D, van der Zon FLA (1999), Activity based costing and decision support. Int J Logist Manag 10(1):71–82
Fang Y, Ng ST (2011) Applying activity-based costing approach for construction logistics cost analysis. Constr Innovat Inf Process Manag 3:259–281
Gaussin M, Hu G, Abolghasem S, Basu S, Shankar MR, Bidanda B (2013) Assessing the environmental footprint of manufactured products: a survey of current literature. Int J Prod Econ 146:515–523
Guggemos AA (2003) Environmental impacts of on-site construction processes: focus on structural frames. University of California, Berkeley
Guggemos AA, Horvath A (2005) Comparison of environmental effects of steel-and concrete-framed buildings. J Inf Syst 11(2):93–101
Guggemos AA, Horvath A (2006) Decision-support tool for assessing the environmental effects of constructing commercial buildings. J Archit Eng 12(4):187–195
Hendrickson C, Horvath A, Joshi S, Lave L (1998) Economic input-output models for environmental life-cycle assessment. Environ Sci Technol 32(7):184A–191A
Hitchcock G (1993) An integrated framework for energy use and behaviour in the domestic sector. Energy Build 20:151–157
IBM (2008) Mastering carbon management—balancing trade-offs to optimize supply chain efficiency. IBM Corporation, New York
International Energy Agency (1998) Mapping the energy future: energy modelling and climate change policy. Paris
Jing R, Cheng JCP, Gan VJL, Woon KS, Lo IMC (2014) Comparison of greenhouse gas emission accounting methods for steel production in China. J Clean Product 83:165–172
Junnila S, Horvath A (2003) Life-cycle environmental effects of an office building. J Infrastruct Syst 9(4):157–166
Kavgic M, Mavrogianni A, Mumovic D, Summerfield A, Stevanovic Z, Djurovic-Petrovic M (2010) A review of bottom-up building stock models for energy consumption in the residential sector. Build Environ 45:1683–1697
Kelly S (2011) Do homes that are more energy efficient consume less energy? A structural equation model for England's residential sector, EPRG Working Paper, Electricity Policy Research Group, University of Cambridge
Kua HW, Wong CL (2012) Analysing the life cycle greenhouse gas emission and energy consumption of a multi-storied commercial building in Singapore from an extended system boundary perspective. Energy Build 51:6–14
Leif G, Anna J, Roger S (2010) Life cycle primary energy use and carbon emission of an eight-storey wood-framed apartment building. Energy Build 42(2):230–242
Li X, Zhu Y, Zhang Z (2010) An LCA-based environmental impact assessment model for construction processes. Build Environ 45(3):766–775
Lin BQ, Liu HX (2015) CO_2 mitigation potential in China's building construction industry: a comparison of energy performance. Build Environ 94(1):239–251. ISSN 0360-1323
Maltz A, Ellram L (1997) Total cost of relationship: An analytical framework for the logistics outsourcing decision. J Bus Logist 18(1):45–66
MIT (1997) Energy technology availability: review of longer term scenarios for development and deployment of climate-friendly technologies. Massachusetts Institute of Technology Energy Laboratory, Cambridge, Massachusetts, USA
Ng ST, Shi J, Fang Y (2009) Enhancing the logistics of construction materials through activity-based simulation approach. Eng J Constr Archit Manag 16(3):224–237
Oladokun MG, Odesola IA (2015) Household energy consumption and carbon emissions for sustainable cities—a critical review of modelling approaches. Int J Sustain Built Environ 4:231–247
Rossi B (2012) Life-cycle assessment of residential buildings in three different European locations. Build Environ 51:395–401

Sharrard AL, Matthews HS, Ries RJ (2008) Estimating construction project environmental effects using an input-output based hybrid life-cycle assessment model. J Infrastruct Syst 14(4)

Shen L, Lu W, Yao H, Wu D (2005) A computer-based scoring method for measuring the environmental performance of construction activities. Autom Constr 14(3):297–309

Smith RA, Kersey JR, Griffiths PJ (2003) The construction industry mass balance: resource use, wasters and emissions. Viridis and CIRIA, UK

Todd JA, Crawley D, Geissler S, Lindsey G (2001) Comparative assessment of environmental performance tools and the role of the green building challenge. Build Res Inf 29:324–335

Wang CW, Ma ZD (2016) Quota estimation method and application prospect of carbon emission in construction project. Constr Econ 37(4):59–61

Veys A (2008) A Financial accounting based model of carbon foot printing using an example in the built environment, Master Thesis, Imperial College, London, UK

Chapter 38
Causal Loop Analysis on the Impact of Schedule Risks in Prefabrication Housing Production in Hong Kong

W.K. Huang, X.X. Xu, K. Chen, H.Y. Wu and Z.D. Li

38.1 Introduction

Every country is dealing with its own housing problems, but none compares with Hong Kong where housing has always been a major concern to most over the past decades. A total of 2,671,900 permanent residential flats were in stock by end of 2014, of which 1,496,500 (56%) were private flats, 781,500 (29%) were public rental housing and 393,900 (15%) were subsidized housing (HKCSD 2015). On the demand side, there was about 147,000 general applications of public rental housing at the end of December 2015, the average waiting time for which was 3.7 years (HKHA 2016). Hong Kong Housing Authority reiterated an ambitious housing plan to supply 93,400 public housing rental units until 2020 (HKHA 2016). However, Hong Kong is suffering from a series of constraints such as labor shortages, time,

W.K. Huang (✉) · X.X. Xu · H.Y. Wu
College of Civil Engineering, Shenzhen University,
Shenzhen, Guangdong Province 518060, China
e-mail: hwk727@163.com

X.X. Xu
e-mail: 702096844@qq.com

H.Y. Wu
e-mail: szwhyme@163.com

K. Chen
Department of Real Estate and Construction, The University of Hong Kong, Pok Fu Lam, Hong Kong
e-mail: leochen@connect.hku.hk

Z.D. Li
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
e-mail: zhengdao.clyde@connect.polyu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_38

and environmental issues to deliver its housing plans. Against this background, prefabricated construction is envisioned as a solution.

Given the constraints in delivering housing plans, prefabrication has been increasingly advocated owing to its potential benefits such as rapid process, cleaner and safer working environment, and better quality. However, potential benefits cannot be supported without overcoming its inherent drawbacks of fragmentation, discontinuity, and poor interoperability, which raise a variety of risks that impose pressure on the time management of prefabrication housing production (PHP). To help address schedule delay problem encountered in the construction of prefabrication housing, many studies have investigated risk-related issues in the management of PHP. However, these studies only consider risks from static and isolated perspectives, despite that these risks are coherently interrelated with each other and might vary along with time. Previous studies also do not sufficiently consider their quantified influence on the schedule of PHP and fail to predict potential delays through simulations. Thus, this research proposes a dynamic model to evaluate and simulate potential risks found in four major prefabrication construction processes, employing the system dynamics (SD) method. The objectives of establishing this evaluation model include (1) exploring interactional, interdependent, and complicated relationships underlying the risk factors that significantly influence time management of PHP; (2) evaluating and simulating the effect of identified risks on the schedule of PHP; (3) comparing and analyzing the potential effect on the schedule of PHP under different risk scenarios.

38.2 Research Background

38.2.1 Prefabrication Housing Production (PHP) in Hong Kong

Housing production in Hong Kong mainly adopts conventional construction technologies characterized by fixed jobsites, labor intensive, formwork and falsework, cast-in situ, wet trades, and bamboo scaffolding. While cast-in situ construction technology has its own strengths (e.g., flexible to design changes), it has received widespread criticisms. In the report “Construct for Excellence”, several problems surrounding the industry has been critically pointed out, which include poor site safety record; inadequately trained workforce; and unsatisfactory environmental performance. Besides, the quality of the in situ construction hinges on the workmanship of construction workers. Given that site environment is less conducive to the possibility of consistent good outputs in an established indoor production facility, close supervision is required. The prevalence of labor-intensive in situ construction methods and relatively low investment in the use of new technologies, inter alia, is obviously the perceived culprits. The wider use of prefabrication, coupled with the use of standardized and modular components, was proposed as a primary strategy to enhance the Hong Kong construction industry.

In comparison with traditional housing production technologies, prefabrication construction allows: (1) More controlled conditions for weather, quality control, improved supervision of labor, easier access to tools, and fewer material deliveries (Tam et al. 2015); (2) Fewer jobsite environmental effects because of reductions in material waste, air and water pollution, dust and noise, and overall energy costs (Hong et al. 2016); (3) Compressed project schedules that result from changing the sequencing of work flow (Tam and Hao 2014); (4) Fewer conflicts in work crew scheduling and better sequencing of craft people (Li et al. 2016); (5) Reduced requirements for on-site material storage, and fewer losses or misplacement of materials (Lu et al. 2011); and (6) Increased worker safety through reduced exposures to inclement weather, temperature extremes, and on-going or hazardous operations (Ingrao et al. 2014). To sum up, using prefabrication can reduce cost, time, defects, and environmental impacts, as well as improve safety, predictability, whole-life performance, and profitability.

38.2.2 Literature Review on Prefabrication

Previous research on the management of prefabricated construction can be mainly divided into five groups: (i) Prospect analysis, including benefits and incentives (Tam et al. 2007), defects and barriers (Polat 2008), and future opportunities (Nadim and Goulding 2010) of the adoption of prefabrication technologies; (ii) Development and practical application that includes a series of analyses of case experiences of the management of prefabricated construction (Meiling et al. 2013) and the evolution of prefabricated building systems (Jaillon and Poon 2009); (iii) Performance evaluation, in which recent studies have moved from “a conventional focus on benefit–cost analysis” to “a more extensive perspective of sustainability”, covering not only economic benefits (Pan et al. 2012) but also environmental (Aye et al. 2012) and social effectiveness (Eastman and Sacks 2008); (iv) Policy environment for technology application, including guidelines and policies (Kale and Arditi 2006), attitude of various stakeholders (Pan et al. 2007), public perspectives, and stakeholder relationships (Jeong et al. 2009); (v) Design, production, transport, and assembly strategies for producing prefabricated construction, which include several sub-topics, namely, production control (Yin et al. 2009), transportation and stockyard layout planning (Marasini et al. 2001), architectural design measures (Leskovar and Premrov 2011), and construction information flow processing (Ergen and Akinci 2008). Although previous studies have contributed to the body of knowledge on the management of prefabricated construction, studies on schedule risk-related issues in the implementation of prefabrication are limited. Moreover, a consensus on the complexity of risks in prefabrication construction exists because of its characteristics including dynamics, uncertainty, and mutual interaction. However, previous research considers risks from a static and isolated perspective, neglecting the fact that interactions between risks are increasing and strengthening along with the prefabrication construction, which increases the difficulty of risk management. From this aspect, systematic analysis can help managers gain a better understanding of system essence, function, and behavior, as well as interaction with the environment. Therefore, this research adopts the system dynamics (SD) method for analysing and evaluating the potential effect of various risks on the schedule of PHP from the dynamic and mutual interaction perspective, which will provide a practical tool for depicting various schedule risk in PHP.

38.3 Methodology

System dynamics (SD), originated by Forrester in the 1960s, is a science that focuses on the structure of complex systems and the relationship between function and dynamic behaviors based on feedback control theory and computer simulation technology. It has been used in a wide variety of applications for macro analysis and management, such as economic development (Meadows et al. 1972), military system management (Fan et al. 2010), energy and resources management (Ansari and Seifi 2013; Ford 1996), and urban planning (Shen et al. 2009). Construction project management generally includes two levels: strategic project management from macro level and operational project management from micro level (Peña-Mora et al. 2008). Strategic project management focuses on scheduling, budgeting, and resource allocation, and contains a significant number of feedbacks. Taking schedule delay as an example, schedule delay tends to increase pressure to workers; pressure exceeding a certain level could reduce work efficiency; with continuous decrease in work efficiency, the construction rate would decline, and finally increase schedule delays. The conventional methodology tends to depict the underlying system variables and comprehend subsequent system behaviors from a separate perspective. Nevertheless, a large-scale complex system normally comprises numerous sub-systems, among which causal relationships are interactive and interactional; that is, one value-changed variable would have an effect on another, in a feedback method, and eventually influence the behavior of the whole system. SD specializes in dealing with the defined characteristics as it could simplify a complex system into operable units through its analysis tools like causal loop diagrams and stock flow diagrams, which contributes to analyzing feedback relationships from a multi-dimensional and dynamic perspective. Therefore, this study uses SD as the main method to investigate the influence of risk on the schedule of prefabrication construction from a strategic perspective.

Normally, a two-step procedure (Fig. 38.1) could be adopted to develop a causal loop SD model, which includes: (1) system description, in which step researchers are required to determine the scope of the proposed system; (2) causal loop diagram, in which, qualitative analysis would be conducted for depicting

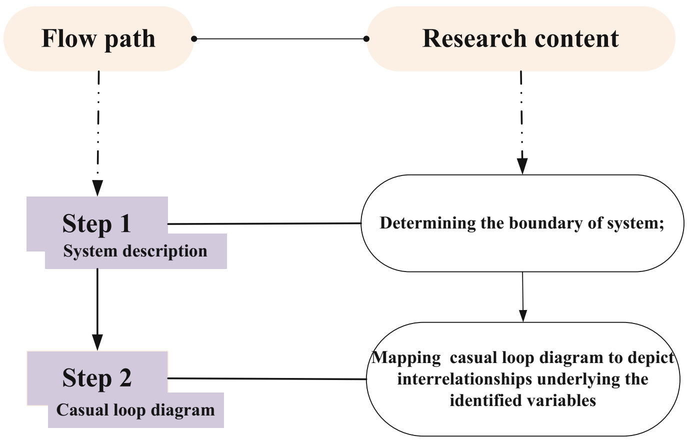


Fig. 38.1 Research flow

interrelationships underlying the identified variables before mapping them into causal loop diagrams.

38.4 Model Development

38.4.1 System Boundary

Different system boundaries will generate different system structures and behaviors. System boundaries should be defined clearly to facilitate the system modeling process as well as meet research objectives. This research divides the SD model into three subsystems: prefabrication supply chain subsystem, schedule risks subsystem, and schedule performance subsystem. The relationship between the three subsystems is illustrated in Fig. 38.2.

(1) **Prefabrication housing production subsystem**

Prefabrication housing construction is known as off-site construction, which refers to structures built at a different location than the construction site (Gibb 1999). Therefore, prefabrication housing construction has a unique supply chain, which includes design, manufacture, storage, transportation, buffer, and assembly on site. Specifically, in the design process, the client will hire an architect, a structure engineer, and a services engineer to design with special considerations to structure safety, buildability, and even transportation convenience. Then, the design information will be transmitted to the manufacturer to produce precast components before storage. Once the transportation order is received, the logistics company would transport the components from storage to the buffer of the construction site. In the end, these components will be installed by an assembly company.

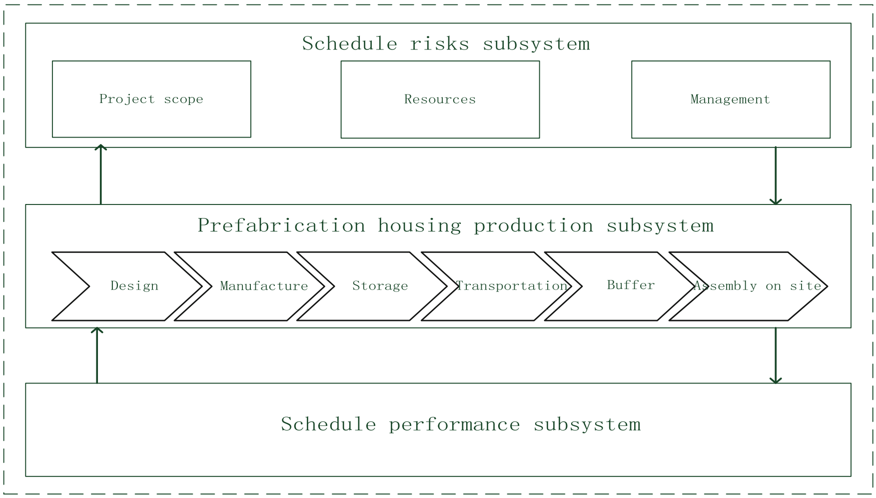


Fig. 38.2 The relationship between the three subsystems

This illustrates the importance of prefabrication supply chain in the prefabrication housing construction.

(2) **Schedule performance subsystem**

Schedule performance subsystem mainly includes two parts, namely, planned schedule and actual schedule. A comparison between them would make it easy to determine whether schedule delay occurred or not. If the actual schedule is consistent with the planned schedule, the project will have good schedule performance; otherwise, the schedule performance will be poor.

(3) **Schedule risks subsystem**

Based on literature review and expert interviews, schedule risks are mainly from three aspects, namely, project scale, resources, and management. Project scale indicates special quantities of housing construction. Owner's demand changes, design drawing changes, and changes in specific construction conditions would lead to project scale changes, which would cause the change in resource demand, and may lead to schedule delay. Resources involve all labor, materials, and machinery, which are needed in the whole supply chain, and can be directly affected by schedule performance subsystem and influence prefabrication supply chain subsystem. For example, the schedule performance subsystem encounters a schedule delay; it needs to increase the amount of resources to finish the job faster. In return, increase in resources will accelerate construction rate and reduce schedule delay. Management is mainly associated with quality problems. Quality problems would entail rework, which could lead to schedule delays. Therefore, management is interrelated with schedule performance subsystem. In addition, completing the job faster may increase the occurrence of project quality problems and installation error rate; hence, management can also be interrelated with prefabrication supply chain subsystem.

38.4.2 Causal Loop Diagram

Based on the analyses above, the causal-loop diagram, which depicts the interrelations underlying various variables, can be drawn, as shown in Fig. 38.3. Four positive feedbacks and three negative feedbacks are defined within the diagram.

Feedback 1: An increase in the number of precast elements to be installed will raise the number of installed precast elements; and subsequently, the number of inspected precast elements increases, which leads to increase in the number of defective precast elements to be reinstalled. The more work completed, the more mistakes will be found. Finally, more defective precast elements to be reinstalled will lead to an increased number of precast elements to be installed. Feedback 1 has four positive correlations, and is considered positive feedback. If feedback 1 is not controlled, its variables will continuously increase, which will cause serious schedule delay.

Feedback 2: Feedback 1 and Feedback 2 have almost the same framework apart from one variable, quality problem. The more precast elements inspected, the more quality problems are found, which will raise the number of precast elements to be installed. Feedback 2 also has also four positive correlations, and is considered positive feedback.

Feedback 3: The increase in the number of inspected precast elements increases will contribute to the installation percentage. If the installation percentage is in line

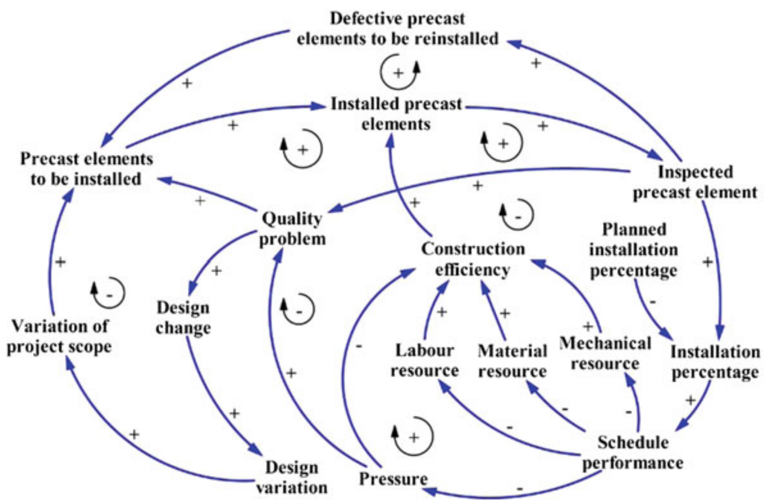


Fig. 38.3 The causal-loop diagram of system dynamics

with the planned installation percentage, a good schedule performance is expected. Otherwise, it will lead to schedule delay, which results in more pressure. The relationship between pressure and efficiency is usually in an inverted U-shaped curve, which shows that proper pressure will increase work efficiency, but excessive pressure will decrease the efficiency, which will finally reduce the number of inspected precast elements. Feedback 1 has four positive correlations and two negative correlations, which are considered positive feedback.

Feedback 4: Apart from resulting in more pressure, bad schedule performance can also change the management strategies of project managers. As the schedule delay increases, the project manager will input more resources (e.g. labor and material), which can rapidly improve construction efficiency. The rest of feedback 4 (from construction efficiency to schedule performance) is the same as that in feedback 3 so that feedback 4 has five positive correlations and one negative correlation, and is considered negative feedback.

Feedback 5: Supposing an increase in the amount of pressure, then the possibility of quality problem in construction will increase, which would also increase the number of precast elements to be installed and installed precast elements accordingly. The correlations from installed precast elements to pressure in feedback 5 are the same as that in feedback 3. Therefore, feedback 4 has six positive correlations and one negative correlation, and is considered negative feedback.

Feedback 6: The increase in the number of quality problems will cause design variations; and subsequently project scope variation will expand, which leads to increase in the number of precast elements to be installed. The rest of feedback 6 (from precast elements to be installed to quality problems) is the same as that in feedback 2. Feedback 6 has six positive correlations; thus, feedback 6 is a positive feedback.

Feedback 7: The correlations from installed precast elements to quality problems in feedback 7 are the same as feedback 5 and the correlations from quality problem to installed precast elements are the same as feedback 6. In general, feedback 6 has eight positive correlations and one negative correlation so that feedback 6 is a negative feedback.

38.5 Conclusion

Schedule delay caused by various risks affects the PHP in Hong Kong. To deal with this problem, a concept model is developed to propose a causal-loop model for qualitatively depicting the effect of various risks on the schedule of PHP by employing an SD model Major schedule risk variables within the three sub-systems are first identified; then a causal loop diagram is formulated to depict the potential interrelationship underlying the schedule risk variables prior to the establishment of quantitative model. This paper is of value in serving as a utility tool for exploring interactional and interdependent relationships underlying the identified risk variables within the three sub-system including schedule risk sub-system, prefabrication housing production sub-system and schedule performance sub-system. Further research can be conducted by building up model for modeling and simulating the effect of various risks on the schedule of PHP by employing an SD model and Monte Carlo simulation method, in which the feedbacks, uncertainty, and dynamics nature of schedule can be well examined.

References

Ansari N, Seifi A (2013) A system dynamics model for analyzing energy consumption and CO_2 emission in Iranian cement industry under various production and export scenarios. Energy Policy 58:75–89

Aye L, Ngo T, Crawford R, Gammampila R, Mendis P (2012) Life cycle greenhouse gas emissions and energy analysis of prefabricated reusable building modules. Energy Build 47:159–168

Eastman CM, Sacks R (2008) Relative productivity in the AEC industries in the United States for on-site and off-site activities. J Constr Eng Manage 134:517–526

Ergen E, Akinci B (2008) Formalization of the flow of component-related information in precast concrete supply chains. J Constr Eng Manage 134:112–121

Fan CY, Fan PS, Chang PC (2010) A system dynamics modeling approach for a military weapon maintenance supply system. Int J Prod Econ 128:457–469

Ford A (1996) Testing the snake river explorer. Syst Dyn Rev 12:305–329

Gibb AG (1999) Off-site fabrication: prefabrication, pre-assembly and modularisation. Wiley, New York

Hong J, Shen GQ, Mao C, Li Z, Li K (2016) Life-cycle energy analysis of prefabricated building components: an input–output-based hybrid model. J Clean Prod 112:2198–2207

Hong Kong Census and Statistics Department (HKCSD) (2015) The Hong Kong annual digest of statistics 2015, http://www.censtatd.gov.hk/hkstat/sub/sp140.jsp

Hong Kong Housing Authority (HKHA) (2016) Number of applications and average waiting time for public rental housing

Ingrao C, Lo Giudice A, Mbohwa C, Clasadonte MT (2014) Life cycle inventory analysis of a precast reinforced concrete shed for goods storage. J Clean Prod 79:152–167

Jaillon L, Poon CS (2009) The evolution of prefabricated residential building systems in Hong Kong: a review of the public and the private sector. Autom Constr 18:239–248

Jeong JG, Hastak M, Syal M (2009) Framework of manufacturer-retailer relationship in the manufactured housing construction. Constr Innov 9:22–41

Kale S, Arditi D (2006) Diffusion of ISO 9000 certification in the precast concrete industry. Constr Manage Econ 24:485–495

Leskovar VŽ, Premrov M (2011) An approach in architectural design of energy-efficient timber buildings with a focus on the optimal glazing size in the south-oriented façade. Energy Build 43:3410–3418

Li CZ, Hong J, Xue F, Shen GQ, Xu X, Mok MK (2016) Schedule risks in prefabrication housing production in Hong Kong: a social network analysis. J Cleaner Prod 134:482–494

Lu W, Huang GQ, Li H (2011) Scenarios for applying RFID technology in construction project management. Autom Constr 20:101–106

Marasini R, Dawood NN, Hobbs B (2001) Stockyard layout planning in precast concrete products industry: a case study and proposed framework. Constr Manage Econ 19:365–377

Meadows DH, Goldsmith EI, Meadow P (1972) The limits to growth. Earth Island Limited London

Meiling JH, Sandberg M, Johnsson H (2013) A study of a plan-do-check-act method used in less industrialized activities: two cases from industrialized housebuilding. Constr Manage Econ 1–17

Nadim W, Goulding JS (2010) Offsite production in the UK: the way forward? A UK construction industry perspective. Constr Innov 10:181–202

Pan W, Dainty AR, Gibb AG (2012) Establishing and weighting decision criteria for building system selection in housing construction. J Constr Eng Manage 138:1239–1250

Pan W, Gibb AG, Dainty AR (2007) Perspectives of UK housebuilders on the use of offsite modern methods of construction. Constr Manage Econ 25:183–194

Peña-Mora F, Han S, Lee S, Park M (2008) Strategic-operational construction management: hybrid system dynamics and discrete event approach. J Constr Eng Manage 134:701–710

Polat G (2008) Factors affecting the use of precast concrete systems in the United States. J Constr Eng Manage 134:169–178

Shen Q, Chen Q, Tang B-S, Yeung S, Hu Y, Cheung G (2009) A system dynamics model for the sustainable land use planning and development. Habitat Int 33:15–25

Tam VW, Hao JJ (2014) Prefabrication as a mean of minimizing construction waste on site. Int J Constr Manage 14:113–121

Tam VW, Tam C, Zeng S, Ng WC (2007) Towards adoption of prefabrication in construction. Build Environ 42:3642–3654

Tam VWY, Fung IWH, Sing MCP, Ogunlana SO (2015) Best practice of prefabrication implementation in the Hong Kong public and private sectors. J Clean Prod 109:216–231

Yin SY, Tserng HP, Wang J, Tsai S (2009) Developing a precast production management system using RFID technology. Autom Constr 18:677–691

Chapter 39
Causes of Delays in Mega Projects—Case of the Zambian Transmission Power Projects

Chaali Kalebuka, Erastus Mwanaumo and Wellington Didibhuku Thwala

39.1 Introduction

Zambia is currently experiencing unprecedentedly high levels of construction projects across the various sectors such as road development, Water and sanitation projects and Telecommunications. The Electrical Power sector is not exempt. The public and the private sector in the electrical power business in Zambia have in the recent years invested heavily in the generation, transmission and distribution infrastructure. USD 420 Million was spent in developing the new 360 MW Kariba north bank extension power station and a further USD 250 Million and USD 2 Billion are being pumped into the construction of the Itezhi-tezhi and Kafue gorge lower hydro power projects respectively (Zesco 2013). A lot more other such investments are being put aside for the implementation of other generation projects as well as transmission and distribution projects. The focus of this study, however, narrows down to only transmission power projects.

One major and most recurring problem with executing such projects, particularly Mega Transmission power projects, has been delays. Project delays are a common phenomenon in the construction business all over the world (Le-Hoai et al. 2008; Aziz 2013; Haseeb et al. 2011). A host of transmission power projects are underway in Zambia and many of them are running behind schedule resulting in negative effects such as cost overruns, schedule overruns and persistent load shedding. To be able to minimize or eliminate the delays in transmission power projects, it is imperative that the factors responsible for these delays and their extents be investigated. This study is aimed at identifying the major causes of delays and their

C. Kalebuka · E. Mwanaumo
School of Engineering, University of Zambia, P.O Box 32379, 10101 Lusaka, Zambia

W.D. Thwala (✉)
Department of Construction Management and Quantity Surveying, Faculty of Engineering and the Built Enviornment, University of Johannesburg, Johannesburg, South Africa
e-mail: didibhukut@uj.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_39

ranking in mega transmission power projects in Zambia through a survey from the perspective of the client and contractor. This study was limited to mega transmission power projects in Zambia only.

39.1.1 Megaprojects

In literature, a variety of terms are used to describe large projects such as complex projects, major projects, giant projects, new animals and megaprojects (Ruuska et al. 2009; Flyvbjerg et al. 2003). Mega construction projects (MCPs) are complex, risky and time-consuming undertakings. Mega construction projects are usually commissioned by governments and delivered by national and international participants with a variety of cultural differences, backgrounds, political systems, and languages (Shore and Cross 2005; Othman 2013a, b). They captivate high public attention and political interest owing to their substantial cost, direct and indirect impact on the community, environment, and budgets (van Marrewijk et al. 2008).

"Mega" comes from the Greek word "megas" and means great, large, vast, big, high, tall, mighty, and important. As a scientific and technical unit of measurement, "mega" specifically means one million. If we were to use this unit of measurement in economic terms, then strictly speaking, megaprojects would be million-dollar (or euro, pound, etc.) projects; indeed, for more than one hundred years, the largest projects in the world were measured mostly in the millions (Flyvbjerg 2014a, b). Project costs have however been escalating since World War II to such extents that they no longer qualify to be called "Megaprojects" but instead "Giga-projects"—Giga being a unit measurement meaning 1 Billion". One such example is the Gautrain, a state-of-the-art rapid rail network in Gauteng, South Africa whose costs were nearly $4 Billion. For the largest of this type of project, a price tag of US$50–US $100 Billion is now common (e.g. The California and UK high-speed rail projects), and a price above US$100 Billion is not uncommon (e.g., the International Space Station and the Joint Strike Fighter) (Flyvbjerg 2014a, b).

Megaprojects, therefore, should not be seen as magnified versions of smaller projects. Megaprojects are a completely different breed of projects in terms of their level of aspiration, lead times, complexity, and stakeholder involvement. Consequently, they are also a very different type of project to manage (Flyvbjerg 2014a, b).

There exist different definitions for Megaprojects and their characteristics. Table 39.1 gives a summary of some of the researcher's definitions of the same.

Zidane in the paper titled 'Megaprojects—Challenges and Lessons Learned' noted the description of megaprojects was wide and varied from author to author. The authors further argued that the mega project definitions could apply to any project that may lack megaproject's characteristics. It was further argued in the paper that the definitions do not clearly define megaprojects and differentiate them from other projects. This exact viewpoint was echoed by Haidar and Ellis (2010), Gellert and Lynch also had a similar viewpoint in report titled mega projects as

Table 39.1 Characteristics of megaprojects (adapted from Othman 2013a, b)

No.	Characteristics of mega construction projects	Authors
Characteristics related to project nature, objective, location, time, cost, and risk		
1	Colossal in size and scope physical infrastructure/ capital asset with a life span measured in decades in order to plan, design, finance and build	Sanderson (2012), Sturup (2009), Bruzelius et al. (2002)
2	Costly and often under estimated projects that require high investment expenditures of: US $1 Billion or more	Bruzelius et al. (2002), Sturup (2009), Flyvbjerg et al. (2003)
3	Risky undertakings, especially when: project priorities and objectives changed	Ruuska et al. (2009)
	Lack of planning and cost estimate	Bruzelius et al. (2002)
Characteristics related to client(s) and performing organization structure		
4	The client is often a government or public sector organization	Sanderson (2012)
5	The main contractor or consortium of contractors are usually privately owned, financed and often from various countries with variety of cultural differences, backgrounds, political systems, and languages, seeking success with different objectives	Ruuska et al. (2009)
6	The performing company often retains an ownership stake in the project after completing the construction phase in a special purpose vehicle and is paid by the client for the service that flows from the asset's operation or use over a number of years	Sanderson (2012)
Characteristics related to engineering design and technical requirements		
7	Complex projects that demand high design knowledge, professional technological skills and logistical support	Sturup (2009)
8	Necessitates multidisciplinary contributions from various organizations	Flyvbjerg et al. (2003)
9	Long termed projects that require program planning, control and highly trained employees especially in the field of project management	Sturup (2009)
10	Requires clearly defines rules and procedures as well as effective communication at all levels	
11	Requires quality front-planning	
12	Projects' captivation due to their size, engineering achievements and aesthetic design call for virtual enterprise for the implementation of the project through exploiting fast-changing opportunities and confronting problems as early as possible	Sturup (2009), Flyvbjerg et al. (2003)
Characteristics related to environment, society, economy and policy		
13	Public acceptance/opposition due to the social, economic, political and environmental impacts	Ruuska et al. (2009)

displacements, with the following view ‘Definitions of mega-projects differ. Most are inexact and tied to specific project types’.

In this study, we will use the cost component as our basis for classifying mega-projects. From existing literature, mega-projects are defined as projects of the cost of at least USD 1 Billion (Bruzelius et al. 2002; Sturup 2009; Flyvbjerg et al. 2003). It is worth to note, however, that USD 1 Billion when viewed with respect to a nation’s economy can range from being a relatively small figure to a relatively huge figure. Let us for example consider two extreme economies of the USA and that of a third world country, Gambia, with respect to the 2013 GDP values as compiled by the World Bank. It will be seen that USD 1 Billion only amounts to 0.00596% of the United States of America’s GDP of USD 16.768 Trillion, while on the other hand the same amount of USD 1 Billion accounts for up to 110.74% of Gambia’s GDP. The argument is that what may be viewed as a mega project in developed economies such as those of USA, China, German, France etc. may be unattainable in relatively smaller economies such as Gambia, Malawi, Senegal, Swaziland, Zambia etc., and similarly what would be considered a mega project in a relatively smaller economy cannot be viewed as such in a developed economy. For the purpose of this study, we will use Nigeria’s GDP (Nigeria being the highest ranked African country in terms of GDP) as our reference to establish the project cost bench mark for mega projects for countries with GDPs less than that of Nigeria. For Countries with GDPs equal to or more than Nigeria’s, USD 1 Billion in accordance with already existing literature will be the benchmark. For Zambia with a GDP less than that of Nigeria, the ratio of Nigeria’s GDP to that of the USA of USD 1 Billion will be used as the benchmark. Thus, all projects with the cost of USD 30 Million and above will be considered as large or mega-projects.

39.1.2 Objectives of Study

- To identify the causes on delays on mega Transmission Power projects in Zambia.
- To establish the ranking of these delays.

39.1.3 Causes of Delays

Many studies on the causes of delays in construction projects have been surveyed. In a survey on time performance of different types of construction projects in Saudi Arabia, Al-Hejji found “change orders by owner during construction” as the only cause of delay, among the 73 identified causes of delay, common between the three main parties to a project i.e. Client, Contractor and consultant. Other important causes of delay were; delay in progress payments, ineffective planning and scheduling by contractor, poor site management and supervision by contractor, shortage of labour and difficulties in financing by contractor. Similarly, a person-interview survey was conducted of 450 randomly selected private residential project owners and developers on Delays and cost increases in the construction of private residential projects in Kuwait. The survey revealed the following as the three main causes of delays: Change orders; Owner's financial constraints; and owner's lack of experience (Koushki et al. 2005).

Aziz (2013) Investigated delay factors in construction projects in Egypt after the Egyptian revolution. Ninety nine (99) delay factors from literature review and interviews with experts in the construction industry were identified. A questionnaire was generated and distributed targeting highly experienced construction professionals including project managers, site managers, technical office managers, technical office engineers, procurement managers, technical consultants, main contractors, and subcontractors from a total of 400 construction firms from which 2500 (83.33%) people responded. The results of the study indicated the following as the five (05) most important factors related to the contractor: (1) Ineffective project planning and scheduling; (2) Poor site management and supervision; (3) Poor financial control on site; (4) Rework due to errors; and (5) Incompetent project team. Those related to the owner being: (1) Delay in progress payments (Funding problems); (2) Selecting inappropriate contractors; (3) Inadequate planning; (4) Change orders; and (5) Conflicts between joint-ownership.

Odeh and Battaineh (2002) conducted a survey to identify the most important causes of construction project delays with traditional type of contracts from the view point of the contractors and consultants. Results from the survey indicated the following as major factors: (1) Owner interference; (2) inadequate contractor experience; and (3) finance and payments of completed work.

Alinaitwe conducted an investigation into the causes and ranking of delays and cost overruns in Uganda's public sector construction projects. Delays factors were compiled on the basis of a review of the literature and discussions with contractors, government ministry officials and consultants working on public projects, as well as the author's personal experience with public-sector construction projects from which 22 factors were identified. From the investigations, the five most important causes of delays and cost overruns were found to be: (1) changes in the work scope (2) delayed payments to contractors (3) poor monitoring and control (4) high inflation and interest rates; and (5) political insecurity and instability.

Frimpong conducted a survey to identify and evaluate the relative importance of significant factors contributing to delay and cost overruns in Ghana groundwater construction projects. The survey targeted the three main project participants; Clients (Owners), contractors and consultants. The main causes of delays according to the study were: monthly payment difficulties; poor contactor management; material procurement; poor technical performance and escalation of material prices. Tumi and Al Hadi Carried out a survey to identify the main factors contributing to delays in construction Projects in Libya. The top four main causes of delays according to the study, in order of importance, were: (1) Improper planning;

(2) lack of effective communication, design errors and shortages of supply; (3) slow decision making and financial issues; and (4) shortage of materials.

Le-Hoai et al. (2008) conducted a survey titled 'Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries', through which 87 Vietnamese construction experts participated. The top four main causes of delays and cost overruns according to the study, in order of importance, were: (1) Poor site management and supervision; (2) Poor project management assistance; (3) Financial difficulties of owner; and (4) Financial difficulties of contractor.

39.1.4 Summary of Causes of Delays in Construction Projects

The literature reviewed highlighted that delays in construction projects can be caused by several factors among which are: change orders; design errors; changes in laws and regulations; changes in specifications; construction mistakes; delayed payments; difficult or different site conditions; Ineffective communication between different parties to the project; Inadequate contractor experience; equipment unavailability; financial processes and difficulties; floods; ineffective planning; Slow decision making; ineffective scheduling by contractor; Conflicts; lack of qualified manpower; material procurement; poor site management and supervision; poor sub-contractor performance; Financial difficulties of owners; Financial difficulties of contractors; and subsurface soil conditions.

39.2 Research Methodology

This study adopted field survey methodology to uncover the factors influencing delay arising during construction stage of mega transmission power projects. The research methodology contains two phases. The first phase involved the identification of the factors of delays in mega transmission power projects through literature review and interviews with the experts in the construction of mega transmission power projects. The literature review was conducted through books, conference proceedings, internet and project management journals. As the result of this phase, 58 factors of delays were identified as responsible in mega transmission power projects in Zambia. Framework of the causes is given in Table 39.3.

The second phase included the preparation of questionaire through which the respondents were requested to rate and rank each of the 58 factors of delays according to frequency of occurrence and severity with regards to their experience in implementing mega transmission power projects in Zambia. A four-point likert

Table 39.2 Frequency and severity weighting

Weight	Frequency (F) weight	Severity (S) weight
1	Never	No effect
2	Occasionally	Fairly severe
3	Frequently	Severe
4	Always	Very severe

scale of 0 to 4 is adopted for evaluating the weighting of each factor as illustrated in Table 39.2.

Data analysis

The collected data was analyzed through the use of techniques which included the Microsoft package of Excel and Statistical Package for Social Science (SPSS) package that facilitated the interpretation of collected data. The following statistical techniques and indices were used to rank the delay factors:

Frequency index: A formula based on Eq. 39.1 is used to rank factors of delay based on frequency of occurrence as indicated by the participants.

$$\mathrm{F.I}\,(\%) = \sum_{n=1}^{4} (F_n P_n) / \left[\sum_{n=1}^{4} 4(P_n)\right] \tag{39.1}$$

where F_n is the frequency weight assigned to option n (ranging from 1 for never to 4 for always) and P_n is the number of participants who responded to option *n.*

Severity index: A formula based on Eq. 39.2 is used to rank factors of delay based on severity as indicated by the participants.

$$\mathrm{S.I}\,(\%) = \sum_{\mathrm{m}=1}^{4} (\mathrm{S_m P_m}) / \left[\sum_{\mathrm{m}=1}^{4} 4(\mathrm{P_m})\right] \tag{39.2}$$

where: S_m is the severity weight assigned to option *m* (ranging from 1 for no effect to 4 for very severe) and P_m is the number of participants who responded to option *m*

Importance index: This index expresses the overview of each factor of delay based on both their frequency and severity. It is computed as per following formula:

$$\mathrm{Imp.I}(\%) = \mathrm{F.I} \times \mathrm{S.I} \tag{39.3}$$

39.3 Results and Discussions

Respondents' profile

A total of 50 questionnaires equally distributed between the client and the contractors were issued out. The response rate from contractors and the owners (clients) is 60 and 80% respectively.

With regards to the number of years involved in construction of mega transmission power projects, 50% of clients and 27% of the contractors amounting to total of 40% for both the client and contractor have experience of between five (5) years and ten (10) years. Further, 40% of the client and 27% of the contractors accounting to a total of 40% have less than 5 years' experience, while the remaining 17% of the respondents having experience of 10 years to 20 years. It will be noticed that 90% of the client have experience of ten (10) years or less in construction of mega transmission projects-part of the reason to explain this is that there has not been activities in the construction of such projects since 1982 (Kabwe —Pensulo 330 kV transmission line) until around 2004.

Ranking of factors of delays

The three indices, these being frequency, severity and importance indices, explained earlier were used to rank delay factors from the perspective of the two project parties (owners and contractors). Table 39.3 shows the list of the factors of delays.

39.3.1 Frequency of Factors of Delays

Table 39.4 shows the ranking of the top five ranked factors of delays in terms of the frequency of occurrence from the perspective of the contractor, client and from both the contractor and client. Rain effect on construction activities, Delay in approving major changes in the scope of work by the client/project owner and Difficulties in financing project by the client/project owner were the highest ranked factors of delays from the perspective of the contractor with frequency indices (F.I %) of 67, 65 and 62% respectively. Similarly, Type of project bidding and award (negotiation, lowest bidder), Delay in progress payments by owner and Rain effect on construction activities were the top three highest ranked factors of delays from the viewpoint of the client (owner) with frequency indices of 75, 69 and 66% respectively. The frequency of occurrence of the factors of delays from a combined perspective of both the client and contractor were as follows: (1) Type of project bidding and award (negotiation, lowest bidder) [69%]; (2) Rain effect on construction activities[66%]; (3) Delay in progress payments by owner [64%]; (4) Delay in approving major changes in the scope of work by the client/project owner [62%]; (5) Difficulties in financing project by the client/project owner [61%].

39.3.2 Severity of Delay Factors

Table 39.5 shows the ranking of the top five ranked factors of delays in terms of the severity of occurrence from the perspective of the contractor, client and from both the contractor and client. The five highest ranked factors of delay in terms of severity from the contractor's point of view are: Rain effect on construction

Table 39.3 List of factors of delays

	Delay causes
1	Accident during construction
2	Unavailability of utilities on site (such as, water, electricity, telephone, etc.)
3	Traffic control and restriction at job site
4	Delay in progress payments by owner
5	Unrealistic contract duration
6	Delay to furnish and deliver the site to the contractor by the owner
7	Change orders by owner during construction
8	In effective delay penalties
9	Corruption
10	late in reviewing and approving design documents by owner
11	Type of project bidding and award (negotiation, lowest bidder)
12	poor communication and coordination by owner and other parties
13	Slowness in decision making process by owner
14	Unavailability of incentives for contractor for finishing ahead of schedule
15	Suspension of work by owner
16	Difficulties in financing project by contractor
17	Difficulties in financing project by the client/project owner
18	Rework due to errors during construction
19	Conflicts between contractor and other parties
20	Poor contract management
21	poor site management and supervision by contractor
22	poor communication and coordination by contractor with other parties
23	Ineffective planning and scheduling of project by contractor
24	Improper construction methods implemented by contractor
25	Inadequate contractor experience
26	Delay in site mobilization
27	Delay in performing inspection and testing
28	Delay in approving major changes in the scope of work by the client/project owner
29	Inflexibility (rigidity) of owner
30	Inadequate experience of consultant
31	Mistakes and discrepancies in design documents
32	Delays in producing design documents
33	Unclear and inadequate details in drawings
34	Complexity of project design
35	Insufficient data collection and survey before design
36	Misunderstanding of owner's requirements by design engineer
37	Changes in material types and specifications during construction
38	Delay in material delivery
39	Damage of sorted material while they are needed urgently
40	Delay in manufacturing special building materials

(continued)

Table 39.3 (continued)

	Delay causes
41	Late procurement of materials
42	Late in selection of finishing materials due to availability of many types in market
43	Equipment breakdowns
44	Shortage of equipment
45	Low level of equipment-operator's skill
46	Low productivity and efficiency of equipment
47	Shortage of labour
48	Unqualified workforce
49	Low productivity level of labour
50	Personal conflicts among labour
51	Effects of subsurface conditions (e.g., soil, high water table, etc.)
52	Delay in obtaining permits from council/municipality etc.
53	Rain effect on construction activities
54	Fluctuations in cost/currency
55	Effect of social and cultural factors
56	Differing site (ground) conditions
57	Changes in government regulations and laws
58	Delay in performing final inspection and certification by a third party

Table 39.4 Frequency index (F.I %) and ranking of delay factors

No.	Contractors	Owners (clients)	Both owners and contractors
1	Rain effect on construction activities	Type of project bidding and award (negotiation, lowest bidder)	Type of project bidding and award (negotiation, lowest bidder)
2	Delay in approving major changes in the scope of work by the client/project owner	Delay in progress payments by owner	Rain effect on construction activities
3	Difficulties in financing project by the client/project owner	Rain effect on construction activities	Delay in progress payments by owner
4	Inflexibility (Rigidity) of owner	Delay in material delivery	Delay in approving major changes in the scope of work by the client/project owner
5	late in reviewing and approving design documents by owner	Fluctuations in cost/ currency	Difficulties in financing project by the client/project owner

Table 39.5 Severity index (F.I %) and ranking of the five highest delay factors

No.	Client		Contractor		Overall	
	Factors of delays	S.I (%)	Factors of delays	S.I (%)	Factors of delays	S.I (%)
1	Inadequate contractor experience	88	Rain effect on construction activities	71.7	Rain effect on construction activities	78
2	Difficulties in financing project by the client/ project owner	83	Delay in approving major changes in the scope of work by the client/project owner	70.0	Difficulties in financing project by the client/project owner	76
3	Rain effect on construction activities	83	Difficulties in financing project by the client/project owner	68.3	Difficulties in financing project by contractor	72
4	Late procurement of materials	80	late in reviewing and approving design documents by owner	66.7	Inadequate Contractor experience	71
5	Type of project bidding and award (negotiation, lowest bidder)	79	Slowness in decision making process by owner	65.0	Delay in approving major changes in the scope of work by the client/project owner	71
	Difficulties in financing project by contractor	79				

activities; Delay in approving major changes in the scope of work by the client/project owner; Difficulties in financing project by the client/project owner; late in reviewing and approving design documents by owner; and Slowness in decision making process by owner with corresponding severity indices (S.I %) of 71.7, 70.0, 68.3, 66.7 and 65.0% respectively.

From the client's perspective, the following were the six (6) highest ranked factors of delays in terms of severity: Inadequate Contractor experience. (88%); Difficulties in financing project by the client/project owner (83%); Rain effect on construction activities (83%); late procurement of materials (80%); Type of project bidding and award (negotiation, lowest bidder) (79%); and Difficulties in financing project by contractor (79%).

The five highest ranked delay factors in terms of severity from the perspective of both the client and contractor are: Rain effect on construction activities (78%); Difficulties in financing project by the client/project owner (76%); Difficulties in financing project by contractor (72%); Inadequate Contractor experience (71%); and Delay in approving major changes in the scope of work by the client/project owner (71%).

Table 39.6 Importance index (%) and ranking of the top five ranked delay factors

Rank	Contractor		Client		Overall	
	Delay causes	IMP. I (%)	Delay causes	IMP. I (%)	Delay causes	IMP. I (%)
1	Rain effect on construction activities	47.8	Type of project bidding and award (negotiation, lowest bidder)	59.3	Rain effect on construction activities	51.5
2	Delay in approving major changes in the scope of work by the client/project owner	45.5	Rain effect on construction activities	54.8	Type of project bidding and award (negotiation, lowest bidder)	48.3
3	Difficulties in financing project by the client/project owner	42.1	Difficulties in financing project by the client/project owner	50.6	Difficulties in financing project by the client/project owner	46.4
4	late in reviewing and approving design documents by owner	40.0	Delay in material delivery	49.1	Delay in approving major changes in the scope of work by the client/project owner	44.0
5	Inflexibility (rigidity) of owner	39.1	Delay in progress payments by owner	49.0	Delay in progress payments by owner	42.8

39.3.3 Importance of Delay factors

Importance index expresses the overview of delay factors based on both their frequency and severity. It is basically the product of the severity index and the frequency index. Table 39.6 shows the five highest ranked factors of delay according to the contractor, client and both the contractor and client.

From the contractor's perspective, the five most important causes of delays in mega transmission power projects are: (1) Rain effect on construction activities; (2) Delay in approving major changes in the scope of work by the client/project owner; (3) Difficulties in financing project by the client/project owner; (4) late in reviewing and approving design documents by owner; and (5) Inflexibility (Rigidity) of owner. From Table 39.6, it is noticed that 80% of the top five ranked factors of delays from the perspective of the contractor are attributed to the owner/client, with the remaining 20% attributed to nature. What this means, from the viewpoint of the contractor, is that the major factors causing delays on mega transmission power projects in Zambia are totally out of the control of the contractors.

Similarly, the five most important causes of delays from the perspective of the client are: (1) Type of project bidding and award (negotiation, lowest bidder); (2) Rain effect on construction activities; (3) Difficulties in financing project by the client/project owner; (4) Delay in material delivery; and (5) Delay in progress payments by owner.

The overall rankings of factors of delay according to the importance index are: (1) Rain effect on construction activities; (2) Type of project bidding and award (negotiation, lowest bidder); (3) Difficulties in financing project by the client/project owner; (4) Delay in approving major changes in the scope of work by the client/project owner; and (5) Delay in progress payments by owner.

39.4 Recommendations

Based on the finding of this study, and with large transmission power projects in mind, some recommendations are made as below:

1. Project Schedules.
   Project schedules should be made in such a way that they accommodate the rainy season. Transmission power projects are rain sensitive, erecting towers for instance while it rains is a very risky thing. It is thus worthy to schedule the projects in such a way that the months when it rains heavily in a year are excluded from the schedule i.e. a project that needs twelve (12) months to complete should be scheduled for fourteen (14) or fifteen (15) months.
2. Type of project bidding and award
   The criteria for contract award needs to take an improved form by giving less weight to lower prices and accord more weight to the contractors' capabilities

and past performances. This will reduce the risks of engaging contractors that would be unfit to perform according to the demands of the project and within the agreed time.

3. Project funding

   Delays in progress payments by client greatly interrupt the cash flow of the contractor which in turn affects the contractor's abilities to pay the sub-contractors. The end result of all this delayed project execution.

   Thus, Contracts should not be effected until all the funds required for the project are secured. Adequate funding levels should always be determined at the planning stage of projects to facilitate timely payments of progress payments, for instance.

4. Proper project planning

   Adequate planning should be performed before project execution which should cater for all project activities and resource needs. This should also take into consideration all the necessary documentations and permits required for smooth project execution. This will ensure all background checks such as the requirements and conditions of grants such as tax exemption (where applicable) are met prior to project commencement.

5. Project implementation units (PIUs)

   There is need to have dedicated project implementation units specific per project. This will ensure that all approval processes on individual project will be faster unlike where many projects share same resources (such as civil personnel) for approvals as well as site supervision activities.

39.5 Conclusion

This study is aimed at identifying the major causes of in mega transmission power projects in Zambia through a survey from the perspective of the client and contractor. This study was limited to mega transmission power projects in Zambia only.

Fifty eight (58) factors of delay were identified from literature and each ranked by each of the respondents to the survey according to their frequency of occurrence, severity and importance. The top five overall most important factors in order of importance were as follows: Rain effect on construction activities; Type of project bidding and award (negotiation, lowest bidder); difficulties in financing project by client/owner; delays in approving major changes in the scope of work by the client; and delay in progress payments. Accidents during construction and traffic control and restriction were the least important factor.

References

Aziz RF (2013) Ranking of delay factors in construction projects after Egyptian revolution. Alexandria Eng J 52:388

Bruzelius N, Flyvbjerg B, Rothengatter W (2002) Big decisions, big risks. Improving accountability in mega projects. Transp Policy 9:144

Flyvbjerg B (2014a) What you should know about megaprojects and why: an overview. Project Manage J 45(2):7

Flyvbjerg B, Bruzelius N, Rothengatter W (2003) Megaprojects and risk: an anatomy of ambition, 1st ed. Cambridge University Press, Cambridge

Flyvbjerg B (2014b) What you should know about megaprojects and why: an overview. Project Manage J 45(2):6–19

Haidar A, Ellis RD (2010) Analysis and improvement of megaprojects. In: Engineering project organizations conference, South Lake Tahoe, CA

Haseeb M, Bibi A, Rabbani W (2011) Problems of projects and effects of delays in the construction industry of Pakistan. Aust J Bus Manage Res 1(5):41–50

Koushki PA, Al-Rashid K, Kartam N (2005) Delays and cost increases in the construction of private residential projects in Kuwait. Constr Manage and Econ 23:293

Le-Hoai L, Dai Lee Y, Lee JY (2008) Delay and cost overruns in vietnam large construction projects: a comparison with other selected countries. KSCE J Civ Eng 12(6):368

Odeh AM, Battaineh HT (2002) Causes of construction delay: traditional contracts. Int J Project Manage 20:70

Othman AAE (2013) Challenges of mega construction projects in developing countries. Organ Technol Manage Constr Int J 5(1):731

Othman AAE (2013b) Challenges of mega construction projects in developing countries. Organ Technol Manage Constr Int J 5(1):734

Ruuska I, Artto K, Aaltonen K, Lehtonen P (2009) Dimensions of distance in a project network: exploring Olkiluoto 3 nuclear power plant project. Int J Project Manage 27:142

Sanderson J (2012) Risk, uncertainty and governance in megaprojects: a critical discussion of alternative explanations. Int J Project Manage 30:432

Shore B, Cross BJ (2005) Exploring the role of national culture in the management of large-scale international science projects. Int J Project Manage 23:55–64

Sturup S (2009) Mega projects and governmentality. World Acad Sci Eng Technol 3:833

van Marrewijk A, Clegg SR, Pitsis TS, Veenswijk M (2008) Managing public–private megaprojects: paradoxes, complexity, and project design. Int J Project Manage 26:591–600

Zesco (2013) Zesco business plan. Lusaka: s.n

Chapter 40
Characterization of Carbon Emissions from the Construction Activities: A Case Study of Shenzhen, China

L.N. Zheng, H. Zhang., H.B. Duan, X.H. Wang, Y.N. Niu and J.Y. Wang

40.1 Introduction

Since reform and opening up, Shenzhen has developed rapidly in construction industry. Statistically, completed building area has reached 19.05 million m^2 of Shenzhen in 2014. Therefore, massive construction activities would bring in huge energy consumption. It is reported that energy consumption in construction industry has contributed over 30% of total energy consumption (Gong et al. 2016). In this context, some previous researches have focused on the carbon emissions of buildings by using life cycle assessment (LCA), these studies show that the carbon emissions of buildings might be related to the materials selected and construction technology. Moreover, some studies also make a contribution analysis to figure out the proportion of carbon emissions from life cycle of buildings.

- As for the impact of materials selected and construction technologies, a paper investigated the energy and greenhouse emissions with the specific materials (alternative wood, steel and concrete), and they found that construction representing 7–10% of the embodied energy is typically high for wood and steel assemblies and low for concrete structural assemblies (Cole 1998). Monahan and Powell (2011) found that the affordable house constructed using a novel offsite panelized modular timber frame system resulted in a 34% reduction of embodied carbon emissions when compared with traditional methods of construction (Monahan and Powell 2011). Gerilla et al. (2007) compares the wooden houses with steel reinforced concrete houses to figure out four types of emissions generation (carbon emissions, nitrogen oxides, sulfur oxides and suspended particulate matter) by trace the life cycle of the two building types (Gerilla et al. 2007).

L.N. Zheng · H. Zhang. · H.B. Duan (✉) · X.H. Wang · Y.N. Niu · J.Y. Wang
School of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: huabo@szu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_40

- In addition, some studies concerned about the proportion of carbon emissions from different phases of buildings. Cai et al. (2010) made a literature review of the carbon emissions and reduction potential of residential buildings from material manufacturing to disposal phase, and they summed up that the use stage is the largest contributor of buildings (Cai et al. 2010). Nässén et al. (2007) estimated the carbon emissions from material manufacturing using input-out analysis, while this method was seldom used in carbon emissions evaluation (Nässén et al. 2007). Gielen (1997) found that material manufacturing accounts for as much as 8–12% of the total CO_2 emissions from the life cycle of buildings in Western European, and they believe that this process should be paid more attention for carbon emissions reduction (Gielen 1997).

From the reviews above, it is obvious that LCA has been widely employed to estimate the carbon emissions of buildings. It is a process includes the upstream (extraction, production, transportation and construction), use, and downstream (deconstruction and disposal) (Ramesh et al. 2010). However, the traditional LCA was the cost and time required assessment (Weitz et al. 1999), and exist much uncertainties, however, only a few studies have measured carbon emissions by considering the inherent uncertainty (Hong et al. 2016), which was difficult to achieve the target owning to the huge demand of empirical data and complicated investigation. So these limitations have encouraged some practitioners to create the SLCA method to make it more feasible and more effective (Weitz et al. 1999). It maps the intrinsic attributes of information technology products to energy use and carbon emissions (Duan and Wang 2015). Actually, SLCA is a streamlined application of the LCA methodology by using generic data, standard modules for energy evaluation (Curran 2011), and this method is appropriate to quantify the carbon emissions for the complicated construction system.

Moreover, due to the energy consumption at use stage of buildings was regarded to be the largest contributor throughout the life cycle of buildings, which has been estimated approximately 85% of the total energy consumption (World Business Council for Sustainable Development (WBSCD) 2007), therefore most researchers pay more attention to the carbon emissions at use stage of buildings. Although LCA method could cover all the process of a building, which was from design phase to disposal phase, the construction activities have never been regarded as a whole part to be considered. Shenzhen as the representative of developed cities in China, the construction area has reached 115.02 million m^2 in 2013, and such massive construction activities definitely deserve the concern about its carbon emissions impact.

Based on the literatures review above, this study used SLCA to answer: (1) How to quantify the carbon emissions from construction activities in Shenzhen; (2) How much does the carbon emissions impact on environment from construction activities by comparing to the use stage.

40.2 Methodology

40.2.1 Streamlined Life Cycle Assessment (SLCA)

This study mainly used SLCA method to estimate carbon emissions from construction activities. The advantages of this method are process simplification and target clear. Furthermore, this method could be implied in studies which have difficulties to obtain data in some processes. There are three steps to conduct this method:

- Determining system boundary of study, this step would help to figure out the objects and scopes of this study.
- Identifying and aggregating the data collected by reviewing literatures, commercial life cycle inventory databases and some official publications.
- Conducting a contribution analysis to evaluate the impacts of components within materials use and construction process.

40.2.2 Scope and System Boundary

In general, the whole life cycle of buildings consist of six phases, namely ‘material mining’, ‘material manufacturing’, ‘building construction’, ‘use’, ‘demolition’ and ‘disposal’. However, this paper only concerns the carbon emissions from construction activities, including materials use and construction process. While construction activities are supposed to include the transport, this process was excluded from this study for lack of associated data. Building materials mainly includes cement, concrete, bricks, gravel and steel, which are falling within the scope of this study. In addition, electricity was the only kind of energy consumption considered in construction process due to the insufficient basic statistic data of oil. The system boundaries of this paper were shown as the following (shown in Fig. 40.1).

As seen in Fig. 40.1, energy input shows the possible energy and materials demand. The colorful block means the process considered in this research, which are not complete life cycle process, but more targeted. Production part shows the products output.

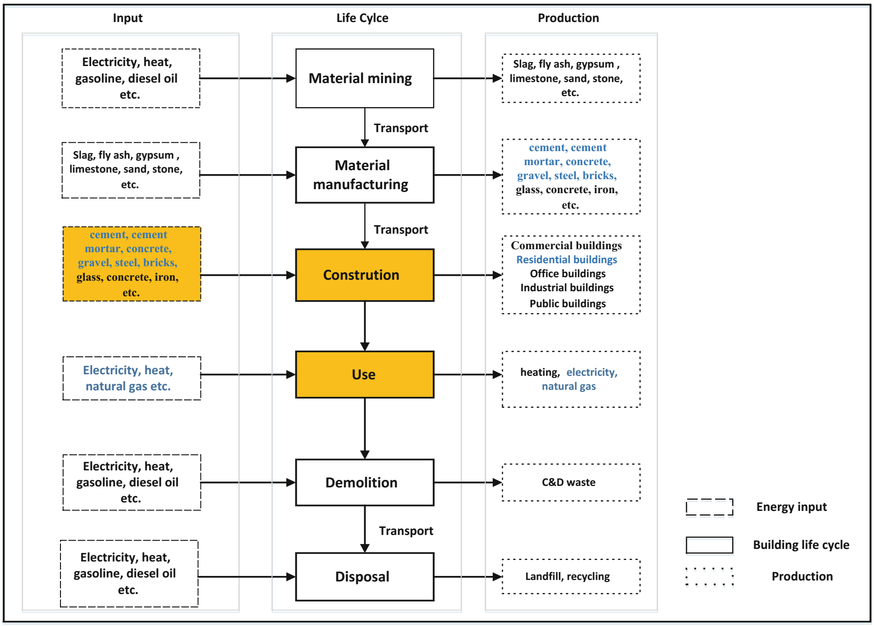


Fig. 40.1 System boundaries

40.2.3 Calculation

Based on the SLCA, three steps have been conducted to estimate the carbon emissions from construction activities.

- Material use

In this process, we have considered five materials, namely concrete, steel, bricks, gravel and cement. Notably, the carbon emissions from material use mainly caused by material manufacturing, thus the carbon emissions factors were derived from material manufacturing. Equation 40.1 has described the carbon emissions from material use in the year of j.

$$\boldsymbol{E}_{m,j} = \sum_{i=1}^{6} \boldsymbol{I}_i \cdot \boldsymbol{A}_j = \sum_{i=1}^{6} \boldsymbol{M}_i \cdot \boldsymbol{q}_i \cdot \boldsymbol{A}_j \qquad (40.1)$$

Where i refers to the material of i; j refers to the year of j; $E_{m,j}$ means the carbon emissions from material use in the year of j, I_i refers to the carbon emissions intensities of material i (expressed as t CO_2/m^2), A_j means the construction area in Shenzhen during the year of j, M_i means the consumption volume of material i in per unit area, q_i means the carbon emissions factors of material i (expressed as t CO_2 eq/unit).

- Construction

Actually, we have investigated the total electricity consumption (including electricity usage of mechanical equipment and the daily life consumption of workers) of 23 projects in Shenzhen, and then calculate electricity consumption in per unit area. Carbon emissions from construction process could be obtained by Eq. 40.2.

$$\boldsymbol{E_{c,j} = W \cdot q_e \cdot A_j} \tag{40.2}$$

Where $E_{c,j}$ means the carbon emissions from construction process in the year of j, W means electricity consumption from construction process in per unit area (kW h/m^2), q_e means the carbon emissions factors of electricity in southern city.

- Use stage

At this stage, we focus on the household energy consumption. Detailed could be seen in Eq. 40.3.

$$\boldsymbol{E_{u,j} = S_j \cdot P_j \cdot (q_e \cdot q_{e,u} + q_g \cdot q_{g,u})} \tag{40.3}$$

Where $E_{u,j}$ means the carbon emissions at use stage in the year of j, S_j means the per capital living space of Shenzhen in the year of j, P_j means the population of Shenzhen in the year of j, $q_{e,u}$ means the electricity consumption in per unit area (kW h/m^2) at use stage, $q_{g,u}$ means the natural gas consumption in per unit area (m3/m^2) at use stage, q_g means the carbon emissions factors of natural gas at use stage (t/m^3).

40.2.4 Data Inventory

In this study, there are several sources offer the basic data to estimate the carbon emissions. Firstly, an attempt has been made to characterize the construction electricity intensities (kWh/m^2) in Shenzhen based on the 23 on-site surveys. Material consumption volume has been collected through the bill of quality, and the carbon emissions factors of material use were obtained from the summary of literatures (Chen 2014; Wang 2009; Liu 2014), details could be seen in Table 40.1. Meanwhile, carbon emissions factors and consumption of natural gas were obtained from the investigation conducted by Wang (2009) and Chen (2014). Per capital living space and population were obtained from Shenzhen Statistical Yearbook (Municipal Bureau of Statistics of Shenzhen (MBSS) 2001). Notably, Owing to the study subject—Shenzhen is a southern city, so we choose southern electricity grid emissions factors from China Life Cycle Database (CLCD).

Table 40.1 Dioxide carbon emissions factors (t CO2 eq/t) and material consumption in per unit area (t CO2/m^2)

Materials	Emissions factors	Material consumption in per unit area
Concrete	0.26	0.18
Steel	1.13	0.06
Gravel	1.01	0.01
Cement	0.58	0.13
Bricks	0.18	0.14

40.3 Results and Discussion

40.3.1 Carbon Emissions from Construction Activities

The results of the carbon emissions throughout the construction activities are specified in Figs. 40.2 and 40.3. The proportion of carbon emissions from cement use dominates the carbon emissions of all materials use (Fig. 40.2a). By the end of 2013, cement has accounted for 32.72% (consistent to the study conducted by (Gielen 1997), which reveals that the carbon emissions of cement accounted for 38% of all the materials), followed by steel (29.01%), concrete (20.66%), bricks (11%) and gravel (6.6%). Actually, the carbon emissions intensities were determined by both carbon emissions factors and material consumption in per unit area. As shown in Table 40.1, despite that the carbon emissions factor of steel is larger than cement, the material consumption in per unit area of cement is 2.3 times larger than steel, therefore the two parameters has influenced the results of carbon emissions from material use.

As seen in Fig. 40.2b, the carbon emissions from material use have been significantly increasing from 2000 to 2013, the result is particularly noticeable since 2007. This probably is the result of the growth of construction area in Shenzhen. The construction area in Shenzhen has galloped ahead from 41.849 million m^2 in 2007 to 115.028 million m^2 in 2013 (Liu 2014), thus expansion of construction industry scale should be responsible for the growth of carbon emissions from construction process.

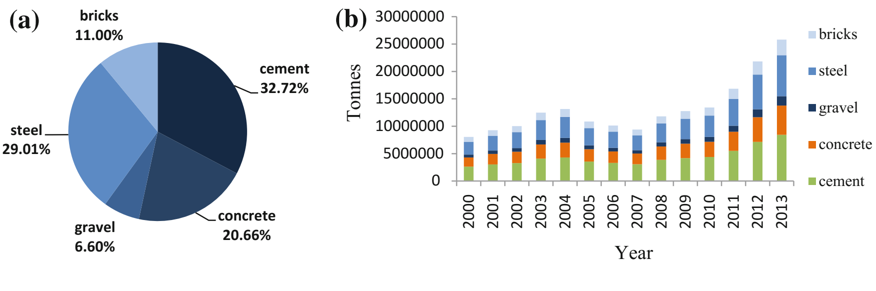


Fig. 40.2 Carbon emissions and its distribution from various materials use

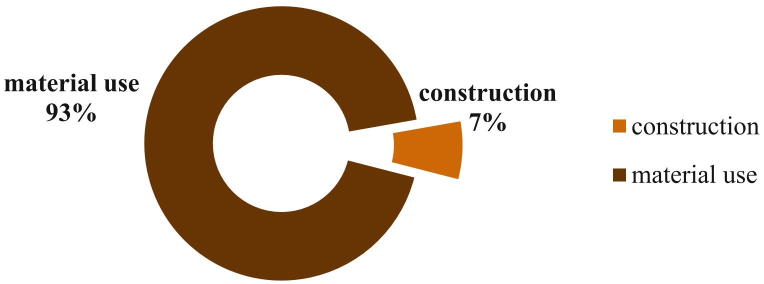


Fig. 40.3 Carbon emissions from construction activities which divided by construction process and material manufacturing

Figure 40.3 reveals the proportion of the two processes from construction activities, from which we could see clearly that construction process has limited impact on the environment, while material use is the largest contributor in construction activities.

40.3.2 Comparison Between Construction Activities and Use Stage

One goal of this study is to figure out how much does the carbon emissions impact on environment from construction activities, thus the comparison with the carbon emissions at use stage is essential to achieve this goal. In Fig. 40.4, it is obvious that the carbon emissions from material use are almost equal to that at use stage. Specifically, carbon emissions from material manufacturing accounted for 46.7%, and that at use stage contributed to 50%. However, this result is inconsistent with

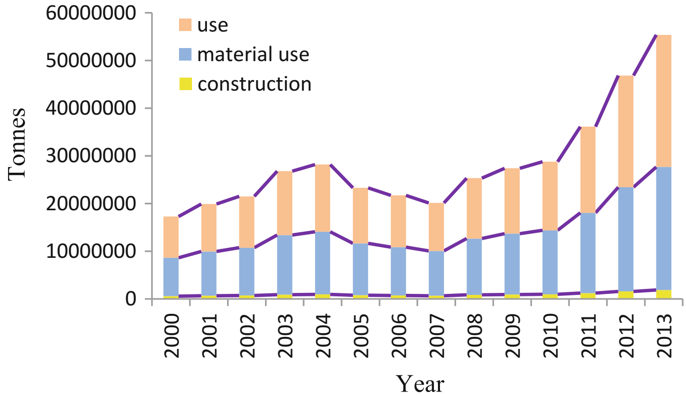


Fig. 40.4 Carbon emissions comparison between construction activities and use stage

other papers studied by Wang (2009) and Wang (2011) (carbon emissions at use stage accounted for 85.5 and 72.9% of total emissions respectively) (Chen 2014; Wang 2011), this is mainly because Beijing and Tianjin which they investigated in their study were northern city, thus the scope of their study including the heating energy consumption in winter. Nevertheless, Shenzhen is a southern city, there is no need to supply heating system in winter, so heat energy was excluded in this study. Therefore, as for such a southern city like Shenzhen, the carbon emissions from construction activities were heavily underestimated in previous studies.

40.4 Constraints and Limitations

This study selected the SLCA method to quantify the carbon emissions from construction activities, which could provide an explicit way to figure out how does this process could influence the greenhouse gas emitter in Shenzhen. However, several limitations should be acknowledged. More specifically, due to the absence of valid data, the transportation from material factory to the construction site was not included in this study. Regarding the carbon emissions, the electricity was the only source considered during construction process, which is mainly because the limitation of survey condition.

40.5 Conclusion

This study presents a model based on the SLCA method to estimate the carbon emissions from construction activities in Shenzhen. The quantitative results show that the material use is the largest contributor to the carbon emissions from the construction activities, and it has greater impact on green house effect in the southern city like Shenzhen when comparing with northern cities. Furthermore, the cement use should be paid more attention for environmentally sound management due to the continuous but rapid carbon emissions growth trend in recent years. In terms of the quantitative results, now that the carbon emissions are inevitable, it is quite necessary to evaluate the carbon emissions during the life cycle of buildings appropriately, since the unsuitable evaluation may cause the negligence of carbon emissions at some stage.

Acknowledgements This study was supported by the Scientific Research Foundation of Introduced High Talent Financial Subsidies of Shenzhen University (000044), NSFC (21507090), NSFC (71272088) and JCYJ20150525092941042.

References

Cai XR, Wang MQ, Fu BQ (2010) Analysis of carbon emissions of residential buildings and measures of energy-saving and emission-reduction. J Disaster Prev Mitig Eng 30:428–431 In Chinese

Chen KH (2014) Quantitative assessment method of GHG emission for construction projects. Master dissertation, Guangdong University of Technology. In Chinese

Cole RJ (1998) Energy and greenhouse gas emissions associated with the construction of alternative structural systems. Build Environ 34(3):335–348

Curran MA (2011) Maintaining quality critical peer review (CPR) as the demand for life cycle assessments increases. In: Proceedings of LCM

Duan HB, Wang JY (2015) Quantification of the carbon emission of road and highway construction in China using streamlined LCA. In: Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate, pp 181–191

Gerilla GP, Teknomo K, Hokao K (2007) An environmental assessment of wood and steel reinforced concrete housing construction. Build Environ 42(7):2778–2784

Gielen DJ (1997) Building materials and CO 2: Western European emission reduction strategies

Gong WP, Zhao ZJ, Liu WZ, Hu P, Zhang QP (2016) Current situation of major resource and construction energy consumption in Chongqing construction engineering. Chongqing Architect 4:5–8 In Chinese

Hong J, Shen GQ, Peng Y, Feng Y, Mao C (2016) Uncertainty analysis for measuring greenhouse gas emissions in the building construction phase: a case study in China. J Clean Prod 129: 183–195

Liu N (2014) Research on carbon emission calculation and emission reduction strategies of building based on life cycle assessment. Master dissertation, Shijiazhuang Tiedao University. In Chinese

Monahan J, Powell JC (2011) An embodied carbon and energy analysis of modern methods of construction in housing: a case study using a lifecycle assessment framework. Energy Build 43 (1):179–188

Municipal Bureau of Statistics of Shenzhen (MBSS) (2001–2014) Shenzhen Statistical Yearbook, http://gdidd.jnu.edu.cn/doc/gdtjnj/sztjnj/2014/index.htm. Accessed on 5 May 2016

Nässén J, Holmberg J, Wadeskog A, Nyman M (2007) Direct and indirect energy use and carbon emissions in the production phase of buildings: an input–output analysis. Energy 32(9):1593–1602

Ramesh T, Prakash R, Shukla KK (2010) Life cycle energy analysis of buildings: an overview. Energy Build 42(10):1592–1600

Wang J (2009) Calculation and analysis of life cycle CO2 emission of Chinese Urban Residential Communities. Master dissertation, Tsinghua University. In Chinese

Wang X (2011) Life cycle assessment for carbon emission of residential building. Master dissertation, Tian Jin University. In Chinese

Weitz K, Sharma A, Vigon B, Price E, Norris G, Eagan P, Veroutis A (1999) Streamlined life-cycle assessment: a final report from the SETAC North America streamlined LCA workgroup. Society of Environmental Toxicology and Chemistry, SETAC North America

World Business Council for Sustainable Development (WBSCD) (2007) Energy efficiency in buildings: business realities and opportunities

Chapter 41
China's Ongoing Policy Instrument for Building Energy Efficiency: Drives, Approaches and Prospects

B. He, X.L. Zhang, L.D. Jiao and L.Y. Shen

41.1 Introduction

Since the Industrial revolution, primary energy resources, such as coal, oil, natural gas, and other fossil fuels have been consumed at a high rate. According to the International Energy Outlook 2015 issued by the U.S. Energy Information Administration (U.S. EIA 2015), the world will see an increase in energy consumption, with an estimate surge of 549.3 quadrillion Btu to reach 765.6 quadrillion Btu by 2035. This presents a sharp energy consumption increase of 39.38% in the next 20 years. Therefore more attentions have been paid on the significance of improving building energy efficiency (BEE) to pursue the mission of sustainable development. The introduction and application of various policy measures for improving building energy efficiency (BEE) has become a growing priority on the policy agenda in many countries.

Currently, according the report of World Energy Outlook 2014 issued by the International Energy Agency (IEA 2014), China firstly surpassed the United States in 2014 to become the world's largest emitter of greenhouse gases, accounted for about 23.4% of global GHG emissions. The construction industry has been always a significant mainstay in China's rapid urbanization and economic development, accounting for 7.03% of gross domestic product in 2014 (National Bureau of Statistics 2014). Building sector's energy consumption in China has become a major contributor affecting the environmental sustainability in the process of rapid urbanization. How to improve energy efficiency of newly-built constructions and

B. He (✉) · L.D. Jiao · L.Y. Shen
School of Construction and Real Estate, International Research Centre for Sustainable Built Environment, Chongqing University, Chongqing, China
e-mail: hebei091@163.com

X.L. Zhang
Urban Research Group, Department of Public Policy, City University of Hong Kong, Shenzhen Research Institute, Shenzhen, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_41

promote the retrofit of the huge stock of existing buildings, are two urgent problems China facing today.

In responding to these challenges brought by the increasing energy consumption, the Chinese government has introduced and issued various policy measures for promoting building energy efficiency. For example, the Ministry of Housing and Urban-Rural Development (MOHURD) and the Ministry of Finance (MOF) have already issued a series of economic incentive programmes for promoting the development of green building, renewable building, building integrated solar PV, and industrialized building (Liu et al. 2014; Wu et al. 2013; Luo et al. 2015; Zhang et al. 2014). According to the statistics of "Twelfth Five-Year Plan for Building Energy Efficiency" (MOHURD, 2012), as of 2010, mandatory standards and codes of building energy efficiency (BEE) have been implemented in construction stage among 95.4% of new buildings. Metering heating charge and energy efficiency renovation for 1.82 billion square meters of existing buildings have been completed in northern heating area of China. Meanwhile, 217 demonstration projects for green building, 386 demonstration projects for renewable energy building, and 210 demonstration projects for building integrated solar PV have been established and widespread. The rapid development of building energy efficiency is the direct result of policies issued by the Chinese government. Building energy efficiency (BEE) policies are system norms that the government issues to manage related elements in the building energy efficiency industry. However, the management of these elements is complicated. For example, the implementation of building energy efficiency is related to research and the development of new technologies and materials of building energy efficiency, infrastructure investment, financial subsidies on building energy efficiency, government procurement and so on. A further problem is that the introduction and application of building energy efficiency are not yet competitive in conventional construction mode, although the Chinese government has made great efforts to promote the development of building energy efficiency.

The proper development and section of BEE policy measures play an important role in achieving the target of building energy efficiency. Whilst there are cases in China where BEE policy measures are developed in past three decades, the development experiences have not been examined. This paper offers an identification and comprehensive analysis on the development of BEE policy measures from 1986 to 2016 in China.

41.2 Research Methods

The research starts with understanding and identifying the typical BEE policies introduced in China. For conducting this identification, a classification framework of BEE policy instrument is formulated according to the principle of policy instrument and the references provided by the International Energy Agency (IEA) (Geller and Attali 2005; Vreuls et al. 2005). The classification framework, as

Table 41.1 A classification framework of BEE policy instrument

Group of policy instrument		Specific policy measure	
PI-A	Direct administrative instrument	PI-A_1	Mandatory code and standard
		PI-A_2	Mandatory administrative regulation
		PI-A_3	Minimum equipment energy performance standard
PI-B	Economic incentive instrument	PI-B_1	Project or product-related subsidy
		PI-B_2	Targeted tax, tax exemption, and tax credit
		PI-B_3	Financing guarantee
		PI-B_4	Third-party financing facilitation
		PI-B_5	Reduced-interest loan
		PI-B_6	Bulk purchasing
		PI-B_7	Grants
		PI-B_8	Technology procurement
		PI-B_9	Certification trading system
PI-C	Information-based instrument	PI-C_1	General information
		PI-C_2	Labelling
		PI-C_3	Information centre
		PI-C_4	Energy audit
		PI-C_5	Education and training
		PI-C_6	Demonstration
		PI-C_7	Government by example
PI-D	Voluntary agreement instrument	PI-D_1	Industrial company
		PI-D_2	Company of Energy production, transformation and distribution
		PI-D_3	Commercial or industrial organization

shown in Table 41.1, guides the investigation on specific BEE policy measures introduced in China. According to the classification framework, BEE policy instruments are classified into four groups: the mandatory administrative instrument, the economic incentive instrument, the information-based instrument, the voluntary agreement instrument. Each group of the BEE policy instruments reflects different degree of mandatory governance and state involvement.

The experiences in the development of BEE policy instruments in China have been discussed. Three attributes are used for conducting the comparison, including the number of BEE policy instruments issued, the development trend of BEE policy instruments, and experiences in using these policy instruments.

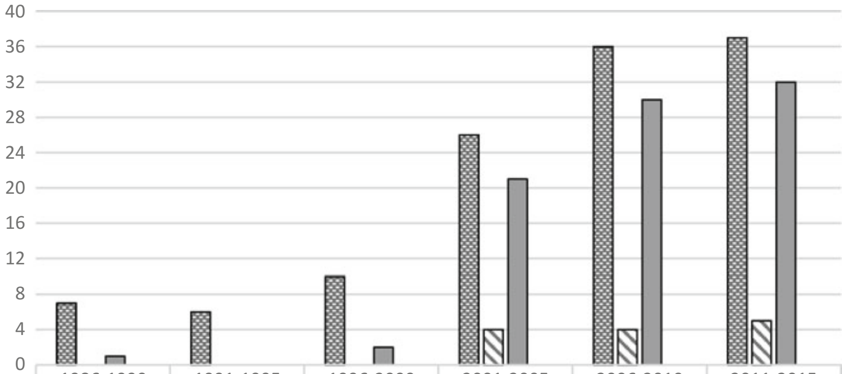
The data needed for identifying specific policy measures in China are retrieved from the relevant sources of official policy text on building energy efficiency. The data sources are approached by visiting the official administration websites.

41.3 Results

By adopting the research methods defined in the previous section, the research results are produced and addressed as follows. By applying the framework of policy instrument as shown in Table 41.1, examination on specific policy measures under each group of policy instrument is conducted.

41.3.1 The Number of BEE Policy Instruments

In referring to the data collection, BEE policy instruments issued in China are summarized, which can also be presented graphically in Fig. 41.1. It can be seen from Fig. 41.1 that China has issued more direct administrative instrument than other three policy instruments for promoting building energy efficiency. China has issued various laws, regulations, standards, codes, and technological guidelines over the past three decades. The data also demonstrate that China has issued a large number of information-based instruments, for example, introducing various BEE labels and certifications, establishing pilot demonstrations relevant to energy-saving materials, construction technologies, and projects. Nevertheless, it appears that China has introduced a relatively small number of economic incentive instruments. And in referring to voluntary agreement instrument, there are few relevant BEE policy instruments issued at national level so far in China.



	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
PI-A	7	6	10	26	36	37
PI-B	0	0	0	4	4	5
PI-C	1	0	2	21	30	32
PI-D	0	0	0	0	0	0

PI-A: Direct administrative instrument PI-B: Economic incentive instrument
PI-C: Information-based instrument PI-D: Voluntary agreement instrument

Fig. 41.1 The total number of BEE policy instruments in China during the period of 1986–2016

41.3.2 The Development Trend of BEE Policy Instruments

The development of BEE policy instruments in China can be demonstrated by examining the number of policy instruments across different periods of time, as shown in Table 41.2. The development of policy instruments is usually through three stages: the pilot demonstration stage, the pervasive campaign stage, and the standardization stage (Kong et al. 2012). By referring to these three stages, the development trend of BEE policy instruments in China is discussed as follows.

In the pilot demonstration stage, efforts were devoted to introducing laws and standards for promoting the application of energy-efficiency materials and technologies. In widespread campaign stage, which can be called the widespread promotion stage, various BEE policy instruments were promoted and applied. Different types of BEE policy instruments issued during this period have developed, in particularly, economic incentive instruments and information-based instruments have been made good developments. The number of BEE policy instruments

Table 41.2 The number of BEE policy instruments issued in China during the period of 1986–2016

Group	Specific instrument	Year					
		1986–1990	1991–1995	1996–2000	2001–2005	2006–2010	2011–2015
PI-A	PI-A_1	3	2	3	14	21	26
	PI-A_2	4	4	7	12	15	11
	PI-A_3	0	0	0	0	0	0
PI-B	PI-B_1	0	0	0	4	3	4
	PI-B_2	0	0	0	0	0	0
	PI-B_3	0	0	0	0	0	0
	PI-B_4	0	0	0	0	0	0
	PI-B_5	0	0	0	0	0	0
	PI-B_6	0	0	0	0	0	1
	PI-B_7	0	0	0	0	1	0
	PI-B_8	0	0	0	0	0	0
	PI-B_9	0	0	0	0	0	0
PI-C	PI-C_1	1	0	0	9	4	4
	PI-C_2	0	0	0	0	7	4
	PI-C_3	0	0	0	2	6	4
	PI-C_4	0	0	0	0	1	1
	PI-C_5	0	0	0	0	0	0
	PI-C_6	0	0	1	2	1	8
	PI-C_7	0	0	1	8	11	11
PI-D	PI-D_1	0	0	0	0	0	0
	PI-D_2	0	0	0	0	0	0
	PI-D_3	0	0	0	0	0	0

developed gradually in this stage, particularly targeting for large-scale public buildings and official buildings as these buildings could set examples for others. In the standardization stage in developing BEE policy measures, governments give more attention on standardizing and promoting specific policy instruments, monitoring continuously the implementation effectiveness of these instruments, and arousing public consciousness on building energy-efficiency. Various BEE policy instruments have been embodied in label programs, certifications, pilot demonstration, and government by example.

41.4 Discussion

China has gained a variety of experiences in introducing and practicing BEE policy instruments. These implementation experiences can be discussed as follows.

41.4.1 Practice of Direct Administrative Instrument

The direct administrative instrument has strong ability to solve problems that market cannot overcome, such as inherent monopoly, information asymmetry, and environmental pollution (Spulber 1989). Law, regulations, administration measures, standards and codes, are the common types of direct administration instruments adopted by governments for promoting energy efficiency in the building sector. Previous studies appreciated that direct administrative instruments can obtain satisfactory effects in a short time, especially when they applied in the crisis management (Rosenthal and Kouzmin 1997). However, the application of direct administration instruments may have limitations. For example, they may encounter poor adaptability, slow response to market changes, and large cost for implementation of government regulation (Li and Colombier 2009). China has issued a large number of BEE regulations and codes at national level in past three decades. Meanwhile, Chinese governments have been revising the direct administration instruments to meet the changes of practices.

41.4.2 Practice of Economic Incentive Instrument

The economic incentive instruments are considered weaker as control measures in comparing to the mandatory administrative instruments (Hillman 2003). Previous research works appreciate that economic incentives for energy-efficiency in the building sector can arouse public and business awareness, and motivate efforts and enthusiasm of implementing BEE policies (Jin et al. 2010). However, economic incentive instrument has limitations in application. Economic stimulus by using incentive programs will weaken the commitments of corporate social responsibility and ethics, and cause vicious competition for business interests between corporations if these economic stimulus are not properly designed and managed. In China, government has introduced various economic incentives for the specific purpose of energy efficiency in the building sector. However, it appears that governments provide relatively less financial resources for implementing BEE policies. Private investments and other types of financial resources have not been attracted and promoted building energy efficiency.

41.4.3 Practice of Information-Based Instrument

In comparing to the direct administration and the economic incentive instrument, information-based instrument is less competent in promoting the application of BEE policy measures. Information-based instruments have advantages of flexibility. They can receive quick response from the market, thus proper adjustments on these instruments can be made in time if necessary. However, the application of information-based instruments also has limitations. Their applications rely largely on the recognition and willingness between various stakeholders including particularly building developers and homeowners. China has taken consistent efforts in promoting information-based instruments. BEE labeling and rating systems have become popular for promoting energy efficiency in building sector. Meanwhile, Chinese government helps to establish BEE information exchange platforms and promote energy-efficient pilot demonstration projects.

41.4.4 Practice of Voluntary Agreement Instrument

Voluntary agreements, refer to policy instruments under which representatives of national or provincial governments enter into negotiation with facility owners or branch organizations to obtain a commitment to reduce energy consumption by a specified amount over a given time period. Such agreements frequently contain energy consumption monitoring protocols and provisions for technical assistance to participating facilities. The signatories generally face financial penalties for failure to meet their commitments under the agreement. This approach is often used in conjunction with targeted tax exemptions. The Chinese government has not yet issued formal policies of relevant voluntary agreement instrument at national level in the building sector. But several typical provinces have already promoted these voluntary agreements. It is expected that there will be an increasing demand for voluntary agreement instruments in the future building sector, because the public will become more willing to participate in these voluntary agreements when governments provide effective guidance and services.

41.5 Conclusion

The findings from this study suggest that the Chinese government has realized the importance of applying policy instruments in promoting building energy efficiency. In line with this development, various BEE policy instruments have been introduced by government in China, typically including direct administrative controls, economic incentives, information-based instruments, and voluntary agreement schemes. Consequently, energy efficiency in the building sector in China has been improved by implementing these policy instruments in recent decades. China has been devoting good efforts in promoting BEE policy instruments, which is evidenced by the increase in the number of these policy instruments issued particularly in the last ten years. The information-based instruments and voluntary agreement instruments have made good development in recent years in comparing to the direct administrative controls and the economic incentives.

Nevertheless, there are rooms for improving the effectiveness of various BEE policy instruments. Direct administrative instruments can be more effective by raising the level of their applicability and continuity. Standards and codes for building energy efficiency should be reviewed and updated to meet new challenges where new technologies and materials are introduced. The effectiveness of economic incentive instruments can be improved by ensuring the continuity of incentive policies seeking for more funding channels, and designing for multiple subsidy measures. Information-based instruments and voluntary agreements can find more effective application by engaging in effective communication and cooperation between government departments and various building stakeholders, particularly, the public, building developers, and building users.

References

Geller H, Attali S (2005) The experience with energy efficiency policies and programmes in IEA countries. Learning from the critics. IEA. IEA Information Paper, Paris

Hillman AL (2003) Public finance and public policy: responsibilities and limitations of government. Cambridge University Press

International Energy Agency (IEA) (2014) World Energy Outlook 2014. Retrieved from http://www.iea.org/publications/freepublications/publication/WEB_WorldEnergyOutlook2014ExecutiveSummaryEnglishFinal.pdf

Jin ZY, Sun JY, Liu CB, Zhang YL (2010) Economic incentive policy design for green buildings based on externality analysis. Build Sci 6:016

Kong X, Lu S, Wu Y (2012) A review of building energy efficiency in China during "Eleventh Five-Year Plan" period. Energy Policy 41:624–635

Li J, Colombier M (2009) Managing carbon emissions in China through building energy efficiency. J Environ Manage 90(8):2436–2447

Liu L, Liu C, Gao Yun (2014) Green and sustainable city will become the development objective of China's low carbon city in future. J Environ Health Sci Eng 12(1):1

Luo LZ, Mao C, Shen LY, Li ZD (2015) Risk factors affecting practitioners' attitudes toward the implementation of an industrialized building system: a case study from China. Eng, Constr Archit Manag 22(6):622–643

National Bureau of Statistics of China (2014) China's Statistics Year Book 2014. Retrieved from http://www.stats.gov.cn/tjsj/ndsj/2014/indexch.htm

Rosenthal U, Kouzmin A (1997) Crises and crisis management: toward comprehensive government decision making. J Public Adm Res Theor 7(2):277–304

Spulber DF (1989) Regulation and markets. MIT press

U.S. Energy Information Administration (2015) International energy outlook 2015. Retrieved from http://www.eia.gov/forecasts/ieo/index.cfm

Wu Y, Xu R (2013) Green building development in China-based on heat pump demonstration projects. Renew Energy 53:211–219

Vreuls H, Grotte W, Bach P, Bosseboeuf D, Celi O (2005) Evaluating energy efficiency policy measures & DSM programmes. International Energy Agency—SenterNovem

Zhang X, Skitmore M, Peng Y (2014) Exploring the challenges to industrialized residential building in China. Habitat Int 41:176–184

Chapter 42
Chinese Building Energy Service Industry Evolution Based on Ecological Niche

Saina Zheng, Pengpeng Xu, Guiwen Liu and Jinxi Jing

42.1 Introduction

With the reform and opening-up, Chinese economy develops rapidly for past three decades, leading to significant growth in energy consumption. Because of the increasing consumption and decreasing energy amount, the energy shortage has created a bottleneck in economic growth. Therefore, energy efficiency remains a top priority for both the government and businesses in China. According to the World Bank, energy intensity level of primary energy of China is lower than most countries in the world, indicating that more energy is used to produce one unit of output in China. Thus, there is great potential for additional energy conservation, especially in building sector which is considered as a major energy consumer, almost occupying 1/3 of the total consumption (Levine et al. 2007). Facing such urgent situation, EPC (Energy Performance Contract), which can provide a cost-effective routine to overcome technological barriers, cut transaction and implementation costs, and take risks of clients (Sorrell 2007; ICF, NAESCO 2007) has been introduced into China. Since 1997, EPC has been applied in many industries, including building industry, accounting for 21% of the total, thus a new industry called building energy service industry emerged and has made great

S. Zheng (✉) · P. Xu · G. Liu · J. Jing
Faculty of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: Sena.zheng@yahoo.com

P. Xu
e-mail: xupp.cn@gmail.com

G. Liu
e-mail: gwliu@cqu.edu.cn

J. Jing
e-mail: jingjinxi@cqu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_42

achievement all these years. By 2015, the number of ESCOs (Energy Service Companies) has reached 5400, profession jobholders has reached 607 thousand, and the gross output is 312.734 billion (ESCO committee of China Energy Conversation Association, 2015). However, there are still massive barriers hampering the development of building energy service industry, such as no standardized measurement and verification (M&V), lack of trust, complex relationships between stakeholders, long payback period and so on Bannai et al. (2007), EVO (2009), Vine (2005), making the building energy service industry lagging behind. To improve the development of building energy service industry, it would be the top priority to find out the evolution of this industry and the current status. Since the typical evolution in the world is the ecosystem, many researchers apply ecological theory into industry evolution. Braden Allenby analyzed the evolution of culture of America with industrial ecology (Allenby 1998). Tukker and Cohen introduced the relation between the Automotive Transport System and the Industrial Ecology in detail (Tukker and Cohen 2004). In an ecosystem, how to evaluate the evolution? Grinnell first proposed the definition of ecological niche that it is the last allocation unit occupied by different species (Grinnell 1917). Elton modified this definition and demonstrated that ecological niche is the status and character of species in communities (Elton 2001). Nevertheless, since building energy service industry is a relatively new industry, few studies have systematically examined the evolution of it and set foundations for policy suggestions. Such knowledge gap is significant, owing to the challenges faced by Chinese ESCOs and the urgent need for energy conservation. Drawing on quantitative study through a series of incremental steps, this study may help subsequent researchers to better study on the development of building energy service industry.

42.2 Research Methodology

To better clarify the evolution of building energy service industry, this study adopts the method of ecological niche. As an important branch in modern ecology theory, niche theory describes the interactions of ecological element with the surroundings. Based on the ecostate-ecorole theory proposed by Zhu, ecostate represents the current status of the industry while ecorole represents the development tendency of the industry. The development of building energy service industry can be divided into three stages, namely growth stage, stable stage and lagging stage (Fig. 42.1).

The simplified logic sequence of empirical study is showed as follow (Fig. 42.2).

There are three steps for theoretical analysis to evaluate the evolution of Chinese building energy service industry.

Step 1: To develop the structure of building energy service industry ecosystem. Industrial ecology is a concept in which an industrial system is viewed not as an isolation from its surroundings but in concert with them, aiming to optimize the total materials cycle from virgin material to finished material, component, product,

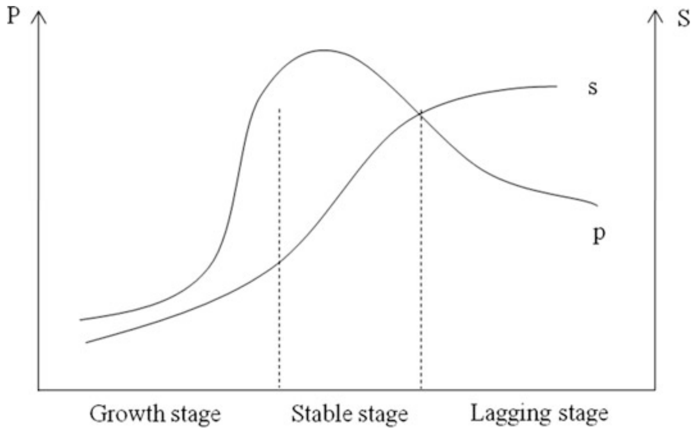


Fig. 42.1 Three stages of building energy service industry

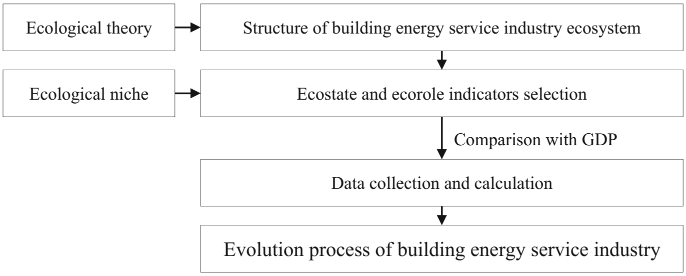


Fig. 42.2 Research framework

waste product, and finally to ultimate disposal. After several decades of developing, industrial ecology is utilized in many aspects. Ayres demonstrated that industrial ecosystem is a complex system which is composed of resource miner, processor, consumer, waste handler, and environment (Ayies et al. 1997).

Like the ecosystem, building energy service industry system is also composed of environment and building energy service. Environment includes nature environment, policy environment, economy environment, social environment etc. The building energy service part consists of BES-producer (Building Energy Service producer), BES-consumer, BES-decomposer, and all of them transfer energy by matter flow, fund flow and information flow, forming the ecological chain (Fig. 42.3).

Step 2: To select ecostate indicators and ecorole indicators which can represent the development of building energy service industry based on the ecological niche. From the perspective of ecological niche, building energy service industry can be viewed as one of the subsystems in economy ecosystem and the industrial resource can be viewed as ecological unit. Building energy service industry niche is the

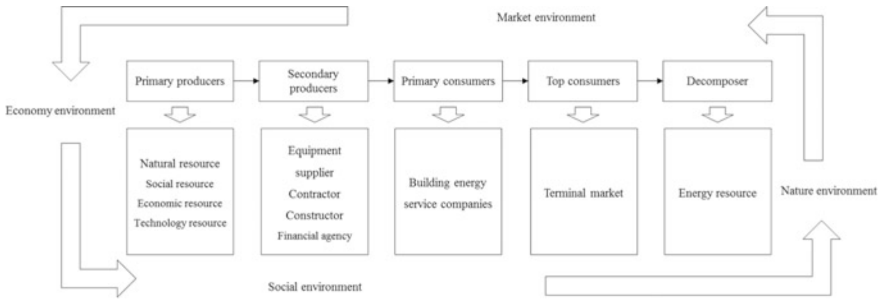


Fig. 42.3 Structure of BES-ecosystem

reflection of these ecological units. In addition, the GDP (Gross Domestic Product) is regarded as a comparison since nominal GDP estimates are commonly used to determine the economic performance of a whole country or region. By comparing with GDP, the development of building energy service industry can be estimated.

Step 3: To form several figures that indicate the evolution of building energy service industry compared with the development of GDP. With the finding shown in the figures, several suggestions are proposed to advance the development of building energy service industry.

42.3 Measurement of Ecostate and Ecorole in Building Energy Service Industry

42.3.1 Selection of Indicators

Following the rule of science, data accessibility, comprehensiveness, and measurability, several indicators are selected as Table 42.1 shows, and then AHP (Analytic Hierarchy Process) method is utilized to determine weight of each indicator.

In this paper, we set GDP (Gross Domestic Product) as a reference and measure the relative niche, since nominal GDP estimates are commonly used to determine

Table 42.1 Index system of building energy service industry

Criterion layer	Weight	Index layer (100 million yuan)	Weight	Total weight
"Ecostate" indicator of BES-industry	0.6	S_1: Gross production	0.5572	0.3643
		S_2: Gross investment	0.3202	0.1921
		S_3: Energy savings	0.1226	0.0736
"Ecorole" indicator of BES-industry	0.4	P_1: Variation of gross production	0.6080	0.2432
		P_2: Variation of gross investment	0.2721	0.1088
		P_3: Variation energy savings	0.1199	0.0480

the economic performance of a whole country or region. By comparing with GDP, the development of building energy service industry can be estimated.

42.3.2 Data Collection and Processing

This paper tries to use the model proposed by Zhu to build building energy service industry niche ecostate-ecorole model (Zhu 1996).

$$N_i = \frac{S_i + A_i P_i}{\sum_{j=1}^{n} (S_j + A_j P_j)}$$

N_i represents for the niche of building energy service industry; S_i represents for ecostate of BES-industry; P_i represents for ecorole of BES-industry; S_j represents for ecostate of industry j; P_j represents for ecorole of industry j and A_i represents for dimension coefficient. The value of N_i ranges between 0 and 1, and value close to 1 indicates that BES-industry has greater impact in all industries.

EMCA (ESCO Committee of China Energy Conservation Association) devotes itself into energy service industry, according to it, the data of building energy service industry can be access to. In all the indicators, "Energy savings" shares different dimension with other indicators, so in this paper, we multiply the amount of energy savings by the price of coal. We set the value of A_i and A_j both 1 and get the result as Tables 42.2 and 42.3.

Based on the statistics calculated, five figures can be drew as followings (see Figs. 42.4, 42.5 and 42.6)

Table 42.2 Index data of building service industry

	S_1	S_2	Energy savings (10,000 Mtce)	Price of coal (yuan)	S3	P_1	P_2	P_3
2003	3.7107	1.7871	11.7579	173.54	0.204047			
2004	7.056	2.3058	15.1704	210	0.318578	3.3453	0.5187	0.114532
2005	9.933	2.751	18.0978	240	0.434347	2.877	0.4452	0.115769
2006	17.3355	3.9732	26.1387	270	0.705745	7.413	1.2222	0.271398
2007	45.4797	13.755	67.0971	304.81	2.045187	28.14	9.7818	1.339442
2008	87.633	24.507	119.5467	418.55	5.003627	42.147	10.752	2.95844
2009	123.4128	41.0172	200.0838	394.35	7.890305	35.784	16.5102	2.886677
2010	175.6209	60.3771	223.6185	453.31	10.13685	52.206	19.3599	2.246546
2011	262.5546	86.6103	346.1619	498.43	17.25375	86.94	26.2332	7.116898
2012	347.2077	117.1065	383.9556	477.5	18.33388	84.651	30.4962	1.080132
2013	452.6802	155.8872	537.5412	500	26.87706	105.483	38.7807	8.54318
2014	556.5777	201.3396	629.1915	480	30.20119	103.908	45.4524	3.324132
2015	656.7414	218.3076	704.2182	550	38.732	100.17	16.968	8.530809

Table 42.3 The niche of building energy service from 2004 to 2015

	S_1	S_2	S3	P_1	P_2	P_3	BES-ecostate	BES-ecorole	Bes-niche	GDP-ecostate	GDP-ecorole	GDP-niche	Relative BES-niche
2004	2.067602	0.572229	0.025016	2.033942	0.141138	0.013732	2.664848	2.188813	3.700912	160289.7	24570.8	106002.1	3.49E-05
2005	3.931603	0.738317	0.039058	1.749216	0.121139	0.013881	4.708979	1.884236	4.634967	184575.8	24286.1	120459.9	3.85E-05
2006	5.534668	0.88087	0.053251	4.507104	0.332561	0.032541	6.46879	4.872206	8.559732	217246.6	32670.8	143416.3	5.97E-05
2007	9.659341	1.272219	0.086524	17.10912	2.661628	0.160599	11.01808	19.93135	25.97036	268631	51384.4	181732.4	0.000143
2008	25.34129	4.404351	0.25074	25.62538	2.925619	0.354717	29.99638	28.9057	45.93609	318736.7	50105.7	211284.3	0.000217
2009	48.82912	7.847141	0.613445	21.75667	4.492425	0.346113	57.2897	26.59522	60.3581	345046.4	26309.7	217551.7	0.000277
2010	68.76561	13.13371	0.967351	31.74125	5.267829	0.269361	82.86667	37.27844	85.97026	407137.8	62091.4	269119.2	0.000319
2011	97.85597	19.33275	1.242778	52.85952	7.138053	0.853316	118.4315	60.85088	130.0264	479576.1	72438.3	316721	0.000411
2012	146.2954	27.73262	2.115309	51.46781	8.298016	0.129508	176.1434	59.89534	163.8837	532872.1	53296	341041.7	0.000481
2013	193.4641	37.4975	2.247733	64.13366	10.55223	1.024327	233.2094	75.71023	213.5503	583196.7	50324.6	370047.9	0.000577
2014	252.2333	49.91509	3.295127	63.17606	12.3676	0.398563	305.4435	75.94222	257.355	634043.4	50846.7	400764.7	0.000642
2015	310.1251	64.46895	3.702665	60.90336	4.616993	1.022844	378.2967	66.5432	290.9695	676708	42664.6	423090.6	0.000688

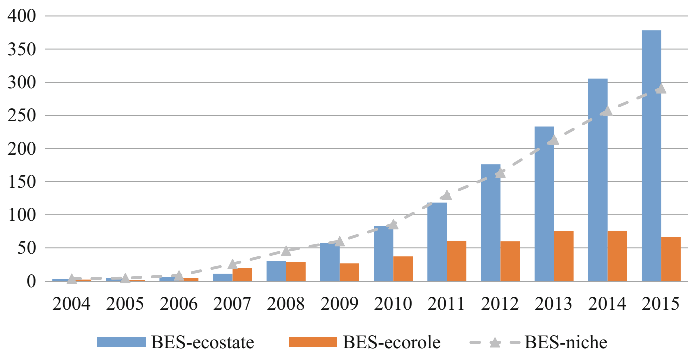


Fig. 42.4 Absolute BES-niche

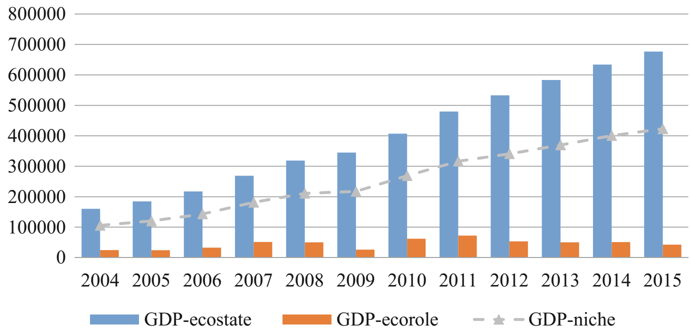


Fig. 42.5 GDP-niche

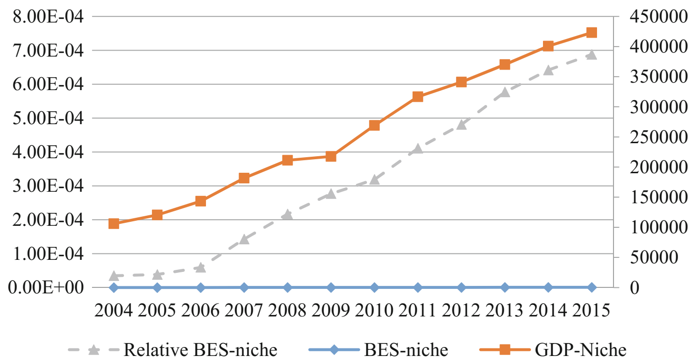


Fig. 42.6 Relative BES-niche

42.4 Disscussion

From 2004, the foundation of EMCA, the number of ESCOs experienced a rapid growth period. In 2004, there existed 60 ESCOs, and in 2007 the number is ten-fold, to 692. While four years later (2011), EMCA has recorded 3900 ESCOs, and in 2015, the number is 5426. It is surely a significant growth from 2004 to 2015, coinciding what Fig. 42.4 tells, BES-niche is developing with exponential growth. Meanwhile, Fig. 42.5 indicates that GDP-niche is increasing at a stable speed with a flat increase in 2008–2009 because of the financial crisis. Taken Figs. 42.4, 42.5 and 42.6 together, it can be revealed that although the BES-niche and GDP-niche are increasing at a relatively stable speed, there are two obvious turning points in relative BES-niche. The first turning point is in 2006 and from 2006, building energy service is advancing rapidly. There are two reasons for this, the first one is that the government published a series of policies concerning finance and technology to advocate the industry and the second one is that ESCO is established in 2004 to promote the building energy service industry and after two years development, it really made a difference since 2006. The second turning point is in 2010 and from then on building energy service industry develops more rapidly rather than before. That is because more and more policies and support are provided by not only the government but also the social capital. In addition, from 2010, China put more emphasis on sustainability and low-carbon ever than before. A closer look at Fig. 42.6, it can be analyzed that although building energy service industry is developing rapidly, compared with development of GDP, it lags far behind. This means the evolution of building energy service industry is not as good as it supposed to be, leaving huge potential for it to develop. As a result, more policies and support are needed to boom the industry. Firstly, it is essential to standardize contracts. Finland, France, Italy, Japan, The Netherlands, Norway, Sweden and the United States have suggested a model energy performance saving contract to be used in public procurement of ESCO services (Westling 2003). Secondly, an energy-saving certification system needs to be set. Performance-based projects are subject to energy-saving certification system, and standardization guidelines is an important activity (Kats et al. 1997; Kromer and Schiller 2000). Finally, it is a must to raise people's awareness of energy conservation. Only in this way will people adopt measures to save energy, improving the development of building energy service industry.

42.5 Conclusion

Since first introduced into China in 1998, building energy service industry make great achievements. This paper makes an analysis of the building energy service industry development utilizing ecological theory. After selecting six indicators and collecting data from EMCA, the graphs of building energy service industry development and GDP development are formed. From the graphs, this paper demonstrated that building energy service industry is developing rapidly because of the policies and financial support, however, lagging far behind GDP development. Based on the findings, this paper attempts to propose several suggestions to advance the industry development. In future studies, by dividing sub-industries of building energy service industry, the bottleneck can be found out and exact corresponding suggestions will be proposed to promote the development of building energy service industry, making it in accordance with GDP development.

Acknowledgements The work described in the current paper was supported by a grant entitled "Study on Synergetic Mechanism and Evolutionary Model of Building Energy Service Industry Development" from the National Natural Science Foundation of China (Grant No. 71403033). The authors would like to thank anonymous reviewers.

References

Allenby B (1998) Context is everything. J Ind Ecol 2(2):6–8

Ayies RU, Ayres LW, Klöpffer W (1997) Industrial ecology: towards closing the material cycle. Int J Life Cycle Assess 2(3):154

Bannai M, Tomita Y, Ishida Y, Miyazaki T, Akisawa A, Kashiwagi T (2007) Risk hedging against the fuel price fluctuation in energy service business. Energy 32(11):2051–2060

Elton CS (2001) Animal ecology. University of Chicago Press

EVO (2009) International energy efficiency financing protocol: standardized concepts

Grinnell J (1917) Field tests of theories concerning distributional control. Am Nat 115–128

Kats G, Rosenfeld A, McGaraghan S (1997) Energy efficiency as a commodity: the emergence of an efficiency secondary market for savings in commercial buildings. In: Proceedings of the ECEEE

Kromer JS, Schiller SR (2000) Measurement and verification protocols–M&V meets the competitive and environmental marketplaces. In Proceedings of the 2000 ACEEE summer study on energy efficiency in buildings

Levine M, Urge-Vorsatz D, Blok K, Geng L, Harvey D, Lang S et al. (2007). Residential and commercial buildings. Climate change 2007. Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Sorrell S (2007) The economics of energy service contracts. Energy Policy 35(1):507–521

Tukker A, Cohen MJ (2004) Industrial ecology and the automotive transport system. J Ind Ecol 8(3):14–18

ICF, NAESCO (2007) Introduction to energy performance contracting. ICF International

Vine E (2005) An international survey of the energy service company (ESCO) industry. Energy Policy 33(5):691–704

Westling H (2003) Performance contracting. Summary report from the IEA DSM Task X within the IEA DSM implementing agreement. International Energy Agency, Paris

Zhu C (1996) The niche ecostate-ecorole theory and expansion hypothesis. Acta Ecol Sin 17(3): 324–332

Chapter 43
Clean Development Mechanism in Airports: The Colombian Case

J.D. González-Ruiz, E.A. Duque and J.C. Restrepo

43.1 Introduction

With the purpose of helping the developing countries and the developed ones achieve their greenhouse gas (GHG) emission reduction targets at low costs, the Kyoto Protocol (KP) determined the Clean Development Mechanism (CDM) as one of the most flexible mechanisms leading towards this goal. The Clean Development Mechanisms can also be transacted in the international carbon markets since they generate the widely-known Certified Emission Reductions (CERs); they similarly encourage sustainable development and closing the existing social gaps in the developing countries (e.g. the power supply coverage). The most industrialised countries that signed the KP committed to credit and finance the least industrialised ones through the CERs. Basically, a CER is the equivalent of a tone of CO_2 reduced. These reduced amounts are negotiable in the carbon market and therefore, they constitute CDMs financing tools to lead investment into clean energy technologies (Schroeder 2009). Without a doubt, the Clean Development Mechanisms have turned into the most effective way for creating conscience on the relevance of making sustainable renewable energy (RE) the planet's main concern.

As it is currently used, the term "Sustainable Development" backdates to the early 1980s. The World Commission on Environment and Development (WCED)

J.D. González-Ruiz (✉) · E.A. Duque · J.C. Restrepo
Business Management School, Institución Universitaria Esumer, Medellín, Colombia
e-mail: jdgonzalez@esumer.edu.co; jdgonza3@unal.edu.co

E.A. Duque
e-mail: eduardo.duque@esumer.edu.co

J.C. Restrepo
e-mail: juan.restrepo43@esumer.edu.co

J.D. González-Ruiz
Faculty of Mines, Universidad Nacional de Colombia, Bogotá, Colombia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_43

in their Brundtland Report defined the terms as “the development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations” (Brundtland 1987). In Latin America, this type of projects has become more relevant as time passes and the potential of the region is explored. The key feature of this Mechanism is that the developed world sets its emission reduction goals and the developing world can benefit from the implementation of clean energy technologies. The following Fig. 43.1 shows some of the forms CDM projects can take.

As shown above, clean agriculture projects, afforestation projects, waste handling projects and others constitute reliable tools for developing CDMs. Particularly in Latin America, Small Hydro Power projects (SHP) represent the greatest potential in this field. These projects constitute a fifth of the world’s electricity and have helped economic growth in nations such as Brazil, Canada, China, the US and Norway (World Bank Institute 2009). Concerning Colombia, this country’s National Energy Generation Expansion Plan, which covers from 2014 to 2028, seeks to increase the country’s installed capacity by 15,489 MW represented mostly by hydroelectric plants, thermal gas and coal. However, from that amount, 10,315 MW is being distributed into hydropower plant projects (UPME—Unidad de Planeación Minero Energética 2015). Likewise, (Duque et al. 2016) state that “Colombia has boundless opportunities of becoming a relevant actor in the global context due to its hydroelectric capacity and its feasibility for participating in the international carbon credit market through the sale of Certified Emission Reductions”.

Additionally, an important factor that stimulates the development of CDM projects in this country is the possibility of connecting them to the National Interconnected Electric System (the grid) and thus, offer higher greenhouse gas reductions while improving the life quality of the communities that are not connected to this grid. It has been widely demonstrated that the development of a country or region is sturdily linked to its accessibility to power.

It is clear that to boost the development of sustainable energy in Latin America, it is necessary to design instruments leading to the implementation of CDMs as means for creating clean RE projects. This is mainly why, different funding alternatives to traditional systems for developing clean energy should also be taken into consideration. Besides helping meet the KP commitments, CDM projects represent very useful alternatives to raise funds since their financial costs are lower than other mechanisms and, particularly, because they distribute the received benefits among the neighbouring communities resulting in social development.

Indeed, authors have stated that “Latin America’s power demand could be met through these clean projects thanks to this region’s numerous mighty rivers, which generate electrical power” (Duque et al. 2016).

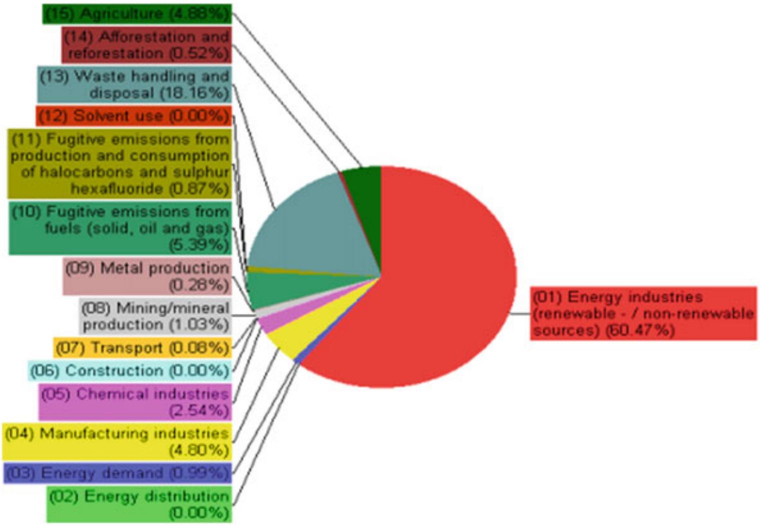


Fig. 43.1 CDM projects by project scope. *Source* Baker & McKenzie (2010)

43.2 The Challenge

On the other hand, thanks to the increasing number of passengers who travel by plane (a consequence of Globalization and its fall in ticket prices), the aeronautics sector has been confronted with diverse situations making it hard for them to meet their needs and GHG emission goals. Due to the KP and other climate change mitigation agreements signed by governments, this sector has emission reduction imposed goals. Besides that, in their quest for boosting customer loyalty, airlines and airports have self-imposed environmental policies. Up-to-date literature on the effects of the aviation industry on climate change has been increasing over the last decade. Many organizations, including the European Organisation for the Safety of Air Navigation (Eurocontrol 2013), are leading the path towards communicating the effects of this industry on the environment and the challenges aviation is facing to mitigate climate change (Eurocontrol 2013). Concerning this, the International Civil Aviation Organization (ICAO) has also devoted full chapters to this topic in their reports (for example the 2010 and 2013 Environmental Reports). Likewise, the Federal Aviation Administration (FAA) has been working on this subject for several years (Transportation Research Board 2012).

Unfortunately, the same reports say that even if the aviation industry "does meet all its targets, it will still have consumed 12% of the global temperature budget of 1.5 °C by 2050. If it fails to reach this target, its share of this budget could rise to as much as 27%" (Carbon Brief Analysis 2016). For the sector, reducing GHG emissions will not be easy taking into account that, the industry does not only emit CO_2 but methane, nitrous oxide and hydro and fluorocarbons into the atmosphere.

Additionally, given that those gases produce diverse warming impacts and have different lifetimes in the atmosphere, scientists have reported that "there are now fewer than five years remaining before the GHG emissions limit is blown. So, if the current rate of emissions continues, the 1.5 °C temperature budget would be used up sometime in 2021" (Carbon Brief Analysis 2016). This is undoubtedly, one of the two major challenges the aviation industry faces however, the second one represents a real issue that must concern all nations in the planet: "Airlines estimate that air travel will grow by an average of just under 5% per year up to 2034" (Carbon Brief Analysis 2016). Based on those figures, it is logic to predict that the polluting emissions that will be generated in the future increase in air travelling constitute the giant to defeat.

In order to face these challenges, international organizations are designing strategies based on the KP and the COP21. The International Civil Aviation Organization (ICAO) in its 37th assembly indicated that it would reinforce its policies and practices concerning environmental protection based on the CDM; literally, it was said that: "the Kyoto Protocol provides for different flexible instruments (such as the Clean Development Mechanism—CDM) which would benefit projects involving developing States" (ICAO 2012). In addition, the ICAO encourages its members to voluntarily establish carbon reducing schemes as mechanisms to control CO_2 emissions, and promotes carbon credit trade. As mentioned before, the world's aviation authorities are working hard in order to come up against the effects of climate change. The ICAO, as a part of the UN, has proposed relevant mechanisms that can lead to reduce the emission of pollutants into the atmosphere. The following figure presents some of these possibilities.

According to Fig. 43.2, aircraft CO_2 emissions from aviation can be reduced thanks to the diverse proposals presented. These may include alternative fuels and their life cycles (switching from petroleum to biofuel, which would need a high availability of bioenergy), incentives to biofuel agricultural production, price policies, updating aircraft technology and many others.

43.3 Great Actions

Several countries have already started working on this issue by implementing diverse mechanisms leading to this important goal. As it is known, the Cochin International Airport in India became the first to be completely powered by solar energy thanks to its 46,150 solar panels operating in the 45 acres of land near the cargo area. This airport is independent from the grid since it generates more power than it is consumed (it can actually generate from 50,000 to 60,000 kW daily). Besides Cochin, the Indian airport authorities have plans to transform 30 of their 125 air terminals into sustainable units.

Mexico City's international airport is another interesting project for the near future. It is looking for becoming the world's most sustainable airport by 2018. Norman Foster, a British architect responsible for several famous constructions has

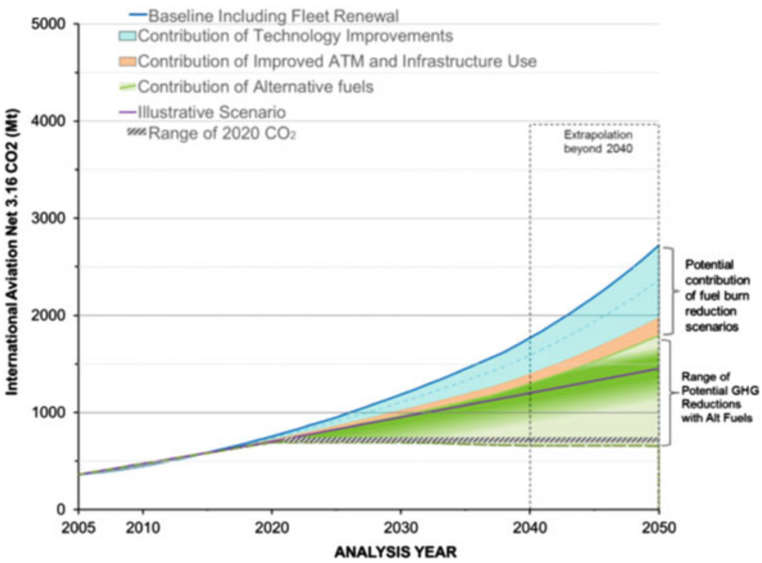


Fig. 43.2 Possible mechanisms recommended by the ICAO. *Source* Carbon Brief Analysis (2016)

been committed to this task. It can also be mentioned that North America has also been developing different projects. For example, the Chicago O'Hare International is recognised since 2003 due to its Sustainable Design Manual, which leads to establishing a "greener airport development". The manual was updated as the Sustainable Airport Manual in 2009 and has since been used as a standard for sustainability design by airports across the country (Telegraph 2015). The following is a list of actions the ICAO has implemented worldwide (Table 43.1).

Concerning the Colombian case, we can mention that El Dorado, its main airport (serving the country's capital city, Bogota) is now among the 23 airports in the world which have been awarded four stars by Skytrax (2016). It is important to notice that so far, only 4 airports have got the 5 Star qualification: Hong Kong's International Airport, Seoul's Incheon International Airport, Singapore's Changi Airport and Tokyo's Haneda International Airport. Among the other 19 terminals qualified Four Stars, there are those of cities such as Amsterdam, Copenhagen, Dusseldorf, Kuala Lumpur, London (Heathrow), Beijing and Shanghai, among others (González-Ruiz et al. 2017).

Given this positive and growing environment, for Colombia, it will be feasible to modernise its main air terminal by the implementation of green technologies and effective managing leading to sustainability. This kind of advances make part of the smart city concept. Undoubtedly, Colombian air terminals will become greener as time passes and el Dorado has already started its transformation. In this way, (Duque et al. 2016) state that "Colombia has boundless opportunities of becoming a relevant actor in the global context and its feasibility of participating in the

Table 43.1 Actions adopted by ICAO to limit or reduce emissions from international civil aviation

Type	Actions
Aircraft-related technology development	a. Aircraft minimum fuel efficiency standards b. Aggressive aircraft fuel efficiency standards, setting standards for the future c. Purchase of new aircraft d. Retrofitting and upgrade improvements on existing aircraft e. Optimising improvements in aircraft produced in the near to mid-term f. Avionics g. Adoption of revolutionary new designs in aircraft/engines h. Alternative fuels
Improved air traffic management and infrastructure use	a. More efficient ATM planning, ground operations, terminal operations (departure and arrivals), enroute operations, airspace design and usage, aircraft air navigation capabilities b. More efficient use and planning of airport capacities c. Conversion of airport infrastructure and ground support equipment to cleaner fuels d. Construction of additional runways e. Enhanced terminal support facilities f. Improved public transport access g. Collaborative research endeavours
More efficient operations	a. Best practices in operations b. Optimised aircraft maintenance (including jet engine cleaning/washing) c. Selecting aircraft best suited to mission
Economic/market-based measures	a. Voluntary inclusion of aviation sector in emissions trading scheme b. Incorporation of emissions from international aviation into regional or national emissions trading schemes, in accordance with relevant international instruments c. Establishment of a multilateral emissions trading scheme for aviation which allows trading permits with other sectors, in accordance with relevant international instruments d. Establishment of a framework for linking existing emissions trading schemes and providing for their extension to international aviation, in accordance with relevant international instruments e. Emissions charges or modulation of LTO charges, in accordance with relevant international instruments f. Positive economic stimulation by regulator: research programs, special consideration and government programs/legislation and accelerated depreciation of aircraft g. Accredited offset schemes h. Explore extension of CDM

(continued)

Table 43.1 (continued)

Type	Actions
	i. Taxation of aviation fuel
Regulatory measures/other	a. Airport movement caps/slot management b. Enhancing weather forecasting services c. Requiring transparent carbon reporting d. Conferences workshops

Source ICAO (2012)

international carbon credit market through the sale of CER (Certified Emission Reductions)". Bogota's air terminal is currently leading towards having more sustainable operations. India, Mexico, Ecuador (with its Galapagos Island green airport), Spain, Germany and the USA have taken the lead in this regard by building sustainable facilities. Many airports throughout the world have extensive programmes to mitigate carbon emissions and programmes as the Airport Carbon Accreditation are gaining ground (Mosvold 2015).

El Dorado's actions towards having more sustainable operations include the control of the neighbouring wildlife[1] (birds and mammals threating the safety of aircraft) and its own waste management system (organic, inorganic, solid and liquid materials). The following table presents how waste management is classified at this air terminal leading to more sustainable operations (Table 43.2).

43.4 The CDM and Airports

In order to guarantee the environmental integrity of the CDM, air terminals are asked to implement methodologies leading to determine a project's emissions baseline or the expected emissions without the project. Reasonably, it is necessary to monitor the emissions once a project is implemented. Then, the difference between the established baseline and the emissions registered will define if the project is effective or not.

In 2013, the Indira Gandhi International Airport (IGIA), New Delhi's airport, was the first airport terminal to register at UN as 'Clean Development Mechanism'. This terminal has been successful in reducing its emissions. It adopted several mechanisms leading to being more energy efficient and mitigating GHG. Thanks to those actions (which include efficient heating, ventilation and air conditioning, improved roof insulation, radar sensor based escalators among others), it reduces 16,413 tons of CO_2 annually (Bangalore Aviation 2013).

[1]Patrols keep track of the facilities; runways, taxiways, ramps, parking decks are frequently being watched taking into account that the terminal is located in the middle of some birds' migration routes.

Table 43.2 El Dorado Airport's classification of its solid waste

Type of waste	Place of origin	Cause
Waste from local and international flights	Platforms, decks and passenger terminal	Human activities (local passengers, visitors and airport staff)
Food waste	Fast food restaurants	Biodegradable waste from food
Packaging and containers	Cargo holds, platforms, decks and passenger terminal	Product wrapping and containers
Waste from cleaning services	Site serviced by the contractor	The action of sweeping, mopping and cleaning in general
Mud	Wastewater treatment plants	Normal operation of the wastewater treatment
Waste incinerator	Waste Incinerator	Controlled combustion of waste
Garden and lawn mowing waste	Green fields	Green fields maintenance processes

Source Ministerio del Medio Ambiente de Colombia (2001)

Concerning the Colombian context, it is clear that the construction of sustainable infrastructure will lead to the establishment of smart cities since this integrates new criteria into the application of technologies, systems, and the capacity to build a carbon-based network leading to the generation of synergies among the different components of the city. Therefore, the integration of sustainable cities will also bring challenges, as well as opportunities (Nam and Pardo 2012). Given this, the Government of Colombia enacted Law 1508 in 2012, which is based on Project Finance arrangements and private involvement mechanisms for building public infrastructure. This Law is estimated to close the coverage gaps between social and economic infrastructure (Congreso de Colombia 2012). In addition, the objective of these regulations is to increase the speed of developing infrastructure projects. In other words, this Law established the parameters to developing infrastructure projects in Colombia, allowing the State to characterize the process of designing, managing and implementing them. This established an instrument to boost private participation since the stakeholders and investors can have strong roadmaps to delineate the different investment schemes.

Nevertheless, in order to build sustainable infrastructure, especially airports, it is essential to find new financial resources to promote the development of environmentally-friendly infrastructure. For this reason, the Clean Development Mechanism is proposed as an alternative leading to improve sustainable projects, which, in turn, will help Colombia to meet its COP21 commitments. Unluckily, this financial resource has not been yet used in Colombia in transport infrastructure projects. It represents a real challenge for project developers to incorporate sustainable features in funding; these facts imply that private investors play a pivotal role. Otherwise, financial resources are becoming increasingly limited. In the current condition (debt crises in the developed countries), rising financial resources will be hard.

Thus, this paper recommends that components such as sustainability and funding (which had never been linked to building airport infrastructure in Colombia) are essential for boosting the development of the sector. Thus, this paper proposes to link these projects' development, via PPPs (including Project Finance), to the conception of environmental sustainability and financial profitability. So, PPPs must be considered as the State's organization tool for boosting the development of green airports. Also, project developers can view it as an instrument that enables and promotes the generation of new sources of funding for the sector. In this way, the development of airports in Colombia must incorporate sustainable financial resources based on green mechanisms like the CDM. Consequently, both closing the coverage gap in air transportation and the environmental issues will be reached.

43.5 Conclusion

This paper analyses the importance of including the Clean Development Mechanism (CDM) in the building of new airport projects in Colombia. As mentioned above, this mechanism has never been used in Colombia before and therefore, it could be a great opportunity for financing and building sustainable infrastructure helping the country to comply with its COP21 commitments. For the Colombian government, PPPs Law 1508 represents a great challenge for including environmental issues in the allocation of projects. Under this concern, investors are interested in receiving incentives, such as tax benefits for building smart city projects like the ones described in this paper. It could encourage private investors to the creation of a securities market of sustainable projects.

We expect that this paper will contribute to future studies. As we explored several challenges that are to be faced in order to develop CDM projects in airport infrastructures, we realised that the path leading to green airport, smart city infrastructure and sustainable development proposals involves a comprehensive understanding of the complexities and interconnections among finance, political, social and technical factors. Future research should include the effects of CDM Airport projects on the population and the urban areas.

Also, further research in this topic should involve the impact of Return on Equity of including the CDM as a financial resource. Accordingly, this analysis will allow having a better understanding of sustainable financial resources on structure capital. Finally, increasing new financial resources for developing sustainable infrastructure requires the establishment of new regulations including green remunerations for encouraging private investors.

References

Baker & McKenzie (2010) The clean development mechanism

Bangalore Aviation (2013) New Delhi is first airport terminal globally to register at UN as ‘clean development mechanism’ project

Brundtland GH (1987) Report of the World Commission on Environment and Development: “ our common future”. UN

Carbon Brief Analysis (2016) Analysis: only five years left before 1.5C carbon budget is blown

Congreso de Colombia (2012) Ley 1508 de 2012. Por la cual se establece el regimen jurídico de las Asociaciones Público- Privadas. Diario Oficial [Online]. Available: http://wsp.presidencia.gov.co/Normativa/Leyes/Documents/Ley150810012012.pdf

Duque E, González-Ruiz JD, Restrepo JC (2016) Developing sustainable infrastructure for small hydro power plants through clean development mechanisms in Colombia. Procedia Eng 145:224–233

Eurocontrol (2013) Challenges of growth 2013—Task 8 : climate change risk and resilience

González-Ruiz JD, Duque E, Restrepo JC (2017) Green airport infrastructure in Colombia: opportunities for public-private partnerships schemes. Pertanika J Sci Technol (Forthcoming)

ICAO (2012) Eligibility of civil aviation projects under the clean development mechanism

Ministerio del Medio Ambiente (2001) Guía ambiental para la operación y funcionamiento de aeropuertos. Bogotá D.C

Mosvold O (2015) Climate change is here to stay: Reviewing the impact of climate change on airport infrastructure. J Airport Manage 9(3)

Nam T, Pardo T (2012) Conceptualizing smart city with dimensions of technology, people, and institutions. New York

Schroeder M (2009) Utilizing the clean development mechanism for the deployment of renewable energies in China. In: IGEC III Special Issue Third Int. Green Energy Conf. (IGEC-III), June 18–20, 2007, Västerås, Sweden, vol. 86, no. 2, pp. 237–242, Feb 2009

Skytrax (2016) The World’s Top 100 Airports—2015 [Online]. Available: http://www.worldairportawards.com/Awards/world_airport_rating_2015.html

Telegraph (2015) The world’s first fully solar-powered airport. Travel/destinations

Transportation Research Board (2012) Airport climate adaptation and resilience. A synthesis of airport practice

UPME—Unidad de Planeación Minero Energética (2015) Plan de Expansión de Referencia Generación – Transmisión 2014–2028

World Bank Institute (2009) State and trends of the carbon market 2009

Chapter 44
Conflict Analysis of Concentrated Rural Settlement Development During Post-disaster Reconstruction in China: A Multi-agent Simulation

Y Peng, Q.X. Li and H.J. Bao

44.1 Introduction

Rural housing reconstruction is one of the most important approaches to realize better recovery of rural areas. Housing, as a residence to shelter people and the process to achieve this function, is essential in post-disaster reconstruction (Johnson 2007). It is partly because that housing is usually the biggest visible losses for the victims and partly for that housing reconstruction delays might result in serious social problems, such as homeless of the low-income people, jobless, and crime (Phillips 1998). Thus, the timely housing reconstruction is not only important for community recovery, but also critical for the security and redevelopment (Wu and Lindell 2004). Resettlement and reconstruction in situ is the two common approaches to housing reconstruction after natural disasters. Resettlement after natural disasters is usually impacted by geological safety, reconstruction cost and development opportunity given by the disaster. The top reason for resettlement is that the former site is subject to continued or expanded vulnerability, which is extremely dangerous for further living (Dikmen 2006). Even if geological safety is not the crucial concern in the decision making, resettlement may still be necessary, as reconstruction in the same site costs much more than resettlement (Dikmen 2006). Furthermore, the government might purposely resettle the victims, as the disaster provides convenient pretexts for population concentration and a chance to re-plan the regional development (Oliver-Smith 1991). Resettlement provides

Y. Peng (✉) · Q.X. Li · H.J. Bao
School of Public Administration, Zhejiang University of Finance & Economics, Hangzhou, PR, China
e-mail: pengyihz@gmail.com

Q.X. Li
e-mail: llqqxxx@126.com

H.J. Bao
e-mail: baohaijun@zufe.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_44

opportunities to improve the livelihood of the affected by better access to employment and public services. Consequently, planned and forced resettlement has been promoted for post-disaster reconstruction in developing countries in recent years (Badri et al. 2006). However, experience shows that resettlement can undermine livelihoods, disrupt social networks, and result in certain social tensions between displaced and host people (Bang and Few 2012).

Concentrated rural settlement (CRS) has been emphasized during reconstruction after 2008 Sichuan Earthquake. Concentrated rural settlement is where settlement is grouped into compact villages or large hamlets (Peng et al. 2014a). CRS within a village would not bring social tensions and disrupt social networks, while compared to reconstruction in situ, CRS within a village would still own the former resources and taking advantage of opportunities to improve infrastructure and public services. If properly managed, the CRS approach would facilitate sustainable development after disasters. China also promotes CRS under normal conditions. The Coordinated Urban-Rural Development Strategy (CURDS), the strategy of new socialist countryside construction, and the "increasing versus decreasing balance" policy (which is a short for "The balance between the increase of construction land in urban areas and the decrease of that in rural areas") are three major policies used to promote CRS even before the 2008 Sichuan Earthquake occurred (Peng et al. 2014a). The local governments of Sichuan Provinces also used the "opportunity window" after the huge earthquake to promote CRS development. Existing studies have been conducted to investigate the logic, the critical determinant factors, the decision process, and suitable deliver approach of CRS reconstruction (Peng et al. 2014a, b; Peng et al. 2013; Peng 2015). These studies have provided a useful clue to understand how to develop CRS during reconstruction after disasters.

However, few studies have been conducted to investigate the potential conflicts during the reconstruction. Similar to CRS development under normal condition, CRS reconstruction may also face farmers' resistance. Without systematic investigation on the behaviors of farmers and local government, it is not only difficult to reduce conflicts during CRS reconstruction, but also presents barriers for sustainable development in future. Therefore, this study aims to investigate the behavior of farmers and local government during CRS reconstruction. Section 44.2 would introduce the research method of this study. Evolutional game analysis is used to find the evolutionarily stable strategy for farmers and local government. Multi-agent simulation is used to validate the evolutional trend of farmers' and local government's behavior during CRS reconstruction. Section 44.3 presents the findings of the study. The impacts of three critical influencing factors on the evolutionary stable strategy have also been examined. Finally, Sect. 44.4 concludes this study with specifying the future studies.

44.2 Research Methods

Game analysis has been used to investigate conflicts between various stakeholders. The essence of the social dispute is the profit games (Sun 2006). Developed at the end of the 1950s, game theory has been a popular tool to explore competitive phenomena and to understand strategic interactions between different agents (Weibull 1995). In the game model, behaviors and decisions are collectively denoted by strategies, and the interplay between strategies is generally characterized by utility functions. The CRS reconstruction mainly involves two stakeholders, namely farmers and local government. Considering the various factors affecting strategy selections, the constituted system has a complicated utility balance process. Therefore, the CRS reconstruction game under the condition of finite sense is essentially an evolutionary process. As a dynamic model, evolutionary game theory reflects the behaviors of players with bounded rationality (Zhang 1999). The model records the repeated interaction processes that finally converge to Nash equilibrium points. This study therefore uses evolutionary game theory to investigate the behaviors of farmers and local government during CRS reconstruction.

Based on the field study, it assumes that local government can implement CRS reconstruction through normal means or special means. Normal means indicates that local government promotes CRS development based on existing policies and farmers' willingness. By contrast, special means indicates that local government forcedly promotes CRS development without considering farmers' willingness. For farmers, they have to accept CRS development or reject such a scheme, namely, choosing reconstruction in situ alternatively. If local government promotes CRS reconstruction with normal means and farmers accept such a scheme, local government would obtain some revenues (L) for providing infrastructure and public services and some political interests (P_1) due to improvement of living environment. Yet, local government would spend some compensation (C_1) for farmers to build CRS. Due to change of living and production way, the farmers face income change ($I_a - I_b$) and increased living cost (C_r) after concentration. However, if farmers reject such a scheme, the interest for local government is zero. The farmers can keep certain value of the old house (V_b) but would spend some reject cost (R_{c1}). Otherwise, if local government promotes CRS reconstruction through special means and farmers accept such a scheme, the local government would obtain less political interests (P_2) due to inappropriate means and pay more compensation to farmers (C_2). The increased living cost for the farmers would be C_{ar}. If farmers refuse, yet CRS would still be implemented as local government forcedly promotes such a scheme. Under this condition, the compensation to farmers would be (C_3) and the farmers have to bear reject cost (R_{c2}), which is assumed to be different from R_{c1}. It should be noticed that farmers face damage loss L_d no matter which approach is selected. This study supposes the probability for local government to

Table 44.1 The payoff matrix for a strategy game between local government and farmers

Farmers / Government	Accept	Reject
Implement by normal means	$(L_a + P_1 - C_1,$ $C_1 + I_a - L_d - C_{ar})$	$(0, V_b + I_b - L_d - R_{c1})$
Implement by special means	$(L_a + P_2 - C_2,$ $C_2 + I_a - L_d - C_{ar})$	$(L_a + P_2 - C_3,$ $V_b + I_b + C_3 - L_d - R_{c2})$

promote CRS with normal means is x and that with special means is (1−x) while the probability for farmers to accept CRS is y and that to reject CRS is (1−y). The payoff matrix for local government and farmers can therefore be shown in Table 44.1. The results of the evolutionary game analysis would be presented in the Section of Findings.

In addition, with the computer science development in recent decades, multi-agent models have been proposed to explore the different interactions of complex systems that arise in nature, societies, and engineering applications (Railsback 2006). Compared with the equation-based models of aggregate populations, the agent-based model is a bottom–up research method that focuses on the examination of systems from the individual perspective, the interacting components that can evolve over decentralized adaptive mechanisms, and the collective behaviors from agent interactions in a changing environment. Extensive publications have been made on the use of multi-agent systems to simulate strategic dynamic interactions among agents in recent decades. In this context, this study employs the multi-agent simulation to investigate the strategy selection in CRS reconstruction, aiming to enhance understandings on their interactions and resulting dynamics.

There are many multi-agent simulation platforms, including Swarm, Repast, and NetLogo. NetLogo can simulate many objectives and is suitable for complex social-natural systems changing with time. In addition, the programming language is simple, flexible, and user-friendly. Therefore, this study uses NetLogo to investigate the dynamic process of bargaining between farmers and local government during CRS reconstruction. This study assumes three types of agent in the simulation, namely, farmers, local government and environment. Environment is a virtual agent, which generates the activity space and records the attributes change of other agents. In the simulation, environment is set as a square, where the agents of local government and farmers are randomly distributed and randomly move in each cycle as shown in Fig. 44.1.

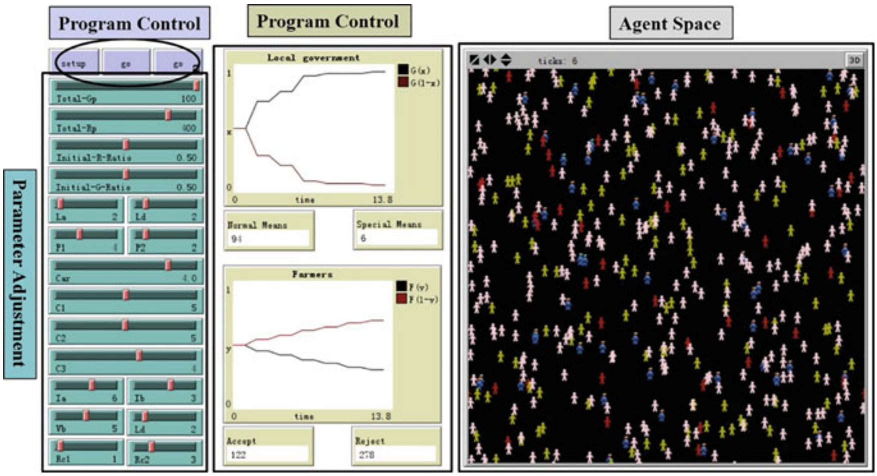


Fig. 44.1 Multi-agent simulation for bargaining between local government and farmers during CRS reconstruction

44.3 Findings

44.3.1 Results of Evolutionary Game Analysis

Based on the payoff matrix, the expected return for local government to implement CRS with normal means is shown in Eq. (44.1).

$$UG_1 = y(L_a + P_1 - C_1) \tag{44.1}$$

Otherwise, when the local government implements CRS with special means, the expected return is shown in Eq. (44.2).

$$UG_2 = y(L_a + P_2 - C_2) + (1 - y)(L_a + P_2 - C_3) \tag{44.2}$$

Therefore, the average expected return for local government is shown in Eq. (3).

$$UG = xUG_1 + (1 - x)UG_2 \tag{44.3}$$

Based on Eqs. 44.1, 44.2, and 44.3, the dynamic equation for local government to implement CRS reconstruction with normal means can be shown in Eq. (44.4).

$$\frac{dx}{dt} = x(UG_1 - UG) = x(1 - x)[(P_1 + L_a + C_2 - C_3 - C_1)y - (L_a + P_2 - C_3)] \tag{44.4}$$

On the other hand, the expected return for farmers to accept CRS is shown in Eq. (44.5).

$$\mathrm{UF}_1 = x(\mathrm{C}_1 + \mathrm{I}_a - \mathrm{L}_d - \mathrm{C}_{ar}) + (1-x)(\mathrm{C}_2 + \mathrm{I}_a - \mathrm{L}_d - \mathrm{C}_{ar}) \tag{44.5}$$

The expected return for farmers to reject CRS is shown in Eq. (44.6).

$$\mathrm{UF}_2 = x(\mathrm{V}_b + \mathrm{I}_b - \mathrm{L}_d - \mathrm{R}_{c1}) + (1-x)(\mathrm{V}_b + \mathrm{I}_b + \mathrm{C}_3 - \mathrm{L}_d - R_{c2}) \tag{44.6}$$

Therefore, the average expected return for farmers is shown in Eq. (44.7).

$$\mathrm{UF} = y\mathrm{UF}_1 + (1-y)\mathrm{UF}_2 \tag{44.7}$$

Based on Eqs. 44.5, 44.6, and 44.7, the dynamic equation for farmers to accept CRS reconstruction can be shown in Eq. (44.8).

$$\begin{aligned}\frac{\mathrm{d}y}{\mathrm{d}t} = y(\mathrm{UF}_1 - \mathrm{UF}) = y(1-y)[\mathrm{R}_{c2} + (\mathrm{I}_a - \mathrm{I}_b) + (\mathrm{C}_2 - \mathrm{C}_3) - \mathrm{V}_b - \mathrm{C}_{ar} \\ + (\mathrm{C}_1 - \mathrm{C}_2 + \mathrm{C}_3 + \mathrm{R}_{c1} - \mathrm{R}_{c2})x]\end{aligned} \tag{44.8}$$

The dynamic equation characterizes the learning speed and direction for the stakeholders participating in bargaining. According to the Firedman, the five equilibrium points of the dynamic bargaining system are O(0,0), A(0,1), B(1,0), C (1,1), and D(x_D,y_D), where

$$x_\mathrm{D} = \frac{\mathrm{R}_{c2} + (\mathrm{I}_a - \mathrm{I}_b) + (\mathrm{C}_2 - \mathrm{C}_3) - \mathrm{V}_b - \mathrm{C}_{ar}}{\mathrm{C}_2 - \mathrm{C}_1 - \mathrm{C}_3 + \mathrm{R}_{c2} - \mathrm{R}_{c1}},$$

$$y_\mathrm{D} = \frac{\mathrm{L}_a + \mathrm{P}_2 - \mathrm{P}_3}{\mathrm{P}_1 + \mathrm{L}_a + \mathrm{C}_2 - \mathrm{C}_1 - \mathrm{C}_3}$$

In addition, according to Firedman, the equilibrium point is an evolutionary stable strategy (ESS) if its Det(I) > 0 and Tr(I) < 0. The four ESS equilibrium points are demonstrated in Table 44.2. Except for the equilibrium point C(1,1), other three equilibrium points imply conflicts between local government and farmers during CRS reconstruction.

44.3.2 Results of Multi-agent Simulation

The initial settings for multi-agent simulation are listed as follows: (1) The number of local government agents is 10 while that for farmers are 400. The initial proportion of strategy for local government to promote CRS through normal means (x) or farmers to accept CRS (y) is 0.5. (2) Each simulation cycle indicates one month for the bargaining between local government and farmers. The total number of cycles is less than 80, which indicates the bargaining process of 7 years. (3) Each agent can learn from and imitate the behaviors of other agents during the

Table 44.2 The ESS equilibrium points of the evolutionary game analysis

Equilibrium	Det (J)	Tr (J)
O(0,0)	$-(L_a + P_2 - C_3) * (R_{c2} - V_b - C_{ar} + \Delta I + \Delta C)$	$-(L_a + P_2 - C_3) + (R_{c2} - V_b - C_{ar} + \Delta I + \Delta C)$
A(0,1)	$-(P_1 - P_2 + C_2 - C_1) * (R_{c2} - V_b - C_{ar} + \Delta I + \Delta C)$	$(P_1 - P_2 + C_2 - C_1) - (R_{c2} - V_b - C_{ar} + \Delta I + \Delta C)$
B(1,0)	$(L_a + P_2 - C_3) * (R_{c1} + C_1 + \Delta I - V_b - C_{ar})$	$(L_a + P_2 - C_3) + (R_{c1} + C_1 + \Delta I - V_b - C_{ar})$
C(1,1)	$(P_1 - P_2 + C_2 - C_1) * (R_{c1} + C_1 + \Delta I - V_b - C_{ar})$	$-(P_1 - P_2 + C_2 - C_1) - (R_{c1} + C_1 + \Delta I - V_b - C_{ar})$

where $\Delta C = C_2 - C_3$, $\Delta R_c = R_{c1} - R_{c2}$, $\Delta I = I_a - I_b$.

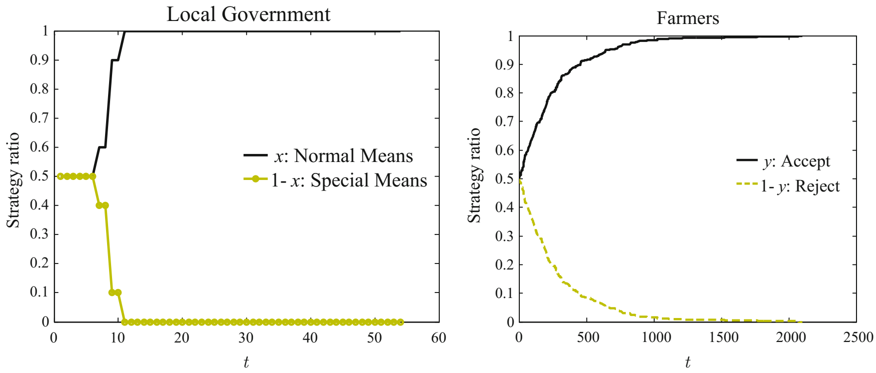


Fig. 44.2 The ESS is (normal means, accept) when satisfying the conditions of C(1,1)

evolutionary process. (4) The simulation would be stopped if the proportion of each strategy does not change with time. Based on such settings, the simulation results can be found in the follows.

CRS development under the equilibrium condition of C(1,1) is used for illustration as it is the ideal condition without conflicts. The relevant parameters are set as $L_a = 2$, $V_b = 5$, $P_1 = 4$, $P_2 = 2$, $R_{c1} = 1$, $R_{c2} = 3$, $C_1 = 6$, $C_2 = 5$, $C_3 = 4$, $I_a = 3$, $I_b = 2$, $C_{ar} = 0.5$, $L_d = 2$, which satisfies the conditions of C(1,1). As shown in Fig. 44.2, the ESS is, that is to say the stable strategy of the multi-agent simulation is (normal means, accept). CRS development under other equilibrium conditions can be simulated through similar ways.

44.3.3 Analysis of Influencing Factors

This study also investigates the impacts of various influencing factors on the ESS. In order to simplify the discussions, this section investigates the impacts on the ESS of C(1,1), which is the optimal strategy for CRS development and social security. The influencing factors mainly include the initial proportion of strategies, the income gap after concentration, and loss of house damage. It should be noticed that such analysis is also applicable to ESS of other three cases.

(1) **The impact of the initial proportion of strategies**

The initial proportion of strategies for local government to implement CRS development with normal means (*x(t)*) is between zero and one while that for famers to accept CRS development (*y(t)*) is also between zero and one. This study considers various combinations of initial strategy for local government and farmers, namely, [0.3,0.3], [0.3,0.5], [0.5,0.5], [0.7,0.3], and [0.7,0.7].

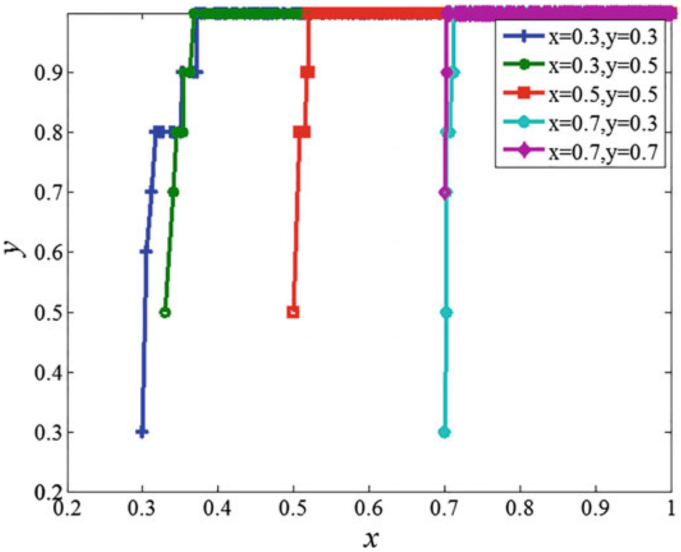


Fig. 44.3 The system's strategy evolution path under different combinations of initial strategy proportion

As shown in Fig. 44.3, the horizontal ordinate indicates the initial proportion of strategies for local government to implement CRS development with normal means while the longitudinal coordinate implies the initial proportion of strategies for famers to accept CRS development. It is found that the strategy gradually approaches the equilibrium point (1,1), namely, the ESS is (normal means, accept). The closer the initial proportion to the equilibrium point (1,1), the faster the strategy becomes to (normal means, accept). This trend means it would be faster to realize the optimal strategy if the proportion for local government to implement CRS development with normal means is higher and that for farmers to accept CRS development is higher. The analysis demonstrates that it would be better to clearly deliver the advantages and disadvantages to farmers in order to attract farmers' participation when initiating CRS development. Such measures are useful to generate high proportion of accepting CRS and therefore realize the optimal strategy (normal means, accept).

(2) **The impact of income gap after concentration**

The income gap after concentration is assumed as $\Delta I = I_a - I_b$, which is the income after concentration subtracts the income before concentration. This study investigates the impact of income gap after concentration on ESS through setting with four values, namely, −2, −1, 1, and 2.

It can be found in Fig. 44.4 that with the increasing of income gap after concentration, the ESS converts from (special means, refuse) to (normal means, accept). In practice, effective measures should be taken to expand the income

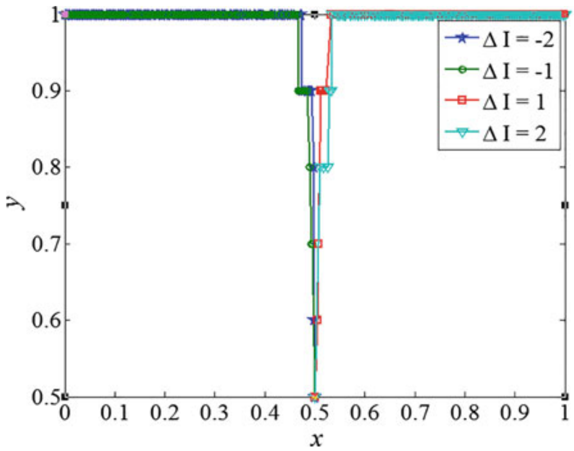


Fig. 44.4 The system's strategy evolution path under different values of income gap after concentration

source, increase income and reduce worries of living after concentration in order to promote CRS. In addition these measures should be clearly delivered to farmers in order to attract their participation.

44.4 Conclusion

CRS development during post-disaster reconstruction involves the general interests of farmers and local government. This study investigates the interest conflict between farmers and local government for CRS development during post-disaster reconstruction. This study develops the evolutionary game model to find the ESS based on the assumption of bounded rationality. Through NetLogo, multi-agent modeling is conducted to simulate the ESS and identify the impacts of critical factors. The findings demonstrate that the optimal strategy can be achieved through dynamically adjusting the interests of farmers and local government. Meanwhile, without proper management, there would be conflicts between farmers and local government in CRS development during post-disaster reconstruction.

The findings provide implications for local government to promote CRS development during post-disaster reconstruction. It can facilitate to better develop the rural areas using the opportunity window of post-disaster reconstruction. The findings show that the strategy (normal means, accept) is the optimal one in practice, which has positive impacts on CRS development and social security. In order to reach such a strategy, the interest of accepting CRS development for farmers should be improved. For example, in short term, the benefits of CRS should be clearly shown to farmers through village committee. The interest allocation scheme should be thoroughly discussed in order to attract more farmers to participate in CRS development. In long term, the increased building and living cost should be clearly told to the farmers. The local government should set a clear industry development planning, provide more job opportunities, and increase income in order to reduce worries of increased living cost after concentration. In addition, the benefits of promoting CRS through special means for local government should be reduced. Increasing the punishment cost and enhancing supervision on special action are useful to change the strategy of special means to normal means.

However, there are still some limitations in this study. The inner heterogeneity of farmers and local government are not considered in this study. Therefore, it is difficult to characterize the different choices of farmers and therefore cannot reflect the situation of different villages having different percentage of selecting CRS development. Future studies would improve the model and validate the simulation results with real-life data. In addition, more influencing factors should be investigated in order to better understand the behaviors of farmers. Such understandings would provide more references to CRS development during post-disaster reconstruction.

Acknowledgements This work was supported by National Natural Science Foundation of China (grant numbers 71503228), Natural Science Foundation of Zhejiang Province of China (grant numbers LQ16G030006), and Qianjiang Talents Program of Zhejiang Province (QJC1602006).

References

Badri SA, Asgary A, Eftekhari AR, Levy J (2006) Post-disaster resettlement, development and change: a case study of the 1990 Manjil earthquake in Iran. Disasters 30(4):451–468

Bang HN, Few R (2012) Social risks and challenges in post-disaster resettlement: the case of Lake Nyos, Cameroon. J Risk Res 15(9):1141–1157

Dikmen N (2006) Relocation or rebuilding in the same area: an important factor for decision making for post-disaster housing projects, http://www.grif.umontreal.ca/pages/DIKMEN_Nese.pdf. Accessed on 16 Nov 2010

Johnson C (2007) Strategic planning for post-disaster temporary housing. Disasters 31(4):435–458

Oliver-Smith A (1991) Successes and failures in post-disaster resettlement. Disasters 15(1):12–19

Peng Y (2015) A comparison of two approaches to develop concentrated rural settlements after the 5.12 Sichuan Earthquake in China. Habitat Int 49:230–242

Peng Y, Shen LY, Tan C, Tan DL, Wang H (2013) Critical determinant factors (CDFs) for developing concentrated rural settlement in post disaster reconstruction: a China study. Nat Hazards 66(2):355–373

Peng Y, Shen QP, Shen LY, Lu C, Yuan Z (2014a) A generic decision model for developing concentrated rural settlement in post-disaster reconstruction: a China study. Nat Hazards 71 (1):611–637

Peng Y, Shen LY, Zhang XL, Ochoa JJ (2014b) The feasibility of concentrated rural settlement in a context of post-disaster reconstruction: a study of China. Disasters 38(1):108–124

Phillips B (1998) Sheltering and housing of low-income and minority groups in Santa Cruz County after the Loma Prieta earthquake. In: Nigg JM (ed) The Loma Prieta, California, Earthquake of October 17, 1989: recovery, mitigation, and reconstruction, US geological survey professional paper 1553-D. United States Government Printing Office, Washington, DC

Railsback SF (2006) Agent-based simulation platforms: review and development recommendations. Simul Model Pract Theory 82:609–623

Sun LP (2006) Game: conflict of interest and harmony in ruptured society. Social Sciences Academic Press, Beijing (in Chinese)

Weibull J (1995) Evolutionary game theory. MIT Press, Cambridge, pp 847–858

Wu JY, Lindell MK (2004) Housing reconstruction after two major earthquakes: the 1994 Northridge earthquake in the United States and the 1999 Chi-Chi earthquake in Taiwan. Disasters 28(1):63–81

Zhang WY (1999) Game theory and information economics. Shanghai People's Publishing House, Shanghai (in Chinese)

Chapter 45
Construction and Demolition Waste Management: Experiences Learning from Developed Countries and Their Enlightenment to China

X.H. Wang, H. Zhang, L.N. Zheng, H.B. Duan, Y.N. Niu and J.Y. Wang

45.1 Introduction

As the rapid development of construction industry in the past few decades, China has been the country with the largest generation of construction and demolition (C&D) waste in the world (Jian and He 2012). Approximately 2.4–3.4 billion tons of C&D waste from 2007 to 2013 is estimated by Wang et al. (2016) based on a more reliable data resource. However, the recycling rate of C&D waste is less than 10%, and the majority of the waste has been disposed of landing or simple dumping (Wu et al. 2016), which triggers environmental safety issues. For example, *Shenzhen landslides* occurred at 20th Dec, 2015 was due to improper dumping. The accident led the death of 68 people, and the landslide area reached 380 thousand square meters (Xinhua News Agency 2016). In recent years, China has made considerable efforts to improve C&D waste management. For instance, *Regulations on Urban Construction and Demolition Waste Management* released by MOHURD (Ministry of Housing and Urban-Rural Development of the People's Republic of China) provides the policy support on the comprehensive recycling of C&D waste (Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) 2005). *Circular Economy Promotion Law* passed in 2008 by The State Council also claims that C&D waste should be made a comprehensive utilization and carried out comprehensive utilization or harmless disposal by qualified operators (2009). *Preferential Catalog of Value Added Tax on Product and Service to be Comprehensively Utilized* by State Administration of Taxation in 2015 required 70% of the refractory materials and other specific building materials

X.H. Wang · H. Zhang · L.N. Zheng ·
Y.N. Niu · J.Y. Wang
School of Civil Engineering, Shenzhen University, Shenzhen, China

H.B. Duan (✉)
Smart Cities Research Centre, Shenzhen University, Shenzhen 518060, China
e-mail: huabo@szu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_45

products in which the waste residue accounts more than 70% are exempt from VAT (value added tax) (State Administration of Taxation (SAT) 2015).

However, China is still at the its initial stage for C&D waste management compared with a few developed countries such as the United States (U.S.) and Germany. Germany is one of the pioneer countries to utilize C&D waste. C&D waste (except for wood, glass, plastic and metal) in 2012 in Germany reached a total of 192 million tons (excluding soil and stones) and the recycling rate was as high as 68% (The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) 2015). In recycling resources, 3.25 million tons of waste concrete was recycled in the form of recycled aggregate in the United States annually. About 68% was used in road base and foundation, 6% for mixing new concrete, 9% for mixing asphalt concrete, 3% for slope protection, 7% for general backfill and other applications accounting for 7% (Sun and Chen 2012).

Thus it can be seen that C&D waste management has been a major issue for China and it warrants significant attention. The principle objective of this paper is to figure out: the relative policies and regulations of C&D waste management, current situation and deficiency. Secondly, a comparative analysis of domestic and foreign C&D waste management are conducted. Finally, the gaps between China and developed countries from the perspective of environmentally sound management of C&D waste are pointed out, the problems and recommendations from China are put forward accordingly.

45.2 C&D Waste Generation and Disposal

A growing number of C&D waste is accompanied by mainly but not limit to solid waste, used bricks, mortar concrete, scrap steel, wood. And C&D waste mostly comes from three aspects: construction, demolition, building renovation. In order to better understand the current status of C&D waste management in China, it is essential to represent data about waste amount and recycling rate. Through review on studies related to C&D waste in China, it was found that the generation is valued by many scholars. Zhang (2013) adopted Grey Forecasting Model to predict the C&D generation amount from 2012 to 2015 and it reached around 2.1 billion tons in 2015. Besides, a more accurate estimation on C&D waste by Wang et al. (2016) is about 2.5 to 3.5 billion tons. Almost all of these estimations suggest that the amount of C&D waste in China is huge and increasing annually (see in Fig. 45.1).

Recycling rate of C&D waste differs significantly between countries owing to different levels of economic development and technology. Research reports from abroad, however, figure out that the recycling rate in most developed countries is obviously higher (see in Fig. 45.2).

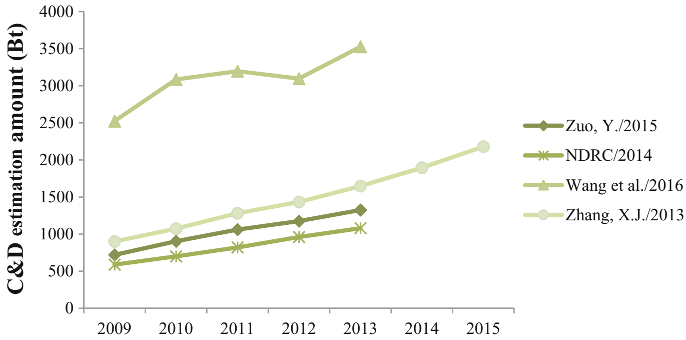


Fig. 45.1 The estimation on C&D waste generation from different sources. *Notes* 1. NRDC (2014) is abbreviation format of Report on the comprehensive utilization of resources in China by National Reform and Development Commision (2014). 2. Zhang (2013) predicted the C&D waste generation amount from 2012 to 2015 through Grey Forecasting Model. 3. The calculation approach in the paper of Zuo (2015) is similar to Zhang's

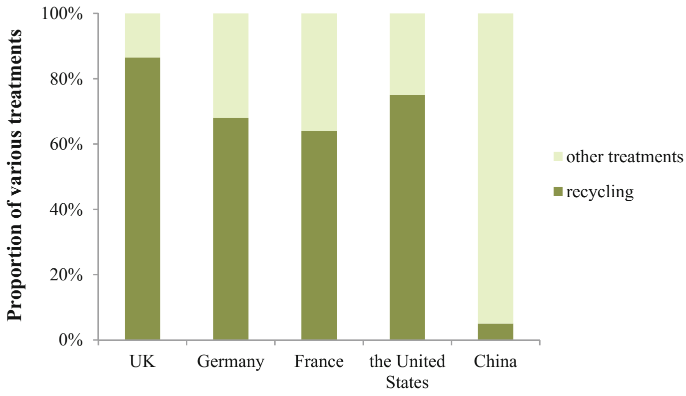


Fig. 45.2 Comparison of recycling rate on C&D waste between China and developed countries. *Source* The treatment data of France (2008) and UK (2012) is from reports of European Commission (2015). That of Germany (2015) is from BMUB (State Administration of Taxation (SAT) 2015) and that of the United States (U.S.) (2007) is from EPA (2004). The recycling rate of China is from NDRC (2014). *Note* Other treatment consists of mainly dumping in China, landfill in Germany, or incineration

At present, the recycling of C&D waste in China mainly concentrated on the scrap metal, steel which are of higher added value. On the other hand, most of the C&D waste is for exposed open air or landfill without any treatment, which not only generates the high cost of waste removal, but also takes up land, and the process of garbage piling up will cause environmental pollution. Accordingly, there exists an urgent need to resource-processing system for C&D waste.

45.3 C&D Waste Management

45.3.1 The Developed Country

45.3.1.1 The United States

As a developed country, the United States formed mature C&D management system in policies and regulations. In the United States, C&D waste is not explicitly regulated at federal level. *The Solid Waste Disposal Act* of 1965 is the first federal effort to improve waste disposal technology and has been revised for 5 times. The Resource Conservation and Recovery Act (RCRA), primary law governing the disposal of solid and hazardous waste, gives EPA the authority to control hazardous waste from the "cradle-to-grave." Besides, RCRA sets forth a framework for the management of non-hazardous solid wastes and is a federal law that encourages management mode of environmentally friendly (Laquatra and Pierce 2011). Under the RCRA,states are encouraged to develop comprehensive relevant plan to manage C&D waste. Any project that generates hazardous waste such as C&D waste is potentially subject to RCRA (Environment Protection Agency (EPA) 2004). Some of the hazardous waste which is likely to exist in construction waste is classified and specially managed under RCRA. Each type of RCRA hazardous waste is given a unique hazardous waste code using the letters D, F, K, P, or U and three digits (e.g., D001, F005, P039). Building materials containing lead and asbestos are also regulated by EPA.

At present, there are mainly several ways of C&D waste management in the United States generally as follows: pollution prevention, reducing, reusing, recycling, rebuying, pollution prevention (P2). For recycling, many building components can be recycled where markets exist, and the C&D waste which is processed by specific recovery mechanism and the recovery management office can be used as material components. For instance, asphalt, concrete, and rubble are often recycled into aggregate or new asphalt and concrete products and wood can be recycled into engineered-wood products, as well as mulch, compost, and other products.

45.3.1.2 Germany

Nowadays, a legal framework at national level for sustainable management of C&D have been existing in Germany. According to the statistics from German Ministry of Environmental Protection, Germany has developed more than 180 laws and regulations related to a waste disposal from 1970s till now (Sui 2010). First is the Legal obligations for specific C&D activities. *Ordinance on the Management of Municipal Wastes of Commercial Origin and Certain Construction and Demolition Wastes* contains important elements related to C&D waste management. For example, this ordinance addresses separation and requirements regarding the pre-treatment of construction and demolition waste. In addition, other instruments might also create good conditions for the sustainable management of C&D waste such as standards for recycled C&D waste and guide for requirements concerning the use of recycled building materials in engineering structures (The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) 2015). In terms of financial support, non-classified C&D waste is charged higher than the classified, and it will charge higher for the C&D waste that has been polluted than the non-polluted. Meanwhile, the price of building materials after recycling treatment is lower than that of original building materials. These ensure the recycling use of C&D waste. As with production technologies, Germany has a series of standards on quality protection of recycling building materials, and makes a clear request for specific components of the C&D waste which is used as concrete aggregate. All these have effectively promoted the recycling of C&D waste.

Usually, due to a small amount of C&D waste and industrialization process already experienced, the developed countries have different conditions on C&D waste management with China. Very much attention should be focused on the advanced technologies and a relatively completed legal system in developed countries. Key issues related to the resource reduction and classification of C&D waste should be also highlighted.

45.3.2 China

Nowadays, regulations and policies are significant instruments for C&D waste management in China, and provisions related to C&D waste are involved in the following several laws. *The Law on Solid Waste* is the first fundamental law on solid waste treatment (Chen et al. 2010), which requires producers pay for the waste. *Laws of Prevention and Control of Environmental Pollution Caused by Solid Waste* (revised, 2015), it brings C&D waste into legal management. The law confirmed the extended responsibility system through imposing the responsibilities for pollution prevention and control to producers, sellers, importers and users who generated solid waste, therefore to pay more attention to the life cycle management of solid waste (2005). Under *Cleaner Production Promotion Law*, the construction projects should adopt architectural design schemes, building and decoration materials, building structure fittings and equipment which are all conducive to the protection of environment and resources. The government encourages recycling of raw materials through preferential tax policies (The State Council 2002). To some extent, it controls the output of C&D waste from the source.

In *Regulations on Urban Construction and Demolition Waste Management*, three outstanding characteristics are involved in (latest issued) (Ministry of Housing and Urban-Rural Development of the People’s Republic of China (MOHURD) 2005): charge system for C&D waste disposal, approval system for C&D waste disposal and the increase of punishment. In terms of recovery, the target elaborated in *Implementation Plan of the Comprehensive Utilization of Bulk Solid Waste* is: by 2015, the comprehensive utilization rate of solid waste is above 50%, and C&D

waste utilization rate reached more than 30%. There is still a large gap compared with the developed countries (National Development and Reform Commission (NDRC) 2011a).

In sum, there is lack of specialized requirements for circular utilization of renewable resources. Secondly, laws and regulations on the C&D waste treatment have different legal effect as laws are formulated by the National Congress and its Standing Committee while regulations are enacted by the State Council. The source of C&D waste is managed in principle without mandatory method, where there is little law on the source of C&D waste management, which is difficult to achieve the intended purpose with limited enforcement. Moreover, comprehensive laws of circular economy haven't been formulated in our country at present. The policy system on the C&D waste management in is shown as Table 45.1.

Table 45.1 C&D waste disposal policy system (National level)

Name (issue time)	Category	Release department	Note
Environment Protection Law (2005) (2014.4.24)	Law	The State Council	
Laws of Prevention and Control of Environmental Pollution Caused by Solid Waste (2005) (1995.10.30)		The State Council	*Chapter* 1, *No. 5*
Cleaner Production Promotion Law (2002) (2003.01.01)		The State Council	*Chapter* 4, *No. 33*
Renewable Energy law (2005) (2005.2.28)		The State Council	
Circular Economy Promotion Law (2009) (2008.8.29)		The State Council	*Chapter* 4, *No. 33*
Regulation of City Appearance and Environmental Sanitation Management (1992) (1992.6.28)	Statute	The State Council	*Chapter* 3, *No. 29*
Regulations on Urban Construction and Demolition Waste Management (Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) 2005) (2005.3.01)	Rule	Ministry of Housing and Urban-Rural Development (MHUD)	*No. 5*
Notice on the Responsibility Division of the Departments of the Construction and Demolition Waste-Reuse (National Development and Reform Commission(NDRC) 2011b) (2010.10.25)		The Central Editing Office	
Guidance on 12th Five-Year Comprehensive Utilization of Resources (National Development and Reform Commission (NDRC) 2011c) (2011.12.10)	Subject Plan	National Development and Reform Commission (NDRC)	
Implementation Plan of the Comprehensive Utilization of Bulk Solid Waste (National Development and Reform Commission (NDRC) 2011a) (2011.12.10)		NDRC	

45.3.3 Shenzhen

As the representative of developed cities in China, Shenzhen has experienced rapid urban expansion through increasing sharply in construction activities. Approximately 30 million cubic meters spoil generated annually in Shenzhen (Shenzhen Municipal Audit Bureau (SMAB) 2015). The construction activities produce about 6 million cubic meters annually in Shenzhen, and 60% of them is landfilled. However, the exiting C&D waste landfills have exceeded their bearing capacity (Shenzhen Municipal Audit Bureau (SMAB) 2015).

In the context, a series of regulation, measure and policy were established since 2009 (Table 45.2). Take *Regulation on Emission Reduction and Utilization of Construction and Demolition Waste in Shenzhen* as an example, it regulates that Construction Administrative Department is in charge of construction waste reduction and recycling C&D waste charging fee system and C&D waste site classification system are involved in it. Therefore, the cycling treatment of the refuse and clay residue in Shenzhen face a huge challenge and chance.

In terms of engineering practices, South University of Science and Technology is the first project in which the C&D waste is utilized on the spot. The materials which have been processed on site will be transported to chose workshops or other construction sites to be made into renewable building materials products or materials laying the foundation of the ground (2011). In addition, Shenzhen Huawei Building Materials Company has transformed the C&D waste into new energy-saving building materials, taking the leading position in recycling of C&D waste. The successful operation of the project will set an example for comprehensive utilization of C&D waste.

Table 45.2 C&D waste disposal policy system in Shenzhen

City	Name (implement time)	Release department
Shenzhen	Regulation on reduction and utilization of construction and demolition waste in Shenzhen (2009.05) (Municipality Oceanic Administration of Shenzhen 2014)	Standing Committee of the People's Congress in Shenzhen
	Technical specification for construction and demolition waste reduction (2011.10) (Ministry of Housing and Urban-Rural Development in Shenzhen 2011)	Ministry of Housing and Urban-Rural Development in Shenzhen
	Operational management approach of landfills of construction and demolition waste in Shenzhen (Shenzhen Urban Management Bureau (SUMB) 2013) (2012.02)	Shenzhen Urban Management Bureau
	Measures for the administration of transportation and disposal of construction waste in Shenzhen (2014) (2014.01)	Shenzhen Municipal Government

Because of the low proportion of the waste backfill and the comprehensive utilization ratio of C&D waste, Shenzhen plans to be newly built 27 landfills from 2015 to 2018. The total capacity will reach 93 million 200 thousand cubic meters.

45.4 Existing Problems of C&D Waste Management in China

To sum up, through the comparison with the C&D waste management in the United states and Germany, there are outstanding problems of C&D waste management in China in the following aspects:

(1) Unsound policy management on C&D waste

Firstly, it is embodied there is few laws used to specially manage C&D waste and the existing laws can't form a mutual complement and perfection. Secondly, responsibilities of the institutions managing C&D waste are not divided clearly, which leads to the duty among the relevant institutions including NDRC, The Housing Construction Bureau scattered or overlapped. Thirdly, the supervision system on C&D waste is imperfect including each stage of generation, collection, transportation and recycling or landfill.

(2) Lack of awareness of C&D waste management

Only a few economically developed cities do carry out the management of C&D waste actively, whereas the second tier-cities even smaller prefecture level cities are rarely aware of the hazards of C&D waste.

(3) Weak technical support for recycling C&D waste

At present, only a small number of enterprises such as Beijing Teda Company which is the first company utilizing C&D waste in Beijing have advanced technologies. Besides, it is difficult to make use of the recyclable materials in C&D waste because of the low degree of classification.

45.5 Conclusions and Recommendations

Current situations on C&D waste management in China has been illustrated in this paper, and there is great disparity with the developed countries. Regulations and statutes are important tools for construction and demolition (C&D) waste management. With the continuous development of China's economy, China has been making considerable attempts to C&D waste management. However, there still remains great challenges such as a lack of specific regulations on C&D waste management. Therefore efforts must also be directed at strengthening legal management and supervision to guarantee the effectiveness of C&D waste management from the legal level. Special laws and institutions of C&D waste are recommended. To attain the goals in *Twelfth Five-Year Comprehensive Utilization of Resources Guidance* and enhance the recycling of construction waste in China, it is recommended to control and reduce generation and discharge quantity of C&D waste in site from source such as the material selection and to utilize the C&D waste generated from construction site directly as far as possible. Finally, it is necessary to carry out preferential policies and financial support for the materials which is processed by the C&D waste raw materials.

In a long run, it should therefore draw lessons from advanced technologies and management experiences in developed countries and to propose corresponding suggestions to solve the crisis of C&D waste management in China.

Acknowledgements This study was supported by Scientific Research Foundation of Introduced High Talent Financial Subsidies of Shenzhen University (000044), NSFC (25107090), NSFC (71272088) and JCYJ 20150525092941042.

References

Chen XD, Geng Y, Fujia T (2010) An overview of municipal solid waste management in China 2010(30):716–724

Environment Protection Agency (EPA) (2004) RCRA in focus: construction demolition and renovation. https://www.epa.gov/

European Commission (EC) (2015) Construction and demolition waste. http://ec.europa.eu/environment/waste/construction_demolition.htm

Jian ZX, He X (2012) Investigation on building waste and reclaim in Wenchuan earthquake disaster area. Resour Conserv Recycl 61(5):109–117

Laquatra J, Pierce M (2011) Waste management at the construction site. Integr Waste Manag 2011 (1):281–300

Ministry of Housing and Urban-Rural Development in Shenzhen (2011) Technical specification for construction and demolition waste reduction. http://www.szjs.gov.cn/csml/zcfg/xxgk/zcfg_1/jngl/201111/t20111107_1765453.htm

Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) (2005) Regulations on urban construction and demolition waste management. http://www.mohurd.gov.cn/zcfg/jsbgz/200611/t20061101_159078.html

Municipality Oceanic Administration of Shenzhen (2014) Regulation on emission reduction and utilization of construction and demolition waste in Shenzhen. http://www.szfdc.gov.cn/xxgk/zcfg/fgk/csghl/201308/t20130819_95011.htm

National Development and Reform Commission (NDRC) (2011a) Implementation plan of the comprehensive utilization of bulk solid waste. http://www.gov.cn/zwgk/2011-12/30/content_2033653.htm

National Development and Reform Commission (NDRC) (2011b) Notice on the issuance of "12th Five-Year" comprehensive utilization of resources guidance and Implementation of the comprehensive utilization of solid waste. http://www.gov.cn/zwgk/2011-12/30/content_2033653.htm

National Development and Reform Commission (NDRC) (2011c) Guidance on 12th five-year comprehensive utilization of resources. http://www.gov.cn/zwgk/2011-12/30/content_2033653.htm

National Development and Reform Commission (NDRC) (2014) Annual report of the comprehensive utilization of resources in China (2014). http://www.sdpc.gov.cn/xwzx/xwfb/201410/W020141009609573303019.pdf

Shenzhen Municipal Audit Bureau (SMAB) (2015) Shenzhen 2015 annual performance audit work report. http://www.sz.gov.cn/szsj/zxbs/sjgzbg/jxsjgzbg/201512/t20151224_3412313.htm

Shenzhen Municipal Government (2014) Measures for the administration of transportation and disposal of construction waste in Shenzhen. http://www.szum.gov.cn/zfwg/zcg/zcfg_1/201412/t20141204_2749114.htm

Shenzhen Special Zone Daily (2011) Million tons of construction and demolition waste is utilized in site. In Chinese. http://sztqb.sznews.com/html/2011-09/16/content_1749124.htm

Shenzhen Urban Management Bureau (SUMB) (2013) Statistical information on landfill in Shenzhen in 2012. http://www.szum.gov.cn/zfwg/zcg/zcfg_1/201412/t20141204_2749114.htm

State Administration of Taxation (SAT) (2015) Preferential catalog of value added tax on product and service to be comprehensively utilized. http://szs.mof.gov.cn/zhengwuxinxi/zhengcefabu/201506/t20150616_1256758.html

Sui YW (2010) Analysis on the reasons of high recovery rate of construction and demolition in Germany. In Chinese

Sun LR, Chen JL (2012) Current situation and benefit analysis of resource utilization on construction and demolition waste. Eur Architectural Tech 43(7):598–600

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) (2015) Construction and demolition waste management in Germany. http://ec.europa.eu/environment/waste/studies/deliverables/CDW_Germany_Factsheet_Final.pdf

The State Council (1992) Regulation of city appearance and environmental sanitation management. http://www.gov.cn/gongbao/content/2011/content_1860772.htm

The State Council (2002) Cleaner production promotion law. http://www.npc.gov.cn/wxzl/gongbao/2012-05/29/content_1728285.htm

The State Council (2005) Laws of prevention and control of environmental pollution caused by solid waste. http://www.gov.cn/flfg/2005-06/21/content_8289.htm

The State Council (2005) Environment protection law. http://www.npc.gov.cn/huiyi/lfzt/hjbhfxzaca/2014-04/25/content_1861320.htm

The State Council (2005) Renewable energy law. http://www.nea.gov.cn/2012-01/04/c_131260380.htm

The State Council (2009) Circular economy promotion law. http://www.gov.cn/flfg/2008-08/29/content_1084355.htm

Wang XH, Zheng LN, Wu HY, Duan HB, Wang JY (2016) Quantity and treatment status of C&D waste in China. International symposium on construction and real estate management in 2016. In press

Wu HY, Duan HB, Wang JY, Niu YN, Zhang G (2016) Demolition waste generation and recycling potentials in a rapidly developing flagship megacity of South China: prospective scenarios and implications. Constr Build Mat 113(15):1007-1016

Xinhua News Agency (2016) 69 Victims have been found at the scene of the landslide accident in Shenzhen. http://www.js.xinhuanet.com/2016-01/13/c_1117758999.htm

Zhang XJ (2013) Studies and analysis on the resourcization of city construction waste in China. In Chinese

Zuo Y (2015) Research of Chinese construction waste resource utilization and recommendations. In Chinese

Chapter 46
Construction Project Manager Health and Safety Interventions Towards Improving Workers' Performance

W. Ayessaki and J. Smallwood

46.1 Introduction

The construction industry is one of the most labour intensive industries (Agapiou et al. 1995; Kalsum 2010; Rowlinson and Walker 1995), and the largest employer in most countries worldwide (Ameh and Shokumbi 2013; Mee-Edoiye and Andawei 2002). Productivity trends in the South African construction industry have notable effects on national productivity and on the economy as a whole (Allmon et al. 2000; Pekuri et al. 2011).

Since workers constitute a large part of the construction cost and workers' hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, the improvement of workers' performance should be a major and continual concern to achieve projects' objectives. Worker performance is thus an important factor contributing to the timely completion and success of a construction project (Kalsum 2010).

This research seeks to enhance the Project Management Body of Knowledge (PMBOK) in the area of performance improvement, with H&S as a pivot. It also seeks to be reminiscent of CPMs' influence on project parameters such as productivity and H&S, and how it may contribute to higher profitability and higher standards of construction.

W. Ayessaki · J. Smallwood (✉)
Department of Construction Management, Nelson Mandela University, Port Elizabeth, South Africa
e-mail: john.smallwood@mandela.ac.za

W. Ayessaki
e-mail: winnyam@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_46

46.2 The Literature Review

46.2.1 H&S Culture and Perception

A survey undertaken by Smallwood and Deacon (2001) concluded that H&S culture impacts H&S practices, the allocation of resources to H&S, and performance relative to H&S. Although any success will remain questionable, various national and international initiatives have endeavoured to persuade the industry to change the culture relative to H&S. Furthermore, there remain a number of specific issues and challenges, which indirectly affect worker H&S and their performance. These include the transient nature of the workforce, competitive tendering and focus on price, a one-off product where design and construction are separated, the lack of leadership and evidence of traditional management style, and a risk-taking culture (ENTEC UK Ltd 2001).

46.2.2 Profitability, Performance and Productivity

Profitability is often confused with productivity. The difference between these concepts is that profitability takes into account monetary effects, while productivity relates to a real process that takes place among purely physical phenomena. Profitability, just as productivity, is also seen as a relationship between output and input, but the relationship is monetary; thus the influence of price factors is included (Tangen 2005).

46.2.3 The Construction Work Environment

Accidents affect the profitability of a project, and both direct and indirect costs could arise from site accidents (Mthalane et al. 2008). According to Khosravi et al. (2014), many attempts have been made to investigate factors that influence H&S performance on construction sites. Previous studies have however not been able to provide a holistic framework that would help CPMs address the different policy, process, personnel, and incentive aspects that may affect construction H&S, despite all the research conducted (Teo et al. 2005).

According to Lamm et al. (2007), there is growing and undeniable evidence that a healthy and safe working environment can increase labour productivity and in turn boost business profitability. However, a few issues cannot be overlooked, such as the negative outcomes, the best way to evaluate occupational H&S measures in terms of increased productivity, and their economic implications. It is also evident that items such as a high level of cooperation between the management and employees are key ingredients in ensuring the success of an occupational H&S intervention and the consequent growth in productivity.

Ergonomic deficiencies in the industry are believed to be the main cause of workplace health hazards, low levels of H&S, and reduced worker productivity, and quality. Awareness is still low in developing regions, although ergonomics applications have grown significantly in developed countries. Ergonomics technology can eradicate or mitigate H&S problems in the workplace if properly utilised and improve performance. Fewer injuries result in lower medical and compensation costs, less loss of wages and workdays, and financial benefits to the organisation (Shikdar and Sawaqed 2004).

Site layout planning is also frequently overlooked, in spite of the importance of site space as a resource, and the attitude of engineers has been that it will be attended to as the project progresses. However, a good site layout is vital in order to promote healthy, safe, and efficient operations, minimise travel time, reduce material handling, and avoid hindering material and equipment movements, particularly on large-scale projects (Samdani et al. 2006).

46.2.4 Construction Project Management and H&S

46.2.4.1 Design

A hundred construction accidents were reviewed by Gibb, Haslam, Hide and Gyi (Gambatese et al. 2005), and it was determined that changes in the permanent design would have mitigated the probability of the accidents in 47% of the cases. Construction Prevention through Design (CHPtD) is a process in which architects and engineers specifically consider workers' H&S when designing a building. Design professionals have customarily sought to design buildings or other facilities that ensure occupants' H&S, meet functional requirements, conform to quality standards, are cost-effective, and can be erected within a client's deadline. CHPtD can, therefore, be thought of as an alternative way of designing for constructability (Toole and Gambatese 2008).

46.2.4.2 Hazard Identification and Risk Assessments (HIRAs)

With prevention of injury incidents being one of the principal aims of H&S management, it is crucial to identify the causes of injury incidents and develop equivalent prevention measures in the industry (Leung et al. 2012).

46.2.4.3 Financial Provision for H&S

A study conducted by Chiocha et al. (2011) revealed that the inability, or rather the apparent reluctance of organisations to allocate adequate 'budget towards investigations relative to H&S issues' is notable.

46.2.4.4 Communication

According to the SACPCMP (2000), a CPM should have the knowledge and the ability to "establish and implement communication management processes including the preparation of agenda, chairing and preparing minutes of all necessary meetings on the project."

46.2.4.5 Partnering

Partnering has been designated "the most significant development to date as a means of improving project performance" and it represents an essential shift from the conventional adversarial relationships in construction (Bygballe et al. 2010). It is also defined as a relationship between two or more organisations, which is formed with the intent of improving performance in the delivery of projects (Ali et al. 2010).

46.3 Results and Findings

The study reported on entailed the compilation of more than 50 tables, however, due to the length constraints applying to papers, only the key findings relative to an aspect of the study are presented.

Table 46.1 presents the extent to which respondents agree that workers' motivation affects their performance. A 4.36 mean MS, which is $> 4.20 \leq 5.00$,

Table 46.1 Extent to which workers' motivation affects their performance (ECMBA and SACPCMP)

Group	Response (%)						MS
	Unsure	Strongly disagree				Strongly agree	
		1	2	3	4	5	
ECMBA	0.0	8.3	0.0	16.7	33.3	41.7	4.00
SACPCMP	0.0	0.0	0.0	0.0	45.8	54.2	4.54
Mean	0.0	2.8	0.0	5.6	41.6	50.0	4.36

indicates that in terms of the mean they agree to strongly agree/strongly agree with the statement.

Table 46.2 presents the extent of the relationship between poor training and WMSDs. The 3.47 mean MS, which is > 3.40 $\leq$ 4.20, indicates that respondents' concurrence with regards to the statement 'poor training is related to workers' experiencing WMSDs is between neutral to agree/agree.

In terms of the percentage of contract sums allocated towards H&S, the percentage 'unsure' responses is notable −45.5, 30.4, and 59.1% (Table 46.3). Approximately a third of the respondents indicated that provision in the form of provisional sums and detailed H&S preliminaries items is > 4%, and the second highest percentages are relative to '> 0 $\leq$ 1%'.

Table 46.4 indicates the extent to which inadequate H&S affects workers' performance according to ECMBA members. Poor site conditions are ranked first with a 4.17 MS (> 3.40 $\leq$ 4.20), which indicates that poor site conditions have between an impact to a near major/near major (negative) impact on workers' performance. They are followed by poor site planning, accidents and poor maintenance of welfare facilities; WMSDs are ranked last with a 2.33 MS, which indicates that they have between a minor to near minor/near minor impact on workers' performance. They are preceded by inadequate financial provision for H&S, lack of contractor pre-qualification in terms of H&S and inadequate medical examinations. 9/16 (56.3%) factors have MSs > 3.00, which indicates that the negative impact is major as opposed to minor.

Table 46.2 Extent of the relationship between poor training and WMSDs (ECMBA and SACPCMP)

Group	Response (%)						MS
	Unsure	Strongly disagree				Strongly agree	
		1	2	3	4	5	
ECMBA	16.7	16.7	16.7	33.3	8.3	8.3	2.70
SACPCMP	16.7	0.0	8.3	8.3	54.2	12.5	3.85
Mean	16.7	5.6	11.1	16.6	38.9	11.1	3.47

Table 46.3 Percentage of contract sums allocated towards H&S (SACPCMP)

Form	Response (%)						
	Unsure	0%	> 0% $\leq$ 1%	> 1% $\leq$ 2%	> 2% $\leq$ 3%	> 3% $\leq$ 4%	> 4%
Provisional sum	45.5	9.1	13.6	0.0	0.0	0.0	31.8
Detailed H&S preliminaries	30.4	0.0	17.4	13.0	4.3	0.0	34.8
Preliminaries items	59.1	4.5	4.5	4.5	4.5	0.0	22.7

Table 46.4 Extent to which inadequate H&S affects workers' performance (ECMBA)

Factor	Response (%)						MS	Rank
	Unsure	Minor				Major		
		1	2	3	4	5		
Poor site conditions	0.0	0.0	8.3	16.7	25.0	50.0	4.17	1
Poor site planning	0.0	8.3	0.0	16.7	50.0	25.0	3.83	2
Accidents	0.0	8.3	8.3	16.7	33.3	33.3	3.75	3
Poor maintenance of welfare facilities	0.0	0.0	16.7	25.0	33.3	25.0	3.67	4
Inadequate H&S measures	0.0	8.3	0.0	33.3	33.3	25.0	3.67	5
Poor provision of welfare facilities	0.0	0.0	25.0	25.0	16.7	33.3	3.58	6
Poor constructability	0.0	8.3	16.7	16.7	41.7	16.7	3.42	7
Illness/Ill health	8.3	0.0	16.7	16.7	41.7	16.7	3.33	8
Inadequate risk assessments	0.0	8.3	0.0	58.3	33.3	0.0	3.17	9
Inadequate design	8.3	0.0	25.0	25.0	33.3	8.3	3.00	10
Poor integration of design and construction	8.3	8.3	8.3	33.3	41.7	0.0	2.92	11
Exposure to HCSs	8.3	0.0	33.3	16.7	41.7	0.0	2.83	12
Inadequate medical examinations	8.3	8.3	16.7	41.7	25.0	0.0	2.67	13
Lack of contractor pre-qualification in terms of H&S	16.7	8.3	0.0	50.0	16.7	8.3	2.67	14
Inadequate financial provision for H&S	8.3	16.7	16.7	33.3	8.3	16.7	2.67	15
WMSDs	25.0	8.3	8.3	25.0	33.3	0.0	2.33	16

Table 46.5 indicates the extent to which inadequate H&S affects workers' performance according to SACPCMP CPMs. Accidents are ranked first with a 4.13 MS ($> 3.40 \leq 4.20$), which indicates that accidents have between an impact to a near major/near major (negative) impact on workers' performance. They are followed by inadequate H&S, poor site planning, poor site conditions, and poor constructability. Inadequate design is ranked last with a 3.17 MS, which indicates that it has between a near minor impact to an impact/impact on workers' performance. It is notable that 4 out of 5 uppermost factors indicated by the CPMs correspond to those indicated by GCs in Table 46.4. All factors also have MSs above the 3.00 midpoint, which indicates that the negative impact is major as opposed to minor, consistent yet again with the findings in Table 46.4.

CPM interviewees generally agreed with the findings, relative to HCSs, HIRAs, constructability, design and programme revisions, inadequate H&S, satisfaction with project aspects, financial provision, contractor pre-qualification, resource allocation towards H&S, workers' performance, review of H&S plans and partnering. A few trends have arisen from the interviews such as:

Table 46.5 Extent to which inadequate H&S affects workers' performance (SACPCMP)

Factor	Response (%)						MS	Rank
	Unsure	Minor				Major		
		1	2	3	4	5		
Accidents	0	12.5	4.2	16.7	41.7	37.5	4.13	1
Inadequate H&S measures	0	0	0	37.5	33.3	29.2	3.92	2=
Poor site planning	0	0	0	37.5	33.3	29.2	3.92	2=
Poor site conditions	0	8.3	4.2	29.2	37.5	29.2	3.92	4
Poor constructability	0	0	16.7	20.8	25	37.5	3.83	5
Inadequate risk assessments	0	0	12.5	20.8	29.2	33.3	3.75	6
Inadequate financial provision for H&S	0	8.3	12.5	33.3	25	29.2	3.71	7
Lack of contractor pre-qualification in terms of H&S	0	0	12.5	12.5	50	16.7	3.54	8
Illness/Ill health	4.2	0	20.8	25	16.7	33.3	3.5	9
Poor integration of design and construction	0	0	29.2	16.7	20.8	29.2	3.42	10
Poor maintenance of welfare facilities	0	0	20.8	33.3	20.8	20.8	3.33	11
Exposure to HCSs	0	0	25	25	25	20.8	3.33	12
WMSDs	8.3	0	12.5	29.2	33.3	16.7	3.29	13
Inadequate medical examinations	4.2	4.2	16.7	41.7	20.8	16.7	3.25	14
Poor provision of welfare facilities	0	4.2	20.8	29.2	25	16.7	3.21	15
Inadequate design	0	4.2	20.8	25	20.8	20.8	3.17	16

- The socio-economic status of workers: it has transpired in one of the interviews that one of the major issues with workers' performance relative to H&S is their social and economic reality they live in. Many workers live in sub-standard conditions and face many socio-familial difficulties, which can hinder their performance;
- Compliance: industry stakeholders tend to do the bare minimum as to 'comply' with regulations. They do not look beyond compliance to see the potential benefits of using H&S as a tool, and
- H&S and welfare awareness: clients, GCs, CPMs and other construction industry stakeholders value H&S and worker welfare. It is, therefore, important that awareness is raised so that they act in a better manner.

46.4 Conclusions

- Most small-size and medium-size contractors do not provide welfare facilities;
- Site conditions and welfare facilities are the least satisfactory project aspects among those used to evaluate H&S;
- Many CPMs do not review H&S plans;
- WMSDs can lead workers to work unsafely, which is the major cause of occupational injury incidents;
- Clients do not always have H&S objectives;
- H&S is the least of considerations when CPMs pre-qualify GCs;
- Insufficient financial provision is made for H&S on projects;
- Communication among/knowledge of industry stakeholders is important and yet found to be inadequate during projects, and
- CPMs require good communication skills.

46.5 Recommendations

Based upon the study undertaken and the conclusions, the following recommendations are made:

- CPMs need to make better use of their influence to convince clients with respect to: adequate financial provision for H&S; pre-qualifying contractors in terms of H&S, ensuring H&S is duly implemented during projects, and promoting partnering;
- CPMs need to improve communication channels between project stakeholders. Often what happens at worker level does not align with management's perceptions and vice versa, and project stakeholders have a different understanding of matters at hand;
- Legislators need to raise client awareness regarding H&S and worker welfare and need to provide more incentives for H&S compliance in order to assist CPMs with improving project H&S performance and therefore CWs' performance;
- Training and education institutions need to empower workers and industry professionals with H&S knowledge, and
- The quality of CPM H&S interventions towards improving workers' performance needs to be further interrogated.

References

Agapiou A, Price ADF, McCaffer R (1995) Planning future construction skill requirements: understanding labour resource issues. Constr Manage Econ 13:149–161

Ali A, Moh-Don Z, Alias A, Mamarussaman S, Pitt M (2010) The performance of construction partnering projects in Malaysia. Int J Phys Sci 5(4):327–333

Allmon E, Haas CT, Borcherding JD, Goodrum PM (2000) U.S. construction labour productivity trends, 1970–1998. J Constr Eng Manage 126:97–104

Ameh OJ, Shokumbi BB (2013) Effectiveness of non-financial motivational scheme on construction workers output in Nigeria. Ethiop J Environ Stud Manage 6(3):263–272

Bygballe LE, Jahre M, Sward A (2010) Partnering relationships in construction. J Purchasing Supply Manage 16:239–253

Chiocha C, Smallwood J, Emuze F (2011) Health and safety in the Malawian construction industry. Acta Structilia 18(1):68–80

ENTEC UK Ltd. (2001) Establishing effective communications and participation in the construction sector. HSE Res Rep. Sudbury: HSE Books, p 391

Gambatese JA, Behm M, Hinze JW (2005) Viability of designing for construction worker safety. J Constr Eng Manage 131(9):1029–1036

Kalsum U (2010) Assessing the performance of construction workers in Peninsula Malaysia. Int J Eng Technol 7(2):47–60

Khosravi Y, Asilian-Mahadi H, Hajizadeh E, Hassanzadeh-Rangi N, Bastami H, Behzadan AH (2014) Factors influencing unsafe behaviors and accidents on construction sites: a review. Int J Occup Saf Ergonomics 20(1):111–125

Lamm F, Massey C, Perry M (2007) Is there a link between workplace health and safety and firm performance and productivity? New Zealand J Employ Relat 32(1):75–90

Leung M, Chang IYS, Yu J (2012) Preventing construction worker injury incidents through the management of personal stress and organizational stressors. Accid Anal Prev 48:156–166

Mee-Edoiye M, Andawei MM (2002) Motivation, an alternative to improve workers' performance in today's construction industry. Quant Surv 40(3):2–6

Mthalane D, Othman AAE, Pearl RG (2008) The economic and social impacts of site accidents on the South African society. In: Proceedings of the 5th post graduate conference on construction industry development, Bloemfontein, South Africa, 16–18 March 2008, pp 1–10

Pekuri A, Haapasalo H, Herrala M (2011) Productivity and performance management—managerial practices in the construction industry. Int J Perform Meas 1:39–58

Rowlinson SM, Walker A (1995) The construction industry in Hong Kong. Longman, Hong Kong

SACPCMP (2006) Construction project manager: identification of work and scope of services for construction project managers registered in terms of the project and construction management professions, Act No. 48 Of 2000. SACPCMP, Johannesburg

Samdani SA, Bhakal L, Singh AK (2006) Site layout of temporary construction facilities using ant colony optimization. In: Proceedings of the 4th international engineering and construction conference, international committee, Los Angeles Section, August 27–29, pp 1–10

Shikdar AA, Sawaqed NM (2004) Ergonomics, and occupational health and safety in the oil industry: a managers' response. Comput Ind Eng 47:223–232

Smallwood J, Deacon C (2001) The role of health and safety culture in construction. In: Akintoye, A (ed) 17th annual ARCOM conference, 5–7 September 2001, University of Salford. Association of Researchers in Construction Management. 1:111–120

Tangen S (2005) Demystifying productivity and performance. Int J Prod Performance Manage 54(1):34–46

Teo EAL, Ling FYY, Chong AFW (2005) Framework for project managers to manage construction safety. Int J Project Manage 124(1):67–71

Toole TM, Gambatese J (2008) The Trajectories of Prevention through Design in Construction. J Saf Res 39:225–230

Chapter 47
Construction Work Productivity in South Africa: A Case of Gauteng Province Construction Industry

A.S. Sibande and N.J. Agumba

47.1 Introduction

Yan Aw, explains that small and medium sized contractors often make huge losses because of being less productive. Productivity is a major issue because it determines the future lifespan and profitability of a company relating to the amount of work being done. Contractors face problems when it comes to improving productivity because of the few number of skilled workers they have (Yan Aw 2001). According to Refaat, Hany, and Mohamed, a company that mostly minimizes input and maximizes output has the highest productivity improvement because profit is gained and then excellent quality of work is delivered (Abdel-Razek et al. 2006).

The enhancement of productivity in the construction industry suggests that by improving productivity, projects are completed more quickly, projects costs are lowered and the profit increases. Improving productivity also has an advantage of the contractor's winning more bids (Hammad et al. 2011). Productivity guarantees long term growth and development of the company. It has a positive effect to the society because as the productivity grows in the companies, the finance of the company also grows. This means that there might be an increase in the wages or salaries of the workers involved (Yan Aw 2001).

A.S. Sibande
Department of Construction Management and Quantity Surveying, University of Johannesburg, Doornfontein campus, Corner Seimert and Beit street, Johannesburg, South Africa
e-mail: sibandesibusiso@ymail.com

N.J. Agumba (✉)
Department of Construction Management and Quantity Surveying, Durban University of Technology, Corner Botanic Garden Road and Steve Biko Road, Berea, Durban, South Africa
e-mail: justusa@dut.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_47

The existence of situations that stifle the contractors from pursuing there set goals causes demotivation to the workers. These factors are: workers having poor interpersonal relationships, poor work attitudes, poor workmanship. These effects of demotivation slow down the rate of production in construction projects, therefore not completed on time and in good quality. These effects will lead to the company's reputation being dented. This should be improved or mitigated through acknowledgement of work that the labourers do in order to make them feel confident about their work and contributions (Ng et al. 2011).

There are many issues facing the construction industry globally and in South Africa, one of which is poor productivity on construction projects. Poor productivity can have significant impact on companies losing millions of rands in profit. In line with poor productivity, the construction industry is faced with poor quality of work, cost and time overrun, which is coupled by incompetent employees (Construction Industry Development Board 2015). Hence, this research focuses on the investigation of the factors that affect productivity in the construction industry, the effects of low productivity on construction projects, and the mitigation methods that can be used to improve productivity in the Gauteng Province in South Africa. In order to answer the problem statement. Three specific research questions were suggested, namely;

- What are the factors affecting contractors in achieving the required productivity in South Africa construction industry?
- What are the effects of poor productivity in the construction industry?
- What are the mitigating methods used to improve productivity in the South Africa construction industry projects?

47.2 Literature Review

47.2.1 Factors Affecting Construction Project Productivity

According to Horner and Talhouni, they opined that the causes of poor productivity in the construction industry, include; reduced supervision; absenteeism at work; increased accidents on site; decreased morale; and poor workmanship which results in the reworks on projects (Horner and Talhouni 1995).

Overtime is also an issue, much as it increases the output of work delivered, it also increases costs and at times reduces productivity. Further, schedule compression due to early delays in the projects causes compression of time for activities to compensate interruptions and to complete the assigned tasks on schedule. Therefore, when overtime is linked with schedule compression, this causes productivity losses because of shortage of materials or the equipment used for working. This will affect the planning and coordination of the tasks and unavailability of skilled labourers. Furthermore, mismanagement of construction teams on the construction sites, affects productivity. For example, steel fixture crew that has to wait before they can fix the reinforcement rods if the carpenter's framework is incomplete (Gudecha 2012).

According to Thomas, small accidents from nails and steel wires on site can also stop the work and this in turn decreases productivity. Further, insufficient lighting in the working space decreases productivity. This is because workers will not be able to see clearly in a darker working environment. The lack of equipment and poor quality of material are the factors resulting in poor productivity. The use of old equipment is a reason for a number of breakdowns happening on construction sites, also for the labourer to finish work on time is difficult because it take them a longer period and this reduces productivity (Thomas 1991). The use of poor material which is used for conducting work is also a problem because it leads to unsatisfactory work and this can be rejected by the supervisors after inspection which reduces productivity as well (Gudecha 2012).

The lack of compensation and increased labour age also affects productivity negatively (Odesola and Idoro 2014). Gundecha, explains that past literatures show that the lack of site experience on labourers is also a factor which affects productivity negatively, this means that in order to achieve good productivity, it is important to pay particular attention to the labour experience because this play a major role in the improvement of productivity (Gudecha 2012). According to Odesola and Idoro, the absenteeism of supervisors stifles productivity due to supervision and delegating duties (Odesola and Idoro 2014).

If improper tools and equipment are provided to the labourers, this will affect productivity. Further, the material storage location can be far from where the work is done due to a bigger size of construction site. Furthermore, the improper scheduling of the works, and the shortage of equipment which result in loss of productivity. Poor site layout contributes to loss of productivity. For example workers driving or walking long distances to the cafeteria, rest areas, washrooms or entrances. It has also been inferred that natural factors i.e. weather conditions and the geographical conditions could affect productivity on projects. If the weather conditions are too extreme (e.g. heavy rainfall or too cold) and last for a longer period, this could causes delay of work, thus affecting productivity (Thomas and Sudhakumar 2014).

External factors: External factors also include the weather conditions which is a significant factor that contractors and the management team need to consider for the completion of any construction project. Works such as formwork, concrete casting, external plastering, external painting and external tiling also affect construction productivity negatively because during winter seasons, they take time to dry (Gudecha 2012).

Political factors: Political factors especially when disputes arises during construction, delay the project proceedings because of court cases, etc. The government's taxation policies also influence the willingness to work and expansion of plants (Kumar 2004).

47.2.2 Effects of Poor Productivity on Construction Projects

Gundecha explains that clients end up terminating contracts with the contractors because of poor productivity, this in turn gives the company a bad name which makes other clients to not want to make relationships with company. He further explains that overtime adds on to poor productivity and the effects of this is that there will be a huge increase on costs because of the added hours on labour productivity meaning that overtime will have to be paid for (Gudecha 2012).

The other effect is that construction employees are only productive for 3.5 h of the 8 h shift they spend working on construction sites, this means that the money paid for the full 8 h of the shift does not mean that the construction team or workers were productive for that long. Cost overrun is also experienced due to over time, hence might lead to disputes (Aibinu and Jagboro 2002).

47.2.3 Mitigation Methods Used to Improve Productivity

Lim expressed the importance of various programmes for on-site performance improvement of a medium-sized construction. These programmes included problem identification, data collection and data analysis. This means that the methods of placing these various programme phases which are taken into practice and identify the problems, this needs to be examined as well so that the improvement of productivity can be easier (Lim 1996).

A report by McGraw-Hill Construction Research & Analytics, suggests that addressing risk management early in the project is imperative. This needs to be an ongoing process and it is critical because this will increase the opportunity for innovative solutions that are also less costly, thus improving the productivity of the company as well. Further, they indicated the use of Alternative Dispute Resolution (ADR) systems that include adjudication, mediation, conciliation, negotiation, mini-trial and arbitration. These methods avoid litigation and thus improving productivity because the contractors will abstain from court cases that drag for a long time (McGraw-Hill Construction Research & Analytics 2011).

Proper planning is one of the top priorities that contractors must consider and it is a necessity to get it right the first time. This means that the site setup is supposed to be seen as the most crucial part of the project. Bad planning could mean a reduction of productivity in the later parts of the project in terms of double handling or rework (Chan 2002).

Gupta and Kansal, explained that clarification of technical specifications is important to improve productivity in the construction projects. Supervision of construction works must be improved as well so that work can have progress, thus improving productivity. Supervisors are in this case responsible for the productivity and activity of labours. They have to manage the workforce and also make sure that work is completed in time as per specifications. The methods of construction also have to be managed in order to improve productivity. The construction method is mostly related to ways of working. This is because it depends mostly on the intelligence of people who are involved on the construction project. The use of wrong methods will result in cost and time overrun so it is important to improve and use more productive construction methods (Gupta and Kansal 2014).

47.3 Research Methodology

Quantitative method was used, hence a deductive approach. A structured questionnaire was used for collecting the data. A total of 65 questionnaires were distributed to a random sample of respondents, of which 42 usable questionnaires were returned, representing 64.6% response rate. According to Fellows and Liu, random sample is mainly used where there is no evidence of variation in the structure of the population and therefore each member of the population has an equal chance of being selected (Fellows and Liu 1997). The target population were the construction workers i.e. architects, quantity surveyors, civil engineers, construction managers, project managers and other professionals in the construction industry in the Gauteng Province in South Africa. The questionnaires were distributed using emails and drop and collect method. The two methods were used in order to improve the response rate of the respondents. The data was analysed using statistical package for social science (SPSS) version 22. The questionnaire was divided in four sections; section A explored the demographic data like the sex, age level of education, education qualification of respondents, etc. Section B looked at the factors affecting productivity of workers in the construction industry; Section C aimed at evaluating the effects of worker productivity in the construction industry; Section D explored the mitigation methods to improve productivity in the construction industry. Section B, C and D were on a 5-point Likert scale. The Likert-scale questions are discussed based on mean score. Therefore, the difference between the upper and lower ends of the used scale is 4.0 since there are five points. Hence, each range can be equated to 0.80 because the extent of the range is determined by a division between 4.00 and 5 (4/5). In this current study the meanings of the range are: $>4.21 \leq 5.00$ strongly agree; $>3.41 \leq 4.20$ Agree; $>2.61 \leq 3.40$ Neutral; $> 1.81 \leq 2.60$ Disagree; $> 1.00 \leq 1.80$ strongly disagree.

47.4 Findings and Discussions

47.4.1 Profile Data Results

The profile of the respondents suggest that, 59.5% of the respondents were male and 40.5% were female. On age group, 33.3% were in the age group 20–25 years, 16.7% of the respondents were in the age group 26–30 years, 28.6% were in the age group 31–35 years, 7.1% of the respondents were in the age group 36–40 years, 11.9% were in the age group 41–45 years, and 2.4% in the age group of 51–55 years. In relation to professional qualification, results showed that 28.6% were quantity surveyors, 16.7% were civil engineers, 9.5% were project managers, 19% were construction managers, 16.7% were architects and 9.5% selected others, which included an artisan and a site agent.

The respondent's years of experience, suggest that 23.8% of the respondents had 1–5 years of experience, 31% had 6–10 years of experience, 21.4% had 11–15 years, 14.3% had 16–20 years, and 9.5% had 20 years and above of experience in the construction industry. Furthermore, the results indicated that 9.5% of the respondents had Matric Certificates (grade 12), 26.2% had a diploma, 57.1% of the respondents had Bachelor's Degree, and this also includes respondents with B-Tech Degrees. The last 7.1% of the respondents had a Master's Degree. Further, the number of construction projects that were finished on time, suggests that 14.3% were 1–2 projects, 16.7% were 3–4 projects, 14.3% were 5–6 projects, 19% were 7–8 projects, 35.7% were more than 8 projects.

47.4.2 Factors Affecting Construction Work Productivity in the Construction Industry

Table 47.1 indicates that the most dominant factors affecting productivity include: delay in arrival of material and equipment (SD = 0.622; M = 4.95), and the attitude and morale of workers (SD = 0.177; M = 4.21). The respondents strongly agreed that they affected the projects productivity. The respondents were undecided or neutral on overtime (SD = 0.962; M = 3.38), and site access (SD = 0.869; M = 3.31) as factors that affected productivity. The findings were similar to the findings by Thomas and Sudhakumar, where unavailability of material on time at workplace, delayed material delivered by supplier, strikes, harsh weather conditions are the major factors that affects productivity on the construction industry(Thomas and Sudhakumar 2014). Also, the findings concurred with those of Gundecha, where lack of required construction material were ranked first, the lack of required construction tools/equipment was ranked second, and poor site conditions was ranked fourth which are the major factors affecting productivity (Gudecha 2012). The results were also in line with those of Gupta and Kansal, where lack of construction manager leadership, clarification in technical specifications, labour supervision, labour skills, labour fatigue and method of construction were the major factors affecting productivity in the construction industry (Gupta and Kansal 2014). However the, results were not in agreement with research by Odesola and Idoro, where the craft worker's pride, lack of skills of workers, rework and incompetent supervisors were rated as major factors affecting productivity(Odesola and Idoro 2014).

Table 47.1 Factors affecting construction work productivity in the construction industry

Factors affecting construction work productivity	Std. dev. (SD)	Mean (M)	Rank
Delay in arrival of material and equipment	0.622	4.95	1
Attitude and morale	0.717	4.21	2
Conflicts among colleagues and other construction parties	0.715	3.98	3
Incompetent labourers	0.640	3.93	4
Health and safety factors	0.850	3.90	5
Shortage of equipment and materials	0.850	3.90	5
Labour strikes	0.906	3.90	5
Use of alcohol and drugs	0.814	3.86	6
Project site location	0.864	3.71	7
Delay in handing in of Site	0.944	3.71	7
Mobilization/demobilization of resources	0.687	3.67	8
Weather and season changes	0.954	3.67	8
Crew size inefficiency	0.862	3.48	9
Inadequate planning	0.968	3.45	10
Reassignment of manpower to other work	0.801	3.43	11
Overtime	0.962	3.38	12
Site access	0.869	3.31	13

Source Fieldwork 2015

47.4.3 Effects of Productivity in the Construction Projects

The findings in Table 47.2 indicates that the most critical effect of productivity in the construction industry was: poor quality of work delivered because of time (SD = 0.634; M = 4.50), bad reputation as a company (SD = 0.791; M = 4.36), loss of capital from client (SD = 0.650; M = 4.33), increased project cost because of extension of time (SD = 0.721; M = 4.33), and profit loss (SD = 0.813; M = 4.21). These findings are in line with the findings of Aibinu and Jagboro, where time overrun, cost overrun, disputes, and litigation were major effects of productivity on construction projects (Aibinu and Jagboro 2002). The results were also similar to the findings by Sambasivan and Soon, where also time overrun, cost overrun, disputes, and litigation were major effects of productivity on construction projects (Sambasivan and Soon 2007).

47.4.4 Measures to Improve Productivity

The vital mitigation methods to improve productivity in Table 47.3 were: adherence to construction specifications (SD = 0.594; M = 4.52), ensuring quality of

Table 47.2 Effects of low productivity in the construction projects

Effects of low Productivity	Std. dev. (SD)	Mean (M)	Rank
Poor quality of work delivered because of time	0.634	4.50	1
Bad reputation as a company	0.791	4.36	2
Loss of capital from client	0.650	4.33	3
Increased project cost because of extension in time	0.721	4.33	3
Profit loss	0.813	4.21	4
Arising of disputes	0.794	4.17	5
Termination of contracts by the clients	0.608	4.14	6
Litigation (Solving disputes by the use of Courts)	0.838	4.07	7
Construction project delay	0.825	4.05	8
Company insolvency	0.680	4.02	9
Increased Claims due to breach of contract (e.g. finishing in time)	0.808	3.93	10
Health and safety factors	0.958	3.90	11
Loss of employees (Skilled and unskilled employees)	0.696	3.83	12

Source Field work 2015

works delivered (SD = 0.539; M = 4.38), proper flow of communication with other construction parties (SD = 0.697; M = 4.38), construction works according to the specified specification (SD = 0.665; M = 4.26), use of modern construction technology to save time e.g. new equipment (SD = 0.701; M = 4.26), site management and supervision (SD = 0.692; M = 4.24), and frequent progress meeting (SD = 0.790; M = 4.24). These findings corroborate with the findings of McGraw-Hill Construction (2011) where communication with other members throughout the project lifecycle, engaging in activities that reduce litigation, use of measuring techniques and technology were a major productivity methods used in the construction industry. Further, the results were similar to the findings of Lim, where there is use of new technology, quality material, frequent communication and following the drawing specifications are major mitigation methods for the improvement of productivity (Lim 1996). The results were also similar to those of Gupta and Kansal, where clarification in technical specifications, labour supervision, labour skills, labour fatigue and method of construction were the major factors for the improvement of productivity in the construction industry (Gupta and Kansal 2014).

47.5 Conclusion and Recommendations

The current study suggests that the factors that overwhelmingly affect productivity in the construction projects are, delay in arrival of material and equipment and the attitude and morale of workers. The study also established that the effects of poor

Table 47.3 Measures to improve productivity in the construction industry

Measures to improve productivity	Std. dev. (SD)	Mean (M)	Rank
Adherence to construction specifications	0.594	4.52	1
Ensuring quality of works delivered.	0.539	4.38	2
Proper flow of communication with other construction parties.	0.697	4.38	2
Constructing works according to the specified specifications.	0.665	4.26	3
Use of modern construction technology to save time e.g. new equipment.	0.701	4.26	3
Site management and supervision.	0.692	4.24	4
Frequent progress meeting.	0.790	4.24	4
Proper material procurement.	0.762	4.17	5
Managing health and safety factors.	0.824	4.17	5
Proper project planning and scheduling.	0.881	4.17	5
Target planning according to the work programmes.	0.803	4.12	6
Implementing appropriate construction methods.	0.790	4.10	7
Providing training for workforce.	0.826	4.00	8
Proper planned structure for the flow of information.	0.715	3.98	9
Use of measuring techniques on site e.g. Activity Sampling Technique.	0.731	3.95	10
Employing skilled labour.	1.011	3.95	10

Source Field work 2015

productivity were; poor quality of work delivered because of time, bad reputation as a company, loss of capital from client, increased project cost because of extension of time, and profit loss. Lastly the study found that in order for the construction industry to improve its productivity it must adherence to construction specifications, ensuring quality of works delivered, proper flow of communication with other construction parties, work according to the specified specification, use of modern construction technology to save time e.g. new equipment, site management and supervision, and frequent progress meeting.

47.5.1 Implications of the Study

The study was conducted in the economic hub of South Africa i.e. Johannesburg. Hence, the findings are of importance to the entire country. The researchers believe that the other eight provinces in South Africa can use these findings to develop policies that can improve the productivity in construction projects. It can therefore be suggested that the stakeholders should ensure that all participants involved in construction projects should be properly trained and have technical skills relevant to their work. This will ensure that the projects will be properly planned and effectively executed. Therefore it is recommended that the stakeholders in the construction industry should:

- adhere to the construction specifications;
- ensure quality of the work delivered;
- ensure proper flow of communication with other construction parties;
- use of modern construction technology to save time e.g. new equipment;
- ensure proper site management and supervision; and
- frequently have progress meeting.

47.5.2 Further Study

Recommendation for further study is to test the causal relationship of the strategies proposed to improve productivity and the project outcome in order to develop a model. The study further suggests that the construction companies should concentrate on the strategies in order to stifle poor productivity.

References

Abdel-Razek RH, Elshakour M HA, Abdel-Hamid M (2006) Labor productivity: benchmarking and variability in Egyptian projects. Int J Proj Manage 25:189–197

Aibinu AA, Jagboro GO (2002) The effects of construction delays on project delivery in Nigerian construction industry. Int J Project Manage 20:593–599

Chan P (2002) Factors affecting labor productivity in the construction industry. In: Proceedings of the eighteenth annual ARCOM conference, University of Northumbira, Association of Researchers in Construction Management, pp 771–780

Construction Industry Development Board (2015) Labour and work conditions in the South African construction industry; status and recommendations

Fellows R, Liu A (1997) Research methods for construction. Blackwell, Oxford

Gudecha MM (2012) Study of factors affecting labour productivity at a building construction project in the USA: web survey. Master of Science. Fargo, North Dakota: North Dakota State University of Agriculture and Applied Science

Gupta R, Kansal V (2014) Improvement of construction labour productivity in chambal region. 3 (10):34–37

Hammad MS, Omaran A, Pakir AHK (2011) Identifying ways to improve productivity at the Construction Industry. Acta Technica Corviniensis—Bull Eng 25(3):1–3

Horner R, Talhouni B (1995) Effects of accelerated working delays and disruption on labour productivity. Chartered Institute of Building, London

Kumar A (2004) Chapter 9 cited in V.D Desai small scale enterprises, Himalaya Publication, 5th edn New Delhi, pp 233–234

Lim EC (1996). The analysis of productivity in building construction. Unpublished Ph.D. Leicestershire, Loughborough University, UK

McGraw-Hill Construction Research & Analytics (2011) Mitigation of risk in construction: strategies for reducing risk and maximizing profitability. Company. McGraw-Hill Construction Company

Ng ST, Skitmore RM, Lam KC, Poon AWC (2011) Demotivating factors influencing the productivity of civil engineering projects. Int J Project Manage 22(2):139–146

Odesola IA, Idoro GI (2014) Influence of labour-related factors on construction labour productivity in the south-south geo-political zone of Nigeria 1, 17.

Sambasivan M, Soon YW (2007) Causes and effects of delays in Malaysian construction industry. Int J Project Manage 25:517–526

Thomas HR (1991) Labor productivity and work sampling: the bottom line. J Constr Eng Manage 117(3):423–444

Thomas AV, Sudhakumar J (2014) Modelling masonry labour productivity using multiple regression, In: Raiden AB, Aboagye-Nimo E (eds) Proceedings of the 30th annual ARCOM conference, 1–3 September, Portsmouth, UK, Association of Researchers in Construction Management, pp 1345–1354

Yan Aw B (2001) Productivity of small and medium enterprises in Taiwan (China): an international study. Int J Prod Econ 36(2):1–24

Chapter 48
Contractors' Organisational Culture Towards Health and Safety Compliance in Ghana

Z. Mustapha, C. Aigbavboa and W.D. Thwala

48.1 Introduction

Majority of the Ghanaian construction industries are Small and Medium-Sized-Enterprise (SMEs) contractors (Frempong and Essegbey 2006; Laryea 2010; Ofori and Toor 2012). Kheni et al. (2007) posits that the domination of the SMEs contractors in the Ghanaian construction industry has made it impossible to manage Health and Safety (H&S) effectively. The solutions of H&S should match the problems at hand because H&S accident has its roots in the contractor's organizational culture of an industry or organization. Culture has become popular among the various methods to improve H&S performance. Culture can be improved from one level to another. Culture creates a homogeneous set of assumptions and decision premises in which compliance occurs without surveillance (Grote 2007).

There is no doubt that major accidents have been attributed to a poor contractor's organization culture. It has now become necessary and important, to understand what culture (or more specifically) is depicted in a contractor's organization, to appreciate the concept better and for it to become useful (Grote 2007). Mustapha et al. (2015) in their findings from the study of the application of modified statistical triangle of accident causation in construction health and safety indicated that construction accidents lead to delay in project completion, increase the expenses and ruin the reputation and reliability of contractors. These incidents have placed the construction industry among the industries with unreasonable rates of accidents

Z. Mustapha (✉) · C. Aigbavboa · W.D. Thwala
Building Technology Department, School of Engineering, Cape Coast Technical University, P.O. Box AD. 50, Cape Coast, Ghana
e-mail: zakari.mustapha1967@gmail.com

Z. Mustapha · C. Aigbavboa · W.D. Thwala
Department of Construction Management and Quantity Surveying, Doornfontein Campus, University of Johannesburg, Doornfontein, Johannesburg P. O. Box 17011 South Africa

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_48

both permanent and non-permanent disabilities and even fatalities. Mustapha et al. (2015) posit that not all accidents are preventable since risk is beyond the human intervention and majority of accidents happen when employees disregard safety rules (unsafe acts) and management ignore the presence of unsafe conditions. This paper attempts to substantiate whether the contribution of contractors' organisational culture towards H&S compliance in Ghana will reduce the rate of accidents on sites. It began with contractors' organisational culture and discussed the application of PPE on site in complying with H&S towards accident prevention.

48.2 Methodolgy

The experts (academics and construction professionals) for the Delphi survey were selected for the study based on the criteria that was developed from the research questions under investigation. The construction professionals were selected from building technologists and quantity surveyors. A Delphi Study is a group decision mechanism requiring qualified experts who have deep understanding of the issues at hand (Okoli and Pawlowski 2004).

Expects were expected to meet a minimum of at least five (5) minimum criteria: residency—have lived in any of the Metropolitan/Municipal/District in Ghana at least more than one (1) year, knowledge—has knowledge of H&S in the construction industry, academic qualification—has been presented an earned degree (Bachelors-degree/Masters-degree/Ph.D.) related to any field, certification of employment/experience focusing on construction development or sustainable issues, experience—has a history of or currently performing consultation services for the government of Ghana, individuals, businesses, agencies, companies, and or organizations, relating to construction or other sustainable development.

The experts must exhibit a high degree of knowledge of experience in the subject matter in addition to extensive theoretical knowledge, employment—currently serves (or has previously served) in a professional or voluntary capacity (e.g., at place of employment—institution, business, agency, department, company) as supervisor or manager of establish that is involved with construction or sustainable development in Ghana, influence and recognition—has served or currently serving as a peer reviewer for one or more manuscripts received from a journal editor prior to its publication in the primary literature, with focus of the manuscript(s) on construction or sustainable development, authorship—is an author or co-author of peer-reviewed publications in the field of construction with emphasis in Ghana, has prepared and presented papers at conferences, workshop or professional meetings focusing on construction, sustainable development and H&S, research—has submitted one or more proposals to or has received research funds (grant or contract) from national, local government, regional, and or private sources that support construction, sustainable development and studies related to H&S, teaching—has organised, prepared, and successfully presented one or more H&S or sustainable development training workshops focusing on the group for which expertise is sought. The workshop or course must have been on H&S practices or has served as an individual or as a collaborative instructor in the teaching of one or more Polytechnics or University courses focusing on construction, sustainable development or related field, membership—member of a professional body (as listed on the expert questionnaire).

The expert should also be the representative of a professional body so that their opinions may be adaptable or transferable to the population and finally, willingness —Experts must be willing to fully participate in the entire Delphi survey. The selected expects for the paper represented a wide variety of backgrounds and guarantee a wide base of knowledge (Rowe et al. 1991). Rowe et al. (ibid) recommendations were adopted for the current study. The number of respondents should be large enough to ensure that all perspectives are represented, but not so large as to make the analysis of the results unmanageable by the researcher (Linstone and Turoff 1975). The adoption of five of these criteria was considered more stringent than the recommended number of at least two criteria by Rogers and Lopez (2002) and Dalkey and Helmer (1963). The five minimum criteria were framed after the four recommendations made by Adler and Ziglio (1996), with the inclusion of experts' residency status, which was considered to be compulsory for all selected experts. This was considered significant because experts were required to have a wide-ranging understanding of H&S practices within their locality.

Twenty (20) experts were invited to participate in the Delphi survey, thirteen (13) experts responded to participate and completed the first round, but only nine (9) experts were used for the study. This number was considered adequate based on literature recommendations from scholars which have employed the technique previously. Hallowell and Gambatese (2010) suggested that since most studies incorporate between eight (8) and sixteen (16) panellists, a minimum of eight (8) is reasonable. This was beyond the given limit in the current study. Hallowell and Gambatese (2010) argued that the size of a panel should be dictated by the study characteristics, number of available experts, the desired geographical representation and capacity of the facilitator. Experts were asked to rate the impact of other factors in predicting contractors' organisational culture towards Health and Safety compliance in Ghana. Data obtained from the survey was analysed with Microsoft EXCEL, spread-sheet software. The output from the analysis was a set of descriptive statistics such as means, median, standard deviations and derivatives of these statistics.

48.3 Contractor's Organisational Culture

An organisational culture is important because culture is best understood as "the way we employees work within their environment". It serves as a filter through which strategies are decided, and performance results attained as stated by Saint-Onge (in Fong and Kwok 2009). Organizational culture is also an organization's values, assumptions and expectations (Hooijberg & Petrock in Fong and Kwok 2009). Hence, an organisational culture has an influence on human behaviour, performance at work and safety outcomes as the safety management system. Therefore, culture forms the context within which people judge the appropriateness of their behaviour. It also creates a homogeneous set of assumptions and decision premises in which compliance occurs without surveillance (Grote 2007: 642). The IOSH (2004: 6) contends that it is insufficient to provide safe equipment, systems and procedures if the culture is not conducive to a healthy and safe working environment. Since behaviour is a product of culture just as much as accidents are a product of the prevailing culture (Wiegmann et al. 2002).

48.3.1 The Organisational Triangle

Figure 48.1 shows one of the many models in an organisational model (three organisational components and their relationship). 'Structure', 'processes', and 'culture' are the three components that can be identified in an organisation and its activities (Antonsen 2009; Guldenmund 2010; EU-OSHA 2011).

i. Organisational structure: This is a*formal* aspects of an organisation which distribution of tasks, roles and responsibilities, control, and authority (power). The structure determines how the organisational assignments should be achieved and by whom (Guldenmund 2010; EU-OSHA 2011).
ii. Organisational processes: This refers to the core business and supporting processes in an organisation. These relate to social relationships, communication and exchange of information among the workers in an organisation (Antonsen 2009; EU-OSHA 2011).
iii. Organisational culture or corporate culture: This relates to the *informal* aspects of work and organising of activities within the site. Organisational culture is often described as "the way employees carry out their activities within the site" (Guldenmund 2010; EU-OSHA 2011). Several cultures co-exist within the work environment which is with different units, departments, hierarchical layers, occupations. They are not isolated and have an effect on a specific

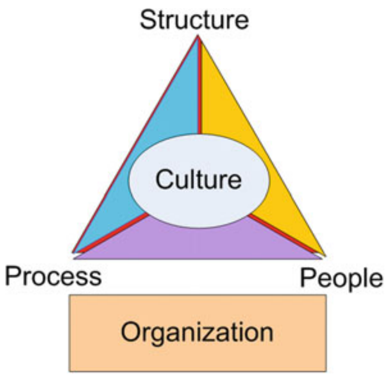


Fig. 48.1 The organisational triangle. *Source* Adapted from Antonsen (2009), Guldenmund (2010), EU-OSHA (2011)

Fig. 48.2 An organisational safety culture. *Source* Adapted from Antonsen (2009), Guldenmund (2010), EU-OSHA (2011)

characteristics of the work being carried out or the industry (Antonsen 2009; EU-OSHA 2011) (Fig. 48.2).

48.3.2 Occupational Safety and Health

Employers are required to provide and maintain a work environment that is safe from any risk to the health of employees since, hazards exist at every workplace. Therefore, employees are enshrined to comply with laid down rules and regulations of their organisations. The (IOSH 2004) contends that it is insufficient to provide safe equipment, systems and procedures if the culture is not conducive to a healthy and safe working environment. Grote (2007) opined that the solutions of H&S should match the problems at hand because H&S accident has its roots in the contractor's organizational culture of an industry or organization. Culture can be improved from one level to another. Dingsdag et al. (2006) argued that a positive culture leads to both improved H&S and as well as organisational performance. This development calls for improvement in the organisational culture of SMEs contractors in Ghana to enable them to put in more effort towards their contribution on H&S compliance. Culture creates a homogeneous set of assumptions and decision premises in which compliance occurs without surveillance as the case of SMEs contractors in Ghana (Grote 2007).

48.4 Discussion of Findings

From the eleven (11) identified attributes or measurement variables, only one (1) attribute or measurement variable (Communication of H&S information to workers) was considered by the experts to have reached consensus with IQD cut-off (IQD $\leq$ 1) score set to achieve consensus (Table 48.1). Four (4) of the attributes or measurement variables were considered by the experts to have very high impact

Table 48.1 Contribution of contractors' organisational culture

Contractors' contribution	Median	Mean	SD	IQD ≤ 1
Communication of H&S information to workers	9	8.57	1.05	0.82
H&S inspection	8	7.71	1.48	1.25
Training of workers on health and safety (H&S)	9	8.43	1.05	1.25
Company H&S policy	8	7.67	1.11	1.5
Update on H&S information to workers	8	8	1.31	2
Provision of signs/notices on sites	7	7.71	1.58	2
Involve workers in H&S program	9	8	1.2	2
H&S staffing	7	7	1.69	2.25
Provision of personal protective equipment (PPE)	9	8	1.51	2.25
Management commitment in H&S	8	7.57	1.84	2.25
Appropriateness of site for erection of residential building	8	7.71	1.58	3

SD = Standard deviation; IQD = Interquartile deviation

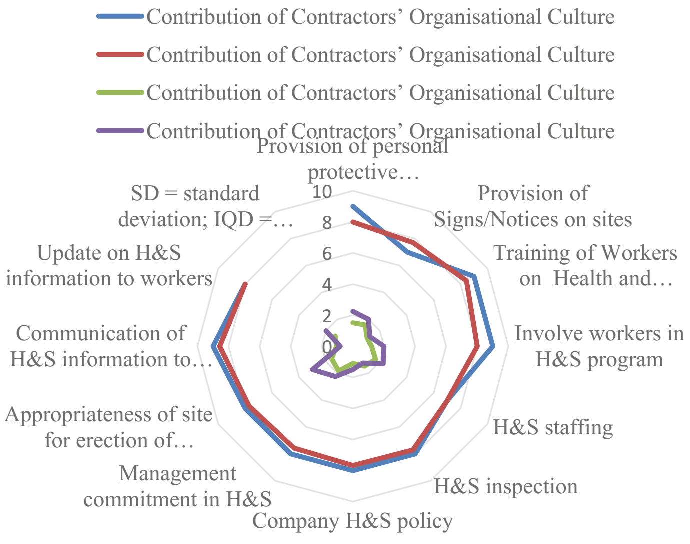


Fig. 48.3 Contribution of contractors' organisational culture

(VHI: 9–10) under the median score. The variables indicate strong consensus. The remaining seven (7) attributes or measurement variables were considered by the experts to have high impact (HI: 7–8.99) on H&S compliance. This indicate good consensus as shown in Table 48.1. Figure 48.3 provides the representation of the attributes or measurement variables that are considered by the experts to have reached consensus on H&S compliance at different degrees.

From the impact ratings of the factors, findings revealed that four of the factors or measurement variables have a very high impact (VHI: 900–10.00), while the remaining seven factors or measurement variables have high impact (HI: 7.00–8.99) on contractors' organisational culture towards health and safety compliance.

48.5 Conclusion

The purpose of the study was to examine the contribution of contractors' organisational culture towards Health and Safety (H&S) compliance in Ghana. It is appropriate for the contractor to be familiar with the culture surrounding its organisation and activities in order to appreciate the concept behind it. This will enable it to eliminate major accidents that have been attributed to a poor contractor's organization culture. It can also be concluded from the findings that the contribution of contractors' organisation culture towards H&S compliance has high influence on the overall H&S regulations in the Ghanaian construction industry.

References

Adler M, Ziglio E (1996) Gazing into the oracle: the Delphi method and its application to social policy and public health. Kingsley Publishers, London

Antonsen S (2009) Safety culture assessment: a mission impossible? J Contingencies Crisis Manage 17(4):242–254

Dalkey NC, Helmer O (1963) An experimental application of the Delphi method to the use of experts. J Insts Manage Sci 9:458–467

Dingsdag DP, Biggs HC, Sheahan VL, Cipolla CJ (2006) A construction safety competency framework: improving OH&S performance by creating and maintaining a safety culture. Cooperative Research Centre for Construction Innovation, Brisbane

European Agency for Safety and Health at Work (EU-OSHA 2011) Occupational health and safety culture assessment—a review of main approaches and selected tools. Available online http://europa.eu. Accessed on 20 May 2016

Fong P, Kwok C (2009) Organisational culture and knowledge management success at project and organisational levels in construction FIRMS. J Constr Eng Manage Technical Papers 135(12): 1348–1356

Frempong G, Essegbey G (2006) Towards an African e-Index, SME e-access and usage across 14 African countries, 25–27. Available online http://www.researchictafrica.net. Accessed on 30 Sept 2014

Grote G (2007) Understanding and assessing safety culture through the lens of organizational management of uncertainty. Saf Sci 45:637–652

Guldenmund FW (2010) Understanding and exploring safety culture. Thesis (Ph.D.) Delft University, The Netherlands. Available online http://repository.tudelft.nl. Accessed on 20 Feb 2016

Hallowell MR, Gambatese JA (2010) Qualitative research: application of the Delphi method to CEM research. J Constr Eng Manage ASCE 136(1):99–107

Institution of Occupational of Safety and Health IOSH (2004) Promoting a positive culture—a guide to health and safety culture, IOSH, 4.2. Leicestershire

Kheni NA, Dainty ARJ, Gibb AGF (2007) Influence of political and socio-cultural environments on health and safety management within SMEs: a Ghana case study. In: Boyd D (ed) proceedings of the 23rd annual ARCOM conference, 3–5 September 2007, Belfast, UK, pp 159–168

Laryea S (2010) Challenges and opportunities facing contractors in Ghana. In: Laryea S, Leiringer R, Hughes W (eds) Proceeding West Africa built environment research (WABER) conference, 27–28 July 2010. Accra, Ghana, pp 215–226

Linstone A, Turoff M (1975) The Delphi method: techniques and applications Reading. Addison-Wesley, MA

Mustapha Z, Aigbavboa CO, Thwala WD (2015) Application of modified statistical triangle of accident causation in construction health and safety. © Springer Berlin, Heidelberg 2015. In: Shen et al. (eds) Proceedings of the 19th international symposium on advancement of construction management and real estate. DOI 10.1007/978-3-662-46994-1_6 57–66

Occupational Safety and Health Administration Occupational Safety and Health Act OSHA (2003) Personal protective equipment, U.S. Department of Labor 3151–12R

Ofori G, Toor SR (2012) Leadership and construction industry development in developing countries. J Constr Dev Countries. Available online http://web.usm.my/jcdc. Accessed on 20 May 2015

Okoli C, Pawlowski S (2004) The Delphi method as a research tool: an example, design considerations and applications. Inf Manage 42:15–29

Rogers MR, Lopez EC (2002) Identifying critical cross-cultural school psychology competencies. J Sch Psychol 40(2):115–141

Rowe G, Wright G, Bolger F (1991) Delphi—A re-evaluation of research and theory. Technol Forecast Soc Change 39:238

Wiegmann DAH, Zhang TL, von Thaden T, Sharma G, Mitchell AA (2002) A synthesis of safety culture and safety climate research. University of Illinois Aviation Research Lab Technical Report ARL-02-03/FAA-02-2

Chapter 49
Convention and Exhibition Center Integrated into High Speed Rail Station: Experience and Idea

Yue Li and Yuzhe Wu

49.1 Introduction

Transportation often plays a key role in the development of the city. In the condition of the limited existing urban land in cities at present, convenient traffic and reasonable planning can stimulate efficient and intensive land utilization. As a transportation of high efficiency, low energy consumption and large capacity, high speed rail has an increasingly important role in the transport system. In 2004, China promulgated the "long-term railway network plan" and proposed the national railway operating mileage reached 10 million km in 2020, planning "four vertical and four horizonal" as the focus of passenger dedicated line which covering more than 90% of the national population. The gradual improvement of Chinese high speed rail network has affected spatial pattern and land use of city deeply.

High speed railway station is the "node" of high speed rail transport network, but it is also the "place" of city, which brings a large number of people and goods, having an impact on the economy, population and industrial structure in urban areas. With the rapid development of high speed railway network, which is one of the hotspots of investigating urban construction inside and outside country is the land use of high speed rail station. The planning and construction of the high speed rail station has an important and practical significance of the integration of urban land use and the improvement of urban space environment. In addition to the basic function of the transport hub, high speed rail station also has the function of commercial, business, finance, real estate and tourism (Li 2004).

Y. Li (✉) · Y. Wu
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: liyue0628@zju.edu.cn

Y. Wu
e-mail: wuyuzhe@zju.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_49

The travel time of cross-city passenger can be divided into urban transportation time and intercity transportation time. The development of high speed rail network has shorten the distance between cities greatly and reduced the time of intercity traffic, but the urban transportation still needs a lot of time. The traffic jam in large cities caused by large urban population and vehicles and the imperfect of transfer system in small cities will increase the time of traffic in the city. The development of information network has reduced the cost of communication, but face to face communication is still irreplaceable in many areas. Convention and exhibition center used to locate in the beautiful scenery or city business district, which brought the transportation cost in the city, providing places for this kind of face to face communication. Therefor, the construction of convention and exhibition center integrated into high speed rail station has irreplaceable advantages. Based on the perspective of business function of high speed rail station, this paper summarizes some experience in Hong Kong and puts forward an idea of constructing convention and exhibition center integrated into high speed rail station which will reduce the time cost and relieve traffic pressure in the city, to provide a new way of land use in high speed rail station.

Through a high degree of integration and construction, foreign high speed rail stations have changed a lot in traffic, daily service and business office, involving all aspects of people's lives. Although the domestic high speed railway has developed rapidly, it started too late. High speed rail station has just been built soon, it has not developed into a mature high speed rail station complex. Cities along high speed railway have not a clear plan of the surrounding land use. Compared with the construction of high speed railway in Japan and the European countries, China's high speed rail construction has some differences. The city in China is in a low urbanization rate at an accelerating stage, facing the rapid expansion of space and the integration of internal structure. Therefore, the development and construction of China's high speed rail station can not be blindly learn from foreign experience, but also from particular circumstances.

49.2 Land Usage and Development in High Speed Rail Stations

At present the study of high speed rail station at home and abroad mainly focus on the spatial structure, functional location, land use and its impact on the space station in urban development. New urbanist Peter Calthorpe proposed TOD (Transit Oriented Development) model, namely to public transport for oriented, emphasizing the comprehensive land use pattern of development, promote the station area of mixed land use and optimized land layout. Based on the TOD model, Chinese scholars proposed ROD (Rail Oriented Development) model, which is high-speed rail station as the core of high-density development of surrounding areas in order to promote a wider range of urban development.

Effect of high speed railway on urban development also has two sides. On the one hand, a high speed rail construction promote inter regional exchanges of personnel, goods and materials, promote the structure reorganization and distribution of cities along, and enhance the overall competitiveness of the cities along. On the other hand, the recession of the Nagoya metropolitan area along the Japanese new trunk line proved that the construction of high speed rail also has a negative effect on urban development. Cities along the high speed rail which is not strong enough will face the risk of being weakened (Tjallingii 2000).

The mainstream theory of study of station land use is the circle-and-layer theory, which believes that land use surrounding stations generally follow the three "circles" model, land use intensity among the various circles descending order. The first circle is the core area with high level of building density and land intensive utilization degree. The second circle is affected area, the land use intensity of which followed by the first. The third circle is the peripheral area, will have changes in structure and fuction affected by high speed rail station. Zhang Xiaoxing also proposed that there is a combination relationship of core and extension in the land use function, space and traffic stracture, formed a circle land use pattern consist of the core hub, hub peripheral region and diffusion affected zone (Zhang 2002). This theory emphasizes the high speed rail station as the core, transportation accessibility for the appeal, the station built around commercial, business, entertainment, residential and other facilities.

In addition, the development of the underground space of high speed railway station is another development direction of the land use. With the development of economy and technology, underground space are widely used as possible. The appropriate exploitation of underground space improves the land use efficiency of high speed rail station and alleviates the land resource constraints of the site area.

49.3 The "Railway + Property" Model in Hong Kong

49.3.1 "Railway + Property"

Hong Kong MTR Corporation was founded in 1975 when the Hong Kong Government was the sole shareholder who hoped the Corporation can be "self-financing". In 2000, the company registered as a limited company and was listed on the Hongkong stock exchange in the same year. The Corporation marked another major milestone on 2 December 2007 when the operations of the other Government-owned rail operator, the Kowloon-Canton Railway Corporation, were merged into the MTR, heralding a new era in Hong Kong railway development. In Hong Kong, the MTR Corporation has 11 subway lines in operation, 4 subway lines in construction, with a total length of 22.09 km, a total of 87 stations and 68 light rail stations. Today, MTR Corporation is involved in a wide range of business activities in addition to its railway operations. These include the development of

Fig. 49.1 Hong Kong operating network and future extension. *Date source* www.mtr.com.hk

residential and commercial projects, property leasing and management, advertising, telecommunication services and international consultancy services (Fig. 49.1).

The operating mode of Hong Kong MTR corporation is the "R + P" (Railway + Property) model, refers to the corporation construct subway and carry cost through real estate development along subway or surrounding subway station. The corporation often choose the land above the station, developing predominantly residential available for sale in cooperation with property developers, while the development of the underground station concourse. At present, the investment property held by the MTR Corporation is mainly in shopping malls and office buildings, providing property management services for the above and other properties. The construction of the subway station brings a large number of people and goods for the surrounding land, enhancing the value of the surrounding property. The large scale property development integrated to subway station facilitates passengers and pulls in new crowds. The two complement each other, forming a virtuous cycle of "Railway + Property", promoting a tripartite win-win situation of government, developers and the corporation.

Public transportation operation system in large cities mostly needs the government subsidies, the MTR Corporation's profit phenomenon is very rare in the international community, own to contributions of property development. In 2014, the corporation had integrated property projects above 39 stations, combining with more than one hundred thousand residential units and more than 2 million m^2 of commercial area, investment property portfolio includes 212,500 m^2 of retail property, 410,006 m^2 of office buildings and property development profits amounted to HK $42 billion. Comprehensive development of the property accounting for the proportion of the profits of the corporation has reached 37.8%, and there is a continued upward trend. The MTR corporation hold strategic vision of the regional sustainable development and prudent commercial principles in the early stage of the construction of the subway, getting land use rights of stations and surrounding areas in accordance with the full market value of the low price from the Hongkong government. In the construction of the railway, MTR corporation signed an agreement with many property developers in the developer to assume all development cost and development risk based on, MTR Corporation and the developers divided the profited according to the profits of proportion apportioned for sale or lease of property (Fig. 49.2).

49.3.2 Analysis of the R + P Model in Hong Kong

MTR Corporation make full use of the advantages of real estate value-added along, convert areas along the railway into a unique integrated commercial and residential community in the construction of the railway, which led to increase in land value, and railway passengers will also therefore increased, the cost of building a new railway can be generated by the sale of property profit sharing, so that fare without government subsidies can be maintained at a reasonable level.

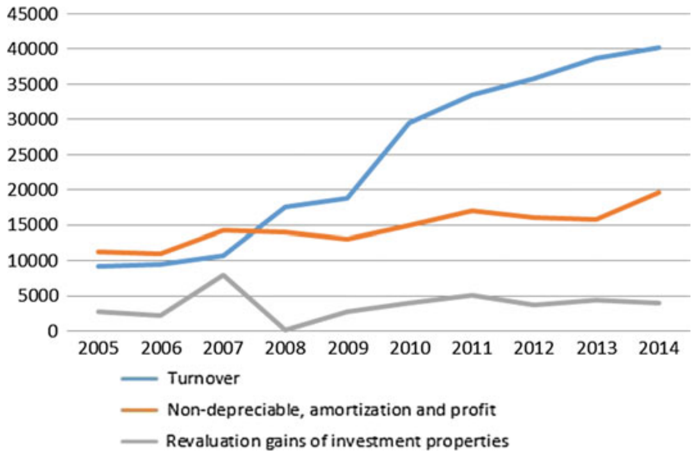


Fig. 49.2 Operating conditions of the MTR corporation from 2005 to 2014. *Date source* www.mtr.com.hk

49.3.2.1 A Clear Plan

A clear plan and precision research in the early stage of the construction is the key to the success of the Hongkong "Railway + Property" model. Although the early amount of work increased cost, but the project development effect is successful, the overall cost is not increased. In the early development of subway stations, the corporation will for a large number of needs analysis in order and the future development and construction of phase matching is the clear pre integration makes planning subway line construction of the MTR corporation is more suitable for urban planning and community development, along the site coverage to meet the community residents travel convenience of life and work.

49.3.2.2 A Precise Position of Function

The development of the subway station in MTR is located in the development of mixed functions, but this does not mean that its function is chaotic. Take Kowloon Station as an example, although the Kowloon Station is a huge complex, there are traffic, residential, commercial, commercial and other functions, different levels have different functions: the underground level is mainly based on traffic function, the upper cover of the property have business, leisure and other functions. Each level of functional positioning is clear, promoting each other, closely linked together constitute the daily operation of the Kowloon Station.

49.3.2.3 A Rational Property Structure

The development of property above stations in MTR mostly is residential and commercial, according to the structure of the property to configure different characteristics and level of development of different regional sites. The Kowloon Station is a model of comprehensive development of the property, its property development order is Residential-Business. Residential first enhance the popularity and the establishment of a regional maturity, business people gather, and business office rise, forming and the central financial district across the sea and a high-end business center.

49.3.2.4 An Intensification Pattern of Land Utilization

The development of Hongkong city is always facing the contradiction between the limited land for construction and the constant expansion of population, so the characteristics of the Hongkong building is high density and super high. The lack of land used for public transportation naturally requires a good convergence of different modes of transport and transfer, and integrated into the public space and the building interior. "Railway + Property" mode gives full play to the role of metro resources in the project construction and the operational period through the integration of resources to intensive use, enriching urban space and guiding the city to the method for three-dimensional development. Kowloon Station in Hong Kong is also the land intensive utilization model, the transportation hub, residential, shopping malls, office buildings, hotels and other forms of integrated land use in subway stations, forming a huge "subway station on the floating island of the city".

The development of Hong Kong MTR station is established in the unique social circumstances, the small area of Hong Kong, densely populated, economic prosperity, a high level of urbanization, created a good environment for the comprehensive development of the Hong Kong MTR Station property. The policy system and development level of cities in mainland China is different with the Hong Kong. It is not wise to blindly copy the development mode, but can learn from the development experience and combine with the high speed rail station in urban development situation and future planning model of development and management in accordance with the development of their own.

49.4 Convention and Exhibition Center Integrated into High Speed Rail Station

49.4.1 "CEC + HSRS"

Compared with air transport, high speed railway has the advantages of short distance transport, compared with ordinary railway, high-speed railway has the advantage of high speed and energy saving. For business activities in close cities, high speed railway is the most efficient and convenient way of transportation in day trip. High speed railway station create a convenient condition for business activities. For example, the Nagoya station, the German central station and the Kowloon Railway Station in Hongkong have made full use of the advantages of the station of the development of commercial functions of land use and benefit from it.

As an important part of business activities, exhibition is the floorboard of all kinds of conferences and exhibitions, refers to in a certain geographical space, some people gathered together to form regular or irregular institutional and non institutional collective activities. Convention and Exhibition Center is a large-scale public building, which is the main function of each type of conference and exhibition. It is the carrier of the exhibition activities, which is closely related to the development of the city. Among factors of the site selection of convention and exhibition center, the transportation convenience and the modern audio-visual equipment are the first, and the second is the access to the property and the modern hotel facilities and the transportation convenience. As the object of the regional market, Exhibition industry has a strong sensitivity to transportation, which is layout in the regional transport hub is more likely to succeed.

Once built up, high speed rail station will become one of the most intensive area of people, goods and informations in the city, providing favorable conditions for the development of exhibition industry. Exhibition center integrated high speed rail station will promote the development of land surrounding station and exhibition industry at the same time. Convention and exhibition center integrated into high speed rail station (CEC + HSRS) has advantage of traffic compared with the rest areas of the city. Meanwhile, high speed rail station positioning convention center will also have a result linkage effects of the surrounding area, such as food, housing, transportation, entertainment and other industries, so that high speed rail station is no longer a simple function of traffic, as well as business functions, business functions.

49.4.2 Advantages of the "CEC + HSRS" Model

49.4.2.1 Relieve Traffic Pressure in the City

Currently most of China's cities face the plight of traffic congestion, developing the city road traffic to solve the problem is obviously difficult, while subway cost a lot and can not be built in the short term. Large conference or exhibition in a short period of time to bring a large number of floating population into the city, resulting in tremendous pressure on the city's traffic. For example, during the Canton Fair in 2015, Guangzhou morning and evening peak hours the city's congestion index than usual rose more than 20%, six kilometer road driving speed decreased significantly, for the morning and evening commute time coincidence, the citizens of Guangzhou office, school pose a serious obstacle. Convention and exhibition center integrated into high speed rail station will gather the crowd who come to participate in the meeting and exhibition at the station area, easing the pressure on the city's traffic.

49.4.2.2 Reduce the Time Cost

High speed rail passengers' travel time is composed of three parts: first is the city traffic time from the point of departure to the high speed rail station, the second is the time in high speed railway, the third is the city traffic time from the high speed rail station to the destination. The first and the third part make up the extra time outside travel. At present, the speed of high speed railway is gradually accelerated, shortening the inter city traffic time. But the extra time outside travel is getting longer and longer. Zheng jian pointed out that the higher the speed of high speed rail, passengers are more sensitive to the length of extra time outside travel. There are two ways to shorten the extra time: one is to shorten the distance between the high speed railway station and the destination, the other is to improve the traffic speed in city. Convention and exhibition center integrated into high speed rail station will shorten the extra time by shortening the distance between the high speed railway station and the destination to zero.

49.4.2.3 Achieve Sustainable Operation

At present, most of China's high speed railway station is difficult to maintain its operation only by ticketing revenue, still needing a long-term subsidy by government. Convention and exhibition center can share the cost of construction and operation of high speed rail station, to achieve sustainable operation. High speed rail station bring a stable source for the exhibition center, the exhibition center brings revenue for the station, forming a virtuous circle of "CEC + HSRS".

49.4.2.4 Urban Transformation

While China is now in the process of rapid urbanization, cities especially small cities have same urban function and image without reasonable planning and clear development position. Convention and exhibition center integrated into high speed rail station not only can drive the change of the urban spatial structure, but also can promote the development of the whole city, especially for the small and medium-sized cities. Place of convention and exhibition is shifting from large city to small and medium-sized city, such as Boao in Hainan province and Wuzhen in Zhejiang province. There are a lot of advantages of small and medium-sized cities to hold the exhibition, such as more possible to get the cooperation from local institution, less rental and service fees and a wealth of tourism resources.

49.5 Conclusion

The construction of high speed rail station has become the focus of the urban development in consequence of the rapid development of high speed railway in China, but still faced with difficulties such as poor connection with city centre and unsustainable operation. Based on the theoretical and practical analysis of development of Hong Kong MTR, this paper summarizes some experience and puts forward an idea of constructing convention and exhibition center integrated into high speed rail station which will reduce the time cost and relieve traffic pressure in the city. The study of high speed rail station in China still belongs to the emerging issues. It is necessary to take successful experience from Hong Kong and other countries for reference, but it is most important to study the construction of high speed rail station from the perspective of urban development and combining our actual condition.

Acknowledgements The authors appreciate the financial support by the National Natural Science Foundation of China (Grant No. 71373231), and the helpful work from the organizing committee of CRIOCM2016 International Symposium on Advancement of Construction Management and Real Estate.

References

Ding CR (2010) The impact of urban spatial structure and land use pattern on urban transportation. Urban Transport of China

Hong LI (2009) Stuttgart 21 rail transit hub promotes sustainable development of urban core. Time Archit

Li C (2004) A trend of integration between the transportation terminal and the city—an analysis of the design of the especially large railway passenger station. Huazhong Archit

Lin CH (2011) Research of impact factors of high-speed railways hub area development in china. Urban Planning International

Scott A (2001) Global city-regions: trends, theory, policy. Oup Catalogue 35(3):326–327

Tjallingii SP (2000) Ecology on the edge: landscape and ecology between town and country. Landscape Urban Plan 48(3–4):103–119

Wang L, Wang C, Chen C, Hao GU (2014) Development and planning of the surrounding area of high-speed rail stations: based on empirical study of beijing-shanghai line

Xue CQ, Zhai H (2010) Urban island floating on the train station: case study of kowloon station development in hong kong. Archit J

Zhang XX (2002) Development of the urban form in the guangzhou railway station area under the transformation by rail transit methods. J South China Univ Technol 30(10), 24-12

Zhang J, Ma X (2010) A study of the development of the high-speed railway station area and the influence on zhengzhou. Henan Sci 1349–1352

Chapter 50
Corporate Social Responsibility Localization in International Construction Business

Meng Ye, Weisheng Lu and Roger Flanagan

50.1 Introduction

With the increasing internationalization of construction business, some environmental issues and social issues occur and attract the attention of the international construction companies (ICCs), such as corruption, poverty, education, health and safety, energy intensity and pollutions. These issues compel ICCs to extend corporate social responsibility (CSR) beyond their home countries, which means companies not only care about the profits but also integrate social and environmental concerns in their business operations and in their interaction with their stakeholders (Commission of the European Communities 2001). International CSR activities are also promoted by international organizations. The International Organization for Standardization launched ISO26000 in November 2010, providing guidance for organizations to operate in a socially responsible way. The Organization for Economic Cooperation and Development (OECD) published the Guidelines for Multinational Enterprises in 2011 recommending that responsible business should be conducted. Likewise, the Global Reporting Initiative (GRI) has started to develop frameworks to help governments and organizations understand and communicate the impacts of business on critical sustainability issues and standardize the CSR reporting. It has published the Construction & Real Estate Sector Supplement (CRESS) since 2011 with the aim of providing sustainability performance indicators and disclosures that are important or unique to the sector.

M. Ye (✉) · W. Lu
Department of Real Estate and Construction, Faculty of Architecture,
University of Hong Kong, Pokfulam, Hong Kong
e-mail: megan828@connect.hku.hk

R. Flanagan
School of Construction Management and Engineering,
University of Reading, Reading RG6 6AW, UK

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_50

However, as examined by Lu et al. (2015), differences in philanthropy activities result mainly from the differences in the regions in which ICCs operate. Taking Hochtief, one ICC listed in *Engineering News Record (ENR)* as an example, Hochtief Asia Pacific is highly involved in working for the rights of Indigenous Australians, while its Europe division supports talented young people from a migrant background. There are other examples that ICCs would have different CSR strategies due to different culture of host countries. Balfour Beatty, another ICC listed in ENR, for example, is a leading sponsor for the London Youth Games, which works with some of the most disadvantaged young people in London, while in South Africa, they give financial and practical support to the Compass Care Centre in Edenvale which provides food and shelter to poor, homeless, and unemployed mothers and their children. These observations present us one puzzle that whether these ICCs always implement CSR activities in different ways in different international markets.

Since construction projects are literally "grounded" in a local environment in the host countries—a building, a bridge, a water plant, or a pipeline is attached to a specific location. Once site is chosen, it is difficult—and always costly—to relocate (Scott 2011). Since each project is connected to a location, ICCs must take the local conditions into account. For example, they take more initiatives to local communities to establish the good relationship with them. Those ICCs would be faced with more complicated institutional environment. Regardless of the local environment of host countries, the strategies implemented by ICCs would be affected by their own institutions in the home countries as well as supranational institutions, such as the World Bank, Transparency International, and the Global Reporting Initiative. Since supranational institutions would affect all the CSR activities in the international market, the differences of CSR activities would only occur because of the institutional environment of home and host countries. Besides, the construction industry is very labor intensive (Hillebrandt and Cannon 1989). A lot of labors would be involved in each project, including local employees and those who are employed from their home countries. Therefore, the occupational health and safety issues should be largely emphasized. In addition to that, the construction industry is a demand oriented industry. The winner-take-all principle requires the good reputation of ICCs. All of these characteristics of the construction industry determine that the CSR activities operated in the construction industry are likely to be localized. CSR localization is introduced to describe the CSR strategies that are responsive to the local context and local stakeholders.

The primary aim of this study is to explore the CSR localization patterns as portrayed by international construction companies (ICCs). The remainder of this paper is structured into four sections. Following this introduction section, the constructs are explained and defined. The research methods section provides a detailed description of the sample and research methods, whereby case study and content analysis of the CSR reports disclosed by ICCs is adopted. The fourth section presents the analysis, findings and discussion. Conclusion and limitation are presented in the last section.

50.2 Construct Explanation

50.2.1 Corporate Social Responsibility (CSR)

Corporate social responsibility (CSR) evolved over several decades like many other business concepts, however, there is still no universally accepted definition of it. Carroll (1999) traced the development of CSR concept and treated it on the basis of decade-by-decade categories (Carroll 1999). Carroll's research revealed that the concept of CSR began in 1950s, expanded during the 1960s, proliferated during the 1970s and there were fewer new definitions in the 1980s but began to mature. Major contributions to the evolution of the CSR definition were identified in the research. It reaches a consensus that the modern phrase corporate social responsibility (CSR) was coined by Bowen and Johnson (1953) with his book named Social Responsibilities of the Businessman (Bowen and Johnson 1953). Davis (1960) set forth the definition that businessmen's decisions and actions which should be due to some reasons beyond the direct economic or technical interest (Davis 1960). McGuire's definition extends beyond economic and legal obligations (McGuire 1963). He also emphases that the corporation must be interested in politics, in the community, in education and in the happiness of their employees, which is more precise. In the 1970s, Harold Johnson presents his definition which is related to stakeholders, in which he emphases that instead of striving only for stockholders, a responsible company should take into account employees, suppliers, dealers, local communities, and the nation (Johnson 1971).

From 1970s to 1990s, Carroll revisited the definition many times and it is suggested in his paper in 1991 that CSR is consisted of four components which are economic, legal, ethical and philanthropic ones (Carroll 1991). Murray and Dainty (2008) also traced the definition of the CSR and gave many examples of definitions (Murray and Dainty 2008). He makes a conclusion that although there are some differences in emphasis, common themes exist in these definitions. For example, they all point out the need to respect for communities and other stakeholders, the need for awareness of social, economic and environmental impacts and they all talk about the business objectives as well as societal goals. It is shown in Dahlsrud (2008) research making a content analysis of existing 37 CSR definitions that CSR is nothing new at a conceptual level with social, environmental and economic impacts and being concerned with stakeholders (Dahlsrud 2008). Carroll and Shabana (2010) pointed out that the majority of definitions are academically derived constructs of CSR (Carroll and Shabana 2010). However, it is different at an operational level due to some development trends, such as globalization and diversification. From the view of CSR definitions, we can see the evolvement and various aspects like environmental, social, economic issues are involved in the definitions, even though there lacks a unified definition. However, whether the CSR practices are performed and how to practice the CSR strategies especially in a specific domain are big problems to pursue.

From the view of CSR definitions in the literature review, we can see that the three aspects, i.e. environmental, social and economic issues, are involved in the

CSR context. The environmental, social and governance (ESG) indicator is used as a proxy representing CSR in the recent studies (Gillan et al. 2010; Giannarakis et al. 2014) and by many independent third parties, i.e. Bloomberg and Morgan and Stanley Capital International (MSCI). MSCI identifies 10 themes and 37 ESG key issues and categorizes them into those three pillars, say environment, social and governance. For environment pillar, there are climate change (e.g. carbon emissions, energy efficiency), natural resources, pollution and waste, and environmental opportunities (e.g. opportunities in clean technology). Social pillar includes human capital, product liability, product liability and social opportunities. Governance pillar includes corporate governance like the board, ownership and accounting as well as corporate behavior, say, business ethics and anti-competitive practices. Similarly, Bloomberg provides very detailed ESG evaluation system. Carbon emissions, energy consumption, water use and waste are for environmental pillar; employee issue, social supply chain, health and safety policy, community are included in social pillar; while governance pillar emphasizes on board structure, board independence, female issue and so on.

In this study, social pillar in the C‘S’R is mainly focused on, since the aspect of ‘society’ already in the label, one would have thought that institutional theory would have been a core conceptual lens in understanding the ‘social’ responsibilities of business all along. Following (Moon 2002) and Chapple and Moon (2005), the social pillar of CSR would be distinguished to three waves: social community involvement, socially responsible production processes, and socially employee relations (Moon 2002; Chapple and Moon 2005). The detailed categories are shown in Table 50.1.

Table 50.1 CSR issues and categories stressed in this study

C‘S’R issues	Sub-issues
Community involvement	General (donation)
	Local economic development (construction related)[a]
	Education, training
	Environment, conservation[a]
	Health, disability
	Sport, culture, arts
	Welfare (Poverty, emergency relief)
	Youth and children
	Others
Socially responsible products	Environment (material recycling)[a]
	Quality
	Health and safety[a]
Employee relations	Employee welfare
	Local employee proportion
	Female employee proportion

[a]Related to the business in the construction industry

50.2.2 CSR Localization

Localization, defined by Singh N, takes into account the inherent diversity that exists in international markets and treats individuals as "cultural beings" whose values and behaviors are shaped by the unique culture in which they live (Singh 2011). When being faced with the multinational environment, different strategic approaches of globally acting are adopted which are the response to the interplay between pressures for integration on the one hand and pressures responsiveness on the other hand (Prahalad and Doz 1987), which are the international, the global, the multinational and the transnational strategy (Bustamante 2011). The multinational strategy allows adapting to local markets, which can be also called localization. It's easier for global enterprises to foster innovation in emerging markets, where there are fewer entrenched systems or traditional mindsets to overcome" (Nidumolu et al. 2009). Additionally, national standards are often even stricter than global ones (Loew 2005), and innovation might come from local subsidiaries having to cope with these standards.

CSR localization here means ICCs in host countries are characterized by a considerable degree of autonomy and develop CSR strategies that are responsive to the local context and local stakeholders (Muller 2006). Due to better knowledge of and more intense and direct relations with local stakeholders, a higher degree local responsiveness and effectiveness of CSR instruments can be expected (Bustamante 2011). Since in this way, CSR strategies implemented by ICCs would be opposite to the centralized coordination mechanism to subsidiaries, CSR localization also means the divergence between home- and host-country CSR contexts.

50.3 Research Methods

50.3.1 Sample

To make the sample comparable, only those ICCs from region of Asia/Australia are selected for this study. Based on the Top 250 International Contractors (TIC 250) listed in 2015 by *Engineering News-Record (ENR),* who has published annual revenue data about contracting firms in the U.S. and some other international markets every year since 1958, thirteen ICCs from Australian and three Asian countries, i.e. China, Japan, and S. Korea are selected for the analysis. Among them, two of the ICCs are from Australia, four from China, three from Japan and four from S. Korea, which are shown in Table 50.2. All of these ICCs are ranked top 100 in the ENR TIC 2015 List based on their international revenue of the construction businesses. International revenue means those revenues from the projects outside their home country. Therefore, all of the selected ICCs are large and multinational firms, which could avoid the significant influence from the factor -firm size.

The first CSR/sustainability reports of the ICCs and reports in the year 2010, 2012, and 2014 are chosen as the basis for the analysis. The chosen year reflect significant dates in the evolution of CSR reporting. The Global Reporting Initiative (GRI) released the first generation of GRI reporting standards in 2000, the third generation (GRI-G3) was released in 2006, the fourth generation (GRI-G3.1) was released in 2010 while the lasted generation (GRI-G4) was released in 2012. However, according to the GRI Sustainability Disclosure Database, most of the companies in the construction industry started to report their CSR activities from 2006 or even from 2011. The years 2010 and 2012 are selected according to the GRI reporting standards. In addition to that, the first CSR/sustainability reports and the most recent reports are selected for supplement to see the overview of the CSR activities. Therefore, regardless of those missing reports, there are 42 CSR/sustainability reports available for the analysis.

50.3.2 Methods

The CSR/sustainability reports were coded using content analysis, an approach adopted by many researchers to analyze CSR reporting (Roca and Searcy 2012; Jenkins and Yakovleva 2006; Wilmshurst and Frost 2000). Content analysis is a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding (Krippendorff 2012; Stemler 2001). It is a continuous and iterative process characterized by two key stages, the first of which requires managing the data, and the second stage involving making

Table 50.2 Profiles of selected sample

Country	Firm	Rankings in 2015	The first year to report	2010	2012	2014
Australia	Leighton	29	2014			√
Australia	Lend Lease	33	2005		√	√
China	CCCC	5	2007	√	√	√
China	CREC	23	2008	√	√	
China	Sinomach	27	2009	√	√	√
China	Gezhouba	44	2011	√	√	√
Japan	OBAYASHI	35	2006	√	√	√
Japan	CHIYODA CORP	39	2006	√	√	√
Japan	Kajima	53	2006	√	√	√
S. Korea	Hyundai E&C	14	2010	√	√	√
S. Korea	GS E&C	26	2010	√	√	√
S. Korea	DAEWOO	43	2008		√	√
S. Korea	POSCO E&C	59	2011	√	√	√

sense of the evidence through descriptive or explanatory accounts (Burden and Roodt 2007).

As listed in Table 50.1, there are 15 CSR issues stressed in this study, which could be categorized into three waves, i.e. social community involvement, socially responsible production processes, and socially employee relations. The 15 CSR issues in each of the 42 CSR/sustainability reports were manually coded into a MS Excel file. In addition to that, the CSR activities reported in the host countries, which is defined those countries outside the country of the headquarters, were deeply paid attention to. Case study for CSR activities of each firm and comparative analysis for different home and host countries were then implemented.

50.4 Analyses, Findings and Discussion

ICCs would not report their CSR activities for all the subsidiaries. Since the CSR/sustainability reports collected are for each whole company, it is explained that overall principles or standards for CSR activities are consistent for the headquarters and their subsidiaries in the host countries. Therefore, not all the host countries where the ICCs implemented projects would appear in the CSR/sustainability reports. Only those countries where ICCs implemented different CSR initiatives or policies would be stressed in the CSR/sustainability reports. Despite the ICCs from Australia, who stressed the policies and activities related to Health and Safety issue in the process of production in U.S.A, Europe, Asia and the Pacific, the host countries mentioned in the reports of other ICCs from China, Japan and S. Korea are mainly centralized in Asia, the Middle East, Africa and South America (shown in Figs. 50.1, 50.2, and 50.3)

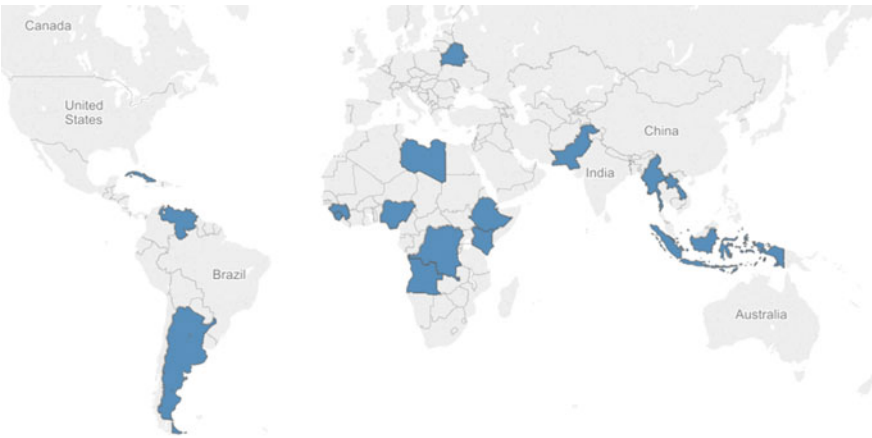


Fig. 50.1 Host countries mentioned in the CSR/sustainability reports of ICCs from China

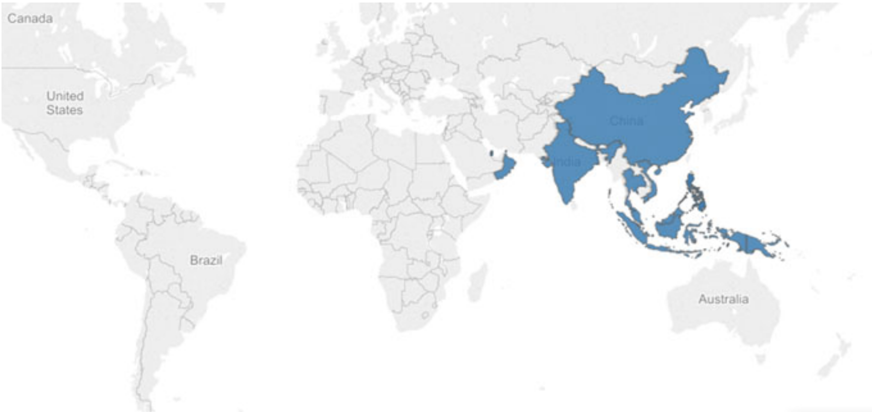


Fig. 50.2 Host countries mentioned in the CSR/sustainability reports of ICCs from Japan

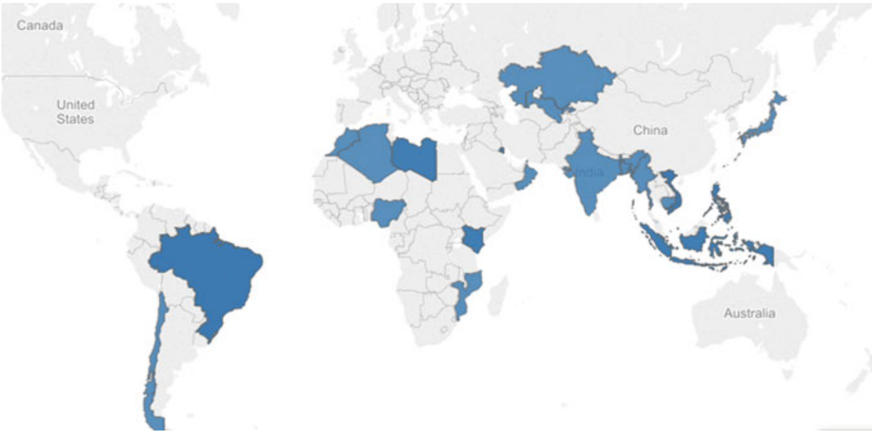


Fig. 50.3 Host countries mentioned in the CSR/sustainability reports of ICCs from S. Korea

Finding 1: Most of the CSR activities reported in these mentioned host countries are related to Community Involvement.

CSR activities outside the home countries were identified and categorized into the three waves, i.e. social community involvement, socially responsible production processes, and socially employee relations and 15 specific CSR issues (shown in Table 50.1). Therefore, there are 94 CSR activity items identified ignoring the reporting year, the company names and even the home countries. The majority of the CSR activity items (85 out of 94) could be classified in the Community Involvement, such as education and training for the community, environment conservation, local economic development, welfare of the community, and disaster relief. Among those CSR activity items, 13/94 were implemented in South

America, 6/94 were in the Middle East, 33/94 were in Africa, almost half of them (41/94) in Asia/Australia, and only 1 item were implemented in Europe. Compared to those developed countries, these host countries are less developed countries located in South America, the Middle East, Africa and Asia/Australia. Therefore, activities for the community are more desired in these countries. For example, in the host countries of Africa, CSR activities related to local economic development and environment conservation were frequently mentioned in the reports; while in the host countries of Asia/Australia, most are southern Asian countries such as Philippines, Vietnam, India and Indonesia, CSR activities related to education are reported the most. It seems that CSR activities would likely be localized when they are desired or required by the host countries

Finding 2: It is easier for the ICCs to implement their CSR activities which are related to the construction businesses

In the CSR/sustainability reports, the construction projects operated in the host countries would be regarded as the CSR activities, since the construction businesses help materialize the built environment, promote the local economic development, and provide a large number of jobs, especially for those eco-projects. For example, Chiyoda, a Japanese construction company, implemented the liquefied natural gas (LNG) plant in Qatar, which would be the expansion of renewable energy. In addition to developing engineering and procurement systems to ensure efficient material procurement and effective quality management, Chiyoda provided safety, environmental and health training to as many as 75,000 construction workers from 86 countries at the peak of construction. CREC, the Chinese company, provided about 25,000 employment positions in 2012 for local labor forces in South America, Southeast Asia, Africa, the Middle East and other overseas areas. Notably, when disaster occurred, construction companies would be expected to implemented CSR activities not just by donation but help rebuild the infrastructure and buildings. Many contractors mentioned disaster relief in their CSR reports, such as reconstruction for the earthquake or typhoon. Since construction is intrinsically ‘irresponsible’; it competes with the natural environment and can have an adverse impact upon it, including land degradation, greenhouse gas emissions, resource depletion, waste generation, and various forms of pollution (Lu and Tam 2013; Ofori 1993; Zhao et al. 2012), companies paid more attention to the environmental issues when implementing CSR activities in the host countries. For example, Hyundai, the construction company from S. Korea, organized ecosystem protection campaign near Bubiyan site in Kuwait and improve the drinking water near refugee areas in Kenya. Obayashi, the Japanese company, promoted the Green Action 25 Plan to continue to conserve energy at Obayashi’s own facilities.

Finding 3: Local policies or the requirements of the local government would strength the CSR localization

ICCs would be expected to hire the local employees and use the local subcontractors when negotiation with the local governments of the host countries, since they always want their citizens to be hired by the construction projects to solve the problems of unemployment and learn more technology. For example, Chiyoda, the Japanese company, signed the contract for the Qalhat project with the Oman Ministry of Oil and Gas. Accordingly, the target for hiring Omani citizens was 35%, more than twice the 15% level normally applied to the construction sector. The company were dedicated to meeting this ambitious goal and conducted our Omanization program with the cooperation of national and local government agencies, subcontractors and, of course, the customer. For CCCC, the Chinese company, the proportion of the local skilled workers was more than 70% in Kenya in 2012, while in 2014, the employee localization rate is up to 47.5% and rate of procurement of local material reaches 46.1%.

50.5 Conclusion and Limitation

This study identified the CSR activities implemented in the host countries and explored the localization patterns of the CSR activities portrayed by ICCs in the international construction market. Forty-two CSR/sustainability reports of ICCs were collected from four countries, i.e. Australia, China, Japan, and S. Korea in the year 2010, 2012, and 2014 as well as their first CSR/sustainability reports to do the content analysis and case studies. All of these ICCs are ranked top 100 in the TIC 2015 List published by ENR based on their international revenue of the construction businesses, which ensure their firm size.

CSR was defined in this study, which would be distinguished to three waves: social community involvement, socially responsible production processes and socially employee relations. The more detailed 15 categories were also identified. It is found that only those countries where ICCs implemented different CSR initiatives or policies would be stressed in the CSR/sustainability reports. Despite the ICCs from Australia, the host countries mentioned in the reports of other ICCs from China, Japan and S. Korea are mainly centralized in Asia, the Middle East, Africa and South America, which determined the first finding that most of the CSR activities reported in these mentioned host countries are related to community involvement, which is more desired by the host countries. Moreover, it is easier for the ICCs to implement their CSR activities which are related to the construction businesses and CSR activities in the host countries would be complied with local policies or the requirements of the local government, so that CSR activities would be more likely to be localized.

The study provides a brief view of the localization patterns of CSR activities for ICCs, through which further investigation of the causes could be explored, e.g. the institutional/culture distance as explained by institutional theory, or the legitimacy to undertake construction business in different local contexts. However, the sample size is too small to stand for all the ICCs. Moreover, more scientific statistical methods should be implemented for a big sample size other than only content analysis and case studies.

References

Bowen HR, Johnson FE (1953) Social responsibility of the businessman. Harper

Burden J, Roodt G (2007) Grounded theory and its application in a recent study on organisational redesign: some reflections and guidelines. SA J Human Resour Manag 5(3):11–18

Bustamante S (2011) Localization vs. standardization: global approaches to CSR management in multinational companies (No. 60). Working papers of the Institute of Management Berlin at the Berlin School of Economics and Law (HWR Berlin)

Carroll AB (1991) The pyramid of corporate social responsibility: toward the moral management of organizational stakeholders. Bus Horiz 34(4):39–48

Carroll AB (1999) Corporate social responsibility evolution of a definitional construct. Bus Soc 38 (3):268–295

Carroll AB, Shabana KM (2010) The business case for corporate social responsibility: a review of concepts, research and practice. Int J Manag Rev 12(1):85–105

Chapple W, Moon J (2005) Corporate social responsibility (CSR) in Asia a seven-country study of CSR web site reporting. Bus Soc 44(4):415–441

Commission of the European Communities (2001) Promoting a European framework for Corporate Social Responsibility. Brussels

Dahlsrud A (2008) How corporate social responsibility is defined: an analysis of 37 definitions. Corp Soc Responsib Environ Manag 15(1):1–13

Davis K (1960) Can business afford to ignore social responsibilities? Calif Manage Rev 2(3)

Giannarakis G, Konteos G, Sariannidis N (2014) Financial, governance and environmental determinants of corporate social responsible disclosure. Manag Decis 52(10):1928–1951

Gillan S, Hartzell JC, Koch A, Starks L (2010) Firms' environmental, social and governance (ESG) choices, performance and managerial motivation. Unpublished working paper

Hillebrandt PM, Cannon J (1989) The management of construction firms: aspects of Theory. Macmillan Press, London

Jenkins H, Yakovleva N (2006) Corporate social responsibility in the mining industry: exploring trends in social and environmental disclosure. J Clean Prod 14(3):271–284

Johnson HL (1971) Business in contemporary society: framework and issues. Wadsworth Pub. Co.

Krippendorff K (2012) Content analysis: an introduction to its methodology. Sage, London

Loew T (2005) CSR in der supply chain: Herausforderungen und Ansatzpunkte für Unternehmen. Institute for Sustainability, Berlin

Lu W, Tam VWY (2013) Construction waste management policies and their effectiveness in Hong Kong: a longitudinal review. Renew Sustain Energy Rev 23:214–223. doi:10.1016/j.rser.2013.02.007

Lu WS, Ye M, Flanagan R, Ye KH (2015) Corporate social responsibility disclosures in international construction business: trends and prospects. ASCE J Constr Eng Manage 04015053. 10.1061/(ASCE)CO.1943-7862.0001034

McGuire JW (1963) Business and society. McGraw-Hill

Moon J (2002) Corporate social responsibility: an overview. International directory of corporate philanthropy. Europa, London, pp 3–14

Muller A (2006) Global versus local CSR strategies. Eur Manag J 24(2–3):180–191

Murray M, Dainty A (2008) Corporate social responsibility: challenging the construction industry. In: Murray M, Dainty A (eds) Corporate social responsibility in the construction industry. Taylor & Francis, London, pp 23–118

Nidumolu R, Prahalad CK, Rangaswami MR (2009) Why sustainability is now the key driver of innovation. Harvard Bus Rev 87(9):56–64

Ofori G (1993) Research on construction industry development at the crossroads. Constr Manag Econ 11(3):175–185

Prahalad CK, Doz Y (1987) The multinational mission: balancing local demands and global vision. The Free Press, New York

Roca LC, Searcy C (2012) An analysis of indicators disclosed in corporate sustainability reports. J Clean Prod 20(1):103–118

Scott WR (2011) The institutional environment of global projects. In: Scott R, Levitt RE, Orr RJ (eds) Global projects: Institutional and political challenges. Cambridge University Press, pp 52–85

Singh N (2011) Localization strategies for global e-business. Cambridge University Press

Stemler S (2001) An overview of content analysis. Pract Assess Res Eval 7(17):137–146

Wilmshurst TD, Frost GR (2000) Corporate environmental reporting: a test of legitimacy theory. Account Auditing Account J 13(1):10–26

Zhao Z-Y, Zhao X-J, Davidson K, Zuo J (2012) A corporate social responsibility indicator system for construction enterprises. J Clean Prod 29–30:277–289. doi:10.1016/j.jclepro.2011.12.036

Chapter 51
Correlation Analysis of Key Influencing Factors to the Total Factor Productivity of the Hong Kong Construction Industry

W. Zhan, W. Pan, A.A. Javed and K.W. Chau

51.1 Introduction

Construction productivity has been a cause of great concern in both the construction industry and academia. Measuring productivity is a quantitative-objective method, which requires quantities of standardised and clearly identified input and output units (Nachum 1999). Productivity changes are a dynamic indicator of the change in the ratio of identified outputs to inputs over time (Carson and Abbott 2012). Different methods are used for productivity measurement including index measurement, linear programming and econometric models (Singh et al. 2000). Commonly, the index measurement approach is applied in productivity studies to indicate the partial factor productivity (PFP) or total factor productivity (TFP) change of an industry over time (Carson and Abbott 2012). PFP measures generally show the ratio of an index of an industry's output to an index of partial input factors. In the case of the construction industry, for example, an index of the length of construction activity per employee is a labour-based partial productivity measure (labour productivity, LP for short). While, TFP measures are the ratio of a total aggregate output quantity index to a total aggregate input quantity index. Compared with TFP, such partial indicators (e.g., LP index) have been increasingly realised and potentially misleading when applied to measure industry-level productivity performance. It is because of materials role (Zhi et al. 2003; Chau and Walker 1988) and impact of intangible measures (e.g., improved technology, management issues and regulations) (Abdel-Wahab and Vogl 2011) in productivity improvement are ignored. Therefore, the TFP approach should be adopted for

W. Zhan (✉) · W. Pan · A.A. Javed
Department of Civil Engineering, The University of Hong Kong, Pok Fu Lam, Hong Kong
e-mail: zhanwt11@connect.hku.hk

K.W. Chau
Department of Real Estate and Construction, The University of Hong Kong, Pok Fu Lam, Hong Kong

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_51

in-depth productivity analysis, particularly when there is a need to identify the inputs or determinants' impact on or contribution to productivity growth or decrease. TFP has become a key consideration for industry-level productivity measurement (Zhi et al. 2003).

The paper aims to identify the key influencing factors to the TFP growth and develop insights and solutions to enhancing construction productivity at industry, organisation, and activity levels. The paper first applies a mathematical productivity model, which is based on a transcendental logarithmic (translog) production proposed by Jorgenson et al. (2016), for measuring the TFP trend of the Hong Kong construction industry. This TFP model is based on a production function theory, which defines the output as a translog function of intermediate input, capital input, labour input and time. Time-series data utilised in this model is collected from government departments' databases such as Architectural Services Department (ArchSD), Census and Statistics Department (CSD), Housing Department (HD), Civil Engineering and Development Department (CEDD) of the Government of the Hong Kong Special Administrative Region (Hong Kong), and private quantity surveying firms such as Rider Levett Bucknall Limited (RLB) from 2003 to 2014. The paper then tests whether or not the productivity of the Hong Kong construction industry exists of a stable and positive causal relationship from the growth rate of output to the growth rate of productivity in the long run. After that the paper reports on correlation analysis to test the relationships between TFP growth and intermediate input growth, capital input growth, and labour input growth by running identified time-series data sets into SPSS® software. From the results of correlation analysis, significant influencing factors that contribute to low productivity growth in the Hong Kong construction industry has been found, identified, and analysed. Finally, this paper draws its conclusions and solutions to improving construction productivity in Hong Kong at industry, organisation, and activity levels.

51.2 Literature Review

A number of studies have devoted to measure the LP level of Hong Kong since the late 1980s. Chau and Lai (1994) presented a method of estimating relative labour productivity trend of construction sector according to the national accounting data. Wong et al. (2006) measured the LP from year 1985 to 2004 based on the index "Gross construction output per man-hour". Moreover, efforts have been made to measure productivity of certain types of projects. Tam et al. (2002) evaluated the labour resource usage and duration of high-rise public housing projects using different construction methods (i.e., on site and off site). However, PFP (e.g., LP) has been challenged by the TFP as discussed in the introduction section.

To measure the TFP at the industry level, all factor inputs should be included as they work together to produce one common output. Measuring the industry level TFP needs a plenty of inputs and outputs data. However, physical measurement of inputs and outputs is not always possible in the construction industry. Therefore, some TFP studies were conducted by using indirect resources. Chau and Walker (1988), for example, presented a method indirectly estimating the TFP in the Hong Kong building industry at industry level by using construction cost and price indices and other statistics. Due to the availability of construction cost and price indices, this kind of indirect method is available in various countries. Existence of biases caused the Chau and Walker's model vulnerable (Zhi et al. 2003). However, Chau revised the previous model by releasing major restrictions, such as constant value shares of inputs, discrete approximation of TFP formula, unrealistic production structure governing the input-output relationship, erroneously use of book profit and tender price index (Chau 1993). Nevertheless, intermediate inputs are not considered into the revised model (VATFP model) because of intermediate inputs are subtracted from both the input and output side (Chau 1993).

On the other hand, production function is widely used in analysing the productivity growth. In this approach, the productivity is measured by a parametric or non-parametric method. Nonparametric methods estimate the TFP index without explicit production function. While, the parametric estimation methods are growth accounting and numerical indices in order to calculate the total productivity factors (Shabanzadeh-Khoshrody et al. 2016). Translog function has been used extensively for the analysis of production due to its flexible functional form (Owyong 2000) and does not impose restrictions on the characteristics of the underlying production structure (Chau 2009). In this paper, parametric translog production function is utilised to estimate the TFP of the Hong Kong construction industry. Jorgenson's production function assumed that there is a translog production function for each industry (including construction industry), giving output as a sum of weighted function of intermediate input, capital input, labour input and time (Jorgenson et al. 2016). This TFP model is recognised as a more comprehensive expression than PFP to evaluate efficiency in the use of resources. Also, it is more realistic and less restrictive than Chau and Walker's model as it does not impose assumption of Hicks Neutrality of technology change (Zhi et al. 2003) and a unity elasticity of substitution (Chau 2009).

51.3 TFP-Based Production Function Model

A TFP model is developed within the context of Hong Kong construction industry drawing on available data sources (e.g., ArchSD, CSD, RLB etc.) to calculate the TFP trend of the Hong Kong construction industry and analyse the impact of inputs and output factors on construction productivity growth.

The TFP-based production function of the construction industry is expressed as:

$$\mathrm{Z} = \mathrm{F}(\mathrm{X}, \mathrm{K}, \mathrm{L}, \mathrm{T}) \tag{51.1}$$

Under the condition of constant returns to scale and producer equilibrium, the productivity expression is:

$$\Delta \ln Z = \overline{V_X}\Delta \ln X + \overline{V_K}\Delta \ln K + \overline{V_L}\Delta \ln L + \Delta \ln TFP \qquad (51.2)$$

$\Delta \ln X$, $\Delta \ln K$, and $\Delta \ln L$ can be expressed as a weighted average of growth rates of individual input, with weights given by average value shares of individual input, for example:

$$\Delta \ln X = \sum \overline{V_{X_i}}[\ln X_i(T) - \ln X_i(T-1)] \qquad (51.3)$$

The value shares of intermediate input, capital input, and labour input are expressed as:

$$\overline{V_X} = \frac{1}{2}[V_X(T) + V_X(T-1)] \quad V_X = \frac{p_X X}{qZ} \qquad (51.4)$$

$$\overline{V_K} = \frac{1}{2}[V_K(T) + V_K(T-1)] \quad V_K = \frac{p_K K}{qZ} \qquad (51.5)$$

$$\overline{V_L} = \frac{1}{2}[V_L(T) + V_L(T-1)] \quad V_L = \frac{p_L L}{qZ} \qquad (51.6)$$

where, Z is the quantity of output, X, K, L are the quantity of the intermediate, capital and labour inputs, and T is time. Δ sign denotes the difference in the value of the corresponding variable between two successive periods, and the bar sign denotes the average value share of the same two successive periods. V_X, V_K, and V_L are the respective proportion of intermediate, capital and labour input to the output. q, p_X, p_K, and p_L stands for the price of output, intermediate, capital and labour inputs.

In order to compute the TFP growth using above equations, the data required are translog index of real output growth, translog indices of real intermediate, capital and labour growth and value share of three inputs. To construct each index, issues of proper measures for output, inputs and value share of inputs are discussed below.

51.3.1 Translog Index of Real Output Growth

In Hong Kong, there is no direct record of industry-level construction output. Net value of construction work performed can be regarded as the industry-level output which is derived as the grand total of overall contract sum for all main contractors and fee sub-contractors less the value of payment for fee sub-contract work recorded (Census and Statistics Department 2014). The industry-level output is calculated as the difference between gross value of construction works (GVCW) performed and value of work rendered by fee subcontractors (FSC) to avoid double counting (see example, Chau and Wang 2005; Chau and Wang 2003). Both GVCW and FSC are available at CSD website (Census and Statistics Department 2016a). After the output is obtained, it needs to be deflated into a real one. Output price index proposed by Chau is widely used (Chau and Wang 2005), but has its limitations. In calculating deflated output for construction industry, price deflators employed for type-specific construction are needed (Census and Statistics Department 2014). Deflators for different types of construction output are suggested and provided by CSD (Census and Statistics Department 2014). The translog index of real output growth is the sum of weighted deflated type-specific outputs, given the weights of value share of each component.

51.3.2 Translog Index of Intermediate Growth

The intermediate consumption in respect of the construction industry comprises the expenses on consumption of building materials and supplies on sites, sundry supplies in business operation, rentals, expenses on repair and maintenance, and other service (Census and Statistics Department 2014). To make the calculation feasible, the intermediate input in this paper only comprises consumption of materials, suppliers, fuel, electricity, water and maintenance service in real terms (MC). MC is deflated by the Material Cost Index (MCI) for calculation (Chau and Wang 2005). MC and MCI are available from the CSD website (Census and Statistics Department 2016a, b).

51.3.3 Translog Index of Capital Growth

The quantity of capital input is measured as the capital service provided. However, such data are unavailable in Hong Kong. Alternatively, the net fixed assets are used as an approximate value to capital stock (Zhi et al. 2003). CSD provides gross additions to fixed assets (GAFA) annually (Census and Statistics Department 2016a). GAFA is calculated as the difference between acquisitions of fixed assets and proceeds from disposal of fixed assets. Chau and Wang (2005) suggested the capital input equals to the sum of capital input in last year and deflated GAFA. The capital input for the base year is derived from Chau and Wang (2005). GAFA is deflated by Deflator for Plant and Equipment which is available in Chau's pervious study (Chau 1993).

51.3.4 Translog Index of Labour Growth

In previous studies, labour input is defined as headcount, however, this measurement ignored the improvement of labour quality over time (Chau and Wang 2005).

Therefore, labour input in this paper is defined as monetary expenditure on labour and deflated by the Labour Cost Index (LCI) (Chau 1993, 2009). Due to the duality nature of production and cost functions. Labour input contains labour cost for main contractor and subcontractors. However, the degree of subcontracting in Hong Kong construction is relative high, projects are often subcontracted even sub-subcontracted out to smaller firms (Chau and Wang 2003). The labour related expenditure is gained from the compensation of employees and payments to labour-only sub-contractors (LC). Both LC and LCI are available from CSD website (Census and Statistics Department 2016a, c).

51.3.5 Value Shares of Intermediate Input, Capital Input, and Labour Input

Based on the accessible data sources and mathematical expressions stated above, the monetary values of real output, intermediate input, capital input, and labour input are listed in Table 51.1. Value shares of intermediate input, capital input and labour input can be calculated based on Eqs. 51.4–51.6 with data presented in Table 51.1.

51.4 Results and Discussion

The translog index of TFP growth is calculated based on the TFP-based production function model presented in Sect. 51.3 with huge number of historical statistical data from government database and private firms survey results. In logical sense, the translog index of TFP growth was transformed into real TFP growth, then to normal TFP index. The annual TFP trend of the construction industry of Hong Kong over the period of 2003–2014 is shown in Fig. 51.1. The overall productivity tendency of the Hong Kong construction is declining over the observation period with average TFP growth rate of −2.15% per annum. In particular, the TFP index shows a slight fluctuation with decrease tendency from 2003 to 2008, following by an increase in 2009. The overall tendency of TFP index decreases from 2009 to the end of the observation period of 2014. However, after 2012 the TFP index experienced a relative stable tendency.

Some researchers suggested that there is a positive correlation between TFP growth and output growth (Zhi et al. 2003). On the other hand, Zhi et al. found that there was a significant and positive correlation between TFP growth and intermediate input growth. However, they also noted that there were insignificant correlations between TFP growth and labour input growth, capital input growth in the construction industry of Singapore over a long period (Zhi et al. 2003).

Table 51.1 Monetary values of real output, intermediate input, capital input, and labour input (million HKD)

Year	Real output	Intermediate input	Capital input	Labour input	Year	Real output	Intermediate input	Capital input	Labour input
2003	85,927	48,186	30,625	38,604	2009	72,904	28,605	37,469	44,326
2004	78,816	44,443	31,552	35,495	2010	78,987	35,312	40,309	49,831
2005	74,308	38,356	32,286	34,521	2011	86,541	36,933	42,847	53,245
2006	71,103	35,630	33,639	35,147	2012	89,458	38,817	46,494	61,756
2007	66,426	33,928	34,154	37,293	2013	95,108	41,317	49,383	61,583
2008	70,830	37,946	36,020	43,658	2014	102,186	45,586	52,876	59,711

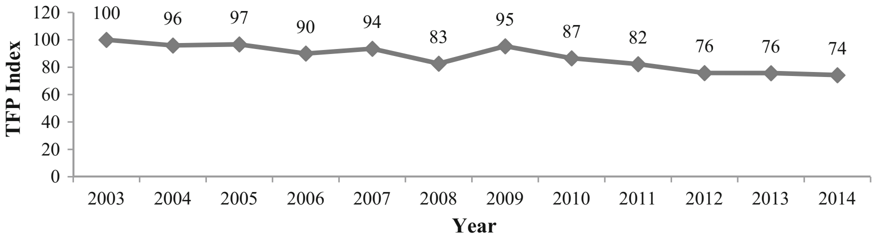


Fig. 51.1 TFP index of construction industry of Hong Kong over 2003–2014 (Base year 2003 = 100)

To test whether the Hong Kong construction industry has the same situation with Singapore, this paper conducted a correlation analysis between TFP growth and output growth. To further study the pattern of TFP growth, correlation analysis studies between TFP growth and inputs growth were conducted. The results of correlation analysis are listed in Table 51.2.

The first correlation analysis shows that there exists insignificant relationship between TFP growth and construction output growth in Hong Kong construction industry, which is converse to the Singapore case (Zhi et al. 2003). The second correlation analysis shows that there are significant relationship between TFP growth with material and labour input growth. However, the negative Pearson correlations suggest that the growth in construction inputs results the decrease of the TFP. It implies that labour input quality and material related to technology progress are generally low in the Hong Kong construction industry.

For labour input, on the one hand, the serious phenomenon of construction labours presents critical problems in Hong Kong. Shortage of 10,000 construction workers (Rowlinson 2014), low registered workers actually engaged (Pan et al. 2016), increasing in vacancies of manual workers on sites (Census and Statistics Department 2016d), and aging workforce (Pan et al. 2016) impose a serious risk of a dramatic labour shortage in the Hong Kong construction industry. On the other hand, the Hong Kong construction industry has suffered from relatively low LP growth. The annual growth of LP of the Hong Kong construction industry was 0.4% during the period from 2000 to 2013, which is however lower than the Asia30's average (1.1%) (Asian Productivity Organisation 2015). According to the LP definition by the Asia Productivity Organisation (2015), Pan et al. indicated that the annual average growth rate of construction workers was lag behind that of construction GDP (Pan et al. 2016). Construction workers shortage, low registered

Table 51.2 Correlation coefficients between $\Delta \ln \mathrm{TFP}$ and $\Delta \ln \mathrm{Z}$, $\Delta \ln \mathrm{X}$, $\Delta \ln \mathrm{K}$, and $\Delta \ln \mathrm{L}$

	$\Delta \ln \mathrm{Z}$	$\Delta \ln \mathrm{X}$	$\Delta \ln \mathrm{K}$	$\Delta \ln \mathrm{L}$
Parson correlation	−0.243	−0.769**	−0.490	−0.656*

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed) workers actually engaged, increasing in vacancies of manual workers on sites, aging workforce, and low LP growth directly or indirectly indicate that manpower shortage and manpower quality problem exists in the Hong Kong construction industry. Manpower issues constraints the increase of construction output (ARCADIS 2015), and therefore have negative effect on TFP growth.

The empirical result of correlation analysis shows the significant relationship between TFP growth and intermediate input growth, which is in a line with Singapore construction industry (Zhi et al. 2003). Intermediate input play an important role in the growth of TFP and material input growth contributes to the growth of TFP. However, the negative relationship suggests that material related to technology progress in the Hong Kong construction industry is generally low. Technology progress for construction involves two aspects: advances in knowledge, and rate of new knowledge diffusion (Zhi et al. 2003). Firstly, R&D activity is considered as one of the sources for advances in knowledge and productivity. However, R&D has been ignored to a large extent in the Hong Kong's construction. The improvements in productivity could rely upon imported technologies and materials which cause lacks of innovation, productivity, and competitiveness for the local industries. Therefore, technological diffusion through materials from other local industries to the construction industry is low. Secondly, although the free trade policy adopted by the Hong Kong Government can improve the efficiency of technological diffusion from overseas to local as well as technological capability of the entire construction industry, the technology gap between Hong Kong and other developed countries narrows (Chau and Wang 2003). The gap will become more difficult to improve productivity through technological diffusion by learning from overseas. For construction materials input, high degree of prefabrication or preassembled forming systems is considered as one of feature of high productivity (Board 1992), and it is also recognised as implementations of lean construction which improving construction performance by reducing wastes (Pan et al. 2015). In Hong Kong, precast concrete has been a popular prefabrication led by the public sector for residential buildings (Pan et al. 2016), but the extent for private buildings in the city is much lower (Pan et al. 2015). Promoting such building industrialisation in industry level will meet capital cost barriers. However, continuous innovation will lead to sustained cost savings in the future by following the innovation 'S' curve theory (Pan et al. 2016; Pan 2006). Then, easing the capital cost barriers and raising the utilisation rate of prefabrication or preassembled forming systems in the whole industry. Consequently, it will help in improving the TFP growth of the construction industry.

51.5 Conclusions

This paper has applied a TFP-based production function model for measuring the industry-level productivity of the Hong Kong construction industry. The results show that the average growth rate of construction industry productivity in Hong

Kong has a negative value of −2.15% per annum over the period from 2003 to 2014.

Through the correlation analysis, the performance of manpower and material technology progress are found to be the key influencing factors to the TFP growth of the Hong Kong construction industry. In light with the identified key influencing factors, recommendations for enhancing TFP growth are developed at industry, organisation, and activity levels. At industry level, the government should formulate policies to attract young workers to address manpower issues such as the shortage of skilled labour, aging workforce, and relatively low construction LP growth. In order to deal with low materials technology progress, firms in the private sector which develop or utilised specialised application machines should be provided with financial incentives, the government should invest in R&D in terms of intermediate input (i.e., material advanced technologies) to improve the performance of construction specific inputs. Also, lean thinking should be promoted to reduce materials and manpower waste at industry level. At organisation level, labour management and labour training and education accounts for organisation-level approaches to improving construction productivity. At activity level, increasing on-site labour co-operation and learning will be beneficial to enhancing productivity.

TFP is revealed to be a better indicator than PFP to identify and analyse the key influencing factors to the industry level construction productivity, as materials role and intangible impacts are accounted for in the TFP model. Future research should quantify the impact of individual factors on productivity, results of which should supplement those of correlation analyses.

Acknowledgements We acknowledge the support from the Construction Industry Council for our research into the productivity of the construction industry.

References

Abdel-Wahab M, Vogl B (2011) Trends of productivity growth in the construction industry across Europe, US and Japan. Constr Manage Econ 29(6):635–644

ARCADIS (2015) International construction costs 2016. Arcadis

Asian Productivity Organisation (2015) APO productivity databook 2015

Board Construction Industry Development (1992) Raising Singapore's construction productivity. Construction Industry Development Board, Singapore

Carson C, Abbott M (2012) A review of productivity analysis of the New Zealand construction industry. Australas J Constr Econ Build 12(3):1–15

Census and Statistics Department (2014) Gross domestic product. Hong Kong SAR. Available at: http://goo.gl/0LD65v. [10/08/2016]

Census and Statistics Department (2016a) Table 116: selected statistics for all establishments in the industry section of construction. Hong Kong SAR. Available at: http://goo.gl/5yD4yu. [10/08/2016]

Census and Statistics Department (2016b) Table 113: index numbers of the costs of labour and materials used in public sector construction projects (April 2003 = 100)-costs of materials index. Hong Kong SAR. Available at: http://goo.gl/XnTTZd. [10/08/2016]

Census and Statistics Department (2016c) Table 112: index Numbers of the Costs of Labour and Materials Used in Public Sector Construction Projects (April 2003 = 100)-Costs of Labour Index. Hong Kong SAR. Available at: http://goo.gl/6IkR1d. [10/08/2016]

Census and Statistics Department (2016d) Quarterly report of employment and vacancies at construction sites. Hong Kong SAR. Available at: http://goo.gl/u1pQUT. [10/08/2016]

Chau KW (1993) Estimating industry-level productivity trends in the building industry from building cost and price data. Constr Manage Econ 11(5):370–383

Chau KW (2009) Explaining total factor productivity trend in building construction: empirical evidence from Hong Kong. Int J Constr Manage 9(2):45–54

Chau KW, Lai LWC (1994) Comparison between growth in labour productivity in construction industry and economy. Constr Manage Econ 12(2):183–185

Chau KW, Walker A (1988) The measurement of total factor productivity of the Hong Kong construction industry. Constr Manage Econ 6(3):209–224

Chau KW, Wang YS (2003) Factors affecting the productive efficiency of construction firms in Hong Kong. In: CIB TG 23 international conference, pp 27–28

Chau KW, Wang YS (2005) An analysis of productivity growth in the construction industry: a non-parametric approach. In: 21st annual ARCOM conference, pp 7–9

Jorgenson D, Gollop FM, Fraumeni B (2016) Productivity and US economic growth, vol 169. Elsevier, Amsterdam

Nachum L (1999) Measurement of productivity of professional services. Int J Oper Prod Manage 19(9):922–950

Owyong DT (2000) Productivity growth: theory and measurement. APO Prod J 19–29

Pan W (2006) *Cost* Effective and innovative solutions using offsite techniques. Construction Productivity Network (CPN) Members' Report E6103, Construction Industry Research & Information Association (CIRIA), London

Pan W, Pan M, Chan S (2015) Lean construction for improving productivity in the Hong Kong construction industry. Build J 57–61

Pan W, Zhan W, Zhao X, Wang J, Lam J (2016) Cost paradigms of future building. In: 2016 symposium on cost management for mega projects, Hong Kong, 6 May 2016

Rowlinson S (2014) Cost escalation in the Hong Kong construction industry report. Department of Real Estate & Construction, The University of Hong Kong

Shabanzadeh-Khoshrody M, Azadi H, Khajooeipour A, Nabavi-Pelesaraei A (2016) Analytical investigation of the effects of dam construction on the productivity and efficiency of farmers. J Clean Prod 135:549–557

Singh H, Motwani J, Kumar A (2000) A review and analysis of the state-of-the-art research on productivity measurement. Ind Manage Data Syst 100(5):234–241

Tam CM, Deng ZM, Zeng SX (2002) Evaluation of construction methods and performance for high rise public housing construction in Hong Kong. Build Environ 37(10):983–991

Wong JM, Chan AP, Chiangn YH (2006) The changing construction labour market: a case of Hong Kong. J Eng Design Technol 4(1):1–17

Zhi M, Hua GB, Wang SQ, Ofori G (2003) Total factor productivity growth accounting in the construction industry of Singapore. Constr Manage Econ 21(7):707–718

Chapter 52
Critical Impact Factors Affecting Carbon Emission: Evidence from STIRPAT Model with Panel Data Analysis

C.Y. Shuai, X.N. Song and S.P. Li

52.1 Introduction

Global warming is today's common challenge faced by all humanity for it has significant impacts on global natural ecosystems, causing temperature increase and sea level rise as well as more frequent extreme climate events, all of which pose a huge challenge to the survival and development of the human race. It is commonly appreciated that the major increase in Greenhouse Gas (GHG) is attributed largely to CO_2 as the principal gas leading to global warming. It is therefore considered significant to analyze the critical impact factors of carbon emission, since different impact factors will directly influence the carbon emission reduction measures of different country.

In line with this aim, an effective method is needed. Based on the comprehensive literature review, impact, population, affluence and technology (IPAT) model is widely applied to investigate the impact factors of environmental degradation. For example, Wu et al. (2016) identified the influencing factors of industrial sector carbon dioxide emissions in China by using the IPAT. Brizga et al. (2013) applied the IPAT index decomposition analysis to study the drivers of CO_2 emissions in the former Soviet Union from 1990 to 2010. Ding and Wen (2014) conducted the improved the IPAT model to study the influential factors of carbon emissions in Yangtze River Delta in China. Using the IPAT model, Wang et al. (2013) examined the impact factors of energy-related carbon emission in Guangdong China.

C.Y. Shuai (✉) · X.N. Song · S.P. Li
School of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: 1391843874@qq.com

X.N. Song
e-mail: 1018500021@qq.com

S.P. Li
e-mail: 861231006@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_52

The above discussions indicate that whilst many researches have applied the IPAT model to study the influencing factors of carbon emission at the national or local level, but there is no study analyzing this from the global perspective. Therefore, the aim of this paper is to investigate the critical impact factors affecting carbon emission at the global level. This paper analyzes the impact factors of carbon emissions of 125 countries that are classified into four income levels including high-income, upper-middle-income, lower-income and low-income. The resource for retrieving these performance data is total from World Bank Database.

52.2 The STIRPAT Method

IPAT is a universally recognized formula to study the influence of human activities on the environment. IPAT specifies that environmental impacts contain three key driving forces including population, affluence (per capita consumption or production) and technology (impact per unit of consumption or production), hence I = PAT. The IPAT equation can be represented as follows:

$$I = P \times A \times T \tag{52.1}$$

The IPAT model is a concise and simple way to examine the impact factors of environmental pressure. Using this model as a basis, Dietz and Rosa developed the STIRPAT model (DietzT 1994). The STIRPAT model maintains the relations among environmental pressure, population, affluence and technology, but is modified to overcome some of the weaknesses within the IPAT model. Specifically, it rejects the unit elasticity assumption and adds randomness for convenience of empirical analysis.

The STIRPAT model is formulated as follows:

$$I_i = aP_i^b A_i^c T_i^d e_i \tag{52.2}$$

After taking logarithms, the model can be represented as follows:

$$LnI_{it} = a + b(LnP_{it}) + c(LnA_{it}) + d(LnT_{it}) + e_i \tag{52.3}$$

Where subscript i denotes the country samples; t denotes the year; b, c, and d are the coefficients of P, A, and T respectively. Previous literatures provide guidelines for choosing variables to measure these factors. Table 52.1 shows the selected variables in this research.

Table 52.1 Variables and definitions

Variable	Supporting reference
CO_2 emissions	Peng et al. (2016), Shang et al. (. 2016)
Urban population	Matsuhashi and Ariga (2016), Guo et al. 2016, Lu et al. (2015)
GDP per capita	Belloumi and Alshehry (2016), Shuai et al. (2017), Shen et al. (2016)
Energy intensity	Tian et al. (2016), Shahbaz et al. (2015), Lu et al. (2016)

52.3 Empirical Analysis and Results

52.3.1 Model Estimation

With the aim of investigating the key impact factors affecting carbon emissions, this process of examination can be divided into three steps, including unit root test, cointegration test and cointegration estimation (Akbostancı et al. 2009). Unit root test is conducted to exam the stationarity of the variables. If variables are determined to be stationary in such a test, a cointegration test should be utilized for testing the long-run equilibrium relationship between the variables. If it is determined that the variables are cointegrated, cointegration estimation can be conducted to establish a regression model. Furthermore, the universally applied unit root test methods are Levin, Lin, and Chu test (LLC) (Levin et al. 2002) and Im, Pesaran and Shin (IPS) (Im et al. 2003). Various scholars adopted Kao cointegration test (Kao 1999) to check the long-run relationship between panel data variables. At last, this study applied Ordinary Least Squares (OLS) technique to estimate the parameters of the variables.

52.3.2 Empirical Results

As mentioned before, this paper selected 125 individual countries and classified into 4 panel groups including high-income, upper-middle-income, lower-middle-income and low-income level.

52.3.2.1 Unit Root Test

The results of unit root test at different income levels are presented in Table 52.2 as follows.

As shown in Table 52.2, the null hypothesis of panel unit of upper middle income group can be rejected at the first difference, and the null hypothesis of panel unit of rest three groups are rejected at second difference.

Table 52.2 LLC & IPS unit root test results

	Variables	LLC		IPS		Order of integration
		Intercept	Intercept and trend	Intercept	Intercept and trend	
High	*LnCO2*	−30.456***	−13.3902***	−37.649***	−29.0493***	2
	LnT	−23.9147***	−13.5153***	−30.351***	−22.6087***	2
	LnA	−28.0935***	−22***	−25.3905***	−19.7291***	2
	LnP	−16.6687***	−34.3113***	−20.0574***	−23.4025***	2
Upper middle	*LnCO2*	−31.8155***	−27.8777***	−24.0722***	−22.8164***	1
	LnT	−19.7389***	−19.2271***	−18.2248***	−16.7114***	1
	LnA	−11.6778***	−11.3003***	−13.6761***	−10.3384***	1
	LnP	−2.13853**	−6.92682***	−4.25558***	−6.73074***	1
Lower middle	*LnCO2*	−18.315***	−13.0739***	−26.7382***	−23.089***	2
	LnT	−21.4828***	−17.8451***	−24.2569***	−21.4623***	2
	LnA	−25.2246***	−22.3156***	−26.8294***	−24.9678***	2
	LnP	−6.43887***	−7.26155***	−9.22987***	−10.4153***	2
Low	*LnCO2*	−11.9054***	−12.7541***	−12.9802***	−14.6805***	2
	LnT	−15.3906***	−13.427***	−13.5203***	−11.8709***	2
	LnA	−13.926***	−10.4362***	−13.0253***	−10.306***	2
	LnP	−9.04141***	−6.34094***	−8.38853***	−6.52279***	2

*** Denotes the rejection of the null of nonstationary at the 1% level of significance
** Denotes the rejection of the null of nonstationary at the 5% level of significance
* Denotes the rejection of the null of nonstationary at the 10% level of significance

52.3.2.2 Cointegration Test

With strong evidence that all the variables are stationary at the first or second difference, the panel cointegration test are applied to estimate the existence of the long-run equilibrium relationship among the variables. Table 52.3 presents the results of cointegration test results at different income level.

As shown in Table 52.3, all the t-statistics of different income level is significant, rejecting the null hypothesis of no cointegration. Therefore, all the four variables in model (5) are cointegrated, which supports the existence of a long-run equilibrium relationship between four variables.

Table 52.3 Kao cointegration test results

Region	t-statistic		t-statistic
High-income	−1.580559**	Lower-middle-income	−2.94229***
Upper-middle-income	−5.088908***	Low-middle-income	−2.772923**

*** Denotes the rejection of the null of nonstationary at the 1% level of significance
** Denotes the rejection of the null of nonstationary at the 5% level of significance

Table 52.4 Regression results of panel data

Country	Logarithmic STIRPAT model	R-squared
High-income	Ln(CO2it) = 0.768164***Ln(Pit) + 0.664392***Ln (Ait) + 0.903938***Ln(Tit) −11.788***	0.995
Upper-middle-income	Ln(CO2it) = 0.562529***Ln(Pit) + 1.030417***Ln (Ait) + 0.910216***Ln(Tit) −11.142***	0.994
Lower-middle-income	Ln(CO2it) = 0.605798***Ln(Pit) + 1.349192***Ln (Ait) + 0.917583***Ln(Tit)	0.99
Low-income	Ln(CO2it) = 0.787265***1Ln(Pit) + 1.133547***Ln (Ait) + 0.295345***Ln(Tit) −12.433***	0.947

52.3.2.3 Cointegration Estimation

If a cointegrating relationship between the variables is found, the next step is to estimate the long-run parameters in model (5). The ultimate results of cointegration estimation of different income levels are integrated in Table 52.4 as follows.

52.4 Discussion

Table 52.4 provides the cointegration estimation results of 4 panel groups. As to the high-income panel group, the key impact factor is technology with the coefficient of 0.903938, followed by factor population with the coefficient of 0.768164 and factor affluence with the coefficient of 0.664392. It is considered that this results benefit from the large investments of exploration of new energy resource (Zhang et al. 2016; Chen and Lu 2017), innovation of carbon reduction technology and establishment of carbon reduction system, such as emission trading system (ETS) and carbon taxes system (Qin et al. 2015; Dong et al. 2016; Wu et al. 2017; Shuai et al. 2017; Shen et al. 2017). As to the upper-middle-income panel group, the key impact factor is affluence with the coefficient of 1.030417, followed by factor technology with the coefficient of 0.910216, and factor population scale with the coefficient 0.562529. As to the lower-middle-income panel group, the top impact factor is affluence with the coefficient of 1.349192, followed by factor technology with the coefficient of 0.917583, and factor population with the coefficient 0.605798, which is also the same with world panel and upper-middle-income panel group. As to the low-income panel group, the top impact factor is affluence with the coefficient of 1.133547, followed by factor technology with the coefficient of 0.295345, and factor population with the coefficient 0.787256.

52.5 Conclusion

The main conclusion from this study can be drawn as follows. In this study, there are 125 countries of four income levels are analyzed by combining the STIRPAT with panel and time series data. The results reveal that the top impact factor of world panel group is affluence, followed by factor technology, and factor population. As to the high-income panel group, the key impact factor is technology, followed by factor population and factor affluence. The key impact factor of upper-middle, lower-middle and low-income panel groups are all factor affluence.

Acknowledgements This paper is funded by the National Social Science Foundation of China (Grant No. 15BJY038 and 15AZD025).

References

Akbostancı E, Türüt-Aşık S, Tunç Gİ (2009) The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 37(3):861–867
Belloumi M, Alshehry AS (2016) The impact of urbanization on energy intensity in Saudi Arabia. Sustainability 8(4):375
Brizga J, Feng K, Hubacek K (2013) Drivers of CO_2 emissions in the former Soviet Union: a country level IPAT analysis from 1990 to 2010. Energy 59:743–753
Chen X, Lu W (2017) Identifying factors influencing demolition waste generation in Hong Kong. J Clean Prod 141:799–811
DietzT R (1994) Rethinking the environmental impacts of population, affluence and technology. HumanEcolRev 2:277
Ding S, Wen Z-M (2014) Study on influential factors of carbon emissions in Yangtze River delta—based on IPAT improved model. Technoeconomics Manage Res 9:021
Dong J, Ma Y, Sun H (2016) From pilot to the national emissions trading scheme in China: international practice and domestic experiences. Sustain 8(6):522
Guo W, Sun T, Dai H (2016) Effect of population structure change on carbon emission in China. Sustainability 8(3):225
Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J econometrics 115(1):53–74
Kao C (1999) Spurious regression and residual-based tests for cointegration in panel data. J econometrics 90(1):1–44
Levin A, Lin CF, Chu CSJ (2002) Unit root tests in panel data: asymptotic and finite-sample properties. J econometrics 108(1):1–24
Lu W, Chen X, Peng Y, Shen L (2015) Benchmarking construction waste management performance using big data. Resour Conserv Recycl 105:49–58
Lu W, Chen X, Ho DC, Wang H (2016) Analysis of the construction waste management performance in Hong Kong: the public and private sectors compared using big data. J Clean Prod 112:521–531
Matsuhashi K, Ariga T (2016) Estimation of passenger car CO_2 emissions with urban population density scenarios for low carbon transportation in Japan. IATSS Res 39(2):117–120
Peng H, Tan X, Li Y, Hu L (2016) Economic growth, foreign direct investment and CO_2 emissions in China: a panel granger causality analysis. Sustain 8(3):233
Qin J, Bai X, Xia L (2015) Sustainable trade credit and replenishment policies under the cap-and-trade and carbon tax regulations. Sustainability 7(12):16340–16361

Shahbaz M, Solarin SA, Sbia R, Bibi S (2015) Does energy intensity contribute to CO_2 emissions? A trivariate analysis in selected African countries. Ecol Indic 50:215–224

Shang W, Pei G, Walsh C, Meng M, Meng X (2016) Have market-oriented reforms decoupled China's CO_2 emissions from total electricity generation? Empir Anal Sustain 8(5):468

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shen L, Yan H, Zhang X, Shuai C (2017) Experience mining based innovative method for promoting urban sustainability. J Cleaner Prod

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017a) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Shuai C, Jiao L, Song X, Shen L (2017) Decoupling analysis on the relationship between economic development and environment degradation in China. In: Proceedings of the 20th international symposium on advancement of construction management and real estate, Springer, Singapore, pp 1207–1216

Tian L, Ding Z, Wang Y, Duan H, Wang S, Tang J, Wang XE (2016) Analysis of the driving factors and contributions to carbon emissions of energy consumption from the perspective of the peak volume and time based on leap. Sustainability 8(6):513

Wang P, Wu W, Zhu B, Wei Y (2013) Examining the impact factors of energy-related CO_2 emissions using the STIRPAT model in Guangdong Province, China. Appl Energy 106:65–71

Wu R, Zhang J, Bao Y, Zhang F (2016) Geographical detector model for influencing factors of industrial sector carbon dioxide emissions in inner Mongolia, China. Sustainability 8:149

Wu Y, Chen J, Song X, Shen L (2017) Relationship between the energy consumption for urban residential buildings and residents' living standards—a case study of the four municipalities in China. In: Proceedings of the 20th international symposium on advancement of construction management and real estate, Springer, Singapore, pp 1229–1238

Zhang X, Ma Y, Ye B, Chen ZM, Xiong L (2016) Feasibility analyses of developing low carbon city with hybrid energy systems in China: the case of Shenzhen. Sustainability 8(5):452

Chapter 53
Critical Risks Associated with BIM Adoption: A Case of Singapore

Xianbo Zhao, Josua Pienaar and Shang Gao

53.1 Introduction

Building information modelling (BIM), defined as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's lifecycle" (Succar 2009, p. 357), has been recognized as one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry (Azhar 2011; Zhao 2017). BIM covers not only software that allows the geometrical modelling and the input of information but also project management-related tools and processes (Bryde et al. 2013). In reality, BIM has been seen as a revolutionary change for managing a project from beginning to end (Chen et al. 2013). It requires the use of information and communication technology (ICT) to simulate the planning, design, construction and operational phases of a building project (Azhar 2011), in order to provide a safer and more productive environment for users, to assert the minimum impact on environment from its existence, and to be more operationally efficient for the owner throughout the project lifecycle (Arayici and Aouad 2010).

Previous studies have identified a number of benefits that can be produced by the use of BIM. A recent study by McGraw Hill Construction (2014) revealed that the

X. Zhao (✉)
School of Engineering and Technology, Central Queensland University, Sydney 2000, NSW, Australia
e-mail: b.zhao@cqu.edu.au

J. Pienaar
School of Engineering and Technology, Central Queensland University, Wayville 5034, SA, Australia

S. Gao
Faculty of Architecture, Building and Planning, The University of Melbourne, Parkville 3010, VIC, Australia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_53

most significant short-term benefits of BIM adoption in Australia and New Zealand were: reduced errors and omissions, enhancement of organization's image as an industry leader, reduced rework, and the most significant long-term benefits were maintained repeat business, reduced project duration and reduced construction cost. In terms of time saving, Autodesk (2008) argued that Revit® Architecture software saved 91% of the time on checking and coordination and 50% on design development, compared with traditional Computer Aided Design (CAD) tools. In addition, BIM has been seen as a critical tool for raising construction productivity. The Singapore government has been actively promoting the BIM adoption in the construction industry, which contributes to the goal of the national productivity drive that raises the productivity of all the sectors. From 1 July 2015 onwards, all plans of the new building projects that have over gross floor area (GFA) of 5000 m^2 should be submitted in BIM format for regulatory approval.

Although the potential benefits of BIM adoption has attracted the attention of the industry practitioners, academics and government policy makers, BIM adoption is also affiliated with risks. Lesny and Reidy (2013) asserted that more use of BIM models would lead to greater risk, which could extend long after project completion, provided that the BIM models are used for lifecycle. In addition, Hanna et al. (2013) indicated that the risks associated with BIM implementation was one of the five main factors influencing the current state of BIM practice. These risks may hinder the achievement of the potential benefits and thus are worth attention. The objective of this study is to assess the risks associated with the BIM adoption in the Singaporean AEC industry. The identification of the critical risks enables practitioners to understand which risks are worth more attention to ascertain the benefits of BIM that they would like to pursue.

53.2 Literature Review

Risk identification is usually recognized as the first step of a risk management process (Zhao et al. 2014; Low et al. 2009). In this study, the risks associated with BIM adoption in the AEC industry were identified through a literature review. Firstly, the relevant articles indexed by the Scopus database were reviewed. In Scopus database, there were 199 journal articles at the time of this study, including those in press, whose titles include either "building information modelling" or "building information modeling". The following search code is input into the search engine: TITLE (building information modelling) OR TITLE (building information modeling) AND TITLE-ABS-KEY (risk) AND LANGUAGE (english) AND SUBJAREA (mult OR ceng OR CHEM OR comp OR eart OR ener OR engi OR envi OR mate OR math OR phys OR mult OR arts OR busi OR deci OR econ OR psyc OR soci).

A total of 30 articles were obtained, including 11 journal articles, 17 conference papers, 1 book and 1 review. Because journal articles tended to provide more detailed information than conference papers this study focused on the 11 journal articles. However, only four of them are relevant to risks of BIM application. Thus, articles and professional reports that were not included in Scopus database, were also reviewed. Most of them were published by BIM professional bodies or software companies. Finally, a total of 20 literatures were reviewed. Content analysis, which can assist in classifying textual material, and reduce it to more relevant and manageable bits of data (Weber 1990), has been widely adopted to determine the major facets of a set of data, by simply counting how many times an activity occurs, or a topic is depicted (Fellows and Liu 2003; Hwang et al. 2013). In this study, risks identified in each literature were first marked down, and then similar risks were assembled. Finally, a total of 16 risks were identified from the 20 literatures, as presented in Table 53.1.

53.3 Method

A large research project that attempts to investigate BIM adoption in the AEC industry in Australia, Singapore and China has been implemented. In this study, a preliminary questionnaire survey was performed to investigate the likelihood of occurrence (*LO*) and magnitude of impact (*MI*) of the risks associated with BIM adoption in Singapore. The comprehensive literature review supported the development of the questionnaire. In the survey, the respondents were asked to assess the *LO* and *MI* of each risk based on their experience. The evaluation of risk criticality (*RC*) is complex and vague, and thus qualitative linguistic terms are unavoidable (Wang et al. 2004). Therefore, five-point Likert scales were adopted in this study (see Table 53.2).

The *LO* and *MI* of each risk can be calculated using Eqs. (53.1) and (53.2), respectively.

$$LO^i = \frac{1}{n}\sum_{j=1}^{n} LO_j^i \tag{53.1}$$

$$MI^i = \frac{1}{n}\sum_{j=1}^{n} MI_j^i \tag{53.2}$$

where n represents the number of the respondents; LO^i denotes the likelihood of occurrence of risk i; LO_j^i denotes the likelihood of occurrence of risk i by respondent j; MI^i denotes the magnitude of impact of risk i; and MI_j^i represents the magnitude of impact of risk i by respondent j. Thus, the *LO* and *MI* of each risk are actually the mean scores assigned by respondents.

This study adopted a *RC* index to evaluate the criticality of each risk. *RC* has been recognized as the function of the *LO* and *MI* (Sun et al. 2008; Fang et al. 2004; Zou et al. 2007; Hwang et al. 2015). Hence, the *RC* of a risk can be calculated as follows:

Table 53.1 Risks associated with BIM adoption

Risk	References									
	Hanna et al. (2013)	Azhar (2011)	Azhar et al. 2012)	Simonian (2010)	Kuiper and Holzer (2013)	Rodriguez (2014)	Arayici et al. (2012)	Hutt (2013)	Ku and Taiebat (2011)	Fan (2013)
Lack of BIM protocols	*		*		*					
Unclear ownership of the BIM data		*	*	*	*					*
Professional licensing issues		*	*	*	*					
Data security		*	*		*					
Uncertainty over design liability		*	*	*	*	*		*		
Reluctance to share information		*	*							
Technological interface among programs		*					*			
Lack of a check mechanism			*							
Cultural resistance										
Cost overrun with BIM	*									
Lack of competency or expertise in using BIM	*									
Poor communication among project participants						*		*		
Lack of collaboration among project participants							*		*	
Interoperability issues			*		*					*
Changes in the BIM model by unauthorized parties						*				
Low quality of BIM data										

(continued)

Table 53.1 (continued)

Risk	References									
	Jensen and Jóhannesson (2013)	Dossick and Neff (2010)	Thompson and Miner (2006)	Sieminski (2007)	Krygiel and Nies (2008)	Becerik-Gerber and Rice (2010)	Hanna et al. (2014)	Chien et al. (2014)	Hsu et al. (2015)	Stanley and Thurnell (2014)
Lack of BIM protocols							*			*
Unclear ownership of the BIM data		*	*	*					*	*
Professional licensing issues			*	*						
Data security										
Uncertainty over design liability		*	*	*				*		
Reluctance to share information		*						*		
Technological interface among programs			*					*	*	*
Lack of a check mechanism										
Cultural resistance	*	*								*
Cost overrun with BIM		*					*	*		
Lack of competency or expertise in using BIM								*		
Poor communication among project participants										
Lack of collaboration among project participants		*								*
Interoperability issues								*	*	
Changes in the BIM model by unauthorized parties										
Low quality of BIM data					*	*				

Table 53.2 Likert scales for LO and MI

LO	Linguistic terms	Likelihood references (%)	MI	Linguistic terms
1	Rarely	<20	1	Very small
2	Somewhat likely	20–40	2	Small
3	Likely	40–60	3	Medium
4	Very likely	60–80	4	Large
5	Almost definite	>80	5	Very large

$$RC_j^i = \sqrt{LO_j^i \times MI_j^i} \tag{53.3}$$

$$RC^i = \frac{1}{n}\sum_{j=1}^{n} RC_j^i \tag{53.4}$$

where RC_j^i represents the risk criticality of the risk i by respondent j; and RC^i denotes the risk criticality of risk i. Thus, RC is still on a full scale of 5, consistent with that of MI and LO.

The population consisted of all the industry practitioners in the Singaporean AEC industry. Because there was no sampling frame in this survey, the sample was a non-probability sample. The non-probability sampling can be used to obtain a representative sample (Patton 2001), and has been recognized as appropriate when the respondents were not randomly drawn from the entire population, but were rather selected based on whether they were willing to participate in the study (Wilkins 2011; Liu et al. 2016; Zhao et al. 2013). A total of 130 questionnaires were sent out and 42 completed questionnaires were received. The response rate was 32%, which was acceptable compared with the norm of 20–30% with most questionnaire surveys in the construction industry (Hwang et al. 2015; Akintoye 2000). In spite of a relatively small sample size, statistical analysis can still be carried out because the central limit theorem holds true when the sample size is greater than 30 (Ott and Longnecker 2001). The profile of the respondents is shown in Table 53.3. Out of the 42 respondents, 67% were from contractors while 33% were from design/consultant firms. In terms of experience, 57% had over 10 years of industry experience, ensuring data quality and reliability. In addition, 52% of the respondents had more than two years of experience in BIM. Because the electronic submission of architectural plans began to become mandatory after 1 July 2013, it has been around two years since most firms started to adopt BIM. Thus, it was not surprising that 33% had adopted BIM less than two years. Six firms did not have BIM experience. There may be two reasons for this. First, these firms conducted only small projects, for which electronic submission in the BIM format for approval was not mandatory. Second, they outsourced BIM-related tasks to BIM moulders or specialists to satisfy the mandatory requirements from BCA.

Table 53.3 Profile of respondents and their firms

Organization type	N	%	Industry experience	N	%	BIM experience	N	%
Contractor	28	67	5–10 years	18	43	None	6	14
Design/consultant firms	14	33	11–15 years	15	36	1–2 years	14	33
			16–20 years	7	17	3–4 years	14	33
			Over 20 years	2	5	≥ 5 years	8	19

53.4 Results and Discussion

The MI, LO and RC of each risk were calculated and analysed, as shown in Table 53.3. To test the significance of these scores, the one-sample t-test was adopted. In terms of MI, 13 risks can exert significant impact on BIM adoption at the 0.05 level. "Lack of competency or expertise in using BIM" received the highest MI score, indicating that inadequate competency or expertise relevant to BIM significantly influenced the BIM adoption in the Singaporean AEC industry. "Cost overrun with BIM" occupied the second position, and "professional licensing issues" was ranked third in the MI ranking. In terms of LO, only six risks were perceived as significantly likely to occur. "Cultural resistance" received the top rank, indicating that the difficulty in cultural change was very likely to occur when practitioners adopted BIM. "Lack of competency or expertise in using BIM", "interoperability issues", "technological interface among programs", "cost overrun with BIM" and "lack of collaboration among project participants" were the other five risks with significantly high LO values. These results suggested that firms adopting BIM were likely to experience issues such as lack of competency or expertise, interoperability, high investment in BIM and inadequate collaboration among various participants in a project. Based on LO and MI, the RC values of the 16 risks were calculated. The one-sample t-test values showed that only four risks were significantly critical to BIM adoption in the Singaporean AEC industry. The small number of the critical risks was attributed to the small number of risks with high LO values.

"Lack of competency or expertise in using BIM" was perceived to be the most critical risk, which was attributed to its high MI and LO scores. Lack of relevant expertise or competency can significantly hinder BIM adoption (Gilligan 2007; Won et al. 2013; Eadie et al. 2013), and has been considered as a critical risk associated with the use of BIM (Hanna et al. 2013). Low-level competency or expertise in using BIM can prevent project team members from obtaining the benefits of BIM. Therefore, training programs were necessary for BIM adoption. Hanna et al. (2013) suggested that potential solutions would involve developing comprehensive standards and training programs for contractors, thus ensuring the adequate BIM implementation in projects. An enhanced level of the relevant competency or expertise enables the project team to obtain the full benefits of BIM throughout the project lifecycle (Eadie et al. 2013).

"Cost overrun with BIM" received the second position in the RC ranking. Although BIM offers the potential for significant savings (Simonian 2010), BIM adoption involves investment. Hanna et al. (2013) reported that the BIM implementation usually represented 1–2% of mechanical, electrical, and plumbing (MEP) project costs, and that the costs of using BIM significantly influenced the status quo of BIM practice. Similarly, Bradshaw (2006) believed that it was a long and costly process to become proficient in BIM considering the cost and time associated with buying and becoming familiar with new software programs. Additionally, the high cost of investment in BIM has been viewed as an important obstacle to the BIM adoption (Won et al. 2013; Eadie et al. 2013; Bernstein et al. 2012; Eastman et al. 2011; Khosrowshahi and Arayici 2012). To mitigate this risk, the Building and Construction Authority (BCA) of Singapore has set up the BIM Fund, which is aimed to help firms establish BIM collaboration capability by covering the costs for training, consultancy services and purchase of hardware and BIM software (BCA 2014) (Table 53.4).

"Lack of collaboration among project participants" was ranked the third in the *RC* ranking, suggesting that collaboration among project participants was not enough in the Singaporean AEC industry and may prevent the achievement of BIM benefits. Ku and Taiebat (2011) revealed that close collaboration between the primary project participants, including the owner, architect, engineer, general contractor, subcontractors, and suppliers, is necessary to fulfill the benefits of BIM. In addition, Sebastian (2011) believed that the fair and open collaboration between the owner and contractors enabled the optimal use of their competencies. The lack of collaboration among different project participants probably can be attributed to the fragmented nature of the AEC industry (Stanley and Thurnell 2014). However, it should be noted that collaborative working makes it difficult to protect intellectual property rights over shared data, information and models (Lesny and Reidy 2013). The intellectual property issues, together with data ownership and design liability issues, result in the lack of collaboration among project participants (Dossick and Neff 2010).

"Interoperability issues" was another critical risk associated with BIM adoption in the Singaporean AEC industry. Interoperability is defined as the ability to exchange data between applications to facilitate automation and avoidance of data re-entry (Azhar et al. 2012), requiring that drawings, master building specifications, standards, regulations, cost and procurement details, environmental conditions, and submittal processes work together (Smith 2014). The introduction of XML Schemas and the Industry Foundation Classes (IFC) has significantly helped to solve interoperability issues (Smith and Tardif 2012; Vanlande et al. 2008), but both approaches have their inherent limitations. Thus, interoperability issues have been viewed as a critical technological risk (Azhar et al. 2012). Some BIM files, which can be opened in a firm, probably cannot be opened in another firm because these firms employ different BIM software applications. Consequently, the efficiency in using BIM could be lowered down and the potential benefits of BIM could not be ascertained.

Table 53.4 Assessment of the risks associated with BIM adoption

Risk	MI			LO			RC		
	Mean	*p*-value	Rank	Mean	*p*-value	Rank	Mean	*p*-value	Rank
Lack of BIM protocols	3.19	0.243	15	3.02	0.850	7	3.05	0.645	12
Unclear ownership of the BIM data	3.38	0.014*	10	2.74	0.078	15	2.98	0.844	15
Professional licensing issues	3.64	0.000*	3	2.93	0.660	11	3.19	0.125	7
Data security	3.33	0.029*	11	2.88	0.463	13	3.05	0.708	13
Uncertainty over design liability	3.29	0.050*	13	3.00	1.000	9	3.10	0.350	10
Reluctance to share information	3.31	0.036*	12	3.14	0.412	6	3.13	0.281	9
Technological interface among programs	3.21	0.107	14	2.71	0.027*	16	2.88	0.216	16
Lack of a check mechanism for designs	3.48	0.003*	5	3.00	1.000	9	3.19	0.146	6
Cultural resistance	2.93	0.706	16	3.67	0.000*	1	3.20	0.167	5
Cost overrun with BIM	3.69	0.000*	2	3.57	0.001*	2	3.58	0.000*	2
Lack of competency or expertise in using BIM	3.83	0.000*	1	3.55	0.000*	3	3.65	0.000*	1
Poor communication among project participants	3.43	0.003*	6	3.02	0.881	7	3.16	0.199	8
Lack of collaboration among project participants	3.40	0.002*	9	3.40	0.004*	4	3.37	0.002*	3
Interoperability issues	3.43	0.002*	6	3.33	0.037*	5	3.34	0.009*	4
Changes in the BIM model by unauthorized parties	3.55	0.000*	4	2.90	0.544	12	3.10	0.295	11
Low quality of BIM data	3.43	0.003*	6	2.79	0.130	14	3.04	0.735	14

* One-sample t-test is significant at the 0.05 level (test value = 3)

53.5 Conclusions and Recommendations

The potential benefits of BIM have attracted industry practitioners to adopt BIM. However, the risks associated with BIM adoption should not be overlooked. This study attempts to assess the risks associated with BIM adoption in the Singaporean AEC sector. The MI, LO and RC of the 16 risks, which were identified from the literature review, were assessed in this study. “Lack of competency or expertise in using BIM”, “cost overrun with BIM”, “lack of collaboration among project participants” and “interoperability issues” were perceived to be the critical risks, according to their RC values with statistical significance. In addition, with respect to MI, “lack of competency or expertise in using BIM” also received the top position. In terms of LO, “cultural resistance” was ranked top. The identification of the critical risks contributes to a better risk awareness in the organizations that were adopting BIM, and enables the industry practitioners to develop appropriate risk response measures.

There are limitations to the conclusions. First, the sample size was relatively small in this survey. Thus, cautions should be warranted when the analysis results are interpreted and generalized. Additionally, the single-source data are very likely to cause common method biases, which is a common limitation of the studies using questionnaire survey (Zhao et al. 2016). Furthermore, the findings of this study are interpreted in the context of Singapore, which may be different from the context of other countries. Nevertheless, this study still provides an understanding of the critical risks associated with the use of BIM. As there have been few studies focused on risks in BIM adoption, this study can contribute to the literature relating to BIM and risk management.

Future studies would investigate the interaction mechanisms among the risks associated with BIM adoption, and identify a networking of risk paths. In addition, the perception on risks among different project participants is also worth attention.

Acknowledgements The work described in this paper was supported by the Central Queensland University New Staff Grant.

References

Akintoye A (2000) Analysis of factors influencing project cost estimating practice. Constr Manag Econ 18(1):77–89

Won J et al (2013) Where to focus for successful adoption of building information modeling within organization. J Constr Eng Manag 139(11)

Arayici Y, Aouad G (2010) Building information modelling (BIM) for construction lifecycle management. Construction and building: design, materials, and techniques. Nova Science Publishers, New York, pp 99–118

Arayici Y, Egbu C, Coates P (2012) Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. J Inf Technol Constr 17:75–92

Autodesk (2008) The five fallacies of BIM. http://images.autodesk.com/apac_korea_main/files/five_fallacies_of_bim_mar08.pdf

Azhar S (2011) Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry. Leadersh Manag Eng 11(3):241–252

Azhar S, Khalfan M, Maqsood T (2012) Building information modeling (BIM): now and beyond. Australas J Constr Econ Build 12(4):15–28

BCA (2014) Technology adoption: building information model (BIM) fund (ENHANCED). http://www.bca.gov.sg/BIM/bimfund.html

Becerik-Gerber B, Rice S (2010) The perceived value of building information modeling in the US building industry. J Inf Technol Constr 15(2):185–201

Bernstein HM, Jones SA, Russo MA (2012) The business value of BIM in North America: multi-year trend analysis and user ratings (2007–2012). McGraw-Hill Construction, Bedford

Bradshaw D (2006) The rewards and risks of BIM. http://www.benchmark-insurance.com/BIM.pdf

Bryde D, Broquetas M, Volm JM (2013) The project benefits of building information modelling (BIM). Int J Project Manag 31(7):971–980

Chen SM et al (2013) A framework for an automated and integrated project scheduling and management system. Autom Constr 35:89–110

Chien K-F, Wu Z-H, Huang S-C (2014) Identifying and assessing critical risk factors for BIM projects: empirical study. Autom Constr 45:1–15

Dossick CS, Neff G (2010) Organizational divisions in BIM-enabled commercial construction. J Constr Eng Manag 136(4):459–467

Eadie R et al (2013) BIM implementation throughout the UK construction project lifecycle: an analysis. Autom Constr 36:145–151

Eastman C et al (2011) BIM handbook—a guide to building information modeling for owners, managers, designers, engineers, and contractors, 2nd edn. Wiley, Hoboken

Fan S-L (2013) Intellectual property rights in building information modeling application in Taiwan. J Constr Eng Manag 140(3):04013058

Fang D et al (2004) Risks in Chinese construction market—contractors' perspective. J Constr Eng Manag 130(6):853–861

Fellows R, Liu A (2003) Research methods for construction, 2nd edn. Blackwell Publishing, Oxford

Gilligan B, Kunz J (2007) VDC use in 2007: significant value, dramatic growth, and apparent business opportunity. In: Construction users roundtable (CURT) national meeting, Stanford University, Stanford, CA

Hanna A, Boodai F, El Asmar M (2013) State of practice of building information modeling in mechanical and electrical construction industries. J Constr Eng Manag 139(10):04013009

Hanna A, Yeutter M, Aoun D (2014) State of practice of building information modeling in the electrical construction industry. J Constr Eng Manag 140(12):05014011

Hsu K-M, Hsieh T-Y, Chen J-H (2015) Legal risks incurred under the application of BIM in Taiwan. Proc Inst Civ Eng Forensic Eng 168(3):127–133

Hutt J (2013) What are the potential risks associated with BIM? http://www.rpc.co.uk/index.php?option=com_easyblog&view=entry&id=626&Itemid=132

Hwang BG, Zhao X, Gay MJS (2013) Public private partnership projects in Singapore: factors, critical risks and preferred risk allocation from the perspective of contractors. Int J Project Manag 31(3):424–433

Hwang BG et al (2015a) Addressing risks in green retrofit projects: the case of Singapore. Project Manag J 46(4):76–89

Hwang BG, Zhao X, Ong S (2015b) Value management in Singaporean building projects: implementation status, critical success factors, and risk factors. J Manag Eng 31(6):04014094

Jensen PA, Jóhannesson EI (2013) Building information modelling in Denmark and Iceland. Eng Constr Archit Manag 20(1):99–110

Khosrowshahi F, Arayici Y (2012) Roadmap for implementation of BIM in the UK construction industry. Eng Const Archit Manag 19(6):610–635

Krygiel E, Nies B (2008) Green BIM: successful sustainable design with building information modeling. Wiley, New York

Ku K, Taiebat M (2011) BIM experiences and expectations: the constructors' perspective. Int J Constr Educ Res 7(3):175–197

Kuiper I, Holzer D (2013) Rethinking the contractual context for building information modelling (BIM) in the Australian built environment industry. Australas J Constr Econ Build 13(4):1–17

Lesny M, Reidy R (2013) Building information modelling—the impact on the insurance market. http://www.lexology.com/library/detail.aspx?g=1857254b-a431-4586-b424-b91b504dfc1d

Liu J, Zhao X, Yan P (2016) Risk paths in international construction projects: case study from Chinese contractors. J Constr Eng Manag 142(6):05016002

Low SP, Liu JY, He SQ (2009) External risk management practices of Chinese construction firms in Singapore. KSCE J Civ Eng 13(2):85–95

McGraw Hill Construction (2014) The business value of BIM in Australia and New Zealand. McGraw Hill Construction, Bedford

Ott RL, Longnecker M (2001) An introduction to statistical methods and data analysis. Pacific Grove, Duxbury

Patton MQ (2001) Qualitative research and evaluation components, 3rd edn. Sage, Thousand Oaks

Rodriguez J (2014) Building information modeling risks. http://construction.about.com/od/Trends/a/Building-Information-Modeling-Risks.htm

Sebastian R (2011) Changing roles of the clients, architects and contractors through BIM. Eng Constr Archit Manag 18(2):176–187

Sieminski J (2007) Liability and BIM. http://www.aia.org/aiaucmp/groups/secure/documents/pdf/aiap037060.pdf

Simonian L (2010) Legal considerations associated with building information modeling. http://www.caed.calpoly.edu/pdci/research-projects/simonian-10.html

Smith M (2014) BIM and project management. http://www.thenbs.com/topics/bim/articles/BIM-and-project-management.asp

Smith DK, Tardif M (2012) Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers. Wiley, Hoboken

Stanley R, Thurnell D (2014) The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. Australas J Constr Econ Build 14(1):105–117

Succar B (2009) Building information modelling framework: a research and delivery foundation for industry stakeholders. Autom Constr 18(3):357–375

Sun Y et al (2008) Safety risk identification and assessment for Beijing Olympic venues construction. J Manag Eng 24(1):40–47

Thompson D, Miner RG (2006) Building information modeling-BIM: contractual risks are changing with technology. https://aepronet.org/Guest%20Essays/GE%20-%202006_09%20-%20Building%20Information%20Modeling.pdf

Vanlande R, Nicolle C, Cruz C (2008) IFC and building lifecycle management. Autom Constr 18 (1):70–78

Wang SQ, Dulaimi MF, Aguria MY (2004) Risk management framework for construction projects in developing countries. Constr Manag Econ 22(3):237–252

Weber RP (1990) Basic content analysis, 2nd edn. Sage, Newbury Park

Wilkins JR (2011) Construction workers' perceptions of health and safety training programmes. Const Manag Econ 29(10):1017–1026

Zhao X (2017) A scientometric review of global BIM research: analysis and visualization. Autom Constr 80:37–47

Zhao X, Hwang BG, Low SP (2013) Critical success factors for enterprise risk management in Chinese construction companies. Constr Manag Econ 31(12):1199–1214

Zhao X, Hwang BG, Phng W (2014) Construction project risk management in Singapore: resources, effectiveness, impact, and understanding. KSCE J Civ Eng 18(1):27–36

Zhao X, Hwang BG, Lee HN (2016) Identifying critical leadership styles of project managers for green building projects. Int J Const Manag 16(2):150–160

Zou PXW, Zhang G, Wang J (2007) Understanding the key risks in construction projects in China. Int J Project Manag 25(6):601–614

Chapter 54
Critical Success Factors of Joint Ventures in the Construction Industry: Literature Review

M.F. Bekale Mba and N.J. Agumba

54.1 Introduction

According to Talman, in his study undertaken in Swaziland, made an important observation, where, JVs make for a thought-provoking paradox as the popularity of joint ventures is as high as the percentage failure of its operation (Talman 2009). Similarly, Govindan supported this previous argument by highlighting the fact that international construction firms have extensively used JVs as a vehicle to enter new construction markets, yet, the failure rate of such ventures has been quite alarming (Govindan 1995).

Indeed, risks are innate in JV construction projects and include the agreement of the contract, partner selection, potential financial distress, improper project feasibility study, project delay, inadequate forecast about market demand, loss due to bureaucracy for late approvals and design changes have been identified worldwide (Kwok et al. 2006; Shen et al. 2001). Thus, the main objective of this study is to identify the main critical success factors that contribute to the successful delivery of JV construction projects. Observing these key success factors will influence the increasing success of the JV construction projects performance. Hence, the researcher has decided to first highlight important aspects of JV concept and progressively identify the possible critical success factors of JVs.

M.F. Bekale Mba (✉) · N.J. Agumba
Department of Construction Management Quantity Surveying,
University of Johannesburg, Johannesburg, South Africa
e-mail: mariefrancoisebm@gmail.com

N.J. Agumba
e-mail: justusa@dut.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_54

54.2 Critical Success Factors of Joint Ventures

Before enumerating and explaining all the relevant critical success factors (CSF) encountered in joint venture construction projects, it is important to first gain knowledge of what a critical success factor entails. In fact, Adnan and Morledge (2003) define critical success factor as those few key areas of activity in which favourable results are unequivocally essential for a particular manager to influence his or her own objectives.

In other words, critical success factors (CSF), are those factors in which success is required in order for the major participants in a project to have the maximum chance of reaching the goals. Adnan, Chong, & Morledge, further highlight that success criteria are the dependent variables by which the successful result of the project will be judged. In other words, it is about how to realize the predefined project goals in JVs (Adnan et al. 2011).

Furthermore, Famakin and Ogunsemi (2012), in their study, carried out in Nigeria, identified key performance indicators or critical success factors as compilations of data measures used to evaluate the performance of a construction operation and thus, the methods management used to evaluate employee performance of a particular task (Famakin and Ogunsemi 2012). Thus, success criteria should be centered on the performance achieved through the numerous management strategies of joint venture (JVs) and these critical success factors can be classified as follows.

Therefore, it can be concluded that from the main ten sources above on Table 54.1 including journals, theses, books and government reports, critical success factors such as: comprehensive and fair written agreement, mutual understanding, inter-partner trust, co-operation between the members, commitment of the partners, the ease of communication between the partners, management control, partner experience seem to appear repeatedly across Table 54.1.

54.2.1 Comprehensive and Fair Written Agreement

To resolve those challenges enumerated in the previous section, some steps have been identified Kale et al. (2013) as well as Hong and Chan (2014), which can eventually make joint ventures successful, and these are:

- Do not accept joint venture agreements too quickly;
- Get to know a partner by initially doing smaller and limited project together;
- Companies with similar cultures and relatively equal financial resources work best together; keeping this in mind when looking for an appropriate partner;
- The joint enterprise must fit the corporate strategy of both parent firms;
- There should be proper legal agreement between both firms;
- Keeping the mission of joint enterprise small and well defined; ensures that it does not compete with partners;

Table 54.1 Critical success factors for JVs

Authors	Critical success factors of joint ventures
Kale et al. (2013)	Comprehensive and fair written agreement
Hong and Chan (2014)	Comprehensive and fair written agreement. Mutual understanding, Inter-partner trust, Commitment of the partners, and The ease of communication between the partners
Construction industry development board	Comprehensive and fair written agreement
Adnan and Morledge (2003)	Comprehensive and fair written agreement, Mutual understanding, Inter-partner trust, Co-operation between the members, Commitment of the partners, The ease of communication between the partners, Management control, and Partner experience
Hyun and Ahn (2013)	Comprehensive and fair written agreement, Mutual understanding, and Inter-partner trust
Manitshana (2012)	Mutual understanding, and The ease of communication between the partners
Govindan (1995)	Inter-partner trust, Co-operation between the members, Commitment of the partners, and Management control
Talman (2009)	Inter-partner trust, and Management control
Lambe et al. (2011)	Commitment of the partners, and Partner experience
Aimin and Barbara (2001)	Management control

Source Literature review

- Give the joint enterprise autonomy to function on its own and set up mechanisms to monitor its results, which should be a separate entity from both partners; and
- Limit the time frame of joint enterprise and review its progress frequently.

Nevertheless, it is a recipe for possible disaster if a JV is not constituted by means of a comprehensive and fair written agreement between the members, which sets out their obligations, rights, risks and rewards (document 1013 2004). Authors Adnan and Morledge put forward the idea that a good JV agreement is an essential success factor and can avoid a great deal of trouble and conflict in future joint venture operations.

Referring to the success of joint ventures, Hyun and Ahn (2013) say that the success of joint ventures and alliances in general, can be evaluated by their stability and the duration of cooperation between partner, yet the end of the joint venture does not essentially signal its failure, but may simply indicate that the objectives of the joint venture have been achieved.

The joint venture participants join through a form of agreement to contribute with resources in the form of skills, experience, financing or physical resources. CIDB document 1013 (2004) states that a good joint venture agreement should contain the following:

- Should clearly and comprehensively set out the contributions to be made by each member towards all the activities of the joint venture in securing and executing the contract and should assign monetary values to each such contribution;
- Should record the percentage participation by each member in all aspects of the fortunes of the joint venture, including risks, rewards, losses and liabilities;
- Should provide for meaningful input by all members to the policy-making and management activities of the joint venture;
- Should provide for the establishment of a management body for the joint venture;
- Should provide measures to limit, as far as possible, losses to the joint venture by the default of a member;
- Should promote consensus between the members whilst ensuring that the activities of the joint venture will not be excessively delayed by failure to achieve it;
- Should provide for rapid, economical and easy interim dispute resolution and for effective final dispute resolution, if required; and
- Should be sufficiently flexible to allow for joint ventures, which vary in nature, objectives, inputs by members, management systems, etc.

54.2.2 Mutual Understanding

According to Adnan and Morledge (2003) and Manitshana (2012), mutual understanding may contribute to the success of joint venture construction projects. In fact, it is extremely important that friendly personal contact is regularly maintained between the leaders of the cooperating organizations (Adnan and Morledge 2003). The careful selection of people who are to work in an alliance will also assist the prospects of mutual bonding of partners. This previous thought is further supported by Hyun and Ahn (2013) in their study undertaken in Korean firms where, successful joint venture performance should embrace partner selection criteria in order to improve trust and mostly mutual understanding.

In fact, partners should be selected not merely on the basis of technical competence but also on an assessment of their ability to form good relationships with people from other organizational and national cultures (Adnan and Morledge 2003). The previous point is supported by Hong and Chan (2014) where mutual understanding is indirectly linked to cultural homogeneity which plays a part to the success of joint ventures (JVs).

54.2.3 Inter-partner Trust

A high degree of trust and co-operation between the members for a successful operation of a joint venture is important (document 1013 2004). Inter-partner trust is often considered to be a very important ingredient of managing relationships (Adnan and Morledge 2003; Hyun and Ahn 2013; Hong and Chan 2014; Govindan 1995). In other words, mutual trust is indispensable to overcome the restrictions of the contractual agreement (Govindan 1995). However, within organizations, trust contributes to more effective implementation of strategy, greater managerial coordination and more effective work teams (Adnan and Morledge 2003).

Moreover, it is argued that the role of trust is presented as a component of social control where three types of trust are identified, namely: contractual trust, capability trust as well as goodwill trust. The authors explain that, contractual trust, which is the lowest most basic level of trust, relates to the expectancy that the other party will fulfill its contractual duties. However, capability trust is related to the expectation that the other party will be experienced enough and able to fulfil promises adequately (Talman 2009). Moreover, goodwill trust, which is the highest level of trust, relates to the expectation that the other party will implement in the concern of the relationship (the JV), even though it is not directly in the interest of the other party (Talman 2009).

54.2.4 Co-operation Between Members

Cooperation plays an important factor as problems solving reflects the degree to which the parties share responsibility both for dealing with problems and maintaining their relationship (Adnan and Morledge 2003). Yet, the review of the effect of cooperation/conflict on joint venture performance has been a prevalent topic for many researchers, according to (Govindan 1995). In fact, the power of one partner can interfere with the goal attainment of another partner and thus conflict is possible only when the interfering party has some power. Therefore, it follows from this argument that, more resources one partner contributes is comparative to the other partner, the more power the partner would have to effect the achievement of the other party's goals (Govindan 1995). The partners must have a willingness to cooperate and share information and resources to enable essential coordination of activity. Therefore, cooperation behaviour between the parent companies help to reduce potentially burdensome monitoring and safeguards costs within the joint venture. However, changes in the environment, of strategies, and bargaining power over the life of the venture can affect cooperation dramatically (Adnan and Morledge 2003).

54.2.5 Commitment of Partners

Adnan and Morledge (2003) as well as Hong and Chan (2014) put forward the idea that commitment reflects the actions of some key decision makers regarding continuation of the relationship, acceptance of the joint goals and the values of the partnership, as well as the willingness to invest resources in the relationship. Moreover, it is believed that a number of researchers argue that relational factors which include trust and commitment contribute to joint venture success (Lambe et al. 2011).

In making this comment, it is opined that, in order for the joint venture to succeed, all the partners to the joint venture agreement should have full commitment to the joint venture as well as to each other, as, without commitment the performance of the joint venture will inescapably suffer (Govindan 1995). Commitment is important as it provides a long-term basis, resources and capabilities to the specific needs of the joint venture for its success (Adnan and Morledge 2003).

54.2.6 Ease of Communication Between Partners

Undoubtedly, for any business to be run appropriately the communication/information aspect plays a major role. Adnan and Morledge (2003), as well as Hong and Chan (2014) emphasized this point by highlighting the fact that the ease of communication between the partners is another potential problem which should be considered when evaluating a potential partner's suitability. In fact, without proper communication, problems can occur as a result of differences between national or ethnic cultures, including language, as well as differing corporate cultures (Adnan and Morledge 2003; Manitshana 2012).

54.2.7 Management Control

Furthermore, management control is a critical factor to the success of joint ventures. According to Adnan and Morledge (2003) and Govindan (1995), it refers to the influence major stakeholder groups have on the organization's decisions and activities which can easily be achieved in joint ventures by reporting to both majority shareholders. In the same way, Aimin, and Barbara, argue that, generally, management control refers to the process by which an organization influences its subunits to achieve its objectives (Aimin and Barbara 2001). More specifically, management control is defined as all the strategies managers use to ensure that the conducts and decisions of people in the organization are in line with the organization's goals and policies and includes the formal control mechanisms of outcome (outcome control and behaviour control); behaviour control, and social control (capability trust, partner selection and goodwill trust). It is believed that, management control is fundamental to successful joint venture performance, as the parent firms in a joint venture (JV) may have opposing interests (Talman 2009).

Thus, insufficient control over a joint venture (JV) can limit the ability of the parent to synchronize its activities, efficiently and utilizing its resources as well as effectively implementing its strategy (Talman 2009). Therefore, joint ventures are created for business purposes; to generate profits for the participating parties and the profits from such ventures will then be apportioned in relationship to the different input of the parties concerned. Therefore, the profitability attribute will also positively influence the joint venture's capital structure, financing costs and leverage (Adnan and Morledge 2003).

54.2.8 Partner Experience

But above all those factors explained previously, partner experience has to be considered. It has been indicated that firms with multinational experience are considered more likely to have the ability to manage and monitor appropriately to the joint venture. Therefore, greater experience, understanding, competence and confidence in managing inputs will result in a more detailed and accurate perceptions of risks (Adnan and Morledge 2003).

As a result, good background experience would enable these partners to provide better local culture, politics and market conditions all at a lower cost than would be incurred by the investor to obtain equivalent information. In addition, Lambe, Spekman, and Hunt, argued that, partners` competence contributes to the alliance success because such a competence has an indirect result on alliance success by confidently influencing the acquisition of complementary resources (Lambe et al. 2011).

All those critical success factors will facilitate the combination of economic resources, skills and knowledge which will be beneficial to the South African construction industry. As a result to the identification of those successful factors, the following selection criteria for selecting the right partner for the joint venture partner should be observed. On the whole, according to Aimin, and Barbara, the success of a joint venture evidently depends on the synergy created by the individual contributions of the partners whereby a good joint venture management lies not only in the implementation of the project, but also incorrect partner selection (Aimin and Barbara 2001).

54.3 Research Methodology

In the present paper, the theory regarding JVs and their general critical success factors (CSF) of joint ventures in the construction industry are assessed and identified. Journals, theses, books and government reports which included authors such as Kwok et al. (2006), Kale et al. (2013) as well as Shen et al. (2001) were reviewed. The researcher conducted a systematic thematic analysis.

A thematic analysis is a systematic approach to the analysis of qualitative data that involves identifying themes or patterns of cultural meaning, coding and classifying data, typically textual, according to themes; and interpreting the resulting thematic structures by looking for commonalties, relationships, overarching patterns, theoretical constructs, or explanatory principles (Boyatzis 2008; SAGE Research Methods 2013). Thus, the researcher reviewed the data, took notes of success factors of JVs in construction projects and sorted them into specific categories or points with the objective to identifying the key issues that are encountered by JV partners when entering JV agreement.

54.4 Findings

Despites the fact that joint ventures face some challenges in the course of its operation, some critical success factors are made available for the success of JVs. Results from the existing journals, theses, books and government reports revealed that factors such as: comprehensive and fair written agreements, co-operation between the members, and the ease of communication between the partners appear to be the most important factors to be implemented. Yet, factors related to management control and commitment of the partners also play a major role for the success of JV projects. Moreover, mutual understanding, inter-partner trust and partner experience appear to be the least to be considered as success factors for JV performance.

54.5 Conclusion

The objective of this study was to identify the critical success factors underlying the JV process. The literature review produced a list of those success factors where the most important success factors which could potentially influence the performance of JVs were found to be comprehensive and fair written agreements, co-operation between the members, and the ease of communication between the partners.

Even though, the main purpose of JV operations remains the spreading of risk inherent in large projects as well as the pooling of resources in a way that permits the execution of projects, it becomes crucial for the partners involved to be aware of the possible success factors and thus try to find by any means a way to implement those success factors in order to resolve issues related to the poor performance of JVs.

References

Adnan H, Morledge R (2003) Joint venture projects in Malaysian construction industry factors critical to success. Assoc Res Constr Manag 3(2):765–774

Adnan H, Chong H, Morledge R (2011) Success criteria for international joint ventures: the experience of Malaysian contractors in the Middle East. Afr J Bus Manag 5(13):5254–5260

Aimin Y, Barbara G (2001) Negotiating control and achieving performance in international joint ventures: a conceptual model. J Int Manag 7:295–315

Boyatzis, RE (2008) Transforming qualitative information: thematic analysis and code development. SAGE Publications, Thousand Oaks, London, & New Delhi

CIDB document 1013 (2004) Construction: joint venture arrangements. Available from: http://www.cidb.org.za/toolkit06/toolkitpages/module5/20supplementaryinformation/5s14%20pgd2-jv%20edition%201.0.pdf. Accessed 05 May 2015

Famakin IO, Ogunsemi DR (2012) Exploring key performance indicators for joint venture construction projects in Lagos State, Nigeria. J Constr Proj Manag Innov 2(2):331–344

Govindan S (1995) Determinants of joint venture performance in the construction industry: cases from the mass rapid transit project in Singapore. PhD. University College London, London

Hong Y, Chan DWM (2014) Research trend of joint ventures in construction: a two-decade taxonomic review. J Facil Manag 12(2):118–141

Hyun JH, Ahn SY (2013) Host country perspectives on partner selection criteria for the success of international joint ventures: an empirical survey of Korean firms. In: Conference proceedings of the 24th international business research conference held in Las Vegas, USA, Conducted by Planet Hollywood. Hankuk University of Foreign Studies, Korea

Kale VV, Patil SS, Hiravennavar AR, Kamane SK (2013) Joint venture in construction industry. J Mech Civ Eng 3:60–65

Kwok HCA, Then D, Skitmore M (2006) Risk management in Singapore construction joint ventures. J Constr Res 1(2):139–149

Lambe CJ, Spekman RE, Hunt SD (2011) Alliance competence, resources, and alliance success: conceptualization, measurement, and initial test. J Acad Mark Sci 30(2):141–158

Manitshana B (2012) Assessment of the critical success factors of joint ventures in the South African construction industry. Master's dissertation. University of Johannesburg, Johannesburg

SAGE Research Methods (2013) Encyclopedia of case study research: thematic analysis. Available from: http://www.uk.sagepub.com/gray3e/study/chapter23/Encyclopaedia%20entries/Thematic_Analysis.pdf. Accessed 8 May 2015

Shen LY, Wu GWC, Catherine SKN (2001) Risk assessment for construction joint ventures in china. J Constr Eng Manag 127(1):76–81

Talman JA (2009) Management control in joint ventures: an analysis based on transaction cost economics and game theory. Unpublished doctoral thesis. Erasmus University Rotterdam, Zurich

Chapter 55
Detection and Quantification of Spalling Distress in Subway Networks

T. Dawood, Z. Zhu and T. Zayed

55.1 Introduction

Subway networks play a key role in the development of an urban area, as one type of its high-capacity public transport. Unfortunately, the facilities in the subway networks experience continuous deteriorations, considering the severe environmental conditions and constant heavy traffic loads that the subway networks experience. In addition, the huge amount of underground water might infiltrate into the subway infrastructures and lead to corrosions of reinforcing steel bars, concrete delamination, spalling, etc. As a result, it is important to provide periodic structure inspection and assessment to keep the subway networks operational in service.

The current subway assessment process is conducted manually based on visual inspection. The manual visual inspection might produce important ideas about the actual infrastructure conditions. However, the inspection results are not always consistent. They are always subjective to the inspectors' knowledge and expertise in nature. Also, the inspection process is time-consuming and labor-intensive, especially considering the fact that some parts or areas in the subway networks are difficult to access. Therefore many distresses are not diagnosed until they progress and become serious.

The limitations associated with the manual inspection highlighted the necessity for automated inspection process with the support of machine vision techniques (Radopoulou and Brilakis 2015). So far, several research studies have been pro-

T. Dawood · Z. Zhu (✉) · T. Zayed
Department of Building, Civil and Environmental Engineering,
Concordia University, Montréal, QC, Canada
e-mail: zhenhua.zhu@concordia.ca

T. Dawood
e-mail: thikradawood2002@yahoo.ca

T. Zayed
e-mail: tarek.zayed@concordia.ca

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_55

posed towards this end, and they have been tested in different types of concrete infrastructures. For example, Koch and Brilakis relied on image thresholding, morphological thinning, elliptic regression and texture extraction to detect potholes in highways (Koch and Brilakis 2011). Similarly, Li et al. (2016) designed an integrated framework for the detection and measurement of potholes on the basis of 2D images with the combination of Ground Penetrating Radar (GPR) data. In addition to the potholes, German et al. (2012) retrieved the spalling properties from concrete column images in an attempt to assess the safety of post-earthquake concrete structures. Adhikari et al. (2013) simulated on-site visual inspection by creating 3D model of a de facto bridge, followed by overlaying 2D digital images on the model to get bridge condition index. Atef et al. (2015) utilized a multi-tier technology to locate water pipes and detect leaks based on the image processing of captured Infrared (IR) and GPR images.

Compared with previous research studies, this paper proposed a novel method to detect and quantify spalling distress in subway networks. The method combined several image processing techniques with regression analysis. Under the framework, the image filtering is first used to identify and extract the spalling regions in an automatic manner. Then, a novel vision-based detector with regression analysis is created to support the 3D scene reconstruction for estimating the spalling depth. The effectiveness of the method has been tested in inspecting and assessing the subway networks in Montreal. The test results showed that the method could complement the current visual inspection practice. It helps to address the subjective nature. Also, it is expected to save the inspection time and cost.

55.2 Related Work

As for the detection and assessment of concrete distress in subway networks, many efforts have been made by researchers. For example, Semaan (2011) proposed a framework for the evaluation of subway stations using the Leveraged Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory (MAUT) and Weibull reliability function to predict the performance of subway infrastructure components. The framework was developed only for assessing subway stations, and it is difficult to investigate the severity of the surface defects on other structures in the subway networks. Therefore, it was still characterized as subjective. Similarly, Kepaptsoglou et al. (2012) presented a model to evaluate the functional conditions of subway stations with the Fuzzy AHP and MAUT to produce the Metro Condition Index (MCI). Again, the model was developed solely for the condition assessment of subway stations, hence it failed in evaluating the entire subway network. Gkountis and Zayed (2013) further enhanced the model of Kepaptsoglou et al. (2012) with the Analytic Network Process (ANP). This way, the interdependencies of different components in the subway network could be established. In 2014, Abouhamad integrated the fuzzy risk index model and risk-based budget allocation model to develop a risk-based asset management framework for subway networks (Abouhamad 2014). This study prioritized rehabilitating the metro stations, but it failed to be validated using an extensive and real life data set.

On the other hand, the use of machine vision techniques for the detection and evaluation of concrete infrastructures, such as bridges, highways, etc., has gained a lot of research interests. For example, in the field of bridge inspections, La et al. (2014) presented a crack detection and mapping algorithm for detecting cracks on the bridge decks. Adhikari et al. (2013) proposed a model for quantifying the cracks in bridges with the support of artificial neural networks and 3D visualization. Abudayyeh et al. (2004) developed an automated bridge inspection method based on digital images and the method was integrated with Bridge Management Systems PONTIS. In the field of pavement defects detection, Li et al. (2016) designed an integrated framework for the detection and measurement of potholes on the basis of 2D images and Ground Penetrating Radar (GPR) data. Yu and Salari (2011) introduced a laser-based detector and classifier for pavement defect inspection. Koch and Brilakis (2011) presented a pothole detection method which involved image thresholding, morphological thinning, elliptic regression and texture extraction. In addition, Atef et al. (2015) utilized a multi-tier technology to locate water pipes and detect leaks based on the image processing of captured Infrared (IR) and GPR images. Guo et al. (Guo et al. 2009) presented a condition assessment approach of wastewater systems grounded in visual pattern recognition techniques. Yu et al. (2006) created a system for inspecting and measuring tunnel cracks. Jahanshahi and Masri (2011) incorporated depth perception, image processing, and pattern recognition for the purpose of crack detection and quantification. Hutchinson and Chen (2006) proposed a statistical procedure for the detection of cracks through utilizing Bayesian Decision Theory. German et al. (2012) retrieved major properties of spalled regions on concrete columns subsequent to detecting the defect in an attempt to assess the safety of post-earthquake buildings. The following two sub-sections briefly describe the technical backgrounds that this research tries to build upon.

55.2.1 Image Filtering

Image filtering techniques are commonly used for defects detection and quantification. Existing techniques could be mainly classified into two categories: (1) filtering in the spatial domain and (2) filtering in the frequency domain. Spatial filters are directly applied in an image. For example, low-pass filters, such as median filter, could be used to minimize image deviations to smooth images. Another example of filtering in the spatial domain is image segmentation, which divides an image into regions or objects of interest. One of the fastest and most applicable segmentation methods is image thresholding. In addition, histogram equalization is often performed to enhance the contrast of the image and enhance the visual quality of the image.

Image filtering in the frequency domain is required to perform the Fourier transform of an image first. The Fourier transform converts the image from the spatial domain to the frequency domain. Then, a series of image processing steps could be conducted in the frequency domain of the image. The results are further converted from the frequency domain back to the spatial domain through the inverse Fourier transform. Examples of the filters in the frequency domain include Gaussian low-pass filters, Butterworth low-pass filters, etc.

55.2.2 Regression Analysis

Regression analysis is a statistical approach which analyzes and models the relationships between two or more variables. The simplest form of this relationship is postulated as a linear way (Kutner et al. 2003), where the value of one dependent variable is predicted from the value of an explanatory variable. In the case when there are more than one explanatory variable, the form could be expressed in a more generic way. Suppose given a dependent variable y and a number of explanatory variables $X_1, X_2, \ldots, X_p$ that may be related to y. The regression analysis is to model the relationship between y and $X_1, X_2, \ldots, X_p$ to quantify the strength of $X_1, X_2, \ldots, X_p$ with corresponding regression coefficients. Also, it would decide which explanatory variable might have no relationship with y at all and which one might contain redundant information about y.

Typically, the regression coefficients in the model are unknown and they are estimated from sampling data through the least squares approach. In addition, there are several methods currently available to check the forms of linearity by observing curvatures in the plots. For example, they check the scatterplot of residuals as opposed to the fitted values or the scatterplot of residuals against each predictor. If the scatterplot proposes a curvilinear relationship, it means the form could be expressed in a polynomial way, as suggested by Kutner et al. (2003).

55.3 Research Objective and Methodology

The main objective of this paper is to create a novel method for detecting and assessing concrete spalling in subway networks. So far, most vision-based methods have been focused on detecting and assessing the cracks and potholes. Few of them have been developed to investigate the detection and quantification of the spalling, although it is one of common defects that could be found in concrete structures.

The proposed methodology includes three steps starting from the image data collection to the modeling of concrete spalling using regression analysis. The overall framework of the proposed methodology has been illustrate in Fig. 55.1. Under the framework, 2D images are first captured for different elements in subway networks using a digital camera. Then, the captured images are processed to remove

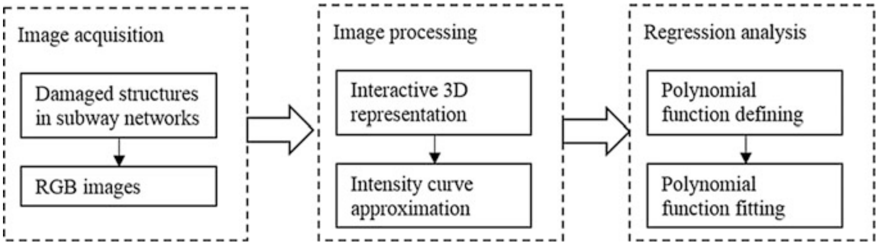


Fig. 55.1 Overall framework

noise and enhance image features related to concrete spalling. The images are further filtered both in the spatial domain and the frequency domain to detect the spalling. Finally, the spalling attributes (i.e. depth in this study) are estimated through the supervised machine learning combined with regression analysis.

55.3.1 Image Acquisition

A myriad of images of subway facilities are always captured with a digital camera. The image data demonstrate all the visible defects and damage on the surfaces of structures, however this research is only focused on spalling regions at concrete surfaces. In order to optimize the quality of image analysis later, the following essential rules need to be taken into account during the process of capturing the digital images. First, it is necessary to make sure that the images are acquired orthogonal to the surface with suitable overlapping to reduce the error of projection and pledge better area coverage. Second, if necessary, artificial lighting could be used to guarantee consistent image qualities. Moreover, close-range images are capable to deliver detailed information of the physical attributes of the objects.

55.3.2 Image Processing for Spalling Detection

A hybrid method with various spatial and frequency domain filters is proposed to enable the detection of spalling regions on concrete surfaces. The method starts by reading, adjusting, and displaying the images. Consider the acquired images are RGB images. It is necessary to explore the color space and split the RGB image into three different channels. An appropriate color channel is then selected for image enhancement and detection.

Subsequently, an image smoothing technique is applied to decrease the variance among the intensities of each pixel without considerably affecting the information regarding the regions of interest (ROI). The smoothing is expected to improve the isolation of distress from the image background by retraining significant distress patterns and meanwhile suppressing the image noise. In this research study, an anisotropic diffusion method proposed by Perona and Malik (1990) is adopted to smooth image data. The method relies on partial differential equations, local gradient function, and implements sequential iterations to limit the smoothing operations in the internal ROI without crossing boundaries between sharp pixel intensities.

The smoothed image is further thresholded to segment the spalling defects from the image background. The main idea behind the thresholding is to select an appropriate threshold value. Here, the selection is based on the trial-and-error strategy in the image histogram, which describes the intensity distribution of all the pixels in the image. Then, a Gaussian 3D filter is established using stacks and hyper-stacks to enhance image resolutions. The process continues with the application of a couple of colored filters, image scaling, calibration, edge detection, etc. Finally, the image surface graph is analyzed and an interactive 3D scene presentation is plotted. These illustrations display pixel intensities in a three dimensional plot to allow a de facto visualization.

55.3.3 Regression Analysis for Depth Estimation

The regression analysis starts by the selection of the predictor (i.e. input) and response (i.e. output) variables. Here, the input variables comprise pixels intensities generated from the image processing step, and the output variable includes the spalling depths taken from in situ measurements. The diagnostic test with a scatter plot is conducted to find the relationship between the input and output variables. The examples of the relationship, such as linear, quadratic, cubic, etc., are checked. When an appropriate relationship is found, its effectiveness is further tested using four criteria, including R-square (R2), adjusted R-square (Adj R2), sum of squares due to error (SSE), and root mean squared error (RMSE).

55.4 Implementation and Results

The proposed methodology was implemented using different software packages, including MATLAB® R2013b and ImageJ. In order to test the effectiveness of the methodology, the images of one subway station in in Montreal's subway network were taken with a digital camera, Canon EOS Rebel XS. The station was opened to the public in 1980. It belongs to one of the 31 stations along the Orange Line of Montreal's subway system. Signs of deteriorations and defects could be found in multiple structural elements. Figure 55.2 shows the image acquisition process as well as examples of the images used for the test. The resolution of the test images is 2592 by 3888 pixels.

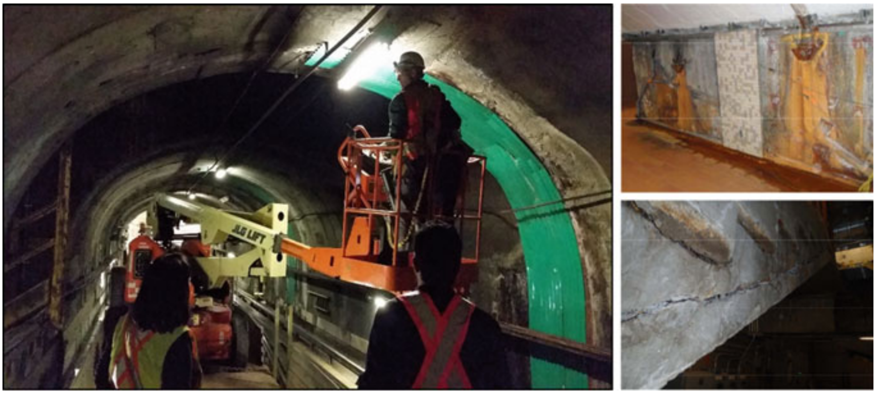


Fig. 55.2 Image acquisition for tests

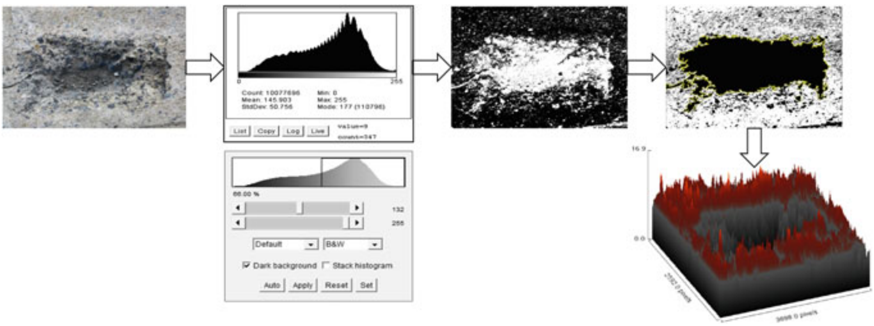


Fig. 55.3 Example of image processing steps

The images were processed on a desktop PC. The technical specification of the desktop PC is Intel Core i3-3220 CPU @3.30 GHz. The operating system is 64-bit. Figure 55.3 shows the main steps involved in the image processing. In the figure, the surface image was thresholded based on the histogram. The thresholding split the image into two parts, where the spalling region in the image was isolated. Then, the boundaries of the spalling region were detected. Moreover, the spalling region was represented in 3D based on the intensity values of the image pixels in the spalling region. Table 55.1 summarized the detection performance of the spalling regions from the images. True positive is the number of correctly detected spalling regions; false positive is the number of incorrectly detected spalling regions; and false negative indicates the number of the spalling regions that were not detected. Recall is the ratio of true positive over the sum of true positive and false negative, while precision is measured as the ratio of true positive over the sum of true positive and false positive.

Table 55.1 Spalling region detection performance

Criteria	True positive	False positive	False negative	Recall (%)	Precision (%)
Results	55	3	5	91.7	94.8

Table 55.2 Statistical diagnostic tests

Criteria	Functions			
	R2	Adj R2	SSE	RMSE
Linear	0.9445	0.9436	9.5158	0.0916
Quadratic	0.9495	0.9478	8.6616	0.0864
Cubic	0.9567	0.9544	7.4364	0.0631

The intensity values were correlated with the depth information. The three relationships (i.e. linear, quadratic, and cubic) relationships were checked. The corresponding functions were estimated (Eqs. 55.1–55.3). Moreover, the effectiveness of the functions was evaluated. The evaluation results were summarized in Table 55.2.

$$y = -0.093x + 17 \tag{55.1}$$

$$y = 0.00043x^2 - 0.22x + 26 \tag{55.2}$$

$$y = 0.000033x^3 - 0.014x^2 + 2x - 83 \tag{55.3}$$

55.5 Conclusions

This research presented an integrated framework for the detection and quantification of concrete spalling distress from the digital images. The framework includes a hybrid algorithm for the detection concrete spalling regions, interactive 3D presentation, and regression analysis to estimate the relationship between spalling intensity and depth. The method has been tested for inspecting one metro station in Montreal. The results showed that the performance of detecting concrete spalling regions was promising. It could reach 91.7% in recall and 94.8% in precision.

Also, the interactive 3D visualization simulated the de facto scene of spalling through the incorporation of depth perception. The schematic representations are helpful in envisioning the level and severity of the spalling on the integrity of structural elements. Also, the regression analysis was conducted to find that the intensities of the spalling regions in the images were correlated with their depth information. Three relationships (linear, quadratic, and cubic) were proposed and tested. The results showed that the cubic relationship fitted better than the other two.

References

Abouhamad M (2014) An integrated risk-based asset management framework for subway systems. Ph.D. thesis. Concordia University, Montreal, Canada

Abudayyeh O, Al Bataineh M, Abdel-Qader I (2004) An imaging data model for concrete bridge inspection. Adv Eng Softw 35(8–9):473–480

Adhikari RS, Moselhi O, Bagchi A (2013) Image-based retrieval of concrete crack properties for bridge inspection. Autom Constr 39:180–194

Atef A, Zayed T, Hawari A, Khader M, Moselhi O (2015) Multi-tier method using infrared photography and GPR to detect and locate water leaks. Autom Constr 61:162–170

German S, Brilakis I, DesRoches R (2012) Rapid entropy-based detection and properties measurement of concrete spalling with machine vision for post-earthquake safety assessments. Adv Eng Inform 26(4):846–858

Gkountis I, Zayed T (2013) Subway station condition assessment using analytic network processes. In: The third international conference on soft computing technology in civil, structural and environmental engineering. Civil-Comp Press, Stirlingshire, UK

Guo W, Soibelman L, Garrett J (2009) Visual pattern recognition supporting defect reporting and condition assessment of wastewater collection systems. J Comput Civ Eng 23(3):160–169

Hutchinson T, Chen Z (2006) Improved image analysis for evaluating concrete damage. Comput Civ Eng 20(3):210–216

Jahanshahi M, Masri S (2011) A novel crack detection approach for condition assessment of structures. In: Computing in civil engineering. ASCE, pp 388–395

La HM, Gucunski N, Kee S, Yi J, Senlet T, Nguyen L (2014) Autonomous robotic system for bridge deck data collection and analysis. In: International conference on intelligent robots and systems (IROS 2014), Chicago, IL

Kepaptsoglou K, Gkountis I, Karlaftis MG, Mintsis G, Vardaki S (2012) Fuzzy analytical hierarchy process model for assessing condition and performance of metro stations. No. 12-2026, Washington, DC: Transportation Research Board

Koch C, Brilakis I (2011) Pothole detection in asphalt pavement images. Adv Eng Inform 25 (3):507–515

Kutner M, Nachtsheim C, Neter J (2003) Applied linear regression models, 4th edn. McGraw-Hill company Inc., New York, US

Li S, Yuan C, Liu D, Cai H (2016) Integrated processing of image and GPR data for automated pothole. J Comput Civ Eng 04016015

Perona P, Malik J (1990) Scale-space and edge detection using anisotropic diffusion. IEEE Trans Pattern Anal Mach Intell 12(7):629–639

Radopoulou SC, Brilakis I (2015) Patch detection for pavement assessment. Autom Constr 53: 95–104

Semaan, N (2011) Structural performance model for subway networks. Ph.D. thesis. Montreal, Canada: Concordia University

Yu X, Salari E (2011) Pavement pothole detection and severity measurement using laser imaging. In: IEEE International conference, Mankato, MN

Yu S, Jang J, Han C (2006) Auto inspection system using a mobile robot for detecting concrete cracks in a tunnel. Autom Constr 16(3):255–261

Chapter 56
Determinants of Business Overdraft Accessibility Within Small and Medium-Sized Enterprises in the South African Construction Industry: A Case of Gauteng Province

O.A. Balogun, N.J. Agumba and N. Ansary

56.1 Introduction

In the South African context in the construction industry, small enterprise is defined as having less than 50 employees, having an annual turnover of less than R5 million, while medium enterprises have between 51 and 200 employees and less than R20 million turnover (National Small Business Act 2004). The SMEs contribute immensely to the gross domestic product of most countries including South Africa.

Despite their importance to the economy in South Africa, construction SME sector is described as largely underdeveloped and lacking the managerial and technical skills and sophistication enjoyed by larger well established firms (Department of Public Works 1999). Martin (2010) opined that lack of knowledge including knowledge of pricing procedures, contractual rights and obligations; law, management techniques and principles as well as technology were a challenge to SMEs. Furthermore, SMEs are more likely to have limited formal education, which is based on a construction craft or trade training such as carpentry, plumbing, electrical installation and bricklaying. This training is probably in the form of learnership (Board 2008). Past studies in South Africa revealed constraints and challenges of capacity and financial resources among SMEs (Fatoki 2014; Agumba et al. 2005). Grimsholm and Poblete (2011), inferred that SMEs are not able to access finance or credit hence stifles their growth and capability.

Credit has been used as a selling tool, to bind customers to a particular vendor and allow them to acquire more substantial goods for which they do not have the

O.A. Balogun · N.J. Agumba (✉) · N. Ansary
Department of Construction Management and Quantity Surveying,
University of Johannesburg, Johannesburg, South Africa
e-mail: justusa@dut.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_56

necessary capital (Mandell 1994). The theory of credit emphasizes that financial institutions would be more willing to extend credit if, in case of default, they could easily enforce contracts by forcing repayment or seizing collateral. The amount of credit in a country would depend to some extent on the existence of legislation that protects the creditors' rights on proper procedures that lead to repayment (Aduda et al. 2012).

The initial capital and expansion capital fund for South Africa construction SMEs has been a perpetual problem even though the government continuously strives to empower this sector into the mainstream economy. It is accepted that construction SMEs are a vehicle of economic empowerment in the construction industry in South Africa. However, they are faced with many challenges to be able to maximize their economic potential. Construction SMEs find it difficult to access credit in the form of business overdraft they apply for. It can be unequivocally indicated that there is lack of studies to determine the predictors determining business overdraft accessibility by construction SMEs. Based on this discussion this study is guided by two specific research questions: viz;

- What are the factors the prevent construction SMEs from accessing credit? and
- What are the personnel factors and firm factors that influence business overdraft accessibility from financial institutions?

56.1.1 Business Overdraft

Overdrafts and loans are the most common form of external financing available to businesses. Used properly, they provide a simple and effective way of financing the growth of your business. Despite their widespread use, they are not always used wisely. Many businesses make the wrong choices or incur unnecessary costs. At best, this raises the cost of financing. At worst, the business runs the risk of failure (Directors briefing, n.d.). An overdraft is the ideal way to manage your cash flow. It is linked to your business account and you can use as much as you need, up to your limit suggested by the financial institution (Standard Bank South Africa, n.d., a). According to the First National Bank in South Africa (FNB) the business overdraft benefits are (First National Bank, n.d.):

- It is linked to your Business Account and provides the ability to make payments even when there are no cash funds available in your account, thus avoiding penalty fees and additional charges;
- No minimum monthly payment as long as you remain within the agreed limit;
- Payments into the overdraft facility make funds available for use again;
- Flexibility, as you can deal with unexpected expenses and capitalise on any opportunities; and
- Monthly repayments are based on the amount of credit you used.

According to Standard Bank South Africa (n.d., b), the benefits of business overdraft are;

- An overdraft is quick and easy to arrange;
- The cash is available when you need it;
- You only pay interest on what you use, not on the full amount of your limit; and
- Sole proprietors can apply for an overdraft or increase their limits at an AutoPlus, via Internet Banking, Cellphone Banking or by calling 0861 012 345/0860 109075.

Despite the benefits suggested. A fee of 1.2% is levied on the unutilized portion of the business banking overdraft facilities. This fee will be accrued daily and recovered monthly (Standard Bank South Africa, n.d., b). However, the FNB bank (First National Bank, n.d.) indicates that *FNB customers applying for business overdrafts of less than R400,000.00 are not required to submit supporting documentation or collateral*. In case of business overdraft of more than R400,000.00 the FNB bank will require the following documents in order to process the credit.

- Security/collateral (customer dependent);
- A business finance application;
- Signed financial information (annual financial statements and year-to-date management accounts); and
- Projections (cash flow statements, income statements and balance sheets).

For non-FNB customers the following are the requirements:

- Six months' bank statement;
- Security/collateral (may be required);
- A business finance application;
- Signed financial information (annual financial statements and year-to-date management accounts);
- Projections (cash flow statements, income statements and balance sheets);
- A business plan to demonstrate the viability and sustainability of the business; and
- Should your application be successful, you are required to open an FNB Business Account.

56.2 Literature Review

56.2.1 Challenges Preventing SMEs from Accessing Credit

According to Alhassan (2014).and Sakara the factors that stifle SMEs from accessing credit are, management expertise, high default rate and monitoring as the challenges banks faced in giving credit to SMEs. Bondinuba (2012), found that the key challenges that make it difficult for SMEs to access finance include policy regulation, inadequate financial infrastructure, stringent collateral security requirement, and lack of institutional capacity of SMEs sector. The key barriers identified include informational barriers, lack of managerial skills within SMEs. Nkuah, Tanyeh and Gaeten inferred that financial activities such as business registration, documentation/recording, business planning, asset ownership, impact heavily on SMEs access to bank credits (Nkuah et al. 2013).

Angela and Motsa (2004) Associates reviewed that entrepreneurs face several problems in their efforts to access finance, particularly from banks; viz., lack of collateral security, refusal to use own collateral, failure to make a remarkable own contribution, blacklisting, failure to review attractive financial records and/or business plans and high risk of small entrepreneurs.

Kayanula and Quartey, argued that factor like availability and cost of finance are the most common constraints faced by SMEs. Others are lack of collateral, informational barriers, regulations and rules that impede construction firms access to finance, the legal framework and policies around investment and financial institutions (FI's) lending are fundamental, lack of access to appropriate technology, weak institutional capacity, lack of management skills and training in the construction firms, and lack of proper book keeping. The legal and regulatory frameworks that exist in Ghana also fail to provide the right support infrastructure to facilitate SMEs lending by the financial institutions. The lack of collateral, lack of proper financial management, lack of fiscal incentives for SMEs, strict prudential regulations which restrict flexibility of FI's, unduly complex or onerous administrative procedures and even simply the lack of a consistent definition or enabling law for SMEs are some of the impediments to SMEs financing. Even though SMEs tend to attract motivated managers, they can hardly compete with larger firms (Kayanula and Quartey 2000). It can be suggested from these discussions that different set of challenges prevents SMEs from accessing finance. Hence, the importance of determining the challenges faced by SMEs in the South Africa construction industry from accessing credit.

56.2.2 Predictors of Credit Accessibility

Fatoki, in his study indicated that the availability of business plan, collateral, maintenance of a good relationship, managerial competency and a good credit score are critical lending requirements (Bondinuba 2012). According to Etonihu, Rahaman and Usman, their findings suggested that education, distance to credit source and types of credit source as major factors that influenced farmers' access to agricultural credit (Etonihu et al. 2013). In a study by Chauke et al. (2013), they found that the predictors for credit accessibility by smallholder farmers were, attitude towards risk, distance between lender and borrower, perception on loan repayment, perception on lending procedures and total value of assets. Ololade and Olagunju (2013), posited that gender, marital status, lack of guarantor, high interest rate predicted access to credit among rural framers in Nigeria.

Fatoki and Odeyemi (2010), results indicate that managerial competencies, business information, networking, location, crime, business size and incorporation are significant determinants of credit approval. Dzadze et al. (2012), in their study established that extension contact, education level and saving habit had significant positive influence on farmers' access to formal credit (Dzadze et al. 2012). Kimutai and Ambrose, opined that the key factors that influenced credit rationing by commercial banks in Kenya are loan characteristics, firm characteristics and observable characteristics. The study established that most of the banks rationed credit in order to reduce risk and to avoid the risk of adverse selection and moral hazard (Kimutai and Ambrose 2013). Beck et al. (2008), found that banks in developing economies, compared to those in developed economies, tend to be less exposed to SMEs, hence charge them higher interest rates and fees.

Musamali and Tarus (Musamali and Tarus 2013), inferred that profile such as ownership structure; size of the firm; business type; and age of the business indeed influence SMEs' access to finance. Alhassan and Sakara (2014), results indicated that, the number of employees, experience in credit use and number of fixed assets possessed, attitude towards risk, business size, sector and form of business in the economy are the critical success factors in accessing bank finance. In view of these discussions there is no consensus of a set of determinants that will predict access to credit. Furthermore, no study has focused specifically on business overdraft accessibility from the financial institutions. Hence, this research poses the question:

- What are the personnel factors and firm factors that influence business overdraft accessibility from financial institutions?

56.3 Research Method

A structured questionnaire survey was used to collect data. Creswell (1994), describes a survey as a quantitative or numeric description of some fraction of the population—the sample. This enables the researcher(s) to generalize their findings from a sample of respondents to a population within the limitations of the sampling method. Convenience sampling was used which consisted of contractors registered with the Construction Industry Development Board (CIDB). A total of 179 SMEs completed the questionnaire survey. Content validity was conducted on the questionnaire using pilot study administered to 30 construction SMEs.

SPSS version 22 was used to perform the binary logistic regression analysis. A binary logistic regression model with a dichotomous dependent variable of Yes or No was modelled. Yes response was defined as having accessed business overdraft and No did not access business overdraft. The dependent variable was coded as 1 and 0, for "Yes" and "No" respectively. The independent variables of the logistic regression model were also coded and were categorical. They were the personnel profile and the firms demographic characteristics of the SMEs: *gender* if male 1 and female 2; *age group,* 30 years and below 1, 31–39 years 2, 40–49 years

3 and 50 years and above 4; *current position*, director 1, owner 2, manager 3 and manager/owner 4; *ownership*, sole proprietorship 1, partnership 2, limited partnership 3, limited liability company 4, corporation (for-profit) 5; *tax number* No, 0 and Yes, 1; *location of business,* city of Johannesburg Metropolitan Municipality 1, city of Tshwane Metropolitan Municipality 2, Ekurhuleni Metropolitan Municipality 4, West Rand District Municipality 4; *collateral* No, 0 and Yes, 1. Logistic regression is recommended over linear regression when modeling dichotomous responses and allows the researcher to estimate probabilities of the response occurring (Pallant 2013). The logistic regression equation takes the following form

$$\ln(p/1-p) = \beta 0 + \beta 1x1 + \beta 2x2 + \ldots + \beta kxk \quad (56.1)$$

where p is the estimated probability of passing, and $x1$, $x2$, …,xk are independent variables.

The estimated probability of the response occurring or passing (p) divided by the probability of it not occurring or not passing ($1-p$) is called the odds ratio. Maximum likelihood method is used to estimate the odds ratios of the model. Values of odds ratios higher than 1 indicate positive association between the variables, odds ratios equal to 1 indicate no association, while odds ratios lower than 1 indicate negative association between each independent variable and the dependent variable of the model.

Furthermore, in order for an independent variable to be a predicator of the dependent variable the p-value should be less than 0.05 at 95% confidence, which connotes its significance in the model. In achieving a fitting model the Hosmer-Lemeshow goodness of fit test should be significant i.e. the value should be greater than 0.05 (Pallant 2013). It can be indicated that the model tested achieved the Hosmer-Lemeshow goodness of fit test at 0.91.

The factors preventing SMEs from accessing credit were measured using Likert scale of 1–5. 1 = Strongly disagree (SD), 2 = Disagree (D), 3 = Neutral (N), 4 = Agree (A), 5 = Strongly agree (SA). The Likert-scale questions are discussed based on their mean score in the interval scale. The difference between the upper and lower ends of the used scale is 4.0 since there are five points. Each range can be equated to 0.80 because the extent of the range is determined by a division between 4.0 and 5.0 (4/5). However, in the current study the intervals are: $>4.21 \leq 5.00$ Strongly agree; $>3.41 \leq 4.20$ Agree; $>2.61 \leq 3.40$ Neutral; $>1.81 \leq 2.60$ Disagree; $>1.00 \leq 1.80$ Strongly disagree.

56.4 Results and Discussions

Table 56.1 indicates that male respondents were the majority than female respondents, at 63 to 37% respectively. Majority i.e. 51% of the respondents were in the age group between 40 and 49 years old. Furthermore, 82% of the respondents were

Table 56.1 Profile of respondents and organization

Gender	Frequency	Percentage
Male	112	63
Female	67	37
Age group		
30 years and below	2	1
31–39 years	49	27
40–49 years	92	51
50 years and above	36	20
Current position		
Director	29	16
Owner	146	82
Manager	3	2
Manager/owner	1	1
Experience of respondent		
1–5 years	15	8
6–10 years	130	72
11–15 years	33	18
16–20 years	1	1
Ownership		
Sole proprietorship	175	98
Partnership	2	1
Limited partnership	1	1
Limited liability company (LLC)	1	1
Location of company		
City of Johannesburg metropolitan	74	41
City of Tshwane metropolitan	42	24
Ekurhuleni metropolitan	34	19
West Rand district municipality	29	16

Source Field data (2015)

owners of the organizations. This finding is in line with the findings of Agumba (2006). This suggests that these categories of organizations are still being managed with the owners. Majority i.e. 72% of the respondents had business experience of between 6 and 10 years. 98% of the SMEs are sole. Furthermore, majority i.e. 41% of the SMEs were located in the city of Johannesburg metropolitan.

Table 56.2 indicates that the SMEs respondents strongly agreed that lack of collateral, lack of cash flow statement and owners equity were hindering SMEs from accessing credit from financial institutions. The means were in the band of 4.21–5.00. Bondinuba (2012), findings corroborates the current outcome that collateral is viewed as a major factor that hinders credit accessibility. The sector of the business, lengthy and vigorous procedure for credit application, high interest rates, location of the business were in the band of 3.61–4.20 suggesting that the

Table 56.2 Contraints in obtaining credit

Constraints of credit accessibility	Mean	Stdev.	Rank
Lack of collateral	4.69	0.58	1
Lack of cash flow statement	4.51	0.98	2
Owner's equity	4.39	1.01	3
Sector of the business	4.14	1.21	4
Lengthy and vigorous procedure for credit application	4.13	1.37	5
High interest rates	3.81	1.51	6
Location of the business	3.76	1.27	7
Lack of good reference on integrity	3.03	1.66	8
Lack of awareness of existing credit schemes	2.97	1.71	9
A general lack of experience and exposure on construction project	2.75	1.73	10
Lack of information on the cost obtaining such service	2.72	1.74	11
Lack of appropriate education and training	2.21	1.68	12
Lack of managerial ability	2.09	1.59	13

Table 56.3 Business overdraft credit accessed

Accessed the credit	Respondents	Percentage
Marked	13	7.26
Unmarked	166	92.74
Total	179	100.00

respondents agreed that they contributed to their difficulty of obtaining credit. Furthermore, the SMEs respondents disagreed that lack of appropriate education and training, and lack of managerial ability were hindering them from accessing credit. These two constraints were in the band of 1.81–2.60.

The result in Table 56.3 infers that of the 179 respondents 13 i.e. 7.26% of SMEs surveyed obtained the business overdraft they applied for. 166 of the SMEs i.e. 92.74% did not either apply for the business overdraft or got the business overdraft. This is imperative to this study as there is lack of studies that have determined the predicators that influence business overdraft accessibility globally.

The result in Table 56.4, suggests that of the seven independent variables i.e. gender, age, location of business, type of business ownership, tax number, current position in the company and collateral or security modelled to predict business overdraft accessibility. The locality of the business predicted business overdraft accessibility. Those businesses that are located in the West Rand municipality of Guateng province in South Africa were likely to receive business overdraft credit than businesses that were located in the city of Johannesburg. The level of significance was less than 0.05 at 0.049 hence indicating a strong predictor. The odd of getting the credit was 6.105. It can further be suggested that we are 95% confident that the actual value of odds ratio in the population lies somewhere between 1.01 and 37.01. Further, because the confidence intervals does not contain the value of 1.00, this result is statistically significant at <0.05. This finding is in line with the

Table 56.4 Predictors of accessing business overdraft

Variable	Exp. (B) odds ratio	95% C.I. for Exp. (B) lower	95% C.I. for Exp. (B) upper	*p*-value
Gender (1)	1.685	0.489	5.805	0.409
Age group				0.907
31–40 years (1)	35336706.514	0.000		0.999
40–49 years (2)	35216122.305	0.000		0.999
50 years and over (3)	59177098.015	0.000		0.999
Current position				0.339
Owner (1)	0.309	0.088	1.084	0.067
Manager (2)	0.000	0.000		0.999
Manager/owner (3)	0.000	0.000		1.000
Ownership				1.000
Partnership (1)	0.000	0.000		0.999
Limited partnership (2)	0.000	0.000		1.000
Limited liability company (LLC) (3)	0.000	0.000		1.000
Tax number (1)	59799061.729	0.000		0.999
Location (municipality)				0.265
City of Tshwane Metropolitan Municipality (1)	3.733	0.618	22.533	0.151
Ekurhuleni Metropolitan Municipality (2)	*2.979*	*0.454*	*19.532*	*0.255*
West Rand District Municipality (3)	6.105	1.007	37.009	0.049
	0.000			0.999

Dependent variable: business overdraft accessibility (0 = unmarked; 1 = marked) sig. at 5%

study of Fatoki and Odeyemi (2010), conducted in South Africa. However, there study focused on generic credit not a specific type of credit. This finding suggests that financial institutions might only consider businesses in West Rand municipality when SMEs apply for business overdraft for their business.

The results in Table 56.4 further indicate that the gender, age, type of business ownership, tax number, and current position in the company were not predicting the business overdraft accessibility. The level of significance of these variables was greater than 0.05, hence poor predictors. The result on the gender of the applicant is not in line with the finding of Ololade and Olagunju (Ololade and Olagunju 2013), as a predictor. Kira and He in Tanzania (Kira and He 2012), established that the location and collateral were predicators of business credit accessibility. However, this current study did not support their findings. Furthermore, it is imperative to mention that collateral was not statistically interpreted in the output result of SPSS despite being included in the analysis as a predicting variable.

However, prior to testing this model, the goodness of fit of the model was tested which indicated a good fit. This result was justified by the Hosmer and Lemeshow test. The significance of the model was greater than 0.05 at 0.913. The result suggests that the independent variables were fitting in the proposed theoretical model.

56.5 Conclusions and Recommendations

The study found that SMEs are constraint from accessing credit because of lack of collateral/security, lack of cash flow statement and owners' equity. High interest rate was also deemed to be a factor preventing SMEs accessing credit. These factors might deter the SMEs business owners not to approach financial institutions but rather request family and friend to support them in acquiring credit.

The researchers established that for SMEs to access business overdraft the location of the business was an imperative factor. The business located in West Rand had a higher probability of accessing the business overdraft than those located in the city of Johannesburg. It is interesting to conclude that, gender, age, type of business ownership, tax number, current position in the company and collateral or security modelled to predict business overdraft accessibility were insignificant. This finding should be interpreted with caution as SMEs from Gauteng were the only respondents who participated. It is opined that the results might be different if the survey was conducted within construction SMEs in all the nine provinces in South Africa. Based on these findings, the researchers recommend that:

SMEs should provide, the requirements requested by the financial institutions as they apply for the business overdraft. However, the study informs the financial institutions that, gender, age, current position of the applicant and the business profile and requirements i.e. the tax number, collateral and type of business ownership are not a panacea in acquiring business overdraft.

In relation to the findings, the researchers propose the need to use other socio-economic and demographic characteristics that were not used in this study as the current factors are not exhaustive in relation to the full characteristic of SMEs. The factors recommended for testing are marital status of the applicant, bank account statement and managerial ability of the respondents.

References

Aduda J, Magutu OP, Wangu GM (2012) The relationship between credit scoring practices by commercial banks and access to credit by small and medium enterprises in Kenya. Int J Humanit Soc Sci 2(9):203–213

Agumba NJ (2006) Evaluating the use of project management techniques in infrastructure delivery by South African small and medium sized contractors. Unpublished masters dissertation. Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

Agumba JN, Adegoke IO, Otieno FAO (2005) Evaluating project management techniques in small and medium enterprises delivering infrastructure in South Africa construction industry. In: Proceedings of 3rd postgraduate conference, construction industry development, Eskom Convention Center, Midrand, 10–12th October

Alhassan F, Sakara A (2014) Socio-economic determinants of small and medium enterprises' (SMEs) access to credit from the barclays bank in Tamale-Ghana, Int J Humanit Soc Sci Stud I (II):26–36

Angela and Motsa Associates (2004) SMME finance sector background paper: a review of key documents on SMME finance 1994–2004. Fin Mark Trust, Johannesburg

Beck T, Aslı, D-K, Maria SMP (2008) Bank financing for SMEs around the world: drivers, obstacles, business models, and lending practices, policy research working paper 4785. World Bank, Washington, DC

Bondinuba FW (2012) Exploring the challenges and barriers in accessing financial facilities by small and medium construction firms in Ghana. Civ Environ Res 2(6):25–35

Chauke PK, Motlhatlhana ML, Pfumayaramba TK, Anim FDK (2013) Factors influencing access to credit: a case study of smallholder farmers in the Capricorn district of South Africa. Afr J Agric Res 8(7):582–585

Construction Industry Development Board (2008) Construction health and safety in South Africa, Status and recommendations. Pretoria, South Africa

Creswell JW (1994) Research design, qualitative and quantitative approaches. Sage, London

Department of Public Works (1999) White paper on creating an enabling environment for reconstruction growth and development in the construction industry, Government Printers, Republic of South Africa. http://www.info.gov.za/whitepaper/1999/environment.htm. Last accessed on 01 Feb 2015

Directors briefing (n.d.) Overdrafts and bank loans. Available from http://www.icaew.com/~/media/corporate/files/library/collections/online%20resources/briefings/directors%20briefings/fi1overd.ashx. Accessed on 05 Aug 2016

Dzadze P, Osei Mensah J, Aidoo R, Nurah GK (2012) Factors determining access to formal credit in Ghana: a case study of smallholder farmers in the Abura-AsebuKwamankese district of central region of Ghana. J Dev Agric Econ 4(14):416–423

Etonihu KI, Rahman SA, Usman S (2013) Determinants of access to agricultural credit among crop farmers in a farming community of Nasarawa State, Nigeria. J Dev Agric Econ 5(5): 192–196

Fatoki O (2014) Factors influencing the financing of business start-ups by commercial banks in South Africa. Mediterranean J Soc Sci 5(20):94–100

Fatoki O, Odeyemi A (2010) Which new small and medium enterprises in South Africa have access to bank credit? Int J Bus Manag 5(10):128–136

First National Bank (n.d.) Business overdraft. Available from https://www.fnb.co.za/business-banking/accounts/overdraft.html. Accessed on 05 Aug 2016

Grimsholm E, Poblete L (2011) Internal and external factors hampering SME growth-a qualitative case study of SMEs in Thailand. Unpublished masters thesis, Gotland University

Kayanula D, Quartey P (2000) The policy environment for promoting small and medium-sized enterprises in Ghana and Malawi. Finance and Development Research Programme, working paper series, paper no. 15. IDPM, University of Manchester

Kimutai CJ, Ambrose J (2013) Factors influencing credit rationing by commercial banks in Kenya. Int J Humanit Soc Sci 3(20):244–252

Kira RA, He Z (2012) The Impact of firm characteristics in access of financing by small and medium-sized enterprises in Tanzania. Inter J Bus Manag 7(24):108–119

Mandell L (1994) The credit card industry: a history. Twayne Publishers, Boston

Martin l (2010) Challenges faced by South African emerging contractors—review and update. In: Proceedings of the construction, building and real estate research conference of royal institute of chartered surveyors, Dauphine Universite, Paris, France, 2nd–3rd September

Musamali MM, Tarus KD (2013) Does firm profile influence financial access among small and medium enterprises in Kenya? Asian Econ Financ Rev 3(6):714–723

National Small Business Act (2004) Number 29 of 2004 Republic of South Africa. Available from: http://www.info.gov.za/view/DownloadFileAction?id=67967. Last accessed on 18 Apr 2016

Nkuah KJ, Tanyeh PJ, Gaeten K (2013) Financing small and medium enterprises (SMEs) in Ghana: challenges and determinants in accessing bank credit. Int J Res Soc Sci 2(3):12–25

Ololade RA, Olagunju FI (2013) Determinants of access to credit among rural farmers in Oyo State, Nigeria. Glob J Sci Front Res Agric Vet Sci 13(2,1):17–22

Pallant J (2013) SPSS, survival manual: a step-by-step guide to data analysis using IBM, SPSS, 5th edn. Allen & Unwin, Sydney, Melbourne, Auckland, London

Standard Bank South Africa (n.d., a) Available from https://www.standardbank.co.za/secure/applications/wcf/overdraft_form.html. Accessed on 05 Aug 2016

Standard Bank South Africa (n.d., b) Business overdraft. Available from http://www.standardbank.co.za/standardbank/Business/Loans-and-finance/Business-Overdraft. Accessed on 05 Aug 2016

Chapter 57
Determination of Project Management Competence Risks in Build Operate Transfer (BOT) Transportation Projects

H. Aladağ and Z. Işık

57.1 Introduction

Partners in BOT models, generally have different perceptions about risk allocation. This situation in the long-term can affect project success by creating dispute between partners. Moreover, BOT projects are generally challenged with both project management problems which require day-to-day supervision (short-term) as well as partnership problems which require more of a strategic approach (long-term) (Abednego and Ogunlana 2006). Therefore, in order to increase the performance of BOT projects by reducing disputes between partners with a proper risk allocation, long-term strategical plans should be considered together with the short-term project management plans. In this context, BOT projects can be considered to have governance concerns because they deal with monitoring and overseeing the processes with complex and large scale features. Furthermore, an effective project management is essential for the sustainability of partnerships between public and private sector. Consequently, in order to obtain an effective project management, risks associated with the project management competence of the partners should be well determined, analyzed and managed to provide stakeholder satisfaction with an efficient project management. In this research, it was aimed to determine project management competence risks and their significance in BOT transportation projects; therefore a comprehensive literature review have been held followed with focus group discussions and a multi criteria decision making analysis.

H. Aladağ (✉) · Z. Işık
Department of Civil Engineering, Yıldız Technical University, Istanbul, Turkey
e-mail: haladag@yildiz.edu.tr

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_57

57.2 Project Management Competence Risks in Build Operate Transfer (BOT) Transportation Projects

In this study, in order to identify project management competence risks in BOT transportation projects PMBOK Guide was used as a base then additional risk factors were incorporated into the list. The detailed explanation of the project management competence risks in BOT transportation projects are as follows:

- **Project Time Management (R1)**: It includes the processes required to ensure timely completion of projects (PMBOK 2004). BOT projects have a funding model that requires a performance-based payment system due to the needed advanced expertise rather than a traditional funding model. Payments that are going to be paid to the private sector by public sector within the framework of the financing model of the BOT project, are generally made after the provision of services instead of during the construction phase (World Bank Group 2016). Therefore, in order to shorten the time of completion and to receive payments, private partner tend to complete construction by fast tracking as a project delivery strategy. In this context, BOT projects are generally very sensitive in terms of time delays and completion time. Increased capital expenditures due to the extra workforce required by the extra speed of fast track construction can be tried to lower by efficient resource and time management. In this context, a detailed work progress schedule should be constituted and controlled by the concessionaire if the estimated work progress schedule is up and running properly.
- **Project Cost Management (R2)**: It includes the processes required to ensure that the project is completed within approved budget (PMBOK 2004). Especially in BOT transportation projects, cost estimating and cost budgeting become more crucial because of the high bidding, construction and maintenance & operation costs. Bidding costs for a BOT project may be very high, especially if it is a large project. Potential developers of a BOT project should pay attention to the parameters such as gathering of information regarding clarifications for the bid, legal issues and host market's parameters, costs for advisers, development of feasibility studies and development of bid documents constitute that define the bidding expenditures (Xenidis and Angelides 2005). Also they require high financial and technological requirements in the design and construction phases that brings labor, material and equipment costs together with construction costs. Since biggest problems in BOT projects arise from cost related factors, a private company who takes on the financial load in a BOT model, should explicitly consider the production and management costs in its cost calculations (Jin 2010). In addition high maintenance and operation costs with their effect on reducing the profit of the shareholders should be evaluated carefully.
- **Project Quality Management (R3)**: It includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. It includes all

activities of the overall management function that determine the quality, objectives and responsibilities (PMBOK 2004). In the BOT projects, the extra speed and general increases in the capital expenditures resulting from fast track construction can cause possible negative effects on the quality of the product. In the context of product quality, the need of an efficient quality management become prominent.

- **Project Human Resource Management (R4)**: It includes the processes required to make the most effective use of people involved with the project. It includes all the project stakeholders (sponsors, customer, partners, individual contributor and etc.) (PMBOK 2004). Taken into account that as complex and large-scaled projects BOT transportation projects highly require expertise and special set of skills during the construction and operation phases, competent workforce and competent partners (private partners, subcontractors and suppliers) should be employed in terms of staff acquisition and team development in project human resource management processes.
- **Project Communications Management (R5)**: It provides the critical link among people, ideas and information that are necessary for success. Everyone involved in the project must be prepared to send and receive communications, and must understand how the communications in which they are involved as individuals affect the projects as a whole (PMBOK 2004). In BOT transportation projects, communication is one of the important challenges on the success of the project and can be a huge downfall by contributing many of the other risks within partnerships (Babiak and Thibault 2009). In BOT projects, wherein a consortium generally comprise of more than one domestic and/or international construction firms receives a concession from the private or public sector to finance, design, construct, and operate a facility stated in the concession contract. In this context, for those construction firms entering into cross-sectoral or overseas construction industries, it can be difficult to collaborate due to the diversity and differences in working method, organizational culture and know-how between partners. Items like performance measures, goal measurements, government regulations, and the nature of funding can all be interpreted differently thus causing blurred lines of communication. In this context, poor communication between partners is considered one of the most important internal risk factors (Shen et al. 2006).
- **Project Risk Management (R6)**: It includes the processes of identifying, analyzing and responding to project risk. It includes maximizing the probability and the consequences of adverse events to project objectives (PMBOK 2004). Risk is inherent in the management of all projects, however, since BOT is a long-term agreement between the public and private sectors that has been made to allocate risks about designing, constructing and operating capital-intensive projects in an appropriate way (Clerck et al. 2012). Thus, BOT projects present a different risk profile than conventional projects (European Commission 2003). As it is seen, BOT models require an effective project risk management due to the nature of themselves. In this context, identification and classification of risks that affect BOT transportation projects have a special significance in terms of

revealing causes and possible effects in order to develop possible strategies to prevent the risks or minimize their effects. In BOT projects, risk is shared by public and private sectors. Moreover, primary motive for choosing a BOT model for public projects is realization of a risk transfer by passing the important risk factors to private sector (Cheung and Chan 2010). As seen, due to this reason BOT models require an effective risk management more than any conventional construction projects.

- **Project Procurement Management (R7)**: It includes the processes required to acquire goods and services to attain project scope, from outside the performing organization. Project procurement management can exist at many levels on the project in the perspective of buyer-seller relationship. Depending on the application area, seller may be called a subcontractor or supplier (PMBOK 2004). In practice, there will be a large number of financing agreements between BOT concessionaire and the sub-contractors in order to complete the related work based on each sub-contractor area of expertise. Similarly there will be a large number of financing agreements between BOT concessionaire and suppliers in order to supply required raw material and products in order to complete the project. Therefore, any delay depending inefficient procurement planning, solicitation, source selection and contract administration will directly affect the schedule of the BOT project where it has indirect effect on income regarding to the completion of the project.
- **Project Stakeholder Management (R8)**: A stakeholder is any individual, group or organization that can affect or be affected by the project. Effective stakeholder management creates positive relationships with stakeholders through the appropriate management of their expectations and agreed objectives. Considering long project duration and complex relationships between huge numbers of partners in BOT projects, possible disputes and negotiations can be prevented in the early stages with an efficient stakeholder management. Besides, diversity in the objectives or incompatible perceptions of the partners will drive project to failure by creating disputes and negotiations in the long-term (Cheung and Chan 2010). Thus, in order to eliminate incompetency in stakeholders' demands and expectations, project stakeholder management can be as useful tool by generating communication and collaboration between partners together with good client relations and high customer satisfaction. For example; cost increases that will occur due to the design changes can be prevented by the inclusion of the all stakeholders into the design process. Similarly, cost overruns due to the changes in project objectives, inadequate distribution of responsibilities, risk and authority in partnership, lack of commitment of each partner can be prevented with an efficient stakeholder management.
- **Contract and Dispute Management (R9)**: Contract management is the management of contracts made with customers, partners, or employees. It can be summarized as the process of systematically and efficiently managing contract creation, execution, and analysis for the purpose of maximizing financial and operational performance and minimizing risk. On the other hand dispute management consists of policies, procedures, systems, skills and resources to enable

organizations to successfully manage disputes (Molenaar et al. 2000). In combination with the BOT characteristics of huge investment, long project duration and complex relationships between public and private sector; risk allocation problems also have always been a challenging part of infrastructure investment and financing due to the nature of incomplete contracting (Jin 2010; Yun-na et al. 2012). Considering that contracts determine rights, responsibilities and concessions for the public and private sectors; contract and dispute management are key determining factors that are stipulating the participation of public and private sectors for achieving effectiveness and efficiency during project life cycle. Given the importance of risk allocation decisions and a growing awareness of their long-term impact, partnerships between public and private sectors in intensive capital network services require risks to be assigned to the contractual party that is better able to mitigate them or to bear them (Marques and Berg 2011). In this context preparation of a proper contract is an important issue for BOT transportation projects to solve risk sharing problems that would influence the long-term and stable cooperation of both partners and aligning BOT contracts with contracting parties' objectives is a common topic in the literature (Gross 2010).

- **Demand Management (R10)**: In BOT transportation projects, the commercial success of the project depends to the return of investment that can be measured by revenues. In projects such as motorway, airport etc., factors such as number of users, the level of passenger traffic, capacity ratio and the prices of the product (tariff) are among the most important ones that can affect the revenues (Abednego and Ogunlana 2006; Boeing Singh and Kalidindi 2006; Chung et al. 2010). In this context, demand management constitutes one of the important project management competence risks in BOT transportation projects in order to gather estimated revenues. Therefore, factors related to pricing policy, traffic volume estimation and construction of an alternative road should be well analyzed regarding the insufficient revenue that endangers the project's success in terms of demand management. Likewise, advertisement and marketing strategies can be developed in order to increase the user count.
- **Process and Documentation Management (R11)**: In project management, process management is the use of a repeatable process to improve the outcome of the project (Thom 2009). Document management can be defined as the software that incorporates document and content capture, workflow, document repositories, output systems, and information retrieval systems. Attitudinally, an efficient process management system also refer to various automation efforts, including workflow systems, XML Business Process languages and packaged ERP systems. In this case, the management emphasizes the ability of workflow engines to control process flows, automatically measure processes, and educating and organizing managers so that they will manage processes effectively. In BOT transportation projects due to the nature of complex and large-scale work, each process should be designed and each activity should be identified and documented as an input in order to manage successor activity.

Thus, connection of all partner, process monitoring, process improvement with performance management, and quality assurance can be obtained.

- **Occupational Health and Safety Management (OSHM) (R12)**: OHSM help organizations to continually improve their safety performance and compliance to health and safety legislation and standards. In doing so, organization establish safer working environments that protect people at work by eliminating, or better managing, health and safety hazards. In BOT projects that have more complex construction work, OSHM has a greater emphasis in contrast with other construction projects. Lack OSHM can lead great tremendous time delays and cost overruns due to the loss of time and workforce in BOT transportation projects.
- **Waste and Energy Management (R13)**: Taken into consideration that the increasing demands in implementing major infrastructure projects in developing countries, a large amount of construction waste is being produced by the BOT transportation projects. Thus, waste management should be an important concern in the implementation of BOT projects. Similarly, with government targets set to reduce greenhouse gas emissions, and the rising need for organizations to control their energy costs, the effective management of a building's energy consumption is now critical. With growing environmental concerns, and increasing legislation to curb energy wastage and reduce carbon emissions it is important to improve an efficient energy management systems lead to significant cost savings especially in operation phase of the BOT project. In BOT projects, during the operation phase the project payment stream is produced, project debt is repaid and the shareholders earn a return on their investment. Thus, bringing significant reductions in operational costs with waste and energy management will increase the concessionaire's profit.
- **Innovation Management (R14)**: By utilizing innovation management tools, the creative capabilities of the work force can be triggered and be deployed for the continuous development of a company in terms of product, process and organization. BOT is considered as a relatively innovative approach to infrastructure development, which enables direct private sector investment in large-scale infrastructure projects especially in developing countries by utilizing technology innovation. Therefore, in order to address the technical and managerial complexity of BOT projects, innovative project management theories and techniques are needed in terms of innovation management (Chan et al. 2005).
- **Operational Management (R15)**: In the BOT framework one of the driving force for the public administration is the taking advantage of the business administration competence of the private sector because BOT transportation projects highly require expertise and special set of skills during the operation phase in order to increase the service competency. Therefore, operational management constitutes one of the important project management competence risks in BOT transportation projects. In this context, operational and maintenance issues that are related with operational management competency and the experience of the private partner, operation cost overrun, operating productivity,

operational revenue, maintenance costs, frequency of maintenance and improvement of maintainability (Chou et al. 2012; Heravi and Hajihosseini 2012; Ke et al. 2010; Hwang et al. 2013) should be considered in terms of operational management.

57.3 Research Methodology and Data Analyses

In the study with the aim of determining significant level of the project management competence risks in BOT transportation projects focus group discussions were carried out with experts from construction companies and universities. Then, gathered data were analyzed with SMART.

57.3.1 Focus Group Discussion

The focus group as an exploratory technique that involves collecting data through a dynamic and interactive group discussion led by a moderator (the researcher) with a group size of 5–10 participants, has long been one of the most widely adopted qualitative research methods (Chan et al. 2012). However, unlike individual interviews, the focus group provides added dimension of the interactions among members by communicating with one another, exchanging ideas and comments on each other's experiences or points of view (Kitzinger 1994). Thus, it is claimed that focus groups enable researchers to study and understand a particular topic from the perspective of the group participants themselves (Wibeck et al. 2007). In the study, number of five participant who expertise in BOT and/or transportation projects were selected. Among the respondents were (1) Industrial representatives: a project manager with a 12 years of experience in public-private partnership transportation projects company with a civil engineering background, a large-size construction company owner whose responsible for a BOT transportation project with a civil engineering background, (2) Academics: two academics from civil engineering department whose area of expertise is transportation and one academic from civil engineering department whose area of expertise is construction management. Firstly participants were asked (1) to discuss project management competence risks related to BOT projects that were determined, (2) to eliminate or add new project management competence risks related to BOT mega transportation projects. After then, respondents were asked to review and rate the final results of focus group discussion in terms of their significant level. Gather data was analyzed with SMART which is a multi-attribute decision making approach.

Table 57.1 Significance level of project management competence risks related to BOT projects

Project management competence risks		Weights	Rank
R1	Project time management	0.0715	3
R2	Project cost management	0.0722	2
R3	Project quality management	0.0601	13
R4	Project human resource management	0.0646	10
R5	Project communications management	0.0672	8
R6	Project risk management	0.0683	6
R7	Project procurement management	0.056	14
R8	Project stakeholder management	0.0683	7
R9	Contract and dispute management	0.070	5
R10	Demand management	0.0646	11
R11	Process and documentation management	0.085	1
R12	Occupational health and safety management	0.0636	12
R13	Waste and energy management	0.0506	15
R14	Innovation management	0.0715	4
R15	Operational management	0.0665	9

57.3.2 SMART

SMART (Simple Multi Attribute Rating Technique) is a basic ranking technique that uses the simple additive weight method to obtain total values as the ranking index by handling data under each criterion (Chai et al. 2013). This method is based on a linear additive model. Major advantages of SMART, are that it is simple to use and it actually allows for any type of weight assignment techniques (Velasquez and Hester 2013). In SMART, weights are derived using direct numerical ratio judgments of the relative importance of attributes. Subjects first rank-order the attributes in importance and assign an arbitrary importance to the least important attribute. Then they judge how much more important each of the remaining attributes is in relation to the least important and assign weights. According to the SMART analyses results, significant level of project management competence risks related to BOT projects are shown in the Table 57.1.

57.4 Conclusion

In this study, with the aim of determining and reveling the significance of determined project management competence risks in BOT transportation projects, first a comprehensive literature review was made, then focus group discussions were carried out with experts and finally gathered data were analyzed with SMART. The result of the study constitutes that according to the results shown in Table 57.1, process and documentation management with a weight of 0.085 has the highest ranking. Thereafter project cost management with the weight of 0.072 comes in second place whereas waste and energy management with a weight of 0.05 has the lowest ranking. In BOT projects, time delays and cost overruns are considered as being of the top priority in terms of capital-intensive nature and long duration of the project. In BOT transportation projects, every increase on cost of raw material, labor costs, overhead cost and cost of capital directly increases the production cost and generally increases the price of the product/service and reduces the demand (Jahren and Ashe 1990) which may become critical for the investment's profitability. Also in BOT transportation projects, the problem of delays is a global phenomenon because project delivery method of BOT can increase the speed of construction. Therefore, it can be assumed that, project cost management and project time management should have top priorities. However, according to the result of SMART analysis; process and documentation management had been identified to have much more significance in the BOT transportation projects. In BOT transportation project contractual liability of the private partner were identified strictly in contracts and controlled by the public partner. Thus, the result can be interpreted that by implementing a well-designed process and documentation management it can be possible to manage time, cost and quality issues in a holistic view even before they exist. The results of the study shows that project innovation management has also a high priority in sustaining the performance of the BOT transportation projects. Taken into account of the nature of BOT transportation project high technology requirements this result seems rational. In BOT models, one of the main drivers for public is the risk transfer of technology innovation. Thus, innovation management skills of the private partner are of the essence for sustaining the competitiveness of the private partner in order to win BOT tenders in the long term.

The work described in this paper is part of an ongoing study that has the aim of developing a risk management model in BOT transportation projects. In this context, the research opens up to future developments such as associating the other risk factors (political risks, legal risks, organization and coordination risks, design and construction risks, financial risks, market risks, environmental risks, social risk) along with the project management competence risks in order to develop risk management model in BOT transportation projects by defining cause and effect relationship between each group. Also the result of the study can be tested on different BOT transportation projects and the comparisons can be analyzed if there exist any different perception in the context of presented information.

Acknowledge The work described in this paper was supported by Coordinatorship of Scientific Research Projects of Yıldız Technical University (Project Number: 2014-05-01-DOP03).

References

Abednego MP, Ogunlana SO (2006) Good project governance for proper risk allocation in public–private partnerships in Indonesia. Int J Project Manage 24(7):622–634

Babiak K, Thibault L (2009) Challenges in multiple cross-sector partnerships. Nonprofit Voluntary Sector Q 38(1):117–143

Boeing Singh L, Kalidindi SN (2006) Traffic revenue risk management through annuity model of PPP road projects in India. Int J Proj Manage 24(7):605–613

Chai J, Liu JN, Ngai EW (2013) Application of decision-making techniques in supplier selection: a systematic review of literature. Expert Syst Appl 40(10):3872–3885

Chan WT, Chen C, Messner JI, Chua DK (2005) Interface management for China's build–operate–transfer projects. J Constr Eng Manage 131(6):645–655

Chan IYS, Leung MY, Yu SSW (2012) Managing the stress of Hong Kong expatriate construction professionals in Mainland China: focus group study exploring individual coping strategies and organizational support. J Constr Eng Manage 138(10):1150–1160

Cheung E, Chan APC (2010) The researcher's perspective on procuring public works projects. Struct Surv 28(4):300–313

Chou JS, Ping Tserng H, Lin C, Yeh CP (2012) Critical factors and risk allocation for PPP policy: comparison between HSR and general infrastructure projects. Transp Policy 22:36–48

Chung D, Hensher DA, Rose JM (2010) Toward the betterment of risk allocation: investigating risk perceptions of Australian stakeholder groups to public–private-partnership toll road projects. Res Transp Econ 30(1):43–58

Clerck DD, Demeulemeester E, Herroelen W (2012) Public private partnerships: look before you leap into marriage. Rev Bus Econ Lit 57(3):249–261

European Commission (2003) Guidelines for successful public–private partnerships. Retrieved from: http://europa.eu.int/comm/regional_policy/sources/docgener/guides/PPPguide.htm. Accessed 29 July 2016

Gross ME (2010) Aligning public-private partnership contracts with public objectives for transportation infrastructure. Doctoral dissertation, Virginia Polytechnic Institute and State University

Heravi G, Hajihosseini Z (2012) Risk allocation in public–private partnership infrastructure projects in developing countries: Case study of the Tehran-Chalus toll road. J Infrastruct Syst 18(3):210–217

Hwang BG, Zhao X, Gay MJS (2013) Public private partnership projects in Singapore: factors, critical risks and preferred risk allocation from the perspective of contractors. Int J Project Manage 31(3):424–433

Jahren CT, Ashe AM (1990) Predictors of cost overrun rates. J Constr Eng Manage 116(3): 548–552

Jin X (2010) Determinants of efficient risk allocation in privately financed public infrastructure projects in Australia. J Constr Eng Manage 136(2):138–150

Ke Y, Wang S, Chan AP, Lam PTI (2010) Preferred risk allocation in China's public–private partnership (PPP) projects. Int J Project Manage 28(5):482–492

Kitzinger J (1994) The methodology of focus groups: the importance of interaction between research participants. Sociol Health Illn 16(1):103–121

Marques RC, Berg S (2011) Risks, contracts, and private-sector participation in infrastructure. J Constr Eng Manage 137(11):925–932

Molenaar K, Washington S, Diekmann J (2000) Structural equation model of construction contract dispute potential. J Constr Eng Manage 126(4):268–277

PMBOK (2004) A Guide to the project management body of knowledge, 3rd edn. Project Management Institute, Pennsylvania USA

Shen LY, Platten A, Deng XP (2006) Role of public private partnerships to manage risks in public sector projects in Hong Kong. Int J Project Manage 24(7):587–594

Thom W (2009) People, Process, and Performance Management in Project Management. Retrieved from The Project Management Hut: http://www.pmhut.com/people-process-and-performance-management-in-projectmanagement. Accessed 29 July 2016

Velasquez M, Hester PT (2013) An analysis of multi-criteria decision making methods. Int J Oper Res 10(2):56–66

Wibeck V, Dahlgren MA, Öberg G (2007) Learning in focus groups an analytical dimension for enhancing focus group research. Qual Res 7(2):249–267

World Bank Group (2016) Concessions, build-operate-transfer (BOT) and design-build-operate (DBO) projects. Retrieved from: http://ppp.worldbank.org/public-private-partnership/agreements/concessions-bots-dbos. Accessed 29 July 2016

Xenidis Y, Angelides D (2005) The financial risks in build-operate-transfer projects. Constr Manage Econ 23(4):431–441

Yun-na WU, Xin-liang HU, Ling-shuang XU, Ze-zhong L (2012) Research on risk allocation of public-private partnership projects based on rough set theory. Commun Inf Sci Manage Eng 2(7):15–20

Chapter 58
Does the Development of China's Building Industry Influence the Global Energy Consumption and Carbon Emissions? an Analysis Based on the GVAR Model

Hong Zhang, Jiawei Chen, Yang Li and Michael J. Seiler

58.1 Introduction

Recently, the relations among economic growth, energy consumption and carbon emissions have attracted much interest. A vast majority of the existing literature examined the long-run or short-run causal effects among the economic growth, energy consumption and carbon emissions. Soytas et al. (2007), Apergis and Payne (2009), Zhang and Cheng (2009), Lean and Smyth (2010). It is noteworthy that these studies generally take a country or region as a closed economy and analyze the intrinsic linkages among economic growth, energy consumption and carbon emissions for a given country or region. In the context of globalization, however, previous studies ignore the impact of foreign countries on domestic energy consumption and carbon emissions through international trading channels.

The purpose of this paper is to extend the current environmental analysis to a global picture with focus on the impact from the China's building industry. The effect of the building industry on global energy consumption and carbon emissions is relatively scarce in contrast to its significance to the global environment. From a global perspective, energy consumption in the building sector accounted for approximately 30–40% of the total energy consumption (IEA 2007). And the CO_2

H. Zhang (✉) · J. Chen · Y. Li
Hang Lung Center for Real Estate of Tsinghua University/Center for Urbanization and Industrial Development, Tsinghua University, Beijing, China
e-mail: zhannie@tsinghua.edu.cn

J. Chen
e-mail: 1030406911@qq.com

Y. Li
e-mail: liy-10@mails.tsinghua.edu.cn

M.J. Seiler
The College of William & Mary, Williamsburg, VA 23187, USA
e-mail: Michael.Seiler@mason.wm.edu

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_58

emissions from the building sector accounted for almost a quarter of all global emissions (IPCC 2007). Given the industrialization and urbanization trends in China, the overall size and developing speed in the building industry has achieved remarkable progress over the past 30 years, and resulting environmental concerns with regards to building energy consumption and GHG emissions cannot be overlooked (Zhang et al. 2013). In 2009, energy consumption of the China's building industry accounted for 27.5% of the national aggregate and is expected to reach 35% in 2020. The building industry also contributed to 25% of national CO_2 emissions (Li and Colombier 2009).

The channels of China's building industry development impact on the global economic growth, energy consumptions and carbon emissions are threefold. First, considering the high dependence on international commodity imports of China (iron, steel and coal), the fast-paced development in China's building industry inevitably has an indirect impact on economic growth, energy consumption and carbon emissions for trading partner countries through international transmission channels. Second, China's government has implemented the "going global strategy" to encourage and support the domestic building industry to seize the international market. As a result, the global economic growth, energy consumptions and carbon emissions will be changed by China's building industry. Third, the Foreign Direct Investment (FDI) can impact the host countries' economic, energy consumption and carbon emissions. (Grimes and Kentor 2003; Fisher-Vanden et al. 2006; Jorgenson 2007; Perkins and Neumayer 2008; Acharkyya 2009).

The remainder of the paper is structured as follows: Sect. 58.2 describes the GVAR model of the "economy-energy-environment" relationship. Section 58.3 presents the variables and data source as well as simulation results based on a series of GIRF. Conclusions are presented in Sect. 58.4.

58.2 GVAR Model of the "Economy-Energy-Environment" Relationship

To investigate the relations among economic development, energy consumption and carbon emissions on a global level, we estimate a GVAR model, as developed in Dees et al. (2007).

In line with Dees et al. (2007), we assume N countries and endogenous country-specific variables X_i (indexed by $i = 1, 2, 3, \ldots N$), which have a country-specific counterpart consisting of weighted averages of the corresponding variables for all other cities in the system, X^* along with deterministic variables, such as a time trend (t). For simplicity, we confine our exposition here to a first-order dynamic specification as in Pesaran et al. (2004). Under this assumption, we can relate the $k_i \times 1$ country-specific variables, X_{it}, to their country-specific counterparts, $X^*_{i,t}$, and exogenous variable, t, as follows:

$$X_{it} = a_{i0} + a_{i1}t + \Phi_i X_{i,t-1} + \Lambda_{i0} X^*_{i,t} + \Lambda_{i1} X^*_{i,t-1} + \varepsilon_{it} \tag{58.1}$$

And the larger-scale global model which corresponds to the country-specific models can now be given by:

$$GX_t = a_0 + a_1 t + HX_{t-1} + \varepsilon_t$$

$$a_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix}, a_1 = \begin{pmatrix} a_{01} \\ a_{11} \\ \vdots \\ a_{N1} \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{0t} \\ \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}, G = \begin{pmatrix} A_0 W_0 \\ A_1 W_1 \\ \vdots \\ A_N W_N \end{pmatrix}, H = \begin{pmatrix} B_0 W_0 \\ B_1 W_1 \\ \vdots \\ B_N W_N \end{pmatrix} \tag{58.2}$$

where, $A_i = (I_{ki}, -\Lambda_{i0})$; $B_i = (\Phi_i, -\Lambda_{i1})$. W_i is a $\left(k_i \times k_i^*\right) \times k_i$ matrix of fixed constants defined in terms of the country-specific weights. W_i can be viewed as the link matrix that allows the country-specific models to be written in terms of the global variable vector X_t.

Ultimately, the model consists of country-specific equations for each country consisting of regional economic variables and environmental variables, plus the country-specific foreign counterpart for each variable, as well as one lag of variables in the system. In general, such a GVAR model allows for interactions among the different countries through three separate but interrelated channels. First, there is a contemporaneous dependence of $X_{i,t}$ on $X^*_{i,t}$ and on its lagged values. Second, there is a dependence of the country-specific variables on common exogenous variables, such as the price of oil. Third, there is a non-zero contemporaneous dependence of shocks in country i on the shocks in country j, measured via the cross-country co-variances, $\sum ij$.

58.3 Simulation Analysis Using GVAR

58.3.1 Variables and Data

The GVAR model in this study contains 33 countries and follows the GVAR toolbox 1.1 developed by Smith and Galesi (2011). Taking the EU (consisting of eight countries: Germany, France, Italy, Spain, the Netherlands, Belgium, Austria and Finland) as a whole, GVAR toolbox 1.1 contains 26 country-specific models. These countries account for more than 80% of the total world GDP, and more than 70% of the global total carbon emissions and energy consumption. Table 58.1 shows these 33 countries in the GVAR model.

Each country model includes three domestic variables: real GDP, energy consumption and carbon emissions, denoted as y, ec and ce. Meanwhile, each country

Table 58.1 33 countries in the GVAR model

Major countries	EU	Other Euro countries	ASEAN countries	LA countries	Others
US, Japan, China, U.K., Canada, Australia, New Zealand, Korea	Germany, France, Italy, Spain, Netherland, Belgium, Austria, Finland	Sweden, Switzerland, Norway	Indonesia, Thailand, Philippines, Singapore, Malaysia	Argentina, Brazil, Mexico, Chile, Peru	India, South Africa, Turkey, Saudi Arab

Note ASEAN refers to the Association of Southeast Asian Nations; LA refers to the Latin America

Table 58.2 Trade matrix of the major countries and regions

Country/region	China	US	Euro area	Japan	ASEAN	L.A.
China	–	0.210	0.176	0.163	0.125	0.053
US	0.153	–	0.155	0.081	0.062	0.172
Euro area	0.127	0.175	–	0.051	0.049	0.059
Japan	0.228	0.207	0.114	–	0.156	0.036
ASEAN	0.133	0.138	0.100	0.153	–	0.003
L.A.	0.119	0.292	0.168	0.051	0.027	–

Note The number in the trade matrix refers to the trade share that the column country occupies for the line country. Data source is the IMF direction of trade weights based on the 2006–2008 average

model includes foreign variables corresponding to their domestic variables: foreign real GDP, foreign energy consumption and foreign carbon emissions, denoted as *ys*, *ecs* and *ces*. The global variables include oil prices as well as the output of the building industry in China, respectively, denoted as *poil* and *yc*.

In order to construct the corresponding foreign variables $X_{i,t}^{*}$, the GVAR model needs to be established in accordance with each country's import and export data, and then the trade-weighted matrix can be setup to reflect the degree of influence between different countries or economies. Table 58.2 presents the trade shares for the focus economies in our GVAR model.

58.3.2 Statistical Tests

58.3.2.1 Dynamic Analysis Based on GIRF Application

To study the dynamic properties of the economy, energy and environment, we make use of the GIRF developed further by Pesaran and Shin (1998) for VECMs. The GIRF is an alternative to the Orthogonalized Impulse Responses (OIR) of Sims (1980). Unlike the OIR, the GIRF is invariant to the ordering of the variables and

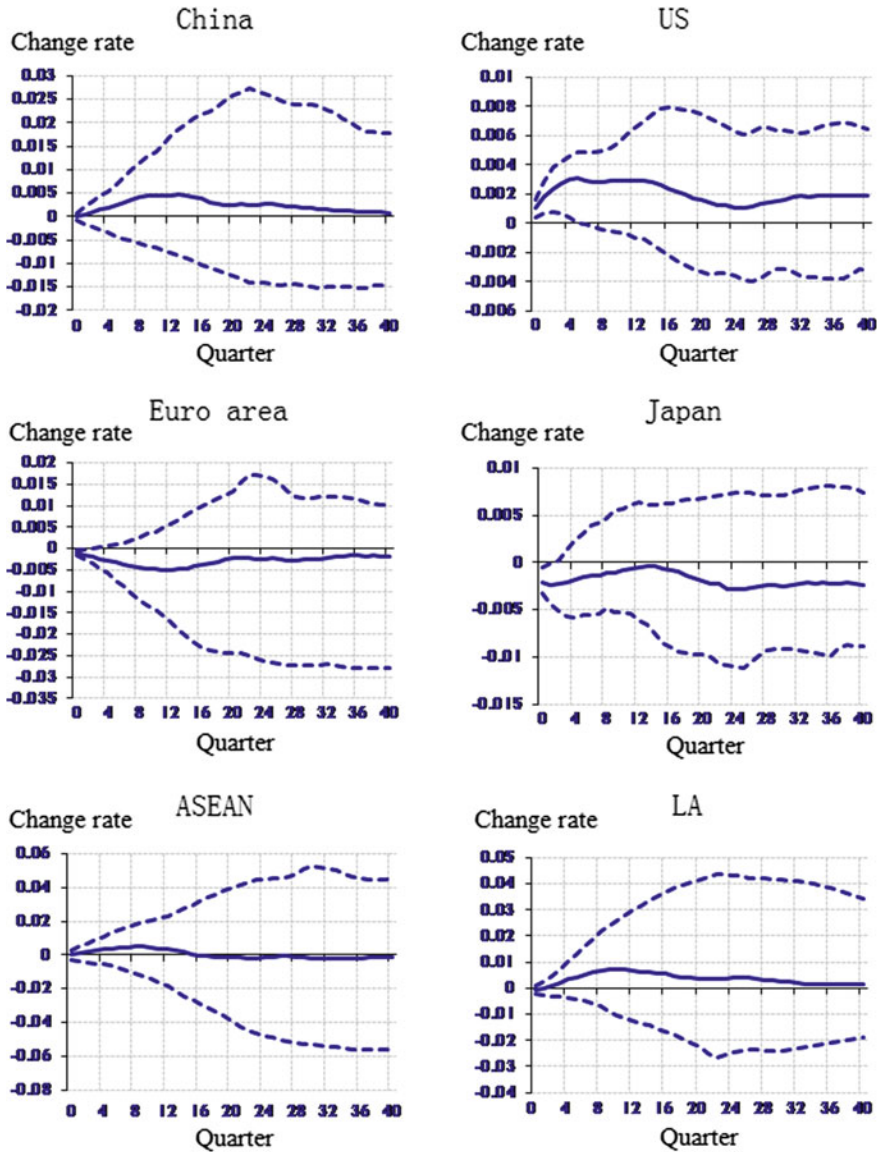


Fig. 58.1 Impacts of the China's building industry on energy consumption in different countries

the countries in the GVAR toolbox system, which is clearly an important consideration. Figures 58.1 and 58.2 show the generalized responses of energy consumption and carbon emissions in six economies, corresponding to a standard deviation (SD) shock of the output in the China's building industry.

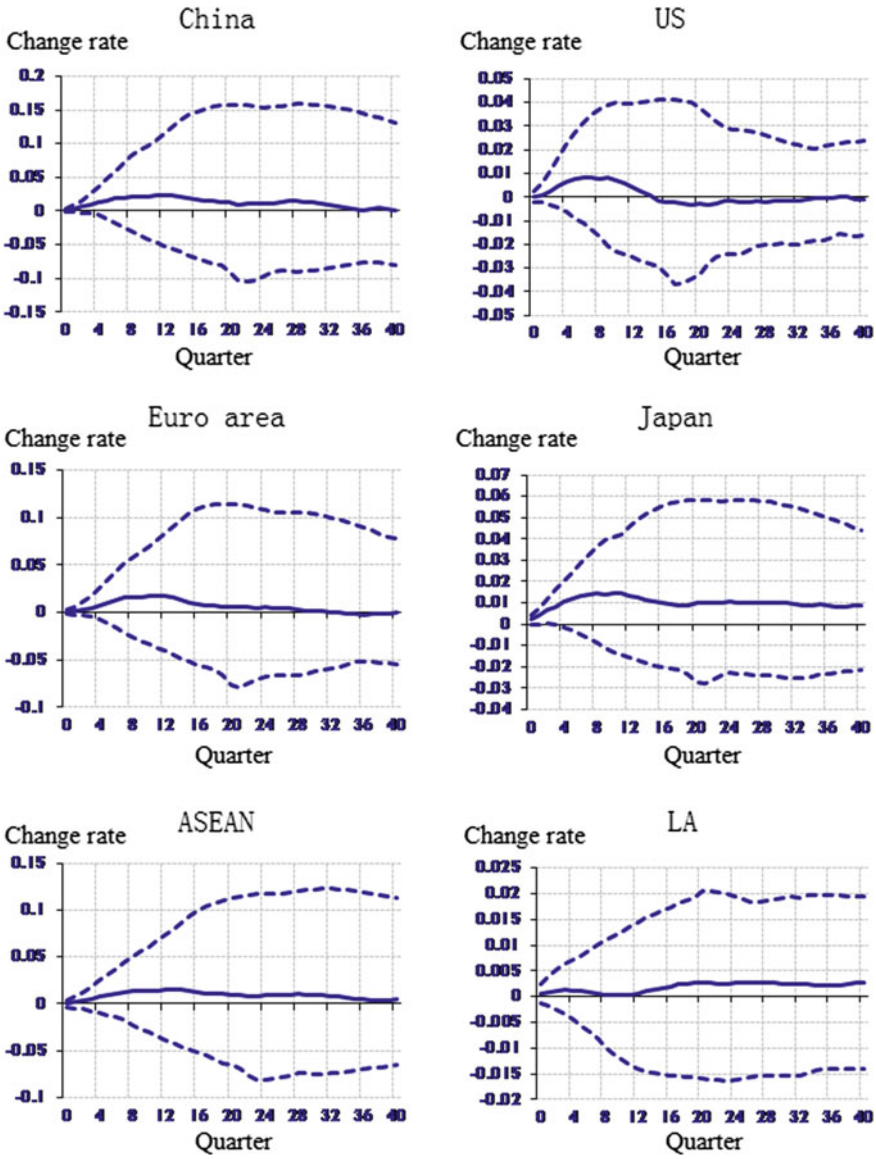


Fig. 58.2 Impacts of the China's building industry on carbon emissions in different countries

58.3.2.2 Impacts of the China's Building Industry on Global Energy Consumption

Figure 58.1 shows the dynamic impacts of the output growth in the China's building industry on the energy consumption in other economies. In response to one

SD positive shock from the building industry in China (3.42%), the energy consumption shows idiosyncratic performance in different economies will increase in China, US, ASEAN and Latin America, and decline in Japan and the Euro area. As far as China is concerned, the economic growth in the building industry produces a sustained positive effect on energy consumption; the peak arrives in three years, approximately 0.46%, with a 3-year cumulative response value of 4.04%. For the US, energy consumption has always presented a positive response with maximum response values of 0.31% in one year (statistically significant), and a 3-year cumulative response of 3.7%. The Euro area, however, shows a negative response, reflecting that the fast developed building industry in China may have negative impacts on energy consumption in the Euro area; the lowest point in three years is −0.50%, with a cumulative response value of −4.42% in three years. Japan is similar to the Euro area, but the 3-year cumulative response is only −1.99%. Finally, energy consumption in ASEAN and Latin America suffers a greater impact as maximum response values appear in the second year, at 0.49 and 0.71%, respectively.

58.3.2.3 Impacts of the China's Building Industry on Global Carbon Emissions

Figure 58.2 shows the dynamic impacts of the output growth in the China's building industry on the carbon emissions in other economies. Unlike energy consumption, all countries show a positive response in carbon emissions, in reaction to one SD shock in the building industry output from China. The response duration is about six years, and the peak appears in approximately 2–3 years. In China, the economic growth in the building industry increases carbon emissions, as high as 2.41%, and a 3-year cumulative response 20.04%; the carbon emissions in the US have a fast response during the first year, with the maximum response values of six quarters subsequent at 0.84%, while the 3-year cumulative response is 7.47%, the Euro area and Japan present the same response curve, where the highest arrives over the first three years, at 1.79 and 1.44%, respectively. ASEAN and Latin America have lower response levels by contrast at 1.32 and 1.34%, respectively.

58.4 Conclusions

Using GVAR, this study establishes a dynamic relations model for economic growth, energy consumption and carbon emissions of 33 countries in the context of international trade from 1979Q2 to 2008Q4. The GVAR model contains 26 VECM models, with each model consisting of three variables to represent the output, energy and the environment. With the application of GIRF, this paper further analyzes the impacts of growth within the China's building industry on energy consumption and the carbon emissions of other countries or regions including the

US, Euro area, Japan and other major economies. The results show that growth in the China's building industry can result in different responses of energy consumption and carbon emissions in different countries.

While foreign trade continues to increase in the face of global economic growth, China's economic growth in the building industry can have indirect impacts on the US, Euro area, Japan and other Asian countries, in terms of energy consumption and carbon emissions. The world economy can also have a strong impact on energy consumption in China through trade channels. Therefore, in future analysis of the environmental impacts caused by economic growth in a given country or region, researchers should not only analyze the endogenous growth of the domestic economy, but also pay attention to the changes produced by interactions in the context of the world economy.

Acknowledgements This paper is supported by National Natural Science Foundation of China (Grant No. 71373143) and Tsinghua University Initiative Scientific Research Program (2015THZ01).

References

Acharyya J (2009) Fdi, growth and the environment: evidence from India on CO_2 emission during the last two decades. J Econ Dev 34(1):43–58

Apergis N, Payne JE (2009) CO_2 emissions, energy usage, and output in Central America. Energy Policy 37:3282–3286

Dees S, di Mauro F, Pesaran MH, Smith LV (2007) Exploring the international linkages of the euro area: a global VAR analysis. J Appl Econometrics 22:1–38

Fisher-Vanden K, Jefferson GH, Ma J, Xu J (2006) Technology development and energy productivity in China. Energy Econ 28(5–6):690–705

Grimes P, Kentor J (2003) Exporting the greenhouse: foreign capital penetration and CO_2 emissions 1980–1996. J World-Syst Res 9(2):261–275

IEA (2007) World energy outlook 2007: China and India insights. France, Paris

IPCC (2007) Climate change 2007: synthesis report. Switzerland, Geneva

Jorgenson AK (2007) Does foreign investment harm the air we breathe and the water we drink? A cross-national study of carbon dioxide emissions and organic water pollution in less-developed countries, 1975 to 2000. Organ Environ 20(2):137–156

Lean HH, Smyth R (2010) CO2 emissions, electricity consumption and output in ASEAN. Appl Energy 87(6):1858–1864

Li J, Colombier M (2009) Managing carbon emissions in China through building energy efficiency. J Env Manage 90(8):2436–2447

Perkins R, Neumayer E (2008) Fostering environment efficiency through transnational linkages? Trajectories of CO_2 and SO_2, 1980–2000. Environ Plann A 40(12):2970–2989

Pesaran H, Shin Y (1998) Generalized impulse response analysis in linear multivariate models. Econ Lett 58(1):17–29

Pesaran MH, Schuermann T, Weiner SM (2004) Modeling regional interdependencies using a global error-correcting macro econometric model. J Bus Econ Stat 22(2):129–162

Sims C (1980) Macroeconomics and reality. Econometrica 48(1):1–48

Smith LV, Galesi A (2011) GVAR toolbox 1.1. http://www-cfap.jbs.cam.ac.uk/research/gvartoolbox

Soytas U, Sari R, Ewing T (2007) Energy consumption, income, and carbon emissions in the United States. Ecol Econ 62(3–4):482–489

Zhang XP, Cheng XM (2009) Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 68(10):2706–2712

Zhang X, Shen GQ, Feng J, Wu Y (2013) Delivering a low-carbon community in China: Technology vs. strategy? Habitat Int 37(1):130–137

Chapter 59
Driving Factors for Promoting Urbanization of Small Towns in Southwest China

Ning Xiong, Zhenhua Huang, Shanshan Zhao and Liyin Shen

59.1 Introduction

Urbanization plays a vital role in the improvement of the social wealth and economic growth, which is the road to industrialization and modernization in various countries (Brown and Neuberger 1977). China's urbanization rate reached to 54.77% in 2014. According to Northam (Ray M Northam) "S" Curve Theory, China's urbanization is in the middle stage (as defined in "S" curve that middle stage urbanization present when urbanization level is from 30 to 70%), but it enters the accelerating development stage. In order to guide healthy development of urbanization in the country, China promulgated the policy "the New National Urbanization Planning"(2014–2020). In addition, the construction for new urbanization was promoted into a prominent position in Third Plenary Session of Eighteenth Communism Conference. The urbanization program becomes China's long-term strategy for its social-economic development. Of which, the development for the urbanization of small towns is one of the key schemes.

Small towns in southwest China in this paper specifically refers to those towns established in Chongqing, and provinces of Sichuan, Yunnan and Guizhou. They are not only large in quantity, but also are subject to relatively low level of development, constrained by topography, environment, social and economic background. The healthy and sustainable urbanization in these small towns play crucial role for the national urbanization development. Nevertheless, there are various factors affecting the implementation of urbanization in the small towns in

N. Xiong (✉) · Z. Huang · L. Shen
School of Construction Management & Real Estate,
Chongqing University, Chongqing, China
e-mail: 178913722@qq.com

N. Xiong · Z. Huang · S. Zhao · L. Shen
International Research Centre for Sustainable Built Environment,
Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_59

Southwest China. The implementation process will be effective if these driving factors can be realized and managed effectively. Therefore, it is important to understand these driving factors.

Existing researches on the driving factors of urbanization focus by large the following issues: government-led urbanization model (also called top-down model), market-oriented urbanization model (also called model), the combination between top-down and bottom-up models (also called binary theoretical model) (Pei 1998), urbanization model by combining the efforts from government, enterprises and individuals (Yuemin 1998), driving by the transformation of industrial structure (Zhang 2001; Wang et al. 2003; Chen 2005), institutional change for driving urbanization (Liu 1999; Yong-Zhong and Chen 2005), driving by comparative advantage between urban and rural areas (Chonglan 2003; Zongping 2009), the driving urbanization by industry agglomeration (Fu 2003; Marshall 1964), driving by the development of agriculture surplus (Shubin and Quanhong 2009), driving by information industry (Zuofeng 2001; Weiwei 2003) and driving by overseas investment (Fengxuan and Chun 1997; Juan et al. 2011). Some scholars have studied the driving factors for the development of small towns, such as government policy and regulation; local economic development; local natural resources, geographical conditions, demographic characteristics, and socio-cultural factors and other driving factors (Li and Sui 2006). There is little research, nevertheless, on the driving mechanism or factors for urbanization in small towns with the contents of Southwest China. Therefore, this study aims to make up for the theoretical knowledge gaps in this area.

This paper firstly summarize and classify the driving factors affecting urbanization in China, which have been presented in the existing literatures. Then the examination is given to the current status of small towns in Southwest China by making use of the data collected from field research. Finally, the driving factors of the urbanization in small town in Southwest China will be identified by incorporating the research work in previous section. The research results can reference for producing a guidance to promote the healthy and sustainable urbanization of small towns particularly in Southwest China.

59.2 Research Method

To achieve the research aim, this study adopts the following research methods. Firstly, literature review will be conducted comprehensively in order to summarize the various types of mechanism and factors of urbanization. The literature review provides theoretical basis for investigating the driving factors of urbanization in small towns. Secondly, field survey are conducted to understand the current development status of small towns in Southwest China, and identify those driving factors affecting urbanization. The data for supporting understanding of current status of these small towns are also from China Statistical Yearbook (2015), China

Urban-Rural Construction Statistical Yearbook (2014) and China Yearbook of Town Survey (2012).

59.3 Principles of Driving Mechanism of Urbanization

There are various types of driving factors for urbanization. To understand these factors, it is necessary to appreciate the driving mechanism for urbanization.

59.3.1 Driving Mechanism for Urbanization

In this section, driving mechanism for urbanization will be discussed from the following perspectives: the driving roles by the actors in urbanization process, driving by the transformation of industrial structure, institutional change for driving urbanization, driving by comparative advantage between urban and rural areas, driving urbanization by industry agglomeration, driving by the development of agriculture surplus, driving by information industry and driving by overseas investment.

59.3.1.1 The Driving Roles by the Actors in Urbanization Process

In the process of urbanization, the actors include governments, enterprises and individuals. Different actors will have different roles in driving urbanization. Urbanization can be divided into two tapes, namely government-led urbanization model (also called top-down model), market-oriented urbanization model (also called bottom-up model). Therefore, the urbanization in China is often described as Mode of Binary (Pei 1998). Ning Yuemin also proposed the concept of "ternary" urbanization motivation theory, by which the government, enterprises and individuals work together for driving urbanization process (Yuemin 1998).

59.3.1.2 Driving Urbanization by the Transformation of Industrial Structure

C.G.Clark concludes in book 'conditions of economic progress' that with the continuous economic development and continuous improvement of people's living standards, the proportion of the first industry in the national economy continues to decrease, while the proportion of secondary and tertiary industries gradually increase. China's famous economist Zhang (2001) suggested that industrialization is endogenous power of urbanization, and urbanization is not possible without urbanization. By echoing this, Wang Dongmei, Liu Tingwei and Chen Liuqin opined that industrialization is the fundamental driving force to urbanization, whilst agriculture is basic force and Tertiary Industry is a force for the following-up development of urbanization (Wang et al. 2003; Chen 2005).

59.3.1.3 Institutional Change for Driving Urbanization

Ronald H Coase and Douglas C North argued the key to economic growth lies in the system. Liu Zhuanjiang opined institurional system has an important impact on the process of urbanization (Liu 1999). Lu Yongzhong and Chen Bo Chong found that institutional change and innovation can help reduce transaction costs, and thereby reducing the potential loss of urbanization (Yong-Zhong and Chen 2005).

59.3.1.4 Driving by Comparative Advantage Between Urban and Rural Areas

The comparative advantages of urban area over rural include better education and health facilities, better economic benefit, and others. Therefore there is a huge attraction to the people from rural area to urban area. This forms a driving force for urbanization. Fu Chonglan found that per capita agricultural labor productivity is low in comparing the secondary and tertiary industries in urban area in China, which leads to a large number of surplus rural labor migration to urban (Chonglan 2003). Cao Zongping pointed out that the majority of the population often choose to live in urban, because there exists big gap between rural and urban such as education condition, which drives the development of urbanization (Zongping 2009).

59.3.1.5 Driving Urbanization by Industry Agglomeration

The economist Marshall proposed industrial agglomeration theory and claimed that professionals, transport facilitation, and technology companies promote the formation of geographic concentration and interdependence. Some scholars pointed out that the industrial agglomeration is the foothold of Urbanization and it can improve industrial competitiveness in urban area (Fu 2003; Marshall 1964).

59.3.1.6 Driving by the Development of Agriculture

The development of agriculture is also a driving force to urbanization. First, the advance of urbanization need agriculture to provide sufficient food and raw materials. Secondly, by the advance of urbanization need agriculture to provide market. Thirdly, the advance of urbanization need the surplus labor force from agriculture to provide factors of production. Di Shubin and Zhang Quanhong indicated that agricultural development is original impetus of urbanization (Shubin and Quanhong 2009).

59.3.1.7 Driving by Information Industry

With the development of information technology, informatization has become an important part of driving force for urbanization. Du Zuofeng opined that informatization could promote industrialization and the upgrade of industrial structure, thus promote the urbanization process (Zuofeng 2001). Fang Weiwei pointed out informatization will promote urban industrial structure to higher class, absorb surplus rural labor force from rural area, and promote urbanization (Weiwei 2003).

59.3.1.8 Driving by Information Industry

With the growing globalization, overseas capital in China plays a key role for the process of urbanization. Xue Feng Xuan, Yangcun observed the importance of overseas investment in China's urbanization and argued that the development of overseas capital is China's new impetus of urbanization (Fengxuan and Chun 1997). Huang Juan's research showed that overseas investment to level of urbanization in China is obvious (Juan et al. 2011).

59.3.2 Driving Factors of Urbanization in China

Based on the above discussions about the driving mechanism to urbanization, the driving factors can be identified into the following groups, as show in Table 59.1

59.4 The Development Status of Small Towns in Southwest China

The driving factors of urbanization in small towns have inevitable connections with a specific social environment. Therefore, the development status of the social environment in small towns in Southwest China will be analyzed in this section from the following aspects based on the understanding of the driving mechanism of urbanization and the factors discussed in the last section.

Table 59.1 Driving factors for urbanization

Category	Factors
Economic factors	Improvement of agricultural productivity industrialization Development of tertiary industry Economic comparative advantage industry agglomeration
Systems factors	Household registration system Employment system Land system Social security system Administrative system Investment and financing system Tax system Enterprise system
Resource endowment factors	Nature Location Environment
Population factors	Migration Population quality
Social factors	Infrastructure Social order Cultural characteristics Social environment
Other factors	Information Overseas investment

59.4.1 Economic Development Status

59.4.1.1 The Status of Industrial Structure

The level of industry and economy in southwest China and China as a whole is shown in Table 59.2. It can be seen that the level of economy in Southwest China is lower than that for whole country. And Southwest region is in the early stage of industrialization, and the evolution of the industrial structure is still at a low-level stage, based on Northam's 'S' theory about industrial structure and urbanization stage.

Table 59.2 Economic development status in Southwest China

Category	Southwest China	China
The three industry structure (2014) (primary/second/tertiary industries)	12.1:45.7:42.2	9.2:42.7:48.1
Three Industries Employment Structure (2014) (primary/second/tertiary industries)	45.9:21.2:32.9	29.5:29.9:40.6
Urbanization rate (2014)	48%	54.77%
The per capital disposable income ratio between urban and rural (2015)	2.87	2.97

Source China Statistical Yearbook

59.4.1.2 The Relationship Between Industry Structure and Employment Structure

According to the data in Table 59.2, the labor force in primary industry accounted for 45.6% of all employees, however, the primary industry only contributed 12.1% of GDP, showing great structural bias. Therefore, the need for development of second and tertiary industries in small towns in Southwest China is important to absorb the surplus population in the primary industry.

59.4.1.3 Income Status

According to the data of Table 59.2, the per capita disposable income of urban residents in Southwest region in 2015 is 2.87 times higher than that of the rural residents. According to international experience, the income ratio of urban and rural residents should not exceed 2:1. It can be seen that the income gap between urban and rural in Southwest China is too severe. According to the mechanism of comparative advantage, attraction of living in urban area is obvious to farmers.

59.4.1.4 Industry Development Status

According to the data in Table 59.3, the size of the economy in the Southwest China is relatively small in comparing to for example Yangtze River Delta. The economic development in Southwest China has a weak foundation. Therefore, the contribution of the town's economy needs to be improved.

Table 59.3 Basic information of small towns in southwestern China

Category	Southwest China	Yangtze River Delta
The number of towns	3356	1457
The number of industrial enterprises (million)	17.43	95.47
Average towns of construction investment (million)	2621.79	14816.15
Average towns of financial funds (million)	296.83	3156.37
Average towns household population (people)	6009	16,081
Towns the average permanent population	870	7244
Household population/permanent residents population	6.91	2.22

Source China Yearbook of Town Survey (2012) and China Urban-Rural construction Statistical Yearbook (2014)

59.4.2 System Status

59.4.2.1 Financial Management

The financial management system has its limitations in Southwest China. The local government in small towns undertook basic public services, environmental protection and urban construction and other large public affairs while lack of financial authority, resulting in low level of governance in town.

59.4.2.2 Social Security System

The social security system in southwest small towns is of limited coverage and is not enough with many weakness in institutional system.

59.4.2.3 Land System

The rural land system is not complete especially for the land transfer system, resulting in that the needs for agricultural modernization and the difficulty of providing large-scale of agricultural land co-exist.

59.4.2.4 Investment and Financing System

The investment on construction of small towns in southwest region depends only on the government for the investment and financing system is not mature while a large sum of money is needed for urbanization. The large scale of urbanization leads to a conflict between the demand for construction capital and the shortage of capital supply.

59.4.3 Resource Endowment Status

Southwest China has a very complex terrain structure with many mountains and there are many types of natural resources such as rivers, trees, pasture. It is a major region in our country with great resources to develop rubber, sugarcane, tea and other tropical economic crops. Southwest has many kinds of mineral resources that have great storage, and it has been found that there are 130 kinds of minerals and non-ferrous metals, accounting for about 40% of the national reserves. Although southwest has very rich natural resources, its exploitation and utilization are still in the low level due to the restricted conditions of the society, economy, technology, history and nature.

59.4.4 Population Status

According to the data in Table 59.3, the number of small towns in Southwest region is 2.3 times of the Yangtze River Delta region. However, the average permanent residents is far below than that in Yangtze River Delta. According to related research, small towns couldn't form specialization effect to bring scale effect unless their people reach 5 million people to form specialization effect to produce scale effect.

According to the data in table, the household population is 6.91 times as permanent residents in Southwest China is 6.91, showing that many people left hometown for other places. In other words, these local small towns have no ability to absorb population.

59.4.5 Social Status

According to the data in Table 59.4, the average financial funds and average investment for each town is lower than the Yangtze River Delta region. Table 59.4 shows that the level of infrastructure in Southwest is far below to that in the Yangtze River Delta. Therefore, a lack of funds in Southwest China cannot meet the needs of the construction for small towns. The special characteristics of mountainous region in Southwest China present the case that infrastructure especially for the traffic facilities are the key problem to urbanization development in Southwest China.

59.4.6 Ecologic Environment Status

There are many ecological issues in Southwest region of China, such as multi-mountain plateau, water scarcity and alpine desert, which tends to lead to natural disasters. Every year the increasing desertification of land occurred mainly in southwest region because of the destruction of vegetation, and drought. Meanwhile, as the industrial towns in Southwest China are mostly in extensive mode and people's environmental awareness is not strong, environment problems in small towns are more prominent.

Table 59.4 The development of infrastructure status

Category	Southwest China	Yangtze River Delta
Sewage treatment rate (%)	32.7	90.02
Road length (km)	29,653	62,971
Road Area (ha)	22,150	49,945
Use of natural gas population	851.3	2535.2
Green coverage rate (%)	8.32	20.33

Source China Urban-Rural construction Statistical Yearbook (2014)

59.5 Driving Factors for Promoting Urbanization of Small Towns in Southwest China

Based on the driving factors of urbanization involved above and discussion of the development status of small towns in Southwest China, combined with the current national policy, the key driving factors of urbanization of small town in Southwest China will be identified in this section (Fig. 59.1).

59.5.1 Industrialization

Because small towns in southwest China are still in the early stages of industrialization, the further development of industry in these towns is still the most important strategy for economic growth. And the industrialization can absorb a large number of agricultural population from the first industry to engage in secondary and tertiary industries and change industry structure, thereby promoting the process of urbanization. In other words, industrialization is the basic driving factor of urbanization in the small towns in Southwest China.

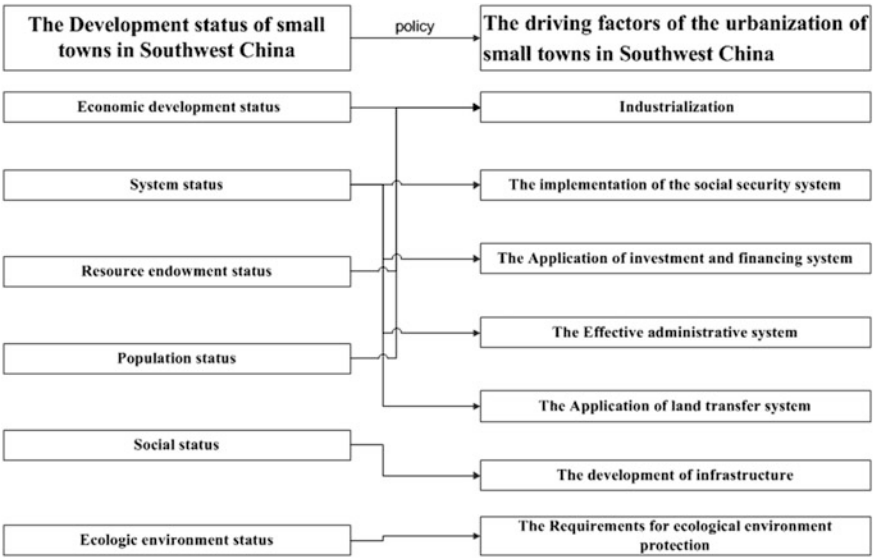


Fig. 59.1 Driving factors for promoting urbanization of small towns in Southwest China

59.5.2 The Implementation of the Social Security System

Currently, the social security system of small towns in southwest region is not perfect. And the Eighteenth session of the Third Plenary in China proposed to accelerate the reform and innovation in the field of social security. The implementation of the policy will improve the social security system. The social security system can solve the worries of farmers thoroughly and accelerate the gradient transfer of population to promote concentration of the rural population in small towns. At the same time, improving the social security system could seize the core issues of urbanization in small towns. "human-oriented urbanization" can lead the urbanization with good quality and efficiency. So social security system is the core driving factor of urbanization of the small towns in Southwest.

59.5.3 The Application of Investment and Financing System

Due to weak financial power and incomplete investment and financing system of the small towns in southwest region, the increasing demand for funds for construction of small towns cannot be met. At present, China has adopted a series of financial mechanism, such as PPP, to appeal the social capital to access to the construction industry in small towns legitimately. The urbanization of the small towns will be improved because the application of the investment and financing system could provide sufficient funds for the construction of small towns to improve its main function and its absorptive capacity. Therefore, the investment and financing system are driving factors for small towns in the Southwest region.

59.5.4 The Effective Administrative System

The financing authority and the governance in the small towns in Southwest area are separate. Currently, the small towns in the southwest region are undergoing to implement power expansion of strong policy for expanding the town economic and social management authority at town level. And effective administrative system are able to improve market efficiency and social justice, and finally enhance the quality and efficiency of the urbanization, which is the driving factor of small towns in the southwest region.

59.5.5 The Application of Land Transfer System

The land transfer system in Southwest China is not intact. The State Council promulgated ‘the policy for guiding the orderly circulation of rural land management rights and developing appropriate scale management in agriculture’ to further improve the land transfer system in 2016. The application of land transfer system can change the farmers’ dependency on the land, and promote the scale management and the intensive use of the rural land to promote the efficiency of agricultural production and farmers’ living standards. Thereby land transfer system provides convenience and creates conditions for transferring rural surplus labor from village to towns, which are the driving factors of small towns in the southwest region.

59.5.6 The Development of Infrastructure

The infrastructure development in small towns in southwest China cannot meet the demand. It will be promoted in line with improvement of investment and financing system and implementing two national development strategies, namely, the strategy of Yangtze River Economic Belt and The Belt and Road strategy. Infrastructure could meet the requirements of the quality life of the people and is the key point to ensure that the main function of the small towns can perform well. The promotion for infrastructure is an important influence factor to attract external investments. Therefore, effective infrastructure will enhance the ability of attraction and radiation of small towns to promote the process of their urbanization.

59.5.7 The Requirements for Ecological Environment Protection

The ecology condition of the small towns in Southwest China is vulnerable and the problems of environment pollution are serious. And ‘the New National Urbanization Plan’ (2014–2020) is designed to implement the most stringent laws of ecological and environmental protection for towns. The implementation of these new policies can enhance the development quality, improve the ecological environment capacity, and meet the people’s increasing requirements on life quality in small towns. This way can enhance the absorptive capacity of small towns to promote healthy and sustainable development.

59.6 Conclusion

There are many driving factors to urbanization in small towns in southwest China. Driving factors to urbanization of small towns in southwest China are identified in this paper, include industrialization, the implementation of the social security system, the application of the investment and financing system, the effective administrative system, the application of the land transfer system, the development of infrastructure and requirements for ecological environment protection. The relevant parties can take measure to promote the influence of these driving factors to ensure the health and sustainability of urbanization in small towns. The factors identified in this paper need further study through case studies to testify their effectiveness and how to define an effective way of urbanization through understanding these factors.

Acknowledges This research was supported by a grant from the General Project of National Social Science Foundation of China (No. 15BJY038).

References

Brown AA, Neuberger E (1997) Internal migration: a comparative perspective. Academic Press

Chen L (2005) The dynamic mechanism of urbanization-from the perspective transfer and development of industrial structure. Mod Econ Res 1:10–15

Chonglan Fu (2003) The small town theory. Shanxi Economic Publishing House, Taiyuan

Fengxuan Xue, Chun Yang (1997) Foreign capital: a new impetus to urbanization in developing countries: a case study of the Pearl River Delta. J Geogr 03:193–206

Fu C (2003) China's urban development report. China Social Sciences Press

Juan Huang, Feng Shang, Pengfei Lei (2011) Research on the impact of FDI on the level of urbanization in China: Based on the data of 21 cities in 2003 to 2007. On Econ Probl 04:44–47

Li S, Sui G (2016) Study on the dynamic mechanism of the development of small towns in Yantai city. J Ludong Univ Seventeenth

Liu Z (1999) World urbanization process and its mechanism. World Econ 12:36–42

Marshall S (1964) The principle of economics, Zhu Zhitai Ze, The Commercial Press, 1964 edition

Pei Y (1998) Chinese rural-urban transformation and the coordinated development of [M]. Beijing: Science Press

Shubin Z, Quanhong Z (2009) Development economics. Wuhan University of Technology press, Wuhan

Wang D, Liu T, Wang X, et al. (2003) Transition and development of industry: intermediary impetus of urbanization. Res Agric Modernization

Weiwei T(2003) Using information technology to promote urbanization of Jiangsu City. Mod Econ Res 1:23–25

Yong-Zhong LU, Chen BC (2005) A study on mechanism of rapid urbanization of China. Econ Geogr

Yuemin N (1998) New urbanization process-Chinese urbanization dynamic mechanism and characteristics study in the 1990. J Geogr 5:470–477

Zhang P (2001) Development economics course. Beijing: Economic Science Press

Zongping Cao (2009) Cost analysis and path selection of rural surplus labor force transfer. Shandong Soc Sci 04:74–77

Zuofeng D (2001) City informatization of. Soc Sci Res 04:34–36

Chapter 60
Estimating the Walking Accessibility Premiums

Linchuan Yang

60.1 Instructions

In recent years, the rapid economic growth and acceleration of urbanization in China have fuelled a considerable expansion in the ownership and use of private automobiles. However, private automobiles have been identified as a crucial cause of a series of vexing contemporary problems (Ewing and Cervero 2010), including but not limited to, traffic congestion, accidents, energy crises, urban sprawl, noise pollution, environmental degradation, reduction in urban life quality, colonization of public space, greenhouse gas and global warming.

Traffic congestion is routine irritations of urban lives in almost all rapidly growing cities in China, predominately caused by automobile-oriented development pattern. It has been regarded as a major impediment to the achievement of economic goals in a host of populous cities, so it receives growing attention of scholars, policy-makers, and researchers. Traffic congestion refers to a stagnant or smoothly crawling traffic phenomenon when traffic demand exceeds available flow capacity of roads, resulting in the temporary overloading of road networks, frequent time delay and long travel time. It is characterized by slow driving speed, high vehicle density, low traffic flow and increased vehicular queue. As expected, it has a number of negative impacts on both urban systems and individuals. For urban systems, it is not eco-friendly because it causes odor annoyance, yields local air pollution, increases carbon dioxide emissions, and therefore lowers life quality. Moreover, due to its unpredictability, unstable travel time reduces the operational efficiency of urban systems. For individuals, it prolongs travel time of drivers and passengers, causes frequent delays, and reduces regional economic health. In America, traffic congestion even becomes an incentive for a growing number of

L. Yang (✉)
Department of Real Estate and Construction, Faculty of Architecture,
The University of Hong Kong, Pok Fu Lam, Hong Kong, China
e-mail: yanglc0125@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_60

residents to seek out residences near transit in the quest for less stressful commutes. Hence, transportation is an indispensable dimension of urban sustainability, and a must from a long-term perspective, owing to its integrated and lasting impacts on economic, environmental, social and physical conditions.

Compact development pattern is nearly universally perceived as a critical paradigm of urban design and development now. It is characterized by organizing human activities in compact communities, providing reliable transit to employment and placing urban services within a short distance from home (Condon and Miller 2009). Currently, shaping travel demand and developing an accessible, high-capacity and environment-friendly transport system is perceived as an effective approach to solving a series of vexing contemporary problems. Indeed, reducing the number of motorized trips (trip degeneration), increasing the share of non-motorized (i.e., walking or cycling) trips and decreasing vehicle travel distances and increasing vehicle occupancy levels of the motorized trips are regarded as three well-known transportation objectives (Cervero and Kockelman 1997).

Travel demand is a derived demand as trips are made and distributed on the basis of the desire to reach places [e.g., shopping centers, office buildings] (Cervero and Kockelman 1997). In other words, travel is derived from activity participation. Therefore, studying the journey itself solely seems to be of secondary importance. Instead, linking transportation to what people do (or why people make trips) is worth more exploring. The main purposes of ordinary trips can be divided into two parts: commuting (employment) and utilizing urban services (e.g., education, healthcare, retail). Predominately in an effort to decrease the motorized travel demand, a myriad of geographers, economists, and urban planners have conducted numerous studies on commuting which connects people's homes and job locations. The concept of the co-location of population and employment is usually called jobs-housing balance (Loo and Chow 2011). It reflects the spatial relationship between the number of jobs and housing units within a given geographical area (e.g., census tract), and becomes a major urban planning and public policy issue which has gained extensive popularity and received apparent acceptance (Giuliano 1991).

Walking is a critical travel mode, especially for short trips. Walking is helpful to individuals and the community as it increases fitness and health, promotes social participation and decreases societal costs (Whelan et al. 2006). Furthermore, it is important for getting to local facilities and services and accessing transit (Banister and Bowling 2004). "[I]mproving walkability may be an effective solution for mitigating congestion, promoting environmental conservation, encouraging physical activity, reducing obesity, cardiovascular disease and diabetes, and boosting community livability" (Guo and Loo 2013, p. 124). Two prerequisites of enhancing walkability and encouraging residents' walking activities are (1) safe and continuous walking facilities (for ensuring "How to walk" from the physical perspective); (2) good functional configuration for realizing goals of walking [for ensuring "Why to walk" from the functional perspective] (Wang et al. 2013). Good functional configuration for realizing goals of walking, means locating a variety of trip destinations (activities) in the walk-in catchment area of a property (Wang et al. 2013).

However, walking is a non-motorized travel mode, and can only apply to short trips due to the limitations of pedestrians' physical strength and mental endurance (Wang et al. 2013). Thus, for a destination which is too far away from the origin (beyond an acceptable walking time/distance), people are less likely to walk. Indeed, it is impractical for many residents to get desirable jobs in the walk-in catchment areas of their homes. Actually, most scholars conducted jobs-housing studies at the scale of census tract or traffic analysis zone instead of walk-in catchment area. Therefore, at the scale of walk-in catchment area, mixing housing with urban services has a greater practical significance than mixing housing with jobs (jobs-housing balance) for increasing the utility of walking, promoting walking activities and reducing the motorized travel demand (Wang et al. 2013).

Accessibility is a well-known concept in a series of fields such as transportation, geography, and urban planning and design. Generally, it refers to the potential of opportunities for interaction (Hansen 1959). Walking accessibility, the ease to reach essential destinations in the walk-in catchment area of a property, may affect housing prices as good walking accessibility seems to be critical from the perspective of mobility enhancement. To date, the estimation of the value premiums offered by walking accessibility has been rarely studied. Yang et al. (2016) attempted to fill this research gap. However, it measures the walk-in catchment area merely by a circle with a 700-m radius. The radius's length is calculated by the proportion of walking distance threshold (900 m) to road curve coefficient (1.1–1.4). It is the virtual (instead of actual) representation of walk-in catchment area. Moreover, they draw conclusions by only one pre-specified (semi-log) hedonic price model. Animated by this, this paper decides to make two improvements: (1) generating realistic walk-in catchment areas by conducting a "Network Analysis" based on real-life road networks; (2) using a set of functional forms to gain confidence in the performance of key variables of primary interest. The main contributions of this paper include: (1) adding an empirical study to the relatively limited studies in urban China about the valuations of walking accessibility; (2) comparing the performances of a pre-specified hedonic price model as well as Box-Cox regression models for the studied problem.

The remainder of this paper proceeds as follows. Section 2 introduces hedonic price model and Box-Cox transformation; Sect. 3 describes data and variables; Sect. 4 presents the results; Sect. 5 concludes the paper and points out the limitations.

60.2 Methodology

60.2.1 Hedonic Price Model

It is very difficult to directly evaluate the value of walking accessibility simply based on the traditional economics approach. The hedonic technique is a celebrated tool to estimate the implicit prices for attributes (Freeman III et al. 2014). Hedonic price theory assumes that property prices can be decomposed into the component prices of a bundle of attributes (Rosen 1974). Hedonic prices are the implicit values of the attributes of a product, which can be estimated from a multiple regression equation. Although it has been criticized for quite a few shortcomings [e.g., assumptions, inability to capture off-site benefits, and difficulty in isolating marginal changes] (Brasington 2003), it provides a valuable tool for explaining housing prices in terms of its own characteristics.

60.2.2 Box-Cox Transformation

Box-Cox estimation, a typical nonlinear regression technique, is popular in hedonic studies as it can produce data-specific model specifications (Andersson et al. 2010). Its core philosophy is "let the data speak for themselves". It intends to obtain the "best-fitting" model with the highest goodness-of-fit. Box-Cox transformation can make the residuals more closely normal and less heteroskedastic, and detect non-linearity in model parameters. More detailed information on Box-Cox transformation can be found in (Hossain 2011). Box-Cox models have a host of functional forms, such as the simple left-hand-side model, simple both-side model and separate both-side model.

The simple left-hand-side Box-Cox model is as follows:

$$Y^{(\lambda)} = X\beta + \varepsilon$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, whereas $Y^{(\lambda)} = \ln Y$ for $\lambda = 0$.

The simple both-side Box-Cox model (same parameter for both sides) is as follows:

$$Y^{(\lambda)} = X^{(\lambda)}\beta + \varepsilon$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$, $X^{(\lambda)} = (X^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, whereas $Y^{(\lambda)} = \ln Y$, $X^{(\lambda)} = \ln X$ for $\lambda = 0$.

The most general and flexible functional form, the separate both-side Box-Cox model (different parameters for both sides), is as follows:

$$Y^{(\lambda)} = X^{(\theta)}\beta + \varepsilon$$

where $Y^{(\lambda)} = (Y^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$, $X^{(\theta)} = (X^{\theta} - 1)/\theta$ for $\theta \neq 0$, whereas $Y^{(\lambda)} = \ln Y$ for $\lambda = 0$, $X^{(\theta)} = \ln X$ for $\theta = 0$.

60.3 Data and Variables

60.3.1 Data

The study area is Xiamen Island, the central city of Xiamen. Commonly known as "sea garden", Xiamen is one of the major cities in China and located on the southeast coast of China and west coast of Taiwan Strait. Xiamen has a permanent population of 3.86 million with a total administrative area of 1699.39 km^2 (Xiamen Statistics Bureau 2017). More detailed information on Xiamen can be found in Tang et al. (2013). There are very few newly completed housings in the highly-developed Xiamen Island. Data were collected from soufang (http://xm.fang.com/), a well-known real estate agency website in China. A total of 1840 second-hand housing units in 380 multi- or high-story residential districts were randomly sampled in March 2015. To collect the data in a narrow time window effectively ensures minimal seasonal fluctuations in the real estate market. This guarantees the validity and reliability of data. Thus, a cross-sectional analytical approach can be used.

60.3.2 Variables

The dependent variable is the natural logarithm of the asking price of a house (unit: 10^4 RMB). Table 60.1 shows the definitions and descriptive statistics of independent variables. The potentially contributory destinations concerned are education facilities, hospitals and local shopping centers. It should be noted that high-quality schools (instead of normal schools) are chosen to represent education facilities in order to differentiate good and normal schools because as Yang et al. (2015, 2018) suggested, no distinction between "good" and "normal" schools may lead to biased estimates. The reason is that Xiamen Island is a relatively developed area with very dense urban services and amenities.

In accounting for the value premiums offered by walking accessibility, potential confounders like a property's size, age, local environment and distance from a series of potentially contributory geographical elements, are controlled for. As shown in Table 60.1, the first nine variables are control variables, which are theoretically important variables that need to be statistically controlled for. The latter ten variables are quantified under the platform of GIS.

Table 60.1 Variable definitions and descriptive statistics

Variables	Description	Expected sign	Mean	Standard deviation
Area	Floor area (m^2)	+	111.29	44.96
Age	2015 minus occupation permit year (number of years)	–	11.49	4.97
Local environment	Environment quality of residential districts, rated on a 5-point Likert item from "very bad" to "very good"	+	3.22	0.97
Distance to city center	Euclidean distance to Zhongshan Road (city center) (km)	–	5.99	2.82
Distance to sea	Euclidean distance to sea (km)	–	2.61	1.47
Distance to lakes	Euclidean distance to lakes (km)	–	1.10	0.73
Distance to BRT	Euclidean distance to the nearest BRT station (km)	–	1.67	1.18
Number of bus stops	Number of bus stops within 500 m of the property	+	7.17	3.60
Number of bus routes	Number of bus routes within 500 m of the property	+	24.94	14.00
Primary school	Number of provincial-level demonstration elementary schools in the walk-in catchment area (within 900 m)	+	0.13	0.41
High school	Number of key high schools in the walk-in catchment area	+	0.50	0.65
Hospital	Number of class 2A and 3A comprehensive hospitals in the walk-in catchment area	?	0.59	0.89
Shopping center	Number of local shopping centers in the walk-in catchment area	+	1.67	2.67

Note: + and − means increasing and decreasing effects on the housing prices respectively; ? indicates an unknown sign

60.4 Results

The semi-log functional form has many favourable properties, and it has appeared in numerous practical applications. The coefficients give the implicit price of the characteristics in natural logarithm terms. It is used in this study as the pre-specified functional form.

A piece of Data Analysis and Statistical Software, STATA, was employed, using the Ordinary Least Squares (OLS) method to calculate the coefficient associated with each variable. The results are revealed in Table 60.2. Model fit is satisfactory: this model can explain 83.2% of the variations in housing prices. The signs of all

Table 60.2 Results of a pre-specified functional form (semi-log)

Variables	Unstandardized coefficient	Standardized coefficient	t-value	VIF
Area	0.009[a]	0.758	72.04	1.21
Age	−0.014[a]	−0.127	−11.70	1.29
Local environment	0.103[a]	0.181	12.42	2.33
Distance to city center	−0.025[a]	−0.128	−9.56	1.96
Distance to sea	−0.021[a]	−0.056	−4.53	1.69
Distance to lakes	−0.014[c]	−0.018	−1.69	1.29
Distance to BRT	−0.064[a]	−0.138	−11.96	1.46
Number of bus stops	0.004[b]	0.025	2.03	1.72
Number of bus routes	0.001[c]	0.032	1.93	2.95
Primary school	0.044[a]	0.033	2.82	1.47
High school	0.024[a]	0.028	2.79	1.13
Hospital	−0.031[a]	−0.050	−4.25	1.49
Shopping center	0.005[c]	0.022	1.74	1.77
Constant	4.613[a]		98.55	
Performance statistics				
Adjusted R^2	0.832			

[a]Parameters are significant at the 1% level
[b]Parameters are significant at the 5% level
[c]Parameters are significant at the 10% level

variables are consistent with our expectations. Variance Inflation Factor (VIF) is very small (far less than 10) for all independent variables. Therefore, multicollinearity is not a concern.

All independent variables are significant at the 10% level, and nine out of thirteen variables considered are significant at the 1% level. With regard to control variables, as expected, houses with larger floor area, better local environment and nearer to more bus stops and routes, exhibit higher prices. This is indicated by positive signs of the corresponding coefficients. The coefficients associated with other variables are negative, implying that houses at the younger age, closer to the sea, lakes, city center, BRT stations, exhibit higher values.

A comparison of standardized coefficients suggests that floor area adds most to housing prices. Each additional square meter of floor area is associated with a 0.9% increase in the property value. In addition, in determining housing prices, the city center (Zhongshan Road) has a greater effect than sea and lakes. This agrees with Alonso's land-rent theory. The negative signs suggest that as the distance from city center (or sea, lakes) decreases, the property value increases, all else being equal. Moreover, the coefficient associated with Distance to BRT is −0.064, indicating that proximity to BRT stations adds housing value: residential properties closer to a BRT station tend to exhibit higher values, relative to those further away, all else being equal. An increase of one kilometer in distance from BRT stations would decrease housing values by 6.4%, all else being equal. It reveals that proximity to BRT stations is currently capitalized into residential property values. Furthermore, the coefficient associated with Number of bus stops and Number of bus routes are 0.004 and 0.001. This shows that the number of bus stops and routes tends to be associated with housing prices: for every bus stop and route within 500 meters from a property, housing prices were 0.4% and 0.1% higher, respectively, all else held equal.

Three Box-Cox functions are then developed, and the results are shown in Table 60.3. All function forms represent relatively simple applications of the Box-Cox transformation: the simple left-hand-side Box-Cox model; the simple both-side Box-Cox model; the separate both-side Box-Cox model. Table 60.3 also reveals that the most flexible form, the separate both-side Box-Cox model, outperforms other two Box-Cox models.

The estimation and interpretation of the coefficients associated with four walking accessibility measures are of primary interest here. Walking accessibility measures are highly robust and significant in all specifications as revealed in Tables 60.2 and 60.3. Therefore, we can conclude that walking accessibility to four types of destination concerned, has been found to be associated with housing prices. Indicated by the signs of their coefficients, the residential property whose walk-in catchment area locates more high-quality primary schools, high schools, local shopping centers, are more expensive. In contrast, better walking accessibility to high-level comprehensive hospitals is associated with lower housing prices. A possible explantation is that different age groups have differing healthcare needs, which affects location choices. Generally, seniors have higher healthcare needs, go to hospital more frequently, and tend to live closer to hospitals for convenience therefore (Yang 2016; Szeto et al. 2017). In contrast, young adults seldom go to hospital, so they even tend to live far away from hospitals due to nuisance effects of hospitals (e.g., noise, air pollution), especially high-level comprehensive hospitals (Yang et al. 2016).

The following interpretation of the value premiums stemming from walking accessibility is based on the semi-log hedonic price model developed. The coefficients associated with Primary school, High school, Shopping center are 0.044, 0.024, 0.005, respectively. This indicates that for every high-quality primary school, high school and local shopping center in the walk-in catchment area of a property, housing prices are 4.4%, 2.4%, and 0.5% higher, all else held equal. The coefficients associated with Hospital are −0.031, which indicates that for every class 2A and 3A comprehensive hospital in the walk-in catchment area of a property, housing prices are 3.1% lower, all else held equal.

Table 60.3 Results of three Box-Cox transformed functional forms

Variables	Simple LHS Box-Cox model: coefficient (t-value)	Simple both-side Box-Cox model: coefficient (t-value)	Separate both-side Box-Cox model: coefficient (t-value)
Area	0.025[a] (74.88)	0.989[a] (83.84)	0.506[a] (84.21)
Age	−0.041[a] (−13.37)	−0.134[a] (−16.45)	−0.100[a] (−16.26)
Local environment	0.267[a] (12.62)	0.191[a] (10.68)	0.166[a] (10.48)
Distance to city center	−0.070[a] (−10.48)	−0.076[a] (−7.75)	−0.071[a] (−8.47)
Distance to sea	−0.054[a] (−4.49)	−0.018[a] (−3.10)	−0.015[a] (−2.60)
Distance to lakes	−0.040[c] (−1.88)	−0.025[a] (−5.06)	−0.023[a] (−4.27)
Distance to BRT	−0.164[a] (−11.88)	−0.042[a] (−9.44)	−0.047[a] (−9.77)
Number of bus stops	0.012[a] (2.34)	0.003[d] (0.25)	0.004[d] (0.51)
Number of bus routes	0.002[d] (1.47)	0.008[d] (0.84)	0.003[d] (0.48)
Primary school	0.126[a] (3.12)	0.061[a] (5.56)	0.057[a] (5.05)
High school	0.074[a] (3.31)	0.012[a] (2.00)	0.014[b] (2.23)
Hospital	−0.082[a] (−4.43)	−0.023[b] (−4.29)	−0.025[a] (−4.68)
Shopping center	0.011[c] (1.70)	0.005[a] (2.87)	0.005[a] (2.81)
Constant	6.994[a] (58.31)	0.969[a] (15.74)	2.115[a] (40.49)
Left-hand side parameter	0.174[a] (9.62)		−0.039[c] (−1.85)
Right-hand side parameter			0.109[a] (2.64)
Both-hand side parameter		−0.043[b] (−2.02)	
Performance statistics			
Adjusted R^2	0.843	0.867	0.868

[a]Parameters are significant at the 1% level
[b]Parameters are significant at the 5% level
[c]Parameters are significant at the 10% level
[d]Parameters are not significant at the 10% level

60.5 Conclusions

Based on 1840 observations in 380 multi- or high-story residential complexes in Xiamen Island, China, the paper develops a semi-log hedonic price model and three Box-Cox transformed models to empirically estimate the value premiums stemming from walking accessibility. It finds the followings: the externality of urban services have been capitalized into housing prices; walking accessibility to education and commercial facilities have a positive effect on housing prices; walking accessibility to comprehensive hospitals negatively affects housing prices.

There are several limitations that merit further research. On the one hand, this study did not take account of the spatial autocorrelation of the data. Due to the presence of spatial autocorrelation, traditional hedonic price model which fails to account for this, is not as acceptable as before. More sophisticated spatial econometrics methods (e.g., spatial lag model, spatial error model, and spatial Durbin model) can be used to take account of this (Krause and Bitter 2012). On the other hand, due to the absence of rich data, some factors like walking environment evaluation (from the physical perspective), floor area ratio (FAR) and jobs-housing ratio, were not included in our model. We suspect that adding them to the model could enhance the accountability of the model.

References

Andersson DE, Shyr OF, Fu J (2010) Does high-speed rail accessibility influence residential property prices? hedonic estimates from Southern Taiwan. J Transp Geogr 18(1):166–174
Banister D, Bowling A (2004) Quality of life for the elderly: the transport dimension. Transp Policy 11(2):105–115
Brasington DM (2003) The supply of public school quality. Econ Educ Rev 22(4):367–377
Cervero R, Kockelman K (1997) Travel demand and the 3Ds: density, diversity, and design. Transp Res Part D: Transp Environ 2(3):199–219
Condon PM, Cavens D, Miller N (2009) Urban planning tools for climate change mitigation. Lincoln Institute of Land Policy, Cambridge, MA
Ewing R, Cervero R (2010) Travel and the built environment: a meta-analysis. J Am Plan Assoc 76(3):265–294
Freeman III AM, Herriges JA, Kling CL (2014) The measurement of environmental and resource values: theory and methods. Routledge
Giuliano G (1991) Is jobs-housing balance a transportation issue? Transp Res Board 1305: 305–312
Guo Z, Loo BP (2013) Pedestrian environment and route choice: evidence from New York City and Hong Kong. J Transp Geogr 28:124–136
Hansen WG (1959) How accessibility shapes land Use. J Am Inst Planners 25(2):73–76
Hossain MZ (2011) The use of box-cox transformation technique in economic and statistical analyses. J Emerg Trends Econ Manag Sci 2(1):32–39
Krause AL, Bitter C (2012) Spatial econometrics, land values and sustainability: trends in real estate valuation research. Cities 29:S19–S25
Loo BP, Chow AS (2011) Jobs-housing balance in an era of population decentralization: an analytical framework and a case study. J Transp Geogr 19(4):552–562
Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. J Polit Econ 82(1):34–55
Szeto WY, Yang L, Wong RCP, Li YC, Wong SC (2017) Spatio-temporal travel characteristics of the elderly in an ageing society. Travel Behav Soc 9:10–20
Tang L, Zhao Y, Yin K, Zhao J (2013) Xiamen. Cities 31:615–624
Wang H, Huang J, Li Y, Yan X, Xu W (2013) Evaluating and mapping the walking accessibility, bus availability and car dependence in urban space: a case study of Xiamen, China. Acta Geogr Sinica 68 (4):477–490 (in Chinese)
Whelan M, Langford J, Oxley J, Koppel S, Charlton J (2006) The elderly and mobility: a review of the literature. Monash University Accident Research Centre
Xiamen Statistics Bureau (2017) Xiamen Statistical Yearbook 2017

Yang L (2016) The mobility of the elderly in Hong Kong: policy implications. MPhil thesis, University of Hong Kong, Pokfulam, Hong Kong, China

Yang L, Chang Y, Ma Q, Gong Q (2015) The impact of public services on housing prices: a case study of Xiamen Island, China. Urban Rural Plann (2):32–41 (in Chinese)

Yang L, Wang B, Zhang Y, Ye Z, Wang Y, Li P (2018) Willing to pay more for high-quality schools? A hedonic pricing and propensity score matching approach. Int Rev Spatial Plan Sustain Develop 6(1)

Yang L, Zhang X, Hong S, Lin H, Cheng G (2016) The impact of walking accessibility to public services on housing prices: based on the cumulative opportunity measure. South China J Econ (1):57–70 (in Chinese)

Chapter 61
Evaluating the Critical Risk Factors of Reconstruction Urban Renewal Projects: The Developer's Perspective in China

W.D. Wu, G.W. Liu, Z.H. Cai and S.N. Zheng

61.1 Introduction

Industrial transformation and upgrading and shortage of land resources are two serious problems which development of large cities in China have to face in recent years (Zhu et al. 2015). Urban construction land in major cities such as Shenzhen, Shanghai and Beijing has almost run out. Under conditions of severe land shortage, the government is continually searching for a means of providing enough land to meet the market demands and facilitate current and future infrastructure needs. Urban renewal will serve as an important approach to sustainable urban development, therefore urban renewal will become an important direction of the development of Chinese cities.

Since the 21st century, urban renewal has played an important effect on China's urban development,such as enhancing the city image, promoting urban economic development and improving the living environment for citizens. But meanwhile, various kinds of social contradictions caused by urban renewal have become a hot issue that the whole society concerns about (Tian 2009). In particular, residential and commercial types reconstruction urban renewal will generally face social phenomena such as group incidents and half-way project in the implementation

W.D. Wu (✉) · G.W. Liu · S.N. Zheng
Faculty of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: wendongwu@cqu.edu.cn

G.W. Liu
e-mail: gwliu@cqu.edu.cn

S.N. Zheng
e-mail: sena.zheng@yahoo.com

Z.H. Cai
School of Civil Engineering, Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_61

process. According to the Shenzhen City urban renewal industry report, from 2009 to 2013 there were 340 reconstruction urban renewal projects approved, but only 9% of them have obtained development of land from original landowners. Thus, urban renewal projects are more complex than general construction projects, especially they have high levels of complexity and uncertainty. Ignoring risks control and management will result in project failure, not only will the developer suffer a great economic loss, but it may also threat the safety and stability of society. Thus, risk assessment for reconstruction urban renewal projects is particularly important.

61.2 Literature Review

In recent years, urban renewal projects risk areas caught attention of foreign scholars gradually (Kuo 2011; Khumpaisal et al. 2012; Ayres and Thomas 1998; Yu and Lee 2012). Kuo (2011) explored the risks of business urban renewal projects in Taiwan and established a hierarchical risk structure of urban renewal business projects in his study. Sukulpat (2012) stated that risks cause crucial adversities to the progression and profits of urban regeneration projects. In his study he commenced with an introduction to the risks involved in urban regeneration projects, followed by an application of ANP as a risk assessment tool (Khumpaisal et al. 2012). Ayres (1998) selected five projects in the West Midlands and studied the impact of urban renewal on the surrounding environmental risk, and the results showed that urban renewal will significantly increase the risk to the surrounding environment (Ayres and Thomas 1998). Yu and Lee (2012) presented urban regeneration projects are highly complex and uncertain is that there are various stakeholders. Additionally, the relationships among them are very complex so that the success of urban renewal projects depend on how successful coordination of conflict among stakeholders. Although the research on the urban renewal projects risk abroad is earlier than in China, but the national conditions, stage of development of our country and abroad there are a big difference, therefore the foreign research on China's urban renewal projects risk management guidance weak.

Several Chinese studies had discussed the urban renewal projects risk management (Liu and Xu 2005; Gu and Zhang 2010; Xia and Song 2007; Cai and Sai 2014). Liu and Xu (2005) conducted a qualitative study on the urban renewal risk stated that urban renewal projects risk can be summarized into the following six dimensions: Project location risk, demolition and relocation risk, capital risk, urban planning risk, policy risk. Gu and Zhang (2010) used fuzzy comprehensive evaluation method to evaluate urban renewal projects risk. Xia and Song (2007) presented that urban renewal projects likely to generate conflict of stakeholders, thus Social risk is higher than those of general construction projects. Cai and Sai (2014) state that urban renewal projects risk can be summarized into the following three dimensions: government administration risk, external risks, internal risk.

However, these studies were limited to qualitative descriptions the urban renewal projects risk and lacked quantitative research and the actual survey to collect views of the practitioners. Therefore, a quantitative study on urban renewal projects risk is necessary. This paper aims to extract critical risk factors of reconstruction urban renewal projects by using the method of questionnaire and factor analysis to build the risk evaluation indexes system of reconstruction urban renewal projects, which could help developers to enhance the performance of risk management for better chance to success.

61.3 Methodology

Literature review and in-depth interviews were used in this study to identify preliminary risk factors of reconstruction urban renewal projects, and a questionnaire survey as a method to collection data. SPSS 17.0 software was used in this study for factorial analysis to identify key risk factors for urban renewal projects. Figure 61.1 depicts the implementation procedure, with three phases.

61.3.1 Identification of Risk Factors of Reconstruction Urban Renewal Projects

The selection of preliminary factors in this study included two steps: (1) literature review and (2) expert interview. First, this study identified the preliminary risk factors in urban renewal projects based on eighteen papers. Second, interviewed

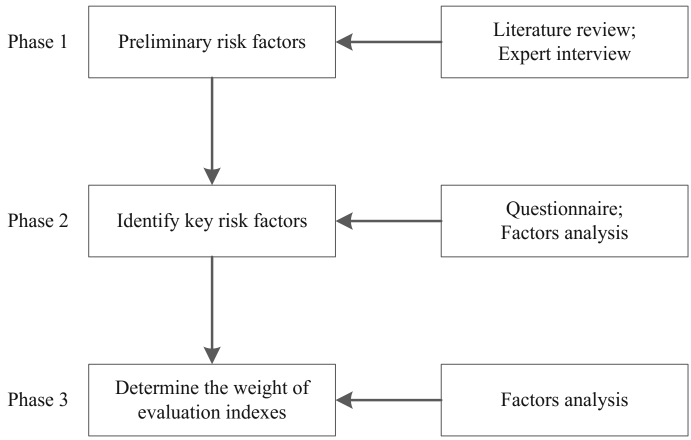


Fig. 61.1 Outline of reconstruction urban renewal projects risk evaluation system

Table 61.1 list of preliminary factors

Risk indicator	Risk indicator	Risk indicator
X1 Project location risk	X11 Project planning risk	X21 Interest rate risk
X2 Risk of urban planning	X12 Stakeholder conflict risk	X22 Landowner approval
X3 Regional development risk	X13 Project orientation risk	X23 Cultural risk
X4 Natural disaster risk	X14 Financing risk	X24 Environmental risks
X5 Contractual risk	X15 Land price risk	X25 Administrative approval risk
X6 demolition and relocation cost	X16 Construction cost	X26 Real estate policy risk
X7 Social conflicts risk	X17 Inflation risks	X27 Financial policy risk
X8 Competitive risks of enterprises	X18 Sale risks	X28 Urban renewal policy risk
X9 Management team of company	X19 Price risk	X29 Construction technology risks
X10 PM team's communication and coordination	X20 National economy risk	

with five industry experts to examine the rationality of the preliminary risk factors including developers and academics, each of them has at least five years of experience in urban renewal. They were asked to assess whether the preliminary list involved all possible urban renewal projects risk, considering the background of the urban renewal in Chinese, and to determine whether any factors needed to add or remove. Finally, 29 risk factors were retained in this study as the main content of questionnaire design (Table 61.1).

61.3.2 Data Collection

The opinions of property developers and experts in the urban renewal field were collected using a questionnaire survey. A five-point Likert scale was used in this research to ask the respondents to evaluate the importance of each risk to the success of reconstruction urban renewal project. In the questionnaire, 5 represented "Absolutely important", 4 represented "Strongly important", 3 represented "Fairly important", 2 represented "Weakly important", 1 represented "Equally important". A total of 200 questionnaires were sent through the mail and web questionnaire platform from October to December, 2015, 122 valid questionnaires were collected in the survey, accounting for effective rate of 61%. Of the total number of respondents, 56.56% were real estate executives, 12.30% were property consultants, 18.85% were academics, 12.35% were government officials and 68% had more than 5 years of experience in urban renewal.

Cronbach's Alpha was used to determine the reliability of the questionnaires. The value of Cronbach's Alpha which was higher than 0.6, indicating that questionnaires were reliable. The value of Cronbach's Alpha in this study was 0.858 which indicating that collected sample was reliable.

61.3.3 Factor Analysis Technique

Factor analysis is a series of methods used to find clusters of related variables; it is also a means of compressing a large number of factors into a smaller, easily understood framework (Norusis 2008). Therefore, factor analysis was used to identify the critical risk factors of reconstruction urban renewal projects in this study. Before using this method, various tests are required to measure whether the data suitable for factor analysis. Therefore, the tests of Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity are required before using factor analysis in this study.

The KMO statistic values are between 0 and 1. When KMO values closer to 0, means that the weaker the correlation between variables which indicates that the original variable is not suitable for factor analysis (Norusis 2008). By contrast, a value close to 1 indicates that the patterns of correlations are relatively compact and that FA would yield distinct and reliable factors (Field 2005). Kaiser (1970) presented that the values of KMO higher than 0.6 show that the sample is suitable for factor analysis.

61.4 Data Analysis

61.4.1 Result of Factor Analysis

This study used SPSS.17.0 software for data analysis. The result of Bartlett's sphericity test is 1080.124, with an associated significance level of 0.000, suggesting that the population correlation matrix is not an identity matrix. The results of KMO in this study is 0.690, which the values is greater than 0.6. The Results of two tests showed that samples of data is suitable for factor analysis.

Initial eigenvalues greater than 1 as the standard to extract the common factor in this study, a total of 6 six clusters were extracted and the total cumulative was 58.94% (Table 61.2). According to the cluster matrix after quarimax rotation (Table 61.3). The factor loading value greater than 0.49 as the standard to extract the critical factors in this study, therefore 22 critical factors were extracted and were divided into six clusters.

Table 61.3 indicates that Cluster F1, F2, F3 and F4 include four critical factors respectively while Cluster F5 and F6 include three critical factors. According to the

Table 61.2 Total variance explained for critical factors

Cluster	Initial eigenvalues		
	Total	% of variance	Cumulative %
F1	5.378	21.513	21.513
F2	2.835	11.341	32.854
F3	2.371	9.483	42.337
F4	1.408	5.630	47.968
F5	1.359	5.434	53.402
F6	1.160	4.642	58.044

Table 61.3 Cluster matrix after varimax rotation

Code	Factors	Factor loading					
		Cluster F1	Cluster F2	Cluster F3	Cluster F4	Cluster F5	Cluster F6
X6	Demolition and relocation cost	0.79					
X7	Social conflicts risk	0.83					
X12	Stakeholder conflict risk	0.62					
X16	Construction cost	0.59					
X23	Cultural risk		0.789				
X24	Environmental risks		0.685				
X25	Administrative approval risk		0.622				
X28	Urban renewal policy risk		0.809				
X1	Project location risk			0.653			
X3	Regional development risk			0.581			
X8	Competitive risks of enterprises			0.500			
X13	Project orientation risk			0.717			
X2	Risk of urban planning				0.660		
X14	Financing risk				0.751		
X15	Land price risk				0.494		
X22	Landowner approval				0.521		
X18	Sale risks					0.599	
X19	price risk					0.795	
X20	National economy risk					0.666	
X9	Management team of company						0.733
X10	PM team's communication and coordination						0.675
X11	Project planning risk						0.581

initial interpretation, these six clusters are associated with the project management and control risk, society and policy risk, development area risk, economic risk, market risk and enterprise management risk respectively. Therefore, the six clusters are renamed as: Cluster F1: Project management and control risk; Cluster F2: Society and policy risk; Cluster F3: Development area risk; Cluster F4: Economic risk; Cluster F5: Market risk; and Cluster F6: Enterprise management risk.

61.4.2 Determination of Index Weight

The reconstruction urban renewal projects risk evaluation indexes system in this study consists of 6 Second-level indexes (Clusters in Table 61.2) and 22 third-level indexes (Factors in Table 61.2). The higher the variance contribution of a common factor suggests that the common factor is more important. Hence the Secondary indicators weight can be obtained by normalizing the six common factors' variance contribution rate (Table 61.2). Third-level indexes in Second-level indexes weight can be determined by factor loading matrix (Table 61.2). The score coefficient of each factor indicates how important this indicator in the common factor it belongs to. Therefore, third-level indexes in Second-level indexes weight can be obtained by normalizing the all factor score coefficient in the common factor which they belong to. Third-level indexes weight can be obtained by multiplying third-level indexes in Second-level indexes weight and weight of Second-level indexes which this third-level indexes is located. Weight at all levels as shown in Table 61.4.

61.4.3 Findings and Discussion

61.4.3.1 Cluster F1: Project Management and Control Risk

There are four critical factors related to project management and control risk of reconstruction urban renewal projects in china in this cluster: (1) demolition and relocation cost, (2) social conflicts risk, (3) stakeholder conflict risk, (4) construction cost. Project management and control risk is the most important cluster of reconstruction urban renewal projects. The cluster accounts for 21.513% of the total variance explained of all factors (Table 61.2).

Furthermore demolition and relocation cost and social conflicts risk are the most important critical factors of project management and control risk Cluster. Social conflicts risk ranking first on the list of the ranking of third-level indexes weight indicates that it is the most important critical factor of urban renewal projects risk. Because reconstruction urban renewal projects involving building demolition has a very complex interests, if not handled properly it will cause social conflict. The risk of social conflict will directly lead to the project termination, not only causing enormous losses to the developers, also threating the safety and stability of society.

Table 61.4 Second-level indexes weight and third level indexes weight

Second-level indexes	Second-level indexes weight	Third-level indexes	Third-level indexes weight (%)	Ranking of third-level indexes weight
Project management and control risk	0.22	Demolition and relocation cost	6.16	2
		Social conflicts risk	6.38	1
		Stakeholder conflict risk	4.84	8
		Construction cost	4.62	11
Society and policy risk	0.20	Cultural risk	5.40	4
		Environmental risks	4.80	10
		Administrative approval risk	4.20	15
		Urban renewal policy risk	5.60	3
Development area risk	0.17	Project location risk	4.59	12
		Regional development risk	4.08	17
		Competitive risks of enterprises	3.40	21
		project orientation risk	4.93	7
Economic risk	0.16	Risk of urban planning	4.32	14
		Financing risk	4.95	6
		Land price risk	3.26	22
		Landowner approval	3.44	20
Market risk	0.13	Sale risks	3.77	18
		price risk	5.07	5
		National economy risk	4.16	16
Enterprise management risk	0.13	Management team of company	4.81	9
		PM team's communication and coordination	4.42	13
		Project planning risk	3.77	19

The term "nail house" refers to people who refuse to move away from demolition zones, usually because of a disagreement about compensation. "Nail House" is a very common phenomenon in the urban renewal in China. If "nail House" phenomenon occurs in urban renewal, urban renewal project will face huge compensation and construction period is forced to be extended. Therefore, demolition and relocation cost ranks second on the list of the ranking of third-level indexes weight.

61.4.3.2 Cluster F2: Society and Policy Risk

According to this cluster, there are four critical factors related to Society and policy risk of reconstruction urban renewal projects in china: (1) cultural risk, (2) environmental risks, (3) administrative approval risk, (4) urban renewal policy risk. The cluster accounts for 11.341% of the total variance explained of all factors (Table 61.2). Cultural risk and urban renewal policy risk are the most important critical factors of society and policy risk Cluster. Cultural risk refers to China's public for the city's culture has had a strong protection consciousness if urban renewal projects causing damage to monuments of the city and urban culture will suffer from strong public resistance. Thus cultural risk is ranked fourth on the list of the ranking of third-level indexes weight. Urban renewal policy risk is another critical factor of urban renewal projects risk, for the reason that now China has no law specifically on urban renewal and government urban renewal management system has not been established so that urban renewal policies change frequently. Instability of urban renewal policy can seriously affect the implementation of reconstruction urban renewal projects, Thus urban renewal policy risk is ranked third on the list of the ranking of third-level indexes weight.

61.4.3.3 Development Area Risk

There are four critical factors related to development area risk of reconstruction urban renewal projects in china in this cluster: (1) project location risk, (2) regional development risk, (3) competitive risk of enterprises, (4) project orientation risk. The cluster accounts for 9.483% of the total variance explained of all factors (Table 61.2). Project orientation risk is the most important critical factors in this cluster. Since the project types, target customers, quality orientation are not accurate, it will affect the project funds cannot be returned.

61.4.3.4 Economic Risk

There are four critical factors related to economic risk of reconstruction urban renewal projects in china in this cluster: (1) risk of urban planning, (2) financing risk, (3) land price risk, (4) landowner approval. Owing to urban renewal projects are usually located in the center of the city region which is a superior location, as it will bring high returns. The cluster accounts for 5.630% of the total variance explained of all factors (Table 61.2) showing that this cluster is lower than that of the previous three clusters. But there is still an important factor in economic risk cluster. Reconstruction of urban renewal projects with large investment and capital flow cycle is long, if you are unable to maintain continuity in the capital, the project can easily fail because of the funding break. Thus financing risk is ranked sixth on the list of the ranking of third-level indexes weight.

61.4.3.5 Market Risk

There are three critical factors related to market risk of urban renewal projects in china in this cluster: (1) sale risks, (2) price risk, (3) national economy risk. The cluster accounts for 5.434% of the total variance explained of all factors (Table 61.2). Reconstruction urban renewal project's development cycle is generally more than five years or a dozen years, affected by the economic situation and policy factors, so that the real estate prices are lower than developers' expectation that there is a high probability in the sales stage. As a result, price risk is ranked sixth on the list of the ranking of third level indexes weight.

61.4.3.6 Enterprise Management Risk

There are three critical factors related to Enterprise management risk of reconstruction urban renewal projects of china in this cluster: (1) management team of company, (2) PM team's communication and coordination, (3) project planning risk. The enterprise management risk cluster's importance is the lowest level of urban renewal projects risk which the total variance explained of all factors only 4.642%. After a long-time practice, enterprise has accumulated a wealth of experience in project management so that enterprise management risk is low.

61.5 Conclusions

On the perspective of developers, through literature review and experts interviews this paper had recognized 29 initial risk factors. Using the method of questionnaire and factor analysis to extract 22 critical factors and divide into six clusters: (1) project management and control risk; (2) society and policy risk; (3) development area risk; (4) economic risk; (5) market risk; and (6) enterprise management risk. This paper indicated that the risk of reconstruction urban renewal projects can be reflected by the 6 clusters.

This study also used the results obtained through factor analysis to confirm weight of the indexes to build the reconstruction urban renewal projects risk evaluation indexes system. The risk evaluation indexes system in this study consists of 6 Second-level indexes (Clusters in Table 61.2) and 22 third-level indexes (critical Factors in Table 61.2). The risk evaluation indexes system can reasonably evaluate the critical risks of reconstruction urban renewal projects, which can help developers to manage project risks effectively.

It should be noted that this study just used factor analysis to extract 22 critical factors to build the reconstruction urban renewal projects risk evaluation indexes system. Explore the underlying relationships among the 22 critical factors and select reconstruction urban renewal project case to demonstrate the effectiveness of the risk evaluation indexes system should be fully considered in the future research.

References

Ayres AD, Thomas MP (1998) Environmental risk perception and urban renewal in the West Midlands. J Environ 18(3):139–148

Cai JG, Sai YX (2014) An analysis of influencing of risk factors in shantytowns renovation project based on interpretative structural modeling. J Sci Technol Manag Res 34(6):240–244

Field A (2005) Discovering statistics using SPSS. Sage Publications Ltd

Gu JL, Zhang JK (2010) Risk management on urban retrofitting projects. J Eng Manag 24(1): 33–36

Kaiser H (1970) A second generation little jiffy. J Psychometr 35(4):401–405

Khumpaisal S, Chen Z, Mulliner E (2012) Applying the analytical risk assessment method for an urban regeneration project, In: Built environment research associate conference

Kuo YC, Ji NC (2011) Exploring risks for urban renewal projects. In: Isarc proceedings

Liu YF, Xu XW (2005) Risk identification of old city reconstruction project. J Urban Rural Dev 2:31–33

Norusis MJ (2008) SPSS16.0 advanced statistical procedures companion. Prentice Hall Press

Tian YP (2009) Old city reconstruction and reconstruction of urban social space-with Wuhan City as an example. Peking University Press (in Chinese)

Xia NK, Song HY (2007) Trains of thoughts and methods of study on risk issues for large scale urban development projects. J Urban Plann Forum 6:84–89

Yu JH, Lee CK (2012) A conflict-risk assessment model for urban regeneration projects using Fuzzy-FMEA. J KSCE J Civ Eng 16(7):1093–1103

Zhu YJ, Li H, Wang W (2015) Research on evolving characteristics and trend of urban renewal. J Urban Prob (9):30–35 (in Chinese)

Chapter 62
Evaluating the Effects of Alleviating Urban Traffic Congestion Using Real-Time Traffic Information on Mobile Devices

M.W. Hu, W.K. Huang and Y. Chen

62.1 Introduction

In recent years, the contradiction between the rapid growth of vehicle number and limited traffic infrastructure of urban roads are increasingly serious, which brings great pressure to the urban traffic and leads to many problems such as traffic congestion (Serdar et al. 2016). As a result, the travel time significantly increases, traffic accidents occur more frequently, and the air quality is declining as well (Huang et al. 2014; Ministry of Environmental Protection of the People's Republic of China 2016). These issues will cause huge economic loss to the society and restrict sustainable development of the city (Zhang 2011; Zhou 2012). As an effective approach to solving the urban traffic problems, the Intelligent Transportation Systems (ITS) improves the traffic system efficiency to a certain degree (Dimitrakopoulos and Demestichas 2012).

With the development of wireless internet, mobile devices and the application program of social network, traveler information apps have been widely used in ITS (Zhang et al. 2014). This kind of apps can be divided into electronic map, parking guidance, navigation, etc. (Intelligent Transportation Society of America 2015). For example, the most popular apps in China are: Baidu Map and Auto Navi Map (Liu et al. 2013). This kind of apps on mobile device can provide an amount of information to travelers at any time anywhere, then they can know the pre-trip or enroute condition of roads ahead. As a result, travelers can adjust their travel plan to

M.W. Hu (✉) · W.K. Huang · Y. Chen
College of Civil Engineering, Shenzhen University, Shenzhen 518060
Guangdong Province, China
e-mail: humw@szu.edu.cn

W.K. Huang
e-mail: hwk727@163.com

Y. Chen
e-mail: 294671663@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_62

increase the efficiency of travel, such as changing departure time, travel mode, and travel route and so on. Based on that, the capacity of highways can be utilized more efficiently and fuel consumption can be saved. In summary, the traffic benefits of traveler information apps is a key topic to be explored now and in the near future.

There is some research about the influence of traffic information on the urban traffic. However, most of them concentrated on traditional traffic information releasing approaches such as Internet websites, radio, television and variable message signs along the roads. These approaches are not good ways for travelers to acquire real-time traffic information during trips. Although the approachs of acquiring traffic information through apps on mobile devices were popularized and promoted in the past two or three years, there is little research on this kind of real-time information release mode.

By the multimethod modeling, traveler behavior model and traffic simulation model were integrated in the complex system simulation software AnyLogic. The agent-based model is built to simulate the traveler's diverse behavior under real-time traffic information. And the traffic simulation models the agents' behaviors into the network. This study focuses on the relationship of traveler's behaviors and traffic benefits, and can provide reference for urban traffic policy formulation.

62.2 Methods

62.2.1 Model Summary

A multimethod model consisting of traveler's behavior and traffic simulation was developed to analyze the performance of traveler information apps in the dynamic space-time scale. The architecture of multimethod model is shown in Fig. 62.1. First, we built traveler agent-based model considering the impact of traveler information on their behaviors. Then, a microscopic traffic simulation model was built to model the changes of trip production and attraction, traffic distribution, traffic model split and traffic assignment influenced by diverse travelers' behavior and collect data of each vehicle to evaluate the traffic benefits.

In this study, AnyLogic simulation platform was chosen to build the comprehensive model. AnyLogic adopts general framework for mapping a real world system to its model, supporting three modeling methods in any combinations, namely Agent-Based Modeling (ABM), Discrete Event Modeling (DEM) and System Dynamics (SD) (Borshchev 2013). We employed ABM and DEM to simulate the traveler's behavior and traffic evolution respectively, where the combination is difficult to be established in traditional traffic simulation software. This innovation can make the result of simulation quite close to the reality.

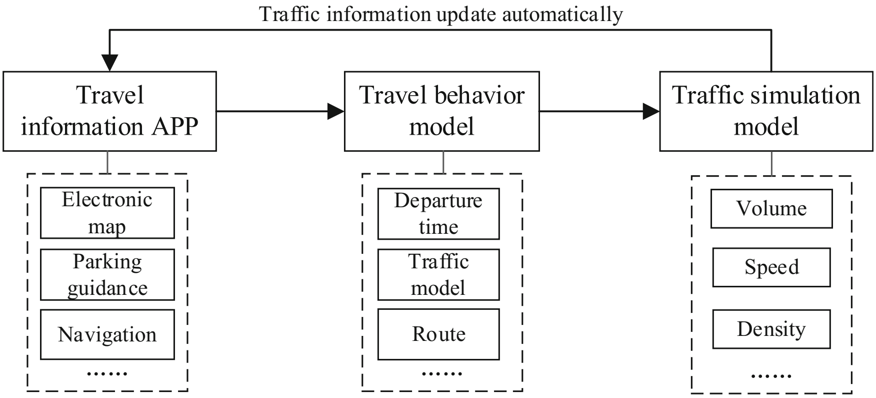


Fig. 62.1 The architecture of multimethod model

62.2.2 Traveler Behavior Modeling

With the rapid development of mobile internet industry and social networks, the number of traveler information apps is rising significantly. The information providers are becoming increasingly diverse, such as government agencies, companies and even travelers. Therefore, more and more travelers begin to get real-time traffic information through social networks and various apps (Zhang et al. 2014). Once the value of the traffic information is accepted, travelers will gradually become accustomed to arranging their travel plan based on this kind of information, which will lead to many complex changes in travel behavior. Diversified traveler information services will have different effects on the travel behavior. How to model and quantify the behavior is critical for developing traveler behavior model.

One of the effective method to model behavior is ABM, a type of modeling complex system. ABM simulate the whole system from the bottom up, namely regarding each entity in the system as an agent and attempting to describe the system by the behavior and relationship of agents. Compared with the traditional aggregate model which simulate the system from the top down, ABM has advantages in terms of reality, efficiency, maneuverability and portability (Wang et al. 2014).

We use AnyLogic as the platform to develop the agent-based model of traveler's behavior. The visual modeling process with AnyLogic can simplify the workload and complexity of ABM development. Users can use the Unified Modeling Language (UML) to define the state of agent quickly, utilize the Statechart to define the behavior and environment of agent to collect data. The process of developing ABM mainly comprises three steps. Firstly, the agents, objects of simulation, need to be chosen. Secondly, the behavior of agent is defined, for example, reaction and state. Finally, the agents are put into simulation environment and let them

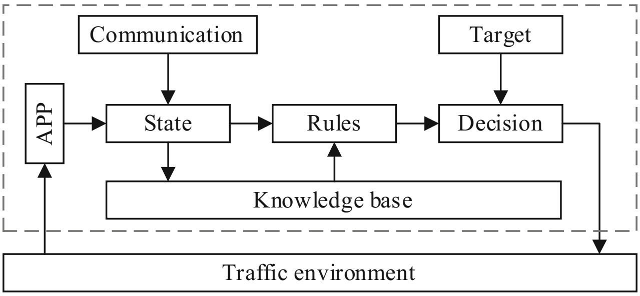


Fig. 62.2 The model structure of traveler agent

communicate with each other and the environment. After all, the presentation of simulation is the combination of many agents' behaviors (Borshchev 2013).

In the agent-based model of traveler, besides basic attributes (e.g. gender, age, the probability of using apps and so on) and driving attributes (e.g. preferred speed, max acceleration, max deceleration and frequency of changing lanes), other complex behaviors can also be modeled, including changing departure time, travel mode and route dynamically. The Belief-Desire-Intention (BDI) agent model is an event-driven execution model providing both reactive and proactive behavior. Taking BDI model as reference (Li 2010), environmental and traffic facilities are set as the *Belief* of the agent. The destination arrival is set as the *Desire* of the agent and the *Intention* of the agent is a set of behaviors, such as searching for the optimal route, perceiving other vehicles, changing lanes, overtaking, waiting and so on. At the end of each simulation step, the driver agent would choose behavior from the set of *Intention* as an activity of the next step, as shown in Fig. 62.2.

62.2.3 Traffic Simulation Modeling

In the up-to-date version 7.3 of AnyLogic, the newly added software library is the Road Traffic Library, which allows users to build traffic simulation model professionally (e.g. highway traffic, urban road traffic and parking lots) (XJ Technologies Limited 2016a). Compared to other traffic simulation software, AnyLogic has an open system architecture and supports secondary development (Borshchev 2013). Furthermore, AnyLogic can work with other software and applets written in Java or other languages, providing greater flexibility for traffic simulation modeling (Hu 2011).

The traffic simulation with AnyLogic generally comprises four parts, namely environment modeling, creating the traffic flow, running the simulation and results analysis. The aim of environment modeling is to provide the necessary environmental information for the agent behavior model establishment. We constructed environment objects by defining them graphically, adding corresponding objects, and setting up animation properties. The commonly used blocks of environment modeling include *Road* (drawing the road segment), *Intersection* (drawing the intersection and linking the road), *Stop Line* (defining the stop line for vehicles), and *Parking Lot* (drawing the parking area) (XJ Technologies Limited 2016b).

The activities of the vehicle are defined in the style of flowcharts, dragging the objects from the Road Traffic Library stencil, setting properties, and connecting objects in a timed sequence. Vehicle's behaviors are a series of traffic-related activities in the process of traveling, and the behavior would be affected by environment, physiological and psychological factors. Vehicles live in the defined environment and move according to simulated physical rules. The most commonly used blocks to simulate vehicle behavior include: *Car Source* (generating cars), *Car Dispose* (disposing incoming cars) and *Car Go To* (guiding the car to go to the specified location). In addition to these modules, there are *Traffic Light* (defining the traffic light phase of intersection) and *Road Network Descriptor* (controlling all vehicles) (XJ Technologies Limited 2016b).

62.2.4 Evaluation Index

In this study, three traffic indicators are chosen to assess the traffic benefits of apps on the mobile devices. Among these indicators, there are travel time, average speed and traffic density. And the definition of each indicator is shown as follows:

(1) **Travel time**

Travel time is the time that the movement of traveler takes between origin to destination (Wang and Guo 2011). The shorter travel time is, the higher transportation efficiency will be. The formulation of travel time is as follow:

$$T_{travelTime} = T_A - T_D = \sum T_i \tag{62.1}$$

where $T_{travelTime}$ represents the travel time (s); T_A represents the arrival time (s); T_D represents the departure time (s); T_i is the time cost in link i (s).

(2) **Average speed**

Average speed refers to the average speed of vehicles on a special road in the simulation time. This indicator used to show the characteristics of traffic flow movement. The higher the road speed is, the shorter the travel time will be (Wang and Guo 2011).

(3) **Traffic density**

Traffic density is the number of vehicles on the road per unit link length. Therefore, it often used to indicate the intensity of the vehicles. This indicator was chosen to identify the change of traffic flow on different routes influenced by the traveler's behavior. The performance of real-time traffic information can be assessed by traffic density (Wang and Guo 2011).

$$K = N/L \tag{62.2}$$

where K represents the traffic density at the time stamp (veh/km); N represents the number of vehicles at the time stamp (veh); L is the length of the observed link (km).

62.3 Case Study

62.3.1 Study Area

In order to study the influence of traveler information apps on urban traffic, we selected a representative urban road network. There are an eastbound expressway and an urban road, which are connected by ramps, as shown in Fig. 62.3. When there is a traffic accident at point C, one of the three lanes would be closed. The capacity of this segment will decrease, which results in traffic congestion. As long as the congestion continues, the real-time information will be sent to travelers through apps so as to provide decision-making for their travel adjustment. Basing on experience and preference, some travelers will choose to go along the expressway continuously (B → C → D, *Route* 2), while others would exit to the urban road through the ramp and go back to the expressway in the next entrance for avoiding congestion (B → G → H → I → D, *Route 1*). The traveler's decision will affect the whole traffic network. Multimethod was used to build a comprehensive model to study the relationship between traveler's behavior and the traffic benefits.

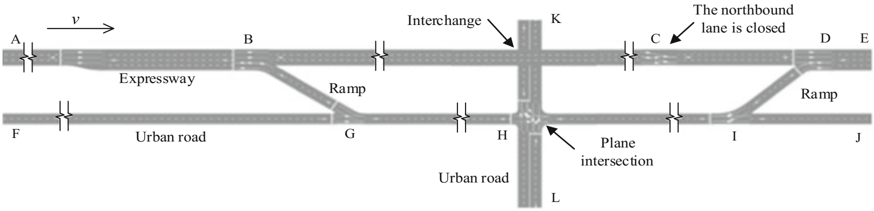


Fig. 62.3 The schematic diagram of simulated road network

62.3.2 *Modeling*

62.3.2.1 Building Traveler Behavior Model

Since the travelers in this research are on the way to his or her destination, we only consider their enroute path changing. Due to individual differences, travelers optimize their travel activities respectively by utilizing these mobile service.

We built an agent-based model of traveler to analyze the dynamic relationship of traveler's behavior and the traffic network performance. In this model, the default route of travelers is the expressway, *Route 2*. While there is traffic congestion on *Route 2*, the traveler agents will check the real-time traffic information through apps on mobile devices and adjust their travel path according to the travel time estimation. As the arithmetic diagram in Fig. 62.4, some travelers tend to choose *Route 1* to save some time, while others would still go straight along the expressway.

62.3.2.2 Building Traffic Simulation Model

Now, we draw the road network as shown in Fig. 62.3 by using environmental markup blocks of Road Traffic Library. The details of each link are shown in Table 62.1. There is a traffic signal control intersection with two phases on *Route 1*. The first signal phase is for northbound and southbound flow, while the other is for eastbound and westbound flow. And the split time of each phase is 60 s.

After the environment is constructed, we defined vehicle's activities in the style of flowchart and assigned travelers to specific route, as shown in Fig. 62.5. The traffic information will be updated automatically and released to the follow-up travelers through apps, so as to provide decision-making basis for their travel. Finally, after running the model, macroscopic data and microscopic data were collected for the evaluation. The former comprises traffic flow volume, average speed and so on, while the latter includes acceleration and speed of each vehicle at the time stamps. In addition, the vehicle flow volume, traffic density of roads, travel distance, and other statistical data can be output qualitatively and quantitatively.

Fig. 62.4 The algorithm of travelers to choose route

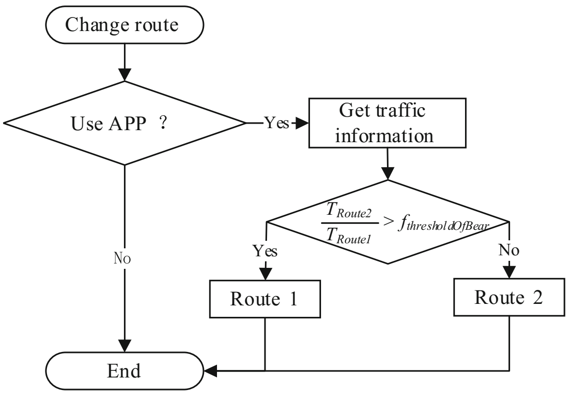


Table 62.1 The parameters of the road network

Link	Type	Length (m)	Flow (veh/h)	Link	Type	Length (m)	Flow (veh/h)
AB	Expressway	1500	4500	HI	Urban road	800	–
BC	Expressway	1300	–	IJ	Urban road	200	–
CD	Expressway	300	–	BG	Exit ramp	100	–
DE	Expressway	200	–	ID	Entrance ramp	100	–
FG	Urban road	1000	400	KH	Urban road	300	400
GH	Urban road	450	–	LH	Urban road	300	400

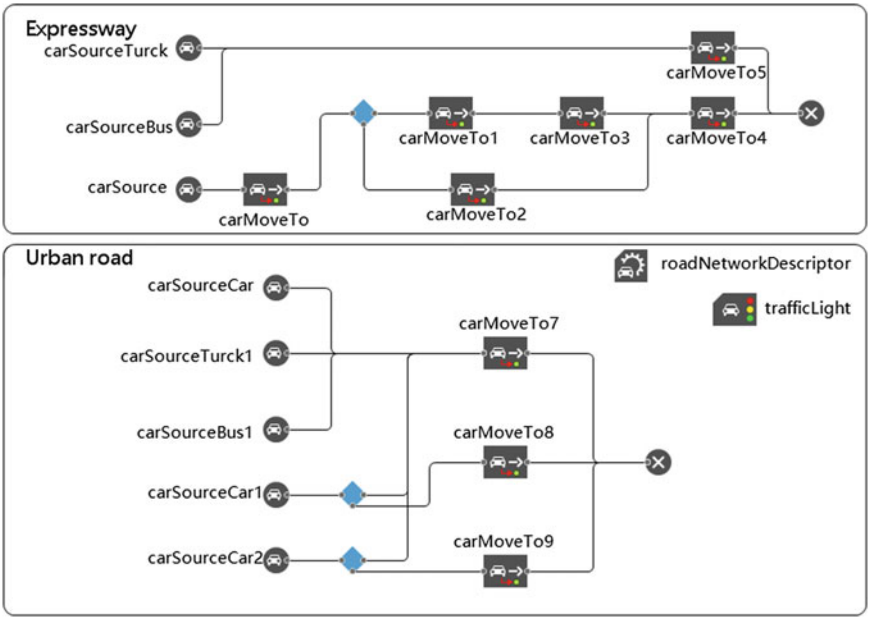


Fig. 62.5 Defining vehicle's activities in the style of flowchart

62.4 Analysis and Discussion

The traffic performance with or without apps' guidance were simulated and analyzed in this section. Based on the fact that travelers are developing the habit of using apps to acquire traffic information, the impact of the penetration rate of apps on the traffic benefits is studied further.

62.4.1 The Traffic Benefits of Apps

When the real-time traveler information is not acquired, the arrival vehicles at point C cannot pass through timely, and thus the length of congested road increase gradually. The vehicles on the expressway have to move slowly at the speed of about 18 km/h, leading to the slight fluctuation of the average density. When the congested area is extended to link AB from link BC, the average speed in the link AB will also reduce as shown in Fig. 62.6a. Therefore, the average traffic density of link BC keeps in a relatively steady state, as shown in Fig. 62.6c.

With the real-time traffic information is acquired through apps on mobile devices, travelers can dynamically adjust their travel paths. As a result, the average speed and traffic density of expressway and urban road fluctuate periodically as shown in Fig. 62.6b, d respectively. When the level of service on the expressway is high (Stage 1), the travelers will preferentially choose *Route 2*. With more vehicle arrivals, the average traffic density in *Route 2* increases continuously and the congestion spreads. As the expressway become more and more congested (Stage 2), more travelers would change to *Route 1* preferentially. As a result, the average traffic density of *Route 1* increases gradually in the first few minutes. In addition, since a portion of travelers change their path, the average traffic density of *Route 1* rises to a certain extent and then remains stable. At the same time, the congestion of *Route 2* will alleviate gradually. And the average speed of *Route 2* will rise. When the estimated travel time of both routes is almost equal, most of subsequent travelers will choose *Route 2* preferentially again, leading to a periodical trend.

Furthermore, the guidance of apps will change the travel time statistical characteristics. The travel time probability density distribution is shown in Fig. 62.7.

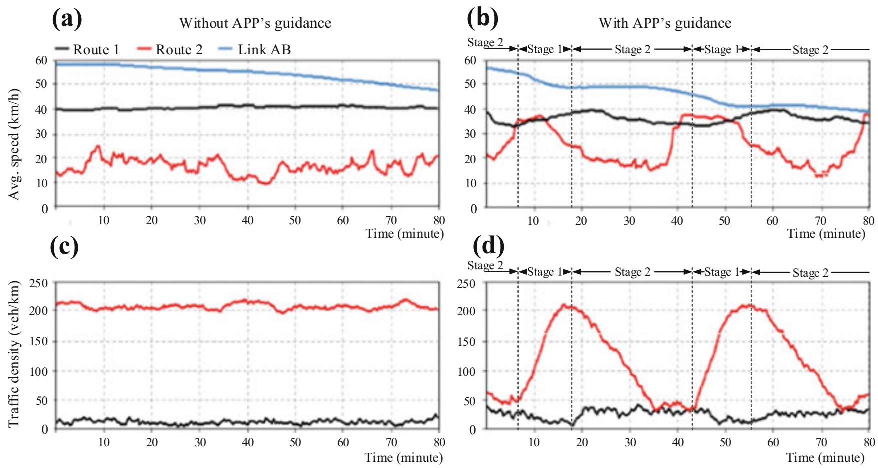


Fig. 62.6 The compare of simulation result without and with apps' guidance

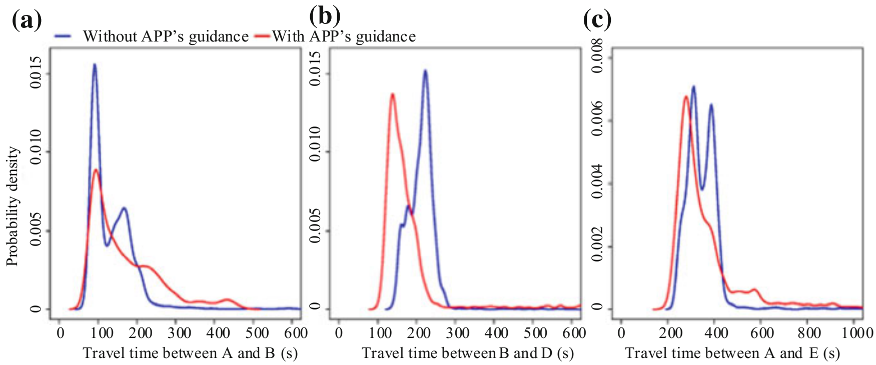


Fig. 62.7 The distribution of travel time of link AB, BD and AE

Firstly, without apps' guidance, the traffic condition on the expressway becomes worse and the congested road extends from BC to AB. Therefore the traffic on link AB changes from smooth to congested, which leads to a bimodal distribution in Fig. 62.7a. However, when travelers change path, speed decrease and lane changes are always subsequently, which will also affect the speed of adjacent cars. As a result, the average travel time of link AB increased by about 19%. Compared with no app's guidance, traffic condition on link BD is improved significantly, with average travel time decreasing about 36%.

In summary, the average travel time from node A to node D without app's guidance is 461 s, while average time with app's guidance is 373 s, reduced by 19.1%. Therefore, in the one hour simulation period, the total travel time of all vehicles can be reduced by 110 vehicle hours under the guidance of traveler information app.

62.4.2 Apps Penetration Rate

In order to compare the impact of different apps penetration rate on the traffic network performance, simulations with different parameters have been run. The results show that more travelers choose *Route 1* when congestion occurs as the apps penetration rate rises, as shown in Fig. 62.8a. When the penetration rate is about 95%, the ratio between travelers choosing *Route 1* and *Route 2* is almost equal, mainly caused by some travelers with high tolerance threshold value who are reluctant to change route easily.

However, the relation curve between traffic benefits and the penetration rate is like a "U" curve. In other word, both the higher rate and the lower rate will reduce the traffic performance of the whole network, as shown in Fig. 62.8b. When the rate is about 30%, about 10% of total vehicles will shift to *Route 1* when congestion

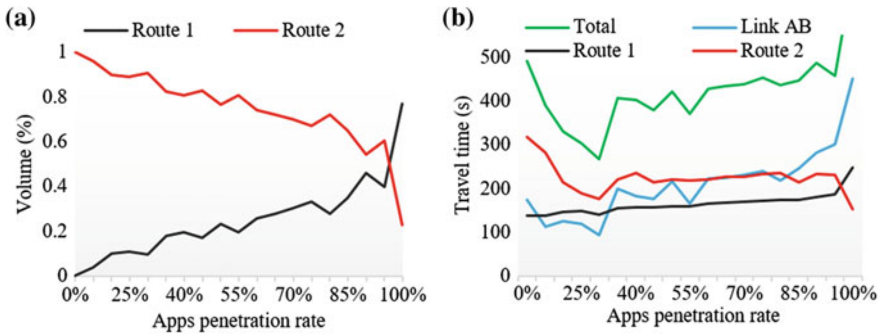


Fig. 62.8 **a** The relationship of route choice and apps penetration rate; **b** the relation curve between average travel time and app penetration rate

occurs, which will significantly improve the benefits. And the total average travel time will be reduced from 461 to 373 s, saving about 19.1% of the travel time.

62.5 Conclusion

This study attempts to answer: will the real-time traffic information provided by the apps brings benefits on network level or just benefits limited users in a micro-level network? Thus a multimethod modelling integrating the traveler agent-based model, traveler's behavior model and traffic simulation model was developed. In this modelling, the communication among travelers and the the service provider (obtaining the real-time traffic information by mobile device apps, and mapping the travel into the traffic network) were realized. It makes the result of the simulation more close to the reality than the traditional traffic simulation.

The simulation results show that the traffic information released by apps can help traveler to avoid congestion by diverting traffic volume before the bottleneck of the traffic system. Average travel time between origin to destination decreases by 19.1% with apps. In addition, the sensitivity analysis of the apps' penetration rate shows that the benefit is optimal when the rate is about 30%.

The comprehensive model established in the paper was an exploratory attempt of a new method. There are still some shortcomings, such as the network and the modeled behavior of traveler is relatively simple. In future, the model could be further developed by expanding its scale, types and variety of behaviors, and used to assess the impact of apps on urban traffic network level providing technical support for the urban traffic and management.

Acknowledgements The authors thank Shenzhen Science and Technology Plan (Grant Number: JCYJ20140418181958475) for funding and support.

References

Borshchev A (2013) The big book of simulation modeling: multimethod modeling with AnyLogic 6. AnyLogic North America

Dimitrakopoulos G, Demestichas P (2012) Intelligent transportation systems. Encycl Oper Res Manage Sci 5:63–67

Hu M (2011). A survey and simulation of passenger flow organization of the Shenzhen urban rail transit station. In: International conference of Chinese transportation professionals, pp 2991–2997

Huang X, Yun H, Gong Z, Li X (2014) Source apportionment and secondary organic aerosol estimation of $PM_{2.5}$ in an urban atmosphere in China. Sci China Earth Sci 57:1352–1362

Intelligent Transportation Society of America (2015) National/Regional smartphone apps. http://www.itsa.org/knowledgecenter/market-data-analysis/smartphone-apps 2016. Accessed 16 Aug 2003

Li J (2010) An agent-oriented simulating approach to study the driver's behavior under real-time traffic information. Harbin Institute of Technology

Liu Z, Dai L, Yang Y, (2013) Analysis on business model of traffic information APP. Transportation Information Industry, pp 127–128

Ministry of Environmental Protection of the People's Republic of China (2016) China vehicle emission control annual report 2015

Serdar Ç, Antonio L, González MC (2016) Understanding congested travel in urban areas. Nat Commun 7

Wang W, Guo X (2011) Transportation engineering. Southeast University Press, Nanjing

Wang D, Yao E, Yang Y, Zhang Y (2014) Modeling passenger flow distribution based on disaggregate model for urban rail transit, pp. 715–723

XJ Technologies Limited (2016a) AnyLogic 7 road traffic library reference guide. St. Petersburg, Russian Federation

XJ Technologies Limited (2016b) AnyLogic 7 road traffic library tutorial. St. Petersburg, Russian Federation

Zhang C (2011) Research on traffic dynamic information dissemination strategies. Jilin University

Zhang X, Chen Y, Yan S (2014) Influence of smart phone application on mode choice behaviors. J Transp Inf Saf 32:27–38

Zhou W (2012) Modeling travel behavior under urban dynamic road traffic information. Dalian University of Technology

Chapter 63
Evaluation of Construction Waste: Management Problems and Solutions

T. Quinn and J.J. Smallwood

63.1 Introduction

The growth in construction activities over the past two decades has resulted in an increase in the amount of construction waste. This growth has contributed to the reduction of available landfill space, which has become a challenge in terms of the environment (Bakshan et al. 2015).

Effective waste management on construction sites can increase profits for construction firms, lessen the environmental footprint of the construction industry as a whole, and promote sustainability.

There are health and safety (H&S) risks associated with poor construction waste management, these need to be identified so as to reduce incidents on site.

All project stakeholders are affected by the generation of construction waste, and contribute thereto in varying ways. Given the aforementioned, a study was conducted to determine the: level of waste; extent to which factors contribute to material wastage; respondents' awareness of aspects related to construction waste; impact of waste on various aspects, and perceptions and practices relative to waste management.

T. Quinn · J.J. Smallwood (✉)
Department of Construction Management, Nelson Mandela University, Port Elizabeth, South Africa
e-mail: john.smallwood@mandela.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_63

63.2 Review of the Literature

63.2.1 Construction Team Influence

Construction in South Africa is firmly established in traditional methods, this is evident in the way that South African buildings are built with the same materials and only slightly improved upon techniques.

Managers play a vital role in the construction process, they ensure all processes are adhered to and that the project will be completed within the required time and budget. This should mean that they should also have an invested interest in the effective management of waste. Ameh and Daniel (2013) mention that material wastage on construction sites accounts for cost overruns and any improvement in building materials management on construction sites has the potential to enhance the construction industry's performance with cost-saving benefits. Their study also determined that poor supervision was ranked first among fifteen material wastage contributory factors. Furthermore, they determined the average percentage contribution of building material wastage to project cost overruns to be between 21 and 30%.

A study conducted by Yuan (2013) identified that poor workers' material handling and delivery skills are responsible for a large portion of avoidable construction waste. Yuan also identified that workers who had undergone training became motivated and contributed to a significant reduction in waste.

There are many accidents on construction sites, many of which are avoidable, a percentage of which happen because workers place and dispose materials in a negligent manner (Teo et al. 2005). The incorrect placement of materials (waste and usable materials) and what is known in South Africa as poor 'housekeeping', lead to accidents that can be classified as object strikes.

63.2.2 Designers' and Project Managers' Contribution to Waste

A study conducted by Osmani et al. (2007) determined that waste management is not a priority in the design process. Furthermore, the responding architects seemed to take the view that waste is mainly produced during site operations and rarely generated during the design stages; however, about one-third of construction waste could essentially arise from design decisions. Greenwood (2004), inter alia, concurs that a substantial amount of waste is generated from the design process. The current focus of construction is on productivity, remaining within in budget and on time. Architects focus design on client brief and artistic taste, however, in the end the client is the decision maker.

It can be deemed the architect and project manager's function to persuade the client to consider implementing waste reducing techniques (Kofoworola and

Gheewala 2009). When designing a structure, an architect will consider the materials necessary to match a client's taste using their own discretion. It is at the early stages when decisions are made with respect to material specifications. Construction waste is effectively generated throughout the project from inception to completion with the pre-construction stage accounting for a considerable amount (Osmani et al. 2007).

63.2.3 *Global Effects of Waste*

The generation of construction waste not only causes problems for the construction industry itself, it also affects the wider global state of climate change, as well as pollution (Ma 2011). The construction industry is accountable for environmental damage, as it capitalises on the earth's renewable and non-renewable natural resources (Dixit et al. 2010).

Landfill sites are becoming more difficult to find in a growing population and communities are not likely to accept landfills near their residences (Reddy 2011). Therefore, it would be counterproductive for the property and construction industry to devalue the aesthetics of a natural area by contributing excessive amounts of construction waste to dump sites.

Esin and Cosgun (2007) state that construction and demolition debris that are dumped into forests, streams, ravines, and empty lots cause erosion, contaminate wells, water tables and surface water, attracts pests, creates fire hazards and detracts from the beauty of natural areas. They also mention that waste may contain hazardous materials such as asbestos, heavy metals, persistent organic compounds and volatile organic compounds, all of which is much more difficult to dispose of than household waste.

The construction industry should also be aware that conventional 'raw materials' used in home construction cannot be used without impacting the environment as the emission of pollutants into the atmosphere and water result from the manufacturing of construction materials (Treloar et al. 2003).

63.3 Research Method

The descriptive survey method was adopted, which entailed both electronic delivery and hand to hand courier delivery of a self-administered questionnaire. The questionnaire was compiled using five-point Likert scale questions to assess the perceptions of construction professionals across various disciplines regarding construction waste, in particular the project parameters, material waste, as well as awareness with respect to waste minimisation. Respondents were also afforded the opportunity to communicate any comments in general with respect to construction waste.

54 questionnaires were distributed, and a total of 30 responses were included in the analysis of the data, which equates to a response rate of 55.5%. Respondents either had some sort of experience in terms of site waste management or they were in a position to change the amount of waste produced on construction sites.

63.4 Research Findings

Table 63.1 indicates the level of wastage of materials in terms of percentage responses to a range of 'very low' to 'very high', and mean scores (MSs) between 1.00 and 5.00. 5/16 (31.3%) MSs are > 3.00, which indicates that the wastage is high as opposed to low.

It is notable that no materials have MSs > 4.20 $\leq$ 5.00. However, 2/16 (12.5%) of MSs are > 3.40 $\leq$ 4.20 (medium to high/high wastage)—cement plaster, and cement mortar. The materials ranked third to sixth have MSs > 3.40 $\leq$ 4.20 (low to medium/medium wastage)—timber for other uses, timber for formwork, bricks, and ceramic/vitrified tiles.

Table 63.1 Level of wastage of materials

Material	Response (%)						MS	Rank
	Unsure	Very low	Low	Medium	High	Very high		
Cement plaster	3.4	3.4	13.8	31.0	20.7	27.6	3.57	1
Cement mortar	3.4	3.4	24.1	17.2	27.6	24.1	3.46	2
Timber for other uses	10.3	3.4	13.8	37.9	31.0	3.4	3.19	3
Timber formwork	6.9	6.9	17.2	27.6	34.5	6.9	3.19	4
Bricks	6.9	6.9	24.1	27.6	27.6	6.9	3.04	5
Ceramic/Vitrified tiles	6.9	6.9	24.1	44.8	10.3	6.9	2.85	6
Concrete	3.4	6.9	48.3	24.1	13.8	3.4	2.57	7
Concrete blocks	10.3	6.9	51.7	13.8	17.2	0.0	2.46	8
Clay tiles (roofing tiles included)	17.2	6.9	37.9	37.9	0.0	0.0	2.38	9
Paints	13.8	20.7	27.6	34.5	3.4	0.0	2.24	10
PVC	25.0	25.0	21.4	21.4	7.1	0.0	2.14	11
Steel reinforcement	6.9	37.9	34.5	17.2	3.4	0.0	1.85	12
Fibre-cement roof sheets	24.1	24.1	44.8	3.4	3.4	0.0	1.82	13
Aluminium	20.7	41.4	27.6	6.9	3.4	0.0	1.65	14
Steel formwork	17.2	48.3	27.6	6.9	0.0	0.0	1.50	15
Structural steel	17.2	58.6	17.2	3.4	3.4	0.0	1.42	16

The materials ranked seventh to thirteenth (43.8%) have MSs > 1.80 ≤ 2.60 (very low to medium/medium wastage)—concrete, concrete blocks, clay tiles (roofing tiles included), paints, PVC, steel reinforcement, fibre-cement roof sheets.

The results are notable as the most common type of building construction in South Africa, namely masonry construction, entails three of the top five waste inducing materials, namely bricks, and cement mortar, and plaster. In addition to the actual construction waste, such materials impact on sustainability due to the raw materials and energy consumed in their production. The choice of such construction is based upon tradition and 'culture', however, such a choice is often made by architects in their design. Furthermore, the use of steel formwork (MS = 1.50), as opposed to timber formwork (MS = 3.19), will promote sustainability as steel formwork is more durable and has a longer lifespan than timber formwork. Construction managers are the key decision makers in this regard, although structural design and details will have an influence on the type of formwork that can be used.

Table 63.2 presents the extent to which the respondents believe seventeen factors contribute to material wastage in terms of percentage responses to a range of 1 (minor) to 5 (major), and MSs between 1.00 and 5.00. 13/17 (76.5%)

Table 63.2 Extent to which factors contribute to material wastage

Factor	Response (%)						MS	Rank
	U	Minor	Near minor	Contribution	Near major	Major		
Negligence and care free attitude of workers	6.9	0.0	0.0	17.2	20.7	55.2	4.41	1
Poor supervision	0.0	0.0	3.4	31.0	27.6	37.9	4.00	2
Negligence and care free attitude of management	6.9	0.0	3.4	20.7	44.8	24.1	3.96	3
Rework	3.4	0.0	13.8	20.7	24.1	37.9	3.89	4
Poor material handling	3.4	3.4	3.4	20.7	51.7	17.2	3.79	5
Inadequate workers' skill	3.3	0.0	20.0	13.3	30.0	33.3	3.79	6
Construction related errors/Omissions	3.3	0.0	3.3	40.0	30.0	23.3	3.76	7
Absence of appointed site waste manager	13.3	6.7	10.0	6.7	43.3	20.0	3.69	8
Inadequate integrated waste reduction plan	20.0	6.7	3.3	23.3	40.0	6.7	3.46	9
Inadequate waste management plan	13.8	3.4	10.3	31.0	27.6	13.8	3.44	10
Client design changes	0.0	6.7	6.7	50.0	26.7	10.0	3.27	11
Theft and vandalism	3.4	10.3	20.7	31.0	17.2	17.2	3.11	12
Inadequate management of the design process	10.0	10.0	16.7	30.0	23.3	10.0	3.07	13
Design related errors	3.3	10.0	20.0	36.7	23.3	6.7	2.97	14
Inappropriate specification	3.3	13.3	23.3	26.7	23.3	10.0	2.93	15
Buildability problems	10.3	6.9	24.1	34.5	20.7	3.4	2.88	16
Improper packaging	6.9	13.8	27.6	20.7	31.0	0.0	2.74	17

MSs are > 3.00, which indicates that the contribution is major as opposed to minor. Negligence and care free attitude of workers' was ranked first out of 17 other factors with a mean score of 4.41 (> 4.20 $\leq$ 5.00) and therefore the contribution can be deemed to be near major to major/major.

The factors ranked second to tenth (52.9%) have MSs > 3.40 $\leq$ 4.20 (contribution to near major/near major contribution)—poor supervision, negligence and care free attitude of management, rework, poor material handling, inadequate workers' skill, construction related errors/omissions, absence of appointed site waste manager, inadequate integrated waste reduction plan, and inadequate waste management plan. It is notable that the aforementioned are those which are under the direct control of the construction team.

The factors ranked eleventh to seventeenth tenth (41.2%) have MSs > 2.60 $\leq$ 3.40 (near minor contribution to contribution/contribution)—client design changes (11th), theft and vandalism, inadequate management of the design process (13th), design related errors (14th), inappropriate specification (15th), buildability problems (16th), and improper packaging. It is notable that one of the aforementioned are client originated and four are design originated.

When the surveys completed by the designers were separated and evaluated, design related contributors were ranked thirteenth and fifteenth. This indicates that either the designers' contributions to waste is negligible, or construction teams and designers themselves are unaware as to designers' impact on the generation of waste on sites. The literature indicates that the latter is in fact the case.

Table 63.3 presents a comparison between respondents' awareness of eight aspects related to construction waste versus how enhanced awareness of the aspects could contribute to the reduction of waste in terms of MSs between 1.00 and 5.00, based upon percentage responses to a range of 'not' to 'very'. It is notable that all the 'contribution' MSs are greater than the 'awareness' MSs, which indicates that the respondents acknowledge that their awareness is not optimum. Although 'Costs attributable to construction waste' has the highest 'contribution' MS, 6/8 (75%) of

Table 63.3 Respondents' awareness of aspects related to construction waste versus how enhanced awareness of aspects could contribute to the reduction of waste

Aspect	Awareness	Contribution	Difference
Alternative materials with less inherent waste	2.90	3.97	1.07
Construction waste as a percentage of national waste	2.40	3.37	0.97
Construction waste management solutions	2.73	4.07	1.33
Costs attributable to construction waste	3.33	4.30	0.97
Environmental impact of construction waste	3.37	3.97	0.60
Final location of construction waste	3.50	3.97	0.47
Health and safety risks associated with construction waste	3.50	4.03	0.53
Time spent re-working and carting away of unused materials	3.30	4.17	0.87

Table 63.4 Impact of waste on various aspects

Aspect	Response (%)						MS	Rank
	U	Minor	Near minor	Impact	Near major	Major		
Cost	0.0	0.0	20.0	36.7	36.7	6.7	4.18	1
Pollution	0.0	0.0	20.0	43.3	33.3	3.3	4.14	2
Health and safety at waste dumping locations	0.0	3.3	13.3	43.3	33.3	6.7	4.14	3
Time	0.0	3.3	26.7	20.0	43.3	6.7	4.11	4
Health and safety on site	0.0	0.0	16.7	50.0	26.7	3.3	4.00	5
Aesthetics (waste dumping locations)	0.0	3.3	30.0	30.0	30.0	6.7	3.93	6
Quality	0.0	3.3	30.0	33.3	26.7	6.7	3.89	7
Productivity	0.0	13.3	30.0	26.7	23.3	6.7	3.64	8

the aspects impact directly on sustainability. The findings also indicate the role of designers and constructors, that waste management is a multi-disciplinary issue, which needs to be addressed at industry, organisation, and project level.

Table 63.4 presents the extent to which waste impacts on eight factors in terms of percentage responses to a range of 1 (minor) to 5 (major), and MSs between 1.00 and 5.00. All the MSs are >3.00, which indicates that the impact is major as opposed to minor.

It is notable that no aspects have MSs > 4.20 $\leq$ 5.00. However, all eight MSs are >3.40 $\leq$ 4.20 (impact to near major/near major impact). Although cost is ranked first, it is followed closely by pollution, and health and safety at waste dumping locations. In essence 4/8 (50%) of the aspects are linked directly to sustainability. Furthermore, the aspects highlight the incentives for contractors to manage, or rather, mitigate waste. Secondly, ultimately clients bear the cost as the cost of waste is built into contractors' cost structures, and estimates. Thirdly, there are internal and external publics' issues in terms of the impact on image.

Further findings include that 96.7% of the respondents believe that there needs to be more done to prevent waste—only 3.3% being unsure.

53.3% of respondents work for organisations which employ waste management strategies, 30% do not, and 16.7% are not sure, the latter constituting a finding in itself.

63.5 Conclusions and Recommendations

Waste has its origin in the design, procurement, and construction phases of projects. The responsibility for mitigating waste therefore resides with all stakeholders; the client, the designers, as well as the contractors. Factors that contribute to waste range from poor supervision to poor material handling, to more indirect factors such as theft and vandalism. In terms of responsibility for waste management, architects seemed to take the view that waste is mainly produced during site operations and rarely generated during the design stages.

The level of waste relative to materials that are related to wet works indicates that fundamental change is necessary in terms of the materials used to construct elements such as walls.

There is a lack of general awareness with respect to aspects related to construction waste, however enhanced awareness of such aspects could contribute to the reduction of waste.

The benefits for construction waste management far outweigh the cons, which is underscored by the finding that 96.7% of the respondents believe that more needs to be done to prevent waste. The rationale for implementing effective waste management strategies and systems is economic, social, and environmental related, which will benefit all project stakeholders, and in addition, society at large, and ultimately promote sustainability.

References

Ameh OJ, Daniel EI (2013) Professionals' views of material wastage on construction sites and cost overruns. Organ Technol Manage Constr Int J 5(1):747–757

Bakshan A, Srour I, Chehab G, El-Fadel M (2015) A field based methodology for estimating waste generation rates at various stages of construction projects. Resour Conserv Recycl 100:70–80

Dixit MK, Fernández-Solís JL, Lavy S, Culp CH (2010) Identification of parameters for embodied energy measurement: a literature review. Energy Build 42(8):1238–1247

Esin T, Cosgun N (2007) A study conducted to reduce construction waste generation in Turkey. Build Environ 42(4):1667–1674

Greenwood R (2004) Construction waste minimisation: good practice guide. Centre for Research in the Built Environment, Wales

Kofoworola OF, Gheewala SH (2009) Estimation of construction waste generation and management in Thailand. Waste Manage 29(2):731–738

Ma U (2011) No waste: managing sustainability in construction. Gower Publishing Limited, Surrey

Osmani M, Glass J, Price ADF (2007) Architects' perspectives on construction waste reduction by design. Waste Manage 28(7):1147–1158

Reddy PJ (2011) Municipal solid waste management: processing energy recovery global examples. BS Publications, India

Teo EAL, Ling FYY, Ong DSY (2005) Fostering safe work behaviour in workers at construction sites. Eng Constr Archit Manage 12(4):410–422

Treloar GJ, Gupta H, Love PED, Nguyen B (2003) An analysis of factors influencing waste minimisation and use of recycled materials for the construction of residential buildings. Manage Environ Qual Int J 14(1):134–145

Yuan H (2013) Critical management measures contributing to construction waste management: evidence from construction projects in China. Proj Manage J 44(4):101–112

Chapter 64
Evaluation of Procurement Systems of Public Sector Funded Projects

A.E. Oke, C.O. Aigbavboa and B.A. Tong

64.1 Introduction

Procurement is a key process of a construction project. However, for procurement to influence the project's targeted outcome, a suitable procurement system has to be selected and utilized accordingly (Ruparathna and Hewage 2013; Georghiou et al. 2014). This is an important pre-contract process. Babatunde et al. (2010) noted that before the project commenced, it is every client's aim to have a quality structure delivered to them on time and within the allocated budget.

Procurement systems are chosen as the focal means as they determine tendering and contractual processes through all project phases, from inception to handover. Procurement systems or strategies, as best known, may also serve as levers for the re-engineering of construction project processes as a whole. The need for relevant procurement system is related to execution and performance of building projects. This performance is measured in terms of cost, time, quality, satisfaction, sustainability, etc. Projects in South Africa have encountered cost and time overruns as a result of the delays (Kagioglou et al. 2001) which were possibly influenced by the procurement system adopted for the projects. The Gautrain project for instance encountered cost and time overruns as the project was initially estimated to cost R7 billion and was projected to be completed at nearly R25 billion and surpassed any of the largest construction projects ever executed in the country (Du Plessis 2010). This emphasizes the importance of procurement systems to be used on

A.E. Oke (✉) · C.O. Aigbavboa · B.A. Tong
Department of Construction Management and Quantity Surveying,
University of Johannesburg, Johannesburg, South Africa
e-mail: emayok@gmail.com

C.O. Aigbavboa
e-mail: caigbavboa@uj.ac.za

B.A. Tong
e-mail: tongtongb@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_64

projects as this overruns are mainly due to procurement systems and alternatives not being taken into considerations (Nkado et al. 2010). This research is aimed at identifying divers factors contributing to the choice of various procurement systems in order to minimize or reduce challenges of public funded projects due to the adopted systems.

64.2 Procurement Systems for Construction Projects

The construction industry is considered as one of the most competitive industry and yet a risky industry to do business in due to inherent difficulties encountered by the industry. Such risks are as a result of poor cooperation, limited trust and ineffective communication. Often, these difficulties affect the relationship among construction stakeholders. However, the relationship-based procurement has shown growth on the construction projects internationally. Factors influencing this sort of growth are joint-ventures, joint-ownerships, consortiums and various forms of joint production and selling (Mohammadhasanzadeh et al. 2014).

Procurement is regarded as an important and key process in a construction project as it is a tool to manage contracts. Its activities have to link with the project's requirement as this will enable the contractor to deliver projects according to specification and to client's satisfaction. Furthermore, Ruparathna and Hewage (2013) noted that procurement is a complex process having a numerous options in terms of the availability of the options and directions of the project. According to Laedre et al. (2006), the procurement systems in a construction project is one of the most important aspects for proper attention. The type of a procurement system suitable for a construction project is dependent on several aspects which are based on the goals and requirements of the project. These aspects are; functionality, cost, time, type of client, nature of project, quality required, etc. and they all concern with both private and public funded projects (Laedre et al. 2006). There are a number of types of procurement systems available for construction projects, these include traditional; design and build; and various management procurement systems. Each of these systems has their threats, opportunities, strengths and weaknesses.

The selection of a procurement system to suit a particular project can be a challenging task to execute due to the systems' potential benefits as well as their respective risk (Tookey et al. 2001). Furthermore, procurement can be used as a tool to attain improved value-for-money as risks will be properly managed. As a result of this, cost escalation, time overruns and other challenges can be reduced but this can only be achieved through choosing and applying the suitable procurement systems for a particular project.

64.3 Methodology

Quantitative research approach was adopted for this research because it enable events in the social work to be examined through relationships between constituent elements. These elements were identified through review of literature materials on procurement options available for construction projects. Opinions of construction professionals practicing in Gauteng region of South Africa were sought through survey method. These professionals with direct involvement and adequate knowledge of procurement systems are architects, quantity surveyors, construction managers, construction project manager and site managers. The roles of these professionals differs but their contribution assisted in obtaining related findings since they all play significant roles in ensuring successful delivery of construction project.

For ethical consideration, there were no exception to participation, in as much as such is a practicing member of the group of professionals identified for the study. In addition to that, the research imposes no social harm on participants and it was emphasized that the research is academically based and that their participation is voluntary.

Using questionnaires, data were obtained through convenience sampling of these professionals. 5-point Likert scale was used to evaluate the procurement systems of public funded projects. The scale used are 1 = Never (N); 2 = Seldom (SE); 3 = Sometimes (SO); 4 = Often (O); and 5 = Always (A). The scale was then employed to compute Mean Item Score (MIS) and Standard Deviation (SD) that were used to order the importance of identified variables.

64.4 Analysis

40 questionnaires were obtained from the respondents, 42% are female while 58% are male with an average of about 11 years of experience. 65% are engaged in private sector, 30% are from public sector while 5% belonged to the two groups. They have been involved in several projects and are currently engaged in at least 1 projects as at the time of the survey.

64.4.1 Procurements Methods of Public Funded Project

This section evaluates generic procurement systems suitable for use in projects funded by the public sector. Table 64.1 indicate that design, tender and bill is the most suitable option. This is followed by management procurement; design and build; design, build, finance and transfer; build operate and own; and renovate, operate and transfer. The least option is build operate and transfer.

Table 64.1 Procurement systems of public funded projects

Procurement systems	Mean item score	Standard deviation	Rank
Design, tender and bill	4.30	9.03	1
Management procurement	3.75	5.48	2
Design and build	3.63	6.32	3
Design, build, finance and transfer	3.48	5.05	4
Build, operate and own	3.45	6.16	5
Renovate, operate and transfer	3.33	5.87	6
Build, operate and transfer	3.30	4.00	7

Table 64.2 Choice of procurement systems

Factors	Percentage (%)	Standard deviation	Rank
Clarity allocation of responsibility	11.53	2.31	1
The degree of price competition pertaining to the procurement options	11.49	1.53	2
Which of the parties should carry the risk	11.17	3.51	3
The time required for the project to be finished	11.14	6.66	4
Quality level required of the project	11.06	3.79	5
The type of construction contract	11.04	3.79	6
The ability and authority for the client to effect changes	10.86	5.51	7
Sustainability of the procurement method to tackle complex projects	10.49	9.45	8
Certainty of project completion	10.22	3.06	9

64.4.2 Factors Determining Choice of Procurement Systems

Table 64.2 shows the response of the respondents on the factors determining the type of the procurement systems to be used. Their response was as follows; clarity allocation of responsibility was ranked first with MIS of 11.53%, the degree of price competition pertaining to the procurement options was ranked second with MIS of 11.49%, which of the parties should carry the risk was ranked third with MIS of 11.17%, the time required for the project to be finished was ranked fourth with MIS of 11.14%, quality level required of the project was ranked fifth with MIS of 11.06%, the ability and authority for the client to effect changes was ranked seventh with MIS of 10.86%, sustainability of the procurement method to tackle complex projects was ranked eighth with MIS of 10.49% and certainty of project completion was ranked ninth with MIs of 10.22%.

Table 64.3 demonstrates the respondents' ranking on the procurement barriers which impact on the innovation and changes of culture and attitude of the South African construction industry. The respondents ranked incomplete design first with MIS of 10.56%, planning was ranked second with MIS of 10.53%, communication

Table 64.3 Influences of procurement systems usage

Barriers	Percentage (%)	Standard deviation	Rank
Incomplete project design	10.56	3.21	1
Planning	10.53	5.69	2
Communication	10.33	4.51	3
Insufficient information	10.20	0.58	4
Sources of funding	10.08	2.31	5
Insufficient in-house capabilities	9.81	4.51	6
Consultants' procurement competency	9.77	4.73	7
Relationship with suppliers	9.74	6.66	8
Management of procurement risk	9.65	6.03	9
Procurement competency by procurers	9.33	9.51	10

was ranked third with MIS of 10.33%, insufficient information was ranked fourth with MIS of 10.20%, sources of funding was ranked fifth with MIS of 10.08%, insufficient in-house capabilities ranked sixth with MIS of 9.81%, consultants' procurement competency ranked seventh with MIS of 9.77%, relationship with suppliers ranked eighth with MIS of 9.74%, management of procurement risk ranked ninth with MIS of 9.65% and lastly procurement competency by procurers was ranked tenth with a standard deviation of 9.33%.

64.4.3 Discussion of Findings

Deign, tender and bill as well as the Management procurement were the most preferred systems that suits projects funded by the public sector. In agreement, Yin et al. (2014) highlighted that the traditional procurement method gives a clear guidance to both the contractor and the sub-contractor. In addition to that, the study conducted by Watermeyer (2005) stated that the infrastructure projects in the sub-Saharan Africa are delivered using the traditional pre-planned approach. Furthermore, Construction Development Board (CIDB) (2010) emphasized the importance of the public sector having an in-house capability, completed documents and complete designs prior to the invitation of tenders' commencement.

The main aim of having procurement in place is to ensure that the client's desires are achieved on time, with the required quality standards and within the allocated budget. Factors determining the type of procurement systems are majorly degree of price competition pertaining, certainty of project completion and quality level required of the project. The study conducted by Georghiou et al. (2014) elaborates that there are a number of factors which contribute to the selection of procurement systems of construction projects and they are based on the objectives or need of the client. More so, clarity of allocation of responsibility was listed as one of the eight factors which could possibly affect type of procurement systems for a project.

64.5 Conclusion

Traditional procurement systems which is the Design, Tender and Bill is the most common option for public projects in the study area. This procurement systems is preferred mainly due to its flexibility in terms of giving the contractor a clear guidance on what to do and how to do it. It also allow risk and responsibilities to be shared amongst the parties involved in a contract. However, there are barriers which could possibly hinder the innovations and changes to the culture and attitude of the construction industry. These barriers occur as a result of poor communication and planning as well as incomplete project design.

Allocation of responsibility is an important factor in determining the type of procurement systems to be used. More so, quality level is the main procurement factor which has to be analyzed to help mitigate possible wastages as well as project delays. In order to achieve innovation, there is a need for public sector to have efficient management that can bring aspects of strategic planning in place as well as appointing people who have capabilities and the skill of managing the budget. Procurement systems chosen for a particular project should not only be based on the requirement of cost, quality and time but aspects such as sustainability, economic stability and the construction culture of the project.

References

Babatunde S, Opawole A, Ujaddughe I (2010) An appraisal of project procurement methods in the Nigerian construction industry. Civ Eng Dimens 12(1):1–7

Construction Development Board (CIDB) (2010) Construction procurement: applying the procurement prescripts of the CIDB in the public sector, 5th edn. CIDB, Pretoria, South Africa

Du Plessis J (2010) Injecting a rapid rail link into a metropolis. Civ Eng SivieleIngenieurswese 18 (8):62–65

Georghiou L, Edler J, Uyarra E, Yeow J (2014) Policy instruments for public procurement of innovation: choice, design and assessment. Technol Forecast Soc Change 86(2):1–12

Kagioglou M, Cooper R, Aouad G (2001) Performance management in construction: a conceptual framework. Constr Manage Econ 19(1):85–95

Laedre O, Austeng K, Haugen TI, Klakegg OJ (2006) Procurement systems in public building and construction projects. J Constr Eng Manage 132(7):689–696

Mohammadhasanzadeh S, Hosseinalipour M, Hafezi M (2014) Collaborative procurement in construction projects performance measures, case study: partnering in Iranian construction industry. Procedia Soc Behav Sci 119:811–818

Nkado RN, Laryea S, Leiringer R, Hughes W (2010) Cost escalation of major infrastructure projects: a case study of Soccer City Stadium in Johannesburg. In: West Africa built environment research (WABER) conference, p 265

Ruparathna R, Hewage K (2013) Review of contemporary construction procurement practices. J Manage Eng 21(3):309–314

Tookey JE, Murray M, Hardcastle C, Langford D (2001) Construction procurement systems: re-defining the contours of construction procurement. Eng Constr Archit Manage 8(1):20–30

Watermeyer RB (2005) A generic and systemic approach to procurement: the case for an international standard. Public Procure Law Rev 2005:39

Yin SY, Tserng HP, Toong SN, Ngo TL (2014) An improved approach to the subcontracting procurement process in a lean construction setting. J Civ Eng Manage 20(3):389–403

Chapter 65
Evolutionary Game Analysis on the Low-Carbon City Construction Between Central and Local Government in China

Yingli Lou, Xiangnan Song and Hui Yan

65.1 Introduction

Global warming caused by carbon emission has been recognized as a big threat to the sustainability of the world (Shuai et al. 2017). Cities already account for around two thirds of global energy consumption and more than 70% of global energy-related carbon dioxide emissions (Rudolph and Kawakatsu 2012). So it has been appreciated that cities play a critical role in the pursuit of sustainable development of the whole world and cities are also the focus of an increasing amount of attention for their contribution to fighting climate change (Betsill and Bulkeley 2007; Nishida and Hua 2011; Shen et al. 2016a; Shuai et al. 2017). Recently, low-carbon city construction has become the concern of government. For example, the London's Low-Carbon City Programme (Becky 2012), the Climate Change Action Plan issued in US cities, such as San Francisco (Gavin 2004), Chicago (Parzen 2010); Chinese cities, such as Shenzhen (Shenzhen's Development and Reform Commission 2012); Denmark cities, such as Copenhagen (Plan of Copenhagen Climate Adaptation 2011); Sweden cities, such as Stockholm (Örjan et al. 2010) etc.

As the largest carbon dioxide emitter worldwide, China has given increasing attention to the critical and positive role of cities in fighting the climate change

Y. Lou · X. Song (✉)
School of Construction Management and Real Estate, International Research Centre for Sustainable Built Environment, Chongqing University, Chongqing, China
e-mail: 1018500021@qq.com

Y. Lou
e-mail: 951136852@qq.com

H. Yan
School of Civil Engineering and Transportation, South China University of Technology, Guangzhou, China
e-mail: 16165998@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_65

(Shen et al. 2017) and realizing the ambitious carbon emission commitment made in Paris Agreement by our president Xi. China has initiated low-carbon city pilots in 6 provinces and 36 cities since 2010, which covers almost 42% of the China's population, 57% of the China's Gross Domestic Product (GDP), and 56% of the carbon emissions across the whole country. And China is ready to expand the low-carbon city pilots to more than 100.

The practice of low-carbon city construction cannot develop effectively without the support of central government and local government. The central government in China, as the strong and authoritative decision maker, plays an important and critical role in supporting policies, establishing relevant incentive and punishment mechanism. Acting as the important medium of low-carbon city related policies provider and demander, the Chinese local governments' attitude to the low-carbon city construction has a decisive impact on the overall effect and future of the whole low-carbon city construction in China.

Previous studies have investigated low-carbon city from different perspectives. There are some studies from the macroscopic perspective, which mainly focused on the development path of low-carbon city (Hou and Li 2016; Ouyang 2016; Yang and Wang 2011), the establishment of comprehensive evaluation index system and evaluation model on the low-carbon city construction and development (Du et al. 2015; Liu et al. 2011a; Song 2012; Tan 2017), the related policy analysis (Shen et al. 2016b; Sheng 2016), the experiences mining about the low-carbon city construction (Cheng and Li 2014). And there are some studies from the microscopic perspective, which mainly focused on the carbon emission measurement and assessment on Chinese low-carbon cities (Zheng et al. 2016), the relationship between carbon emissions and city economic growth (Khanna et al. 2014; Liu and He 2015; Liu et al. 2011b). And the existing researches from the perspective of main participants are mainly focused on the participants' position, role and function in developing low-carbon cities. For example, Wang (2012) brought forward an analyzable model of "MOCIC" to put forward some countermeasures and suggestions from the three aspects of government, enterprise and resident. Zhang and Ma (2014) took Zhuhai Special Economic Zone as an example to explore the role and behavior of local government in promoting the process of institutional innovation in the construction of low-carbon city by employing the analysis framework of "first action group" and "second action group". It can be seen that these studies almost adopted qualitative research methods and there are few researches examining the low-carbon city development from the perspective of government by using quantitative research methods.

Active participation of local government is crucial for the construction of low-carbon city, thus policy guidance and incentive measures from central government are the external driving force for local government to carry out low-carbon measures. During the construction of low-carbon city, central government sets policies and controls the situation, meanwhile, local government carries out the policies and supervises public's low-carbon behavior. In this degree, the relations between central government and local government are cooperative, however, their goals are not completely consensus. Central government pays more attention to the sustainable development of whole society from the perspective of whole society and public while local government pays more attention to economic growth, revenue and GDP data etc. If the incentives from central government are insufficient and short-run costs are pretty high, local government will probably take the action of “overtly agree but covertly oppose” and “under the policy to the countermeasure”. It is therefore the aim of this study to research the best strategies decision during the low-carbon city construction between the central government and local government by employing the evolutionary game theory.

65.2 Research Methods

Evolutionary game theory is enlightened in Darwin’s biological evolutionism, combining classical game theory with the dynamic evolution. The assumption and starting point of it is bounded rationality, breaking through the limitation of classical game theory which assumption is complete rationality. The reality is full of asymmetric information and decision makers need learn, trial and adjust to find the optimal strategy. So, the evolutionary game model spreads logical deduction in the group behavior and strategy formed by individual bounded rationality. Surrounding two core concepts: ESS-Evolutionary Stable Strategy and RDE-Replicated Dynamic Equation, the model focuses on strategy adjustment, evolutionary trend and equilibrium problems of dynamic behavior between decision makers.

65.3 The Evolutionary Game Model of Low-Carbon City Construction Behavior Between Local Government and Central Government

65.3.1 Modeling Assumption

(1) Social stability is the primary goal of government, so, the risk preference of local government and central government is risk aversion. The central government includes relevant national sectors which promulgate policy, evaluate and supervise the construction of low-carbon city, such as National Development and Reform Commission, Ministry of Environmental Protection and Ministry of Industry and Information Technology etc. The local government refers to competent department and executive agency of low-carbon city, such as local people’s government, local development and reform commission, environmental protection bureau and construction commission etc.
(2) During the construction of low-carbon city, local government need to spend a lot of manpower, material and financial resources to carry out low-carbon policies, at the same time, the development of low-carbon city can enhance

Table 65.1 The strategies matrix for central government and local government

Central government		Local government	
		Carry out actively	Cope negatively
	Supervision & assessment	(supervision & assessment, carry out actively)	(supervision & assessment, cope negatively)
	Without supervision & assessment	(without supervision & assessment, carry out actively)	(without supervision & assessment, cope negatively)

itself fame and competition, in addition, it is advantageous for local government to obtain state financial support, favorable policies and attract investment. Central government supervises local government's behavior of low-carbon construction. If local government passes the examination, it will obtain support policy from central government, such as tax relief, concessional loans and financial subsidy etc. If not, central government will punish local government, and cancel relevant support policy.

(3) It is assumed that local government has two alternative strategies: carry out actively or cope negatively. Meanwhile, central government has two alternative strategies: supervision & assessment or without supervision & assessment. As a result, the game parties' strategy space is as follows (Table 65.1):

(4) In the evolution of game parties' behavior, it is assumed that the proportion of central government chooses supervision & assessment is "x", the proportion of central government doesn't choose supervision & assessment is "1 − x", and the proportion of local government carries out actively is "y", the proportion of local government cope negatively is "1 − y".

65.3.2 Modeling Establishment

The interpretation of game parties' income and expenditure parameters is as follows:

C_G is the costs of local government for carrying out low-carbon construction actively; P_G is the promotion of city competition after carrying out low-carbon construction actively; L_G is the lifting of city fame after carrying out low-carbon construction actively. It will take money if central government supervises and assesses local government's behavior. So, C_C is the costs that central government spends, such as the costs of monitoring, the costs of investigation and wage etc.; S is reward and invisible welfare that central government gives to local government for carrying out low-carbon construction actively, including tax relief, concessional loans, special funds and favorable policies etc.; F is the punishment that central government imposes on local government for coping negatively; E is social and ecological benefits of local government after carrying out low-carbon construction

Table 65.2 The pay-off matrix for central government and local government

Central government		Local government	
		Carry out actively (y)	Cope negatively (1 − y)
	Supervision & assessment (x)	$Rc - Cc - S + E$, $R_G - C_G + P_G + L_G + S$	$Rc - Cc + F$, $R_G - F$
	Without supervision & assessment (1 − x)	$Rc + E$, $R_G - C_G$	Rc, R_G

actively. R_G is the return of local government supposing it follows its traditional development, and, R_G is also the return of local government supposing it copes with low-carbon construction negatively; R_C is the return of central government supposing the city follows its traditional development. Therefore, the game pay-off matrix is as follows (Table 65.2):

65.4 Results and Discussion

65.4.1 Results of Replicated Dynamic Equations

U_{C1} is the average expected revenue of central government when it supervises and assesses the low-carbon construction carrying out by local government; U_{C2} is the average expected revenue of central government when it doesn't supervise and assess the low-carbon construction carrying out by local government; $\bar{U}_C$ is the expected revenue of the group. So the operational equations are as follows:

$$U_{C1} = y(Rc - Cc - S + E) + (1 - y)(Rc - Cc + F) = Rc - Cc + F + y(E - S - F)$$
$$U_{C2} = y(Rc + E) + (1 - y)Rc = Rc + yE$$
$$\bar{U}_C = xU_{C1} + (1 - x)U_{C2} = Rc + x(F - Cc) + yE - xy(S + F)$$

U_{G1} is the average expected revenue of local government when it carries out low-carbon construction actively; U_{G2} is the average expected revenue of local government when it copes with low-carbon construction negatively; $\bar{U}_G$ is the expected revenue of the group. So the operational equations are as follows:

$$U_{G1} = x(R_G - C_G + P_G + L_G + S) + (1 - x)(R_G - C_G)$$
$$U_{G2} = x(R_G - F) + (1 - x)R_G = R_G - xF$$
$$\bar{U}_G = yU_{G1} + (1 - y)U_{G2} = R_G - xF - yC_G + xy(P_G + L_G + S + F)$$

65.4.2 Analysis and Discussion on the Evolutionary Stable Strategy of Central Government

This paper builds the Replicated Dynamic Equation about the proportion of central government's supervision and assessment according to the Game pay-off matrix:

$$F(\mathrm{x}) = \frac{dx}{dt} = x(U_{C1} - \bar{U}c) = x(1-x)[F - Cc - y(S+F)]$$

Let $F(\mathrm{x}) = 0$, the possible stable state of equation can be calculated as follows:

$$x = 0, \quad x = 1, \quad y = \frac{F - Cc}{S+F}$$

According to property of evolutionary stable strategy, it is an evolutionary stable strategy (ESS) when $F'(x) = \frac{dF(x)}{dx} = (1-2x)[F - Cc - y(S+F)] < 0$.

Then, we discuss the issue separately under three different conditions according to the value of $F - Cc$.

(1) If $F - Cc < 0$, then $F - Cc - y(S+F) < 0$, so the evolutionary stable strategy is $x = 0$.

It means that central government will not supervise and assess the low-carbon construction carrying out by local government when the costs that central government spends are greater than the punishment that central government gives to local government.

If $\mathrm{F} - \mathrm{Cc} > 0$, $\frac{F-Cc}{F+S}$ and y are both between 0 and 1, we need compare the value of them to analysis the evolutionary stable strategy.

(2) If $0 < y < \frac{F-Cc}{F+S} < 1$, then $F - Cc - y(S+F) > 0$, so the evolutionary stable strategy is $x = 1$.

It means that if the proportion of local governments that carry out low-carbon construction actively is less than $\frac{F-Cc}{F+S}$, central government will gradually realize that the policy implementation of low-carbon city is not carried out effectively by local government. Finally, central government will supervises and assesses the low-carbon construction timely on behalf of whole benefits to realize the aim of low-carbon society.

(3) If $0 < \frac{F-Cc}{F+S} < y < 1$, then $F - Cc - y(S+F) < 0$, so the evolutionary stable strategy is $x = 0$.

It means that if the proportion of local governments that carry out low-carbon construction actively is greater than $\frac{F-Cc}{F+S}$, carbon emission of whole society is improved effectively. It is not necessary for central government to supervise and assess local government which take it a lot of manpower, material and financial resources. Therefore, the optimal strategy for central government is without supervision and assessment.

65.4.3 Analysis and Discussion About the Evolutionary Stable Strategy of Central Government

This paper builds the Replicated Dynamic Equation and Evolutionary Stable Strategy about the proportion that local government carries out low-carbon construction actively according to the Game pay-off matrix:

$$F(y) = \frac{dy}{dt} = y(U_{G1} - \bar{U}_G) = y(y-1)[C_G - x(P_G + L_G + S + F)]$$

Let $F(\mathrm{y}) = 0$, we can calculate the possible stable state of equation:

$$y = 0, \quad y = 1, \quad x = \frac{C_G}{P_G + L_G + S + F}$$

According to property of evolutionary stable strategy, it is an evolutionary stable strategy (ESS) when

$$F'(y) = \frac{dF(y)}{dy} = (2y-1)[C_G - x(P_G + L_G + S + F)] < 0$$

Then, we discuss the issue separately under different conditions according to the relative value of C_G and $P_G + L_G + S + F$.

(1) If $C_G > P_G + L_G + S + F$, because $0 < x < 1$, then $C_G - x(P_G + L_G + S + F) > 0$, so the evolutionary stable strategy is $y = 0$.

Since local government pursues immediate interests, when the costs of local government for carrying out low-carbon construction are less than all proceeds it can earn, local government's motivation will decline dramatically. After long-time strategy adjustment, local government will cope with low-carbon construction negatively.

(2) If $C_G < P_G + L_G + S + F$, because $\frac{C_G}{P_G + L_G + S + F}$ and x are both between 0 and 1, we need discuss the issue separately under two different conditions:

If $0 < \frac{C_G}{P_G + L_G + S + F} < x < 1$, then $C_G - x(P_G + L_G + S + F) < 0$, so the evolutionary stable strategy is $y = 1$.

If the costs of low-carbon construction are pretty low, and the proportion of supervision & assessment is greater than $\frac{C_G}{P_G+L_G+S+F}$. After long-time study, imitation and strategy adjustment from each other, and under the pressure of central government, local government will carry out low-carbon construction.

If $0<x<\frac{C_G}{P_G+L_G+S+F}<1$, then $C_G-x(P_G+L_G+S+F)>0$, so the evolutionary stable strategy is $y=0$.

At the beginning of low-carbon construction, if the momentum of supervision & assessment is not enough, and after long-time evolution, local government will not carry out low-carbon construction under the influence of fluke.

65.5 Conclusions and Recommendations

It can be found that the dynamic impact process of each influencing factor on strategy selected and decision among central government and local government can get deep quantitative analysis based on evolutionary game theory. It provides important and valuable references for helping policy designers adopt effective policies and measures to promote the development of low-carbon city in China.

From the above analysis through the Replicated Dynamic Equations of central government, it can be seen that the costs that central government spends, the punishment that central government imposes to local government for coping negatively are the most important impact factor for the central government decision about whether or not carrying out monitoring and assessing the low-carbon city process. From the above analysis through the Replicated Dynamic Equations of local government, it can be seen that the costs of local government for developing low-carbon construction should be given the highest consideration. Furthermore, the rewards and invisible welfare that central government gives to local government for carrying out low-carbon construction actively, the promotion of city competition and city fame after carrying out low-carbon construction actively are also important impact factor for the local government decision about whether or not to develop low-carbon city positively.

It can be summarized that these impact factors will to a large extent determine the success of implementing low-carbon city in China. However, it appears that currently the central government has insufficient financial support and dynamic supervision to the local governments' low-carbon practice. Therefore, it is appreciated that the central government can promote the low-carbon city development through setting up a special fund supporting low-carbon city construction and encouraging local government to develop carbon market. On the other hands, the local government should give more attention to local long-term development and profits, thus the final ESS can be realized finally.

Acknowledgements This study is part of the research project sponsored by the Chinese National Social Science Program Fund, entitled "Assessment indicators for low-carbon city (15AZD025)".

References

Becky H (2012) A low-carbon London now and beyond. In: Paul W (ed) Base London 2012 report, London, England

Betsill M, Bulkeley H (2007) Looking back and thinking ahead: a decade of cities and climate change research. Local Environ 12:447–456

Cheng H, Li C (2014) On the experiences of foreign low carbon city construction with the perspective of good governance. Chin Pub Adm 32–35

Du D, Zhuang G, Xie H (2015) Study on the evaluation of low-carbon cities from "promoting construction by evaluation" to "the combination of evaluation and construction". Urban Dev Stud 22:7–11

Gavin N (2004) Climate action plan for San Francisco local actions to reduce greenhouse gas emissions. San Francisco Department of the Environment San Francisco Public Utilities Commission, San Francisco

Hou F, Li M (2016) The development path research of energy low-carbon transformation of the Changzhutan City group. Spec Zone Econ 94–98

Khanna N, Fridley D, Hong L (2014) China's pilot low-carbon city initiative: a comparative assessment of national goals and local plans. Sustain Cities Soc 12:110–121

Liu J, He Y (2015) Decoupling analysis between the economic growth and carbon emissions in Chinese low-carbon cities pilots. Sci Technol Prog Policy 32:51–55

Liu Z, Geng Y, Xue B, Dong H, Han H (2011a) Low-carbon city's quantitative assessment indicator framework based on decoupling model. China Popul Resour Environ 21:19–24

Liu Z, Geng Y, Xue B, Fu J, Tang X (2011b) Relationships between economic growth and CO_2 emissions for low-carbon pilot provinces in China. Resour Sci 33:620–625

Nishida Y, Hua Y (2011) Motivating stakeholders to deliver change: Tokyo's cap-and-trade program. Build Res Inf 39:518–533

Örjan L, Charlotta H, Adi M (2010) Stockholm action plan for climate and energy 2010–2020

Ouyang H (2016) Research on the development path of national pilot low-carbon city (town) based on the perspective of carbon emission reduction. Urban Dev Stud 23:15–20

Parzen J (2010) Lessons learned: creating the Chicago climate action plan: city of Chicago department of environment, Chicago. J Great Lakes Res 36(sp2):115–117

Plan of Copenhagen Climate Adaptation (2011) Copenhagen carbon neutral by 2025, City of Copenhagen

Rudolph S, Kawakatsu T (2012) Tokyo's greenhouse gas emissions trading scheme: a model for sustainable megacity carbon markets. Market Based Instrum Nat Experiences Environ Sustain 77–93

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016a) A global perspective on the sustainable performance of urbanization. Sustainability 8:783

Shen L, Song X, Wu Y, Liao S, Zhang X (2016b) Interpretive structural modeling based factor analysis on the implementation of emission trading system in the Chinese building sector. J Clean Prod 127:214–227

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Sheng G (2016) Policy analysis of the low–carbon city construction in China. Ecol Econ 32:39–43

Shenzhen's Development and Reform Commission (2012) The mid-long term planning for Shenzhen low-carbon development

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Song W (2012) Appraisal of low-carbon development to 28 cities along the Yangtze River. Areal Res Dev 31:139–144

Tan Y, Shuai C, Jiao L, Shen L (2017) An adaptive neuro-fuzzy inference system (ANFIS) approach for measuring country sustainability performance. Environ Impact Assess Rev 65:29–40

Wang Y (2012) Countermeasures study on Chinese low-carbon urban construction from the perspective of behavior subject theory. Sci Technol Manage Res

Yang R, Wang J (2011) Searching for China's low-carbon city development path: a landscape oriented perspective. Urban Dev Stud 18:53–59

Zhang W, Ma Z (2014) The local government role and behavior of institutional innovation in low carbon city pilot: a case of Zhuhai City. Chin Pub Adm 353

Zheng H, Hu J, Wang W (2016) When will 100 Chinese cites reach peak carbon? China Popul Resour Environ 26:48–54

Chapter 66
Examining Critical Factors Affecting Knowledge Transfer in Public-Private Partnership (PPP) Projects

T.T. Liu and Y.C. Wang

66.1 Introduction

In recent years, Public-Private Partnerships (PPPs) have been seen as important delivery models for the provision of public facilities and associated services in China, due to advantages such as alleviating the government's budgetary constraints, better risk allocation and improved level of service quality (Liu and Yamamoto 2009). PPPs have been increasingly used in infrastructure sectors, such as power station, water and wastewater treatment, public housing and urban rail (Kumar and Fouzdar 2016). In order to promote wider application of PPPs, a PPP center was set up within the Ministry of Finance to coordinate PPP activities at a national level, to offer expert advice assisting the planning and execution of PPP projects and to provide a platform for knowledge sharing (Zhang et al. 2015). The China's National Development and Reform Commission (NDRC) has established a database for PPP projects, delivering information regarding project pipelines to the market (Liu et al. 2016). A series of policies and guidelines, such as *Note on Standardizing Contract Management in Public-Private Partnership Projects* and *Guidelines on standardized PPP contract*, have been released to provide China's approach to PPP procurement and the government's position in transactions (Xu et al. 2010).

Despite the Chinese government's growing interests in using PPPs, prior studies show that PPP procurement are complex, given the longer timeframes, wider scope of services contracted and complicated contractual arrangements (Shang et al. 2016). Also, PPPs represent relatively new delivery models. Both public and private sector practitioners are new to the process, and are generally in lack of knowledge and experience to structure and carry out a PPP transaction. It is likely that PPP projects may lead to sub-optimal outcomes, as suggested by considerable

T.T. Liu (✉) · Y.C. Wang
School of Economics and Management, Beijing Jiaotong University, Beijing, China
e-mail: t.liu@bjtu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_66

international experiences. PPP teams recognize the benefit of knowledge transfer such as avoiding making similar mistakes, mitigating potential risks, and facilitating innovation through the utilization of best practices (Robinson 2010). Successful knowledge transfer can result in an organization accumulating or assimilating new knowledge, increasing PPP projects' intellectual capital or resource. It is therefore of great importance to transfer the knowledge gained from previous projects to later attempts.

Given the inherent complexity of knowledge and the diversity of processes and mechanisms associated with the knowledge transfer, successful transfer of knowledge is not usually easy to achieve. It is especially challenging for PPP projects. Due to the private sector's concern over intellectual properties and commercial confidentiality, they may be reluctant to share or transfer knowledge. The knowledge recipient's absorptive capacity is another hindrance to knowledge transfer because organizations involved in PPPs generally lack of prior knowledge and capabilities to manage new PPP-related knowledge. With regard to the complexity and special characteristics of knowledge transfer in PPP projects, it is crucial to identify the critical factors affecting knowledge transfer, based on which strategies and management interventions can be derived to facilitate such knowledge management process.

This paper aims to identify the critical factors for improving knowledge transfer processes in PPP projects. Based on a thorough literature search, this research first identifies twenty-five factors, under five categories. A questionnaire survey was then conducted to evaluate the relative importance of each factor. Following a statistical analysis, the critical factors were drawn out and discussed in detail. This research provides useful reference for organizations involved in PPPs on how to increase the effectiveness and efficiency of knowledge transfer. It also sets out directions for practitioners to design mechanisms and processes so that the knowledge accumulated in previous projects can be better captured and applied in future PPPs.

66.2 Literature Review

66.2.1 PPPs: Theories and Practices

Despite the worldwide use of PPPs in the provision of public infrastructure and related services, there is no unified definition about this term. The definitions of PPPs vary among countries given their specific context and policy objectives. According to the World Bank (2007), PPPs are "an agreement between a government and a private firm under which the private firm delivers an asset, a service, or both, in return for payments contingent to some extent on the long-term quality or other characteristics of outputs delivered". In general, a PPP usually embraces a range of interrelated activities from (1) planning, (2) financing, (3) design,

(4) construction, (5) operation and maintain to (6) monitoring and regulation of services. Based on the interaction of these activities, PPP are implemented using different models, such as Design, Build, Finance, Operate (DBFO) and Design, Build, Finance, Maintain (DBFM).

Since being introduced by the UK government in the 1990s, PPPs have been widely used around the globe. Similar to countries such as Australia, the PPP development in China can been generally divided into two main phases, with the first generation being primarily motivated by private finance and the second generation of PPPs focusing on introducing private sector's skills and expertise to increase value for money for taxpayers. The release of the policy note *Suggestions on Promoting and Guiding Private Investments* and the execution of pilot PPP project, Beijing Metro Line 4 (Liu and Wilkinson 2013), has been seen as the watershed for the two generations of PPPs. Previously, PPPs were implemented in a variety of sectors such as water and wastewater, venues, land transport and power stations, mainly in the form of BOT. As for the second-generation PPPs, the government has set out clear policy objectives for adopting and promoting PPPs, which are to leverage the private sector's finance and expertise to enhance the efficiency of asset delivery and level of service quality. A number of PPP projects have been conceived, procured and implemented under the current policy directions.

China faces legal and regulatory restrictions on private sector involvement in public sector procurement (Ling et al. 2014). Despite the availability of a series of policies and guidelines allowing private sector participation in some infrastructure sectors, uncertainties remain regarding the legitimacy of the government's entering into PPP contracts. In addition, the guidelines for PPPs are relatively limited with a few documents setting out specific legal directions for PPP projects. Due to the lack of policies and guidelines, it is difficult for the public bodies to structure and manage PPP arrangements in China, as opposed to countries such as the UK, Canada and Australia, where a range of guidance documents are available. Without a consistent and standard approach towards PPPs, the industry is likely to be reluctant to enter into China's PPP market, owing to uncertainties around risk allocation and payment mechanisms.

66.2.2 Knowledge and Knowledge Transfer in PPP Projects

Knowledge is referred to as the insight, perspective and experience that guide people's thoughts, behaviors and decisions. It is the product of learning which is personal to an individual (Quintas 2005). Knowledge is usually categorized into explicit and tacit knowledge. Explicit knowledge is captured and stored in certain formats such as text, photographs and videos. It can be reused in a consistent and repeatable way (Chansoo et al. 2015). Tacit knowledge, on the other hand, is stored inside people's minds and it is difficult to codify and express. It can be technical, such as an expert's know-how or cognitive like values, beliefs and perceptions

(Martin 2015). PPP projects involve long-term interaction and collaboration between diverse groups, including architects, engineers, quantity surveyors, legal and financial advisors, construction managers and other team members. The preparation and implementation of PPPs involve both explicit and tacit knowledge. Explicit knowledge is written down in documents, such as guidance on value for money assessment, business case development toolkit, risk allocation matrix, procurement procedures and standardized contract. Examples of tacit knowledge include valuation of risks in PPP projects, contract negotiation tactics and skills for preparing well-articulated output specifications (Xu et al. 2015).

Knowledge transfer can be described as a change process involving the movement of knowledge or skills from one specialized knowledge entity, such as individuals, groups and organizations to another or from one place to another (Carlile and Rebentisch 2003). The purpose of knowledge transfer is to absorb new knowledge and taking advantage of it in an effective and efficient fashion. Knowledge transfer is broadly considered as important for construction projects (Mochamad and Rudi 2015). It is especially vital for organizations entering into or engaging with PPPs. As a new form of procurement, parties are not familiar with the process and structure, and are lack of skills and expertise in the field. Also, PPPs entail long contract period, mistakes made in the procurement stage arising from lack of knowledge may negatively affect the service delivery outcomes. Organizations involved in PPPs have commonly recognized the needs to transfer lessons learned for improvement and better performance of PPP projects (Nodni and Elhag 2009).

There are a variety of mechanisms available for transferring knowledge. In some projects, an information system is used to share and transfer knowledge that can be documented. Team members can access to it through project intranet (Linda et al. 2000). As a PPP project proceeds, a case study extracting the best practices and lessons learned serves as a useful technique for transferring the knowledge created and accumulated in the current project to latter endeavors. Sometimes a public entity, such as the Office of the Auditor-General in New Zealand, will conduct an independent review of PPP projects, assessing the performance of PPPs to date and summarizing good practices and lessons learned. The recommendations made in the review report have important implications to later projects. Also, a dedicated PPP unit has been established in many countries, such as the UK, Australia and China, which acts as a center of expertise. The expert advice provided by such organizations is important for knowledge transfer and sharing across projects.

66.2.3 Factors Affecting Knowledge Transfer in PPPs

Based on a comprehensive literature review, twenty-five factors which may affect knowledge transfer in PPP projects were identified. Through a content analysis, the factors can be grouped under five categories, as shown in Table 66.1.

Table 66.1 Factors affecting knowledge transfer in PPP projects

Factors Reference	Szulanski (2000)	Cummings et al. (2003)	Argote et al. (2000)	Galbraith (1990)	Cohen et al. (1998)	Cohen et al. (1990)	Khamseh and Jolly (2008)	Tang (2006)	Jefferies et al. (2002)	Doubra et al. (2009)	Kwawu et al. (2010)	Kwawu et al. (2010)	Liyanage et al. (2009)
(A) *Knowledge-related factors*													
Articulability of knowledge	√	√											
Embeddedness of knowledge		√	√										
Observability of knowledge				√									
(B) *Capability-related factors*													
Reliability of knowledge source	√												
Absorptive capacity of recipient	√				√	√	√						
Retentive capacity of recipient						√		√					
Experience of PPP teams									√				
Innovation capability of PPP teams										√			
(C) *Pathway-related factors*													
Use friendly technology											√		
Strategically planning and												√	

(continued)

Table 66.1 (continued)

Factors Reference	Szulanski (2000)	Cummings et al. (2003)	Argote et al. (2000)	Galbraith (1990)	Cohen et al. (1998)	Cohen et al. (1990)	Khamseh and Jolly (2008)	Tang (2006)	Jefferies et al. (2002)	Doubra et al. (2009)	Kwawu et al. (2010)	Kwawu et al. (2010)	Liyanage et al. (2009)
operationally planning													
Feedback mechanisms												√	
Protection for knowledge transfer							√						
(D) *PPP projects-related factors*													
Support from the team leaders												√	
Political support													√
Cost & budget availability											√		√
Avoiding time overturns													√
Support from experts													
(E) *Culture-related factors*													
Concern & trust													
Communication & collaboration											√		√
Win-win											√		√
Training & education								√					
Learning culture								√					

(continued)

Table 66.1 (continued)

Factors Reference	Szulanski (2000)	Cummings et al. (2003)	Argote et al. (2000)	Galbraith (1990)	Cohen et al. (1998)	Cohen et al. (1990)	Khamseh and Jolly (2008)	Tang (2006)	Jefferies et al. (2002)	Doubra et al. (2009)	Kwawu et al. (2010)	Kwawu et al. (2010)	Liyanage et al. (2009)
Management & leadership culture												√	
Rewards & incentives											√		
Openness											√		
Total number of factors identified from each reference	3	2	1	1	1	2	2	3	1	1	6	4	5

Factors Reference	Carrillo et al. (2008)	Davenport et al. (1998)	Disterer (2001)	Wong (2005)	Holsapple et al. (2000)	Rhodes et al. (2008)	Schofield (2013)	Mohammad et al. (2013)	Hamid et al. (2010)	Shu et al. (2007)	Nurdiana (2011)	Total number of references for each factor
(A) *Knowledge-related factors*												
Articulability of knowledge						√	√		√	√		6
Embeddedness of knowledge							√					3
Observability of knowledge												1
(B) *Capability-related factors*												
Reliability of knowledge source												1
Absorptive capacity of recipient									√	√		6
Retentive capacity of recipient												2

(continued)

Table 66.1 (continued)

Factors Reference	Carrillo et al. (2008)	Davenport et al. (1998)	Disterer (2001)	Wong (2005)	Holsapple et al. (2000)	Rhodes et al. (2008)	Schofield (2013)	Mohammad et al. (2013)	Hamid et al. (2010)	Shu et al. (2007)	Nurdiana (2011)	Total number of references for each factor
Experience of PPP teams												2
Innovation capability of PPP teams							√					2
(C) *Pathway-related factors*												
Use friendly technology												1
Strategically planning and operationally planning												1
Feedback mechanisms												1
Protection for knowledge transfer									√			2
(D) *PPP projects-related factors*												
Support from the team leaders												1
Political support												1
Cost & budget availability												2
Avoiding time overturns												1

(continued)

Table 66.1 (continued)

Factors Reference	Carrillo et al. (2008)	Davenport et al. (1998)	Disterer (2001)	Wong (2005)	Holsapple et al. (2000)	Rhodes et al. (2008)	Schofield (2013)	Mohammad et al. (2013)	Hamid et al. (2010)	Shu et al. (2007)	Nurdiana (2011)	Total number of references for each factor
Support from experts	√											1
(E) *Culture-related factors*												
Concern & trust		√	√				√		√	√		5
Communication & collaboration								√				3
Win-win												2
Training & education				√							√	3
Learning culture									√			2
Management & leadership culture		√	√		√			√		√		6
Rewards & incentives		√	√							√		3
Openness												1
Total number of factors identified from each reference	1	3	3	1	1	1	4	2	5	5	1	59

66.3 Research Methods

66.3.1 Data Collection

The research objective was to identify the critical factors influencing the effectiveness and efficiency of knowledge transfer in PPP projects. In order to achieve the objective, a comprehensive literature research was first conducted to summarize the factors that may affect the knowledge transfer in PPP context. A list of twenty-five factors were identified from literature review. A questionnaire survey was then conducted to assess the importance of each factor, based on which critical factors were drawn out. Using a five-point Likert scale from 1 to 5, in which 1 represents "least important" and 5 symbolizes "most important", the respondents were asked to rate the degree of importance of the identified factors based on their experience

Three principal criteria were used for the selection of survey respondents: (1) having a good comprehension of PPPs; (2) with hands-on experience PPP projects and (3) being familiar with concept and practices of knowledge transfer. The target respondents include practitioners from PPP project Company, public procuring authorities and consultancy companies. Survey respondents were identified from the NDRC's website providing information about PPP projects, involved organizations and professionals. Potential respondents were approached by online survey software called *Questionnaire Star* and e-mails. Meanwhile, questionnaire were also distributed to respondents directly when the researchers attend a series of PPP seminars. A total of 100 questionnaires were sent with 63 being returned, representing a response rate of 63%. Table 66.2 shows the background information of the respondents.

Table 66.2 Background information of questionnaire survey respondents

Characteristic		No.	%
Experience in PPP projects	<3 years	28	44
	3–5 years	17	27
	5-10 years	14	22
	≥ 10 years	4	7
Organization type	Government agencies	6	10
	State-owned enterprises	13	21
	Private enterprises	33	52
	Financial institutions	7	11
	Others	4	6
Positions in their organizations	Senior-level management	7	11
	Middle-level management	46	73
	Low-level management	8	13
	Undertaker	2	3

66.3.2 Data Analysis

One sample t-test of the mean was implemented using the Statistical Package for Social Science (SPSS), in accordance with the sample's ratings, to check if the factors confirmed within the questionnaire were critical in affecting knowledge transfer in PPP context. The t-test results are provided in Table 66.3. The significant level for the tests was set at 0.05. As shown in Table 66.3, only one factor, namely embeddedness of knowledge (sig.0.331), has a significance level greater than 0.05, indicating that it is not statistically significant with regard to knowledge transfer in PPP projects, whilst the other 24 factors have an influence.

Using SPSS descriptive statistics, a ranking of the factors was conducted to identify the critical factors affecting knowledge transfer in the PPP context (Chang et al. 2011). Table 66.4 gives the rankings of the top ten critical factors. Based on the content analysis (Krippendorff 1980), the top 10 critical factors can be classified into four groups: (1) knowledge-related factors; (2) capability-related factors; (3) PPP projects-related factors; and (4) culture-related factors. In the following section, a discussion of the critical factors, under four categories, is presented by incorporating the questionnaire survey results and findings from prior studies.

66.4 Survey Discussion

66.4.1 Knowledge-Related Factors

66.4.1.1 Articulability of Knowledge

Articulability of knowledge largely influences knowledge transfer in PPP context. This agrees with Szulanski's study (2000), which showed that explicitation of knowledge, as one of knowledge attributes, plays an important role in the knowledge transfer. Knowledge is a kind of capacity reserving in human's brain, and reflects as the capacity for explaining and transferring information based on knowledge. The implementation of PPPs involves a considerable amount of implicit knowledge, such as know-how from the constructors, experience in estimating the value of potential risks and negotiation skills for PPP contracts. Implicit knowledge is highly based on individual knowledge, which is difficult to express, observe and format. This research confirms Cummings and Teng's finding (2006) that the harder it is to express the knowledge, the more difficult it is to transfer knowledge.

Table 66.3 One-simple t-test result for the 25 factors affecting knowledge transferring in PPP projects

No.	Factors	Mean	t-value	SD	Significance (2-tailed)
(A) *Knowledge-related factors*					
1.	Articulability of knowledge	4.81	28.529	0.503	0.000
2.	Embeddedness of knowledge	3.11	0.980	0.900	0.331
3.	Observability of knowledge	3.90	10.424	0.689	0.000
(B) *Capability-related factors*					
4.	Reliability of knowledge source	4.57	16.053	0.777	0.000
5.	Absorptive capacity of recipient	3.81	8.984	0.715	0.000
6.	Retentive capacity of recipient	3.46	3.184	1.148	0.002
7.	Experience of PPP teams	4.76	21.837	0.640	0.000
8.	Innovation capability of PPP teams	4.33	16.342	0.648	0.000
(C) *Pathway-related factors*					
9.	Use friendly technology	4.06	10.049	0.840	0.000
10.	Strategical planning and operational planning	3.84	6.655	1.003	0.000
11.	Feedback mechanisms	3.38	2.445	1.237	0.017
12.	Protection for knowledge transfer	4.22	12.577	0.771	0.000
(D) *PPP projects-related factors*					
13.	Support from the team leaders	4.30	14.547	0.710	0.000
14.	Political support	4.54	16.588	0.737	0.000
15.	Cost & budget availability	3.27	2.875	0.745	0.006
16.	Avoiding time overturns	3.65	6.252	0.826	0.000
17.	Support from experts	4.32	13.419	0.779	0.000
(E) *Culture-related factors*					
18.	Concern & Trust	4.56	18.520	0.667	0.000
19.	Communication & Collaboration	4.46	19.614	0.591	0.000
20.	Win-win	3.38	2.395	1.263	0.020
21.	Training & Education	4.24	14.264	0.689	0.000
22.	Learning culture	4.32	15.658	0.668	0.000
23.	Management & leadership culture	4.30	14.547	0.710	0.000
24.	Rewards & Incentives	4.67	27.839	0.475	0.000
25.	Openness	3.49	2.858	1.366	0.006

66.4.2 Capability-Related Factors

66.4.2.1 Experience of PPP Teams

PPPs are a relatively new procurement form and practitioners are continuously learning from the experience. The research results concur with (Kwawu et al. 2010) that the experience of PPP teams has a significant impact on knowledge transfer.

Table 66.4 Rankings of significant factors affecting knowledge transferring in PPP contexts

Rank	Factors affecting knowledge transfer in PPP projects	Mean
1	Articulability of knowledge	4.81
2	Experience of PPP teams	4.76
3	Rewards & incentives	4.67
4	Reliability of knowledge source	4.57
5	Concern & trust	4.56
6	Political support	4.54
7	Communication & collaboration	4.46
8	Innovation capability of PPP teams	4.33
9	Support from experts	4.32
10	Learning culture	4.32

When the knowledge source lacks experience, PPP teams may fail to identify the value of acquired knowledge and the potential usefulness of accumulated knowledge. They tend to lack of the ability to comprehend the knowledge and transform knowledge into expression, leading to low efficiency of communication and then hindering the outcomes of knowledge transfer in PPP projects (Szulanski 2000).

66.4.2.2 Reliability of Knowledge Source

This research finds that the reliability of knowledge source directly affects the process of knowledge transfer. This is consistent with previous finding that the reliability of knowledge source is one of the most critical factors affecting knowledge transfer in other contexts. Authorities are more likely to be believed and the knowledge from them is more likely to be transferred (Liu et al. 2010). When the reliability of knowledge source is not confirmed, the knowledge recipient would then doubt the credibility and usefulness of the knowledge, resulting in the outcomes of knowledge transfer being compromised (Joanne 2000).

66.4.2.3 Innovation Capability of PPP Teams

In this research, the innovation capability is found to be a critical factor for knowledge transfer in PPPs. This is in line with Eaton et al. (2006) that the ability to bring forward innovation is essential to ensuring successful knowledge transfer. Innovation is defined as the use of knowledge in the development and introduction of new products, processes or services (Dodgson and Gann 2002). Innovation is desired in construction projects because of the objectives to increase quality and reduce costs and timeframes (Gann 2000). In the case of PPPs, innovation is particularly desirable as it is believed to be an important driver for value for money outcomes. The project organizations' management commitment to looking for innovative ways of executing PPPs beyond one-off project will enable them to establish partnerships with other organizations so that their experience and knowledge can be shared and transferred.

66.4.3 PPP Projects-Related Factors

66.4.3.1 Political Support

Hardcastle et al. (2005) were of a view that political support is crucial for the progression of PPP transactions, especially in the early stages. This research confirms that it is also the case for knowledge transfer in PPP projects. For projects with strong political support for knowledge transfer, the project team members will place much emphasis on summarizing and extracting best practices or lessons learned as projects progress, which is conducive to the formulation of a high-quality case study report or post-project review. Such documents would serve as valuable resources for future practitioners to refer to Dulaimi (2007).

66.4.3.2 Support from Experts

Unlike traditional procurement, PPPs involve the participation of client and service providers at all levels and across a wide range of disciplines (Carrillo et al. 2008). External legal, financial and technical advisors are usually engaged to ensure that the procurement processes are carried out as planned and contractual and financial arrangements are in line with the project's characteristics (Jefferies et al. 2002). The advisors, with rich PPP experience, provide the knowledge and expertise needed to structure and run a PPP. Through regular communication, meetings and seminars, PPP advisors' professional skills and insights greatly contribute to knowledge transfer.

66.4.4 Culture-Related Factors

66.4.4.1 Rewards & Incentives

Knowledge is a type of valuable resource. It takes considerable time and energy to acquire and accumulate. This research showed that rewards and incentives play a significant role in knowledge transfer, confirming (Osterloh and Frey 2010) assertions that both knowledge sources and recipients need incentives to achieve knowledge transfer. It is understandable that PPP teams are reluctant to transfer knowledge. They tend to be concerned about their due rewards or they are unwilling to spend time and resource to support knowledge transfer. Also, they may fear the possible loss of a competitive edge. On the other side of knowledge transfer, some recipients may be unwilling to absorb and apply new knowledge because the use of new knowledge is likely to change the way they are used to conduct their business, especially for staff working in organizations such as public sector entities and construction firms. Facing such barriers, designing reward and incentive mechanisms seem to be particularly critical for organizations involved in PPPs to facilitate knowledge transfer.

66.4.4.2 Concern & Trust

In line with Liyanage et al. (2009) findings, concern and trust is found to be vital for knowledge transfer in PPP projects. With mutual concern and trust, both sides of knowledge transfer are willing to communicate and support each other. Concern brings about mutual understanding, which helps to remove the barriers impeding knowledge transfer. Trust results in common expectations of reliability, consistency, and plausibility. Trust reduces the fear that others will act opportunistically (Daveport and Prusak 1998). When lacking trust between PPP teams, the knowledge recipients may cast doubt on the quality and applicability of new knowledge. They would engage with PPPs based on their own experiences rather than adopting the received PPP knowledge.

66.4.4.3 Communication & Collaboration

Knowledge transfer depends on good communication and collaboration between the knowledge sources and recipients so that the knowledge sources can better comprehend the need of recipients and the recipients have a correct understanding of PPP knowledge and apply it effectively. This reinforces (Infrastructure Australia 2008) points that communication and collaboration is the core for better performance of PPP projects. Knowledge transfer is the process for communication and collaboration between both sides, especially in PPP context, as a large portion of PPP knowledge is implicit, such as how to arrange the capital structure and the skills of drafting well-defined specifications. Such implicit knowledge largely relies on communication to transfer, in the form of daily interactions and informal talks or formal meetings, workshops and seminars.

66.4.4.4 Learning Culture

Knowledge transfer is a process that contributes to PPP teams' organizational learning. Learning culture, in turn has an influence on processes of knowledge transfer, as suggested by (Disterer 2001). Learning culture influences team members' motivation for learning and their learning capacity. A conducive learning culture will foster knowledge recipients to absorb and apply transferred knowledge (Berman and Heilweg 1989).

66.5 Conclusion

Owing to the complexity of PPP procurement, it is important that best practices and lessons learned from previous experiences can be transferred to latter attempts so as to mitigate potential risks, avoid making same mistakes and ultimately improve the PPP performance. Knowledge transfer, therefore plays a significant role in smooth development of PPP programs. This research aims to identify the critical factors for improving knowledge transfer processes in PPP projects. Based on a thorough literature search and an empirical questionnaire survey, this research showed the critical factors are: (1) knowledge-related factors such as articulability of knowledge; (2) capability-related factors including experience of PPP teams, reliability of knowledge source, and innovation capability of PPP teams; (3) PPP projects-related factors such as political support, and support from experts. (4) culture-related factors including rewards & incentives, concern & trust, communication & collaboration, and learning culture.

Given the special characteristics of PPP procurement, PPP teams need to adopt appropriate approaches to facilitate effective knowledge transfer. PPPs involve a large proportion of implicit knowledge, which is difficult to observe and express. Such unique features of knowledge require PPP teams to adopt commensurate means to facilitate knowledge transfer, such as setting up regular meetings, seminars and workshops. Lacking of capability in relation to knowledge transfer, PPP teams are suggested to engage experienced advisors and consult with experts from central PPP unit for capacity building. Given the importance of culture in knowledge transfer, conducive culture should be cultivated in PPP organizations. For example, appropriate rewards and incentive mechanisms are desired to motivate team members to transfer knowledge. Both formal and informal communication should be encouraged so that trust and collaboration can be better fostered. Also, a systematic training program is advocated to facilitate the cultivation of learning culture.

This research supports findings from prior studies highlighting the important features of knowledge transfer. Many of these findings have been extended by the research that are relevant to practitioners and experts involved in knowledge transfer in PPP projects. Clearly, transferring knowledge smoothly requires systematic thinking of how best to achieve knowledge transfer. This research provides useful reference for organizations involved in PPPs on how to increase the effectiveness and efficiency of knowledge transfer. It also sets out directions for practitioners to design mechanisms and processes so that the knowledge accumulated in previous projects can be better captured and applied in future PPPs.

Acknowledgements The authors would like to thank the National Natural Science Foundation of China for financially supporting this research (Grant No.: 71502011). It is also supported by the Fundamental Funds for Humanities and Social Sciences of Beijing Jiaotong University (Grant No.: 2015jbwj013).

References

Berman S, Heilweg S (1989) Perceived supervisor communication competence and supervisor satisfaction as a function of quality circle participation. J Bus Commun 26(1):103–122
Carlile PR, Rebentisch ES (2003) Into the black box: the knowledge transformation cycle. IEEE Eng Manage Rev 31(4):1180–1195
Carrillo P, Robinson H, Foale P, Anumba C, Bouchlaghem D (2008) Participation, barriers, and opportunities in PFI: the United Kingdom experience. J Manage Eng 24:138–145
Chang Y, Suzanne W, Regan P, Erica S (2011) Identifying factors affecting resource availability for post-disaster reconstruction: a case study in China. Constr Manage Econ 29:37–48
Chansoo P, Ilan V, Manuel B (2015) Transfers of tacit vs. explicit knowledge and performance in international joint ventures: the role of age original research article. Int Bus Rev 24(1):89–101
Cummings JL, Teng B (2006) The keys to successful knowledge-sharing. J Gen Manage 31(4):2–12
Daveport T, Prusak L (1998) Working knowledge: how organizations manage what they know. Harvard Business School Press, Boston, MA, p 52
Disterer G (2001) Individual and social barriers to knowledge transfer. In: Proceedings of the 34th annual hawaii international conference on IEEE, 8025
Dodgson M, Gann DM (2002) The intensification of innovation. Int J Innov Manag 6(1):1–31
Dulaimi MF (2007) Case studies on knowledge sharing across cultural boundaries. Eng Constr Archit Manage 14(6):550–567
Eaton D, Akbiyikli R (2006) An evaluation of the stimulants and impediments to innovation within PFI/PPP projects. Constr Innovation 6(2):63
Gann DM (2000) Building innovation: complex constructs in a changing world. Thomas Telford, London
Hardcastle C, Li B, Akintoye A, Edwards PJ (2005) Critical success factors for PPP/PFI projects in the UK construction industry. Constr Manage Econ 23:459–471
Infrastructure Australia (2008) National public private partnership policy framework [Online]. Available: http://www.infrastructureaustralia.gov.au
Jefferies M, Gameson R, Rowlinson S (2002) Critical success factors of the BOOT procurement system: reflection from the stadium Australia Case Study. Eng Constr Archit Manage 9 (4):352–361
Joanne R (2000) From Know-how to Show-how? questioning the role of information and communication technologies in knowledge transfer. Technol Anal Strateg Manage 12(4):429–443
Krippendorff K (1980) Validity in content analysis. Comput strategien Für Die Kommunikations Anal, 69–112
Kumar G, Fouzdar YS (2016) Risk management in PPP (Public private partnership) projects. Int J Eng Technol Sci Res 3(5):305–313
Kwawu W, Elhag T, Ballal T (2010) Knowledge transfer processes in PFI: Identification of barriers and enablers. The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors
Linda A, Paul I, John ML, Richard LM (2000) Knowledge transfer in organizations: learning from the experience of others. Organ Behav Hum Decis Process 82(1):1–8

Ling F, Ong S, Ke Y, Wang S, Zou P (2014) Drivers and barriers to adopting relational contracting practices in public projects: comparative study of Beijing and Sydney. Int J Proj Manage 32 (2):275–285

Liu T, Wilkinson S (2013) Can the pilot public–private partnerships project be applied in future urban rail development? A case study of Beijing Metro Line 4 project. Built Environ Proj Asset Manage 3(2):250–263

Liu Z, Yamamoto H (2009) Public-private partnerships (PPPs) in China: present conditions, trends, and future challenges. Interdisc Inf Sci 15(2):223–230

Liu N, Wu J, Xuan Z (2010) Impact of different individual behavior on knowledge transfer processes within the organization. Int Conf Artif Intel Comput Conf 2:352–360

Liu TT, Wang Y, Wilkinson S (2016) Identifying critical factors affecting the effectiveness and efficiency of tendering processes in Public-private partnerships (PPPs): a comparative analysis of Australia and China. Int J Project Manage 34(4):701–716

Liyanage C (2009) Knowledge communication and translation—a knowledge transfer model. J Knowl Manage 13(3):118–131

Martin D (2015) Knowledge (explicit, implicit and tacit): philosophical aspects, International encyclopedia of the social & behavioral sciences (Second edn.), pp 74–90

Mochamad AW, Rudi W (2015) Knowledge management maturity in construction companies. Procedia Eng 125:89–94

Nodni D, Elhag T (2009) Innovation and knowledge transfer in PPP/PFI projects: a literature review.In: 9th international postgraduate research conference (IPGRC)

Osterloh M, Frey BS (2010) Academic rankings and research governance, Ssrn Electron J, 4

Quintas P (2005) The nature and dimensions of knowledge management. In: Anumba CJ, Egbu C, Carrillo PM (eds) Knowledge management in construction, Blackwell, Oxford, pp 10–30

Robinson H (2010) A knowledge management framework to manage intellectual capital for corporate sustainability. In: Organizational learning and knowledge: concepts, methodologies, tools and applications, pp 803–818

Shang Z, Albert PC, Feng YB, Duan HX, Ke YJ (2016) Critical review on PPP Research—a search from the Chinese and international journals. Int J Project Manage 34(4):597–612

Szulanski G (2000) The process of knowledge transfer: a diachronic analysis of stickiness. Organ Behav Hum Decis Process 82(1):9–27

Xu YL, John FY, Chan Albert P C, Daniel Chan W M, Shou QW, Ke YJ (2010) Developing a risk assessment model for PPP projects in China—a fuzzy synthetic evaluation approach. Autom Constr 19(7):929–943

Xu YL, Chan Albert PC, Xia Bo, Queena K Qian, Liu Y, Peng Y (2015) Critical risk factors affecting the implementation of PPP waste-to-energy projects in China. Appl Energy 158 (15):403–411

Zhang S, Gao Y, Feng Z, Sun W (2015) PPP application in infrastructure development in China: institutional analysis and implications. Int J Project Manage 33(3):497–509

Chapter 67
Explication of Challenges with Acceptance of Marketing Functions in the Management of Construction Business Enterprise

J.E. Yankah, C. Aigbavboa and W. Thwala

67.1 Introduction

Marketing management is now widely adopted by manufacturing, distribution and many more service industries. Although marketing has a wide application in many industries, it has not yet been applied to any great extent by construction businesses (Moore 1984; Morgan and Morgan 1990; Morgan and Morgan 2006; Pheng 1991; Peck 1994; Rwelamila and Bowen 1995; Yankah 2015a, b), except those engaged in speculative house building where its benefits are comparatively understood. With serious reduction in demand for construction services in recent years, coupled with intense competition in the construction industry, marketing is expected to arouse the interest of the management construction business.

It is therefore satisfying that there is an increasing recognition in the industry about the role of marketing in the operations of construction business enterprises. In their findings, Naranjo et al. (2011) concur that: '*Construction enterprises are aware of the importance of involving marketing in their management functions as a way to adapt themselves not only to the continuous changes in the industry, but also to satisfy their clients' demands, while being competitive and improving their business strategy*' (Naranjo et al. 2011: 245). This, notwithstanding, the adoption and implementation of marketing in the construction industry continue to remain an uphill struggle with little to no success. The industry is known to have a record of poor performance in most of the marketing management related functions of managing a construction business enterprise (Preece et al. 2003; Naranjo et al. 2011).

J.E. Yankah (✉) · C. Aigbavboa · W. Thwala
Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
e-mail: ekowjonas@yahoo.com

J.E. Yankah
Department of Building Technology, Cape Coast Technical University, Cape Coast, Ghana

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_67

Yet the role of marketing in the operations of a business enterprise remains indispensable especially in the current business environment characterized by intense competition. In the words of Kotler and Keller (2012: 3), the indispensable role of marketing is summed up as: "*Finance, operations, accounting, and other business functions won't really matter without sufficient demand for products and services so the firm can make a profit. In other words, there must be a top line for there to be a bottom line. Thus financial success often depends on marketing ability*" of business enterprises especially those operating in intensely competitive business environments such as the case of the construction industry. The 'bottom line' as noted by Kotler and Keller (2012), is effective demand for the services of the business enterprise, which to a large extent is achieved through marketing management. It is upon this that the business enterprise can survive competition, to grow and to be profitable. In the absence of demand for construction services offered by the business enterprise, the business enterprise may cease to exist, which will render all other business functions such as estimating, scheduling, production among others irrelevant.

In their study Yankah and Dadzie (2015) used the contingency theory to explain the need for marketing in the operations of a business enterprise. The study showed that business enterprises need to achieve appropriate relation with their environment in order to survive, and is achieved by effective marketing management practices. This view is supported by Morgan's (1997) argument that survival is an issue of adaptation. This argument suggests that survival of a business enterprise depends on adaptation of business to changes that occurs in the business environment. Through marketing, business enterprises are able to identify changes in client desires resulting from variation in taste, aspirations and purchasing power (Yisa et al. 1995), in order to design offerings that meet such desires to ensure clients' satisfaction. This results in greater demand for such offerings upon which business survival derives its anchor.

Despite all the knowledge, an extensive search of leading electronic journal databases, including EBSCOHost, Emerald, Google Scholar and Science Direct suggest that little to nothing is known about what underpins the reluctance and the resistance with which the construction industry is adopting marketing. This study therefore attempts to explicate the challenges with utilization of marketing in the construction industry by drawing on the key constructs from the Technology Acceptance Model (TAM), which has been suitably modified for that purpose. The objectives are:

1. To determine the suitability of the constructs of the TAM for examination of issues with marketing acceptance in construction industry.
2. To modify/alter the TAM constructs for the purpose of examining challenges with marketing in construction.
3. To use existing empirical evidence to support the propositions in the modified TAM for construction marketing.

The rest of the article is structured as follows: First, a review of extant literature relevant to marketing management processes is undertaken. This is followed by a description of the Technology Acceptance Model (TAM). Parallels are drawn from the TAM and supported by other empirical works to explain what underpins the rather low utilization of marketing in the construction industry. Finally, implications, limitations and directions for future research are offered.

67.2 Marketing in Construction and Technology Acceptance

67.2.1 Marketing Management Process

Marketing management function in a business enterprise involves the practical application of marketing techniques and the management of a firm's marketing resources and activities (Kotler and Keller 2012). The application of marketing techniques and the management of firms' resources involves five main step which are; (1) understanding the marketplace and customer needs and wants, (2) designing a customer-driven marketing strategy, (3) constructing an integrated marketing program that delivers superior value, (4) building profitable relationships and creating customer delight, and (5) capturing value from customers to create profits and customer equity (Kotler and Keller 2012). Figure 67.1, shows the simple marketing model.

These processes require certain actions to be undertaken in order to realize its implementation. The performance of such actions is influenced by factors such as perceptions about marketing in terms of its benefits as well as the ease with which it can be used in the construction industry.

67.2.2 Technology Acceptance Model (TAM)

TAM is an adaptation of the Theory of Reasoned Action (TRA) to the other fields. TAM posits that perceived usefulness and perceived ease of use determine an individual's intention to use a system with intention to use serving as a mediator of

Fig. 67.1 A simple model of the marketing process. *Source* Kotler and Armstrong (2012)

actual system use. Perceived usefulness is also seen as being directly impacted by perceived ease of use.

Researchers have simplified TAM by removing the attitude construct found in TRA from the current specification (Venkatesh et al. 2003). Attempts to extend TAM have generally taken one of three approaches: by introducing factors from related models, by introducing additional or alternative belief factors, and by examining antecedents and moderators of perceived usefulness and perceived ease of use.

67.2.3 Similarity with Technology Acceptance in an Organization and Marketing Acceptance as Management Function in Construction

Marketing application in construction business can be likened to acceptance of new technology in an organization. Most often organizations examine the usefulness of the technology in question and analyze the ease with which such technology can be used. If these two factors are perceived positively, the likelihood is that the organisation will accept the new technology for use with no reluctance or resistance. If the two factors are not perceived favourably, then reluctance and resistance comes along with adoption of such technology. Similarly, the situation of marketing acceptance in the construction industry suggests that these two factors are involved in marketing's adoption by construction businesses.

Marketing as a management function in the operations of a construction business enterprise is unpopular news, which is received with indifference by construction business management. According to Morgan and Morgan (1991), marketing within the professional sector of the construction industry is considered at worst as a concept which is alien to the industry, and at best as an emerging new development that is viewed with skepticism. As a result, Moore (1984) noted that marketing management has not yet been applied to any greater extent in the construction industry. Morgan and Morgan (1990) similarly observe that marketing is less developed in the professional industry and often performed in most firms in an ad hoc basis.

Pheng (1991) notes that marketing has attracted only little attention among professionals, a situation which in the author's view is in direct contrast to the role of marketing in the consumer goods industry (Gummesson 1979), because marketing is accepted as one of the cornerstones of servicing the needs of clients and customers. Peck (1994) further indicated that some consulting firms are still struggling to understand and implement effective marketing programmes and this in the view of Rwelamila and Bowen (1995), suggests that construction businesses are still clinging to an out-dated, bull market philosophy: 'As long as we do good work we will always have plenty of work'.

With such perception of marketing in the construction industry, the adoption and implementation of marketing in construction industry can be likened to adoption and implementation of technology in an organization, especially if it is a new technology. This underscores the suitability of TAM or a TAM based models for examining the issues with marketing acceptance in the construction industry.

67.3 Methodology

By design, this study is descriptive. The study uses literature review as a method to identify, summarize, synthesize relevant extant construction marketing research reports and show the gaps in existing research knowledge on the low utilization of marketing in construction business management.

Although current and most recent research reports are preferred, in this study no published literature was discounted by age due to the peculiar nature of occurrence and characteristic focus of existing research report. The low priority given to marketing in construction is reflected in the paucity of reported research and helpful general literature (Yisa et al. 1996). Such literatures, and most especially published empirical research findings, according to Naranjo et al. (2011) are scarce and the few available are also intermittent in their nature of occurrence. The paucity of literature on construction marketing and the sparse and intermittent nature of occurrence of the existing few research works compelled the researcher to select all useful available literature on the subject irrespective of age of the paper.

The key constructs in TAM: perceived usefulness and the perceived ease of use, are examined and a comparison made with issues with marketing acceptance in the construction industry.

The TAM posits that for technology to be adopted and used, two issues are involved, namely: the perceived usefulness and perceived ease of using it. These issues create behavioural intentions to use the technology. The actual usage takes place after this intention is created. Figure 67.2, shows the relationship between the constructs that makes up the TAM.

The constructs are suitably modified to support its application to marketing issues in construction. This study posits that the behavioural intention to implement marketing is influenced by the two variables in the TAM. For the purpose of

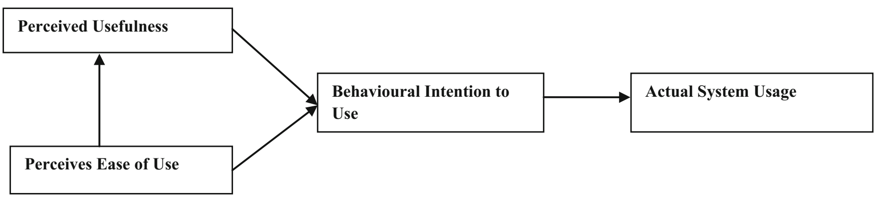


Fig. 67.2 Technology Acceptance Model (TAM). *Source* Venkatesh et al. (2003)

marketing implementation in a construction business enterprise, the perceived usefulness was examined within perceived benefits of marketing and the perceived view of marketing as a source of competitive advantage. The perceived ease of use was also examined within availability of marketing resources in construction businesses in terms of manpower, skills and budget. These two variables have the tendency to influence the required actions to be performed towards the implementation of marketing in business enterprise. This in turn results in the implementation of marketing in construction business enterprise. This is illustrated in Fig. 67.3.

The use of the TAM is motivated by the arguments that suggest that some reluctance to the adoption of marketing exist in construction businesses (Moore 1984; Morgan and Morgan 1990, 1991; Pheng 1991; Peck 1994; Rwelamila and Bowen 1995). Again, that reluctance can be examined within these two factors: perceived usefulness of marketing and the perceived ease of use of using marketing as a management function in the management of construction businesses enterprises. This proposition is based on the TAM which posits that organizations acceptance and utilization of new technology is influenced by the perceived usefulness and the perceived ease of use of the technology.

After that, existing empirical research reports relevant to the constructs in the modified model are examined to establish the validity of the propositions.

67.4 Findings

67.4.1 Perceived Usefulness

The usefulness of marketing in the management of construction business enterprise is examined in the context of the perceived benefits of marketing and the perceived view of marketing as a source of competitive advantage.

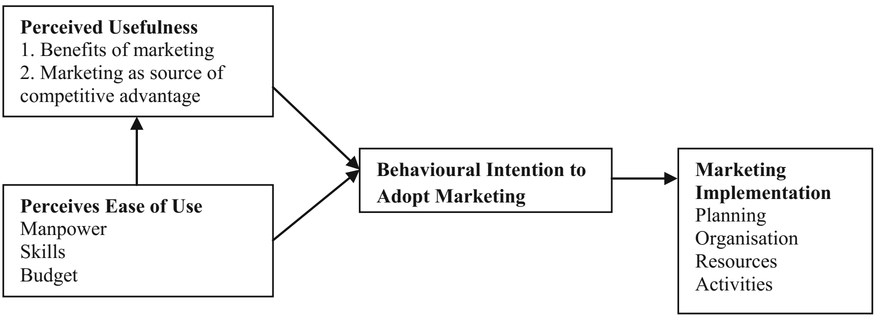


Fig. 67.3 Marketing acceptance model for construction business enterprise. *Source* Author's construct based on TAM

67.4.1.1 Perceived Benefits of Marketing

In a study by Dikmen et al. (2005), ten perceived benefits of marketing were identified. Table 67.1 gives the list of the ten identified perceived benefits of marketing and their relative importance based on average scores.

An examination of the figures indicates that benefits such as increase in sales, improvement of reputation, creation of new markets, development of company image and entrance to new markets had the highest values of importance (Table 67.1). Dikmen et al. (2005) notes that, these factors are about sales, advertisement and public relations, and also constitute the most visible benefits of marketing function. A similar finding by Richardson (1996) indicates that misconception that marketing and selling are equal or thinking of marketing as being all about advertising and public relation are common in the construction industry. It is therefore not surprising that benefits in terms of customer satisfaction and customer loyalty are among the benefits that received the lowest scores from the Turkish construction firms surveyed.

The few academic research works that have been conducted in other different countries comprises that of Morgan (1990) in the United Kingdom, Rwelamila and Lethola (1998) in South Africa, and Marr et al. (1996) in New Zealand give support to the findings of Dikmen et al. (2005) in Turkey. Morgan (1990) found that very seldom firms have their own marketing departments or specific individuals responsible for marketing. Even when marketing department exists, the consulting firms still struggle to implement marketing functions effectively. Merr et al. (1996) measured the perception of marketing by private engineering consultancies in New Zealand and found that competing on price is one of the major barriers to the consulting engineer's adoption of the marketing concept. The result obtained by Rwelamila and Lethola (1998) gives support to Morgan (1990) and Marr et al. (1996). Significant findings in such studies have shown that construction firms are slow in adopting marketing principles. Other authors have also found that marketing is not integrated into the structure of construction firms operations, as a core

Table 67.1 Relative importance of perceived benefits of marketing based on average scores from the perspectives of Turkish contractors

Perceived benefits	Mean value
Increase in profits	3.93
Increase in sales	4.51
Increase in customer satisfaction	3.69
Development of company image	4.31
Development of product/Services	3.42
Entrance to new markets	4.29
Creation of new markets	4.33
Improvement of customer loyalty	3.44
Improvement of reputation	4.38
Improvement of total quality	3.20

Source Adopted from Dikmen et al. (2005: 262) management function (Winter and Preece 2000; Bennett 2005; Yisa et al. 1996; Cicmil and Nicholson 1998).

The lack of understanding of the true meaning of marketing has led to this situation where construction business enterprises misconstrue what marketing is and its associated benefits. It is not surprising that the common theme that is running through available construction marketing literature is that the construction industry has performed poorly in marketing its products and services (Yisa et al. 1995). Although, marketing has been established in manufacturing and many other service industries, in construction it is either been ignored or grossly misunderstood (Yisa et al. 1995). Many other studies have reported existence of many deeply held misconceptions or misperceptions or misunderstandings about the appropriateness and value of general management skills and marketing skills in particular, in the construction industry (Fisher 1989; Richardson 1996). Peck (1994) further indicated that some construction consulting firms are still struggling to understand and implement effective marketing programmes. Morgan and Morgan (1990) also stated that marketing is less developed in the construction industry and often performed in most firms in an ad hoc basis.

The lack of understanding and misconceptions about the true meaning of marketing has resulted in the 'less beneficial mindset' about marketing. As a result marketing is not much adopted in construction. This is obvious in the sense that firms will invest in activities they are sure of their potential benefits in terms of increasing profit, growth and survival in their business environment. If that cannot be said about marketing, then it is not considered as a right cooperate strategy.

67.4.1.2 Marketing as a Source of Competitive Advantage

In an industry that is characterized by extreme competition, managers of businesses will seek out ways to achieve competitiveness relevant for achieving profitability and survival. Competition and high risk have been considered as the construction industry's biggest challenge (Schaufelberger 2009). Mochtar and Arditi (2001) contend that, the construction industry is typically characterized by extreme competitiveness, high uncertainty and risks, and generally low profit margins when compared to other industries. These conditions, compels construction companies to constantly seek ways to outbid their competitors and to explore new and/or less crowded areas of construction that may provide more jobs and higher profits. In this context, marketing may help construction companies to differentiate themselves from their competitors, cultivate and/or keep clients, and thereby create competitive advantage (Arditi et al. 2008; Chen and Mohamed 2008).

In a study by Dikmen et al. (2005), fifteen sources of competitive advantage were identified. Table 67.2 gives the list of the fifteen identified sources of competitive advantage and their relative importance based on average scores.

Table 67.1, gives all potential sources of competitive advantage. Table 67.1 further highlights the role of marketing for gaining competitive advantage as indicated by the mean values. To Turkish construction firms, the most important

Table 67.2 Ranking of different sources of competitive advantage based on average scores

Sources of competitive advantage	Mean value	Rank
Financial capability	4.42	4
Technical capability	4.53	1
Experience	4.51	2
Client relations	4.44	3
Creativity	3.82	12
Marketing capability	3.84	11
Adaptation capability	3.64	14
Professional management	4.27	7
Business development ability	4.35	6
Quality of product and services	4.40	5
Image of the firm	4.20	8
Political power	3.44	15
Human resources	3.87	10
Strategic alliance	3.75	13
Cost advantage	4.18	9

Source Adopted from Dikmen et al. (2005: 263)

sources are: Technical capability, Experience, Client relations, Financial capability and Quality of product and services. The fact that these factors are mainly production related indicates that production related factors are considered more important sources of competitive advantage than the managerial factors.

The reliance on production efficiency as a source of competitive advantage is a phenomenon that is not limited to the Turkish construction businesses alone. Similar phenomena are reported in construction industry in many other countries. Rwelamila and Bowen (1995), points out that construction companies are still clinging to an out-dated, bull market philosophy: 'As long as we do good work we will always have plenty of work.

It comes as no surprise that marketing did not receive any higher as a source of competitive advantage. The position of marketing capability as the 11th among 15 specified sources of competitive advantage suggests that marketing is not perceived as a significant source of competitive advantage. Since these are views of top managers and directors of marketing of Turkish construction companies, it has the potential to influence the management practices of Turkish construction companies. It is therefore obvious that this also account for the low utilization of marketing in the management of construction business enterprise.

This is confirmed by the management structure of construction companies. Cicmil and Nickolson (1998), notes that marketing is not part of the core business functions of construction businesses. Figure 67.4 shows the details to this assertion. It is obvious that the addition of marketing to the business functions appears to be a wishful thinking. Morgan and Morgan (1991) states that marketing within the construction profession is considered at worst as an alien concept, and at best as a new development that is viewed with scepticism. Similarly, Pheng (1991) observed that marketing has attracted only little attention among construction professionals. Morgan and Morgan (1990) also stated that marketing is less developed in the professional industry and often performed in most firms in an ad hoc basis. This augments the assertion that marketing is not seen as a source of competitive advantage by most construction business companies.

67.4.2 *Perceived Ease of Use of Marketing*

This is examined in the context of the availability of resources for marketing management in a construction enterprise. The resources are categorized into manpower, skills and budget.

67.4.2.1 Manpower

Manpower refers to the number of persons assigned a specific task to perform. Yisa et al. (1995) appraised a system where there exist adequate numbers of employees whose responsibilities are wholly dedicated to marketing functions. The adequacy of personnel who are assigned the marketing management responsibility is always as issue. Most often the persons are in-house staffs who have their own tasks to perform in addition to the marketing function. The inadequacy of personnel for marketing function in construction enterprises impedes the marketing management effort.

67.4.2.2 Skills

The employment of marketing professionals, comprising of individuals who have professional qualification in marketing is indispensable for effective implementation of marketing programmes in a business enterprise. The lack of such professional in the industry makes the application of marketing in construction a rather difficult task.

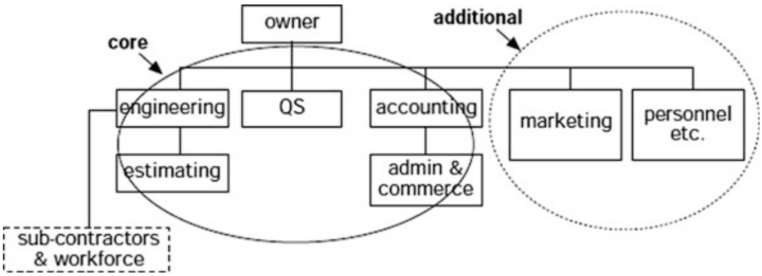


Fig. 67.4 An outline of a typical organisational structure development in a small/medium construction contracting company. *Source* Adopted from Cicmil and Nickolson (1998: 99)

67.4.2.3 Budget

Davis (1981) stated the composition of marketing budget with many construction firms in the past as wages, sales expenses, product literature, and limited public-relations activities. In recent times, both professionals and practitioners have been seen to be engaged in other marketing activities that include professional activities designed to influence the market place, market research; cooperate identity programs and other marketing aids, such as the use of information services (Yisa et al. 1995). The allocation of enough funds from annual turnover to support annual expenditure of marketing is highlighted as necessary ingredients for the overall success of the marketing programme. This is where the challenge is. It is generally accepted that profit are low in the construction industry. The low profits are also used to support production efficiency since construction enterprises pay more attention to production than management issues. This leads to the neglect of allocating many funds to the management of marketing in construction businesses. Lack of funds for marketing management means that little to nothing can be done.

67.4.3 Marketing Implementation

A structured marketing approach formulated in line with the organizations aims and objectives provide the basis for successful marketing programme.

A strategic approach to marketing entails marketing planning, organisation of the marketing functions and allocation of resources before execution of the marketing activities. Dickmen et al. (2005) argues that knowledge about the way of carrying out marketing activities in a firm is necessary for assessing the extent to which marketing is implemented in a firm. Existence of marketing department, the number of people working in the department, status of the head of marketing in the organization and the existence of an independent sales department besides the marketing department are some of the criteria that are used for such assessment.

Again, specific marketing activities such as marketing research, marketing planning, advertising, public relations, in-house marketing education and marketing intelligence also adds to such criteria of assessment (Dikmen et al. 2005). Yisa et al. (1995) sorted out the all the above and added more to those criteria and categorized them into three issues as follows: marketing planning, organization for marketing and marketing resources. A forth category is made up of parameters and constituents of marketing activities (Naoum 2001; Arditi et al. 2008).

When the above actions take place, then marketing has been implemented. But looking at the issues highlighted earlier, this appears to be a challenging task for the construction business enterprises management.

67.5 Discussions

The study has explicated the low utilization of marketing in the management of construction business enterprise, by the TAM. To the best of the authors' knowledge, it is the first study that demonstrates the relationship between perceived usefulness marketing and perceived ease of using marketing as a management function, as factors that affects constructions businesses' marketing performance. The study contributes to construction marketing literature by demonstrating the importance of affective factors and organizational factors in the context of marketing performance of industries where indifferent attitude to marketing exits such as construction industry.

67.5.1 Summary of Findings

The study finds that the adoption and implantation of marketing can be examined in the context of the TAM. This is due to the similarities regarding new technology adoption by organizations and marketing adoption by the construction industry.

In the construction industry, perceived usefulness of marketing is a factor that is determined by the perceived benefits of marketing and marketing's role as a source of competitive advantage. These are affective factors that relate to the construction business enterprises' managements perceptions. Again, the perceived ease of use is determined by such factors as manpower, skills and budget. These are organizational factors.

The actions undertaken with respect to marketing are largely influenced by the above factors. The actions undertaken towards marketing implementation includes existence of marketing department, the number of people working in the department, status of the head of marketing in the organization and the existence of an independent sales department besides the marketing department. Other activities such as marketing research, marketing planning, advertising, public relations, in-house marketing education and marketing intelligence are also important.

67.5.2 Managerial Implications

The findings indicate that perceived usefulness of marketing and the ease of use of marketing as management function affect the implementation of marketing in construction businesses.

The perception about the usefulness of marketing can be improved through education and training of construction management team members. Consequently, construction education should feature some marketing related courses with the state-of-the-art course content that reflects currents developments in marketing.

With that knowledge, construction management team members will be abreast with the usefulness of marketing.

Management must make needed resources in terms manpower, skills and budget available in appropriate quantities. This will make is easier in overcoming the challenges with the ease of use of marketing in construction business enterprises. Employment of non technical staff and marketing professionals for the management of marketing department and the improvement of marketing skills level together with allocation of adequate funds for marketing activities are critical issues that demands management attention.

67.5.3 Limitations and Directions for Future Research

The paper is based on reported construction marketing research. The arguments put up could be supported with more empirical findings to improve the paper's contribution to knowledge and make the information current.

Future research must focus on the behaviour of construction business managers towards marketing in their business enterprises.

References

Arditi D, Polat G, Makinde SA (2008) Marketing practices of U.S. contractors. J Manage Eng 24 (4):255–264

Bennett R (2005) Marketing policies of companies in a cyclical sector: an empirical study of the construction industry in the United Kingdom. J Bus Ind Mar 20(3):118–126

Chen L, Mohamed S (2008) Impact of the internal business environment on knowledge management within construction organizations. Constr Innov Inf Process Manage 8(1):61–81

Cicmil S, Nicholson A (1998) The role of marketing function in operations of a construction enterprise: misconceptions and paradigms. Manage Decis 36(2):96–101

Davis JR (1981) Marketing strategy for growth. Consulting engrs Oct

Dikmen I, Birgonul MT, Ozcent I (2005) Marketing orientation in construction firms. Evidence form Turkish contractors. Build Environ 40:257–265

Fisher N (1989) Marketing for construction industry: a practical handbook for consultants, contractors and other professional. Longman's, London

Gummesson E (1979) The marketing of professional services—an organisational dilemma. Eur J Mark 13(5):308–318

Kotler P, Armstrong G (2012) Principles of marketing. Pearson, London

Kotler P, Keller K (2012) Marketing management. Prentice Hall, New Jersey

Marr NE, Sherrard MJ, Prendergast GP (1996) Marketing of professional services: the case of consultancy engineering. Serv Ind J 16(4):544–562

Mochtar K, Arditi D (2001) Role of marketing intelligence in making pricing policy in construction. J Manage Eng 17(3):140–148

Moore AB (1984) Marketing management in construction industry: a guide for contractors. Butterworth's, London

Morgan RE (1990) Marketing professional services: an empirical investigation into consulting engineering services. In: Proceedings of the 1990 marketing education group annual conference, pp 973–994
Morgan G (1997) Images of organization. Sage Publications, Thousand Oaks
Morgan RE, Morgan NA (1990) Marketing consulting engineering services. Civ Eng Surv June 20–21
Morgan RE, Morgan NA (1991) An appraisal of the marketing development in engineering consultancy firms. Constr Manage Econ 9(1):355–368
Morgan RE, Morgan NA (2006) An appraisal of the marketing development in engineering consultancy firms. Constr Manage and Econ 9(4):355–368
Naoum SG (2001) Dissertation research and writing for construction students. Reed Educational and Professional Publishing, Great Britain
Naranjo G, Pellicer E, Yepes V (2011) Marketing in construction industry: state of knowledge and current trends. DYNA 170(78):245–253
Peck WF (1994) Making the most of marketing. J Manage Eng 10(6):17–21
Pheng LS (1991) World markets in construction: a regional analysis. Constr Manage Econ 9:63–71
Preece C, Moodley K, Smith P, Collar P (2003) Construction business development: meeting new challenges, seeking opportunity. Elsevier, Oxford
Richardson B (1996) Marketing for architects and engineers: a new approach. Chapman & Hall, London
Rwelamila PD, Lethola T (1998) Marketing engineering services: an opportunity for a building services engineer. Int J Cost Estimation Cost/Sched Control Proj Manage 40(7):27–31
Rwelamila PD, Bowen PA (1995) Marketing of professional services by quantity surveying consultancy practices in South Africa. RICS Res, London
Schaufelberger J (2009) Construction business management. Prentice-Hall, Upper Saddle River
Venkatesh V, Morris M, Davis F (2003) User acceptance of information technology: towards a unified view. MIS Quarterly 27(3):479–501
Winter C, Preece CN (2000) Relationship marketing between specialist subcontractors and main contractors—comparing UK and German practice. Int J Constr Mark 2(1):1–11
Yankah JE (2015a) Marketing performance of quantity surveying consulting firms. Int J Constr Eng Manage (IJCEM) 4(6):230–237
Yankah JE (2015b) Marketing practices of quantity surveying consultancy firms. Afr J Appl Res (AJAR) 2(2):140–152
Yankah JE, Dadzie DK (2015) Explication of the need for developing the marketing function of professional service organization. J Mark Consum Res 15:187–195
Yisa SB, Ndekugri IE, Ambrose B (1995) The marketing function in the UK construction contracting and professional firms. J Manage Eng 11(4):27–33
Yisa SB, Ndekugri I, Ambrose B (1996) A review of changes in the UK construction industry. Eur J Mark 30(3):47–64

Chapter 68
Factors Influencing Safety Training Transfer on Construction Sites: A Literature Review

R. Prasad, Y. Feng and M. Hardy

68.1 Introduction

Safety has been a paramount issue within the construction industry, which has prompted industry stakeholders to invest a significant amount of resources in the prevention of workplace accidents through safety training programs (Dong et al. 2004; Tam et al. 2004). Construction safety training programs enables workers to possess the relevant skills and knowledge essential to carry out their day-to-day work related tasks in a safe and efficient manner (Cooper 2000). More specifically, construction workers are often required to apply the relevant skills and knowledge gained from the classroom to the workplace. A concept more commonly known as training transfer, which is explained in detail below.

68.1.1 The Concept of Training Transfer

Training transfer refers to the acquisition of skills and knowledge gained in one situation (classroom) and then applying them in another or similar situation (workplace) (Baldwin and Ford 1988; Baldwin et al. 1991; Blume et al. 2010). Training transfer is based on the theory of transfer of learning (Baldwin and Ford 1988). Generally, training transfer occurs when the effects of prior learning influences the performance of a subsequent activity (Holding 2013). There are three types of training transfer; positive transfer, negative transfer and zero transfer (Simons 1999). Positive transfer is the acquisition of a new skill or problem solving ability through prior training or learning and as results in increased performance.

R. Prasad (✉) · Y. Feng · M. Hardy
School of Computing, Engineering and Mathematics, Western Sydney University, Kingswood Campus, Locked Bag 1797, Penrith, NSW 2751, Australia
e-mail: roneel.prasad@westernsydney.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_68

Negative transfer is the non-acquisition of a new skill or problem solving ability through prior training or learning and results in no changes to performance. In this situation, the exposure to the training or learning activity has a detrimental effect on the trainee rather than a positive effect. Zero transfer is the lack of acquisition of any new skills or problem solving abilities as past training or experience has had no effect on the trainee in the training process (Leberman et al. 2006).

Training transfer is a key contributor in the success of training programs and is especially important for the construction industry, as construction organisations invest time and resources into safety training programs with an expectation of some form of transfer of that training into the workplace. In addition, training transfer has attracted much attention from industrial-organisational (I-O) psychologists, learning and training researchers and human resource development (HRD) researchers (Leberman et al. 2006; Burke and Hutchins 2007; Schultz 2010; Kozlowski and Salas 2009; Holton et al. 2003). A commonly shared view of these disciplines is that improving the factors, which influence safety-training transfer, will result in improved workplace safety and health performance (Hua et al. 2011; Wenzel and Cordery 2014; Taylor et al. 2009). Therefore, this literature review seeks to identify a list of factors, which can be used to improve safety-training transfer in the construction industry. The methodology and results are presented below.

68.2 Methodology and Results

A literature review methodology was adopted for this research, which was largely concentrated on identifying factors, which received the greatest amount of attention in the literature on safety training transfer. The search for relevant literature commenced with conducting a broad keyword search on reputable academic journal websites, provided in Table 68.1. These databases were chosen as they provided the most thorough coverage in the field of construction management and safety training transfer. In addition, the search criterion was expanded to include literature from additional fields, which have conducted research studies on the topic of safety

Table 68.1 List of databases searched

Journal of Safety Science	Journal of Safety Research
Construction Management and Economics	Journal of Applied Psychology
International Journal of Project Management	Journal of Safety Research
Journal of Construction Engineering and Management	Journal of Accident Analysis and Prevention
Journal of Civil Engineering and Management	Emerald Insight and ScienceDirect
Journal of Occupational Accidents	Google Scholar, Web of Science and Scopus
PsycINFO American Psychological Association	PubMed and MEDLINE

training transfer. Therefore, the literature search was expanded to include the disciplines of health sciences, psychology and vocational education.

The selection criteria was scholarly and academic journals, relevant books and print media, in the English language which addressed the keywords construction, safety training, training transfer and training or safety training in the construction industry. These keywords were combined with basic Boolean terms such as “and”, “or” and “not”. In addition, the keywords were combined with words such as impact, effect, affect, literature review, factors, summary, influences, construction workplace, worksites, sites and international. The expansion of the key word combination provided a significant number of publications, which were narrowed down and shortlisted by initially reading the titles and abstracts. The relevant literature meeting the above-mentioned selection criteria, were then shortlisted and further, examined. They were examined by reading the introduction, discussion, conclusion, recommendations and the relevant headings and sub-headings. The relevant literature were analysed using a framework, which was to answer the following research question: “What are the Factors which Influence Safety Training Transfer on Construction Sites?” The findings of this literature review are presented below.

68.3 Discussion

68.3.1 Previous Research

Safety training has become an axiomatic part of the construction industry and has evolved from a basic requirement for the purposes of work and employment to an exact science (Hale 1984). Over the last few decades, several researchers have contributed to the development of theoretical frameworks, constructs and concepts, which have contributed towards the body of knowledge on construction management and safety training transfer (Tam et al. 2004; Kontoghiorghes 2001; Goldenhar et al. 2001; Bahn and Barratt-Pugh 2011; Fang et al. 2006). Some of the more notable contributions of empirical based research have been largely concentrated on framework of variables that influence design and delivery of training in work organisations (Tannenbaum and Yukl 1992). In addition, Yamnill and McLean (2001) contributed a comprehensive list of theories which underpinned transfer of training. Most recently, Burke and Hutchins (2007) have provided useful measures of effectiveness, integrative literature reviews and analytical literature reviews concerning safety and health in the construction industry (Burke and Hutchins 2007; Burke et al. 2006, 2011). The main factors influencing safety-training transfer are presented below.

68.3.2 Factors Influencing Training Transfer

68.3.2.1 Safety Training Versus General Training

Safety training is unique when compared to other forms of training in the workplace. Generally, the purpose of a general workplace-training program is to enable the trainee to possess general skills and knowledge to conduct their day-to-day work related tasks. However, construction safety training provides the trainee with the specific workplace related health and safety skills and knowledge, in addition to general training to conduct day-to-day work related tasks. More specifically, the trainee is made aware of the hazards and dangers which are specific to construction workplaces and provides valuable training in the foreseeability and prediction of potential accidents and injuries (Authority ASQ 2013). It has often been debated that the difference between safe and unsafe employees is that safe employees are often found to be better equipped to recognise hazards, identify or foresee hazardous actions and understand the consequences of those actions (Vredenburgh 2002).

68.3.2.2 Training Ability

The ability to be trained or trainability is often dependent of the inter-related constructs of cognitive ability; self-efficacy and motivation were found to be directly linked to the effectiveness of training programs. Cognitive ability relates to the influence of general mental ability in the training and learning arena. Research has shown that trainees with higher general ability scores in tests are able to better generalize and apply training material (Clark and Voogel 1985). However, trainees should not be expected to have high level cognitive ability but in the domain of training, overall general intelligence was perceived as the most effective predictor for transfer (Ree and Earles 1991).

68.3.2.3 Training Self-efficacy

Self-efficacy is the level intuition a trainee possess relation to their competency to perform tasks in the training arena and therefore their ability to transfer. There are four stages in the development of training self-efficacy beliefs in trainees, which includes previous experience, modelling, social and verbal persuasion and psychological states (Alliger et al. 1997).

68.3.2.4 Previous Experience

The experience of being able to complete training related tasks and activities is perhaps the most important factor in the training transfer process. Trainees that have attempted and fail to deal with training or workplace tasks or challenges can often undermine and often weaken their self-efficacy measures in the training arena (Bandura 1994). As a result, the trainee is discouraged from any future training programs and therefore experiences zero transfer.

68.3.2.5 Modelling or Vicarious Experience

Modelling is training or learning through vicarious experience. This usually occurs through observations on how a task or activity is performed and then attempting to perform an identical or similar task or activity themselves. Training through modelling enables the trainee to gain confidence by observing people who are similar to them and therefore increases their beliefs in their own abilities in mastering a similar activity. In addition, modeling increases a trainees ability to effectively transfer their training (Bandura 1994). Modelling is underpinned by the theory of multiple intelligences, which recognises seven distinct learning styles (Gardner 2011). The literature suggests that due to the visual and hands-on nature of construction work, naturally, construction workers tend to be visual learners. Therefore, safety training programs should incorporate a visual aspect into the training along with theory and practices to maximise training transfer (Gardner 2011; Goetsch 2013).

68.3.2.6 Social and Verbal Persuasion

The effectiveness of training programs can be influenced by social factors surrounding the trainee, which usually includes their organisations, co-workers and managers or supervisors (Noe 1986). Encouragement by these parties can have a positive effect on the trainee's confidence in performing a task and leads the trainee to believe in their own abilities. However, if the trainee is experiencing discouragement or negativity towards training programs from these social factors, studies have shown that it has a negative influence on training transfer (Chiaburu et al. 2010). An effective method of minimising social influences during training programs is to provide the trainee with constructive feedback. The benefits of this is twofold, the first is that the trainee maintains a sense of efficacy throughout the training process. The second is that the trainee is able to overcome any self-doubt that they may be experiencing in regards to undergoing training or applying what they have learned during training (Bandura 1994).

68.3.2.7 Psychological States

Training transfer is often influenced by trainee's psychological states such as moods, emotions, physical reactions and stress levels as they are undergoing a training program. These factors can have an influence on the trainee's psychological beliefs regarding their own abilities as a person. In addition, trainees that exhibit or experience nervous behavior may begin to develop self-doubt and begin to harbor a weak sense of self-efficacy. However, confident and anxiety free trainees will exhibit a sense of excitement which in turn fosters a greater sense of self-efficacy (Bandura 1994). The way trainees interpret and evaluate emotional states is a catalyst in the development of their self-efficacy beliefs. Therefore, minimising or controlling anxiety can have a positive impact on the trainee's self-efficacy beliefs. As a result, trainees are able to make better generalisations between learned material and how they can effectively apply them in the workplace (Noe 1986).

68.3.2.8 Pre-training Design

The design and delivery of safety training programs has a significant impact on the overall outcome of the training. Training literature suggests that a comprehensive needs analysis yields information which helps in the development of instructional objectives and training criteria for the trainee (Tannenbaum and Yukl 1992). In addition, Holton (1996) suggested that training design, individual characteristics (self-efficacy and training retention) and work environment (feedback and supervisor support) are interrelated and have a significant influence on training transfer. Training literature suggests that safety-training programs are often generalised and conducted to satisfy some form of regulatory requirement. The construction industry has been one of the major offenders in conducting training programs largely to satisfy legislative or other requirements. Therefore, construction organisations need to conduct safety-training programs, which is better suited and has more relevance with the work or job task (Authority ASQ 2013).

68.3.2.9 Simulating Workplace Conditions in Training

An important factor in the effective transfer of vocational learning into job performance is the contents of the training program. The training contents including the materials and methods of delivery should be relatable to or simulate actual workplace conditions. Although, this is not always achievable, training organisations and the construction organisations can collaborate through periodic training evaluation, which facilitates the alignment of training content with actual work practices. An advantage of periodic content analysis is that organisations can enhance trainee motivation levels to improve learning performance (Ford and Wroten 1984; Bramley 1990). Similarly, others argue that commonalities between the training and work environment has a positive effect on job performance following training (Bramley 1990). In addition, trainee feedback on effectiveness of a training program will yield valuable information with any ongoing or future training content design and delivery. Research has shown that trainees, who recognised the practicability of training content, were more likely to transfer their training (Alliger et al. 1997).

68.3.2.10 Post-training Design

In addition, construction organisations need to understand that they have the ability to improve the quality of health and safety of their members by instituting a systematic and comprehensive health and safety-training program (Barbeau et al. 2004). A large part of the construction industry conducts safety-training programs that are generally aimed at new employees rather than existing and more experienced members of the organisation (Authority ASQ 2013). The training transfer of new employees can be maximised by providing them with more experienced members of the organisation who act as mentors for the new employee. Both new and more experienced employees should be paired together until the new employee has settled in and become familiar with the new workplace or work environment (Vredenburgh 2002).

68.3.2.11 Error Management Training (EMT)

EMT involves encouraging and fostering training conditions where the trainee is able to make errors during training and learn from those errors. EMT has been linked in the promotion of effective training transfer by providing instructions to the trainee after an error, on how to avoid those errors or take corrective actions (Burke and Hutchins 2007). EMT has been found as an effective method of facilitating the use of learned safety skills and knowledge in the workplace. In addition, trainees who receive EMT were found to be able to transfer their training more often and with more success when compared to those that didn't receive EMT (Heimbeck et al. 2003). However, it is important to note that trainees should be provided with information on incorrect actions or behaviors as well as communicating with them the intended target actions and behaviors. In addition, organisations benefit from this type of training in the form of an effective strategy for the promotion of safety training transfer.

68.3.2.12 The Role of Technology in Training Transfer

Due to the rapid advances in online and computer based technologies a new wave of safety training design and delivery has emerged. These include video conferencing, on-line and internet based safety training programs and virtual reality (VR) simulations. Although, these forms of training may reduce or eliminate the need to travel or attend traditional classrooms, there is still a heavy reliance on the use of classrooms to deliver technology-based training. In addition, the implementation of technology-based training delivery is occurring at an alarming rate without much reliance on the science, theory or research behind training (Kontoghiorghes 2001). Theoretical-based research is necessary to help in uncovering guidelines and principles, which aids training designers in designing and delivering vigorous distance training programs (Schreiber and Berge 1998). The above-mentioned factors have provided a snapshot of some of the influences on safety training transfer construction in the construction industry. The conclusions and recommendations of this literature review are presented below.

- Previous experience
- Modelling/vicarious experience
- Social and verbal persuasion
- Psychological states
- Pre-Training Design
- Simulating Workplace Conditions in Training
- Post-Training Design
- Error Management Training (EMT)
- The role of Technology in Training Transfer

68.4 Conclusions and Recommendations

This paper identified a broad range of factors influencing training transfer of safety training programs in the construction industry. The factors have revealed that the science and research of general training theory and practices are applicable to construction safety-training programs. However, it is important to note that construction safety training is rather unique and presents a specific set of challenges when compared to general training theory and practices. Cognition, self-efficacy and motivation are proving to be key factors in the effective transfer of training on an individual level. While pre-training, delivery and post-training follow-up of training programs seems to be the key factors in the effective transfer of training on an organisational level. Whereas, training design, training content, error management training and the rise of technology in the delivery of training seems to the key factors in the effective transfer of training in the training arena. In conclusion, the traditional method of conducting safety training was inefficient in the transfer process, as trainees were not able to generalise or provide feedback on their learning and training. However, by providing adequate support, guidance and feedback to the trainee before, during and after training, could prove to be a more effective method in increasing the transfer of safety training programs in the construction industry. This approach enables the trainee to build confidence, generalise and better understand and apply their learning into the workplace.

References

Alliger GM et al (1997) A meta-analysis of the relations among training criteria. Pers Psychol 50 (2):341–358

Authority ASQ (2013) Training for the White Card for Australia's construction industry. Australian Skills Quality Authority (ASQA), 2013, Melbourne, Victoria

Bahn S, Barratt-Pugh L (2011) Construction induction training: how effective for the housing and civil construction industries in WA?

Baldwin TT, Ford JK (1988) Transfer of training: a review and directions for future research. Pers Psychol 41(1):63–105

Baldwin TT, Magjuka RJ, Loher BT (1991) The perils of participation: effects of choice of training on trainee motivation and learning. Pers Psychol 44(1):51

Bandura A (1994) Self-efficacy. Wiley Online Library, Hoboken

Barbeau E et al (2004) Assessment of occupational safety and health programs in small businesses. Am J Ind Med 45(4):371–379

Blume BD et al (2010) Transfer of training: a meta-analytic review. J Manage 36(4):1065–1105

Bramley P (1990) Evaluating training effectiveness. McGraw-Hill, Maidenhead

Burke LA, Hutchins HM (2007) Training transfer: an integrative literature review. Hum Resour Dev Rev 6(3):263–296

Burke MJ et al (2006) Relative effectiveness of worker safety and health training methods (research and practice) (author abstract). Am J Public Health 96(2):315

Burke MJ et al (2011) The dread factor: how hazards and safety training influence learning and performance. J Appl Psychol 96(1):46–70

Chiaburu DS, Van Dam K, Hutchins HM (2010) Social support in the workplace and training transfer: a longitudinal analysis. Int J Sel Assess 18(2):187–200

Clark RE, Voogel A (1985) Transfer of training principles for instructional design. ECTJ 33 (2):113–123

Cooper MD (2000) Towards a model of safety culture. Saf Sci 36(2):111–136

Dong X et al (2004) Effects of safety and health training on work-related injury among construction laborers. J Occup Environ Med 46(12):1222–1228

Fang D, Chen Y, Wong L (2006) Safety climate in construction industry: a case study in Hong Kong. J Constr Eng Manag 132(6):573–584

Ford JK, Wroten SP (1984) Introducing new methods for conducting training evaluation and for linking training evaluation to program redesign. Pers Psychol 37(4):651–665

Gardner H (2011) Frames of mind: the theory of multiple intelligences. Basic Books, London

Goetsch DL (2013) Construction safety and health. Pearson, Upper saddle River

Goldenhar LM, Moran SK, Colligan M (2001) Health and safety training in a sample of open-shop construction companies. J Saf Res 32(2):237–252

Hale AR (1984) Is safety training worthwhile? J Occup Accid 6(1):17–33

Heimbeck D et al (2003) Integrating errors into the training process: the function of error management instructions and the role of goal orientation. Pers Psychol 56(2):333–361

Holding DH (2013) Principles of training: the commonwealth and international library: psychology division. Elsevier

Holton EF (1996) The flawed four-level evaluation model. Hum Resour Dev Quart 7(1):5–21

Holton EF, Baldwin TT, Salas E (2003) Improving learning transfer in organizations. In: Holton E, Baldwin TT (eds) Jossey-Bass, San Francisco

Hua N, Ahmad R, Ismail A (2011) The impact of the supervisor's role in training programmes on the transfer of training: a case study in four East Malaysian local governments. Res Pract Hum Resour Manag 19(2):24–42

Kontoghiorghes C (2001) Factors affecting training effectiveness in the context of the introduction of new technology—a US case study. Int J Train Dev 5(4):248–260

Kozlowski SW, Salas E (2009) Learning, training, and development in organizations. Taylor & Francis, Routledge

Leberman S, McDonald L, Doyle S (2006) The transfer of learning: participants' perspectives of adult education and training. Gower Publishing Ltd., Aldershot

Noe RA (1986) Trainees' attributes and attitudes: neglected influences on training effectiveness. Acad Manag Rev 11(4):736–749

Ree MJ, Earles JA (1991) Predicting training success: not much more than g. Pers Psychol 44 (2):321–332

Schreiber DA, Berge ZL (1998) Distance training: technology to maximize learning and meet business objectives. Jossey-Bass business and management series. ERIC, 1998

Schultz DP (2010) Psychology and work today: an introduction to industrial and organizational psychology, 10th edn. Schultz SE (ed). Prentice Hall, Upper Saddle River

Simons PR-J (1999) Transfer of learning: paradoxes for learners. Int J Educ Res 31(7):577–589

Tam C, Zeng S, Deng Z (2004) Identifying elements of poor construction safety management in China. Saf Sci 42(7):569–586

Tannenbaum SI, Yukl G (1992) Training and development in work organizations. Annu Rev Psychol 43(1):399–441

Taylor PJ, Russ-Eft DF, Taylor H (2009) Transfer of management training from alternative perspectives. J Appl Psychol 94(1):104

Vredenburgh AG (2002) Organizational safety: which management practices are most effective in reducing employee injury rates? J Saf Res 33(2):259–276

Wenzel R, Cordery J (2014) Training transfer research: a manager's guide and bibliography. Australian Institute of Management, Perth

Yamnill S, McLean GN (2001) Theories supporting transfer of training. Hum Resour Dev Quart 12(2):195–208

Chapter 69
Factors Influencing the Construction Time and Cost Overrun in Projects: Empirical Evidence from Pakistani Construction Industry

Ahsen Maqsoom, Muhammad Umar Khan, Muhammad Tariq Khan, Shahfahad Khan, Naeemullah and Fahim Ullah

69.1 Introduction

The construction industry is the backbone of national economy and considered a basic unit through which physical development is achieved (Maqsoom and Charoenngam 2014). Better project performance leads to better construction industry. Cost, time and quality are the key variables used to measure the performance of the project. The negative effect of time overrun and cost overrun is not limited just to the construction sector but influence the overall economy of a country.

The increasing complexity of infrastructure projects and the environment within which they are constructed places greater demand on construction managers to deliver projects on time, within the planned budget and with high quality (Enshassi et al. 2003; Al-Najjar 2008). The successful execution of construction projects and keeping them within the estimated cost and schedule mainly depends upon the construction methodology used, which requires thorough engineering holding and judgment. Due to disliking nature of owners, contractors and consultants; many projects experience extensive delays and thereby exceed initial time and cost estimates (Maqsoom et al. 2014). This problem arises mainly due to the lowest-bidder awarding and more evident in the traditional or adversarial type of contracts. Awarding the public projects to the lowest bidder is the common practice in developing countries including Pakistan.

A. Maqsoom (✉) · M.U. Khan · M.T. Khan · S. Khan · Naeemullah
Department of Civil Engineering, COMSATS Institute of Information Technology, Wah Cantt, Pakistan
e-mail: ahsen.maqsoom@ciitwah.edu.pk

F. Ullah
Department of Construction Management, National University of Sciences and Technology (NUST), Islamabad, Pakistan
e-mail: fahimullah@nit.nust.edu.pk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_69

Pakistan being developing economy needs to come up with best performance especially in the construction sector in order to compete with other developing economies. According to different surveys and reports, it is clear that Pakistan is having better growth rates but it should be optimized more in such way that it can compete with construction industries of developed economies. This research aims to achieve the following objectives: (1) to identify the internal and external factors causing time overrun and cost overrun in Pakistani construction projects, (2) to analyze the influence of internal and external factors on time and cost overrun, and (3) to formulate a framework which will be helpful for the firms for efficiently managing their project performance based on results and recommendation from the construction industry.

69.2 Literature Review

Time overrun is a major problem that affects the progress of project and delays the projects activities. Stumpf (2000) defines delay as an act or event that increase time required to complete the task under contract. Al-Gahtani and Mohan (2007) defined the time overrun as the increase in time to complete the project after the due date of project in contract. Kaming et al. (1997) defines the time delay as the extension of time beyond planned completion dates traceable to the contractors. Choudhury and Phatak (2004) and Chan (2001) defined the time delay as the difference between the projects' actual completed time and the estimated time.

Cost overrun is defined as the increase of actual cost over estimated cost. Jackson (1990) defined cost overrun as ratio between change in contract costs and estimated costs. The calculation is in percentage for easier comparison and the equation for calculation cost overrun is: Cost overrun = (change in contract estimated amount)/(original estimated cost). Choudhury and Phatak (2004) defined cost overrun as the difference between the original cost estimate in contract for specific project and the actual cost after the completion of that project. Costs overrun is also known as cost escalation, cost increase or budget overrun (Zhu and Lin 2004).

Mezher and Tawil (1998) researched the causes that affect time completion in the construction industry in Lebanon. They conclude that owners had more concern with financial problems; contractors regarded contractual relationships the most important, while consultants considered project management issues to be the most important factors causing time overrun in construction projects. Odeh and Battaineh (2002) investigated the contractors and consultants in Jordan construction industry and founded top ten factors that cause time overrun. These factors are owner interference, inadequate contractor experience, financing and payments problems, labor productivity, slow decision making, improper planning and subcontractors related issues. Aibinu and Jagboro (2002) studied the growing problem of construction delays in Nigeria, they tested the effect of delays on the delivery of construction projects in that country. They had a survey by collecting data through questionnaire from 61 construction projects and identified that time and cost overrun is frequent and affects the project completion. They further found that owners' project management procedure, no allowance contingency planning and bad estimation of contract management were the main factors that caused time delays in Nigeria.

Kaming et al. (1997) conducted a research on the cost overrun in the construction projects and found some common factors that are weather condition, change in material rates, inaccurate estimation of cost, complexity of projects, contractors less experience about the site geography, contractor less experience about the project and non-familiarity with local regulations. He also studied the cost overrun in high risk construction projects of Indonesia. He pointed out four main factors that affect the cost overrun in construction projects that are increase in material cost, incorrect management of quantity take-off, productivity of labor and increase of labor wages in markets. Chimwaso (2001) studied the factors causing cost overrun in the construction projects. He divided the factors into two groups that are critical and other factors. The nine factors that are considered as critical by Chimwaso (2001) include incomplete design at the time of tender, additional work at owner's request, changes in owner brief, lack of cost planning and monitoring during pre and post contract stages, poor soil conditions at site, adjustment of prime cost and provisional sums, re measurement of provisional works, logistics due to site location and lack of cost reports during construction stage.

69.3 Research Methodology

Keeping in view the research objectives mentioned above, a structured questionnaire was developed considering the factors as identified on procurement related factors, site operation related factors, design and documentation related factors and labors related factors causing the time and cost overrun in construction projects. The questionnaire was pilot tested in December 2015 on nine contractors' firms, 3 of the respondents were Project Directors, 3 were General Manager, 2 Site Managers and 1 was CEO. Improvements were made based on the suggestions and recommendations by the respondents.

The author attempted to develop the simple questionnaire. All the factors were divided in such way that it became easy for the respondent to pick the right answer without any ambiguity. In addition, some of the answers were arranged in ratios rather than fixed numbers or figures that made the questionnaire easy to understand and respond without hesitation. Proper choices for some questions were also provided so that respondents are comfortable to respond the questionnaire.

In Jan 2016, the final questionnaire was mailed to the population of contractor firms all over Pakistan. Questionnaires were also distributed by hands among different firms. The Head of Administration of University and the Head of Pakistan Engineering Council (PEC) endorsed the questionnaire by a cover letter, thus providing the legitimate authority to distribute questionnaire among the registered contractors' firms of Pakistan Engineering Council (PEC). The questionnaire was sent to 180 firms in total. The respondents were asked to rate the variables using Likert scale (where 1 = the least important; 5 = the most important). Total of 130 responses were received. 17 responses were discarded as they were incomplete. Completed questionnaire number was 113 (39 from building, 43 from civil works, 26 from electrical and mechanical and 5 from other specialization) which is a response rate of 62.7% from Pakistani construction industry. All the firms which have responded the questionnaire were registered member of PEC and were attributed to construction sector; they were specialized in multiple fields of construction including building and civil, petrochemical, electrical and mechanical.

69.4 Findings and Discussion

The first phase of the analysis is related to the design and documentation related issues causing the time overrun and cost overrun. These factors were taken from earlier researches on design and documentation factors causing the time overrun and cost overrun. Some of the factors were self-developed as they were considered important for influencing the completion of projects within time and estimated cost. The results for this phase are presented in Fig. 69.1.

Design changes during construction having Mean Importance Rating (MIR) = 4.02 for time overrun and MIR = 3.75 for cost overrun and improvement in standard drawings at construction stage (MIR = 3.87 for time overrun and MIR = 3.84 for cost overrun) are highly ranked and most important factor that causes time overrun and cost overrun respectively. These factors are self-explanatory and are general practice while performing a project. Especially when the project is in its construction stage, the contractor usually receives

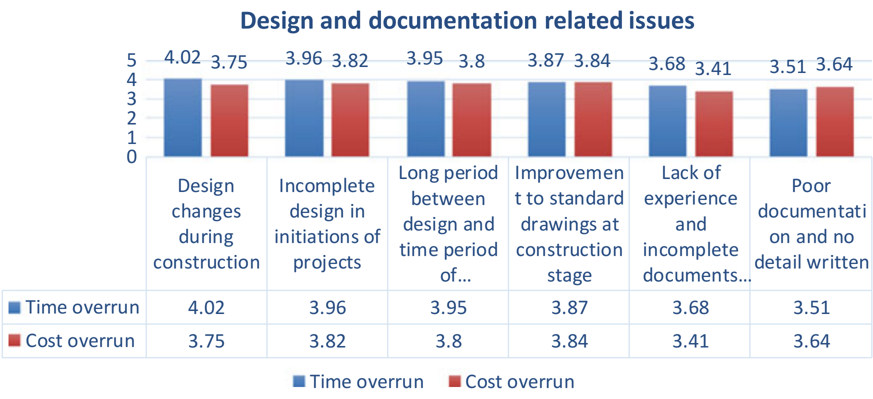


Fig. 69.1 Design and documentation issues causing time and cost overrun. *Note* Means <1.5 = unimportant; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5.0 = very important

information from the higher authorities or the client that design should be modified. These factors greatly influence the time and cost of the project, as the project will not be completed on time and within the allocated budget, if design changing is required during the construction phase of the project. Enshassi et al. (2003) also found the improvements to standard drawings during construction stage, design changes and inaccurate quantity take-off as critical factors causing cost overrun in construction projects of Gaza.

Poor documentation and no detail written (MIR = 3.51 for time overrun and MIR = 3.64 for cost overrun) along with lack of experience and incomplete documents by consultant (MIR = 3.68 for time overrun and MIR = 3.41 for cost overrun) were considered moderately important factors causing the time overrun and cost overrun respectively. Poor documentation and no detail written was the lowest ranked factor because, usually all the contractors seem up-to-date regarding the project documentation; it is a vital step to show the progress report and track record of the project to the client and other stakeholders. Also, poor documentation and no details written influence the reputation of the contractor firms. Lack of experience and incomplete documents by consultant is low ranked factor because most of the consultants in Pakistan have good experience and they have a large number of experienced and high-tech manpower i.e. most of them have already worked in overseas especially in Middle East. Secondly, client is responsible for the incomplete documents e.g. if client provide documents containing design of the project and later on the client want to change the design hence it is not the problem which has arisen due to consultant but it has arisen due to the client. Hence both these factors are ranked least important and the percentage of occurrence of these factors is negligible in construction industry of Pakistan.

The second phase of the analysis is related to the labor related issues causing the time overrun and cost overrun in Pakistani construction projects (Fig. 69.2). Bad performance of subcontractors and nominated suppliers (MIR = 4.01 for time overrun and MIR = 3.9 for cost overrun) is highly ranked and important factor. In a project the link between the contractor and sub-contractor is very much important. In construction projects usually the full authority is in hands of contractor, sub-contractors are usually ignored in the project because of which their performance is not up to the mark. Nominated suppliers are those who have the duty to deliver the material and machinery on time to the project site. When nominated suppliers and subcontractors do not hand over their tasks on time, it causes time overrun and cost overrun.

Poor technical performance and shortage of technical staff (MIR = 3.85 for time overrun and MIR = 3.58 for cost overrun) is the second highest ranked factor among the whole factors for labor related issues. Poor technical performance and shortage of technical staff can be due to the over difficult task, low individual aptitude skill and knowledge, evidence of strong effort, despite poor performance and lack of improvement over time. This factor causes time overrun and cost overrun in the construction projects in Pakistan.

Labor strike (MIR = 3.49 for time overrun and MIR = 2.94 for cost overrun) is ranked as moderately important factor among the labor related issues. Exceeding

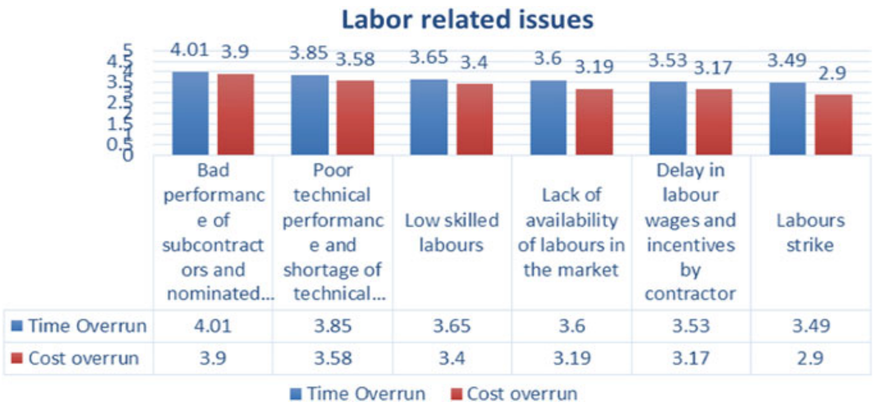


Fig. 69.2 Labor related issues causing time and cost overrun. *Note* Means <1.5 = unimportant; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5.0 = very important

the normal hours of work of an employee which are 8 h a day, not having proper meal periods, paying less than 10% of his wage for night shift differential, under time work on any particular day is offset by overtime work on any other day, not giving right of weekly rest day, not giving compensation for rest day, not giving chance of service incentive leave and minimum wages are some of the main reasons which causes labor strikes in Pakistan. This factor mainly causes the time overrun and partially causes cost overrun in construction projects in Pakistani construction industry.

The third phase of analysis is related to the procurement related issues causing the time overrun and cost overrun in Pakistani construction projects (Fig. 69.3). Material cost fluctuation and shortage of materials (MIR = 3.91 for time overrun and MIR = 3.72 for cost overrun) is considered as highly important factor that causes time overrun and cost overrun respectively in the construction projects in Pakistan. Most of the industries require significant amount of raw material and labor and therefore shortage and increase in cost of raw material can adversely affect the project results. In 2008 the drastic change in the stock exchange affected many prices, especially at that time the United Arab Emirates faced great loss in construction and other industries. Similarly, Pakistan has faced the same problem in material cost.

High rent of machinery (MIR = 3.81) is considered as top ranked factor causing cost overrun in Pakistani construction projects. Depending on the context and the activity, a contract can be for construction or for procurement of equipment, machinery, etc. Inexperienced contractors if ignore the correct estimation of rent of machinery in their bids, it can lead to increase in project cost compared with the estimated cost. High rent of machinery (MIR = 2.86) and misunderstanding of material transportation (MIR = 3.3) are considered as moderately important and lowest ranked among all the factors causing the time overrun in the construction

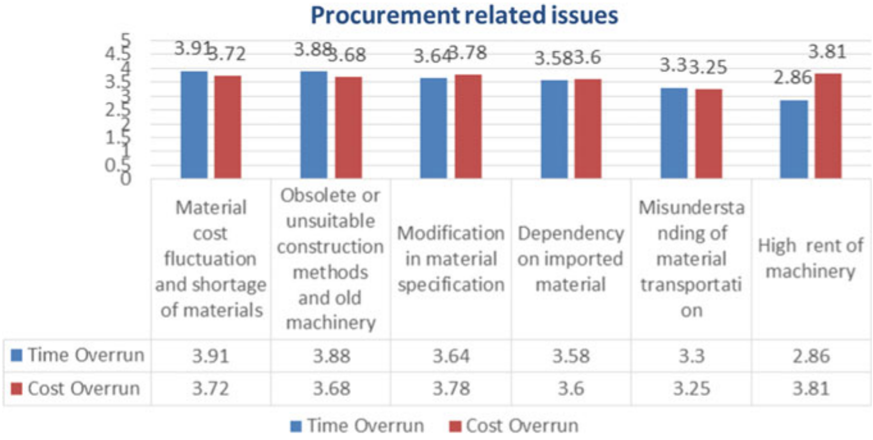


Fig. 69.3 Procurement related issues causing time and cost overrun. *Note* Means <1.5 = unimportant; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5.0 = very important

projects in Pakistan. These are lowest ranked because high rent of machinery has lesser effect on the project completion time, while estimating the project cost, rent of machinery is also calculated and the machinery is procured before starting of construction phase. Misunderstanding of material transportation means ambiguity between the demand and supply and the material properties. This phenomenon is very rare because of better communication system and on time delivery of the information. Issue arises while the project is in construction stage and contractor need raw material that has to be imported from the other country which may include the machinery with high cost or any other products and raw material that has to be used in construction. It is costly and time consuming to import such a material from the other country. Hence to some extent, the misunderstanding of transportation can cause time overrun in the projects.

The fourth phase of the analysis is related to the site operation related issues causing the time overrun and cost overrun in Pakistani construction projects (Fig. 69.4). Problem in land acquisition (MIR = 4.07 for time overrun and MIR = 3.85 for cost overrun) is the big hurdle in launching project in different areas, because in Pakistan the system is decentralized and the power is given to people because of democracy. The problem of land acquisition usually occurs, especially when large construction projects are being constructed. Displacing or taking land from many societies and groups in Pakistan is considered against their social and cultural norms. This factor causes time overrun as well as cost overrun in the construction projects in Pakistan.

Poor site management and supervision by contractors (MIR = 4.04 for time overrun and MIR = 3.66 for cost overrun) was considered as second highest and important factor causing time overrun as well as cost overrun in the construction projects in Pakistan.

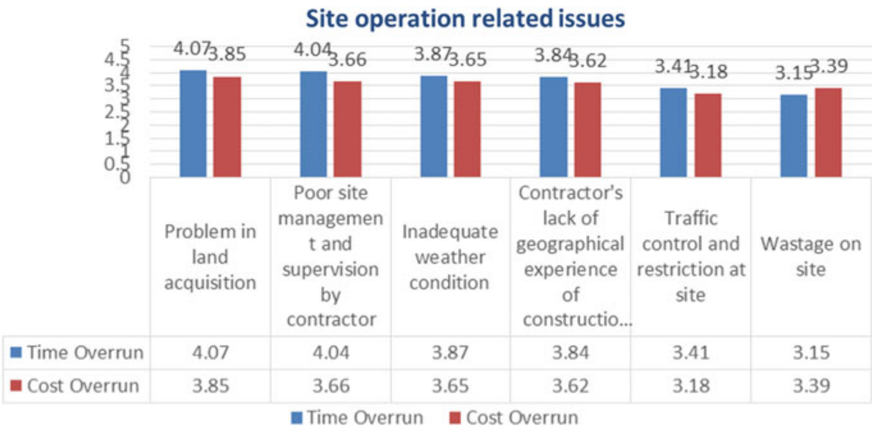


Fig. 69.4 Site operation related issues causing time and cost overrun. *Note* Means <1.49 = unimportant; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5.0 = very important

Poor site management and supervision by contractor is because of many reasons, the big reason among them is corruption. The supervisor and the contractor in many projects and construction works use low quality material and less amount of associated material to achieve good strength that's why they don't face the people of the locality where the project is going on because the people of the locality asks the reason behind the use of low quality material, this is the main reason behind poor site management.

Wastage on site (MIR = 3.15 for time overrun and MIR = 3.39 for cost overrun) and traffic control and restriction at site (MIR = 3.41 for time overrun and MIR = 3.18 for cost overrun) are moderately important and lowest ranked issues causing time overrun and cost overrun respectively in the construction projects. The main reason behind this issue is that the material needs to be transferred if unusable, and if this material remains on the site it can cause blockage to the machinery and less land will be available for the future material that has to be used. It is to be mentioned here that construction site vehicle incidents can and should be prevented by effective management throughout the operation of construction at site. Accident occurs due to the site operation issues and managers, workers, visitors to sites, and member of the public can all be at risk because of these issues, so it must be properly handled on site. Accident cases are in abundance in Pakistan because of poor safety measures on site.

69.5 Conclusion

The aim of this paper was to investigate and analyze the factors influencing the time overrun and cost overrun in construction projects especially in Pakistani construction industry. Regarding the design and documentation related issues, design changes during construction and improvements to standard drawings are critical factors causing time overrun and cost overrun respectively whereas, lack of experience and incomplete documents by consultant and poor documentation with no detail written are least important factors for cost overrun and time overrun respectively. Among labor related issues, bad performance of subcontractors and nominated suppliers and poor technical performance and shortage of technical staff are highly ranked factors causing both time and cost overrun. Whereas, labor strikes are moderately important factor causing cost and time overrun and is ranked lowest. Among procurement related issues, material fluctuation and shortage of material is the critical factor causing time overrun and cost overrun respectively. Whereas, high rent of machinery and misunderstanding of material transportation are least important factors causing time overrun and cost overrun respectively. Among site operation related issues, problem in land acquisition is critical factor causing time and cost overrun whereas wastage on site and traffic control and restriction on site are least important factors causing time and cost overrun in Pakistani construction projects.

The findings of the study should be viewed in the limitation that only one country from the developing countries, i.e. Pakistan, has been taken into account and also the sample represent only contractor firm's views. The results are valuable for all developing countries' contractors. The authors of this research call for future studies to be conducted which measures the impact of size and experience on the time and cost overrun of construction projects.

Acknowledgements The author would like to pay gratitude to Pakistan Engineering Council (PEC) for providing the list of registered contractors and for endorsing and forwarding the questionnaire to the Pakistani contractor firms.

References

Aibinu AA, Jagboro GO (2002) The effects of construction delays on project delivery in Nigerian construction industry. Int J Project Manage 20(8):593–599

Al-Gahtani K, Mohan S (2007) Total float management for delay analysis. J Cost Eng 49(2):32–37

Al-Najjar J (2008) Factors influencing time and cost overruns on construction projects in the Gaza Strip. Islamic University, Gaza

Chan APC (2001) Time cost relationship of public sector projects in Malaysia. Int J Project Manage 19(4):223–229

Chimwaso KD (2001) An evaluation of cost performance of public projects; case of Botswana. Department of Architecture and Building Services, Private Bag 0025, Gaborone, Botswana

Choudhury I, Phatak O (2004) Correlates of time overrun in commercial construction. In: ASC proceedings of 4th annual conference, Brigham Young University, Provo, Utah, 8–10 Apr

Enshassi A, Lisk R, Sawalhi I, Radwan I (2003) Contributors to construction delays in Palestine. J Am Inst Constr 27(2):45–53

Jackson JT (1990) Technical specifications effect on construction. J Constr Eng Manage 116 (3):463–467

Kaming PF, Olomolaiye PO, Holt GD, Harris FC (1997) Factors influencing construction time and cost overruns on high-rise projects in Indonesia. Constr Manage Econ 15(1):83–94

Maqsoom A, Charoenngam C (2014) Motives and competitive assets of Pakistani international construction contracting firms: impact of size and international experience. J Financ Manage Property Constr 19(2):138–151

Maqsoom A, Charoenngam C, Masood R, Awais M (2014) Foreign market entry considerations of emerging economy firms: an example of Pakistani contractors. Proc Eng 77:222–228

Mezher TC, Tawil W (1998) Causes of delay in the construction industry in Lebanon. Eng Constr Archit Manage 5(3):252–260

Odeh AM, Battaineh HT (2002) Causes of construction delay: traditional contracts. Int J Project Manage 20(1):67–73

Stumpf G (2000) Schedule delay analysis. Constr Eng J 42(7):32–43

Zhu K, Lin L (2004) A stage-by-stage factor control frame work for cost estimation of construction projects. In: Owners driving innovation international conference, http://flybjerg.Plan.aau.dk/JAPAASPUBLISHED.pelf

Chapter 70
Feasibility Analysis of Using Construction and Demolition Waste in Sea Reclamation Projects in Hainan

X.L. Li, Y. Li, H.Y. Wu, J.Y. Wang, H.B. Duan and X.X. Xv

70.1 Introduction

With the steady development of international tourism island, Hainan is facing with the increasing demand for sea areas and the scale needed continues to expand, thus sea reclamation has became one of the most effective ways to solve the problem of lack of land space (Wang et al. 2015). In 2014, 219 sea reclamation projects have created 4741.65 ha land, which need massive earth fillings. In recent five years, meanwhile, more than 20 million m^2 building has been constructed and approximately 10 million tons C&D waste has been generated annually in Hainan province (Hainan Statistical Yearbook 2015). However, the majority of waste is disposed in landfills except a small proportion is used as backfills (Yuan 2012). Due to the limitation of capacity of landfill sites, this way of disposing C&D waste is unsustainable (Shi et al. 2011). Therefore, considering waste utilization and the demand for large amount of fillers in sea reclamation works, this paper based on the analysis of C&D waste generation, waste components and disposal ways in Hainan, discusses the feasibility of C&D waste application in sea reclamation projects from three aspects, i.e. legal regulation, technology and environment. The results could provide valuable information for sea reclamation and utilization of C&D waste.

X.L. Li · Y. Li · H.Y. Wu · J.Y. Wang (✉) · X.X. Xv
School of Civil Engineering, Shenzhen University, Shenzhen Shi, China
e-mail: wangjy@szu.edu.cn

H.B. Duan
College of Civil Engineering, Shenzhen University, Shenzhen Shi, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_70

70.2 C&D Waste Components and Generation in Hainan

70.2.1 C&D Waste Components

When considering C&D waste it is important to define what is meant by the term. In general, C&D waste is defined as the waste arising from construction, renovation and demolition activities including land excavation or formation, civil and building construction, demolition activities and building renovation (Shen et al. 2004; Lu et al. 2011). Although buildings are varied in the structures and construction techniques, the main components of C&D waste are commonly the same, including concrete, brick and block, mortar, metal, timber formwork, glass and plastic, etc. (Formoso et al. 2002; Li et al. 2010; Wu et al. 2015). Moreover, C&D waste is divided into inert waste and non-inert waste, where the inert waste, comprising soil, brick and block, and concrete, is deposited at filling areas for land reclamation, while the non-inert waste consists of metals, timber, wood, plastics and other organic waste, is disposed of at landfills (Poon et al. 2001; Yuan et al. 2013).

Through extensive investigations on the conventional construction projects in Hainan, the components of construction waste and demolition waste are shown respectively in Figs. 70.1 and 70.2. As can be seen from the figures, among all kinds of waste generated from construction activities, the total proportion of concrete, brick and masonry, mortar and other inert waste is as high as 60%, while the percentage of the inert waste from demolition activities is nearly 85%.

70.2.2 C&D Waste Generation

Since construction companies until now are not obliged to record and report the qualitative and quantitative characteristics of the C&D waste generated, there is a lack of available generation information of C&D waste in most cities in China, which leading to the difficulty of estimation (Kofowworola and Gheewala 2012). In literature, various methods have been employed to predict the generation of C&D waste, for instance, multivariable regression modeling method, time series forecasting method, gray system forecasting method and so on (Zuo and Fu 2009; Shu 2007). Taking into account that C&D waste system is a symbolic gray system (Wang et al. 2009), and the gray system theory has been employed to predict the amount of electronic waste and industrial solid waste, this paper develops a gray model (GM (1,1)) to forecast the generation of C&D waste in Hainan by analyzing the data of the past six years (2009–2014).

In order to evaluate the quantity of C&D waste generated every year, two assumptions were made: (a) new construction activity generated 60 kg/m^2 of waste (Zhang 2009), and (b) demolition construction area accounts for 30% of the construction floor area. Since demolition waste generation indicators are influenced by building structure, functional use, removal method and other factors (Chen et al. 2007),

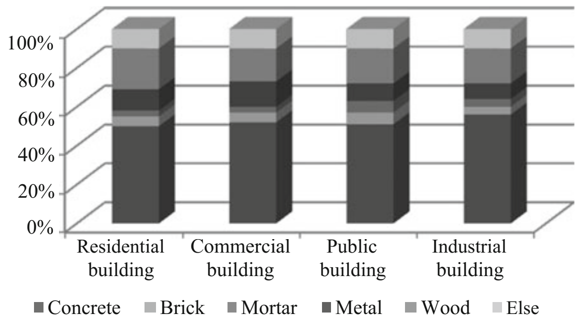


Fig. 70.1 Construction waste components

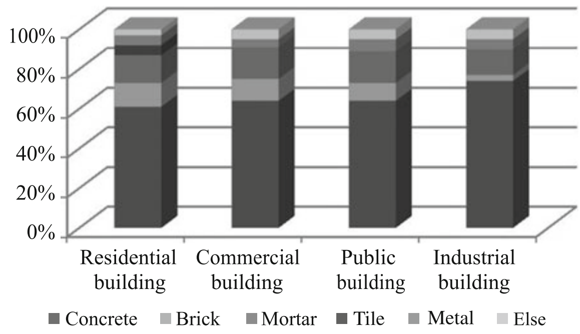


Fig. 70.2 Demolition waste components

this research applied the empirical coefficient method to obtain demolition waste indicators through a wide spot investigation. Finally, the GM (1,1) model was obtained as follows:

$$X^{(1)}(\mathrm{k}+1) = 36{,}398.76\mathrm{e}^{0.0263\mathrm{k}} - 36{,}066.46 \tag{70.1}$$

As can be seen from Table 70.1, the validity of the gray model is confirmed and thus it can be used to predict the total output of C&D waste accurately. And the prediction formula is:

$$\mathrm{X}^{(0)}(\mathrm{k}+1) = \mathrm{X}^{(1)}(\mathrm{K}+1) - \mathrm{X}^{(1)}(\mathrm{k}) \tag{70.2}$$

Therefore, according to the model, the generation of C&D waste in Hainan from 2009 to 2020 can be forecasted and the results are shown in Fig. 70.3.

Table 70.1 The verification of the prediction model

				(Unit: 10,000 t)
Year	Actual value	Prediction value	Absolute error	Relative error (%)
2009	332.3	332.3	0	0
2010	686.3	970.23	283.93	41.37%
2011	1313.3	996.09	317.21	24.15%
2012	1095	1022.64	72.36	6.61%
2013	1053.8	1049.90	3.90	0.37%
2014	967.7	1077.89	110.19	11.39%
$0.35 < C = 0.3969 < 0.5$, $P = 1.00 > 0.95$				

Note C is the ratio of the mean square error; *P* is the possibility of small error

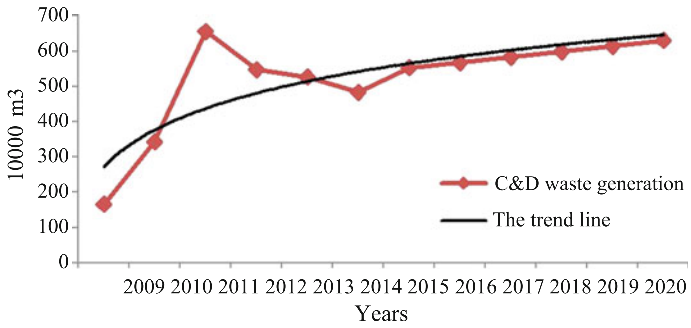


Fig. 70.3 C&D waste generation from 2009 to 2020 in Hainan

70.3 Sea Reclamation Cases and Experience

70.3.1 Sea Reclamation Case

Sea reclamation refers to the transformation of original waters, lake or river into the land. It is a very effective method to manufacture flat for the urban development, especially for coastal cities with characteristics of less land resources (Yang et al. 2015). Therefore, many coastal countries in the world have adopted this approach to obtain additional flat in recent years.

Netherlands is one of the oldest and largest countries where adopting sea reclamation to expand its land. It has begun conducting large-scale sea reclamation since 13th century and now there is 41,526 km^2 of land, a quarter of which sourced from the sea (Chen 2010). Japan is a small and densely-populated country. In order to relieve the contradiction between shortage of land resource and population growth, it has taken the reclamation way to get new land. What's more, high-speed development in Japan generated a great deal of C&D waste, which is used as the main reclamation land materials (Shi et al. 2011).

The activities of sea reclamation in China were started from the 1950s and 1960s. To the end of that century, the area of sea reclamation in coastal regions has reached 12,000 km^2, with an average reclamation area of 230–240 km^2 per year. Particularly, coastal cities with poor land resources, such as Shenzhen, Shanghai, Hong Kong, Macao and Taiwan, have been taking sea reclamation in ways to expand land scales, in order to meet the demand for urban development.[1]

70.3.2 Experience Summary

With the rapid development of industrialization and urbanization, the shortage of land resource has become an important bottleneck to restrict economic development of the coastal areas. Sea reclamation has already became a great approach to expand land spaces and avoid the restriction from the policy to a certain extent (Liu and Liu 2008). According to the domestic and external sea reclamation cases, the following points are summarized:

- Protecting the marine environment in the process of sea reclamation and exploring the sustainable development ways between economy and environment;
- Controlling the scale of sea reclamation strictly, in order to avoid environmental damage caused by large-scale reclamation;
- Improving the way of sea reclamation effectively and taking efficient advantage of the additional land;
- The most important point is, C&D waste generated in the process of road construction, tunnel bridge construction, port excavation and urban renewal can be used as fillings in sea reclamation projects, which achieves the purpose of turning waste into treasure.

70.4 Feasibility Analysis

70.4.1 Quantity Demand

The prediction model built in this study indicates that it produces about 10 million tons of C&D waste each year in Hainan Province from 2015 to 2020, and the amount will continue to increase over time. Meanwhile, the wide surveys still show that inert waste accounts for 60% of the construction waste and 85% of the demolition waste, which can meet the demand for fillers in sea reclamation projects to a certain extent. Therefore, using inter C&D waste as a filler in sea reclamation

[1] http://www.chinanews.com/tw/2012/12-13/4404263.shtml.

works is available from the quantitative point of view and it is and will be a very promising and worth considering task.

70.4.2 Legal Aspect

Over the past decades, a series of marine environment protection policies including regulations, codes and initiatives have been conducted by governments. In order to find the relevant laws about sea reclamation, an extensive reading has been done and the following four regulations are known as the most representative (see Table 70.2). In accordance with the contents of these four legislations, it can be seen that inert construction waste could be used in sea reclamation under the certain condition, such as obtaining the license from government, meeting the environment protection standards and so on.

Therefore, under the premise of meeting environmental standards, the ideal of inert construction waste applied to reclamation projects has obtained legal support to a certain extent.

70.4.3 Technical Aspect

According to the sea reclamation cases mentioned above, using the garbage and silt as the main materials in sea reclamation works has be appeared in Japan long years ago. In some sea reclamation projects in Hong Kong, when choosing sludge or waste as fillers, it will flat seabed at first to dug up the bottom sludge, and lay films with the characteristic of preventing water leakage on the seabed and the embankment, and then pour the fillers into the landfills. Thus, in other countries and regions, the use of construction waste in reclamation is feasible from technical aspect.

On the other hand, according to "*The Limitation on Infilling Components of Sea Reclamation and Enclosure Project (GB30736-2014)*", the composition requirements of infilling components are described clearly, and it also provides some detection methods for experiments. Inert C&D waste could be texted to meet the various components requirements of the filling material in sea reclamation projects after treatment.

Therefore, by combining the experience of sea reclamation cases and analyzing the different requirements of filling materials in reclamation projects, the inert construction waste used as fill material in sea reclamation projects meets the requirements from technical aspect.

Table 70.2 The relevant laws about sea reclamation

Laws	Published year	Article	Contents
Marine Environmental Protection Law of the People's Republic of China	2000	20	Any unit may not dump any kinds of waste into the sea without the permission of the state administrative department of marine affairs. If necessary, the unit must submit written applications to marine administration
		29	Anyone who want to dump land-sourced pollutants into the sea, shall implement strictly for compliance with the provisions and standards made by the state or local regions
		56	The evaluation procedures and standards in accordance with waste toxicity, harmful substance content and the impact upon the marine environment
Prevention of Marine Construction Projects Influencing the Marine Environmental Management Regulations	2006	8	The evaluation procedures of environmental impact and the pollutant emissions management system
		21	The scale of sea reclamation must be controlled strictly and the fillers used in sea reclamation works should be conformed to the relevant environmental protection
The Limitation on Infilling Components of Sea Reclamation and Enclosure Project (GB30736-2014)	2014	–	Construction waste and abandoned soil with low organic materials generated in the process of construction, renovation, demolition and other activities, such as gravel, sand, mud, concrete, rubble and brick can be used as sea reclamation fillers because there is no significant chemical reactions between these kinds of waste and the surrounding marine materials
Environmental Health Planning Guidelines in Hainan (Trial)	2009	17	The inert construction waste can be used as the alternative fillers in reclamation, port construction, road construction and other projects

70.4.4 Environmental Aspect

Sea reclamation projects are widely implemented in the global not only improve the industrial economy, but also result in some huge hangovers, for instance, marine pollution, ecological degradation, waterway blockage shoreline and other environmental problems have emerged in endlessly (Yang et al.). Therefore, the marine environmental impact must be considered if wanting to take advantage of the construction waste in sea reclamation.

The marine environmental impact of construction waste used in land reclamation can be assessed and analyzed in accordance with "*Water Quality Standards (GB3097-1997)*" and "*Marine Sediment Quality (GBl8668-2002)*". According to "*Water Quality Standards*," the sea water quality is divided into four categories depending on the different function and protection goals of the sea area, and the standard for each kind of water is carried out. Therefore, relying on the regulations of above water quality standards, and combination with the chemical composition of inert construction waste to analyze, it is easy to see that the impact of inert construction waste on the seawater quality is in the affordable range.

"*Marine Sediment Quality*" provides various types of deposits required to meet the indicators, and the inert construction waste indeed meets all of the requirements, and the composition of inert construction waste can also satisfy the quality requirements of marine sediments through classification and sorting process, which finally has no serious impact on marine environment.

70.5 Conclusions and Suggestions

The results show that, theoretically, using C&D waste in sea reclamation projects is one of possible ways to disposal C&D waste and solve the practical problem of insufficient fillers in sea reclamation projects, if the potential pollution of C&D waste could be treated well. To be concrete, the following issues must be paid attention to when applying C&D waste in sea reclamation projects:

- The C&D waste must be classified and sorted strictly before being used in sea reclamation activities. Due to the complex composition of C&D waste, the non-inert wastes, especially waste decoration materials, toxic and hazardous waste must be treated separately, and can not be applied in sea reclamation projects.
- Pay attention to environmental protection constantly. When using the non-inert waste as filler in sea reclamation projects, the backfill materials must be checked and met the required indicators (physical, chemical, radiological and biological content, etc.). Moreover, the environmental state of the backfill area should be tested regularly, in order to ensure that the fillers can not cause pollutions to the surrounding marine environment.

- For government, it is necessary to increase financial and technical support to promote this approach into implementation. At the stage of classification, sorting, collection, transportation and disposal, it consumes a significant portion of costs to manage C&D waste, and a vast majority of contractors driven by short period economic interests may ignore the recycling value of C&D waste.

Acknowledgment This work was supported by the Technology Research and Development Program of Shenzhen (grant number JCYJ20160520173631894).

References

Chen J (2010) Excessive sea reclamation will bring retaliatory consequences. Econ Inf Daily, 25 June 2010

Chen J, He PJ, Shao LM (2007) Methods discussion on quantity estimating of demolition waste. Environ Sanitation Eng 06:1–4

Formoso CT, Soibelman L, De Cesare C et al (2002) Material waste in building industry: main causes and prevention. J Constr Eng Manage (4):316–325

Hainan Statistical Yearbook (2015) http://www.stats.hainan.gov.cn/2015nj/index-cn.htm

Kofowworola OF, Gheewala SH (2012) Estimation of construction waste generation and management in Thailand. Waste Manage 29(2):731–738

Li J, Mi X, Ding Z, Wang J (2010) Investigation and analysis on generation rate of construction waste. Constr Econ 1:83–86

Liu W, Liu BQ (2008) Current situation and countermeasures of sea reclamation in China. Guangzhou Environ Sci 23(02):29–30

Lu WS, Yuan HP, Li JR et al (2011) An empirical investigation of construction and demolition waste generation rates in Shenzhen city, South China. Waste Manage 31(4):680–687

Poon CS, Yu A, Ng LH (2001) On-site sorting of construction and demolition waste in Hong Kong. Resour Conserv Recycl 32(2):157–172

Shen LY, Tam V, Tam CM et al (2004) Mapping approach for examining waste management on construction sites. J Constr Eng Manage 130(4):472–481

Shi P, Xie J, He GF (2011) Inspiration of Chinese waste disposal mode from land reclamation in Japan. Trans Oceanol Limnol 03:168–172

Shu Y (2007) Grey model predication of urban refuse in Hefei city. Environ Sci Manage 32(9):5–8

Wang GQ, Zhang HY et al (2009) The prediction by gray model on the production of construction and demolition waste of Beijing. Environ Eng 27(s1):508–511

Wang Y, Wang T, Fu SY (2015) Discussion about the status and management strategies of land reclamation in Hainan. Ocean Dev Manage 8:56–59

Wu H, Wang J, Duan H et al (2015) An innovative approach to managing demolition waste via GIS (geographic information system): a case study in Shenzhen city, China. J Cleaner Prod

Yang B, Zhu JB, Ma RM, Reflection on sea reclamation. Ocean Dev Manage (10):22–25

Yang B, Zhu JB et al (2015) Reflections on the sea reclamation. Ocean Dev Manage 10:22–25

Yuan HP (2012) A model for evaluating the social performance of construction waste management. Waste Manage 32(6):1218–1228

Yuan HP, Lu WS, Hao JJ (2013) The evolution of construction waste sorting on-site. Renew Sustain Energy Rev 20:483–490

Zhang XL (2009) Feasibility analysis of construction waste applied in sea reclamation. Civil Eng Archit 6(01):53–56

Zuo HK, Fu SL (2009) The prediction of construction waste generation with a lack of historical data. Environ Sustain Dev 37(5):106–109

Chapter 71
Female Student Enrolments in Construction Management Programs

B.L. Oo and E.C. Widjaja

71.1 Introduction

Women workforce has been seen as an untapped resource in the construction industry worldwide (Fielden et al. 2000; Sewalk and Nietfeld 2013). Over the past decades, there is a considerable amount of research attempted to document the issues of under-representation of women in construction from different perspectives such as: (i) the experiences of women currently working in the construction industry (e.g., Dainty et al. 2000; Lingard and Lin 2004; Moore and Gloeckner 2007); (ii) the enrolment and retention of female students in construction management (CM) programs (e.g., Bigelow et al. 2015; Francis and Prosser 2014; Sewalk and Nietfeld 2013; Shane et al. 2012); and (iii) the retention of female students in the construction industry upon their graduation (e.g., Adogbo et al. 2015; Ling et al. 2016; Worrall et al. 2010). This paper falls into the category of study on enrolment of female students in CM programs. While there are similar studies in the UK and US, there is a lack of study in Australia context. The specific objectives of this paper are: (i) to examine the trends of female student enrolments in CM programs in Australian universities in New South Wales (NSW) state between 2006 and 2015; and (ii) to explore factors affecting female students' choice of CM programs and their perceptions of the construction industry and construction jobs. The research findings have implications on the recruitment processes of educational institutions towards sustainable increment of female students in CM programs.

B.L. Oo (✉) · E.C. Widjaja
Faculty of Built Environment, UNSW, Sydney, Australia
e-mail: bee.oo@unsw.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_71

71.2 Female Students in Construction Management Programs

The considerably low female student enrolments in CM programs have continued to draw efforts from faculty to attract female students to CM degrees, and ultimately the construction industry. It appears, however, the assumption that the overall women participation in the construction industry would increase with an increase in female student enrolments does not seem to be plausible when one looks at: (i) the reported high proportion of female graduates choose not to enter the industry (Ling and Poh 2004); and (ii) the difficulties in recruitment of young graduates into construction industry in different countries (Ling et al. 2016). Indeed, as pointed out by Moore and Gloeckner (2007, p. 136), "attracting female students to CM programs is half the battle for academia. Retaining them through graduation and sending them out into the industry are equally important to the future of the construction industry."

71.2.1 Female Student Enrolments

In terms of enrolment trends in CM programs, Dainty and Edwards (2003) reported a significant decline in the number of graduates (male and female) applying for, and accepting, places on building degree courses in the UK between 1994 and 2000, with a decrease of 28% over the analysis period. Surprisingly, their analysis further showed that the number of applications from female graduates had experienced an increase trend in the range of 7–16% over the period. It is noted that the courses covered in their study were: building construction and technology, architectural engineering, building services engineering, facilities management, construction management, fire safety, building surveying, building economics, quantity surveying and hybrid combinations of these subjects. At Colorado State University, the numbers of female CM graduates conferred between 2000 and 2010 have ranged from 4.6 to 12.6% with an average of 7.9% (Del Puerto et al. 2011). In a Construction Engineering program at one Midwestern university, the largest program in the US with almost 400 enrolments, the recorded percentage of female students vary from the top 15% in 1995 to a low point of 7% in 2006 (Shane et al. 2012). With a series of attempts aimed at retaining female students in the program including activities to integrate them into the program and to create an identity through involvement with extracurricular student groups, encouragingly, they recorded an increase from the low point of 7% in 2006 to 14% in 2010. It is noted that a survey with responses from 26 CM programs in the US revealed that the average percentage of female students was 9.77% over a five-year analysis period (Sewalk and Nietfeld 2013). In a more recent study, the recorded percentages of female enrolments range from 5.7 to 9.6% for five universities in the US with large enrolments (more than 340 students) in CM programs (Bigelow et al. 2015). It can be seen that the percentages recorded in the literature are generally below 10%. Also, the areas of focus for previous studies in the US are varied along with the reported statistics on female student enrolments in CM programs. These include: identifying the major factors affecting students' choice of CM programs and strategies for attracting female students to CM programs (e.g., Adogbo et al. 2015; Bigelow et al. 2015; Del Puerto et al. 2011; Koch et al. 2009), and the barriers preventing female students from enrolling in CM programs (e.g., Sewalk and Nietfeld 2013). For example, Bigelow et al. (2015) found that the two most influential factors in attracting female students to CM programs were internships and awareness of career opportunities. Sewalk and Nietfeld (2013), on the other hand, identified that the main barriers preventing female students from enrolling in CM programs were the perceptions and stereotypes of the construction industry.

71.2.2 Graduates' Perceptions and Career Expectations

Previous findings on graduates' perceptions of the construction industry are largely consistent with the industry being perceived as male-dominated, and jobs in construction are competitive, demanding, stressful and involve long working hours (e.g., Adogbo et al. 2015; Ling et al. 2016; Ling and Ho 2013). Not surprisingly, these graduates' perceptions are also consistent with studies that involved professional women working in the industry (e.g., Dainty et al. 2000; Ling et al. 2016; Worrall et al. 2010). Authors have suggested various strategies in attracting young graduates to work in the industry including: developing mentoring program and support network; providing a better work-life balance; and increasing graduates' interest with the inclusion of internship and work experience program in CM programs (Adogbo et al. 2015; Moore and Gloeckner 2007).

In examining the CM graduates' career aspiration, Ling et al.'s (2016) findings show that almost half of their survey respondents would not take up a construction job upon graduation. The respective respondents were significantly discouraged by image of the industry and the job nature including: low salaries compared with other industries; mentally and physically challenging and dirty work environment; lack of job security; and long working hours with no work-life balance. Bennett et al. (1999) compared male and female CM graduates' career expectations and found that female students had significantly higher financial expectations in terms of expected salary and budget responsibility than male students, while male students had significantly higher expectations in relation to the number of people they expect to supervise. These findings are consistent with the experiences of the professional male and female in their samples. Interestingly, the majority of the female students in their study were attributing the qualities of success in construction environment equally to men and women. Nonetheless, it has been reported that women in construction experience barriers as their careers develop (e.g. Dainty et al. 2000; Worrall et al. 2010).

71.3 Research Method

For the first part of the study, through the authors' personal contacts, the enrolment data was collected from the academia in CM programs of the respective universities. It should be noted that: (i) there are four universities in NSW that offer CM programs and one of the institutes was unable to provide the data due to confidentiality concerns, and (ii) there is an institute offering Engineering degree with specialization in construction management and this institute has not been included in this study as the respective degree is an engineering degree. The three universities in this study are the University of New South Wales (UNSW), the University of Newcastle (UON), and Western Sydney University (WSU).

In the second part of the study, current female students in CM program (known as construction management and property, CMP) in the UNSW were requested to complete a survey questionnaire based on a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree). Table 71.1 shows the items included in the questionnaire, which can be broadly grouped into three categories: (i) factors affecting students' choice of degree; (ii) students' perceptions of the construction industry and construction jobs; and (iii) students' career expectations.

In analyzing the survey data, apart from descriptive statistics, one sample *t*-test was applied to the survey dataset to test the significance of the students' responses.

Table 71.1 Measurement items on students' choice of degree, perceptions and career expectations

Category	
Students' choice of degree	
F1	My high school counsellor was influential in making me choose my degree program
F2	My parents were influential in making me choose my degree program
F3	My friends and peers were influential in making me choose my degree program
F4	My high school counsellor was helpful and resourceful in feeding me with information on possible career opportunities
Students' perceptions of the construction industry and construction jobs	
P1	The construction industry is male-dominated; it is no place for a woman
P2	Construction management jobs require getting dirty and undertaking manual labour
P3	Construction management jobs require longer than usual hours
P4	Construction management jobs provide ample remuneration
P5	Construction management jobs are not highly regarded as other occupations such as engineering
Students' career expectations	
C1	I am likely to stay in the industry for the next 10 years
C2	I feel that females are given the same career opportunities as their male counterparts
C3	I feel that the expectations of women versus that of men are equal
C4	I feed that there is sufficient career support for women (i.e., mentoring and career planning)

This was done by comparing the mean scores of the sample to a test-value of 3 (i.e., the neutral score) to evaluate the students' responses if they at least agreed (mean score that is statistically greater than 3), or disagreed and/or neutral (mean score that is statistically below or equal to 3) for each specific item. Rather than simple averaging, this provides an objective measure in identifying a specific item(s) that calls for attention to address the students' concerns. Also, as the one sample *t*-test involved testing of multiple items, the FDR (Benjamini-Hochberg) correction method using a false discovery rate of 0.05 was applied in identifying the statistically significant items. In this, all of the *p*-values from the *t*-tests that are smaller than the FDR critical value are significant (see McDonald 2014 for FDR procedures).

71.4 Results and Discussion

The first part of the results shows the enrolment trends in CM programs across the three universities between 2006 and 2015. Figure 71.1 shows the total number of enrolments that clearly indicate an increasing trends for all the three universities in the past decade. In comparison with the UNSW, the numbers of enrolments in the UON and WSU have increased remarkably in which the total enrolments have almost tripled over a ten-year period. One possible explanation for the observed trends is that the CM programs entry requirements for the UON and WSU were lower than the UNSW. Nonetheless, these increasing enrolment trends in CM programs are in stark contrast to the reported declining trends in construction-related courses in the UK (Dainty and Edwards 2003).

The enrolment trends were further examined in terms of percentage of female student enrolments as shown in Fig. 71.2. While the percentages for the WSU are rather stable at below 5% for the study period, it can be seen that both the UON and UNSW trends had recorded a rather steep increase in the past decade based on the

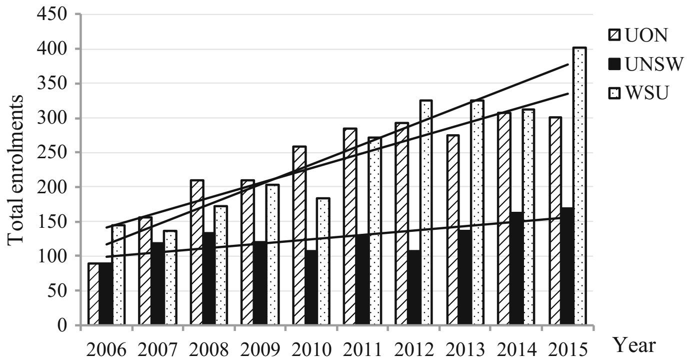


Fig. 71.1 Total enrolments at the three universities between 2006 and 2015

trendlines. For the UNSW, the recorded percentages are as high as above 20% for years 2011 and 2015. Surprisingly, the recorded percentages greater than 10% in the UON and UNSW in most of the years are in contrast to data from the universities in the US as highlighted in the literature review. With the high number of international students in higher education in Australia (Department of Education and Training 2016), it is worth further examining the composition of local and international female students for the reported female enrolments as shown in Fig. 71.3. For all the three universities, the majority of the female students were generally local students, especially for WSU. The higher number of international female students in the UON and UNSW can be partly explained because international students would prefer to pursuit their degrees in more prestigious universities. Nonetheless, this examination indicates that there is a lack of evidence to claim that the reported percentages in Fig. 71.2 were resulted from significantly high number of international female student enrolments.

For the second part of the study, Table 71.2 shows the characteristics of the survey respondents in the UNSW CMP program. The numbers of responses received were 33, representing a response rate of 44.6%. The majority of the students were in their first year (63.64%) and there was a group of students (36.36%) working in the construction industry while studying. Among these, most of them were working on part-time basis and started less than a year ago. It should be noted that those who claimed working full-time (9.09%) were normally also studied full-time with the arrangement of a day-off from work. Interestingly, there was a small group of students (15.15%) who actually moved to CMP program from other undergraduate degree programs. Because the make-up of the respondents with first year students and students with experience working in the construction industry, their responses regarding the choice of degree; perceptions of the construction industry and construction jobs; and career expectations were considered reliable.

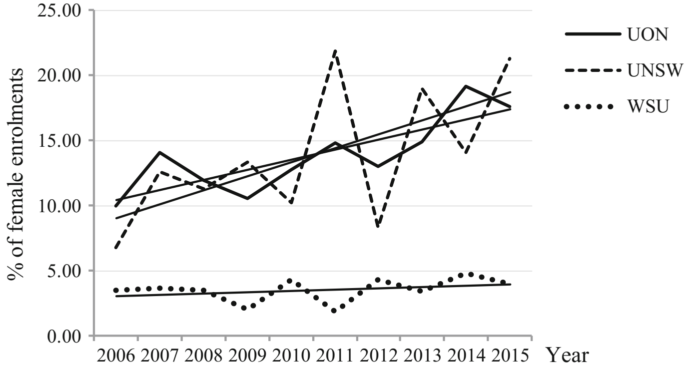


Fig. 71.2 Percentage of female enrolments at the three universities between 2006 and 2015

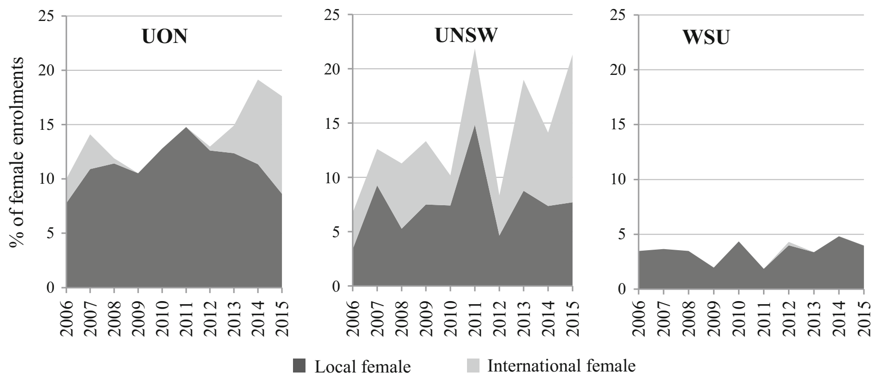


Fig. 71.3 Percentage of local and international female enrolments

Table 71.2 Characteristics of current female students in the UNSW CMP program

Characteristic	Frequency	Percentage
Age group		
18–19	20	60.61
20–21	9	27.27
22+	4	12.12
Level of study		
Year 1	21	63.64
Year 2	1	3.03
Year 3	5	15.15
Year 4	6	18.18
Working in the construction industry while studying		
Yes	12	36.36
No	21	63.64
Type of work		
Part-time	8	24.24
Full-time	3	9.09
Internship	1	3.03
Years of working experience in the construction industry		
<1 year	8	24.24
1–2 years	3	9.09
2–5 years	1	3.03
Was CMP program your first undergraduate pursuit?		
Yes	28	84.85
No	5	15.15

Table 71.3 shows the one-sample *t*-test results for the measurement items. In terms of factors affecting the choice of degree, it can be seen that the respondents significantly disagreed that their high school counsellors (F1), friends and peers (F3)

were influential in their choice of degree. In addition, the results indicate there is a lack of information on career opportunities in construction from their high school counsellors (F4). Indeed, high school counsellor was rated as the least influential person for students' choice of careers in construction management in a US-based study (Koch et al. 2009). Nonetheless, there is evidence that counsellors who personally knowing someone in the construction industry, and having a better self-rated knowledge of construction careers would encourage young women, but not young men, to consider a construction career (Francis and Prosser 2014). Not surprisingly, parental influence was also noted (F2) with a mean score of 3.36, which is however not statistically significant.

Considering the respondents' perceptions of the construction industry and construction jobs, the results show their disagreements (at statistical significant level, $p < 0.05$) that there is no place for women in the male-dominated construction industry (P1), and that construction management jobs are dirty and require manual labour (P2). However, they agreed with the need to work longer hours (P3) in the industry that provides ample remuneration (P4) at statistical significant level $p < 0.05$. Interestingly, these findings are generally consistent with responses from students who reported being likely to take up a construction jobs in Ling et al. (2016). Thus, it appears that these industry aspects would not have negative impact on the respondents' decision to take up a construction management job, despite the lack of consensus among the respondents on the image of construction management jobs (P5). This is further demonstrated by their responses to item C1 where they agreed with the statement: "I am likely to stay in the industry for the next 10 years ($p < 0.05$)". For the other three items on students' career expectations (C2–C4), the responses were mixed and not statistically greater than the neutral. These can partly be explained by the different levels of exposure to the construction industry among the respondents as indicated by their characteristics in Table 71.2.

Table 71.3 One-sample *t*-test results

Item	Mean	*t*-value	Sig (2-tailed)	FDR critical value	FDR Sig.
F1	1.73	−8.027	0.0000	0.0038	Sig
F2	3.36	1.677	0.1032	0.0077	Not Sig.
F3	1.94	−5.754	0.0000	0.0115	Sig.
F4	2.45	−2.796	0.0087	0.0154	Sig.
P1	2.33	−3.370	0.0020	0.0192	Sig.
P2	2.48	−2.273	0.0299	0.0231	Sig.
P3	3.39	2.425	0.0212	0.0269	Sig.
P4	3.55	4.707	0.0000	0.0308	Sig.
P5	2.94	−0.304	0.7628	0.0346	Not Sig.
C1	3.79	4.713	0.0000	0.0385	Sig.
C2	2.64	−1.877	0.0697	0.0423	Not Sig.
C3	2.94	−0.329	0.7445	0.0462	Not Sig.
C4	3.00	0.000	1.0000	0.0500	Not Sig.

71.5 Conclusions

Overall, the enrolment data clearly indicate a steady increasing trend in female enrolments in CM programs in the past decade for three Australian universities in New South Wales. While little is known about female students in CM programs in Australia, the survey results here do provide an overview of female students' choice of degree; and their perceptions of the construction industry and construction jobs; as well as their career expectations. It is, however, recognized that: (i) the questionnaire survey was limited to current female students at one university only, and (ii) the increasing trend may be explained by many different factors (such as the construction boom experienced in New South Wales). These have prompted the need for further studies in order to sustain the trend of increment, especially in identifying the effective factors in attracting female students to CM programs, and the various strategies or recruitment activities in place in retaining female students in CM programs. It is suggested that further studies should adopt both qualitative and quantitative research approaches that involve both academia and students in providing a useful insight on female enrolments in CM programs in Australia.

References

Adogbo KJ, Ibrahim AD, Ibrahim YM (2015) Development of a framework for attracting and retaining women in construction practice. J Constr Dev Countries 20(1):99–115

Bennett JF, Davidson MJ, Galeand AW (1999) Women in construction: a comparative investigation into the expectations and experiences of female and male construction undergraduates and employees. Women Manage Rev 14(7):273–292

Bigelow BF, Bilbo D, Mathew M, Ritter L, Elliott JW (2015) Identifying the most effective factors in attracting female undergraduate students to construction management. Int J Constr Educ Res 11(3):179–195

Dainty AR, Edwards DJ (2003) The UK building education recruitment crisis: a call for action. Constr Manage Econ 21(7):767–775

Dainty AR, Bagilhole BM, Neale RH (2000) A grounded theory of women's career under-achievement in large UK construction companies. Constr Manage Econ 18(2):239–250

Del Puerto C, Guggemos AC, Shane JS (2011, April) Exploration of strategies for attracting and retaining female construction management students. In: 47th ASC annual international conference proceedings, pp 6–9

Fielden SL, Davidson MJ, Gale AW, Davey CL (2000) Women in construction: the untapped resource. Constr Manage Econ 18(1):113–121

Francis V, Prosser A (2014) Exploring vocational guidance and gender in construction. Int J Constr Educ Res 10(1):39–57

Koch DC, Greenan J, Newton K (2009) Factors that influence students' choice of careers in construction management. Int J Constr Educ Res 5(4):293–307

Ling FYY, Poh YP (2004) Encouraging more female graduates to enter the construction industry. Women Manage Rev 19(8):431–436

Ling FYY, Ho SWK (2013) Understanding and impressions of jobs in the construction industry by young adults in Singapore. J Prof Issues Eng Educ Pract 139(2):109–115

Ling FYY, Leow XX, Lee KC (2016) Strategies for attracting more construction-trained graduates to take professional jobs in the construction industry. J Prof Issues Eng Educ Pract 142 (1):04015009

Lingard H, Lin J (2004) Career, family and work environment determinants of organizational commitment among women in the Australian construction industry. Constr Manage Econ 22 (4):409–420

McDonald JH (2014) Handbook of biological statistics, 3rd edn. Sparky House Publishing, Baltimore, Maryland

Moore JD, Gloeckner GW (2007) A theory of women's career choice in construction management: recommendations for academia. Int J Constr Educ Res 3(2):123–139

Sewalk S, Nietfeld K (2013) Barriers preventing women from enrolling in construction management programs. Int J Constr Educ Res 9(4):239–255

Shane J, del Puerto CL, Strong K, Mauro K, Wiley-Jones R (2012) Retaining women students in a construction engineering undergraduate program by balancing integration and identity in student communities. Int J Constr Educ Res 8(3):171–185

Worrall L, Harris K, Stewart R, Thomas A, McDermott P (2010) Barriers to women in the UK construction industry. Eng Constr Archit Manage 17(3):268–281

Chapter 72
Financial Simulation in Operation and Maintenance of Railway Transportation: A Case Study of Greater Jakarta Light Rail Transit

H.Z. Rahman, P. Miraj and J.S. Petroceany

72.1 Introduction

Compared to other developing countries in the region, Indonesia as a South–East Asian country is experiencing significant economic growth in recent years. Greater Jakarta consider as central economic activity in the country which greatly contributes to the increasing growth of national Gross Domestic Product (GDP). Despite its huge contribution, this megapolitan city of Indonesia has many problems that concern various stakeholders from academics, practitioners, industries and government bodies particularly in mobility and connectivity sector for the people.

Greater Jakarta that consist of Jakarta Metropolitan, Bogor, Bekasi, Depok and Tangerang mainly relies the transportation on private vehicles either motorbikes or cars. In the records of Polda Metro Jaya (Jakarta Metropolitan Police) 2014, growth of private vehicles is around 12% which shown by daily purchase of motorbikes for about 4000–4500; in the meantime 1600 new cars are registered every day. In 2014, total private vehicles are about 17,523,967 units which dominated by motorbikes around 13,084,372 units, followed by private cars about 3,226,009 units, 673,661 of freight cars, 362,066 units of buses and special vehicles around 137,859 units. Compared from registered vehicles in 2006 where 7 million units are produced, there is significant growth of vehicles ownership during the last decade. Without proper planning and development from related parties, the traffic will get worst and decrease productivity in greater scale. Thus competing in global scale will require more efforts to be achieved (Quddus et al. 2009; Johansson and Mattsson 2012).

One of the solutions to cope with the congestion problem is by introducing rail-based transportation. It is a mass transport that capable in moving people with great volume and higher speed compared to buses (Chang 2010; Berawi et al. 2014). Railway transportation is one of the promising infrastructure sectors that

H.Z. Rahman · P. Miraj (✉) · J.S. Petroceany
Department of Civil Engineering, Universitas Pancasila, South Jakarta, Indonesia
e-mail: perdanamiraj@yahoo.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_72

potentially become economic backbone of Indonesia in the future years (Zetha et al. 2012; Berawi et al. 2015). Currently, the government encouraging national railway system development with network connectivity expansion and transportation services improvement. The action started by initiating Greater Jakarta Light Rail Transit (LRT) project development. It is an acceleration project from the government to provide alternative accessibility for commuters and in longer run expected to reduce vehicles population.

Greater Jakarta LRT project construction appoints PT Adhi Karya as the main contractor. Their work supported by presidential law no 98/2015 and no 99/2015 to accelerate urban transportation in the capital city of Indonesia. The company main task is to build infrastructure such as elevated track, stations and operation facilities. The government through ministry of transportation will then take over the project for tendering on the LRT operation and maintenance. This action aimed to regulate proper tariff from government for the people with rational price.

Although other sectors are already familiar with this type of tendering, the application for railway sector is relatively new either for regulator, operator and also supporting industries. It because current railway operation and maintenance is mainly conducted by single State Owned Enterprises through PT Kereta Api Indonesia (KAI) and its subsidiary, Jakarta Commuter Line (KCJ) which runs greater Jakarta line. Since most of stakeholders only had real experience in heavy rail project development, formulating proper policy will takes time and consume huge energy from related parties. Therefore, this research aims to contribute financial simulation of operational and maintenance particularly in Greater Jakarta LRT project to help the regulator in gain insight, produce better regulatory framework and propose the best contract for business entity. It is expected to attract private sector involvement and therefore accelerate infrastructure project development in Jakarta Metropolitan and its supporting areas.

72.2 Overview of Jakarta Light Rail Transit

Jakarta Light Rail Transit (LRT) is a mass transit system that uses a smaller and slower of train compared to mass rapid transportation (MRT) system. It is considerably cheaper and provides better flexibility in term of technical and technology wise. The system will connect Jakarta Metropolitan and other suburban areas such as Bekasi and Bogor. Visualization of LRT route can be seen in following Fig. 72.1.

First phase of construction consist of three main line. Cibubur–Cawang Line will be construct with elevated line, has 5 stations and total length for about 13.2 km. While Cawang–Dukuh Atas Line also use elevated line with 8 stations and 10.2 km length in total. Last, Bekasi Timur–Cawang Line has 16.88 km elevated and 0.6 at grade line with 4 stations. The budget require to construct these infrastructure in phase one is about US$196 million which supported 51% from government capital and 49% of public funding through right issue. The construction and ownership of

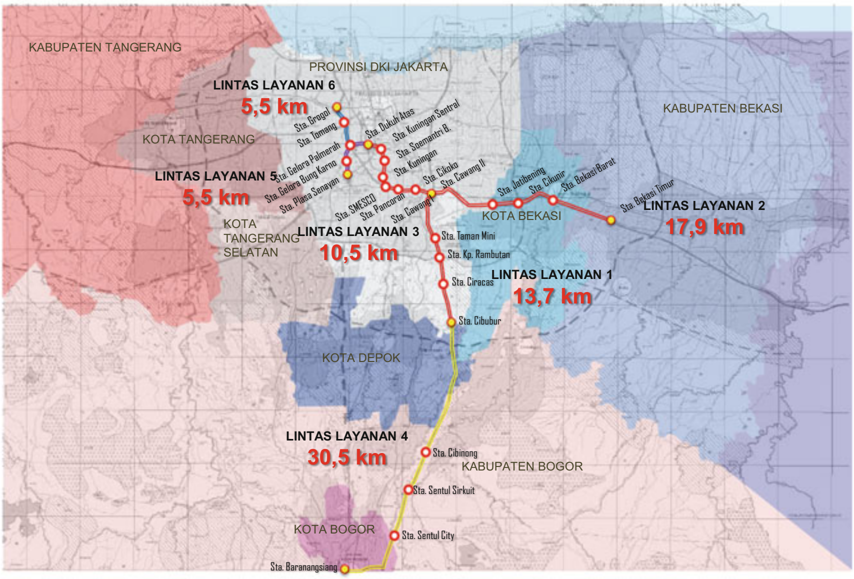


Fig. 72.1 Greater Jakarta LRT route plan—Unpublished Report. *Source* PT. Adhi Karya, 2015

rolling stock depot remains undecided between PT Adhi Karya as the main contractor or the bidder for this development.

However, the initial stage shows two best alternative locations for car depot includes 8 hectare around Cibubur Station and 6 hectare on east side of Bekasi Timur Station. Furthermore, phase two of LRT construction includes Cibubur–Bogor route and Dukuh Atas–Palmerah–Senayan route. And, the last phase route is planned along Palmerah–Grogol (The Third Railway Survey and Design Institution Group Corporation 2015).

72.3 Research Methodology

This research was conducted by using desk study from various reports that supported by directorate General of Railways, Ministry of Transportation, Republic Indonesia and qualitative analysis through in-depth interview. In-depth interview was conducted by using structured manner to gain input and also as a means to validate the research output. Respondents consist of 5 persons from academics, operator, government bodies and practitioners. They hold minimum master degree in transportation and related area; have experience more than 10 years in railway project and public private partnership in Indonesia.

There are several assumptions that being made in calculating financial analysis of Greater Jakarta LRT. It describes as follows:

1. The increase of annual operational and maintenance cost considers transportation sector inflation for about 5.46% (Statistics Indonesia, Inflation 2015).
2. Overhaul activity will be conducted every 10 years with estimated cost around US$0.044 million/car (TOSTEMS, Inc. 2015). In 2027, the numbers of cars will about 37 units and increases to 56 units in 2042.
3. Existing plan from various reports shows that the Greater Jakarta LRT has passenger estimation for about 210,000 passengers. However, considering Manila LRT that only achieved 40% of their targeted revenue in the first operational phase, this analysis will use passengers demand with pessimist scenario with 35% of current demand or estimated for about 73,500 passengers per day.
4. Tariff in the first year of operation stage have to accommodate lower level income from greater Jakarta area, therefore it will limited to 15,000 rupiah or US $1.12 in the first five years and then increases according to 5 year inflation rate.
5. Other revenues assumed for about 1% from total fare box during the first ten years and expected to increase 0.5% every others 10 year.
6. General inflation will be around 5.95% and the life cycle cost for about 30 year.

72.4 Result and Discussion

In conducting the financial evaluation of Greater Jakarta LRT, the calculation involves only operations and maintenance activities. This is because the entire financing of investments have been assigned to PT Adhi Karya as the main contractor and government will reimburse construction cost of the project through the ministry of transportation. LRT facilities will be divided into the operating staff; maintenance staff and facilities maintenance items, while the LRT infrastructure consists of maintenance staff and infrastructure maintenance items (Li and Toda 2014). Facilities and infrastructure will produce base price which exclude overhead and contingency.

The first simulation assumed that initial cost for about US$1.27 billion firstly supported by the government. Government will be also procuring the rolling stock (RS) from respective LRT contractor during the construction period and all of the 37 units of LRT car are ready upon operational phase. The construction period estimated require three years from ground breaking which started in 2016 (Fig. 72.2).

On the other hand, while construction of LRT infrastructure is being conducted by the appointed contractor from the government, the bidder is responsible to construct depot which estimated require US$20.87 million. When the operational phase is launched, the bidder will also be responsible to maintain depot and infrastructure; also operate and maintain rolling stock. As the demand for about

35% from current estimation, annual passengers demand estimated around 30,660,000. With the ticket price is set around US$1.12, operational and maintenance cost in the first year of operation is about US$24.66 million, the result shows an internal rate of return for about 27.67% with payback period six year.

The second simulation also assumed that initial cost supported by the government. Government no longer responsible in procuring US$126 million of rolling stock (RS) yet obliged to construct the depot stations for about US$20.87 million. On the other hand, the bidder is responsible to invest for rolling stock procurement and also its maintenance. They also are responsible to maintain infrastructure that

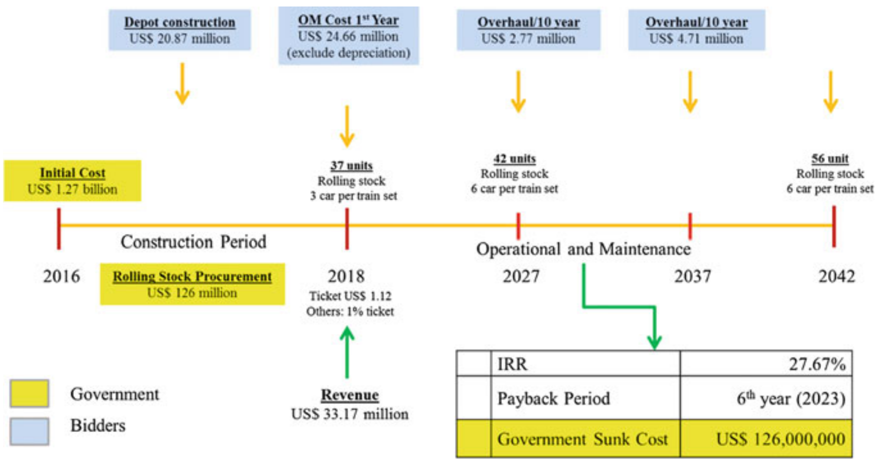


Fig. 72.2 Diagram simulation where bidders responsible for depot construction

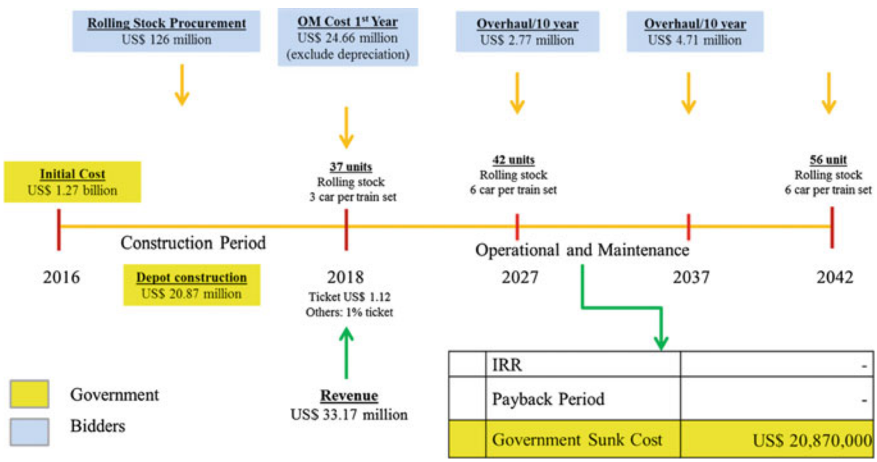


Fig. 72.3 Diagram simulation where bidders responsible for RS procurement

constructed by using public funds. Figure 72.3 will be shown the distribution of responsibility for the two parties.

As the demand for about 35% from current estimation, annual passengers demand estimated around 30,660,000. With the ticket price is set around US$1.12, operational and maintenance cost in the first year of operation is about US $24.66 million, the result shows insignificant internal rate of return for the project. It means with US$126 million of rolling stock borne by the private, this scenario for the project is considered unfeasible.

72.5 Conclusion

Greater Jakarta LRT project expected accelerate a better transportation system in capital city of Indonesia. The result of this research contributes for knowledge dissemination in international debate about Light Rail Transit development particularly in developing countries. There are assumptions that being set, firstly ticket price limit to US$1.12, and then operational and maintenance cost in the first year of operation calculated for about US$24.66 million. The output produces two simulations that showed government involvement for the project through sunk cost in initial cost plus rolling stock procurement and initial cost with depot construction.

Operation and Maintenance with private investment in depot construction is proposed as the best scenario compared to Operation and Maintenance with private investment in rolling stock. OM with government support in rolling stock produces internal rate of return for about 27.67%. In contrary, OM with government support only for LRT depot made the project unfeasible in business perspective.

Acknowledgements This research is fully supported by Directorate of Investment–Directorate General of Railways, Ministry of Transportation, Republic of Indonesia.

References

Berawi MA, Susantono B, Miraj P, Berawi ARB, Rahman HZ, Husin A (2014) Enhancing value for money of mega infrastructure projects development using value engineering method. Proc Technol 16:1037–1046

Berawi MA, Berawi ARB, Prajitno I, Nahry N, Miraj P, Abdurachman Y, Tobing E, Ivan A (2015) Developing conceptual design of high speed railways using value engineering method: creating optimum project benefits. Int J Technol 6(4):670–679

Chang JS (2010) Assessing travel time reliability in transport appraisal. J Transp Geogr 18(3):419–425

Johansson B, Mattsson LG (eds) (2012) Road pricing: theory, empirical assessment and policy. Springer Science & Business Media

Li G, Toda C (2014) Discussions on the local rail transit system in the urbanization. Proc-Soc Behav Sci 138:193–198

Quddus MA, Wang C, Ison SG (2009) Road traffic congestion and crash severity: econometric analysis using ordered response models. J Trans Eng 136(5):424–435

Statistics Indonesia, Inflation, 2015. https://www.bps.go.id/LinkTabelStatis/view/id/901

TOSTEMS, Inc. (2015) Study on medium capacity transit system project in Metro Manila, The Republic of The Philippines, Final Report

The Third Railway Survey and Design Institution Group Corporation (2015) Inner city transportation LRT Indonesia, Feasibility Study Report

Zetha HR, Berawi MA, Sesmiwati, Susilowati, Dofir A (2012) Application of value engineering at public private partnership project to improve quality of feasibility study (case study: airport railway in Indonesia). In: International conference on value engineering and management (ICVEM), Hong Kong

Chapter 73
Finding Academic Concerns on Real Estate of U.S. and China: A Topic Modeling Based Exploration

Z.R. Zhang, M.S. Qiang and H.C. Jiang

73.1 Introduction

Real estate, defined as "property consisting of buildings and lands" or "the business of selling land and buildings", is often considered to be affected by the process of urbanization (Liu and Zou 2012). It also interacts with politics, economy and social change (Hin David Ho and bin Ibrahim Muhammad 2010; Kim and Kim 2000; Hebb et al. 2010). Studies of real estate are necessary in understanding the complexities, especially from the aspect of the world's major economies.

As the two largest countries, in terms of Gross Domestic Product (GDP), in the world, China and the U.S. both have a complicated real estate market. China has the largest population in the world with 1.3 billion people, and it also owns a rapid economy growth in the last three decades and becomes the world's second-largest economy since 2010 (Cai 2010). After the reformation of real estate market in China began in 1998 (Guan et al. 2013), urban house prices have risen 155% nationwide (Peter and Lucie 2014). Both the national and regional economy were largely affected by the real estate market because of its tight connection with other industries (Ren et al. 2014). After the Global Financial Crisis of 2008, Chinese government implemented an expansionary monetary policy, which stimulates the real estate industry to further develop (Mingqi 2010). However, even though this policy has created a rapid economy increase in a recessionary world, modifications like increasing property taxes, raising mortgage rates and down-payment requirements were also made due to the worry of the increasing inflation (Peter and Lucie 2014).

Z.R. Zhang
Department of Construction Management, Tsinghua University, Haidian Qu, China

M.S. Qiang · H.C. Jiang (✉)
Department of Hydraulic Engineering, Tsinghua University, Haidian Qu, China
e-mail: jhc13@mails.tsinghua.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_73

As for the U.S., with the largest scale of economy in the world, its economic status has a great influence on the world (Feldkircher et al. 2015). As Allen and Carletti (2013) point out, the financial crisis is primarily caused by the cycles of boom and bust in real estate market, such as the Global Financial Crisis of 2008 caused by the subprime crisis, which happened in the U.S. and soon affected the whole world. With these characteristics mentioned above, China and the U.S. both have significant positions in the research field of real estate. Hence, a comprehensive examination of real estate studies focusing on China and/or the U.S could help to understand the key issues in their real estate industry, especially the issues after the Global Financial Crisis of 2008.

Differences between the real estate markets of China and the U.S are distinctive, since China is the largest socialist country while the U.S. is the world's number one capitalist country. These differences have been reported in previous studies. For example, Zalesko (2015) points out, the competitiveness of socialism and capitalism is different, which can be reflected in many aspects including the real estate. In addition, in the Global Financial Crisis of 2008, the speculative borrowing and subprime mortgage in the real estate market was the major cause of the U.S. recession, while the Chinese government stimulated the economy by expansionary real estate policies (Mingqi 2010; Allen and Carletti 2013). Zhang et al. (2008). find that although the development processes of real estate market in China and the U.S. are different, in both two countries housing price is determined by land price, while in Japan land price is determined by housing price. Szelenyi (2011) investigates the similarities and the differences between the real estate bubbles in China and the U.S. Wang and Wang (2012) compare the differences between the two countries from the aspects of political environment, legal system and culture. Zhang and Wang (2013) argue that the agglomeration of China's real estate industry is lower than that of the U.S. from the sub-industrial and industrial concentration ratios. These studies all give insights into presenting the differences between China's and the U.S.'s real estate industries from a specific perspective. But none of them gives a comprehensive review. Hence, in order to fill in gap, this paper aims at building an overall figure illustrating the differences between China and the U.S. real estate industries.

Scholars' opinions are usually the most scientific and objective knowledge of a discipline and academic paper is the most common form to present scholars' opinions. However, although these textual data are valuable for policy making and theoretical research, traditional bibliometric methods like thematic reviews, manual content analysis and citation-co citation analysis are considered to be time-consuming, subjective and inefficient to process them (Jiang et al. 2016). Recently, big data technologies, especially quantitative text analysis methods, augment the value of the massive textual data of academic papers. These text analysis methods, such as structural topic modeling, provide a potential of revealing the underlying intellectual structure in a large-scale textual data set related to a complicated subject and find differences of topic prevalence between explanatory variables, such as nationality and time (Tvinnereim and Fløttum 2015). In general, this study aims at finding major academic concerns of real estate in the two countries of China and the U.S. based on a large-scale data set of current studies.

73.2 Methods

The key methods in this study contains two parts. The first step is to collect the raw material. The collection criteria should ensure the authority and the representativeness of the data used in the analysis. Secondly, structural topic modeling was used to model the collected data with an R package called "STM", offered by Roberts et al. (2014). We also employed SPSS to calculate the correlation coefficient and MS Excel to assist in processing data and plotting figures. The technical details about the model estimation are shown as follows.

73.2.1 Data Collection

To ensure the authority and representativeness of the original data, we selected Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI) and Chinese Science Citation Database (CSCD) as the data source. The three databases are all provided by the Institute for Scientific Information (ISI), a part of Thompson Reuters Corporation and are integrated into one web interface, namely, Web of Science. The SCI-EXPANDED and SSCI database are recognized as the world's most authoritative scientific and technical literature sources. The CSCD has recorded more than 1200 journals in China since 1989, considered as the most authoritative reference source in China. In addition, all of the three databases provided keyword search function in the web interface, which brings much convenience to the data collection process. The abstract rather than the full text of a paper is the target of the collection, as it provides more precise information of key points of a paper. English abstracts are provided by Web of Science for all papers indexed in the three databases.

On March 1st, 2016, we accessed the Web of Science to perform the data collection task. Two criteria were used in the search process: (1) the selected paper should contain "real estate" and "China" in the title, abstract or keywords, and (2) the selected paper should contain "real estate" and one of the three words including "US", "USA" or "United States" in the title, abstract or keywords. We got 618 abstracts of papers with the first search criterion, called "papers about China", and 493 abstracts of papers from the second, called "papers about USA". Some papers contained both "USA/US/Unite States" and "China" in the title, abstract or keywords and were identified separately. We also deleted 17 articles published in 2016, since the annual trend analysis should include all papers published in a year. Finally, we got 427 abstracts talking only about China, 557 abstracts talking only

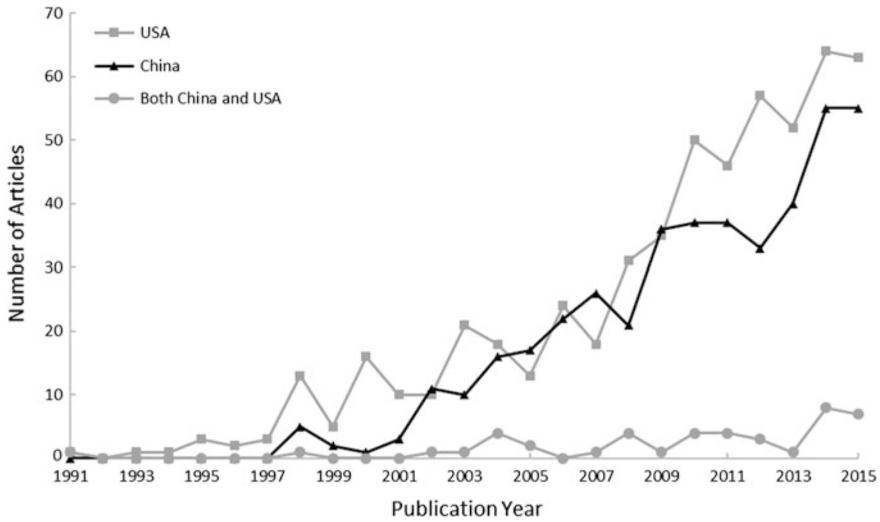


Fig. 73.1 Number of collected abstract

about USA, and 43 papers that talking about both of them. The annual numbers of articles published from 1991 to 2015 are shown in Fig. 73.1.

73.2.2 Pre-processing

Some pre-processing steps were performed before the statistic work and subsequent topic modeling. Common stop words, referring to frequent but trivial words, such as “the”, “of”, “and”, etc., were excluded, because these words carried little information. Numbers, punctuations and terms with no more than three characters were also removed. In addition, in order to uncover more meaningful intelligence within the real estate discipline in China and the U.S., the search key words, including “real”, “estate”, “China”, “US”, “USA”, “United” and “States” were removed before modeling. Terms sharing a common stem were consolidated. For instance, “study”, “studies” and “studying” were all stemmed as “studi-”.

73.2.3 Structural Topic Modeling

Structural Topic Model (STM) is a combination and extension of the correlated topic model, the Dirichlet-Multinomial Regression topic model and the Sparse Additive Generative topic model (Roberts et al. 2014). In STM, a dataset of documents can be summarized as a couple of topics. A topic is a distribution on a vocabulary and a document is a distribution on topics. For example, a paper related to trend analysis of house price may have two topics, including "house price" and "time series". The "house price" topic may have words related to house price, such as "land", "house", "price", and "location", with high probability and the "time series" topic may have words related to time series methods, such as "moving", "average", "seasonality" and "trend", with high probability. The topic distribution for each document and the term distribution for each topic are latent variables. The major task for structural topic modeling is to infer these latent variables.

The number of topics is the only parameter need to be determined manually in modeling. We ran several models with different numbers of topics and tried to select the model with the most semantics. We tested the possible topic numbers from 4 to 20, and finally found that the model with 9 topics has a relatively high semantic coherence and held-out likelihood while still holds reasonable low residuals and a lower bound (Blei et al. 2003). Thus, the 9-topic model was chosen in the further analysis.

73.3 Results and Discussion

In this section, we interpreted the induced 9 topics by their most discriminating terms and the most representative abstracts. Then, we compared the difference of the academic concerns on real estate of U.S. and China.

73.3.1 Topic Interpretation

The induced 9 topics are presented in Table 73.1, which contains the most discriminating terms, the topic proportion in the whole corpus and the suggested labels of each topic.

The interpretation of each topic is based on the most discriminating terms which have the highest frequency and exclusivity in each topic and the representative abstracts of each topic. In STM model, each abstract has a topic distribution. The abstracts which have a relatively higher proportion of a certain topic than other abstracts are called the representative abstracts for this topic. For example, the most representative abstract for topic 4 is shown in Fig. 73.2. Topic 4 accounts for about 80% of the whole abstract, much higher than the proportions of other topics and this abstract is also with the highest proportion of Topic 4 compared with other abstracts in the whole dataset. According to Table 73.1, Topic 4 discusses causality test methods used in real estate studies. By reading the text given in Fig. 73.2, we can find that this abstract indeed focuses on using Granger Causality test methods in real estate market research. Based on the procedure mentioned above, we interpreted the induced 9 topics. Interpretations of key topics are given as follows:

Table 73.1 Most discriminating terms by induced topic, with suggested topic labels and proportions

Topic #	Most discriminating terms	Label	Proportion (%)
1	reit, return, portfolio, inflat-, hedg-, shock, stock, timberland, monetary-, crash	Finance/bubbles	15.62
2	apprais-, energi-, environment, evalu-, survey, contamin-, databas-, dam, resourc-, conserv-	Environment/substance	11.15
3	credit, tax, mortgag-, lend, bankruptci-, crisi-, canada-, risk, lymphoma, financi-	Credit/mortgage/crisis	9.28
4	causal, equilibrium, empir-, market, rent, relationship, offic-, granger, test, variabl-	Causality test methods	13.25
5	fiscal, debat-, racial, today, polit-, inequ-, argu-, segreg-, ict-, actor	Politics/equality	10.99
6	suburban, migrant, urban, sprawl, spatial, villag-, citi-, plan, space, district	Urbanization	10.29
7	intens-, land, bank, drive, rise, cultiv-, farmland, farm, capita, declin-	Rural real estate	7.52
8	stage, hous-, chines, registr-, enterpris-, mechan-, put, establish, problem, analyz-	Commercial housing	12.66
9	industry-, fdi, service-, forest, firm, total, manufactur-, foreign, sector, output	Foreign investment/other industries	9.24

Fig. 73.2 Sample abstract and its topic proportion and text

Topic 1: Finance/Bubbles. This topic concentrates on finance and bubbles related to real estate and accounts for the largest proportion in the corpus, indicating that finance and bubbles are the most prominent issues in real estate research. The most discriminating words in Topic 1, such as reit, portfolio and hedge funds, are common terms used in the financial research. The most representative abstracts of the topic talk about the bubbles of the Turkish Lira (Deviren et al. 2014) or bubbles detection (Jiang et al. 2010). In addition, other discriminating words, including "inflat-" (inflationary), "shock", and "crash" are all terms often used in studies of bubbles. The term "timberland" may confuse us at the first glance. But after a careful reading, we found that it indicates the timberland property and the unique features of this asset were compared with traditional financial market (Mei and Clutter 2010). Hence, the theme is in the range of "finance".

Topic 2: Environment/Substance. This topic indicates the connection of real estate and real world substance, such as using the aerial laser scanning to acquire data for real estate databases or employing content-based image retrieval system for real estate market. On the other hand, this topic tends to emphasize the effect of real estate on the environment. The most discriminating words, such as "appraise", "environment", "contaminants" are words related to environment effect.

Topic 3: Credit/Mortgage/Crisis. This topic also concerns crisis in real estate and focuses on the aspects of mortgage and credit, hence includes terms such as "credit", "mortgag-", "bankruptci-", and "risk". One of the discriminating word is "lymphoma", which seems to have no relation with this topic at the first glance. However, after a careful reading, we found that this word refers to Lyme disease, which is an epidemic disease and has led to depreciation of real estate values in the U.S. (Edelman 1991).

Topic 4: Causality Test Methods. As the discriminating word "causal" indicates, this topic focus on causality test methods which can help us understand the relationship between real estate and other factors. "Equilibrium", "test" and "variable" are frequently used in the test of causality, while the empirical evidence is needed to prove the association between real estate and other markets, like financial market and stock market. Also, "granger", which means the Granger causality test, is useful in determining whether a time series could forecast another. This topic accounts for the second largest proportion in the whole corpus, indicating that causal test methods are widely used in current real estate research.

Topic 5: Politics/Equality. Concerned with politics, "debate" and "argument" are impossible to avoid. This topic exactly reflects some political concerns about real estate, especially equality issue. Even today, racial segregation is a universal problem in communities and subsequently influences real estate. Many publications have been focusing on it.

Topic 6: Urbanization. "Suburban" is a town or other area where near a larger city, these areas are places where urbanization tends to happen. Urbanization concerns urban "sprawl" and "spatial" changes. "Villages" turn into cities in this process. In addition, urbanization is largely concerned with urban "planning". Since different "districts" in cities have various characteristics, like the number of migrants, they play different roles in the city development. These key terms are all shown in Table 73.1.

Topic 7: Rural Real Estate. In rural area, "cultivation", or "farm", largely depend on the supply of "farmland". However, rural estate also needs more "land" to construct more buildings. Normal indexes like construction land per "capita" in rural area could indicate the changes during this procedure. These key terms related to rural real estate development are also shown in Table 73.1.

Topic 8: Commercial Housing. After China's reformation of the urban housing system in 1998, commercial housing in China is largely developed. Private "enterprises" come upon the stage and play an important role in the housing market. However, "problems" like high prices and contractors without registration is largely concerned both by researchers. So they conducted a lot of analysis on this topic.
Topic 9: Foreign Investment/Other Industries. Foreign direct investment ("FDI") is important in the real estate industry since real estate usually costs a large amount of money. Also, real estate industry needs lots of raw materials like woods and furniture, which concerns both "forests" and "manufacture" industry. In this topic, the relationship between real estate and other industries is specially emphasized.

These induced topics conform to the prior knowledge of real estate, which is a complex economic sector involving many scientific, technical, environmental and political issues.

73.3.2 Differences of China and the U.S.

To find the differences of real estate between China and the U.S., we compare the differences of academic concerns between China and the U.S on real estate. A variable indicating which country the abstract belongs to was added to the topic-abstract distributing matrix. Under a confidence interval of 95%, we drew the differences of topic distribution between China and the U.S. in Fig. 73.3. As it shows, Topics 1, 2, 3, 5 are more often to be seen in the papers concerning the real estate of the U.S., while Topics 6, 7, 8, 9 are more frequently discussed in papers focusing on China's real estate.

Generally speaking, the differences of academic concerns (topics) between China and the U.S. are determined by their different stages in real estate development. For instance, Topic 6, urbanization, has a significantly higher level in

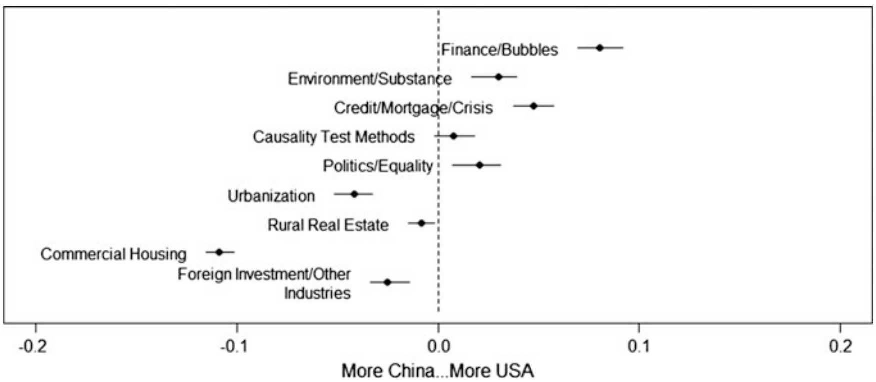


Fig. 73.3 Differences of China versus USA

China. This is related to the rapid development of urbanization of China in these years. China is experiencing an accelerated urbanization process, while in the U.S. this process occurred more than one century earlier (Lin and Ouyang 2014). Since the development of urbanization brings the sprawl of urban area and the construction of new buildings, real estate cannot be ignored in this process. Thus the more focus on urbanization in China is reasonable. In addition, Topic 7, rural real estate, indicates the spatial expansion towards of traditional agricultural lands. During this process, the value changes of rural real estate are noticed by researchers. Topic 8, commercial housing, has the highest tendency towards China. With the rapid development of real estate, the housing quality in China is greatly concerned by scholars. Zhang et al. (2007). find that housing quality is significant to the development of real estate industry. In addition, Topic 9, foreign investment or other industries, is related to development of national economy in China. Foreign direct investment accounts for a large share in the real estate industry, after the opening up policy released in China.

With regard to the U.S., academic concerns are quite different. Because the real estate industry is relatively mature in the U.S., American researchers hold less concerns about the connection of real estate with the national economy development. The most important thing they are focusing on is the finance and bubbles. As is well known, the Global Financial Crisis of 2008 caused by the subprime mortgage started from the real estate market of the United States. Before and after the crisis, researchers are interested in illustrating their understandings of the bubbles which are highly related to the real estate. Similar reasons are for the higher prevalence of Topic 3 in the U.S., as this topic also focusing on crisis related to the real estate. With regard to Topic 4, causality test methods may be more likely to be used in analyzing the real estate market of the U.S., as the market data of the U.S. is more completed than that of China. The higher prevalence of Topic 2 in the studies of the U.S. presents that the U.S.' studies are more often to consider the effects of real estate on the reality and are more interested in employing novel methods in the real estate studies (Dodds et al. 2009). Another interesting topic is Topic 5, politics or equality. In the U.S., scholars have less self-censorship to avoid the sensitive political issues, while Chinese scholars do not (King et al. 2013). In addition, racial segregation and equity are more prominent political issues in the U.S. than in China. As a result, Topic 5, Politics/Equity, is more addressed in the U.S.'s studies.

73.4 Conclusions

Real estate is one of the most important industries of national economy. In the U.S., as Bureau of Economic Analysis shows, real estate accounted for 11.13% of the added value of Gross Output by industry in 2014, while in China it occupied 5.98%. In both countries, real estate plays an important role in the development of whole economy. Since their economic scales are much larger than other countries in the world, the fluctuation in the economies of China and the U.S. often brings a butterfly effect to the world economy. It has been proved that the Global Financial Crisis of 2008 started in the real estate market of the U.S. and then spread over the world causing serious damages. In the Financial Crisis, China's real estate seems to be a boom, which is different from the U.S.'s. But no one has given a throughout comparison between the two important countries in real estate.

In this paper, we illustrate the whole differences of real estate between China and the U.S. by analyzing academic papers. We find that the major differences of real estate of China and the U.S. are the development stage of real estate and the national economy, the stress of connections with finance and effect towards the real world, the research methods employed and the political and racial background. The underlying causes of these differences should be explored in the future study. This research suggests a novel method to analyze the major academic concerns in the real estate based on structural topic modeling. It holds an excellent performance in the analysis process. In more general terms, this research implies that the structural topic modeling can be applied into the analysis of experts' opinions in a variety of disciplines.

References

Allen F, Carletti E (2013) Systemic risk from real estate and macro-prudential regulation. Int J Bank Acc Finance 5(1/2):28–48

Blei DM, Ng AY, Jordan MI (2003) Latent dirichlet allocation. J Mach Learn Res 3:993–1022

Cai F (2010) Demographic transition, demographic dividend, and Lewis turning point in China. China Econ J 3(2):107–119

Deviren B, Kocakaplan Y, Keskin M, Balcılar M, Özdemir ZA, Ersoy E (2014) Analysis of bubbles and crashes in the TRY/USD, TRY/EUR, TRY/JPY and TRY/CHF exchange rate within the scope of econophysics. Phys A Stat Mech Appl 410:414–420

Dodds WK, Bouska WW, Eitzmann JL, Pilger TJ, Pitts KL, Riley AJ, Schloesser JT, Thornbrugh DJ (2009) Eutrophication of U.S. freshwaters: analysis of potential economic damages. Environ Sci Technol 43(1):12–19

Edelman R (1991) Perspective on the development of vaccines against Lyme disease. Vaccine 9 (8):531–532

Feldkircher M, Huber F, Moder I (2015) Towards a new normal: how different paths of US monetary policy affect the world economy. Econ Notes 44(3):409–418

Guan Yu, Jiao FY, Zhu HZ, Ren JS (2013) Real estate prices and consumption in China: 1998–2011. Inf Technol J 12(10):2030–2036

Hebb T, Hamilton A, Hachigian H (2010) Responsible property investing in Canada: factoring both environmental and social impacts in the Canadian real estate market. J Bus Ethics 92 (S1):99–115

Hin David Ho K, bin Ibrahim Muhammad F (2010) Explaining the macro-economy and retail real estate sector dynamic interaction between prime and suburban retail real estate sectors. J Property Investment Finance 28(2):77–108

Jiang ZQ, Zhou WX, Sornette D, Woodard R, Bastiaensen K, Cauwels PP (2010) Bubble diagnosis and prediction of the 2005–2007 and 2008–2009 Chinese stock market bubbles. J Econ Behav Organ 74(3):149–162

Jiang H, Qiang M, Lin P (2016) Finding academic concerns of the three gorges project based on a topic modeling approach. Ecol Ind 60:693–701

Kim CH, Kim KH (2000) The political economy of Korean government policies on real estate. Urban Stud 37(7):1157–1169
King G, Pan J, Roberts ME (2013) How censorship in China allows government criticism but silences collective expression. Am Polit Sci Rev 107(02):326–343
Lin B, Ouyang X (2014) Energy demand in China: comparison of characteristics between the US and China in rapid urbanization stage. Energy Convers Manage 79:128–139
Liu CM, Zou RC (2012) Study on the development of Chinese real estate in the context of urbanization. Appl Mech Mater 174:2284–2288
Mei B, Clutter ML (2010) Evaluating the financial performance of timberland investments in the United States. Forest Sci 56(5):421–428
Mingqi X (2010) The role of macroeconomic policy in Chinas high economic growth amidst the global financial crisis. Seoul J Econ 23(1):123–144
Peter G, Lucie P (2014) The China transformation and the real estate bubble. China Transform Real Estate Bubble 7(10):11–15
Ren H, Folmer H, Van der Vlist AJ (2014) What role does the real estate–construction sector play in China's regional economy? Ann Reg Sci 52(3):839–857
Roberts ME, Stewart BM, Tingley D (2014) stm: R package for structural topic models. R Package 1:12
Szelenyi I (2011) Third ways. Mod China 37(6):672–683
Tvinnereim E, Fløttum K (2015) Explaining topic prevalence in answers to open-ended survey questions about climate change. Nat Clim Change 5(8):744–747
Wang H, Wang K (2012) What is unique about Chinese real estate markets? J Real Estate Res 34 (3):275–289
Zalesko M (2015) Capitalism vs. socialism—an attempt to analyze the competitiveness of economic systems. Ekonomia i Prawo 14(1):61–79
Zhang H, Wang Y (2013) Concentration ratio for Chinas real estate industry based on an integrated CR index. J Tsinghua Univ Sci Technol 53(5):630–635
Zhang S, Ma T, Wang F (2007) Establishing insurance system of housing quality assurance in China. Tumu Gongcheng Xuebao (China Civil Engineering Journal) 40(1):85–89
Zhang H, Wu J, Kong P (2008) Granger causality test-based research on inter-relationship between housing price and land price. Tongji Daxue Xuebao/J Tongji Univ (Natural Science) 36 (8):1148–1152

Chapter 74
From Paper-Based to Cloud-Based Safety Information System in Infrastructure Construction Projects

Patrick X.W. Zou, Percy K.Y. Lun, Palaneeswaran Ekambaram, Sheirf Mohamed and Dean Cipolla

74.1 Introduction

Working in construction industry is considered more risky than in many other industries. Statistical figures suggested that both the rates of serious injuries and fatalities in construction have been consistently higher than their corresponding overall industrial average rate. According to Safe Work Australia industry statistics reports (Safe Work Australia 2014a, b), the Australian construction industry recorded 402 fatalities and 140,448 serious injury claims from 2003 to 2013. These records accounted for 14 and 10% of the total national work-related fatality and serious injury compensation claims, respectively, which were the third highest amongst all industries over the ten-year period. The need for better safety performance in the construction industry is eminent. Recent studies have reported that information technology (IT) innovations can be implemented in current construction safety management systems through various applications. The aim of this research is to develop a cloud-based safety information management system (named as MapSafe) for infrastructure construction projects.

P.X.W. Zou (✉) · P.K.Y. Lun · P. Ekambaram
Swinburne University of Technology, Melbourne 3122, VIC, Australia
e-mail: pwzou@swin.edu.au

S. Mohamed
Griffith University, Gold Coast, Australia

D. Cipolla
John Holland, Melbourne 3004, VIC, Australia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_74

74.2 Traditional Paper-Based Safety Management System

This section provides an example of a construction company's safety management system for context and clarity. COMPANY T is one of the largest multinational construction organisations based in Australia. This company adopts a six-level safety management system for its global operations (Fig. 74.1). The system is topped by the company's vision and values. Safety vision and values are important to all workers within a company. A clear and sound safety vision not only provides certainty and clarity of safety commitments within the company to the workers but also sets the foundation for a strong workplace safety culture amongst the workforce together with well-defined values. The safety vision of COMPANY T is that "safe projects are successful projects and that all injuries are preventable".

The second level of COMPANY T's safety management system is about policies. Safety policies are developed based on safety vision and values to explicitly express principles and guidelines for achieving the safety objective (Fernández-Muñiz et al. 2009). Effective safety policies are important in the construction industry because they provide clarity and boundaries in approaches for

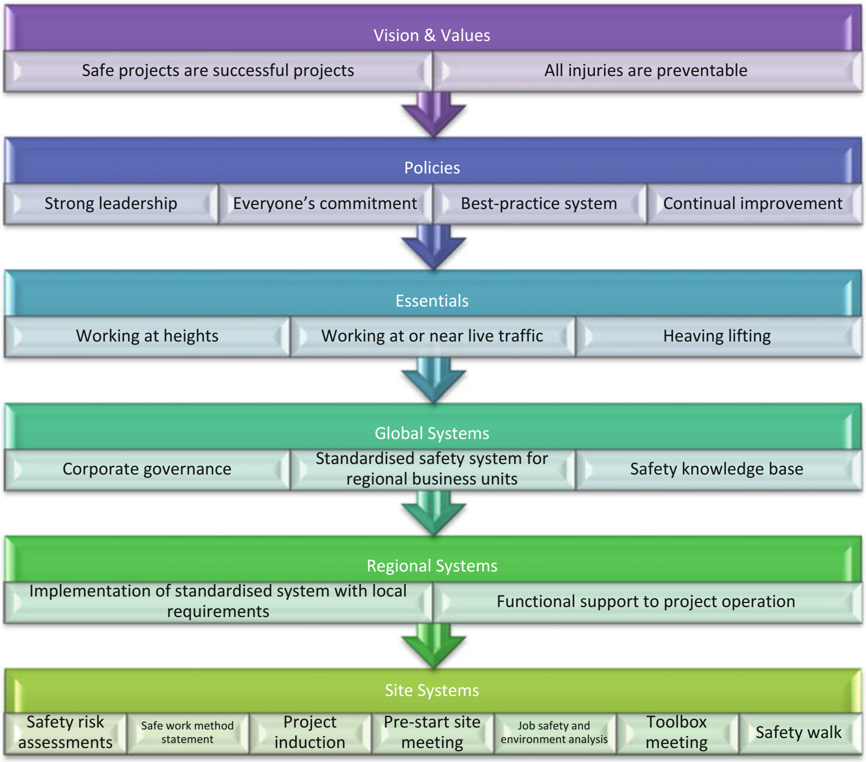


Fig. 74.1 Construction safety management system of COMPANY T

performing different tasks and duties, thus shaping the safety culture within the company. COMPANY T's safety policy is "strong leadership, everyone's commitment, best-practice system and continual improvement". The third level element of the safety management system in COMPANY T is the essentials. This company refers the essentials to as standard guidelines and accredited training programs which are developed for the most common but high risk operations identified within the construction industry. According to Safe Work Australia (2014a), four work-related injury mechanisms consisting of vehicle incidents or rollovers, being hit by falling objects, being hit by moving objects and falls from heights caused over 70% of the total fatalities between 2009 and 2012. Operations adjacent to live traffic (on construction sites or public roads), heavy lifting, and working at heights during the construction process have been identified as high risk factors for triggering the four injury mechanisms. In response to the above risks, construction contractors have created mandatory operating procedures and checklists for the competencies required to help control these activities. Mandatory hold points and checks are in place for working at heights, working at or near live traffic and heavy lifting are required as the company's essentials. Global operational systems are the forth level element of COMPANY T's safety management system. The company provides corporate governance guidance including operating standards, guidelines and procedures to regional business units. Another function of the global systems is to act as an organisation-wide safety knowledge base. The safety knowledge base is a global resource made available to everyone within the organisation for continual improvement in safety performance.

COMPANY T as an international corporation, it has also designed regional safety systems as the fifth level. This level is adapted to the local environment with requirements based on its global systems. The company has a safety department at the corporate level to fulfil its corporate safety governance function. The safety department within the regional business unit level offers onsite assistance and support for local projects. Finally, COMPANY T has further developed site systems as the sixth level element that are fundamental and which encapsulate all elements listed in the abovementioned levels. In general, site safety systems at the project delivery level consists of tools for controlling information and processes (Cheng et al. 2012). The tools of COMPANY T's site systems include the safety-related risk assessment (SRA), safe work method statement (SWMS), project induction, pre-start site meeting, job safety and environment analysis (JSEA), toolbox meeting and safety walk. For the purpose of this research, construction safety management systems (CSMS) are herein referred to as site systems.

SRA and SWMS are the primary tools for collecting and analysing safety information in construction operations. SRA is a risk identification process which allows assessors to identify risks in construction activities thus designing mitigation treatments in order to enhance the overall safety performance. Although the SRA process focuses more on the delivery phase of projects traditionally, it has been gaining momentum to be implemented as early as possible in the project design phase. Recent studies have shown that designers can have a positive influence on construction safety if the consideration of site safety has been incorporated in the project design (Behm 2005; Gambatese and Hinze 1999; Gambatese et al. 2008; Hadikusumo and Rowlinson 2002, 2004; Wilson and Koehn 2000). SWMS on the other hand is a complete process developed for assessing the safe conduct of construction activities. Contents of SWMS are collective information regarding work methodologies, permits required from relevant authorities, safety risk assessment and mitigation plan and the implementation of the essentials. SWMS as the essential part of the CSMS should encapsulate the whole CSMS in the project delivery phase. During construction operations, all participants involved in the project must attend a mandatory project induction, where workers are advised on all essential information of the project such as the minimum personal safety equipment for carrying out individual tasks, the brief of the project emergency plan, how to report hazards and incidents and major potential hazards of the project and how they are controlled.

The daily pre-start site meeting is a site coordination meeting conducted at the beginning of each shift with each project team. During the briefing, workgroups discuss their planned works and assess any potential interfaces between different workgroups that may cause safety issues. All discussed information is recorded in a daily pre-start record book which requires all workers to sign prior to conducting any duties. Every activity onsite must be assessed through a work breakdown analysis called JSEA by all involved personnel together with work supervisors before being carried out. In JSEA, planned activities are first broken down step-by-step according to their construction sequences and safety risks would then be identified and assessed for each step. The mitigation measure for each risk is also proposed and all details are recorded in JSEA for implementation on site. In addition to the regular pre-start site meeting and JSEA, toolbox meetings are held periodically to remind workers of potential safety-related risks that may have raised concerns across the project site or the industry. Moreover, inspections, audits and reviews of safety practices and safety measure implementation are to be carried out during the regular scheduled safety walk. Through the walk, project safety personnel can review the safety measure implementation level onsite hence identify potential improvements required for better safety management. The review of the current safety management system has identified the shortfalls regarding data capture and information sharing, which is a slow manual process. This paper presents an empirical study with the main goal to increase practical effectiveness and efficiency of the current safety management system by digitising the system.

74.3 Research Process and Methods

The research was done by replicating some of the critical safety management functions as described in the previous section in a cloud-based GIS system with end results to be visualised in a map on a mobile device. First, a suitable cloud computing provider has been selected based on three criteria: functionality, flexibility and cost. Platform as a Service (PaaS) is one of the cloud computing service which is considered the most suitable method for delivery of the system, the functionality of the platform plays the critical role in the resulting system. The chosen platform also needs to give users a certain degree of flexibility to adapt the resulting system with other IT services. Another consideration is initial setup and system maintenance costs. The selection process of the cloud computing provider is discussed in the System Design section. Selection of the safety functions in the system is also based on three criteria: real-time information sharing requirements, locations based information and information visualisation requirements. The selected safety functions should have location based safety data which need to be shared on a map in real-time. Similar to the other database system, setting up a GIS requires defining relationships between different types of data. Based on the design objectives of MapSafe, it requires input data from the users and also project parameters data. The types of input data are solely dependent on the included safety functions apart from location data which is a pre-requisite data type of GIS. Project parameter data is unique to each project which contains the project information for setting up the system in the first instance.

74.4 Results

74.4.1 System Design

The system *MapSafe* has been designed and developed based on the current (paper-based) safety management system of the construction company discussed in the previous section. This MapSafe system enables users to capture text-based safety data in the field with any mobile devices. The captured data is then processed in real-time and displayed on a map almost simultaneously. MapSafe comprises of four core components: web portal, data storage, data processing, and data visualisation. All of these components are contained in the same cloud. The design of the MapSafe system and its workflow is shown in Fig. 74.2.

The selection of cloud provider is based on functionality, flexibility and economics as discussed in the Research Process and Methods section. Google inc. (Google) is one of the PaaS cloud providers for application developers. Google Drive is a free file hosting application that assists users to upload and organise files (data) stored in the Google cloud. Google offers each personal user with 15 GB of free cloud storage through Google Drive. This offer makes Google Drive a very attractive platform as the data storage component of MapSafe. In addition to the data storage function, Google Drive also provides a range of free Google applications that are suitable to be employed for the development of MapSafe: Google Sheets and Google Forms can be used as the data capture and processing components of the system as they are readily interconnected by default; Google Docs and Gmail can be adapted as the system's data reporting function within the storage and processing component; while Fusion Tables and Google Maps act as the data

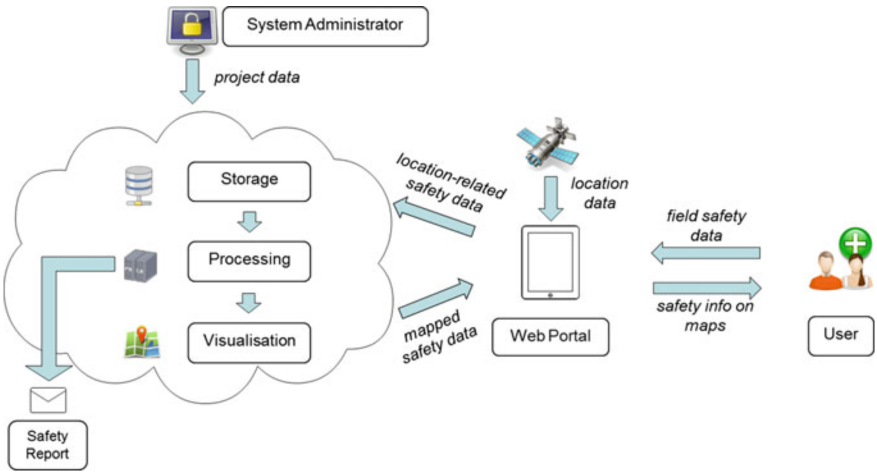


Fig. 74.2 System design of MapSafe: web portal, data storage, data processing, and visualisation

visualisation component of the system. The details of individual functions of these applications will be discussed in the following sections.

74.4.2 Web Portal

A web portal is a user interface that provides users access to all of the functions provided in MapSafe. The web portal is a simple web page written in Hyper Text Markup Language (HMTL) with embedded JavaScript. HTML is the programming language of web pages which can be understood by web browsers. JavaScript is a dynamic programming language that allows interactions between web browsers and users, control browsers and alter contents of browsers (Flanagan 2006). In the MapSafe portal, it contains buttons linked to the corresponding safety data capture forms stored in the cloud. A map is also embedded in the web page displaying the real-time safety information of a project. There are also searching options that specify particular features to be displayed on the map. Another important function of the web portal is to obtain the current location of the user via the HTML built-in location tracking function. The obtained location data serve two purposes. First, the user can visualise the person's current location in relation to other information on the map. Second, the location data provide the location awareness of the captured safety data to MapSafe when the data are submitted. The web portal and its four functions (pre-start meeting record form, safety incident report, request for permit to penetrate ad allocate a job safety analysis) of MapSafe is shown in Fig. 74.3.

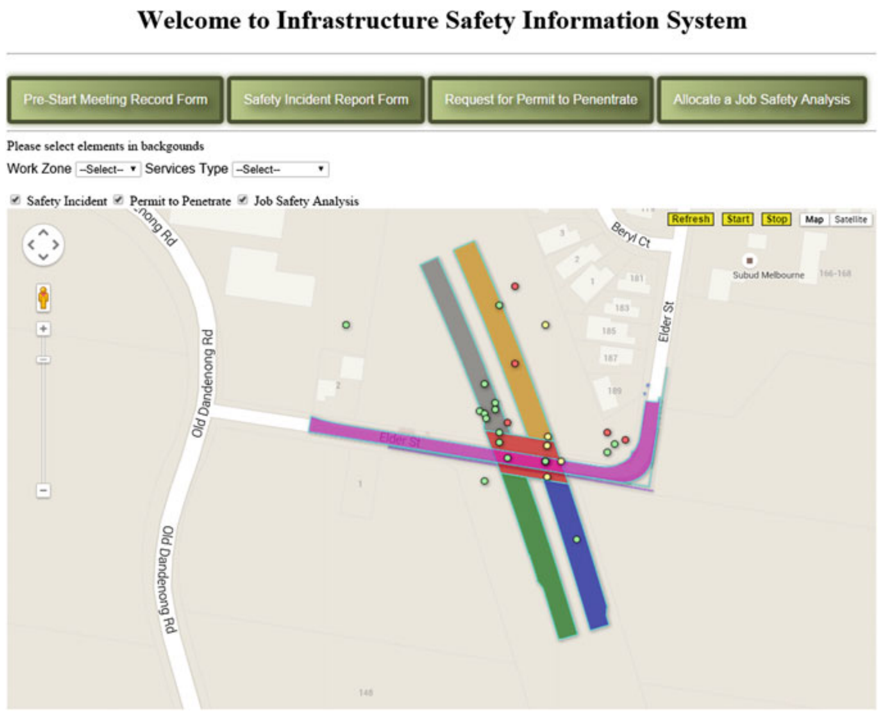


Fig. 74.3 Web portal of MapSafe: functionalities of linking field safety forms, searching of project data and displaying of field safety data

74.4.3 Data Storage

The data storage function of MapSafe utilises the Google cloud storage through Google Drive. Each file uploaded to Google Drive is assigned with a unique encrypted key for file identification. Unlike the conventional computer filing system, this unique encrypted key offers greater flexibility for the folder structure within Google Drive as files can be freely moved between folders without losing their references or links to others. There are three types of data stored and used in the system, namely, application data, project data and field safety data. Project data and field safety data are both stored in Google Sheets. The data storage function of MapSafe through Google Drive is illustrated in Fig. 74.4.

74.4.4 Application Data

The application data are the representation of applications employed in the system and hosted in Google Drive. It includes the web page for web portal, Google Forms,

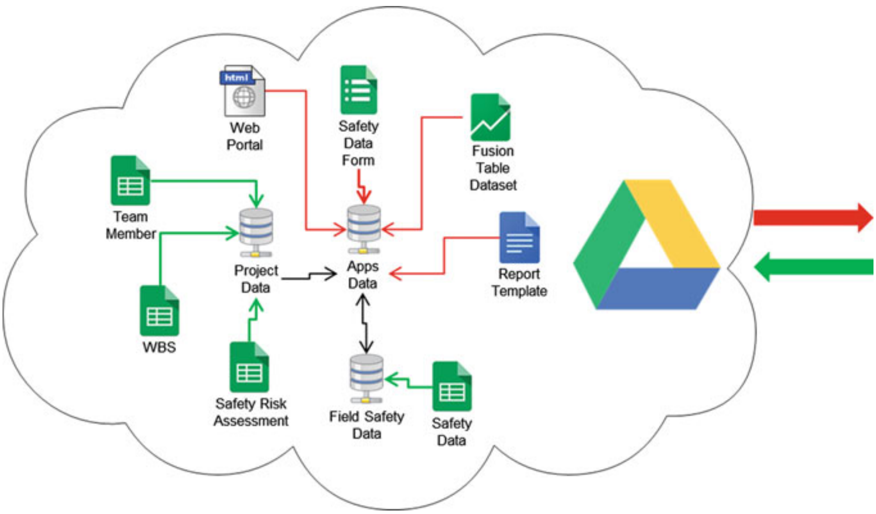


Fig. 74.4 Concept of data storage via Google Drive: Inter-relationships between application data, project data and field safety data within cloud storage and Google Drive as access to and from the outside world

Google Docs, Google Sheets and Fusion Table. Discussion on the web portal can be found in the previous section. Google Forms is a data collection application which has a readily deployable web interface for data entry. Each form in MapSafe represents a field safety function. The forms are pre-stored with the project data such as work zones and details of project personnel, which will be discussed in the next section. Examples of Google Forms with the pre-stored project data of the MapSafe system are shown in Fig. 74.5.

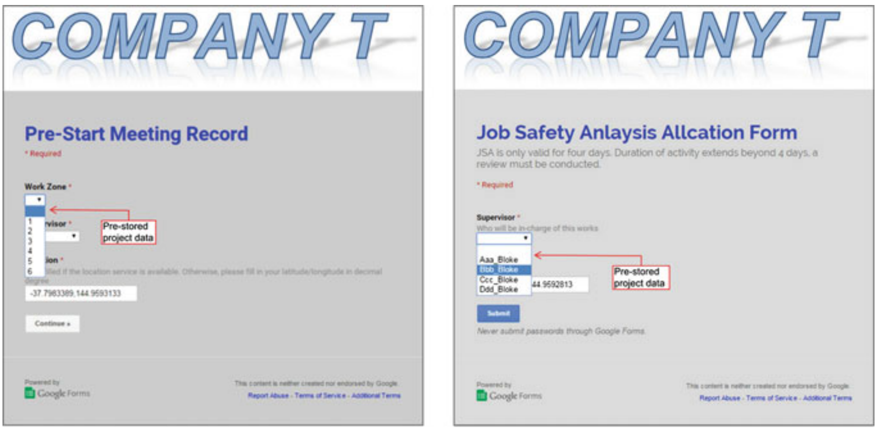


Fig. 74.5 Examples of pre-stored project data in Google Forms

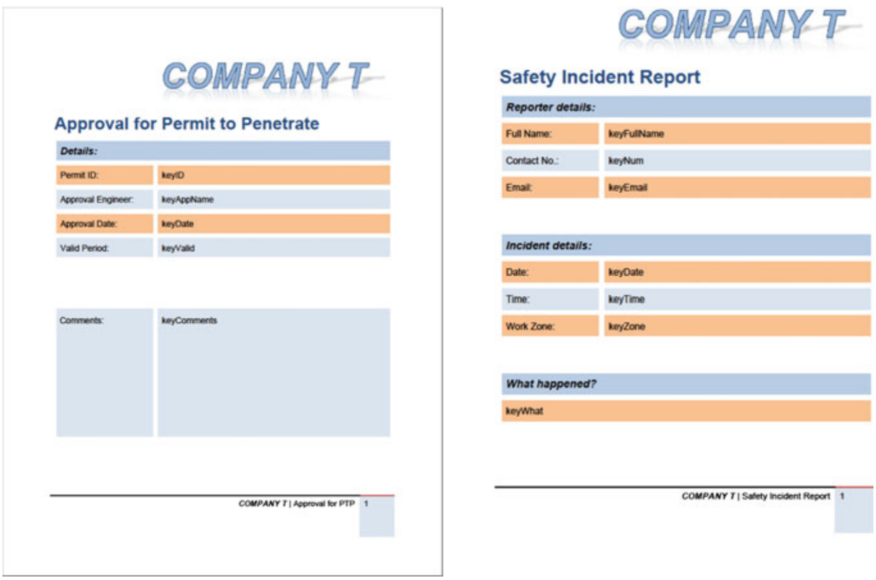


Fig. 74.6 Examples of report templates created in Google Docs

Another type of application data hosted in Google Drive is Google Docs. The function of Google Docs is to translate form data into a report format. Templates in the Google Docs format are created and stored in Google Drive. The system will create reports using a pre-determined template when an individual form is submitted. Google Docs will also create a report in .pdf format, although the pdf report will only exist temporarily for email transmission purposes. The templates of some of the reports created by Google Docs for MapSafe are displayed in Fig. 74.6.

The final two applications of the MapSafe system stored in Google Drive are Google Sheets and Fusion Tables. Google Sheets serves both the data storage and data processing functions of the system while Fusion Tables is used for the visualisation processing application. Further discussion on Google Sheets and Fusion Tables will be covered in the data processing section and visualisation section, respectively.

74.4.5 Project Data

Project data is the input of any kind of project-related information by system administrators during the initial system deployment or system maintenance of a project. Project data can be classified into three categories. The first category is information about the project's management and safety data, such as work breakdown structures (WBS), details of team members and safety risk assessments of the

Table 74.1 Examples of project data required in MapSafe Google Forms (Y = yes)

Project data	Job safety analysis	Permit to penetrate request	Pre-start meeting	Safety incident report
Supervisor	Y	Y	Y	
First aider	Y			
Work zone	Y	Y	Y	Y
Work area plan	Y			
Hazard	Y			
Action	Y			
Responsible engineer		Y		
Approval engineer		Y		
Company			Y	
Presenter			Y	

project. The format of the data is required to be in Google Sheets for storage, simplifying the data entry process for Google Forms. Google Forms enables data to be pre-stored for the data input selection. Data such as personnel details and safety risk assessments of the project are pre-loaded into Google Forms, ensuring precise and uniform data entry as well as ensuring important safety information is not overlooked. The amount of project data pre-stored in MapSafe depends on the requirements for individual field safety documentation of each project. Table 74.1 shows some basic project data that may be required in Google Forms for the MapSafe system.

The second project data category is data that contains geographical annotation and visualisation attributes. This type of data represents the geometry and location data of the project and can be used for mapping applications. The format of the data can be in the Keyhole Markup Language (.kml) and comma-separated values (.csv) formats. The .kml format is the open standard for web-based mapping as it shares a similar structure to HTML. The .kml format can store the geometry, description, display style (such as line width and colour) of a design element. The advantage of using the .kml format is that it can handle complex geometry such as polylines and polygons, enabling detailed presentations of complex elements on maps. The .csv format is the alternative file structure for storing point-based geographical information for mapping. The information stored using this format is text-based and comma-delimited. Both the .kml and .csv formats are required to be imported into Fusion Tables for visualisation. Samples of the .kml and .csv file structures used in MapSafe are shown in Fig. 74.7.

The third category of the MapSafe data is the supporting information of the project. This type of data is not supported by GIS directly but is essential for maintaining construction safety in the field. It is stored in the cloud storage and can be referenced via a hyperlink embedded in an element in GIS as an attribute. It is to

Fig. 74.7 Structures of .kml file (left) and .csv file (right)

note that the display and visualisation of this type of data requires an external third party application on a user's device.

74.4.6 Field Safety Data

Any type of data captured using the created Google Forms in MapSafe is classified as the project's field safety data. Although most of the information collected in individual forms is different, the location data are the mandatory information required to be submitted for each form. The location data displayed using a geographic coordinate system (based on degrees of latitude and longitude) are automatically obtained from web browsers. Some of the field safety data can also be pre-stored using the project data; for instance, the field job safety analysis should refer to the project's safety risk assessments, therefore the field data for safety hazards and their corresponding actions should be readily available to be selected in the created Google Forms.

74.4.7 Data Processing

Google Sheets is responsible for the processing of data in MapSafe. It is a spreadsheet application for data processing and is fully integrated with Google Forms. The data processing function of the system is triggered when a form is submitted by users using Google Forms. Once the submission button in the form is clicked, the following three processes will take place. First, Google Forms will copy the input data onto Google Sheets automatically if a pre-determined connection is established between the two apps. Next, Google Sheets will update a pre-linked

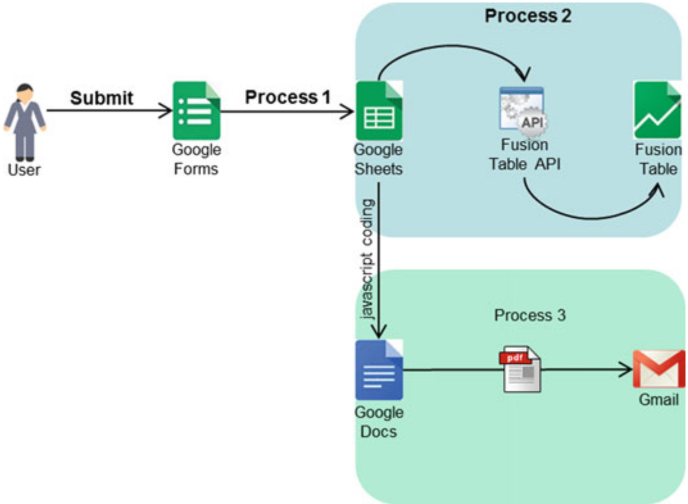


Fig. 74.8 Workflow of data processing: Process 1—field data uploaded into Google Sheets, Process 2—Google Sheets updates Fusion Table via API, Process 3—Google Sheets creates reports in Google Docs and email the .pdf file of the report

table in Fusion Tables with the new data. Finally, a report in the .pdf format will be generated using Google Docs and sent to the intended report recipient(s) via Gmail. The second and third processes are not the built-in functions of Google which need additional instruction coding written in JavaScript within the respective Google Sheets. It is also to note that Fusion Table API v2 is required for accessing Fusion Tables from Google Sheets. The workflow within the MapSafe data processing component is illustrated in Fig. 74.8. API, which stands for application programming interface and is a set of programming codes facilitating interactions between applications within the web environment. Fusion Tables API v2 needs to be activated during the data updating process to permit the table created using Fusion Tables updated by Google Sheets. API is used to get access to Fusion Tables because, unlike Google Sheets, Fusion Tables is not fully integrated into Google Drive. Fusion Tables is regarded as an independent product outside Google Drive as it is currently in its experimental stage.

74.4.8 Data Visualisation

Fusion Tables and Google Maps together form the data visualisation component of MapSafe. Fusion Tables is a data manipulation and processing application for the visualisation and mapping of data. Google Maps, on the other hand, is a web mapping application. Google Maps with a built-in base map acts as the visualisation platform to display the data inputted by users in Fusion Tables.

74.4.9 Fusion Tables

Fusion Tables has a similar data structure as a spreadsheet where a row represents an element and the values in a column are the entities of the element. For mapping applications, one of the entities of the element must be the location data represented in the latitude/longitude-based geographic coordinate format. The functionality of Fusion Tables is further enhanced by its support of data query for data analysis. Fusion Tables also supports various data input formats including the comma-separated values (.csv), keyhole markup language (.kml) and Google Sheets formats. The discussion of individual data formats can be found in the previous sections. While the point location represents the basic geometry of geographic information, Fusion Tables can also handle complex geometry such as polylines and polygons.

Google Maps is a web mapping application which primarily offers users to view and search places of interest with its detailed database of the road network. It provides street maps with driving/walking directions as well as satellite and 360 degree panoramic street images of different countries. Google Maps also allows the customisation of maps by adding temporary features. All added features must contain the location or geometry data displayed in the latitude/longitude-based geographic coordinate format.

74.4.10 Visualisation Method

Data visualisation method of MapSafe is to utilise the techniques of Fusion Tables dataset and the Google Maps layer object (layer). A dataset is a group of data which is stored in a Fusion Tables. Such data may include project data and field safety data as discussed in the previous sections. Google Maps layer is graphical representation of dataset on Google Maps. Such graphical representation may be as a single point or more complex geometry. One Fusion Table dataset creates one layer on Google Maps only. Multiple layers are possible to be displayed on a single Google Maps in web page with the combinations of the above techniques. In the case of MapSafe, the web page is the web portal as discussed previously.

The process of visualising Fusion Tables datasets on Google Maps is to create a Google Map and Google Maps layers in the web portal using Google Maps JavaScript API. The API performs two tasks during the process. Firstly, it enables Google Maps to embed an instance in the Web Portal. Secondly, the API enables Google Maps to access the targeted Fusion Tables Datasets and converted them in to layers showing the instance. Figure 74.9 is the illustration of the data visualisation process.

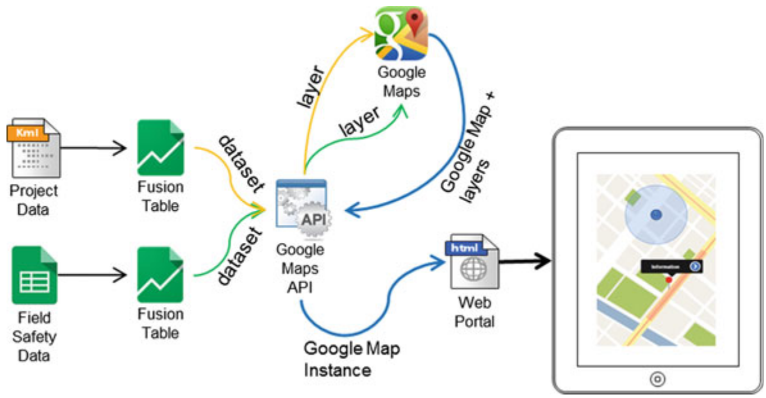


Fig. 74.9 Data visualisation process: importing of raw data into Fusion Tables, Fusion Table as layers in Google Maps, Google Maps as an instance embedded in web portal

74.5 Conclusion and Future Research

In this research a cloud-based Safety Information System (MapSafe) has been developed as a promising platform to enhance the practice of safety management in infrastructure construction projects. MapSafe integrates several currently available IT including cloud computing, GIS and the mobile technology, in an economical manner. It offers an electronic online real time method to communicate safety information and collect safety data in construction sites. The safety data captured using MapSafe is stored and processed automatically in the cloud system. The processed safety information is visualised on a map instantly on mobile device to allow real-time safety decision making. The safety related information such as design drawings (in the pdf format) and building information models can also be easily accessed through the MapSafe interface which is a real advantage in the data management aspect. MapSafe has been trial-tested with a real case project and is expected to find application as a safety information management system in the construction industry.

The current state of MapSafe has presented future development in four areas: workflow automation of complete lifecycle management of various safety functions, real-time statistical analysis of individual safe activities, system security, and web portal layout and functionality. In addition, in future following-on research, algorism can be developed to analyse the data captured by this MapSafe system to identify trends and patterns to improve construction site safety.

Acknowledgements The authors would also like to thank Company T for providing valuable information regarding current construction safety management system.

References

Behm M (2005) Linking construction fatalities to the design for construction safety concept. Saf Sci 43(8):589–611

Cheng EW, Ryan N, Kelly S (2012) Exploring the perceived influence of safety management practices on project performance in the construction industry. Saf Sci 50(2):363–369

Fernández-Muñiz B, Montes-Peón JM, Vázquez-Ordás CJ (2009) Relation between occupational safety management and firm performance. Saf Sci 47(7):980–991

Flanagan D (2006) JavaScript: the definitive guide. O'Reilly Media, Inc.

Gambatese J, Hinze J (1999) Addressing construction worker safety in the design phase: designing for construction worker safety. Autom Constr 8(6):643–649

Gambatese JA, Behm M, Rajendran S (2008) Design's role in construction accident causality and prevention: perspectives from an expert panel. Saf Sci 46(4):675–691

Hadikusumo BHW, Rowlinson S (2002) Integration of virtually real construction model and design-for-safety-process database. Autom Constr 11(5):501–509

Hadikusumo B, Rowlinson S (2004) Capturing safety knowledge using design-for-safety-process tool. J Constr Eng Manage 130(2):281–289

Safe Work Australia (2014a) Work-related traumatic injury fatalities Australia 2013. Canberra

Safe Work Australia (2014b) Australian workers' compensation statistics 2012–13. Canberra

Wilson JM, Koehn EE (2000) Safety management: problems encountered and recommended solutions. J Constr Eng Manage 126(1):77–79

Chapter 75
Game Analysis of Stakeholders in Urban Renewal Based on Maximization of Social Welfare

J.F. Li, Y.S. Wang, N. Lu, Y. Du, Y. Zhang and F.F. Liu

75.1 Introduction

Urban renewal refers to the reconstruction of old cities when the cities develop at a certain stage to meet the requirements for intensive development of lands. Urban renewal is in essence a process of adjusting the interests of all stakeholders which involved in the urban renewal. Urban renewal involve multiple stakeholders, reflects the interests game of multi parties. There are three main interest groups in the urban renewal, namely the government, developers, the relocated residents or owners. The realization of the respective interests of the tripartite stakeholders is the most important driving force to carry out the urban renewal. But the reconstruction process involves problems in various aspects such as laws, regulations and policy risk, investment risk, land ownership, land transaction specifications, compensation and resettlement of relocation and conflicts of interest and other issues. Especially, compensation and resettlement of relocation and conflicts of interest becomes increasingly obvious. It will be vital significance both in theoretical and practical sense to do a good research on how to balance the interests of all parties well and take sustainable development in the future into its consideration.

J.F. Li (✉) · Y.S. Wang · N. Lu · Y. Zhang · F.F. Liu
School of Civil Engineering and Transportation,
South China University of Technology, Guangzhou, China
e-mail: ljfeng@gdadri.com

J.F. Li · Y. Du
Architectural Design and Research Institute of Guangdong Province,
Guangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_75

75.2 Literature Review

Most of the domestic and foreign scholars on the research of the urban renewal were mainly focused on the sustainability and benefits of the urban renewal. Firstly is the literature review about domestic researches. Cao et al. (2006) pointed out that the urban renewal is a complicated social system. The residential renovation should improve the residents' living conditions and environment for fundamental purpose. It makes the ecological, social and economic benefits to achieve the organic unity (Cao et al. 2006). Xiong (2008) believe that in order to achieve the target of a harmonious society, urban renewal should adopt the planning methods from single to comprehensive, and advocate the continuation of history and culture, context and inheritance. Wei and Jin (2009) expounded the relation between the unity of the large-scale renovation and small-scale renewal,proposed to explore the comprehensive utility "appropriate scale and suitable scale" of the old city reconstruction mode. Lei et al. (2012) studied the "Three Old Reconstruction" plans of various pilot projects in Guangdong Province. They put forward the evaluation system framework of the "Three Old Reconstruction". The evaluation system framework includes the evaluation indicator system to evaluate the improvement in the intensive land utilization after the reconstruction and the evaluation indicator system to evaluate the impacts of the reconstruction on social, economic and ecological benefits (Lei et al. 2012). Zhong and Cao (2013) took Guangzhou North Shore Cultural Pier as an example. Through field research, they analyzed the land utilization benefits in the three old reconstruction zones under the background of urban renewal from the economic, social and environmental aspects Zhong and Cao (2013).

Secondly is the literature review about researches in foreign countries. Hemphill et al. (2002) thought urban renewal should consider economic, environmental and social sustainability and proposed a hierarchical model of urban renewal evaluation to analyze the sustainability of urban renewal via the Delphi method and multiple criteria. Brindley (2003) and Bromley et al. (2005) argued that urban renewal should consider the sustainable development of the society. Hunt (2006) pointed out that only dominated by a single developer large-scale construction to deal with the complex in the city's economic, social, cultural, and other issues is a fatal flaw. Urban renewal should adopt progressive planning reconstruction and small-scale old city reconstruction. Lee and Chan (2008) took the urban renewal projects in Hong Kong for an example and established an urban renewal evaluation model featuring sustainable development from the following three aspects: economic, social and environmental benefits. Lee and Chan (2008) confirmed the key factors of improving the social sustainability of urban renewal projects through the form of a questionnaire survey (Lee and Chan 2008).

In summary, domestic scholars mainly made researches on the interest distribution of urban renewal and urban development from various perspectives. The western scholars' researches in general are less in terms of efficiency. This paper constructs the static and dynamic game model of the main stakeholders of the urban renewal. Through balanced analysis, combined with practical application, this article seeks urban renewal mode to realize the benefits of all stakeholders and provides feasible ideas and methods for government to promote urban renewal.

75.3 Assumptions & Establishment and Analysis of Game Models

Game theory is a study on decision makers' decision making and its equilibrium when their actions under the given information structure directly interact on each other (Li 2009). In general, a standard game should include eight aspects, which are participants, behavior, information, strategy, order, benefit, result and balance. This paper uses the method of game theory to construct the static and dynamic game model of the main stakeholders who involved in the urban renewal.

Static game model and its solution

75.3.1 Game Analysis Between Government and Residents

If the government carries out a high standard renewal, it shows that the government decides to complete the urban renewal (Qu 2009). Set the following parameters: R indicates government revenue, and g stands for social and environmental benefits. Assuming g can be quantified, and g_1 is larger than g_2 . g_1 stands for the government reform increased cost because of the residents' nonsupport of urban renewal, g_2 stands for benefit when government don't carry out the reform because of the residents' nonsupport of urban renewal; R_0 indicates economic benefits residents obtained after urban renewal; H indicates the original income the residents maintain when they don't support urban renewal, such as rent, etc.; C indicates the total cost of urban renewal requires that government bears independently; C_1 indicates the cost of government high standard renewal, which transfers to the residents' income, such as the compensation for the demolition; C_2 indicates the cost of government low standard transformation.C_1 is larger than C_2; θ indicates the rate of government undertakes high standard transformation plan; δ indicates the rate of residents support the renewal. Game model between government and resident is as Table 75.1.

(1) Given θ, then the expectation function that residents support renewal ($\delta = 1$) and don't support renewal ($\delta = 0$) are:

Table 75.1 Game model between government and resident

Residents	Government	
	High standard	Low standard
Support	$C_1 + M + R_0 - H, R - C_1$	$C_2 + M + R_0 - H, R - C_2$
Nonsupport	$H, -g_1$	$H, -g_2$

$$U_p(1,\theta) = (C_1 + M + R_0 - H) * \theta + (C_2 + M + R_0 - H) * (1-\theta)$$
$$= (C_1 - C_2) * \theta + C_2 + M + R_0 - H \quad (75.1)$$

$$U_P(0,\theta) = H * \theta + H * (1-\theta) = H \quad (75.2)$$

$$\text{Given } U_P(1,\theta) = U_P(0,\theta), \quad \text{then } \theta^* = \frac{(2H - C_2 - M - R_0)}{(C_1 - C_2)} \quad (75.3)$$

If θ is larger than θ^*, residents support the renewal. On the contrary, if θ is smaller than θ^*, residents don't support the renewal.

(2) Given δ, then the expectation function that government choose high standard renewal (θ = 1) and high standard renewal (θ = 0) are:

$$U_g(1,\delta) = (R - C_1) * \delta + (-g_1) * (1-\delta) = (R + g_1 - C_1) * \delta - g_1 \quad (75.4)$$

$$U_g(0,\delta) = (R - C_2) * \delta + (-g_2) * (1-\delta) = (R + g_2 - C_2) * \delta - g_2 \quad (75.5)$$

$$\text{Given } U_g(1,\delta) = U_g(0,\delta), \quad \text{then } \delta^* = \frac{g_1 - g_2}{(g_1 - g_2) - (C_1 - C_2)} \quad (75.6)$$

If δ is larger than δ^*, government will carry out high standard renewal; on the contrary, if δ is smaller than δ^*, government will adopt high standard compensation. There is a Nash equilibrium point between government and residents, that is, if government undertake the high standard renewal at the rate of $\theta^* = \frac{(2H-C_2-M-R_0)}{(C_1-C_2)}$, the residents will support the renewal at the rate of $\delta^* = \frac{g_1-g_2}{(g_1-g_2)-(C_1-C_2)}$, Government and residents proceed the game through the adjustment of θ^* and δ^*. In practice, the values of H, M and R_0 can be calculated, and national minimum standards for compensation is also provided, so the key point of government and residents game is C_1.

75.3.2 Game Analysis Between Government and Developer

If the government provides enough preferential, developers will participate in the urban renewal, otherwise, the developers will turn to other projects, which are mainly determined by expected benefit (Gao 2012). Set the following parameters: E indicates net income that developers obtain from urban renewal; T indicates the income that developers obtain when develop other projects in the city, which is also the industry average profit; F indicates developer's benefit gains from preferential that government provides. Game model between government and developer is as Table 75.2.

Table 75.2 Game model between government and developer

Developer	Government	
	Provide	Not provide
Participate	$E+F$, $R-F$	E, R
Non-participate	T, $R-C$	T, R

Assuming that α is the rate of government provides the preferential policies, and β is the rate of developers participating in urban renewal. Given α, then the expectation function that developers choose to participate in renewal ($\beta = 1$) and not to participate ($\beta = 0$) are:

$$U_d(1,\alpha) = (E+F) * \alpha + E * (1-\alpha) = F\alpha + E \tag{75.7}$$

$$U_d(0,\alpha) = T\alpha + T * (1-\alpha) = T \tag{75.8}$$

$$\text{Given } U_d(1,\alpha) = U_d(0,\alpha), \quad \text{then } \alpha^* = \frac{(T-E)}{F} \tag{75.9}$$

when α is larger than α^*, developers will participate in urban renewal. On the contrary, when α is samller than α^*, developers will not participate in urban renewal. The determination of α^* has a direct relationship with T, E and F. The numerical value of these determines whether the developers will participate in urban renewal. (1) If E is larger than T, urban renewal project will certainly attract the active participation of developers. (2) If E is equal to T and $U_d(1,\alpha)$ is larger than $U_d(0,\alpha)$, regardless preferential that government provides, developers will participate. It shows in Fig. 75.1; (3) If E is smaller than T, developers will not participate in the transformation generally. In order to attract developers' participation, government will provide series of preferential policies. We can see from Fig. 75.2, if the preferential policies ($F\alpha$) government provides can make up for the income difference $(T-E)$ of the developer to develop the project, that is ($F\alpha$) is larger than $(T-E)$, developers will be involved in the profitable urban construction renewal.

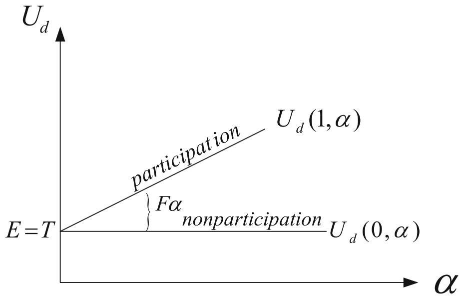


Fig. 75.1 Developer's utility map1 (E = T)

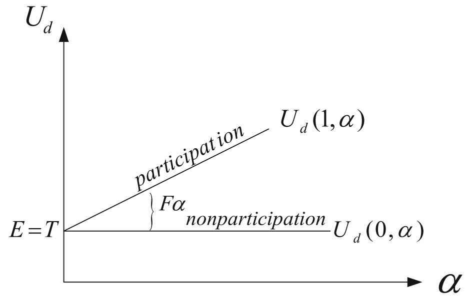


Fig. 75.2 Developer's utility map2 ($E < T$)

75.3.3 Game Analysis Between Resident and Developer

For the rational planning of the city, government strictly control planning indicators, the volume, building density and others of the projects, which control the development strength of the developers, and then affect their income level. In order to pursue greater develop profits, developers may take illegal development means to avoid the loss of collective interests. At this time residents will supervise the developer's behavior (Chen 2009).

Therefore, the residents' strategies are {Supervision} and {Non supervision}, the developers' strategies are {Regulation renewal} and {Illegal renewal}. Set the following parameters: W indicates demolition and resettlement costs Residents get; V indicates average revenue for developers; C indicates cost of development. The investment ratio of the residents is x; developer investment ratio is $(1-x)$, transformation income is also carried out in this proportion; t indicates loss of profits that developers carry on regulation renewal, which can be transformed into the interests of the residents: T indicates the excess profits developers gains when carry on illegal renewal, and T is larger than t; U indicates developer's additional losses caused by intensified contradiction, such as prolonged construction period, etc. By exercising supervision,residents can restore the deprived interests of the developers, otherwise, they will suffer the loss. Game model between resident and developer is as Table 75.3.

Defining the Nash equilibrium with drawing line method: (1) Developer benefits are $(1-x)(V-C)-W-t$ when choose regulation renewal and resident benefit is $W+t+x(V-C)$ when choose supervise the project; (2) Developer benefits are $(1-x)(V-C)-W-T-U$ when choose illegal renewal and resident benefits are $W+T+x(V-C)$ when choose supervise the project.

Because T is larger than t, when choose supervise the project resident benefit is more than non-supervise. The most conducive strategy to the developers is

Table 75.3 Game model between resident and developer

Developer	Resident	
	Supervision	Non supervision
Regulation renewal	$(1-x)(V-C)-W-t$, $W+t+x(V-C)$	$(1-x)(V-C)-W-t$, $W-t+x(V-C)$
Illegal renewal	$(1-x)(V-C)-W-T-U$, $W+T+x(V-C)$	$(1-x)(V-C)-W+T$, $W-T+x(R-C)$

regulation renewal, and resident choose supervision,then Nash equilibrium is reached. That is, only the selection of combination strategy, {Regulation Renewal, Supervision} can both achieve the win for the developer and resident, and the benefits are $\{(1-x)(V-C)-W-t, W+t+x(V-C)\}$.

Dynamic game model and analysis

Urban renewal emphasizes the participation of various stakeholders, achieving their own benefits in the process of the game (Meng et al. 2009). Establish a dynamic game model and analyze the benefits of all stakeholders.

75.3.4 *Expected Benefit Function of the Game Participants*

Expected benefits are the participants' gains and losses after making the decision in the game. U_i indicates the expected benefits of the participants. It is a multivariate function of the participants' strategies. U_g,U_p,U_d express the benefits of government, residents and developers respectively.

(1) Government expected benefits. Through the promotion of urban renewal, government get the land income, the improvement of city image and investment environment, the promotion of urban competitiveness and the sustainable development of the city.
(2) Resident expected benefits. Refer to the income of all persons who have been transformed, including the improvement of the living conditions and residential environment and the social security after the renewal.
(3) Developer expected benefits. The input of the developers is mainly the cost of resettlement and development operations. As long as the renewal profits are more than average community profit of other projects, developers will motivate to participate in the renewal.

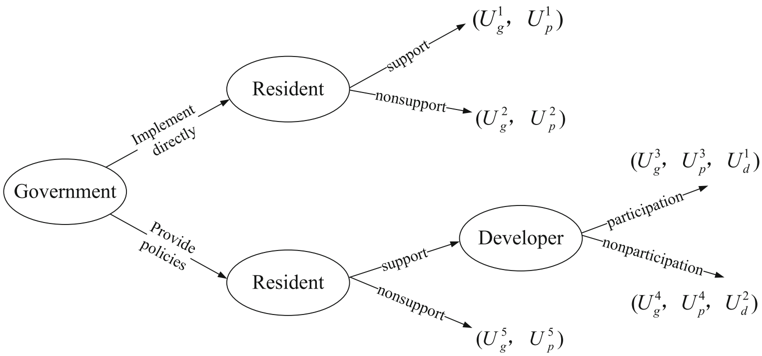


Fig. 75.3 Dynamic game extensive form of urban renewal

75.3.5 Action Strategy and Model Establishment of the Three Party Games

Stage 1: The government is in the beginning of the game model, and gives the first choice of strategy according to the city development. They have two choices with implement directly or provide policies.

Stage 2: Residents are the second choosers of the game. They also have two choices with support or nonsupport relative to the government's strategy. When government chooses implementation directly, game will end no matter what residents choose. The corresponding expected benefits are $U_1 = (U_g^1, U_p^1)$ and $U_2 = (U_g^2, U_p^2)$; If the government chooses provide policies and residents choose nonsupport, the game ends. The corresponding expected benefits are $U_5 = (U_g^5, U_p^5)$. Only when people choose support, the developers begin to choose action, and the game will come into the third stage.

Stage 3: On the basis of government choose provide polices and resident choose support, the developers will make a choice with participation or nonparticipation. The corresponding expected benefits are $U_3 = (U_g^3, U_p^3, U_d^3)$ and $U_4 = (U_g^4, U_p^4, U_d^4)$.

According to the hypothesis and analysis above, we can get the complete urban renewal dynamic game, as shown in Fig. 75.3.

75.3.6 The Equilibrium Results Analysis of the Game

In the model, according to the needs of urban development, the government should make a strategic choice, and then the residents and developers choose according to their own income level. Government decision-making is influenced by the choices of residents and developers. The process of mutual influence is the process of adjusting the interest among the three.

In the case of developers choose participation and residents choose support, if U_g^1 is larger than U_g^3, government will choose implement directly, at this time, the renewal model of the government led implementation directly will be formed; if U_g^1 is smaller than U_g^3, government will provide policies, at this time it will form renewal model of developers participating or cooperating between government and market. When the developers choose nonparticipation, if U_p^4 is larger than U_p^5, residents still support, at this time the government will choose provide policies if only U_g^3 is larger than U_g^1, the equilibrium result is the formation of residents self-financing renewal model.

From the above equilibrium analysis, we can know that there are four main modes of urban renewal:

Mode 1, government implements the urban renewal directly. This mode is driven by the government's direct organization and leadership, using government resources to implement the urban renewal. This mode requires the government has a relatively strong financial strength.

Mode 2, residents complete the urban renewal themselves. This mode in the macro grasp of the government, led by the residents of urban renewal, needs residents have a good financial strength and professional development capabilities.

Mode 3, developers participate in the urban renewal. Under the guidance of the government and the coordination with residents, developers directly or indirectly participate in urban renewal.

Mode 4, government coordinate with market. This model is under government leading, formulates corresponding development strategies, takes market's guidance and fairness into account, and completes the established urban renewal project based on the principle of the operation of the market economy.

75.4 Case Analyze

In recent years, with the rapid pace of urbanization, Guangzhou city continues to expand, making the problem of urban village prominent. The renewal involves the benefits of many stakeholders, so it is the most difficult, deserving the government's high attention.

Lieder village is one of the urban village renewals of government leading, market participating to complete successfully. Used for the renewal of land area is about 235,000 m^2. The total removal buildings area are 600,000 m^2, in which the construction area of 330,000 m^2 are legal, accounting for 55% and 270,000 m^2 are illegal, accounting for 45%. The village had many illegal buildings.

75.4.1 The Renewal Construction Scheme and Fund Source

According to the renewal plan, the whole Lieder village would be pulled down and rebuilt (Li 2009). East Bridge was mainly used for the resettlement of residents; Southwest Bridge is development land of collective economy, mainly for star hotel construction, namely Lieder Center; West Bridge was sold at a price of 4.6 billion to developers for commercial, office and hotel, equivalent to the sale floor price of 8095.3 Yuan/m^2 (Liang 2009). District indicators are as Tables 75.4 and 75.5.

75.4.2 Removal Compensation and Resettlement Program

The main removal compensation schemes are as follows (Liang 2009): (1) Temporary placement compensation fee: To the area of legitimate construction, housing and shops are 25 Yuan/m^2/month. Extra construction area is 10 Yuan/month. Temporary resettlement subsidies calculated by 36 months; (2) Relocation subsidies: according to two calculation of one into one out, the compensation standard is 30 Yuan/m^2; (3) To the building area that owns legal property of the demolished house, remove a square meters back a square meters; (4) Illegal construction will be given 1000 Yuan/m^2 compensate the material loss.

Table 75.4 Main technical and economic indexes of lieder village

Land name	Total planning land area (m^2)	Land can be used for construction (m^2)	Total construction area (m^2)	Calculate the volume ratio of area (m^2)	Integrated volume ratio	Total building density (%)
East bridge	171138.9	132275.8	877,889	687,251	5.2	27.8
Southwest bridge	49933.1	32135.7	231,623	173,500	5.4	37.8
West bridge	114,176	71,175	778,216	568,230	7.98	40

Table 75.5 Parameter of land auction of west bridge

Land name	Land area (m^2)	Construction area (m^2)	Starting floor price (Yuan/m^2)	Auction floor price (Yuan/m^2)	Starting price (billion Yuan)	Auction price (billion Yuan)
West bridge	114,176	56,8230	6335	8095.3	3.86	4.6

75.4.3 Basic Indicators

Based on the above data, we can analyze the three party's strategy choice (Meng et al. 2009). The parameters are as follows: S_0 indicates the present land area of Lieder village: 235,587 m^2; R_1 indicates the present volume ratio of Lieder village: 2.55; $Q_0(Q_0 = S_0R_1)$ indicates the total removal area of Lieder village: 600,000 m^2; C_0 indicates the relocation compensation cost of Lieder village: 682.2 million Yuan; C_1 indicates the residents resettlement housing cost of Lieder village: 2370.3003 million Yuan; C_2 indicates the total supporting facilities cost of Lieder village new district operating development land: 56.94 million Yuan; C_3 indicates the other cost of Lieder village resettlement area reconstruction: 526.7334 million Yuan; S_1 indicates the resettlement construction land area of Lieder village new district reconstruction plan: 132,275.8 m^2; S_2 indicates the operating and developing construction land area of Lieder village new district reconstruction plan: 71,175 m^2; R_2 indicates integrated volume ratio of Lieder new district reconstruction plan: 6.07; R_3 indicates the resettlement housing volume ratio of Lieder village new district reconstruction plan: 5.2; R_4 indicates represents the land volume of business development of the new district planning: 7.98; P_0 indicates the compensation price of Lieder village demolition: 1137 Yuan/m^2; P_1 indicates the cost price of Lieder village Resettlement housing: 3300 Yuan/m^2; P_2 indicates the operating development land cost: 8095.3 Yuan/m^2; P_3 indicates the selling prices that the developers develop property: 20,000 Yuan/m^2; P_4 indicates the property market price with similar location and type 20,000 Yuan/m^2; P_5 indicates the unilateral operating property cost: 4000 Yuan/m^2; P_6 indicates the unilateral operating property floor price that government transfers: 11,912 Yuan/m^2; I indicates the average rate of return of property development industry: 15%; A_3 indicates the Lieder center in Southwest Bridge: 231,623 m^2.

75.4.4 Basic Hypothesis and Analysis

(1) The land area of new district reconstruction plan is equal to the original land area used for urban renewal. It is equal to the resettlement construction land area and the operating and developing construction land area of new district reconstruction plan, namely $S_0 = S_1 + S_2$.
(2) The resettlement house area of urban renewal project is equal to the actual demolition house area. The demolition compensation ratio is 1:1.
(3) The selling prices that the developers develop property is equal to the property market price with similar location and type, namely $P_3 = P_4$;
(4) The benefits of urban renewal consist of economic benefits, social benefits and environmental benefits. Owing to the social benefits and environmental benefits is difficult to be quantified, in order to simplify the calculating, we just calculate the economic benefits.

(5) The final result of the game is stakeholders constantly adjust their expected benefits in the process of dynamic game to reach an agreement.

75.4.5 Three Party Decision Analysis

Through the calculation, we can analyze the decision-making of government, resident and developer in the Lieder village renewal.

(1) Government decision-making

The expected benefits of the government is equal to the total revenue obtained from selling business development land subtract the total cost of Lieder village renewal.

$$U_g = P_2 S_2 R_4 - (C_0 + C_1 + C_2 + C_3 + A_3 P_5) = 92.21\,(\text{million Yuan}) \qquad (75.10)$$

Lieder village renewal is basically no need of government financial investment. Besides, renewal can improve urban environment and social security.

(2) Residents decision-making

Lieder village resident population was 18,118, 5662 households. Average residential area was 106 m^2/household (documented 58.3 m^2/household, undocumented 47.7 m^2/household). The renewal period is 36 months. We can see the economic benefits analysis in the Tables 75.6 and 75.7.

Table 75.6 Property income the each household share in lieder village renewal

Main economic income	Compensation amount (Yuan)	Instruction
Temporary placement compensation	69,642	Documented 25 Yuan/m^2, undocumented 10 Yuan/m^2; calculated by 36 months, 1934.5 Yuan/month
Relocation subsidies	3180	30 Yuan/m^2
Undocumented compensation	27,000	Material compensation 1000 Yuan/m^2
Relocation expenses	−5000	
Rental expenses	−40,500	25 m^2/person, 75 m^2/household, average rents 15 Yuan/m^2/month
Total	54,322	

Table 75.7 Rental income the each household in lieder village renewal

Main economic income	Area (m^2)	Amount (Yuan/m^2/month)	Period (month)	Income (Yuan)
Rental income	53	12	36	22,896

Instruction Lieder village rents generally only 10–15 Yuan/m^2, take the middle value, rent by half of the house

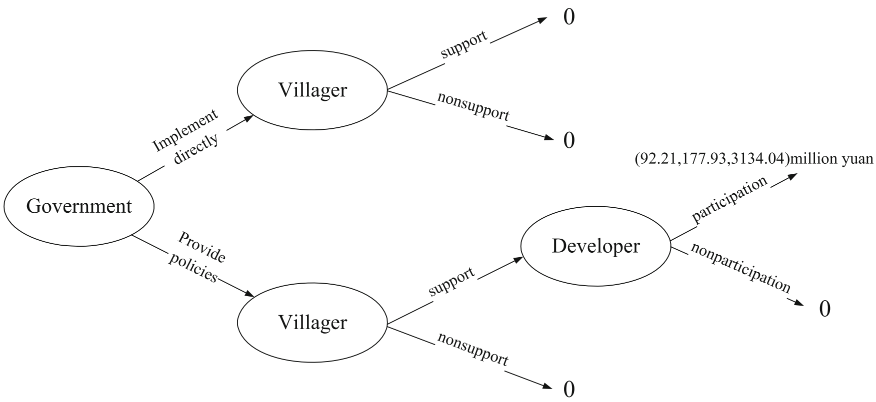


Fig. 75.4 Three stakeholders game model of lieder village renewal

The expected benefit of the villagers after the renewal is as follows:

$$U_p = 5662 \times (54322 - 22896) = 177.93\,(\text{million Yuan}) > 0 \quad (75.11)$$

By supporting the renewal, villagers can not only get the land compensation, and the original equal legal construction area, but also improve the living environment and gain income.

(3) Developers decision-making

The expected benefits of the developers is as follows:

$$U_d = S_2R_2(P_4 - P_5 - P_2) - S_2R_2(P_5 + P_6)I = 3134.04\,(\text{million Yuan}) \quad (75.12)$$

Developers' expected benefits are much higher than the equivalent commercial development in Guangzhou.

Based on the above analysis, the three stakeholders should support and participate in the Lieder village renewal actively. The game model of the three stakeholders in this case is shown in Fig. 75.4.

75.5 Conclusions

(1) The essence of urban renewal is the adjustment of interest among stakeholders. The game equilibrium results come to four kinds of urban renewal mode, that is, government implements the urban renewal directly, residents complete the urban renewal themselves, developers participate in the urban renewal and government coordinates with market. The ideal mode is that government provides policies, residents support, and developers participate, three stakeholders achieve win.

(2) No matter what kind of mode adopted, the protection of the residents' interests is the core issue of urban renewal and the important factor of social harmony and stability. Therefore, protecting the residents' benefit improving the level of the residents' welfare is the first question the government should take into consideration.

(3) Attract strong financial strength developers to participate in can reduce the government financial burden, which is conducive to solve the problem of insufficient funds and make up for the lack of professional ability and operational capacity of the residents, and is choice to the promote urban renewal smoothly.

(4) Through the analysis of the Lieder village case, the paper draws the feasibility of the renewal mode—government provides policies, villagers support and developers participate, and proves that the mode's operability and validity.

References

Brindley T (2003) The social dimension of the urban village: a comparison of models for sustainable urban development. Urban Des 8:53–65

Bromley R, Tallon A, Thomas C (2005) City centre regeneration through residential development contributing to sustainability. Urban Stud 42(13):2407–2429

Cao K et al (2006) The study on the pattern of the old town rebuilding in Guangzhou—a case of Yuexiu District. J Cent China Normal Univ (Natural Sciences) 2:301–304 (In Chinese)

Chen T (2009) The based on game analysis of the main stakeholders in the inner-city village's transformation. Xian University of Technology, Xian

Gao M (2012) The countermeasures on the reform of "village in the city" under the perspective of game theory. Xi'an University of Architecture and Technology, Xi'an

Hemphill L, McGreal S, Berry J et al (2002) An aggregated weighting system for evaluating sustainable urban regeneration. Property Res 19(04):353–373

Hunt JG (2006) Forms of participation in urban redevelopment projects. In: Innovations in design & decision support systems in architecture and urban planning, Springer, Berlin, pp 375–390

Lee GK, Chan EH (2008) The analytic hierarchy process (AHP) approach for assessment of urban renewal proposals. Soc Ind Res 89(1):155–168

Lei T et al (2012) Construction of an index system for evaluating the reconstruction of old factory buildings, old villages and old towns. J Anhui Agric Sci 40(21):10955–10957

Li L (2009) The economic analysis of reconstruction of the urban village–take Lieder community for example. Jinan University, Guangzhou

Liang Y. (2009) The research on the mode of compensation and resettlement in Liede Vic Reform Guangzhou: Jinan University

Meng Weihua, Zhu Dajian, Zhou Xinhong (2009) Game model and empirical research on the transformation of the village in City. Lead Theor City 05:13–19

Qu W (2009) Analysis on interest mechanism of urban renewal. Shandong University, Shandong

Wei Z, Jin C (2009) The model design based on government-led, multi-party participation in an orderly pattern of gradual transformation of the old city——Take Bengbu City for example. J Anhui Inst Archit Ind (Nat Sci) 2:30–34 (In Chinese)

Xiong X (2008) Historic district renovation: a sociological perspective. Planners 12 (In Chinese)

Zhong Y, Cao Y (2013) Analyzing the benefits of urban renewal for the renovated regions: a case study of North Bay Culture Wharf in Guangzhou. Urban Insight 1:133–141 (In Chinese)

Chapter 76
Game-Based Construction Process Learning for Students' Education: A Case Study of Concreting Game

Fei Feng, Zhiyang Lin, Wenfeng Yue, Ke Chen, Ming Kang and Yonghong Cao

76.1 Introduction

In traditional construction courses, students in the classroom are asked to listen to the teachers and just watch PPT in the classroom. Even they have one or two visits to the real construction site, it is very hard for them to clear the steps for every construction work due the lack of construction conception and the poor imagination of the dynamic process.

Among the various construction process education methods, three-dimensional (3D) digital game-based learning is believed to have a great potential (Lee et al. 2014). The game-based education method can attract students by combining various learning strategies with civil engineering knowledge.

F. Feng (✉) · W. Yue · M. Kang · Y. Cao
School of Civil Engineering, Chongqing University, Chongqing, China
e-mail: ff73@cqu.edu.cn

W. Yue
e-mail: 20105898@cqu.edu.cn

M. Kang
e-mail: kangming@cqu.edu.cn

Y. Cao
e-mail: caoyh@cqu.edu.cn

Z. Lin
School of Construction Management and Real Estate, Chongqing University, Chongqing, China
e-mail: zhiyang.lin@cqu.edu.cn

K. Chen
School of Real Estate and Construction,
The University of Hong Kong, Hong Kong, China
e-mail: leochen@connect.hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_76

In China almost every construction project has concreting process, so it is the primary construction work for every onsite engineer. In that we choose the concreting process as the example to simulate and make a game to simulate the specific process with Graphical User Interface (GUI) navigation. After they finish parts of the game, there is a question phase at last to check how much they remember.

This new approach enables students to interact, and interest in such topics like construction method. The benefits of the education method are: enhanced understanding of complex construction process; better accessibility to real construction site by virtual simulation; more convenient and flexible time for learning practices; and safer site visit with this pre-training tool (Zhang et al. 2016).

76.2 Literature Review

The use of game engine technology is a challenging process that requires skills in computer language, 3D modeling, and computer graphics (Van Rosmalen et al. 2011). Game researchers have questioned the myth that simulated virtual environments should be extremely realistic and emulate the exact physical aspects of the real world (Westera et al. 2008).

On the other hand, the virtual learning courses could lead to an efficient and effective learning (Pan et al. 2006). More and more researchers recently discover the potential that serious games have for supporting construction management research and education (Hartmann 2016). It has been indicated that it is almost impossible to separate students from their technology-enables devices or ask them to think and act differently than how they do outside the classroom (Shirazi and Behzadan 2013). Authentic content related aspects improve a learner's educational motivation as well as learning performance (Alexander et al. 2005). And a pedagogical methodology can improve the quality of learning through transforming traditional instructional delivery techniques into technology-based learning (Zhang et al. 2016).

Recently, growing evidence suggests that employing innovative teaching approaches, such as interactive simulation games, offers more active, hands-on and problem-based learning opportunities for students to synthesize and test acquired knowledge more closely aligned with real-life construction scenarios (Nikolic and Messner 2012). Assessment of student performance showed that the game significantly enhanced the achievement of learning outcomes. Students who faced more complex and open-ended tasks performed better, reaching higher levels of competence earlier in game (Venter and Coetzee 2013).

76.3 Methodology

76.3.1 Framework

This game learning fully combines real construction process with education strategies. The construction process must fully fit into with the actual world, for instance the site layout and the construction steps. Besides the education strategies, like the education psychology and students' reactions, must be considered in the game design.

Combining with this two key points, the game designed in this research mainly includes 3 main parts: (1) the process simulation about real concreting steps, which is the same as the onsite concreting work; (2) the GUI navigation to point out how to act in every step, and the navigation must be very easy to recognized by these students; (3) the question phase by random questions about the game process to ensure whether these students have clear the process, also the questions should be set at different difficulties and related to the course and previous game steps.

Three factors are focused for this research on gaming learning course: (1) the degree of recognition, which means how easy the students can understand the work steps and game models, and how much they can know the real process. This is related to the reality level compared to our 3D digital game models and logistic design; (2) the level of memory, indicating that how much they can remember by our game course after the completion of the course; (3) and the ability to real site, signifying that how much onsite works they can handle when they go to the construction project.

The framework of the game is shown in Fig. 76.1.

76.3.2 Game Process

In this paper, the concreting work is used as the course example. The research team built the real 3D environment by a game engine named Unity, including the sun light, site layout, workers, tools and machines. The 3D environment should be close to the real world. And the interfaces should be humanized and easy to operate too. Figure 76.2 is the beginning interface, which is very easy for students to understand and operate.

Then we simulated every step according to real construction process, for example the Concrete Pumping Truck Preparing process and the Concrete Vibrating process. The process is sufficiently same with the real construction process. To get the best education result, we simulated specific process of the construction work, like how the truck located itself and then put down its pipe to

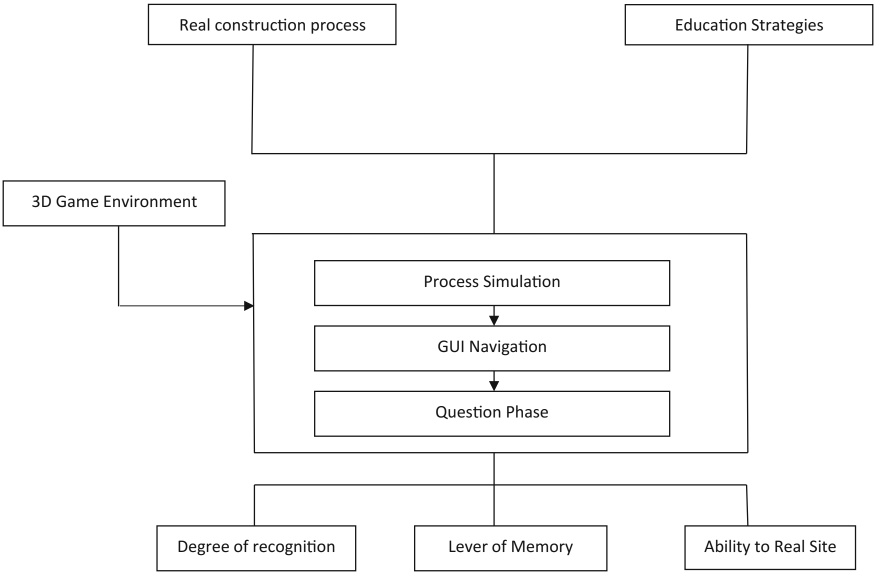


Fig. 76.1 Framework the educational game

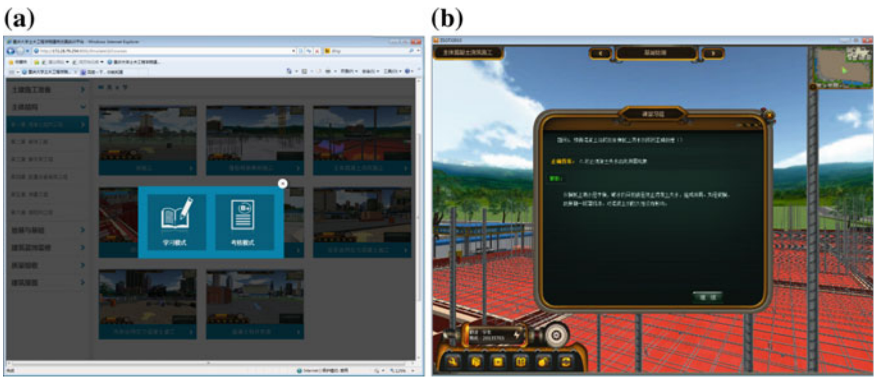


Fig. 76.2 Interface to start

pour the concrete. Every simulated step had been verified by onsite engineers and workers, so that it is believed to have an expected result when being used in the classroom. In this education test, we asked 60 junior students who major in civil engineering and are under their construction course at this semester, most of them have a plan to become onsite engineers after graduation, and they have no onsite construction experience before.

Some of the detailed game process are shown in the Fig. 76.3.

(a) Site Bemoisting
(b) Truck Position
(c) Concrete Pumping Truck Preparing
(d) Concrete Truck Enter the Site
(e) Pumping Pipe in Place
(f) Concrete Vibrating

Fig. 76.3 Detailed process of concreting game

76.3.3 Course Check

When the students finish the 3D digital game about real construction steps, there is a question phase to check their learning effects. This stage includes 11 choice questions, all the questions are set up according to what they just learnt in the class.

Fig. 76.4 Playing game in the classroom

If a student answer 9 of them correctly, then he will pass the final test and can be regarded as get a good study result in the course. And in that case the game system will show the right answers of the rest question, which can help students to enhance their knowledge on concreting process. Figure 76.4 shows students are playing the developed game in the classroom.

On the other hand, if the correct number does not reach 9, then the system will play a short video about the construction process for the student. Then he will get an extra chance to answer these questions again. And in our education test, all the students passed the question phase within 2 times.

In addition to this, the test feedbacks of all the participants showed a positive result. The students said that they were totally clear about the construction process by the game. Also they indicated that the interesting game-based learning method was attractive and they really enjoyed the procedure.

So we can make sure that the game education is totally useful and successful in the construction course and students' education. Figure 76.5 is the questions and answers about the game scenes and process. And Fig. 76.6 is the interface of the question phase result. It is very easy to recognize and linked to our game education.

76.4 Conclusion

Based on the game education, the students can know the concreting process easily and clearly. The game can simulate the work stages directly, and the 3D visual process can enhance the recognition of construction process. Therefore, the student

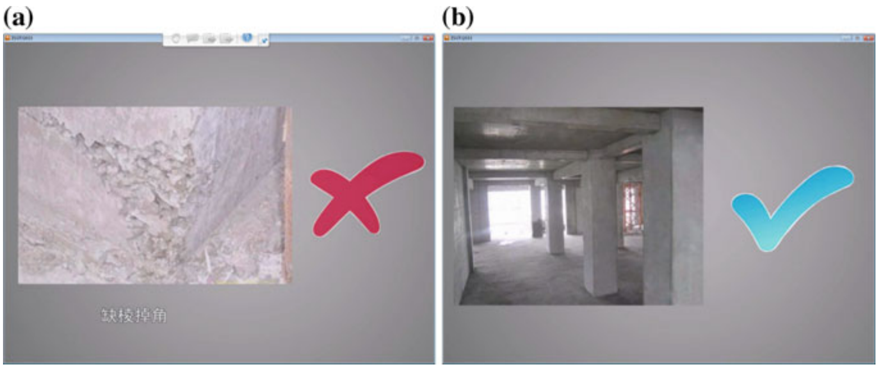


Fig. 76.5 Choice question for course checking

Fig. 76.6 Test result for question phase

can be more familiar with the real construction work. Besides, students can deeply remember about what they have learnt in class during the question phase. Last but not least, the game-based activity learning can improve their ability to solve onsite problem.

In the future work, our research group will develop more interesting games for construction course and students' education, such as beam construction process and construction preparing process.

References

Alexander AL, Brunyé T, Sidman J, Weil SA (2005, November) From gaming to training: a review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games. In: The interservice/industry training, simulation, and education conference (I/ITSEC), NTSA, Orlando, Florida

Zhang C, Lu Y, Xu R, Ye X, Shi Y, Lu P (2016) Game-based active learning for built environment students. In: Proceedings of computing in civil and building engineering, 2016

Hartmann T (2016) Serious gaming in construction management research and education. In: Construction research congress 2016, pp 1948–1957

Lee W, Lin T-H, Castronovo F, Lin K-Y (2014) Serious games for the learning and practices of hazard recognition: understanding the design complexity for 3D construction site modeling. In: Proceedings of computing in civil and building engineering, 2014, pp 2055–2062

Nikolic D, Messner J (2012) Measuring the value of "All Play and No Work": can the rigorous assessment of simulation games drive innovative teaching in construction? In: Construction research congress 2012, pp 2101–2110

Pan Z, Cheok AD, Yang H, Zhu J, Shi J (2006) Virtual reality and mixed reality for virtual learning environments. Comput Graph 30(1):20–28

Shirazi A, Behzadan A (2013) Assessing the pedagogical value of augmented reality-based learning in construction engineering. In: Proceedings of the 13th international conference on construction applications of virtual reality, London, UK Oct 2013

Van Rosmalen P, Klemke R, Westera W (2011) Alleviating the entrance to serious games by exploring the use of commonly available tools. In: Proceedings of the 5th European conference on games based learning, Athens, 20–21 Oct, pp 613–619

Venter CJ, Coetzee J (2013) Interactive learning through gaming simulation in an integrated land use–transportation planning course. J Prof Issues Eng Educ Pract

Westera W, Nadolski RJ, Hummel HG, Wopereis IG (2008) Serious games for higher education: a framework for reducing design complexity. J Comput Assist Learn 24(5):420–432

Chapter 77
Identification and Assessment of Particulate Matters in Asphalt Fumes from Road Construction

D. Chong, M. Kobzeva and Y.H. Wang

77.1 Introduction

Asphalt mixtures are widely used in Hong Kong and mainland China for road pavement construction and maintenance. During road construction, asphalt mixtures have to be heated to 140 °C or above for workability. At such high temperatures, massive particulate matters (PMs) and volatile organic compounds (VOCs) are generated, collectively known as asphalt fumes (Mcclean et al. 2004). Numerous studies have shown that asphalt fumes affect the surrounding air quality and may cause adverse health effects on road construction workers (Yilmaz et al. 2016; Kriech et al. 2011). The VOCs in asphalt fumes has been investigated in another study by the authors of this article (Chong et al. 2013). Therefore the scope of this study is limited to the total respirable PMs of asphalt fumes.

Construction industry has been related to occupational cancers, accounting for more than 30% of all work-related cancers (Serdar et al. 2012). Contact with objects and equipment, falls, exposure to harmful substances and environments accounts for the majority of fatalities in the construction industry. Pavement construction is an important sector in the civil infrastructure construction industry and employs a significant number of specialized workers. In the U.S. and Europe, the asphalt paving industry collectively employs approximately employs 400,000 workers in the production, transport, and placement of asphalt (National asphalt Pavement

D. Chong (✉)
Department of Management Science and Engineering, Shanghai University, Shanghai, China
e-mail: chongdancn@gmail.com

M. Kobzeva
School of Management, Shanghai University, Shanghai, China

Y.H. Wang
Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_77

Association 2011). As in May of 2015, 148 construction companies are listed as approved contractors for road work by the Development Bureau in Hong Kong. It is estimated that at least thousands of workers are employed for road pavement construction. Therefore, the PMs released in asphalt road construction and their effects on workers' health must be carefully examined.

Many epidemiology studies investigate health risk among pavement workers using qualitative exposure data obtained from questionnaires, company records, industrial hygiene measurement, which lack of specific personal exposure levels to asphalt fumes (Boffetta et al. 2003). Asphalt fumes have been verified to be mutagenic, genotoxic, and carcinogenic in animals (Zhao et al. 2004). Asphalt pavement workers are a particularly vulnerable group with increased risks of lung, bladder, stomach, skin and buccal cavity cancers, and leukemia (Serdar et al. 2012). However, the existing studies were mainly performed by professionals from the disciplines of occupational health, not pavement materials. The influences of the wide variety of asphalt materials on asphalt fumes were not studied in detail. In addition, the concentrations and properties of PMs exposed by workers on actual construction sites have not been thoroughly studied.

In view of the potential health risk of PMs generated from asphalt mixture, this study aims to promote the workers' occupational health by addressing the following objectives. (1) Analyze the effects of different asphalt road materials on the concentration variations of PMs. (2) Quantify PMs concentration exposed by road construction workers in field construction sites. (3) Identify the major influencing factors that impact the PMs concentration levels. (4) Assess the potential health effects of PMs on road construction workers. The findings of this study are expected to serve PMs exposure levels for occupational health studies. This study is anticipated to help the pavement industry better understand the occupational health risks presented to onsite workers, establish effective measures to monitor and control the occupational environmental risks, and create a healthy working environment for the pavement industry. The presentation of this paper follows this sequence: introduction of the research method, presentation of the concentration analysis conducted and reporting the results, identification of the impact factors of the PMs, assessment of the effect on human health, and presentation of the conclusions.

77.2 Research Methods

The method framework of this research is shown as follows. Both the laboratory-generated and in situ monitored PMs from asphalt mixtures were collected by PTEF filters. After that, all the PMs samples were delivered into the laboratory for quantifying the weight of PMs absorbed to filters. At last, the concentration of PMs of each sample was calculated.

77.2.1 Collection of PMs Samples

77.2.1.1 In-Situ Monitored PMs Sample Collection

The In-situ monitored PMs samples involved fifty-eight worker-days from twelve asphalt road construction projects located in both Hong Kong and Mainland China. The sampled workers included 16 paver operators, 19 screedmen, 15 rakers, and 8 roller operators. Samplings were conducted during the similar weather conditions to reduce the interference of external environment factors. After samples were taken from construction sites, they were kept in opaque filter cassettes to be transported and stored at −5 °C to prevent degradation.

The in situ monitored PMs samples were collected from pavement workers' breathing zones in accordance with NIOSH Method 5506 (1998). The sampling system consists of a portable air pump, 37-mm Teflon filter, 3-pc filter cassette holder, and a cyclone. The 37-mm diameter filter (PTFE with 2 μm pore size) is placed in a cassette with a support pad. Reparable dust aluminum cyclone operates at 2.5 L/min to conform to the ISO/CEN (International Organization for Standards/European Standards Organization) particle size selection criteria. The portable pump (AirLite® sample pump) is small and lightweight for easy attachment to a worker's belt where it does not interfere with worker activity. The filter cassette holder with cyclone was attached to the worker's lapel near the worker's breathing zone. Figure 77.1 shows an example of a worker who carries on the sampling system. The flow rate of the pump was checked before, during and after sample collection by a calibrator to achieve a stable air intake rate of around 2.5 L/min.

77.2.1.2 Laboratory-Generated PMs Sample Collection

A total of thirty-two laboratory-generated PMs samples were collected from six types of asphalt mixture materials. Laboratory-generated PMs samples were collected from a specially designed asphalt fumes generation system. The idea and design of the generator is referred to the fume generation system used in the study conducted by Binet et al. (2002). Figure 77.2 shows the PMs generation system designed for this study, the PMs generation system is consisted of PMs generator, oven, temperature sensors, temperature data logger, connection tube, PMs measurement device. PMs generator is a steel box with the size of 29.5 cm × 19 cm × 15 cm, the fresh asphalt mixture are contained in the PMs generator after mixing the aggregate and asphalt binder in pugmill. The oven under the PMs generator provides the continue heat for the PMs generator to keep the material at the given temperature. The temperature sensors were inserted into the middle of the material, temperature data logger read the real-time temperature of material. AirLite pump with connection tube transfers the PMs into the PTFE filter in castle to measure the concentration of PMs generated from the asphalt mixtures.

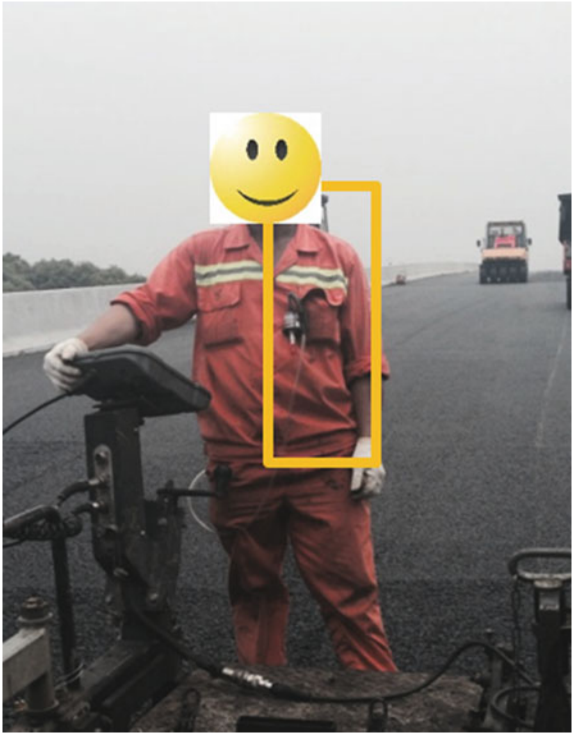


Fig. 77.1 Onsite workers who carry on the PMs sampling system

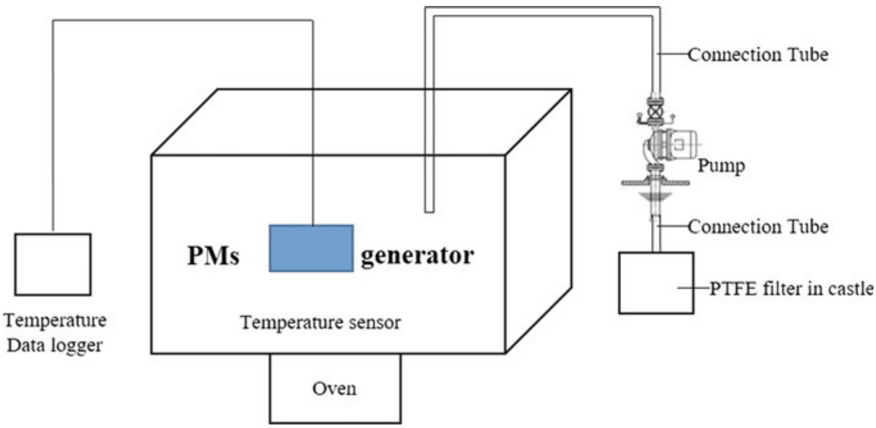


Fig. 77.2 PMs generation system in laboratory

Table 77.1 Six asphalt mixture types for laboratory-generated PMs

Asphalt mixture types	Description
HMA-1	Hot mix asphalt mixture with 5.5% binder content
HMA-2	Hot mix asphalt mixture with 6.5% binder content
WMA-1	Warm mix asphalt mixture with Sasobit warm agent
WMA-2	Warm mix asphalt mixture with Aspha-Min warm agent
PMA	Polymer modified asphalt
RAP	Reclaimed asphalt pavement with 30%

In order to compare PMs generated from different materials, six types of asphalt mixtures were prepared. Table 77.1 shows the details of the six samples prepared for this study. In order to make all materials consistent for experiment measurement, the experiment conditions and mix design parameters are chosen to be the same. All the asphalt mixtures are designed to be 20 mm Wearing Course according to the General Specification for Civil Engineering Works from Civil Engineering and Development Department in Hong Kong.

77.2.2 Quantification of PMs Weight

The analytical method for the characterization of PMs follows the NIOSH Method 5800 (1998). Before sampling, the filter was conditioned in the desiccator chamber for 24 h, the relative humidity in the chamber is kept between 30% and 50%, and the ambient temperature is controlled at around 19.5 °C. After sampling, the filter with the collected PMs was reconditioned to the same level of temperature and humidity for 24 h before being weighed. A microbalance of the order of 0.001 mg was used to measure the weight of filters before and after field PM collection.

77.2.3 Calculation of PMs Concentration

The weights of total particulates were measured by microbalance while the inhalation air volume was recorded by the portable pump. The concentrations of total PMs were calculated by using Eq. (77.1).

$$C_{PMs,j} = \frac{M_{After,j} - M_{Before,j}}{V_{a,j}} \tag{77.1}$$

where,

$C_{PMs,j}$ concentration of total PMs for the jth sample (filter), mg/m^3;
$M_{After,j}$ mass of the jth filter after sampling, mg;

$M_{Before,j}$ mass of the *j*th filter before sampling, mg;
$V_{a,j}$ total inhalation air volume for the *j*th filter during sampling period, which was recorded by the portable pump, m^3.

77.3 Analysis Results

77.3.1 Concentration Variation of In-Situ Monitored PMs Samples

The concentrations of PMs vary among workers performing different tasks. Figure 77.3 shows the average concentrations of PMs by different workers in the twelve projects. The results indicate that the PMs exposure levels are generally consistent with the workers' proximity to the HMA mixture. It appears that the paver operators are the most vulnerable to asphalt fumes while the exposure levels of the roller operators are the least among the workers. The screedmen and rakers are also close to the fresh HMA mixture during paving, hence their exposure levels are both relatively high.

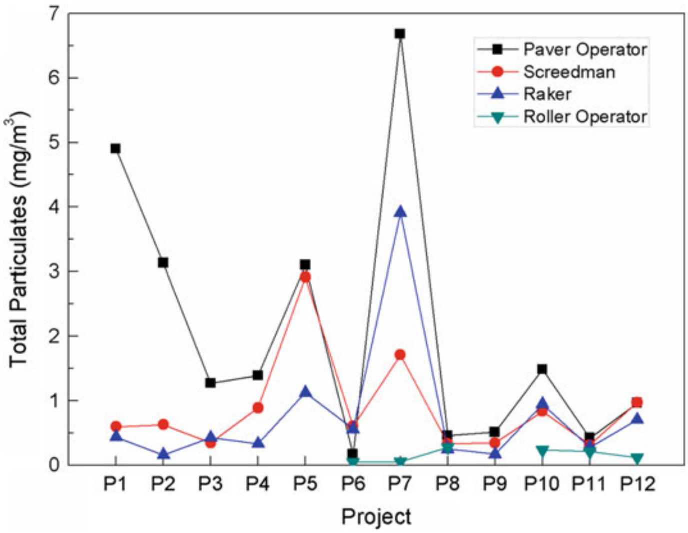


Fig. 77.3 Average concentrations of total PMs by different workers

77.3.2 Concentration Variation of Laboratory-Generated PMs Samples

The laboratory-generated PMs concentrations emitted from reveal variation among six types of asphalt mixtures. Table 77.2 shows the PMs concentrations of thirty-two samples from laboratory PMs generation system. The highest concentration of total PMs is 6.47 mg/m^3 which derives from hot-mix asphalt with 6.5% asphalt binder content at 160 °C. While concentration of total PMs collected from two types of warm-mix asphalt mixtures which are produced at lower temperature is much less than the others. The WMA used Sasobit warm agent causes higher PMs concentration than the one with Asph-Min warm agent. In addition, 30% reclaimed asphalt pavement generally results in higher PMs exposure levels.

77.4 Discussions

77.4.1 Effect of Asphalt Binder on PMs Emissions

PMs concentrations of projects using modified asphalt binders are much higher than those using conventional neat binders. Neat binder is unmodified binder. T-test was performed to statistically evaluate such differences of PMs concentrations. The independent two-sample t-test results are shown in Table 77.3. The Levene's test for equality of variances indicates that the variances of the two groups are different at the significance level of 0.05. Assuming that the variances of the two groups are different, the null hypothesis that the means of the two samples are equal is rejected at the 0.05 significance. Therefore, there is strong evidence that the concentrations of PMs generated by the asphalt mixtures using modified asphalt binders are different from those using neat asphalt binders.

Table 77.2 Concentration of PMs generated from six asphalt mixture types (mg/m^3)

Materials types	Sample no.	Average	Min–Max	S.D.
HMA-1	6	1.086	0.004–5.800	2.324
HMA-2	6	1.415	0.014–6.470	2.583
WMA-1	4	0.049	0.044–0.040	0.012
WMA-2	4	0.007	0.000–0.020	0.009
PMA	6	0.144	0.008–0.737	0.292
RAP	6	1.112	0.000–5.620	2.245

Table 77.3 T-test results of modified asphalt binders and neat asphalt binders (PMs)

	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	T	Df	Sig.	Mean difference	Std. error difference	95% Confidence interval of the difference	
								Lower	Upper
Equal variances assumed	6.173	0.032	5.384	10	0.000	1.515	0.281	0.888	2.142
Equal variances not assumed			4.570	4.389	.008	1.515	0.332	0.626	2.404

77.4.2 *Effect of Asphalt Paving Temperature on PMs Emissions*

The laboratory-generated PMs sample data apparently reveals a difference in PMs concentrations emitted at various paving temperature. Figure 77.4 shows the PMs concentration of all the samples at different temperatures. It can be clearly seen that emission of PMs is proportional to the paving temperature of the asphalt mixtures materials. This tendency can be explained by atmospheric thermodynamics. When the temperature of sample increases, the lower molecular weight hydrocarbons and volatile organic compounds will gain more potential energy and kinetic energy. When the molecules gain sufficient kinetic energy to overcome the intermolecular forces, the molecules will vaporize and the phase will change to gaseous phase. This will increase the emission of asphalt fumes and thus the concentration. Specifically, when the temperature is below 140 °C, a very slight PMs can be detected from the samples. This may due to there are some chemical compounds exist in asphalt that the boiling point is around 140 °C. When the asphalt sample is heated above 140 °C, the chemical compounds would start vaporizing and change to gaseous phase.

77.5 Summary and Conclusions

This study investigated the concentration of PMs in asphalt fumes from both asphalt road construction site and laboratory. In this study, a total of fifty-eight PMs samples collected from the twelve asphalt road construction sites were used to assess the exposure levels of the road construction workers. While a total of thirty-two PMs samples collected from six asphalt mixture materials in laboratory

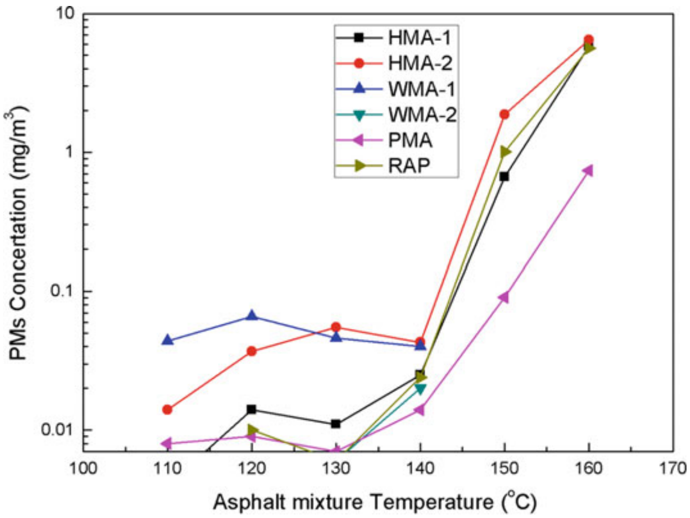


Fig. 77.4 PMs concentrations at different paving temperatures

aimed to identify the factors affecting the concentration levels of PMs. The findings of this study are summarized as followed.

(1) Variations of PMs exposures with job tasks: Paver operators are exposed to the highest level of PMs, followed by screedmen and rakers.
(2) Effects of asphalt mixture types on PMs emissions: Mixtures using modified asphalt binders release more PMs than those using conventional neat asphalt binders. The PMs concentration emitted from hot mix asphalt mixture and reclaimed asphalt pavement mixture are generally higher than warm mix asphalt regardless of the warm agent types.
(3) Effects of asphalt paving temperature on PMs emissions: In general, higher asphalt paving temperature leads to higher PMs concentration, and when the temperature exceeds 140 °C, there is a sharp increase of the PMs concentration.

The findings of this study are expected to help enhance the sustainability of pavement construction industry by improving the health and wellbeing of the workers. It can provide the essential evidences for the further mitigation measures research. Based on the findings, the government may be increasingly aware of the hazardous situation of the pavement working condition and propose the regulations to promote the occupational health of pavement workers.

References

Binet S, Bonnet P, Brandt H, Castegnaro M, Delsaut P, Fabries J, Huynh C, Lafontaine M, Morel G, Nunge H (2002) Development and validation of a new bitumen fume generation system which generates polycyclic aromatic hydrocarbon concentrations proportional to fume concentrations. Ann Occup Hyg 46(7):617–628

Boffetta P, Burstyn I, Partanen T, Kromhout H, Svane O, Langård S, Järvholm B, Frentzel-Beyme R, Kauppinen T, Stücker I (2003) Cancer mortality among european asphalt workers: an international epidemiological study. II. Exposure to bitumen fume and other agents. Am J Ind Med 43(1):28–39

Chong D, Wang Y, Guo H, Lu Y (2013) Volatile organic compounds generated in asphalt pavement construction and their health effects on workers. J Constr Eng Manage 140(2)

Kriech AJ, Osborn LV, Snawder JE, Olsen LD, Herrick RF, Cavallari JM, Mcclean MD, Blackburn GR (2011) Study design and methods to investigate inhalation and dermal exposure to polycyclic aromatic compounds and urinary metabolites from asphalt paving workers: research conducted through partnership. Polycyclic Aromat Compd 31(4):243–269

Mcclean M, Rinehart R, Ngo L, Eisen E, Kelsey K, Herrick R (2004) Inhalation and dermal exposure among asphalt paving workers. Ann Occup Hyg 48(8):663–671

National asphalt Pavement Association (2011) The asphalt paving industry, a global perspective. EAPA, Brussels

NIOSH (1998) Polynuclear aromatic hydrocarbons by hplc (method 5506). The national institute for occupational safety and health (NIOSH)

NIOSH (1998) Polycyclic aromatic compounds, total (pacs) (method 5800). The national institute for occupational safety and health (NIOSH)

Serdar B, Lee D, Dou Z (2012) Biomarkers of exposure to polycyclic aromatic hydrocarbons (pahs) and DNA damage: a cross-sectional pilot study among roofers in south florida. BMJ Open 2(4):e001318

Yilmaz H, Bal C, Neşelioglu S, Büyükşekerci M, Gündüzöz M, Eren F, Tutkun L, Yilmaz FM (2016) Thiol/disulphide homeostasis in asphalt workers. Arch Environ Occup Health 1–5

Zhao H, Yin X, Frazer D, Barger M, Siegel P, Millecchia L, Zhong B, Tomblyn S, Stone S, Ma J (2004) Effects of paving asphalt fume exposure on genotoxic and mutagenic activities in the rat lung. Mutat Res/Genet Toxicol Environ Mutagenesis 557(2):137–149

Chapter 78
Identifying the Relationship Between Housing Market Development and Urbanization Process: Evidence from Jiangsu, China

Jing Du, Yifan Yang and Bing Jiang

78.1 Introduction

According to China's Bureau of Statistics data, China's urbanization rate rose from 43.9 to 54.77% from 2006 to 2014 (National Bureau of Statistics of China 2015), while the world's urbanization rate over the same period rose from 49.5 to 53.4% (World Bank Database 2015). This showed that China's urbanization rate was significantly faster than the world's average, and China had entered the stage of rapid urbanization. However, recent studies on urbanization development in China show that many issues rise up in the current rapid urbanization which would affect long-term development of the national economy. The development progress of urban infrastructure, social security system, universal ideology, education and healthcare has lagged behind urban expansion. Given the various conflicts and problems that have emerged in urbanization during the recent rapid development, transforming the extensional development of urbanization and improving the inherent quality of urbanization are urgently needed.

Over the last decade, high-speed urbanization has heavily relied on land expansion and housing market development. Interactions between urbanization and the housing market are rather significant, showing a remarkable mutual promoting effect. However, mutual inhibition also exists in some cases. For example, the backwardness of the housing market leads to a reduced pace of urban economic development and declined labor demand in related industries, and inadequate supply causes housing prices to increase and the regional economy to become volatile.

J. Du · B. Jiang
Department of Construction Management and Real Estate,
School of Civil Engineering, Southeast University, Nanjing, China

Y. Yang (✉)
Department of Civil Engineering, Faculty of Engineering,
The University of Hong Kong, Pokfulam, Hong Kong
e-mail: seuyangyifan@sina.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_78

Conversely, excessive development of the housing market may also result in surpluses in housing products and lead to “ghost towns” phenomenon while aggravating the rich-poor gap and triggering social conflicts. Mutually-balancing status essentially matters both to housing development and urbanization quality. Investigating the coordination would serve as supporting evidence for local government to enact relative policies either to promote or limit current development trend. Current studies have generally explored the relationship between urbanization and housing market development from one single perspective, identifying the interaction between urbanization rate and housing consumption, urbanization rate and housing investment or urbanization rate and housing price etc., thus lacking a comprehensive assessment of development trend between urbanization and housing market. Reasonably, we need to treat urbanization and the housing market as two systems, both belonging to subsystems under the social macro system, both commonly consisting of indicators from different dimensions albeit in different magnitudes and scopes. The two subsystems interact with each other and mutually perform checks and balances, exerting influence on their respective development. The objectives of this study are to investigate the developing status of and to identify the order parameters that influence the two systems. Results underpinned by synergetic theory comprehensively depict comparable developing steps of both systems.

78.2 Literature Review

Scholars generally suggest that it is insufficient to use the proportion of urban population to reflect the level of urbanization (Hong and Chen 2000). Urbanization needs to be assessed using indicators of multiple aspects, such as economic growth, social and human, resources, population, land, and eco-environment protection (Shen et al. 2015). Similarly, several works state that urbanization progress needs to be scrutinized from a sustainable view. Li et al. (2009) developed a Full Permutation Polygon Synthetic Indicator System to evaluate urban sustainable development. The indicator system includes 52 indicators covering economic growth, ecological construction, environmental protection, social and welfare progress. As the same, a proportion of studies also spot light on the housing market sustainability assessment, with a method of Multiple Criteria Complex Proportional Evaluation used based on various criteria groups (i.e. general economic, housing stock, housing affordability, population and social conditions, housing quality and environmental quality) (Nuuter 2015). Existing indicator systems are good references for the development of new indicator system. Besides, governmental statistical indicator setting rules are also unavoidable to consider since measurable and data-obtainable indicator acts as prerequisite for further evaluation.

Studies on the interaction between urbanization and housing market development commonly focus on detailed one single aspect analyzing the relationship between the macroeconomic fundamentals and housing prices, housing investment, housing demand etc., neglecting that a comprehensive appraisal of relationship of the two subsystems standing on systematic point is also essential. Adams and Foss (2010) analyzed the housing data of 15 OECD countries in the last 30 years and found that some macroeconomic variables, such as economic activities, construction costs and long-term interest rates, have played a significant role in housing market development. Agnello and Schuknecht (2011) conducted a statistical investigation on the housing markets of 18 industrialized countries (including the European countries, the United States, Japan, etc.) from 1980 to 2007 and found that market liquidity and short-term interest rates had important impacts on the housing market.

Many scholars investigate the phenomenon that the advancing urbanization leads to increased housing investment. The hiking of housing prices caused by urbanization has generated in households and businesses good expectations regarding the future economic situation. Consequently, the level of investment has also been increased (Shen 2006). The well-known Tobin's Q theory could explain the effect of changes in the housing market investment (Tobin 1969). In an empirical study on the housing markets in the UK and Sweden, Barot and Yang (2002) showed that the Q values of the two countries were the Granger cause of the housing investment. From the perspective of demand and supply, Edward (1972) estimated the impact of the rapid urbanization in some developing Asian countries on the demand for the housing market and identified the housing shortage problem in the target cities by comparing demand with the market supply. Wang and Zhang (2015) identified key factors that affected increases of housing prices in Chinese cities, including the urban household registration system, income level, land supply, and construction costs. Urban housing prices were the key economic variable restricting people's achievement of permanent migration—that housing prices were too high was the dominant factor for large cities that repelled migrants (Lee 2008). Research Group on China's Economic Growth (CASS) (2011) found that although China has realized land urbanization, the boosting of housing price has hindered the flow of population, thereby affecting the process of urbanization. Some scholars believed that demographic factors were the important reason for housing price fluctuations. Bakshi and Chen (1994) investigated the demographic factors behind the price fluctuations and believed that the age structure of the population had a long-term effect on housing prices. Stuart and Joe (1999) found that in explaining changes in housing prices in California, the variables of population migration and urban structure had a rather high explanatory power. Admittedly, urbanization process has largely released the potential demands of households. Meanwhile, housing policies will also be changed regularly due to urbanization reasons. Desai (2012) studied the housing problem in the process of urbanization in developing countries, especially the housing situation of the non-affluent class, and analyzed the interaction between urbanization and housing policies after tracking the development since the 1960s.

78.3 Methodology

In cases of limited statistical data, fixed numbers of variables and a lack of information, grey system theory enables a good analysis of the system, and it has been applied to studies of economic forecasting and early warning systems (Deng 1989). By analyzing the development coefficients of variables, grey system modeling determines the variables that play a decisive role in the system, which is very important for subsequent studies.

78.3.1 Grey Relational Analysis of Status Variables

Grey relatedness analysis was used to determine whether the selected status variables met the requirements to be status variables of urbanization and the housing market systems. The detailed calculation procedure can be obtained through the studies by Kuo et al. (2008), Lee and Lin (2011), and Tseng (2010). After determining the grey relatedness of each status variable, variables that had an average grey relatedness of less than 0.5 were discarded through comparisons, and the remaining variables were integrated into the grey system model of urbanization for further calculations.

78.3.2 Grey System Model Fabrication

Let $X_1^{(0)} = \left(x_1^{(0)}(1), x_1^{(0)}(2), \ldots x_1^{(0)}(\mathrm{m})\right)$ be the characteristic data sequence representing the situation when X_1 is the driving variable of the urbanization system. Setting n variables that comprehensively reflect the urbanization system were selected, among which variable X_1 was first chosen to construct the GM (1, n) grey system model. Then $X_{\mathrm{n}}^{(0)} = \left(x_n^{(0)}(1), x_n^{(o)}(2), \ldots x_n^{(0)}(\mathrm{m})\right)$ is the related factor sequence of the system. In the GM (1, n) model can be described as:

$$x_1^{(0)}(k) = -az_1^{(1)}(k) + \sum_{i=2}^{N} b_i x_i^{(1)}(k) \tag{78.1}$$

where $x_1^{(0)}(k)$ and $\mathrm{z}_1^{(1)}(k)$ represent the initial sequence and the sequence after transformation of variable X_1 in the urbanization system, respectively; $x_i^{(1)}(k) \quad (i = 2, 3, 4, \ldots n)$ represents the sequence of the other variables excluding variable X_1 in the grey system after transformation; $-a$ is defined as the development coefficient of the system, representing the promoting or inhibitory effect of variables X_1 on the urbanization system, and $b_i x_i^{(1)}(k)$ is defined as the external driving term, representing the synergistic inhibitory effect of other subsystem variables within the urbanization system. The two effects ultimately affect the change rate $dx_1^{(0)}/dt$ of $x_1^{(0)}(k)$. According to the principle of adiabatic elimination method of synergetics, $-a$ is the basis for the determination of order parameters of the system and can be used as the relaxation coefficient to make judgments on the variables.

The development coefficient a_{a1} of X_1 in the urbanization system and the external driving coefficient were estimated using Least Square Estimation on the vector sequence a. Because the external driving factors address the synergies of the remaining variables in the system excluding X_1 and are thus unrelated to the development or changes of X_1, they are not discussed in the next calculations.

Each system variable in the urbanization system (X_2, X_3,…,X_n) was integrated into the model, giving rise to the system development coefficients $(-a_{a2}, a_{a3}, \ldots, -a_{an})$ of the corresponding variables in the grey system of urbanization. Similarly, GM (1, n) models were constructed for variables Y_1,Y_2,…Y_m in the grey system of the housing market to obtain development coefficients of variables in the grey system of the housing market for further studies.

78.3.3 Order Parameter Determination Based on Synergetic Principles

In the system development process, there are a large number of parameters with a short relaxation time, fast attenuation and large damping at the critical point of the system, also known as fast relaxation variables, according to the servo principle in synergetics. In addition, there are a small number of parameters that had far longer relaxation time than the fast relaxation variables but showed no damping at the critical point of the system, known as slow relaxation variables. The fast relaxation variables in a large number are dominated by the slow relaxation variables in a small number. When the derivative of fast relaxation parameters on time is set to zero and the formula is integrated into other equations, the fast relaxation variables can be eliminated. Therefore, the system equation is solely determined by the slow relaxation variables. The slow relaxation variables can characterize the extent of order of the system and determine the direction of the system development. Thus, they are called order parameters.

Prior to modeling the grey systems of urbanization and housing market, we screened a multitude of indicators through literature analysis, questionnaires, and interviews. We obtained 26 variables, each having a significant impact on the system and being likely order parameters of the grey system of urbanization, and 24 variables that might be order parameters of the grey system of housing market.

The system development coefficient sequences of the grey system models of urbanization and the housing market $(-a_{a1} - a_{a2}, \ldots, -a_{an}$ and $- a_{b1}, a_{b2}, \ldots, a_{\mathrm{bn}})$

were obtained through the least square estimation, which reflects the development trend of the variables. Like relaxation coefficients, the smaller the magnitude of a variable's system development coefficient, the smaller the relaxation coefficient in the system development and the less susceptible it is to the influence of other variables while still being able to dominate the variables with a greater development coefficient and guide the direction of system development.

Because of large number of equations and computational complex for a relaxation coefficient, in this study the system development coefficient that reflects the development trend of the system was used to replace the relaxation coefficient to depict the pace of parameter change. The type of variable was determined by the absolute value of the variable. When the development coefficient of a variable was less than that of the majority of the variables by more than one order of magnitude, it indicates that the relaxation time of this variable was longer than that of other variables and was thus a slow relaxation variable, i.e., an order parameter of the system.

78.3.4 Development Function Formulation

Through the analysis on the development coefficients, the order parameters of the urbanization system are determined to provide the basis for the construction of the development function of urbanization and the housing market. Let positive numbers $x_1, x_2 \ldots x_m$ be the m indicators that describe the reasonable process characteristics of urbanization and positive numbers of $y_1, y_2 \ldots y_n$ be the n indicators that describe the reasonable process characteristics of housing market. Then, the functions

$$f(x) = \sum_{i=1}^{m} a_i \widehat{x_i} \tag{78.2}$$

$$g(y) = \sum_{j=1}^{n} b_j \widehat{y_j} \tag{78.3}$$

are the development function of urbanization development and the development function of the housing market, respectively, where $f(x)$ represents the level of urbanization system development, and $g(y)$ represents the level of development of the housing market system.

Because the dimensions of the indicators are different, it is necessary to normalize the indicators. The 0–1 standardization is adopted to obtain the dimensionless values of the indicators $\widehat{x_i}$ and $\widehat{y}_i$, corresponding to the urbanization and housing market systems, where and are weights of indicators corresponding to the urbanization and housing market systems. When the m and n indicators for a particular year are integrated, the values of the development level of urbanization and the housing market in that year can be obtained.

78.4 Case Study

Based on the scientific, comprehensive, representative, comparable and maneuverable requirements of the model, indicators that meet the requirements are selected as the preliminary status variables through a survey of existing statistical rules, collation of literatures related to urbanization and the housing market and consultation with relevant experts and scholars. For indicators that are difficult to obtain or had missing data, measures such as arithmetic mean and trend extrapolation are used to determine the values or data-missing indicators are replaced with other available ones of a similar nature. In this case study, the data are obtained from the 2005–2014 National Bureau of Statistics Database and 2005–2014 Statistics Bureau of Jiangsu Province database. Based on the initially identified indicator system, 23 indicators of urbanization grey system in Jiangsu Province are selected, and 20 indicators of the housing market grey system are chosen.

According to the calculation method described, the relatedness among the indicators of the grey systems of urbanization and the housing market is obtained. In the grey system of urbanization, more than 5 indicators have a relatedness lower than 0.5. Therefore, they are excluded from the grey system modeling of urbanization. In the grey system of the housing market, 20 indicators have good relatedness. Therefore, they all pass the initial screen and are included in the grey system modeling of housing market.

By integrating the indicators into the grey systems of urbanization and housing market, GM (1, n) modeling is conducted, from which the system development coefficient (a_i) of each indicator in each system and its corresponding driving coefficient (b_i) are obtained. The results are tested using the error testing method in grey system theory. Results show that the system development coefficients were all lower than 2, and the average error of the model is less than 5%. Therefore, the model is determined to be valid. Therefore, they are slow relaxation variables and became order parameters of housing market system. The corresponding indicators are shown in Table 78.1.

After obtaining the order parameters of urbanization and housing market grey systems, the development functions of urbanization and housing market are generated (the weights were selected using the entropy value method and will not be discussed here), and the results are shown in Fig. 78.1.

78.5 Results and Discussion

The development of the housing market in Jiangsu Province during 2006–2014 is slightly faster than that of urbanization, which is consistent with the heated investment in the national housing market in recent years. The per capita disposable income in Jiangsu Province is higher than the national average, and so is the ratio of

Table 78.1 Order parameters of urbanization and housing market grey systems

Urbanization rate indicator	*a* value	Housing market indicator	*a* value
$\mathbf{X_1}$ proportion of urban population	0.0100	$\mathbf{Y_2}$ constructed housing area	0.0144
$\mathbf{X_5}$ total fixed asset investment	0.0428	$\mathbf{Y_3}$ completed amount of annual commodity housing investment	0.0095
$\mathbf{X_6}$ total production of construction industry	0.0487	$\mathbf{Y_6}$ average transaction price of commodity housing	0.0889
$\mathbf{X_8}$ proportion of tertiary industries in GDP	0.0300	$\mathbf{Y_7}$ total production of construction industry	0.0139
$\mathbf{X_9}$ proportion of tertiary industry workers in total labor	0.0086	$\mathbf{Y_8}$ built-up area	0.0078
$\mathbf{X_{10}}$ hospital beds per 10,000 people	0.0218	$\mathbf{Y_{10}}$ per capita GDP	0.0079
$\mathbf{X_{11}}$ per capita road area	0.0218	$\mathbf{Y_{11}}$ per capita disposable income	0.0094
$\mathbf{X_{13}}$ drainage pipeline density	0.0133	$\mathbf{Y_{12}}$ per capita public revenue	0.0060
$\mathbf{X_{18}}$ sewage treatment rate	0.0017	$\mathbf{Y_{14}}$ per capita housing area	0.0029
$\mathbf{X_{22}}$ number of employees participating in pension insurance	0.0124	$\mathbf{Y_{17}}$ urbanization rate	0.0154

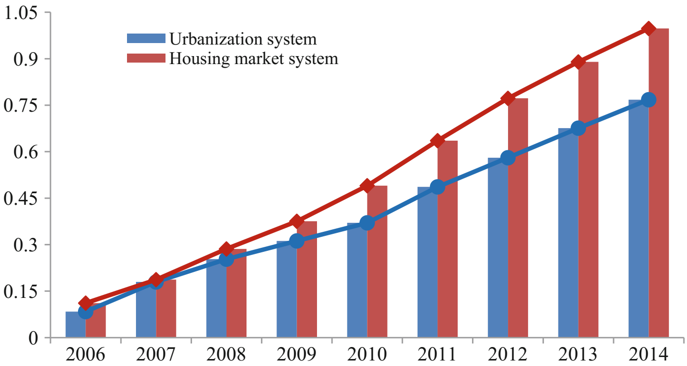


Fig. 78.1 Development function value of urbanization and housing market systems

housing price to income. In recent years, the proportion of housing investment in the province's GDP remains low (5.6% in 2013 in Jiangsu Province, 15% nationally), and the proportion of household expenditure on house purchasing in the household total expenditure is continuously declining. This indicates that the proportion of housing market development only accounted for a low proportion of economic development in Jiangsu Province, and the economic development in the province has good momentum. However, the data from a different angle indicated that, in recent years the urbanization in Jiangsu Province has been inadequate in the development of infrastructure, public services, and human environment.

The current research in some degree underlines previous works in showing critical factors that influence respectively the urbanization and housing market systems. Scrutinizing order parameters selected in current urbanization system, which has broaden the traditional urbanization assessed by urbanization rate to a more reasonable level with public service aspects under consideration, thus basically meets the requirements of sustainability brought up in literatures. The order parameters in housing market also delivered the message that urbanization indeed impacts the housing market conditions through investment, demand and supply, price volatilization channels. Because it is difficult for some indicators to be quantified, and even some indicators may not be given thorough evaluation, the modeling results only reflect the extensiveness of the order parameters in urbanization system and the necessity of coordination from various parties. However, they did not necessarily indicate that the order parameters of the urbanization development of Jiangsu Province were the very indicators obtained by the modeling. When the system is expanded and the selection of indicators is more comprehensive, the order parameters may change, increasing or decreasing in number. This should be recognized as a limitation of the study. Due to the lack of statistical data on affordable housing, it was not included in the modeling. However, the construction of affordable housing plays an important role in stabilizing per capita housing area and allocating reasonable housing under the condition of existing per capita disposable income. The inclusion of per capita public revenue in the order parameters also indicated that the development of housing market especially public housing required a certain degree of public financial support and government intervention.

78.6 Conclusion

Currently, the focus of urbanization studies have shifted from the pace and scale of urbanization to the quality of urbanization. Meanwhile, the population movement and land expansion driven by urbanization all have a profound impact on the housing market. In this study, the order parameters that had a major impact on urbanization and the housing market were obtained through grey system models underpinned by synergetics principles. A case study was conducted with data of Jiangsu Province. Quantitatively, the development pace of the housing market in Jiangsu Province has been proved faster than that of urbanization, and it is necessary to speed up the improvement on the intrinsic quality of urbanization. Through the order parameters, we demonstrated that the quality of urbanization could be comprehensively improved by promoting the citizenship of migrant workers, adjusting and upgrading the industrial structure and improving infrastructure construction. Relative policies need to shift from stimulating urbanization and housing market development through land releasing. Measures should be adopted in some degree to slow down the housing development thus coordinating the current status with existing public service and migration levels. Active policies should be scheduled to facilitate public facility construction thus intrinsically improve the urbanization quality.

References

Adams Z, Foss R (2010) Macroeconomic determinants of international housing markets. J Hous Econ 19:38–50

Agnello L, Schuknecht L (2011) Booms and busts in housing markets: determinants and implications. J Hous Econ 20:171–190

Bakshi GS, Chen ZW (1994) Baby boom, population aging, and capital markets. J Bus 67:165–202

Barot B, Yang Z (2002) Housing price and housing investment in Sweden and the United Kingdom: econometric analysis for the period 1970–1988. RURDS 14(2):189–216

Desai V (2012) Urbanization and housing the poor: overview. International Encyclopedia of Housing and Home, pp 212–218

Deng JL (1989) The introduction of Grey system. J Grey Syst 1:1–24

Edward R (1972) Housing, urban growth and economic development. Orient Culture Service, Taipei

Hong YX, Chen W (2000) The new-type urbanization: evidence from Jiangsu, China. Econ Stud 12:66–71

Kuo Y, Yang T, Huang GW (2008) The use of Grey relational analysis in solving multiple attribute decision-making problems. Comput Ind Eng 55:80–93

Li F, Liu X, Hu D, Wang R, Yang W, Li D, Zhao D (2009) Measurement indicators and an evaluation approach for assessing urban. Landsc Urban Plan 90:134–142. doi:10.1016/j.landurbplan.2008.10.022

Lee B (2008) Structured urban housing: a mechanism of selection for migrants. Chin J Popul Sci 4:53–60

Lee WS, Lin YC (2011) Evaluating and ranking energy performance of office buildings using Grey relational analysis. Energy 36:2551–2556

National Bureau of Statistics of China (2015) Retrieved from http://data.stats.gov.cn/easyquery.htm?cn=C01. Accessed 28 Nov 2015

Nuuter T, Lill I, Tupenaite L (2015) Comparison of housing market sustainability in European countries based on multiple criteria assessment. Land Use Policy 42:642–651

Research Group on China's Economic Growth (CASS) (2011) Urbanization, fiscal expansion and economic growth. Econ Res J 11:4–20

Statistics Bureau of Jiangsu Province (2015) Retrieved from http://www.jssb.gov.cn/2015nj/indexc.htm. Accessed 28 Nov 2015

Shen LY, Zhou JY, Skitmore M, Xia B (2015) Quantifying spatiotemporal patterns of urbanization: the case of the two fastest growing metropolitan regions in the United States. Cities 42:186–194

Stuart AG, Joe PM (1999) House price differentials and dynamics: evidence from the Los Angeles and San Francisco metropolitan areas. FRBSF Econ Rev 1:3–22

Shen Y (2006) The relationship between real estate price and macro-economy. China Water & Power Press, Beijing

Tobin J (1969) A general equilibrium approach to monetary theory. J Money Credit Bank 1:15–29

Tseng ML (2010) Using linguistic preferences and Grey relational analysis to evaluate the environmental knowledge management capacity. Expert Syst Appl 37:70–81

World Bank Database (2015) Retrieved from http://data.worldbank.org.cn/indicator/SP.URB.TOTL.IN.ZS/countries/1W?display=graph. Accessed 28 Nov 2015

Wang Z, Zhang QH (2015) Fundamental factors in housing markets of China. J Hous Econ 25:53–61

Chapter 79
Impacts of Large Construction Projects on Residents' Living Status in China: A Reservoir Project Case

W.S. Lin, Y. Ning, Y.L. Huang and M.J. Liu

79.1 Background

Along with rapid urbanization in China, the number of large construction projects increases considerably. Large construction projects play an important role in accelerating economic, societal development and improving public service quality. However, they might lead to significant social impacts on local communities. Thus, residents might resist to some large construction project sittings, showing NIMBY (not in my backyard) syndrome. This would in turn bring about adverse impacts on economic development and societal stability.

Social impact assessment (SIA) used to identify and evaluate social impact of project development was widely adopted in practice (Jackson and Sleigh 2000; Phadke 2005; Samanta 2015; McCombes et al. 2015). Prior studies developed a series of quantitative and qualitative indicators to measure social impacts of various project interventions (Burdge 2003). However, extent studies fell short of specifying indicators to measure living status changes associated with the intervention of large construction projects. It is also still not known that how large construction projects influence local residents' living status. Therefore, the objective of this research is to develop indices for measuring the social impacts of large construction projects on living status and make suggestions for dealing with local residents' resistance.

W.S. Lin (✉)
Department of Construction and Real Estate, Southeast University, Nanjing, China
e-mail: 1021270231@qq.com

Y. Ning · Y.L. Huang
School of Construction and Real Estate, Southeast University, Nanjing, China

M.J. Liu
Zhenrong Holdings Co Ltd., Guangdong Province, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_79

The paper is organized as follows. Section 79.2 presents the literature review, elaborating the close relationship between NIMBY and large construction projects and current SIA practice in China. Section 79.3 provides value information on the selected project—Gangkouwan reservoir project. Results, discussion and conclusion and recommendations are presented in Sects. 79.4, 79.5 and 79.6 respectively.

79.2 Literature Review

79.2.1 NIMBY and Large Construction Projects

Large construction projects play an important role in accelerating economic development and raising life quality. However, such interventions would bring about complex and profound social impact on local communities (Égré and Senécal 2003), especially for projects that necessitates a considerable range of resettlement and displacement (Scudder 1997; Obitani 2002; Klausen 1964).

NIMBY reflects an organized resistance of communities to the siting of controversial land uses and facilities, which is very common in large construction project development such as infrastructure (e.g., nuclear, conventional waste facilities, conventional power plant) and social facilities (e.g., mental health care, affordable house) (Wolsink 2000). China, as a developing country, has been in the process of large construction. Therefore, NIMBY is so common that has triggers severe public concerns such as PX projects (Li and Station 2016), waste incineration plant (Zhou et al. 2012) and waste treatment station (Yi and Zhijie 2013) and other project.

79.2.2 Social Impact Assessment in China

Social impact assessment of large construction projects has been mandatory in the approval procedure in China. In 1993, Chinese State Planning Commission Investment Institute published “Social assessment method on project investment”, which stipulated the concept, characteristics, aim of conducting social impact assessment. In 1997, former Ministry of Construction published “Social assessment guideline on project investment”. This guideline comprised the assessment of economic, environmental, ecological and natural resource. The Investment Project Feasibility Study Guidelines published in 2002 firstly stipulated that social impact assessment is a mandatory part of the feasibility report. Later in 2004, China Investment Project Social Impact Assessment Guidelines provide more detailed requirements and procedures on conducting social impact assessment.

Despite these regulatory efforts, the impacts of large construction projects on local communities’ living status are not clear. It is also posited by researches that large construction project might have impact on employment, income, production activity, lifestyle, culture, community, political systems, environment, health and well-being, personal and property rights (Tilt et al. 2009; Mathur 2011; Égré and Senécal 2003). However, there is a lack of empirical studies that examine a particular type of projects in China.

In order to bridge this gap in knowledge, this study constructed a framework comprising six aspects (i.e., employment, income, consumption, residence condition, social welfare and overall satisfaction), and tested this framework in a reservoir project.

79.3 Case Study

79.3.1 Case Background

In this study, Gangkouwan reservoir was selected, located in Anhui province, in the middle of China. The reservoir with 32.8 km^2 surface area and 135 m high normal level aimed to achieve multiple functions comprising power generation, irrigation, portable water supply, aquaculture and tourism. Besides, the reservoir has 940 million m^3 in total storage capacity and 430 million m^3 in flood storage capacity. The construction of this project started in October, 1998, lasting for 3 years and 8 months. In addition, the project caused massive relocation and resettlement of 2.5 years, which directly affected 5 towns, 21 communities, 138 villages and 120 companies.

79.3.2 Sampling Strategies

Aiming to eliminate other unnecessary impacts, a comparative study with two contrasting sub-samples (i.e., Groups A and B) was carried out. Group A was set as a contrasting sample which was not influenced by the project, but shares similar cultural, geographic and economic conditions with Group B. Group B received direct social impacts from the project. Such comparison could help to explicate the distinction and distill the real social impact of this project on local residents' living status. Comparative case studies were also undertaken by Huang et al. (2015) in social impact evaluation. So, Meilin, Ningdun, Wanjiaxiang and Nanji, were selected as Group A. But in the process of the selection of Group B, two sub-groups were further collapsed in accordance with the resettlement policies. Group B1 consisting of Gangkou, Qinglong, Zhufeng, Jialu and Fangtang adopted the way of resettling within the town and move backward as Fig. 79.1. Group B2 displaced out of their original town and moved to a new place called Juntian Lake.

Fig. 79.1 Location of sample units

79.3.3 Data Analysis Methods

Three types of data analysis methods were employed. Binary logistic was used to analyze binary data like social welfare. Non-parametric method of Kruskal–Wallis test was used to whether significant difference exists among groups. One-way ANOVA was employed to make multi-comparison between groups.

79.4 Results

79.4.1 Change of Employment Status

79.4.1.1 Employment Rate

Table 79.1 shows before the project employment rate remained stable at around 90%. By contrast, employment rate of contrast groups has great decrease at present, especially for group B1 (from 86.1 to 69.7%), while the control group increase from

Table 79.1 The percentage of unemployment rate among groups in the past and at present

	Past (%)			Present (%)		
Group	A	B1	B2	A	B1	B2
Employment rate	90.8	86.1	96.2	95.8	69.7	91.0

90.8 to 95.8%. Therefore, it might be inferred that this project has caused negative impact on employment rate.

79.4.2 Change of Income

79.4.2.1 Income Level

The results show that before the project, the majority fell into the category of below 30,000 RMB, and only small proportion reached over 30,000 RMB. By contrast, present income level arrived at 30,000–50,000 RMB (see Table 79.2). These changes can also be explained by Table 79.3. Before the project, the income level among group shows no significant difference. However, after this project, significant difference among groups is evident. Besides, comparison results (Table 79.4) show that although the difference is not significant between contrasting and control groups (sig = 0.112 and 0.991), it exists between Groups B1 and B2. Therefore, it is concluded that this project does cause negative impact on income level. The interview results reinforced this results as interviewees from Group B1 expressed more complaints about their income.

Table 79.2 The percentage of various income level among groups in the past and at present

Income level	Past (%)			Present (%)		
	A	B1	B2	A	B1	B2
<2000	17.4	25.4	14.3	0.0	1.5	0.0
2000–5000	20.9	18.7	16.3	7.0	4.5	0.0
5000–10,000	20.9	23.9	20.4	2.3	5.2	4.1
10,000–20,000	11.6	21.6	40.8	16.3	14.2	10.2
20,000–30,000	15.1	3.7	2.0	10.5	25.4	18.4
30,000–50,000	5.8	5.2	6.1	17.4	26.1	36.7
50,000–10,000	3.5	0.7	0.0	30.2	14.9	18.4
>100,000	4.7	0.7	0.0	16.3	8.2	12.2

Table 79.3 Sig. of living status indicators with Kruskal–Wallis test

Living status indicators	Past	Present	Living status indicators	Past	Present
Income level	0.062	0.019	Minimum living allowance	0.518	0.011
Responsibility land	0.000	0.000	Land compensation and fund	0.700	0.000
Responsibility forest	0.712	0.041	Consumption level	0.184	0.577
Animal husbandry	0.019	0.009	Consumption attitude	0.063	0.470
Fishing income	0.175	0.045	Residence type	0.000	0.073
Dividend share	0.700	0.045	Residence area	0.164	0.234

Table 79.4 Multi-comparison among groups with one-way ANOVA

Income level at present				Responsibility land in the past			Responsibility land at present			Responsibility forest at present		
Group	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2
MD	−0.483	0.070	−0.553	−2.954	−2.574	−0.020	−3.274	−2.911	−0.363	−0.248	−0.489	0.242
Sig	0.112	0.991	0.051	0.000	0.000	0.985	0.197	0.033	0.529	0.197	0.033	0.529
Animal husbandry in the present				Animal husbandry at present			Fishing income at present			Divided share at present		
Group	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2
MD	0.082	0.042	0.040	−0.224	−0.021	−0.203	−0.152	−0.042	−0.004	−0.127	0.000	−0.127
Sig	0.002	0.402	0.632	0.005	0.684	0.017	0.015	0.684	0.164	0.069	/	0.069
Minimum living allowance at present				Land compensation and support fund at present			Residence type in the past			Residence type at present		
Group	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2	B1-A	B2-A	B1-B2
MD	−0.230	0.027	−0.257	−0.849	−1.909	1.060	−0.162	0.121	−0.283	−0.058	0.115	−0.173
Sig	0.016	0.954	0.007	0.000	0.000	0.000	0.026	0.432	0.008	0.783	0.317	0.050

79.4.2.2 Income Sources

Table 79.3 shows that differences took place on responsibility land income, responsibility forest income, animal husbandry income, fishing income, dividend shared income, minimum living allowance, and land compensation and fund while other source of income remain stable. However, these differences cannot be seen attributed to this project. For example animal husbandry income, whether in the past or present, the differences between Group B1 and Group A always exist, in fact animal husbandry is not influenced by this project. But for Group B1 fishing income is influenced by this project, while for Group B2 responsibility land, responsibility forest income and minimum living allowance are influenced by this project. Besides, this project caused some changes on land compensation and support fund for Group B1 and Group B2 (see Table 79.4).

79.4.3 Changes of Residence

79.4.3.1 Residence Types

Table 79.5 shows that bungalow gained popularity in the past, which had wide personal space; only a small proportion lived in 2–3-story buildings. But Table 79.3 shows that in the past, significant difference was observed among groups especially between group B1 and other two groups in the past (see Table 79.4). By contrast, the current percentage of bungalow declined dramatically, while 2–3 story building gain rise, making up 70.8, 59.0 and 83.7% from Groups A, B1 and B2 respectively. Besides, small proportion lived in multi-story residential building. Thus, it can be concluded that this project has impact on the residence type.

Table 79.5 The percentage of various residence type and residence area among group in the past and at present

Residence type							Residence area			
State	Past (%)			Present (%)						
Type	A	B1	B2	A	B1	B2		A	B1	B2
Bungalow	65.2	81.3	53.1	28.1	37.3	16.3	Past (m^2)	35.62	37.22	36.68
2–3-story building	34.8	18.7	46.9	70.8	59.0	83.7	Present (m^2)	57.01	55.89	48.87
Multi-residential	0.0	0.0	0.0	1.1	3.7	0.0	Net (%)	60.05	50.16	33.23

79.4.3.2 Residence Area

It can be seen from Table 79.5 that residents have more living spaces, with an increase of 60.05, 50.16, and 32.23% for Group A, Group B1 and Group B2 respectively. However, Table 79.3 indicates there is no significant difference among groups for both before and present. These evidences together supports that this project has not imposed impacts on residence area.

79.4.4 *Changes of Consumption*

79.4.4.1 Consumption Expenses

The results show that in the past, the majority of Groups A, B1, B2 remain under 500 RMB per month accounting for 71.5, 79.8 and 79.6% respectively. However, 78.1, 81.3 and 89.9% of these groups increased over 500 RMB per month after project (see Table 79.6). Given that differences between contrasting group and control group are not significant (see Table 79.3), it is inferred that this rise is not related to this project. Some respondent hold that the rise of consumption is owing to the rise of price and economic progress rather than this project.

79.4.4.2 Consumption Attitudes

As can be seen from Table 79.7 that over half respondents (51.6, 65.7 and 59.2%) indicated their status of low incoming, which is main consumption attitude in the past. However, this tendency went through changes and consumption attitude was more diversified. The percentage of low incoming dropped, while other consumption attitudes increased. However, Table 79.3 also shows that these changes on consumption do not result from this project. Therefore, it is inferred that this project have not causes changes towards consumption attitudes.

Table 79.6 The percentage of various consumption expense among group in the past and at present

Consumption expense	Past (%)			Present (%)		
	A	B1	B2	A	B1	B2
<200	35.2	44.0	34.7	3.3	3.7	0.0
200–500	36.3	35.8	44.9	18.7	14.9	10.2
500–1000	17.6	17.2	16.3	17.6	14.9	22.4
1000–2000	5.5	3.0	2.0	25.3	34.3	28.6
>2000	5.5	0.0%	2.0%	35.2	32.1	38.8

Table 79.7 The percentage of various consumption attitudes among group in the past and at present

Consumption attitudes	Past (%)			Present (%)		
	A	B1	B2	A	B1	B2
Income is not high and live frugally	51.6	65.7	59.2	30.8	38.1	38.8
Saving money for the children's education and healthcare	27.5	22.4	14.3	38.5	33.6	18.4
Consuming only on necessary occasion	17.6	11.2	16.3	26.4	24.6	32.7
Timely consuming without deposit, as long as necessary	2.2	0.7	10.2	3.3	2.2	8.2
Borrowing money is also rational	1.1	0.0	0.0	1.1	1.5	2.0

79.4.5 Change of Social Welfare

Before the construction, the vast majority did not have social insurance. After project, the majority of the respondents indicated that they have rural endowment insurance, Groups B1, B2 and A constituting 57.3, 75.5, 79.8% respectively. Meanwhile 93.9, 98, 92.1% of Groups B1, B2 and A respondents choose rural corporate medical insurance. Other insurance are purchased by the small proportion like urban employees' medical insurance, commercial insurance. The comparison between Groups B2 and A show that this project has significantly positive effect on Group B2 in terms of purchasing rural cooperative medical insurance (see Table 79.8).

Table 79.8 The percentage of various social insurance among group in the past and at present and net impact

Social insurance	Past (%)			Present (%)			Net impact	
	A	B1	B2	A	B1	B2	B1-A	B2-A
Rural endowment insurance	3.4	1.5	0.0	79.8	57.3	75.5	n.s.	n.s.
Rural corporate medical insurance	13.5	13.0	6.1	92.1	93.9	98.0	n.s.	2.282*
Rural resident's minimum living security	0.0	0.8	0.0	2.2	8.4	6.1	n.s.	n.s.
The five Guarantees	0.0	0.0	0.0	0.0	0.0	0.0	nil	nil
Township workers' old-age insurance	1.1	0.8	0.0	6.7	3.8	2.0	n.s.	n.s.
Urban employees' medical insurance	0.0	0.8	0.0	5.6	2.3	4.1	n.s.	n.s.
Urban unemployment insurance	0.0	0.0	0.0	0.0	1.5	2.0	n.s.	n.s.
Urban resident's minimum living security	0.0	0.0	0.0	0.0	0.0	0.0	nil	nil
Commercial insurance	2.2	0.8	0.0	7.9	6.1	10.2	n.s.	n.s.
None	77.5	63.4	93.9	0.0	2.3	2.0	n.s.	n.s.

*Net impact to identify the difference between two groups

79.4.6 Overall Satisfaction

Table 79.9 shows that although this project brought about positive impacts, the living improving satisfaction of contrast groups is noticeably lower than that of the control group. Also, Table 79.9 shows that significant differences appeared among contrasting groups. Comparison results support that there is a dramatic difference between contrast groups and control group. Therefore, it could be concluded that this project has negative impact on the living improving satisfaction.

79.5 Discussion

This case study shows that the reservoir project has positive impact on residence conditions. In the past, the majority chose bungalow and Group B1 had a higher percentage than other two. Interview results show that Group B1 was located in a remote area and resettled in a region with better economic development. Meanwhile, they received monetary compensation, which is helpful to rebuild a house, thereby improving their housing condition. Some respondents attribute those changes to the settlement plan since local government provided immigrate two settlement options, namely self-building and concentrated building. The results also show that the project increased the possibility of accepting rural cooperative medical insurance. Local residents argued that sever disruption to their livelihood and incoming caused by the resettlement intensified their concerns on healthcare. The rural corporate medical insurance as an important guarantee lessened their concerns. Overall, improvement in residence type and increase in the rural cooperative medical insurance could make local people satisfied with their living.

However, noteworthy is that this project also brought about various negative impacts on local residents. These are increasing unemployment, decreasing income. Before the project, local resident raise themselves by working on agriculture and timer production such as tea, crops, wood and bamboo. However, this project disrupted this economic status as the project occupied lands, forests and villages and change the way local residents make their lives. This was compounded by the situation that no alternative approaches are available for them to make money. Immigrants face great challenges in looking for new jobs as they are traditionally famer without any professional skills. Besides, the majority had low education level

Table 79.9 The percentage of various overall satisfactory and multi-comparison among group

Overall satisfaction							
Group (%)	A	B1	B2	Sig at present		0.000	
Better	93.4	47.6	59.2	Group	B1-A	B2-A	B1-B2
Medium	4.4	26.2	18.4	MD	0.698	0.565	1.060
Worse	2.2	26.2	22.4	Sig	0.000	0.000	0.743

and was not in possession of any occupational skills. Therefore, the affected residents suffer from rising unemployment rate and decreasing income.

This study also provides highlighted information that resettlements and compensations plan bring about different impacts on local residents. For local residents who resettled within the region and receive once-off cash compensation, they have no access to income source and livelihood but only self-employed or unemployed. By contrast, those who resettled outside the region got land compensation and cash compensation and retain consistent income and livelihood, so that they more satisfied than the former.

79.6 Conclusion and Recommendations

This study aimed to explore how large construction projects impact local residents' living status and make suggestions for coping with local resistance. A reservoir project was examined in-depth. Embedded into the case, comparative group studies were adopted to surface the real impact of the reservoir project. The living status was operationalized as employment, income, consumption, residence condition, social welfare and overall satisfaction. Structured questionnaire was employed to collect data, complemented by face-to-face interviews and archive data.

The results show that this project brings about huge resettlement and displacement, which increased the unemployment rate, exploited agriculture land, houses and restrained consistent income source and other capital goods. So the local residents are dissatisfied with their life. However, positive impacts were also identifiable. Due to the cash compensation resulted from the resettlement, residents have the capability to rebuild their house and improve their residence conditions.

Although it has proved that fair compensation is effective tool to address contradictory, livelihood restoration is also indispensable. The World Bank in 2011 stated that displaced person should be assisted in their efforts to improve their livelihood and standard of living or at least to restore them, to pre-displacement levels (World Bank 2011). Cash compensation is not sufficient to ensure a guaranteed livelihood recovery. Lack of livelihood alternatives only can accelerate the resistance of communities displaced. Therefore, it is important to provide alternatives that could provide immigrants capacities to gain sustainable development. For those who are vulnerable to the interventions, government should provide opportunities to enhance their skill and knowledge in order to get employment again. Project developers must identify and provide vulnerable residents with sharing project-related employment. This could foster good relationship between developers and impacted communities.

Acknowledgements This research was supported by the National Science Foundation of China (71502032), the National Social Science foundation, China (12BJY021), and the Priority Academic Program Development of Jiangsu Higher Education Institutions.

References

Burdge Rabel J (2003) The practice of social impact assessment background. Impact Assess Proj Apprais 21(2):84–88

Égré D, Senécal P (2003) Social impact assessments of large dams throughout the world: lessons learned over two decades. Impact Assess Proj Apprais 21(3):215–224

Huang Y, Ning Y, Zhang T, Fei Y (2015) Public acceptance of waste incineration power plants in China: comparative case studies. Habitat Int 47:11–19

Jackson S, Sleigh A (2000) Resettlement for China's three gorges dam: socio-economic impact and institutional tensions. Communist Post-Communist Stud 33(2):223–241

Klausen AM (1964) Technical assistance and social conflict: a case study from the Indo-Norwegian fishing project in Kerala, South India. J Peace Res 1(4):5–18

Li J, Station PD (2016) Ethical review of PX project's "NIMBY" events in China. J Eng Stud 8 (1):63–72

Mathur HM (2011) Social impact assessment a tool for planning better resettlement. Soc Change 41(1):97–120

McCombes L, Vanclay F, Evers Y (2015) Putting social impact assessment to the test as a method for implementing responsible tourism practice. Environ Impact Assess Rev 55:156–168

Obitani H (2002) Social conflict and its transformation in a dam construction project: focusing on social movement/networks and beneficiary–victim relationships. JSR 53:52–68

Phadke R (2005) People's science in action: the politics of protest and knowledge brokering in India. Soc Nat Resour 18(4):363–375

Samanta D (2015) Social impact assessment of projects involving land acquisition in India: implications of RFCTLARR Act, 2013. J Manag Public Policy 7(1):27

Scudder T (1997) Social impacts of large dam projects. In: Large dams: learning from the past, looking at the future. Gland, IU CN and World Bank, Washington, DC

Tilt B, Braun Y, He D (2009) Social impacts of large dam projects: a comparison of international case studies and implications for best practice. J Environ Manage 90:S249–S257

Wolsink M (2000) Wind power and the NIMBY-myth: institutional capacity and the limited significance of public support. Renew Energy 21(1):49–64

World Bank (2011) Compulsory land acquisition and voluntary land conversion in Vietnam: the conceptual approach, land valuation and grievance redress mechanism. World Bank, Washington, DC

Yi H, Zhijie Zhao (2013) Effects and drawbacks of environmental impact assessment in avoiding NIMBY. Beijing Daxue Xuebao Ziran Kexue Ban/acta Scientiarum Naturalium Universitatis Pekinensis 49(6):1056–1064

Zhou L, Peng X, Guan E, Zhang Y, Huang S (2012) Public NIMBY attitude survey and WTA estimate of waste incineration facility. Ecol Econ 261:174–177

Chapter 80
Improving Construction Safety Performance Through Error Management: A Literature Review

Minh Tri Trinh and Yingbin Feng

80.1 Introduction

Construction is one of the most hazardous occupations worldwide (Brunette 2004). In fact, construction industry comprised about 7% of the workforce in the world, but contributes to 30–40% fatalities (Sunindijo and Zou 2012).

Generally, construction accidents occur as a result of a random combination of many contributing factors (Chan et al. 2005). These factors are early classified into two main groups including unsafe condition and unsafe behaviour (Heinrich 1959). Based on the classification given above, over the past few decades, there have been considerable studies exploring different approaches to remove unsafe acts and unsafe conditions. So far, the prevention approach has been regarded as a key strategy to prevent accidents and injuries on construction sites that highlight two main ideas: (1) risk management, design legislations and policies to prevent unsafe conditions; and (2) training, safety awareness and behaviour based safety (BBS) to prevent unsafe behaviours (Mitropoulos et al. 2005).

Particularly, the prevention approach focuses on identifying and defining all possible unsafe conditions that may lead to accidents and then develop procedures to avoid or prevent them (Reason 1997). Additionally, a logical nature link between attitudes, intentions and behaviours in human enable organisations to institute norms, rules and procedures for construction safety. Construction organisations traditionally bring a focus on training to motivate and reinforce safe behaviours in the workplace. Therefore, advocates of prevention approach argue that if employees had followed safety procedures, accidents could have been prevented.

M.T. Trinh (✉) · Y. Feng
School of Computing, Engineering and Mathematics, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia
e-mail: trimitri0605@gmail.com

Y. Feng
e-mail: y.feng@westernsydney.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_80

Today, despite continuing efforts of researchers and practitioners, the reality is that accidents and injuries in construction workplace still happen. This reality has been traced back to the limitations in current prevention approach and imperfections in human ability.

More specifically, these limitations refer to the challenges in risk management including risk identification, risk assessment, risk reduction and risk mitigation. The dynamic and inconsistent nature of construction process discourages the safe management programs to address, evaluate and control all types of situational hazards (Mitropoulos et al. 2005). Safety procedures are designed to guide for work as it relates to the current working environment. However, resources in construction workplace such as working conditions, technologies and human resources intentionally or unintentionally fluctuate frequently. Clearly, over time, the divergence between real work activities and designed safety procedures programs for them can be broaden.

In addition, the imperfections in human ability refer to unintentional errors. In the daily life, errors occur at any moment and in any place as people talk and carry out their daily activities. In construction workplace, difficult work tasks or stressors (such as production pressure and time pressure) demand concentration, which is limited human resource (Hockey and Earle 2006). Besides, most of products in construction industry are carried through proceeding projects (Behm 2005). This means that the majority of the workforce is highly transient, with regular movement between construction companies, projects, and work sites (Biggs et al. 2013). There are differences in norms, procedures and rules between various construction projects and companies. Hence, construction workers may unintentionally lose their compliance as they encounter with enormous safety rules and procedures.

Considering that construction industry is labour-intensive and workers are always involved in the procedure of production, it is widely believed that construction safety research and management should keep their focus on human aspect to promote further safety improvement (Sunindijo and Zou 2012). Additionally, since errors cannot be completely eliminated by prevention approach (Rasmussen 1997; Reason et al. 1990; Zhao and Olivera 2006), it is necessary to ask the question of what can be done after an error has happened (Frese 1991, 1995). To bridge this gap, the construction safety needs to be provided with the new approach, which is implemented to respond to the errors and its consequences after errors has occurred.

This paper is aimed at presenting a literature review of research on; firstly, the definitions of errors and the related concepts such as unsafe behaviors, violations, failure, incidents, accidents in the construction environment; secondly, the error management approach in construction safety, identify knowledge gaps, and suggest recommendations for future research.

80.2 Unsafe Behaviour in Construction Safety

Over a few decades, researchers have put effort on identifying factors that contribute to accidents, and introducing accident causation models and human errors theories. One of the most important models that has been widely used and accepted is the Latent Failure Model (aka "Swiss Cheese") first developed by Reason (1990).

According to this model, organisations try to prevent accidents by defences (slides of "cheese") in order to not allow the hazards become loss. The "holes" in the "cheese" mean that none of these defences are perfect. Thus, when these "holes" line up, accidents happen. In contrast, in case that the line-up of "holes" is stopped by one of these defences, accidents are prevented, namely incidents. Reason also used the term failure to refer to the imperfections in each defence. Accordingly, the active and latent failures are distinguished. Latent failure refers to failures in a system that produce a negative effect but whose consequences are not revealed or activated until some other enable condition is met (Woods 2010). Reason (1993) proposed that latent failures can include organisational deficiencies, inadequate communications, poor planning and scheduling, inadequate control and monitoring, design failures, unsuitable materials, poor procedures, deficient training, and inadequate maintenance management. Additionally, active failures are unsafe acts of workers whose negative consequences are easily noticed.

Unsafe behaviour is defined as an inappropriate or undesirable human decision or behaviour that reduces, or has the potential for reducing, effectiveness, safety or system performance (Sanders and McCormick 1998). It is believed that categorising unsafe behaviours will help to explain the origin of them within the context and provide the measures to prevent them (Woods 2010). The classification proposed by Rasmussen (1983), Reason et al. (1990), and Health and Safety Executive (2009) is illustrated in Fig. 80.1.

According to Fig. 80.1, there are two types of human failures or unsafe behaviours including unintentional errors and violations.

Unintentional error: an action or a decision which was not intended, involved a deviation from an accepted standard.

Skill-based errors tend to occur in very familiar activities that operators can carry out without much need for conscious attention. *Slips* are failures that can be described as implemented actions that were not planned, whereas *lapses* causes operators to forget to carry out actions, to lose the workplace in a task or even to forget what they had intended to do.

Mistakes are regarded as actions that are incorrect but thought to be correct by the operator carrying them out. In a *rule-based mistake*, operator chooses the incorrect solution to familiar situations due to incorrect rules. In addition, *knowledge-based mistakes* are associated with limitations in human resources and/or incorrect knowledge of the tasks.

Violation: a deliberate deviation from rules, procedures, instructions and regulations.

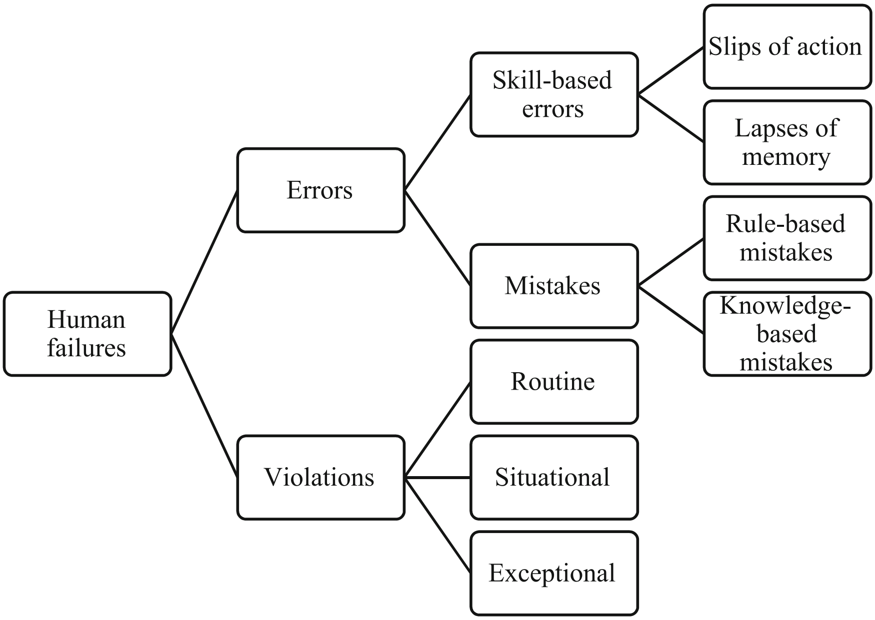


Fig. 80.1 Type of human failure (Health and Safety Executive 2009)

Routine violations refer to situations where it has become custom and practice for employees to carry out work activities in ways that are different from those defined in the organisation's operating procedures and guidelines.
Situational violations refer to situations where procedures and guidelines are disregarded due to working conditions such as time pressure, insufficient staff for workload, unavailable equipment, and weather conditions.
Exceptional violations are uncommon and occur when something unusual has happened in a process such as during an emergency.

80.3 Error Management Approach

As discussed above, unintentional errors and violations are both deviations from rules, procedures, instructions and regulations. Violations are organizationally caused and guided by conscious intentions that can be changed, so they are more easily prevented (Frese and Keith 2015). However, not every unsafe behaviour can be prevented by training and motivating. Due to the imperfection of psychological capabilities, employees may not quite remember and understand all requirements in the large number of policies and safe work procedures on construction. In addition, many accidents reported that employee who has many years of experience at performing a task can also make unexplained errors (Cañas et al. 2003). Thus, many scholars assume that human errors are inevitable in workplace environment (Fedota and Parasuraman 2010).

Unsafe behaviours at work have bad reputation. In construction safety, the negative consequences of errors such as injuries, accidents and damages may be more easily to recognise than the positive outcomes (Reason et al. 1990). In many circumstances, reporting errors is discouraged and those who committing errors are often punished. As a result, employees tend to feel guilty, fear that others will consider them non-compliant and hide their errors rather than report and discuss openly about their mistakes. Nonetheless, unintentional errors may but not necessarily result in negative outcomes such as s injuries, stress, and feelings of embarrassment and incompetence (Cannon and Edmondson 2001; Van Dyck et al. 2005). Therefore, it is necessary for organizations to rely not only on eliminate unsafety behaviours but also enable employees and organisations to discuss and share experience about errors, and learn about errors.

The concept of error management is proposed by Frese (1991). In Frese (1991)'s study, errors and their consequences were discriminated. Error management was regarded as the supplemented strategy to prevention approach. Whereas the prevention of human errors attempts to avoid errors and prevent errors from happening, error management aims to lessen the negative consequences of errors and promote the positive follow-ups (Frese 1991, 1995; Keith and Frese 2005, 2008).

Error management provides a workplace environment where employees are able to detect errors quickly, report errors, tackle and minimize the negative consequences of errors, and learn from errors to reduce future errors (Brown et al. 1996; Frese 1991, 1995). The organisations practising error management are engaged in exploring how errors occur and discovering the strategies to reduce the likelihood of errors in the future (Guchait et al. 2012). By focus on the positive consequences of errors (e.g., learning), Van Dyck et al. (2005) proposed four dimensions of error management practice including learning from errors, thinking about errors, error competence and error communication.

Applying the idea of error management to the organisational level, Van Dyck (2000) introduced the concept of error management culture. The idea is that members of an organisation may share a system of norms and values as well as common practices and procedures (House et al. 2004) that refer to error management (Van Dyck et al. 2005). Employees at all levels of the organisation are appealed to have proactive behaviours such as helping others to resolve errors, communicate openly about errors and learn from errors (Casey and Krauss 2013).

To date, error management and error management culture have been shown to be associated with favourable organisational outcomes such as performance, innovativeness and safety (Keith and Frese 2011). Hofmann and Mark (2006) early perceived error management as one of significant factors of safety climate in nursing sectors. Their findings indicated that a positive safety climate, which involved error management, was considerably related to fewer back injuries and medication errors, and increased patient satisfaction, perceptions of nurse responsiveness, and higher levels of nurse job satisfaction. In construction safety context, Cigularov et al.

(2010) is the first empirical study examining the effects of error management in predicting safety performance and outcomes. Their results showed that error management and safety communication are important predictors of safety behaviours and work-related pain. Krauss and Casey (2014) also define error management climate as “employee’s perception of the extent to which the organization encourages communication about and management of errors and mistakes in the workplace”. They later investigated the relationship between error management climate and other safety concept such as safety communication, safety climate, and safety performance in an international oil and gas company. In firefighting context, the results of Fruhen and Keith (2014) indicate that there is a significant relationship between error management culture and accident occurrence in low and high risk situations. In contrast, error aversion culture which is described as being afraid of committing errors, reacting errors with negative emotion, and likely to cover up errors instead of communicating them to others (Voitker et al. 1999) was found to be positive related to both situations (Fruhen and Keith 2014). These beginning findings of research on error management imply that it is essential to discuss about errors, mistakes of employees and safety incident in complexity workplaces environment (Paul and Maiti 2007). They also raise the questions of what factors impact on error management and how to develop error management culture in the workplace.

In an initial effort to answer the questions above, Van Dyck et al. (2014) found that the relationship between leaders’ espoused priority of safety and error management was mediated by the degree of reporting about incidents in health care organisations. The intentions to report about errors are also found in the significant relationship with perceived control over errors in nursing context. In other study, Casey and Krauss (2013) investigated the relationships between error management practice, safety communication, safety behaviours, and safety incidents in mining context. Their results showed that error management practice predicts both supervisor and co-worker safety support; safety supervisor support predicts safety communication; error management practice and safety communication between team predict safety behaviours; and safety behaviors predict safety incidents.

80.4 Conclusion

In conclusion, this review pointed out the limitation of the prevention approach in preventing unsafe behaviours and accidents. Based on the existing knowledge on construction safety, there is evidence that human errors of construction workers are unavoidable and has been neglected in construction safety.

Accordingly, to deal with human errors, error management approach is increasingly proposed as a promising measure to improve safety performance in different areas, particularly construction industry. However, despite a lot of effort put on this approach, research on error management is still at starting point. The big question found is about the mechanism by which error management culture influences safety behaviours of workers and safety outcomes in construction workplace. Furthermore, it is not clear that how to implement error management culture in construction safety.

With the aim of getting closer to the vision of “zero accidents/injuries” in construction workplaces, we propose the need to provide the construction organisations with error management culture that could alter the likelihood and impact of unintentional errors of workers in construction safety. Moreover, there is a need to develop a model of error management culture, identifies its dimensions and provides the evidence of its impact on safety behaviours of workers and safety performance. Construction organisations can utilised it as the basis for implementing further principles and strategies of safety management programs.

References

Behm M (2005) Linking construction fatalities to the design for construction safety concept. Saf Sci 43(8):589–611

Biggs SE, Banks TD, Davey JD, Freeman JE (2013) ‘Safety leaders’ perceptions of safety culture in a large Australasian construction organisation. Saf Sci 52:3–12

Brown SW, Cowles DL, Tuten TL (1996) Service recovery: its value and limitations as a retail strategy. Int J Serv Ind Manage 7(5):32–46

Brunette MJ (2004) Construction safety research in the United States: targeting the Hispanic workforce. Inj Prev 10(4):244–248

Cañas JJ, Quesada JF, Antolí A, Fajardo I (2003) Cognitive flexibility and adaptability to environmental changes in dynamic complex problem-solving tasks. Ergonomics 46(5):482–501

Cannon MD, Edmondson AC (2001) Confronting failure: antecedents and consequences of shared beliefs about failure in organizational work groups. J Organ Behav 22(2):161–177

Casey TW, Krauss AD (2013) The role of effective error management practices in increasing miners’ safety performance. Saf Sci 60:131–141

Chan AP, Wong FK, Yam M, Chan D, Ng J, Tam C (2005) From attitude to culture: effect of safety climate on construction safety. Hong Kong Polytechnic University

Cigularov KP, Chen PY, Rosecrance J (2010) The effects of error management climate and safety communication on safety: a multi-level study. Accid Anal Prev 42(5):1498–1506

Van Dyck C (2000) Putting errors to good use: error management culture in organizations

Fedota JR, Parasuraman R (2010) Neuroergonomics and human error. Theor Issues Ergon Sci 11 (5):402–421

Frese (1991) Error management or error prevention: two strategies to deal with errors in software design. Universitätsbibliothek

Frese (1995) Error management in training: conceptual and empirical results. In: Organizational learning and technological change, Springer, pp 112–124

Frese M, Keith N (2015) Action errors, error management, and learning in organizations. Ann Rev Psychol 66:661–687

Fruhen LS, Keith N (2014) Team cohesion and error culture in risky work environments. Saf Sci 65:20–27

Guchait P, Kim MG, Namasivayam K (2012) Error management at different organizational levels—frontline, manager, and company. Int J Hosp Manage 31(1):12–22

Health and Safety Executive (2009) Reducing error and influencing behaviour. HSE Books

Heinrich H (1959) Industrial accident prevention. A scientific approach, 4th edn. McGraw Hill, New York

Hockey GRJ, Earle F (2006) Control over the scheduling of simulated office work reduces the impact of workload on mental fatigue and task performance. J Exp Psychol Appl 12(1):50

Hofmann DA, Mark B (2006) An investigation of the relationship between safety climate and medication errors as well as other nurse and patient outcomes. Pers Psychol 69:847–869

House RJ, Hanges PJ, Javidan M, Dorfman PW, Gupta V (2004) Culture, leadership, and organizations: the GLOBE study of 62 societies. Sage Publications, Thousand Oaks

Keith N, Frese M (2005) Self-regulation in error management training: emotion control and metacognition as mediators of performance effects. J Appl Psychol 90(4):677

Keith N, Frese M (2008) Effectiveness of error management training: a meta-analysis. J Appl Psychol 93(1):59

Keith N, Frese M (2011) Enhancing firm performance and innovativeness through error management culture. In: Handbook of organizational culture and climate, vol 9, pp 137–157

Krauss AD, Casey T (2014) Error management climate as a way to align safety objectives with operational excellence. In: SPE international conference on health, safety, and environment

Mitropoulos P, Abdelhamid TS, Howell GA (2005) Systems model of construction accident causation. J Constr Eng Manage 131(7):816–825

Paul P, Maiti J (2007) The role of behavioral factors on safety management in underground mines. Saf Sci 45(4):449–471

Rasmussen J (1983) Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. IEEE Trans Syst Man and Cybern 3:257–266

Rasmussen J (1997) Risk management in a dynamic society: a modelling problem. Saf Sci 27 (2):183–213

Reason (1990) Human error. Cambridge University Press.

Reason J (1993) The identification of latent organizational failures in complex systems. In: Verification and validation of complex systems: human factors issues, Springer, pp 223–237

Reason J (1997) Managing the risks of organizational accidents, vol 6. Ashgate Aldershot

Reason J, Manstead A, Stradling S, Baxter J, Campbell K (1990) Errors and violations on the roads: a real distinction? Ergonomics 33(10–11):1315–1332

Sanders MS, McCormick EJ (1998) Human factors in engineering and design, vol 25. Emerald Group Publishing Limited

Sunindijo RY, Zou PXW (2012) Political skill for developing construction safety climate. J Constr Eng Manage 138(5):605–612

Van Dyck C, Frese M, Baer M, Sonnentag S (2005) Organizational error management culture and its impact on performance: a two-study replication. J Appl Psychol 90(6):1228–1240

Van Dyck C, Dimitrova NG, de Korne DF, Hiddema F (2014) Walk the talk: leaders enacted priority of safety, incident reporting, and error management. In: Leading in health care organizations: improving safety, satisfaction and financial performance, vol 14, pp 95–117

Voitker R, Harry G, Frese M, Batinic B (1999) Error orientation questionnaire (EOQ): reliability, validity, and different language equivalence

Woods DD (2010) Behind human error. Ashgate Publishing, Ltd.

Zhao B, Olivera F (2006) Error reporting in organizations. Acad Manage Rev 31(4):1012–1030

Chapter 81
Improving Mentoring Relationships of Construction Management Professionals

A.E. Oke, C.O. Aigbavboa and M.M. Mutshaeni

81.1 Introduction

Mentoring is an important step in career development and in-service training can be used as the perfect platform for effective mentoring to take place. Rad and James (2007) stressed that mentoring should be a common phenomenon, and it should continuously be to ensure that senior and experienced workers pass their knowledge and experiences to junior ones. Nkomo and Thwala (2014) stated that not having mentors and/or mentees is a major hindrance to progress, which is why mentoring is of vital importance in all industries including construction.

According to Hoffmeister et al. (2011), the built environment/construction industry is quite complex and congested and this distinguished it from other industries. The fact that this industry is quite multifaceted and crowded necessitate the need for effective mentoring for sustaining of practice. Higher institutions require students to go through in-service training before graduation and this should serve as a platform for senior and experienced employees to mentor them. However, most senior employees miss this point by allotting and apportioning jobs and works instead of the actual mentoring. The study therefore investigates ways of enhancing mentoring and mentoring relationships in the construction industry for better performance of new professionals.

A.E. Oke (✉) · C.O. Aigbavboa · M.M. Mutshaeni
Department of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
e-mail: emayok@gmail.com

C.O. Aigbavboa
e-mail: caigbavboa@uj.ac.za

M.M. Mutshaeni
e-mail: mutshaenimadid@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_81

81.2 Requirements for Effective Mentoring

Mentoring has been known to assist in career development, however, effective mentoring can also aid personal development of both mentor and mentee. Having an effective mentor has been known to increase self-confidence, increase self-esteem and increased job satisfaction (Amelink 2010). It can be said that in order for effective mentoring to take place, healthy mentoring relationships need to be established. However, According to Pinho et al. (2005), a mentee may develop negative attitude towards a mentor when a mentor overworks the mentee on a task and takes credit for the accomplishments. This can also happen when mentor spends more time impressing top management and promotes self than necessary.

81.2.1 Characteristics of a Good Mentor

According to Mostafavi et al. (2013), a mentor is a senior and knowledgeable employee/employer who has been in a certain industry (construction in this case) for a long time, thus having more experience. The mentor should be a mentee's role model and should help with the mentee's career and personal development (Rogers 2008). Kerry and Mayes (2014) concluded that all definitions of a mentor should include five basic components, namely: nurturing; functioning; role modelling; focusing on the progress of the mentee; and sustaining a caring relationship over time.

In agreement to this definition, Nkomo and Thwala (2014) added that a mentor should not only focus on career development. The mentor should provide career development opportunities such as assigning tasks that will challenge the mentee, guiding the mentee accordingly, providing sponsoring advancement and assisting the mentee on their perception of the industry. More so, issues relating to social development of the mentee should a concern of the mentor. However, mentoring has been associated with salary increase, promotions, higher job satisfaction, self-respect, recognition and higher organizational commitment (Starr-Glass 2014). The above listed findings have brought rise to the need to identify characteristics that an individual should possess in order to be labeled as a good, effective and effective mentor.

81.2.2 Attributes of a Good Mentee

Mostafavi et al. (2013) viewed a mentee as a less experienced and knowledgeable person hoping to learn and develop socially, personally and professionally, with the help, guidance and support of an effective mentor. It is possible for the mentee to approach and initiate a mentoring relationship but it takes admiration and respect for one to select a possible mentor. However, it is still a mentor's duty to find a mentee who will be ready and willing to work with him/her (Rad and James 2007). It is therefore important to understand basic characteristics required of a mentee for effective mentoring relationship.

Stone (2007) listed the characteristics of an excellent mentee to include demonstration of intelligence and showing initiative to learn and make progress; loyalty to organization; commitment to values; sharing a desire to achieve goals and results with mentor; enjoying challenges; be willing to accept more greater and challenging responsibilities; taking responsibility for personal development and growth; and welcoming mentor's help in identifying lacking areas.

81.3 Methodology

Survey design was adopted for this study because of the nature of variables to be examined, category of data to be collected and character of respondents involved. Using existing literature as the basis for obtaining factors relating to characteristics required of mentor and mentee in a mentoring relationship, quantitative research approach was employed for data collection. Self-designed questionnaires were adopted as research instruments and they were administered on construction professionals practicing in Gauteng region, South Africa. These professionals are architects, quantity surveyors, engineers, construction managers and construction project managers.

In designing the instrument, close-ended questions were adopted and it was ensured that negative, irrelevant, bias and long questions were avoided. First section of the instrument was used to collect biographical information of respondents while the second part related directly with the objective of the study. 5-point Likert scale was employed where 1 = Strongly Disagree (SD); 2 = Disagree (D); 3 = Neutral (N); 4 = Agree (A); and 5 = Strongly Agree (SA). Mean Item (MIS) and Standard Deviation (SD) were computed from the scale and the results were used to assess order of importance of the identified factors.

Using Cronbach's alpha value, reliability test conducted on the three sections in the second part of the instrument, that is: expected attributes from mentee; required virtues of mentors; and factors causing failure of mentoring relationship, indicate values of 0.877, 0.955 and 0.910 respectively. From the assertion of Santos (1999) that 0.7 is an acceptable reliability coefficient, it could be concluded that the instrument adopted for the study is reliable.

81.4 Analysis

45 questionnaires were distributed, 38 were retrieved while 34 adequately completed and found suitable for further analysis. There are 55.9 and 44.1% of male and female respondents respectively indicating adequate representation of the major two gender. Age group of these professionals revealed that 64.7% are between 20 and 25, 29.4% between 26 and 30 while 5.9% are 31 years and older. Considering respondents' year of experience and practice in the construction industry, both groups of mentees and mentors were captured. About 55.3, 23.7, 13.3 and 7.8% have 1–10, 11–20, 21–30 and above 30 years experience respectively. Respondents are also spread across various professions in the industry, these include architecture, engineering, construction management, quantity surveying and construction project management. Of these, 62.1% are junior while 35.9% are senior employees and they have been involved in about 11 projects on the average.

81.4.1 Characteristics Expected of Mentees

The most important attributes that should be possessed by young construction professionals are indicated in Table 81.1. These include willingness to learn; enthusiastic; respectful; motivated and good listeners. Others are energetic; willingness to assist; honesty; communicative; knowledgeable; innovative; and serving heart. The least required factors are multi-tasking and time-efficient.

Table 81.1 Traits required of mentees

Variables	Mean item score	Standard deviation	Rank
Willingness to learn	4.79	0.41	1
Enthusiastic	4.65	0.49	2
Respectful	4.65	0.60	3
Motivated	4.65	0.73	4
Energetic	4.56	0.66	5
Good listener	4.44	0.71	6
Willingness to assist	4.44	0.82	7
Honest	4.38	0.95	8
Communicative	4.35	0.65	9
Knowledgeable	4.26	0.71	10
Innovative	4.26	0.83	11
Serving heart	4.21	0.88	12
Multi-tasking	4.18	0.80	13
Time efficient	4.09	1.11	14

81.4.2 Attributes Required from Mentors

As indicated in Table 81.2, experienced members of the construction industry are expected to be resourceful; encourages communication; knowledgeable; good positive attitude; shared past experience; and honest. They are also require to be energetic; sets a good example; enthusiastic; motivator; encourages new ideas; ability to multi-task; encourages learning and growth; always willing to assist; resourceful; provides guidance; supportive; share knowledge; open to new ideas; and acts as a positive role model. At the lower end are ability to listen, provide constructive feedback; and punctual at meetings.

81.4.3 Failure of Mentoring Relationships

As displayed in Table 81.3, mentoring relationships in the construction industry fails majorly due to company's top management lacked expressed interest; mentor

Table 81.2 Virtues expected of mentors

Variables	Mean item score	Standard deviation	Rank
Respectful	4.32	0.81	1
Encourages communication	4.29	0.63	2
Knowledgeable	4.29	0.68	3
Good positive attitude	4.24	0.74	4
Shared past experiences	4.24	0.78	5
Honest	4.24	0.78	5
Energetic	4.21	0.77	7
Sets a good example	4.21	0.77	7
Enthusiastic	4.18	0.80	9
Motivator	4.18	0.83	10
Encourages new ideas	4.18	0.87	11
Ability to multi-task	4.18	0.87	11
Encourages learning and growth	4.15	0.66	13
Always willing to help	4.15	0.78	14
Resourceful	4.12	0.69	15
Provides guidance	4.12	0.77	16
Supportive	4.12	0.81	17
Shared knowledge	4.09	0.83	18
Open to new ideas	4.09	0.93	19
Acts as a positive role model	4.09	0.99	20
Provides constructive feedback	4.03	0.80	21
Good listener	3.88	1.04	22
Punctual	3.32	0.95	23

Table 81.3 Why mentoring relationships fail

Factors	Mean item score	Standard deviation	Rank
The company's top management lacked expressed interest	2.84	1.34	1
Mentor became manager instead of mentor	2.71	1.32	2
Conversations never focused on personal beliefs & values	2.58	1.06	3
Constant cancellation of meetings	2.55	1.09	4
Mentoring relationship not planned thoroughly	2.55	1.41	5
Lack of review of mentee progress	2.48	1.24	6
The company did not support our mentoring relationship	2.45	1.26	7
Our mentoring relationship did not have clear goals	2.42	1.15	8
Mentor dictating instead of communicating	2.39	1.23	9
Enthusiasm faded	2.35	1.11	10
No constant engagement between mentee and mentor	2.35	1.11	10

becoming manager instead; conversations not focused on personal beliefs and values and constant cancellation of meetings. In some cases, mentoring relationship was not planned thoroughly, review of mentee progress was not carried out, mentoring relationship not having clear goals and mentors dictating instead of communicating with their mentees. Other identified factors are faded Enthusiasm and lack of constant engagement between mentee and mentor.

81.4.4 Discussion of Findings

Findings on basic attributes expected of a young graduate for effective mentoring were similar to the findings by Stone (2007). It was stated that a mentee should demonstrate intelligence, show initiative, be willing to learn, be enthusiastic, be loyal to the organization and respectful. However, Rad and James (2007) stated that it is mentor's duty to find a mentee who will be willing to work with him/her. Concerning reasons for failure of mentoring relationships, Starr-Glass (2014) agreed with the results of this study. It was stated that mentoring relationships are most likely to fail if company's top managers lacks interest in the mentoring relationship and if a mentoring relationship does not have clear goals. Nkomo and Thwala (2014) also concluded that a mentoring relationship lacking communication is more likely to fail.

81.5 Conclusion

For effective mentoring, young professional should be willing to learn and assist, enthusiastic, respectful, motivated, energetic, good listener, honest, communicative and knowledgeable. More so, the most dominant characteristics of effective construction industry mentors are that a good mentor should have good positive attitude, ability to multi-task and sets good example. It also require that such should be respectful, encourages communication, knowledgeable, sharing past experience, honest, energetic, enthusiastic and motivated. In addressing the failure of mentoring relationships, the following should be avoided: constant cancellation of meetings, inadequate planning, not doing a review on progress, company not supporting the mentoring relationship, mentoring relationship lacking clear goals as well as mentor dictating instead of communicating effectively. It is also necessary for company's top management to develop interest in mentoring, mentor should remain a mentor than becoming a manager and conversations should focus on personal beliefs and values.

References

Amelink CT (2010) Overview: mentoring and women in engineering. In: Olio: research on women in science and engineering. Retrieved 22 July 2016 from http://www.AWEonline.org

Hoffmeister K, Cigularov KP, Sampson J, Rosecrance JC, Chen PY (2011) A perspective on effective mentoring in the construction industry. Leadersh Organ Dev J 32(7):673–688

Kerry T, Mayes AS (2014) Issues in mentoring. Routledge, USA

Mostafavi A, Huff JL, Abraham DM, Oakes WC, Zoltowski CB (2013) Integrating service, learning, and professional practice: toward the vision for civil engineering in 2025. J Prof Issues Eng Educ Pract 143(2):70–92

Nkomo M, Thwala W (2014) Assessment of mentoring of construction workers in the South African construction industry: a literature review. In: Proceeding of international conference on education, law and humanities, Johannesburg, South Africa, pp 131–135 Nov 27–18

Pinho SD, Coetzee M, Schreuder D (2005) Formal mentoring: mentee and mentor expectations and perceived challenges. S Afr J Human Resour Manage 3(3):20–26

Rad F, James A (2007) Learning from the past experiences of practicing engineers. Forensic Eng (2006) ASCE 12–21

Rogers M (2008) Coaching, counseling, and mentoring: how to choose and use the right technique to boost employee performance. Career Plann Adult Dev J 24(1):247–253

Santos JRA (1999) Cronbach's alpha: a tool for assessing the reliability of scales. J Ext 37(2):1–5

Starr-Glass D (2014) Three degrees of separation: strategies for mentoring distanced transnational learners. Online tutor, pp 2176–2200

Stone P (2007) Opting out? Why women really quit careers and head home. University of California Press, USA

Chapter 82
Index Decomposition Analysis of Building Energy Consumption in Chongqing: 2000–2014

Xia Wang, Hong Ren, Weiguang Cai and Yan Liu

82.1 Introduction

Broadly speaking, building-related energy consumption refers to the energy consumption caused by building construction and operation in the period of the building lifecycle of 50–70 years, the energy consumption associated with building operation generally account for about 80% of the energy consumption for the whole building lifecycle (Zhou 2015). Therefore BEC which mentioned in this paper is in particular operation energy consumption. According to the internationally accepted classification, it covers energy services such as heating, lighting, air-conditioning, ventilation, cooking, domestic appliances in residential buildings, commercial buildings (office buildings, schools, hotels, shopping malls etc.), and rural buildings (Center 2016).

The building, industry and transportation are three major energy consuming sectors. the research of Tsinghua University Building Energy Conservation Research Center stated that BEC accounts for 27% of total energy consumption in China (Yang 2007). While building sector account for about 40% of the global energy consumption and contribute over 30% of the CO_2 emissions (Yang et al. 2014). With the accelerating urbanization and living standards in China, BEC is likely to continue at a rapid rate, which may lead to a serious pressure on energy conservation and emission reduction.

The building sector has the largest energy conservation and the largest carbon emission potential, which also has the lowest emission reduction cost. Nowadays,

X. Wang (✉) · H. Ren · W. Cai
School of Construction Management and Real Estate,
Chongqing University, Chongqing, China
e-mail: wangxia.@cqu.edu.cn

Y. Liu
Faculty of Civil Engineering and Geosciences,
Delft University of Technology, Delft, The Netherlands

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_82

both developed countries and developing countries are utilizing commercializing advanced technologies to reduce 30–80% of the new and existing buildings energy consumption, and also can generate revenue in the building life cycle (SBCI and U 2009). Intergovernmental Panel on Climate Change (IPCC) predicted that by 2030 the global building sector can reduce carbon emissions with an annual average growth of 6 billion tons (IPCC 2014), and it suggests that the building sector is the largest share and the largest emission potential.

Over the last decade, particularly since the establishment of Chongqing Territory in 1997, the economics of Chongqing has achieved a great development. Nowadays, Chongqing has become the most developed regions in the western China, which has brought much building energy consumption. At present, more and more households are becoming interested in using electricity appliances, that is to say, much energy is needed. Thus, studying the influence factors governing the change of building energy consumption in Chongqing may help policy makers to implement energy-saving planning.

The structure of this paper is planned as follows. The research literature review is presented in Sect. 82.2. The decomposition method and related data are introduced in Sect. 82.3. The main results are given and discussed in Sect. 82.4. Section 82.5 offers the conclusion and policy suggestion.

82.2 Literature Review

There are many models about drivers of energy consumption and CO_2 emissions, IPAT, Stochastic Impacts by regression on population, affluence, and technology (STIRPAT), index decomposition analyses (IDAs), input-output tables are in common use (York et al. 2003; Fan et al. 2006; Li et al. 2015; Wang et al. 2016; Wang 2016; Ang et al. 2004).

Ehrlich and Holden (1971) firstly used TPAT model to set up the formula for analyzing the effects of human activities on the environment, while Commoner were the first to apply the algebraic formula for BEC data analysis. To overcome this limitation, some scholars reformulated the stochastic model, named STIRPAT which is short for stochastic impacts by regression on population, affluence and technology (York et al. 2003). More and more scholars employed the STIRPAT model to analyze the effects of driving forces on a variety of environmental impacts.

Fan examined the impact factors of CO_2 emissions of countries at different income levels during 1975–2000 by using STIRPAT model, and the energy intensity decomposed into the impact of population, affluence and technology (Fan and Lei 2016). Ji used the STIRPAT model to assess the energy-saving effect of China's urbanization on the basis of provincial panel data (Ji 2015). Chu explored the two main policies "carbon tax" and "carbon trading" which is more suitable for Taiwan by using STIRPAT model (Chu et al. 2016). Xu represented a dynamic analysis of the key driving factors of PM2.5 emission in China through the STIRAP model (Xu et al. 2016). Li employed the STIRPAT model to prove that the rapid process of urbanization has the greatest impact on the increasing carbon emissions in Tianjin over the period 1996–2012 (Li et al. 2015). Liu and Chen selected 8 key factors of CO_2 emissions of China through the empirical data from 30 provinces during 2006–2010 (Liu 2016). Tan focused on the CO_2 emission reduction potential of Chongqing as well using LMDI decomposition method to identify the key factors and the STIRPAT model to incorporate (Tan et al. 2016).

There are several papers studying the driving factors of BEC. In this paper, we used the LMDI method to analyze the driving factors of BEC in the province level, taking Chongqing as an example.

82.3 Method and Data

82.3.1 Method

According to the different types of building, BEC can be decomposed as urban residential building energy consumption (UR-BEC) urban commercial building energy consumption (UC-BEC), rural building energy consumption (R-BEC). According to I = PAT model, the total-BEC is factored into the following expression:

$$\mathrm{E} = \sum\nolimits_i E_i = \sum\nolimits_i \boldsymbol{PU_iA_ie_i} \tag{82.3.1}$$

where E is the total annual BEC; E_i is the three categories: UR-BEC, UC-BEC, R-BEC, P is the total population; U_1 is the proportion of rural population; U_2 and U_3 are the same as the proportion of urban population; A1, A2, A3 are the urban residential building area per capita, urban commercial building area per capita, and rural building area per capita, respectively. e_1, e_2, e_3 are the urban residential energy consumption per unit area, urban commercial energy consumption per unit area and rural energy consumption per unit area.

Building energy efficiency (BEE) can be explained as the building energy efficiency per area, but it does not comprehensively reflect the effect of technology and policy on BEC, and it is also affected by the behaviors. For example, the improvement of residential living standards will lead to the increase of BEC per area. In other words, from the perspective of BEE, BEC per area cannot be directly comparable in different periods, and it should be excluded the effect of behaviors. So it is necessary to bring behavior effect factors into the model "I = PAT", and set up "I = PBAT". On the basis of the above analysis, we provide a new concept of residents' energy consumption index which is used to evaluate the impact of behavior factors on BEC. It is assumed that there is a positive correlation between residents' behavior and BEC per capital. The expression shows as follows:

$$B = kI \quad (82.3.2)$$

where B represents behaviors, k is the coefficient, I is an index of BEC per capital which means the changing trend and degree of BEC per capita in a different period.

And energy efficiency effect can be expressed as:

$$T = E_{eff}/B = E_{eff}/(kI) \quad (82.3.3)$$

where T is comparable BEC per area, E_{eff} is BEC per area. And finally total annual BEC is factored into the following expression:

$$E = \sum_i E_i = \sum_i PU_iA_iBT_i \quad (i = 1, 2, 3) \quad (82.3.4)$$

Applying LMDI in its additive form, the change in total- BEC between any years (O and T), Δ_{t0t} is decomposed as follows, respectively:

Additive form:

$$\begin{aligned} \Delta E_{TOT} &= E^T - E^O = \Delta E_P + \Delta E_U + \Delta E_A + \Delta E_B + \Delta E_T \\ &= \sum_i (E_i^T - E_i^O) \end{aligned} \quad (82.3.5)$$

$$\Delta EP = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln(P^T/P^O) \quad (82.3.6)$$

$$\Delta EU = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln(U_i^T/U_i^O) \quad (82.3.7)$$

$$\Delta EA = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln(A_i^T/A_i^O) \quad (82.3.8)$$

$$\Delta EB = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln(B^T/B^O) \quad (82.3.9)$$

$$\Delta ET = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln(Ti^T/Ti^O) \quad (82.3.10)$$

where E^T, E^O is total-BEC in year T and O respectively, ΔE_P, ΔE_U, ΔE_A, ΔE_B, ΔE_T are called population effect, urbanization effect, floor area effect, behavior effect, and building efficiency effect. In addition, B and T are related to k, but k is not the quantification. Actually, k is not the effect on B and T when they are decomposed.

$$\Delta E_B = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln\left(\frac{B^T}{B^O}\right) = \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln\left(\frac{kI^T}{kI^O}\right)$$
$$= \sum_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln\left(\frac{I^T}{I^O}\right) \tag{82.3.11}$$

$$\Delta E_T = \sum\nolimits_i \frac{E_i^T - E_i^O}{\ln E_i^T - \ln E_i^O} \ln\left(\frac{E_{eff,i}^T I^O}{E_{eff,i}^O I^T}\right) \tag{82.3.12}$$

where E_{eff} represents building energy consumption per area, i is the three categories, ΔE_B, ΔE_T are nothing to do with K.

82.3.2 Data Source

The building sector is actually an undefined energy sink due to the wide variety of causes (Lin and Liu 2015). Unfortunately, there is still no authoritative statistics on building energy end-use in China. The current widely used data is the sum of four sectors in the Chongqing Statistical yearbook (2001, 2015): (1) Transport, Storage and Post (2) Wholesale, Retail Trade and Hotel, Restaurants; (3) Others; (4) Consumption. Based on this method, we calculated building energy consumption in Chongqing's over the period 2000–2014 (see Fig. 82.1). The unit of BEC is Ttce (thousand Tons coal equivalent).

Annual data for population, urbanization rate, floor area have been collected from the Chongqing Statistical Yearbooks. The floor area is measured by million square meters. And the population is also measured by 10,000 people.

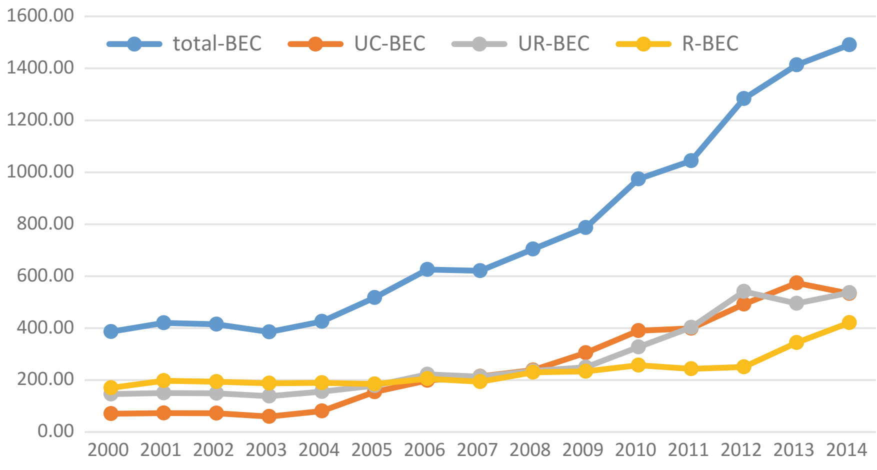


Fig. 82.1 BEC in Chongqing over 2000–2014

82.4 Results and Discussion

82.4.1 Current Building Energy Consumption in Chongqing

According to the above data and statistical method, we can learn from the calculation that the total BEC of Chongqing increased from 386.07 Ttce in 2000 to 1490.45 Ttce in 2014 (see Fig. 82.1), representing an annual growth rate of 11%, which also accounts for about 1.87% of the total BEC of China's building sector. The curve of BEC can be divided into two phases: a slow waved phase between 2000 and 2007 and a rapid growth phase from 2008 to 2014. During the period 2000–2014, the UC-BEC rapidly grew, it jumped from 70.42 Ttce in 2000 to 533.41 Ttce in 2014, with an annual growth rate of 17.8% (see Fig. 82.1). The rapid growth in UC-BEC in Chongqing may attribute to the following reasons. One is the rapid urbanization, which transfers rural labor to urban areas where industrial and service sectors predominate. The urbanization rate increased from 35% in 2000 to 59.6% in 2014 in Chongqing. Another reason is that with the development of residents' living standards, more and more electricity appliances are needed. According to Chongqing statistical Yearbook, the ownership of major durable consumer goods per 100 households kept on increasing over the time. The growth rate of air-conditioner ownership is fast over 2000–2014, owing to the hot weather in Chongqing. The UR-BEC and R-BEC also have a steady growth. The UR-BEC of Chongqing increased from 145.8 Ttce in 2000 to 536 Ttce in 2014, the R-BEC of Chongqing increased from 169.8 Tce in 2000 to 421 Tce in 2014, respectively (see Fig. 82.1).

As the rapid development of new urbanization construction process in Chongqing, the total BEC of Chongqing regions will still have a substantial increase in the next period of time. In particular, if there is no control and restraint from the governmental level or consumers' level, the operation of buildings may cause huge energy consumption and resources.

82.4.2 Decomposition Analysis of Building Energy Consumption in Chongqing

Based on the LMDI method given in Sect. 82.3, the decomposition results in BEC in Chongqing are demonstrated in which maybe owes to the rapid development of BEC technology. Another reason is the implementation of commercial BEE retrofit policies in Chongqing (Hou et al. 2016).

Table 82.1 and Fig. 82.2. The result illustrates that behavior effect (the development of residents' living standards) have had a positive impact of increasing BEC in Chongqing. The total change of BEC by the behavior effect is 1106.21 Ttce, which makes up for about 72% of the total change of BEC in the period.

Table 82.1 Decomposition of BEC in Chongqing (Ttce)

Influence factor	ΔE_p^t	ΔE_u^t	ΔE_A^t	ΔE_B^t	ΔE_T^t	ΔE_{TOT}^t
2000–2001	2.78	19.86	14.57	33.84	−14.56	56.49
2001–2002	2.13	27.01	16.90	−4.94	−16.90	24.20
2002–2003	1.66	19.56	20.16	−29.66	−20.17	−8.46
2003–2004	1.43	15.17	41.70	40.38	−41.67	57.02
2004–2005	0.78	17.92	18.85	91.36	−18.32	110.59
2005–2006	2.03	18.60	52.41	107.87	−52.38	128.54
2006–2007	1.77	20.99	18.98	−4.53	−18.98	18.23
2007–2008	5.38	22.88	43.97	82.85	−43.96	111.12
2008–2009	5.22	23.43	36.16	82.90	−36.09	111.63
2009–2010	7.82	23.47	77.15	165.75	−55.49	218.69
2010–2011	11.94	37.33	71.57	94.78	−96.29	119.33
2011–2012	10.27	41.01	152.22	238.71	−152.03	290.20
2012–2013	11.36	31.67	77.89	129.70	−77.61	173.01
2013–2014	10.41	30.98	180.59	77.19	−180.51	118.66
2000–2014	75.00	349.90	823.12	1106.21	−824.96	1529.27

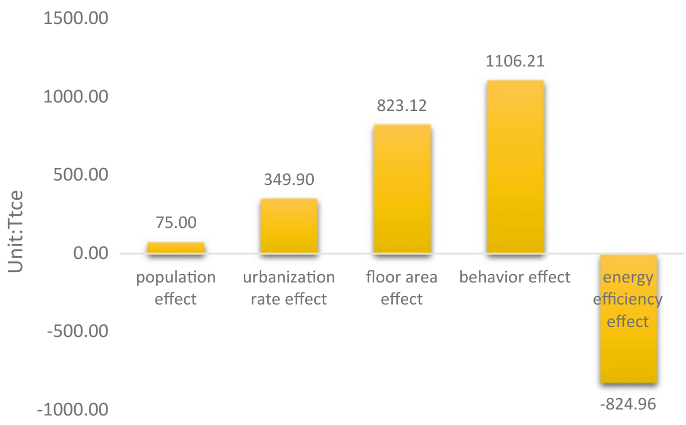


Fig. 82.2 Decomposition results: components of the changes in building energy consumption in Chongqing

The floor area effect is the secondary positive impact on increasing BEC. The aggregate change of BEC by floor area effect achieves 823.12 Ttce. In Chongqing, the floor area increased to 1543.83 million m^2 in 2014 from 745.75 million m^2. The rapid growth of floor area directly leads to the increasing energy consumption of home electricity appliances, such as air conditioners, TVs, refrigerators.

The urbanization rate effect and population effect are also positive factors that increase BEC in the study period of time. The aggregate change of BEC by the urbanization rate effect and population effect are 349 and 75 Ttce respectively.

As shown in Table 82.1, the urbanization rate effect increases from 19.86 Ttce in 2000 to 349.90 Ttce in 2014 it grows up 17.57 times. The rapid urbanization process has multiple impacts on BEC. One reason is that with accelerating urbanization process, the total floor area will certainly grow up. Another reason is that urbanization process rapidly promotes the development of tertiary industry, and will lead to the increasing commercial BEC.

Among all factors, energy efficiency (technology) effect have had a dampening impact on BEC. The aggregate building energy-savings contribute by energy efficiency effect is 826.96 Ttce, which account for 53.95% of the overall change over the period of 2000–2014 especially at last six years of the whole period, during the period 2009–2010, 2010–2011, 2011–2012, 2012–2013, 2013–2014, energy demand from energy efficiency effect contributed most to decrease. The largest contribution appeared from 2013 to 2014, which maybe owes to the rapid development of BEC technology. Another reason is the implementation of commercial BEE retrofit policies in Chongqing (Hou et al. 2016).

82.5 Conclusions and Policy Recommendations

Although in recent years, the Chinese government has developed a series of BEC policies, there is still a big gap compared with developed countries. The BEC per meter in China is only 1/2–1/3 of that in the major developed countries currently (Zhou 2015). Nowadays, as the development of urbanization process in China, BEC will be growth rapidly, it has become the main three energy consuming regions in China (Lin and Liu 2015). In this research, the LMDI method is used to identify which is the significant factor governing the changes in BEC in Chongqing. The main results are as follows.

Industry, transportation and building are the three major energy consuming sectors, in which the building sector having the largest share and the largest energy conservation potential. BP Sta-tistical Review of World Energy shows that China accounts for 21.9% of total primary energy consumption in the world in 2012 (Center 2016). The building sector accounts for about 27.0% of the country's energy consumption (Yang 2007).

The BEC rapidly increased during the study period of time 2000–2014. Moreover, the growth rate of UC-BEC is faster than UR-BEC and R-BEC. Our result also illustrates that the behavior effect plays a significant role in increasing BEC in Chongqing, followed by the floor area effect. And the urbanization rate effect and population effect are also major positive impact on increasing BEC. However, energy efficiency effect is a negative factor of BEC.

More efforts should be made from the following aspects: (1) a "low-carbon lifestyle" is needed. We cannot follow the life mode of the developed countries, such as America, Japan and Germany ect. (2) It is important to promote energy-saving technologies and products and to provide a suitable service level. (3) Nowadays, the service level of the rural region is still far lower than that of the urban region in Chongqing. If following the lifestyle of urban residents, the requirement of rural residents for home appliances will inevitably grow up. Therefore, BEE should be promoted and a low-carbon lifestyle should be also encouraged.

Acknowledgements This research was supported by grants from the Social Science and Humanity on Young Fund of the Ministry of Education P.R. China (No. 15YJC630003).

References

Ang BW, Liu FL, Chung H-S (2004) A generalized Fisher index approach to energy decomposition analysis. Energy Econo 26(5):757–763

Center, T.U.B.E.C.R (2016) Annual report on China building energy efficiency

Chongqing Statistical Yearbook (2001–2015) National bureau of statistics of China

Chu P-Y, Lin Y-L, Guo C-S (2016) The effect of ecological elasticity in Taiwan's carbon reduction policies: the STIRPAT model. J Manage Sustain 6(1):121

Ehrlich PR, H.J.P (1971) Impact of population growth

Fan Y et al (2006) Analyzing impact factors of CO_2 emissions using the STIRPAT model. Environ Impact Assess Rev 26(4):377–395

Fan F, Lei Y (2016) Decomposition analysis of energy-related carbon emissions from the transportation sector in Beijing. Transp Res Part D: Transport Environ 42:135–145

Hou J et al (2016) Comparative study of commercial building energy-efficiency retrofit policies in four pilot cities in China. Energy Policy 88:204–215

IPCC (2014) Climate change 2013: summary for policymakers

Ji X, Chen B (2015) Assessing the energy-saving effect of urbanization in China based on stochastic impacts by regression on population, affluence and technology (STIRPAT) model. J Cleaner Prod

Li B, Liu XJ, Li ZH (2015) Using the STIRPAT model to explore the factors driving regional CO_2 emissions: a case of Tianjin, China. Nat Hazards 76(3):1667–1685

Lin B, Liu H (2015) China's building energy efficiency and urbanization. Energy Build 86: 356–365

Liu Y. et al. (2016) Driving factors of carbon dioxide emissions in China: an empirical study using 2006–2010 provincial data. Front Earth Sci

SBCI U (2009) Buildings and climate change: a summary for decision-makers. Available from: http://www.unep.org/SBCI/pdfs/SBCI-BCCSummary.pdf

Tan XC et al (2016) China's regional CO_2 emissions reduction potential: a study of Chongqing city. Appl Energy 162:1345–1354

Wang Q et al (2016) Exploring the relationship between urbanization, energy consumption, and CO_2 emissions in different provinces of China. Renew Sustain Energy Rev 54:1563–1579

Wang S. et al. (2016) The relationship between economic growth, energy consumption, and CO_2 emissions: empirical evidence from China. Sci Total Environ 542(Pt A):360–371

Xu B, Luo L, Lin B (2016) A dynamic analysis of air pollution emissions in China: evidence from nonparametric additive regression models. Ecol Ind 63:346–358

Yang X, Wei QP, Jiang Y (2007) Study on statistical method for building energy consumption. Constr Conserv Energy

Yang L, Yan H, Lam JC (2014) Thermal comfort and building energy consumption implications—a review. Appl Energy 115:164–173

York R, Rosa EA, Dietz T (2003) STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts. Ecol Econ 46(3):351–365

Zhou L, Chen WY (2015) Status and decomposition analysis on building energy consumption of China in the last decade. J Renew Sustain Energy 7(6)

Chapter 83
Indicators for Guiding Sustainable Development of Townships in Mountainous Regions in Southwest China

Y. Chen, Y.T. Ren, Y.L. Huang and L.Y. Shen

83.1 Introduction

Promoting sustainable development of mountainous townships in Southwest China is a key driver for the national strategies of Belt and Road Initiative, Great West Development Strategy, and New-type Urbanization. The basis of implementing sustainable development of mountainous townships approach is a set of scientific, systematical, and effective indicators for guiding the implementation. The indicator system should allow for effective application in the mountainous townships, and for effective policymaking. The indicator system can also be used as a standard for assessing the sustainability of mountainous townships, and identifying deficiencies, so as to avoid the blind start of various development projects.

Many research studies have pointed out the importance of indicator system in the field of sustainable development of urbanization. For example, Koroneos et al. (2012) and Venturelli and Galli (2006) pointed out that the sustainable indicator system is an indispensable tool in providing the necessary information for the planning and decision-making of the sustainable development of cities and towns. Domestic scholars also reach a consensus on this argument. They emphasize that the indicator system as a guiding tool in the process of sustainable development in practice is magnificent (Li 2013, 1999). Many practical experiences have echoed the importance of indicators in guiding practice. According to reports, Oregon under the guidance of "Oregon Benchmark" which contains 159 indicators has been in the leading position of the US in land planning, land conservation and economic

Y. Chen (✉) · Y.T. Ren · Y.L. Huang · L.Y. Shen
School of Construction Management & Real Estate, Chongqing University, Chongqing, China
e-mail: 14787807784@163.com

Y. Chen · Y.T. Ren · Y.L. Huang · L.Y. Shen
International Research Centre for Sustainable Built Environment, Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_83

and social sustainable development (Jv and Luo 2002). At present, "Oregon Benchmark" has become a template for other states' learning (Lan 2004). For another example, in Sustainable Seattle, the indicators of sustainable community play an important role in the process of sustainable development in Seattle, which is famous for the "clean and green" in the world. The above discussions demonstrate that the power of an effective indicator system for the sustainable development of mountainous townships cannot be underestimated.

There is considerable amount of literatures on establishing indicators for sustainable development of urbanization. For example, United Nations proposed an indicator system for sustainable urban development in 2007, which aims to better serve policy decision-making. It includes four dimensions, namely social, economic, environmental and institutional (Indicators of sustainable development 2007). In another research, the evaluation index system of green and ecological small town is established by using analytic hierarchy process, where the indicator system includes 4 components, including ecological environment, urban construction and management, social and economic system (Yu et al. 2014). In examining Tianjin city as an example, Chen proposed the indicator index system for sustainable development which was divided into two categories, namely the constraint index and the reference index, and the target value was also proposed (Chen and Li 2012). Da applied the principle of Pressure-State-Response (PSR) in establishing an indicator system for the sustainable development of small towns. The Irish scholars, Visvaldis V, Ainhoa G and Ralfs P established 108 indicators for investigating the sustainable development of the small town Valmiera (Visvaldis et al. 2013).

Nevertheless, the above mentioned indicator systems are proposed in the context of developed cities, many of these indicators are considered not suitable for guiding the development of small mountainous towns in Southwest China. Although some studies have been conducted in the context of China, their effectiveness are considered limited for two major reasons. First, some indicators cannot be used because the data for their application are not available, or because indicators do not reflect the updated conditions or backgrounds of these mountainous townships (Shen and Zhou 2014). Second, there is no research which focused on the context of townships in mountainous regions in Southwest China. Therefore, this study aims at filling in the research gap in this perspective.

83.2 Methodology

83.2.1 Principle

In order to develop a set of effective indicators for guiding the sustainable development of townships in mountainous regions in Southwest China, certain principles should be followed.

(1) Applicability: The selected indicators using in the assessment of sustainable development condition should be available by the means of current technology and the local policy (Ma et al. 2015).
(2) Integrity: The indicators should be widely selected to address the main factors affecting the sustainable development of townships in Southwest China, and also be specific enough to stress the characteristics of those small mountainous towns (Ma et al. 2015; Wang 2014; Wu and Wang 2005; Shen et al. 2016).
(3) Purpose-driven: Different indicators will serve for different purposes. It is therefore important to define the aims of indicators.
(4) Locality: The selection of indicators should take into account the characteristics of the local background, such as the factors under the dimensions of ecology, humanity, nature, etc. (Ma et al. 2015; He et al. 2011).
(5) Dynamic: The indicators selected should reflect the dynamic process and future development trend (He et al. 2011; Fan and Xiong 2002; Shen et al. 2017) of township in mountainous region in southwest China.
(6) Key factors: Key indicators must not be ignored in the process of developing indicator system.
(7) Understanding on the typical barriers affecting sustainable development for townships in mountainous regions in Southwest China: Lu Yuantang (Lu et al. 2003; Shuai et al. 2017) etc., referred that the reason why China has not adopted a public-recognized indicator system for sustainable development is the lack of experience and the sustainable development knowledge. Therefore, investigation should be given on the barriers to sustainable development to the townships in mountainous regions in Southwest China, and this will be conducted through both literature review and practical surveys. The typical barriers in mountainous regions in Southwest China include: dispersion and low density of geographical layout; small scale of towns; lack of development orientation with considering local characteristics; overall low development standard; incapability of poor public service in managing infrastructure construction; lack of the professional managers and dedicated technical personnel; lack of financing channels; inefficiency and chaos of land usage and management; and presence of rugged terrain conditions and natural disasters.

83.2.2 Research Approaches

In order to establish the indicators for guiding sustainable development of townships in mountainous regions in Southwest China, the research methods employed include comprehensive literature review, practical investigation on a number of typical mountainous towns and interviews with government officials who are in key position in these towns. These towns are carefully selected to ensure that they have the characteristics of mountainous regions. Literature review will lead to formulating the framework of indicator system by considering the characteristics of townships in mountainous region in Southwest China. This framework is presented for discussion in practical cases. As the result, the framework will be further improved.

83.2.3 Framework of Indicators

The literature review has referred to 27 series of indicator systems, among which 6 series come from the official published documents, and the other 21 series come from academic literature. And only 1 in these 27 systems is relevant with mountainous sustainable townships.

By referring to these indicator systems, these indicators which have been included in more than three systems are collected for formulating the framework. As a result, a framework which contains 42 indicators for sustainable development in mountainous regions in Southwest China is proposed, as shown in Table 83.1.

83.3 Establishment of Indicators for Guiding Sustainable Development of Townships in Mountainous Regions in Southwest China

The framework of Table 83.1 has been presented for discussions with various officials who serve for townships in mountainous region of Southwest China. There were 30 participants for various discussions, which were conducted in six townships. These six townships were selected with considering that they are typical towns in mountainous regions, including Degan, Tanghe, Tiaodeng in Chongqing, and Yongxing, Chaole, Dalucao in Guizhou. The participants include 2–3 key officials from each township and 2–3 researchers. The results of discussions can be summarized as follows:

Certain indicators are added based on the following arguments: ① Interview discussions suggest that indicators should give an emphasis on the issue of scattered layout, poverty-stricken towns, lagging financing system, and limited credit market capital supply. In this context, the scale economic effect of small towns in the Sub-theme indicators and other five indicators including the number and proportion of poverty-stricken households, financial institutions dot density (number/sq.km), categories and worth of leading industry, the number of towns associated with investigated towns, the distance from the central town are added to the core indicators. ② High quality land is precious in Southwest China because of the restrictions of terrain. On the other hand, the lack of management mechanism has aggravated the situation of chaos in land use and management. So we added land supply rate (supplied state-owned construction land area/qualified construction land area to be and has been supplied), transfer ratio of farmers' land (transferred

Table 83.1 A framework of indicators for sustainable development in mountainous regions in Southwest China

Theme	Sub-theme	Core indicator	Core indicator
Economic A_1	Economic strength B_1	Gross domestic product C_1	Gross value of industrial output C_2
		Gross value of tertiary industry C_3	Per capita disposable income C_4
		Local government financial income C_5	Retail sales of social commodities C_6
		Village fair trade turnover C_7	Market share of products C_8
	Economic growth potential B_2	Indices of gross domestic product C_9	Growth speed of tertiary industry C_{10}
		Industrialization of agriculture C_{11}	The proportion of social capital accounting for total investment C_{12}
		Scale of industrial agglomeration C_{13}	
Social A_2	Population B_3	Resident population C_{14}	Density of population C_{15}
	Education B_4	Illiteracy rate among young and middle-aged people C_{16}	
		The proportion of education investment accounted for total investment C_{17}	
	Technology B_5	The proportion of scientific investment accounted for total investment C_{18}	
		The rate of introduction of advanced varieties C_{19}	
	Health B_6	The coverage of basic medical insurance programs C_{20}	
		Average number of doctors assigned to per thousand C_{21}	
		The coverage rate of old-age insurance C_{22}	
	Culture B_7	The proportion of culture and entertainment facilities investment accounted for total investment C_{23}	
		Public square area and park area C_{24}	
	Transportation B_8	The area of hard pavement road owned by per capita C_{25}	
Resources A_3	Land B_9	Per-person cultivated land area C_{26}	Construction land area per capita C_{27}
	Water B_{10}	Per capita water amount C_{28}	
	Minerals B_{11}	Reserves of major mineral resources C_{29}	
	Tourism B_{12}	Grade and quantity of natural	The grade and quantity of historical landscape C_{31}

(continued)

Table 83.1 (continued)

Theme	Sub-theme	Core indicator	Core indicator
		landscape C_{30}	
		The grade and quantity of intangible cultural heritage C_{32}	
Environment A_4		Per capita public green space area C_{33}	Air-quality indexesC_{34}
		Areas with permissible noise levelC_{35}	Penetration rate of drinking-water C_{36}
		Penetration rate of clean energy C_{37}	Penetration rate of hygienic toilet C_{38}
		Sewage treatment rateC_{39}	Collection rate and decontamination rate of garbage C_{40}
Governance A_5	Government services B_{13}	Public satisfaction index of government services C_{41}	The sharing and transparency of government affairs' information C_{42}

land area/collective-owned land area) and compensation for land expropriation to assess land resources. ③ The quantity and quality of managers and dedicated technical personnel in different regions differ greatly. Therefore, the overall quality of administrators was increased as one of themes. This dimension includes average years of work experience for administrators, average educational level of administrators, average number of staff and workers from different departments, administrators' professional counterparts rate. ④ Investment on preventing natural disaster also cannot be ignored in mountainous towns in Southwest China.

Combined with on-the-spot investigations and the results from the interview discussions, the following indicators are removed from the framework, namely village fair trade turnover, market share of products, industrialization of agriculture, scale of industrial agglomeration, penetration rate of hygienic toilet, public satisfaction index of government services, the sharing and transparency of government affairs' information. The area of hard pavement road owned by per capita cannot directly reflect transportation ability. Thus, this indicator is replaced by normal operation rate of highway.

The above amendments have been incorporated into the framework in Table 83.1. Consequently, a final version of indicator system for guiding sustainable development of mountainous townships in Southwest China is presented as Table 83.2.

83.4 Discussion and Conclusion

The establishment of indicators should be based on the development situations and existed typical barriers affecting sustainable development for townships in mountainous regions in Southwest China. The indicators will be able to assist decision makers in identifying appropriate policies for implementing sustainable development of mountainous townships and dealing with emerging problems associated with the urbanization of mountainous townships. In other words, the goal of the indicator system is to guide sustainable development of mountainous townships in practice. That is why this study has been conducted by employing an on-the-spot investigations and interviews in mountainous regions in Southwest China. The indicator system established is structured hierarchically with six dimensions, namely (1) economic, (2) social, (3) resources, (4) environment, (5) overall quality of administrators and (6) governing the nature calamity.

The proposed indicator system of guiding sustainable development in mountainous townships in Southwest China has certain limitations, including that the data needed are not necessarily available, and the experience using the system may not be established. It is important for the local governments to establish a mechanism for data collection and unifying statistics caliber for data collection. How to establish the effective statistics caliber and data collection channels will be an important issue for the further research.

Table 83.2 Establishment of indicator system for guiding sustainable development of mountainous townships in Southwest China

Theme	Sub-theme	Core indicator
Economic A_1	Economic strength B_1	Gross domestic product C_1
		Gross value of industrial output C_2
		Gross value of tertiary industry C_3
		Per capita disposable income C_4
		Local government financial income C_5
		Retail sales of social commodities C_6
		Number and proportion of poverty-stricken households C_7
	Economic growth potential B_2	Indices of gross domestic product C_8
		Growth speed of tertiary industry C_9
		The proportion of social capital accounting for total investment C_{10}
		Financial institutions dot density (number/sq.km) C_{11}
		Categories and worth of leading industry C_{12}
	Scale economic effect B_3	Number of towns associated with investigated towns C_{13}
		Distance from the central town C_{14}
Social A_2	Population distribution B_4	Resident population C_{15}
		Density of population C_{16}
	Education B_5	Illiteracy rate among young and middle-aged people C_{17}
		The proportion of education investment accounted for total investment C_{18}
	Technology B_6	The proportion of scientific investment accounted for total investment C_{19}
		The rate of introduction of advanced varieties C_{20}
	Health B_7	The coverage of basic medical insurance programs C_{21}
		Average number of doctors assigned to per thousand C_{22}
		The coverage rate of old-age insurance C_{23}
	Culture B_8	The proportion of culture and entertainment facilities investment accounted for total investment C_{24}
		Public square area and park area C_{25}
	Transportation B_9	Normal operation rate of highway C_{26}

(continued)

Table 83.2 (continued)

Theme	Sub-theme	Core indicator
Resources A_3	Land B_{10}	Per-person cultivated land area C_{27}
		Construction land area per capita C_{28}
		Land supply rate (supplied state-owned construction land area/qualified construction land area to be and has been supplied) C_{29}
		Transfer ratio of farmers 'land (transferred land area/collective-owned land area) C_{30}
		Compensation for land expropriation C_{31}
	Water B_{11}	Per capita water amount C_{32}
	Mineral B_{12}	Reserves of major mineral resources C_{33}
	Tourism B_{13}	Grade and quantity of natural landscape C_{34}
		The grade and quantity of historical landscape C_{35}
		The grade and quantity of intangible cultural heritage C_{36}
Environment A_4		Per capita public green space area C_{37}
		Air-quality indexesC_{38}
		Areas with permissible noise levelC_{39}
		Penetration rate of safe drinking-water C_{40}
		Penetration rate of clean energy C_{41}
		Sewage treatment rateC_{42}
		Collection rate and decontamination rate of garbage C_{43}
Overall quality of administrators A_5		Average years of work experience for administrators C_{44}
		Average educational level of administrators C_{45}
		Average number of staff and workers from different departments C_{46}
		Administrators' professional counterparts rate C_{47}
Governing the nature calamity A_6		Investment on preventing natural disaster C_{48}

Acknowledgments This research was supported by a grant from the Project of National Social Science Foundation of China (No. 15BJY038).

References

Chen SN, Li Y (2012) Research on the construction planning and assessment indicator system of ecological small mountainous town—taking the construction of ecological small mountainous town in Tianjin as an example: Diversity and tolerance, Annual National Planning Conference 2012, Kunming, China

Fan WG, Xiong N (2002) The indicator system of sustainable town in eastern coastal region. Econ Geogr 22(01):37–40

He TX, Liao J, Wei X (2011) Construction of comprehensive assessment indicator of urban ecological civilization. Econ Geogr 31(11):1897–1900

Indicators of sustainable development: guidelines and methodologies (2007). United Nations

Jv ZS, Luo M (2002) Sustainable development in Oregon. Land and Res 03:52–53

Koroneos CJ, Nanaki EA, Xydis GA (2012) Sustainability (Sustainability), 4(12):1867–1878

Lan, GL (2004) Research on the construction and application of indicator system of sustainable development. Doctoral dissertation, Tianjin University, Tianjin, China

Li ZB (1999) An assessment method for sustainable utilization of mountainous region. J Mt Sci 17 (1):67–70

Li TX (2013) Research progress of indicator system of sustainable development at home and abroad. Ecol Environ 06:1085–1092

Lu YT, Wang JN, Li YS (2003) Research and application of sustainable development of assessment indicator system in China. Env Prot 11:17–21

Ma YM, Wu YM, Wu BJ (2015) Comprehensive assessment of sustainable development in the Yangtze River Delta Region Urbanization—Based on the method of entropy method and quadrant. Econ Geogr 35(06):47–53

Shen L, Zhou J (2014) Habitat International (Habitat International), 44:111–120

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) Sustainability 8(8):783

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Habitat Int 60:19–33

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Appl Energy 187:310–325

Venturelli RC, Galli A (2006) Ecological indicators (Ecological Indicators), 6(1):228–237

Visvaldis V, Ainhoa G, Ralfs P (2013) Procedia Computer Science (Procedia Computer Science), 26:21–32

Wang WX (2014) Research on the assessment indicator system of sustainable development of resource small mountainous town: 2014 (Ninth) Urban Development and Planning Conference Tianjin, China

Wu J, Wang YY (2005) Construction of assessment indicator system for sustainable development of small mountainous towns. Territory Nat Res Study 02:11–13

Yu J, Zhou JH, Xu SX et al (2014) The research on the sustainable development and the establishment of the assessment indicator system of green ecological small mountainous town. Constr Sci Technol 15:26–29

Chapter 84
Influential Factors in Construction Industry of Yemen

Najib AL-Fadhali, Ng Kim Soon, Rozlin Zainal, Abd Rahman Ahmad and Abdel Hafiz Ali Hasaballah

84.1 Introduction

Accomplishment in development projects is reliant on the compelling association of numerous, particular groups, each of which brings its own capacity, experience, information and ability towards finishing the joint task, yet which additionally bring their own targets, objectives and administration styles, which may not be completely complementary (Doloi et al. 2012). As indicated by Doloi (2013), development venture achievement relies on upon the multi-firm venture associations included cooperating attractively. The development division is a vital segment for the improvement and financial development of Yemen, which is a creating nation (Sultan 2005; Al-Sabahi et al. 2014). The construction projects in Yemen represents the fourth largest source of labor jobs in the country, about 9–10% of the working population and the average yearly growth rate of the sector is about 5.4%, effectively contributing to the economic growth of Yemen (Ahmed 2014). With the comparatively large volume of investments currently in this sector as well as a probable increment in foreign funding from World Bank and other donor agencies for developmental projects, the demand for services in this sector is bonded to increase steadily (Ahmed 2014). Accomplishing construction projects within the time specified is seldom in Yemen. The funds allocated for the projects are not properly utilized as well (Ahmed 2014). Therefore, there is the need to identify the

N. AL-Fadhali (✉) · N.K. Soon · R. Zainal · A.R. Ahmad
Faculty of Technology Management and Business,
University Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia
e-mail: eng.najeebfadhali@gmail.com

N.K. Soon
e-mail: ksng@uthm.edu.my

A.H.A. Hasaballah
Department of Business Administration, College of Business and Economics,
Qassim University, Buraydah, Kingdom of Saudi Arabia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_84

factors influencing construction projects successful completion among internal stakeholder in Yemen, assess the extents to which these factors affect successful completion, impact of the internal stakeholder on project successful completion and how the problems of construction projects successful completion delay can be addressed. There is the requirement for a methodical examination of the reasons for the delay in projects' completion and developing a clear understanding among constructions projects professionals. Hence, this research focuses on proposing an influential factor (IF) model of internal stakeholder for construction projects completion in Yemen. It is believed that this proposed research when completed, will improve the structure of the construction project sectors as well as adding value to the economy of Yemen.

84.2 Literature Review

Since project successful completion is connected with cost and time invade, the phenomenon of project completion failure has involved sympathy toward development experts and additionally a subject of study for scientists.

84.2.1 Construction Projects in Yemen

The construction projects in Yemen has represented the fourth largest employer of the workforce in the country, between to 9 and 10% of the working inhabitants, the average yearly increase rate of the sector is almost 5.4%, effectively contributing to the economic development in Yemen. With the comparatively large volume of investments currently in this sector as well as a probable increase in foreign funding from World Bank and other donor agencies for developmental projects, the demand for services in this sector is bonded to increment steadily (Ahmed 2014).

Yemen has established an unparalleled building tradition, the wealthy, particular and orderly pattern of the traditional Yemeni architecture and townscape is really wonder. Until thirty years ago, this tradition was being successfully preserved (Al-Ansi 2012). The main pressure was and yet is the fast pace of alteration from the traditional to modern and traditional building methods. Recent history, however, has demonstrated that it was not likely for the local construction industry to overcome with the vast growth in modern forms of construction that have occurred over the past decades.

84.2.2 Construction Projects Stakeholders

The idea of stakeholder theory was first created from a scholastic exploration stream being embraced in the US in the 1960s that characterized stakeholder as those gatherings with high adequate impacts in an association that would precipitate that association to stop to exist without their bolster according to Li et al. (2013) and Stoney and Winstanley (2001). Subsequent, Freeman (1984) built up this definition and portrays "an accomplice in a relationship" as "any gathering or person who can influence or is impacted by the accomplishment of the association's targets". The task administration establishment (PMI) embraced this definition and expressed: "A partner is an individual, gathering, or association who may influence, be impacted by, or comprehend itself to be affected by a choice, action, or result of an undertaking" (PMI 2013).

The Project Management Body of Knowledge (PMBOK) takes note of that a stakeholder has numerous partners whose interests might be connected, or in a struggle (PMI 2013). An accommodating representation by Briner et al. (1997) appeared in Fig. 84.1, gives a generally acknowledged mapping of a stakeholder's principle partners. The distinguishing proof and administration of such stakeholders, along these lines, turns into a generous capacity for any association in crisis. It is likewise contended that an association's focal points are essentially respondent on its ability to enough manage stakeholders according to Verbeke and Tung (2013). Contingent upon the relationship between the partners and the association, they can, as a rule, be isolated into two principle classifications, 'internal stakeholder' and 'external stakeholder' (Olander 2006, 2007). Internal stakeholders are those effectively connected with and formally connected to the project, for example, owners, consultant, contractor, subcontractor, designer, employees, and supplier. This association much of the time is straightforwardly inspired by the project and has a general and authoritative collaboration with the organization (Atkin and Skitmore 2008). They are in some cases alluded to as primary stakeholders.

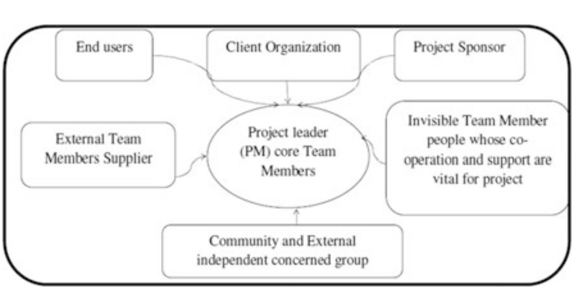


Fig. 84.1 Stakeholder mapping (Briner et al. 1997)

84.2.3 Project Successful Completion

Project completion's Success has dependably been the last focus of each movement of a task included development and building ventures as stated from the study by Salazar et al. (2013). Project completion successfully has been widely talked about in the development and undertaking administration writing. Most studies have concentrated on the extent of undertaking achievement which implies the best approach to gauge accomplishment of project and components influencing project achievement. Doloi et al. (2011) stated that a standout amongst the most widely recognized methods for measuring project achievement fulfillment is the triangle of cost, time and required quality. Additionally, a couple ponders have extended assignment accomplishment criteria into new perspectives, for example, stakeholders support and fulfillment, owners advantage, up and coming planned to an association (Heravi 2014).

84.3 Research Methodology

A total of seven (3) constructs will be involved in the study. All the names of these internal stakeholders are used to group the factors that will be used in the study. The constructs are; contractor related factor (CONTF), consultant related factor (CNOSF), owner related factor (OWNRF) and designer related factor (DESNF). All these constructs are mentioned in the concepts of the definition of stakeholder in construction projects in many studies (Cleland and Ireland 1999; Atkin and Skitmore 2008; Heravi 2014). This research intends to study the effect of these groups (internal stakeholders) on construction projects with regards to successful completion on time.

After reviewing the literature, a total of seventy-three (37) factors is selected. These factors are selected based on how each of the factors is related to each of the construct. Any factor that is related to any construct in the study, it was grouped under that concept. Please refer to Appendix 'A' for the details of these factors and their resources. The main reason for selecting these factors is because numerous research studies like (Doloi et al. 2012; Doloi 2013; Fallahnejad 2013; Odeh and Battaineh 2002; Assaf and Al-Hejji 2006) all used most of these factors in their research studies. These articles were all published in high impact journals. These journals have a number of citations by several researchers. Hence, Factors Affecting Project Successful Completion Related to internal stakeholder is shown in Table 84.1.

Table 84.1 Factors that affecting project successful completion on time

A.	*Consultant related factor*	B.	*Contractor related factor*
1.	Poor project management	1.	Money cash flows during construction and financial difficulties
2.	Poor contract management	2.	Poor procurement programming of materials
3.	Lack of responsibility	3.	Non-adherence to contract conditions
4.	Poor coordination among parties	4.	Capability of the firm's construction team
5.	Inadequate experience	5.	Lack of Contractor experience
6.	Delay in approving major changes in the scope of work by consultant	6.	Poor Site management and supervision
7.	Delay in approval of shop drawings	7.	Planning and scheduling deficiencies
8.	Consultant architect's reluctance for change	8.	Mistakes during constructions
9.	Mistakes and discrepancies in contract documentations	9.	Inadequate modern equipment and using old technology
C.	*Owner related factor*	D.	*Designer related factor*
1.	Change orders	1.	Project design complexity
2.	Slow decisions from the owner	2.	Lack of communication between design team and clients in design phase
3.	Delay in running bill payments to the contractor	3.	Design errors made by the designers
4.	The conflict between owners and other parties	4.	Lack of adopts standardization in design
5.	Bureaucracy in owner's organization	5.	Insufficient data collection and survey before design
6.	Lack of motivation for contractors for an early finish	6.	Lack of experience of the design team in construction project
7.	Late of site delivery	7.	Mistakes and delays in producing the design documents
8.	Incapable representative and inadequate planning	8.	Understanding of owner's requirements by design engineer
9.	Poor experience in the construction projects		
10.	Inappropriate contractual procedure		
11.	Selecting inappropriate contractors		

84.3.1 Preparation of Questionnaire

For the purpose of the quantitative aspect of the research which forms the dominance of the research instrument, the use of five (5) point Likert scale is adopted. The pilot study was completed by posting and interviewing of organized survey questionnaire amongst the selected experts of owners, consultant and contractors who are involved in handling construction projects. In this respects, the respondents were solicited to approve the contents from the questionnaire and show the level of importance of the causes which utilizing 5-point Likert scale as Extremely Significant (ES), Very Significant (VS), Moderate Significant (MS), Slightly Significant (SS) and Not Significant (NS). An aggregate of 10 respondents required in this pilot study. The dominant part of respondents had Engineering education and quite a long while of experience in handling construction projects extending from 10 to 30 years with aggregate proficient experience of the 10 respondents. The Data collected from the pilot study was analyzed utilizing Average Index (AI) calculation. The AI calculated for each factor was evaluated for its significance using the range adopted from Abdullah (2010) and Memon et al. (2011) which as follows: 1.00 < AI < 1.50 Not Significant, 1.50 < AI < 2.50 Slightly Significant, 2.50 < AI < 3.50 Moderately Significant, 3.50 < AI < 4.50 Very Significant and 4.50 < AI < 5.00 Extremely Significant. It can be seen that out of 67 factors in the questionnaire survey; noted that only 33 factors fall in the range of very significant (3.50 < AI < 4.50) and 12 variables were in the range of moderately significant (2.50 < AI < 3.50). Subsequently, for the questionnaire survey, this study considered 33 factors that fall in the range that are very significant factors only. Last questionnaire survey sets were circulated among the professionals including owner, contractors and consultant to comprehend their perception regarding the level of significant of the influential factors affecting project completion.

84.3.2 Respondent's Position Demography

Respondents required in the study are occupied with various position and division of construction development associations. These included the project Manager, architect, mechanical engineer, structural engineer, electrical engineer and quantity surveyor as summarized in Table 84.2.

Table 84.3 shows that majority of the respondent (i.e. 27.6%) have project manager position in their organization. Structural Engineers represented (18.7%) in this study. Electrical Engineers represented (19.4%) of this survey. Mechanical

Table 84.2 Respondent position involved in survey

Position		Frequency	Percent	Valid percent	Cumulative percent
Valid	Project Manager	78	27.6	27.6	27.6
	Structural Engineer	53	18.7	18.7	46.3
	Electrical Engineer	55	19.4	19.4	65.7
	Mechanical Engineer	47	16.6	16.6	82.3
	Architect	42	14.8	14.8	97.2
	Quantity Surveyor	8	2.8	2.8	100.0
	Total	283	100.0	100.0	

Engineers represent in (16.6%) of this research while Architects and Quantity Surveyor represented in (14.8 and 2.8%) respectively.

84.3.3 Respondent's Organization Demography

Respondents required in the survey are occupied with various parts of construction development associations. These included owners, consultants and contractors firms as compressed in Table 84.3.

Table 84.4 shows that majority of the respondent (i.e. 43.8%) are engaged contractors firms. Only 37.1% respondents are related to the consultant firms while 19.1% of the respondents are related to the owner firms. Furthermore, a significant number of respondents were contractor's representatives followed by consultants and owner.

84.3.4 Respondent's Project Handled Demography

The involved the respondents in the questionnaire survey have a huge experience in handling different sorts of projects of various size in terms of the contract amount. Table 84.4 summarize the details of types of the large projects that handled by the respondents.

Table 84.5 exhibits that 31.1% of respondents have experience of handling commercial construction projects, 29.7% of respondents are involved with development work of Infrastructure projects, 19.8% of respondents have experience of handling Industrial projects, and 19.4% of respondents are possessed in development work of Residential projects.

Table 84.3 Respondent's organization

Type of organizational respondent	Total
1. Owner	54 (19.1%)
2. Consultant	105(37.1%)
3. Contractor	124 (43.8%)
Total	283 (100%)

Table 84.4 Type of projects the respondent with most involvement

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Residential	55	19.4	19.4	19.4
	Commercial	88	31.1	31.1	50.5
	Industrial	56	19.8	19.8	70.3
	Infrastructure	84	29.7	29.7	100.0
	Total	283	100.0	100.0	

Table 84.5 Academic qualification of respondents

		Frequency	Percent	Valid percent	Cumulative percent
Valid	1. Bachelor Degree	270	95.4	95.4	95.4
	2. Master Degree	11	3.9	3.9	99.3
	3. Doctor of Philosophy	2	.7	.7	100.0
	Total	283	100.0	100.0	

Table 84.6 Respondent's experience

		Frequency	Percent	Valid percent	Cumulative percent
Valid	1. 1–5 years	29	10.2	10.2	10.2
	2. 6–10 years	36	12.7	12.7	23.0
	3. 11–15 years	96	33.9	33.9	56.9
	>16 years	122	43.1	43.1	100.0
	Total	283	100.0	100.0	

84.3.5 Respondent's Expertise Demography

Respondents' expertise was assessed based on their qualification and working experience. Academic qualification and working experience are very important aspects and play very important role in understanding any problem. Tables 84.5 and 84.6 show the summary of the respondent's qualification and experience respectively. As demonstrated in Table 84.6, it can be seen that a large number of respondents i.e. 270 of 283 (with 95.4%) have obtained bachelor engineering degree, followed by 11 (3.9%) respondents having master certificates and 2 (0.7%) having Ph.D. certificates.

Table 84.7 show that respondents participating in questionnaire survey have many years of experience in construction projects. A noteworthy number of respondents i.e. 29 of 283 with 10.2% respondents are occupied with construction industry for below 5 years and 36 respondents (12.7%) respondents have experience of over 5 years and below 10 years and 96 respondents (33.9%) respondents have experience of over 10 years and below 15 years, the remaining 122 (34.1%) respondents have experience of above 16 years. These demonstrate that respondents were sufficiently equipped and skilled for participating in the study survey.

Table 84.7 Ranking of overall data

Factors affecting project completion	Overall		Owner		Consultant		Contractor	
	AI	Rank	AI	Rank	AI	Rank	AI	Rank
1. Money cash flow during construction	3.84	1	3.77	1	3.92	1	3.82	1
2. The conflict between owners and other parties	3.75	2	3.67	4	3.79	2	3.76	3
3. Delay in running bill payments for the contractor	3.72	3	3.68	3	3.70	8	3.78	2
4. Poor project management	3.70	4	3.60	6	3.76	4	3.70	4
6. Slow decisions from the owner	3.69	5	3.71	2	3.78	3	3.56	11
7. Lack of contractor experience	3.67	6	3.60	6	3.61	12	3.78	2
8. Design errors made by designers	3.66	7	3.54	9	3.61	12	3.78	2
9. Poor site management and supervision	3.62	8	3.48	13	3.76	4	3.60	7
10. Improper Selection of contractors	3.60	9	3.62	5	3.71	7	3.49	15
11. Frequent design changes	3.60	9	3.52	11	3.74	5	3.55	12
12. Poor contract management	3.59	10	3.46	15	3.72	6	3.58	9
13. Lack of responsibility	3.58	11	3.43	17	3.65	10	3.59	8
14. Incapable representative	3.58	11	3.51	12	3.63	11	3.58	9
15. Lack of experience of design team in construction project	3.58	11	3.45	16	3.65	10	3.59	8
16. Poor coordination among parties	3.57	12	3.55	8	3.55	14	3.61	6
17. Lack of communication between design team and the clients in the design phase	3.57	12	3.53	10	3.67	9	3.54	13
18 Inadequate experience	3.53	13	3.39	19	3.55	14	3.58	9
19. Poor Planning	3.53	13	3.43	17	3.58	13	3.53	14
20. Mistakes during constructions	3.53	13	3.54	9	3.58	13	3.46	17
21. Poor procurement of materials	3.51	14	3.56	7	3.51	16	3.46	17
22. Inadequate modern equipment with using old technology	3.49	15	3.52	11	3.43	21	3.53	14
23. Bureaucracy in owner's organization	3.49	15	3.47	14	3.52	15	3.48	16
24. Delay in approving major changes in the scope of work by consultant	3.46	16	3.40	18	3.33	22	3.64	5
25. Inappropriate contractual procedure	3.45	17	3.40	18	3.51	16	3.44	19
26. Misconception of owner's requirements by design engineer	3.45	17	3.37	20	3.37	20	3.57	10
27. Delay in approval of shop drawings	3.44	18	3.35	21	3.51	16	3.42	21

(continued)

Table 84.7 (continued)

Factors affecting project completion	Overall		Owner		Consultant		Contractor	
	AI	Rank	AI	Rank	AI	Rank	AI	Rank
28. Non adherence to contract agreement	3.41	19	3.40	18	3.39	19	3.44	19
29. Lack of motivation for the contractor to early completion	3.41	19	3.39	19	3.34	8	3.41	22
30. Consultant architect's reluctance for change	3.37	20	3.39	19	3.46	17	3.29	24
31. Mistakes and discrepancies in contract documentations	3.36	21	3.22	23	3.31	23	3.45	18
32. Incomplete data collection and survey before design	3.36	22	3.27	22	3.33	22	3.43	20
33. Lack of adoption of standardization in design	3.30	23	3.22	23	3.37	20	3.30	23
34. Capability of the firm's construction team	3.26	24	3.17	24	3.33	22	3.27	25

84.4 Ranking of Factors Affecting Project Successful Completion on Time

Hierarchical assessment of factors that influence project completion was done to locate the most potential effects based on the ranking study. The evaluation was carried out with the utilization of average index value as overall. The results of assessment are discussed in next sections.

84.4.1 Ranking of Overall Data

The overall ranking on factors affecting project completion is tabulated in Table 84.7.

Table 84.7 demonstrates the rank of every factor based on the different groups of respondents like the owner, the consultant and the contractor and also the overall respondents. This paper chooses only the top five most critical factors that influentially affect the project completion successfully which adopted the same methodology of Abdullah (2010). The top five critical factor are ranked by overall respondents, include the money cash flow during construction (AI = 3.84), Conflict between owners and other parties (AI = 3.75), Delay in running bill payments for the contractor (AI = 3.72), Poor project management (AI = 3.70), Slow decisions from owner (AI = 3.69). The ten critical factors are presented in more detail with comparison with other countries in the following section.

(i) **Money cash flow and financial difficulties faced by contractors**

This element was found as the first significant donor that negatively affecting to project successful completion as indicated by particular time and cost with AI estimation of 3.84 as concurred by contractor and consultant groups while owners' representative rated this factor as the second rank. This is valid for temporary workers since they assume an essential part in the achievement of any development extend particularly for physical execution of works. Henceforth, sufficient income and money related soundness of temporary workers is exceptionally basic in keeping development progress as arranged. Cash flow management will help in determining the projected final cost and consider the projections of future cost (Ali and Kamaruzzaman 2010) which will help in effective cost management and avoid time and cost overrun. Olatunji (2008) stated that cash flow problem is very critical, however, there is a direct relationship with the level of discrepancies in the virtues of client commitments in terms of cash-flow to the contractor, thus the scenario puts the contractor in a difficult position to optimize effective planning.

(ii) **Conflict between owners and other parties**

This factor was found as the second significant factor that can negatively influence to project completion according to specific time and cost as agreed by contractor and consultant groups respectively ranked as 3rd and 2nd while owners' representative rated this factor as 6th rank. The disputes between the contractual parties are one of the most important obstacles to the success of the projects which are to accompany the syndrome in engineering projects and because of interest between the parties to a conflict. This result is compatible with the study of Meng (2012) which proofed that the conflict wills significantly affecting negatively to success of the project.

(iii) **Delay in progress payment by owner**

Delay in progress payment is the third major factor contributing that can negatively affecting the project successful completion. In any case, there is some difference for the positioning among the respondent groups. Contractor's group ranked this factor at 2nd place. On the contrary consultant and owner groups ranked this factor as moderately significant by placing at 8th and 5th rank respectively. In the construction industry, mostly the contractors depend on the monthly payments received from the owner. If the payment is delayed, the cash flow of the contractors is disturbed which affect the procurement of material and slowing the progress of work resulting in delaying activities which lead to time overrun and consequently face cost overrun. Hence, contractor's group ranked it as a very significant factor while according to consultants and owner, the contractors must have strong financial position.

(iv) **Poor project management**

Poor project management is the fourth major factor contributing that can negatively affect the project successful completion. In any case, there is some difference for the positioning among the respondent groups. Consultant and contractor groups ranked this factor as the 4th rank while the owner ranked by placing at 8th place. This is contributing in delaying in change design when the owner wants change in scope during the construction stage, approval of material and inspection of completed work. Owners make changes in scope which leads to frequent design and specification changes which lead to waste of material and delay in completing activities as stated in a study by Kikwasi (2013). Consequently, project budget is overrun. Project management is all about good communications.

(v) **Slow decision from owner**

A slow decision from the owner is the 5th major factor contributing that can negatively affect the project successful completion. In any case, there is some difference for the positioning among the respondent groups. Consultant and owner groups ranked this factor as the 3th rank while the ranked by placing at 12th place. Slow decision from owner affects all project teams. Change in the design documents during the construction stage including drawings and specifications, does not provide the contractor with the clear defined basis to plan the resources needs of a construction project. This finding is concurrently with the findings from other countries (Haseeb 2011) this factor significantly affecting the time overrun as well as will significantly affect to cost overrun and ranked it as the third rank in construction industry in Pakistan. The information flow between all project team members was neither timely nor well organized and the decision-makers were not clearly identified.

84.4.2 The Effects of (IF) to Project Successful Completion

The consequences of (IF) to project successful completion are ranked based on average index values as shown in Table 84.9. The results from the table show that 4 out of 5 factors had average index value in the range of $3.50 < AI < 4.50$. The 5 significant effects include effects the project delivered on schedule time, effects the project delivered on dedicated cost, effects the project delivered with the satisfaction of the stakeholder of the project and effects the project delivered with the fulfillment of the technical specification of the project as well.

The (IF) affects the project to delivery on approved schedule time is ranked as the 1st consequences which caused the delay in implementation of project during its specific agreed in the contract and approved schedule date. However, there is slight disagreement between the respondent groups. Contractors, the owner placed this factor as 1st ranked while the consultant placed this factor as 2nd ranked.

Project completion delay, cost overrun happens about in every project except their effect contrasts from project to project. Through a development construction project, an occurrence of delay may happen from any of the factors identified with the enthusiasm of stakeholder of the projects which may influence antagonistically

Table 84.9 Ranking of the effects of (IF) to project successful completion on time

The effects of the negatively influential Factors to project successful completion	Overall		Owner		Consultant		Contractor	
	AI	Rank	AI	Rank	AI	Rank	AI	Rank
1. Negatively affects the project delivered on schedule time	3.74	1	3.78	1	3.69	2	3.73	1
2. Negatively effects the project delivered on dedicated cost	3.71	2	3.69	2	3.70	1	3.72	2
3. Negatively affects the project delivered with satisfaction of the stakeholder of the project	3.65	3	3.67	3	3.61	3	3.63	3
4. Negatively affects the project delivered with fulfillment of the technical specification of the project	3.53	4	3.54	4	3.51	4	3.49	4
5. Negatively affects the project delivered with meeting all the project objectives/requirements	3.49	5	3.52	5	3.48	5	3.46	5

by bringing on unsettling influence of work, loss of profitability, loss of time, cost invades, claims or here and there end of agreements (Tumi et al. 2009; Haseeb 2011).

The (IF) affects the project to delivery on the dedicated cost is ranked as the 2nd consequences which caused increasing the dedicated cost of project during its life cycle. However, there is slight disagreement between the respondent groups. Contractors, the owner placed this factor as 2nd ranked while the consultant placed this factor as 1st ranked. Cost overrun is a noteworthy issue that happens all inclusive including Yemen. Cost increasing is come about because of different elements which are fundamental to recognize for enhancing cost execution in development projects. Cost overrun is a worldwide wonder in the development business and once in a while activities are done inside the planned expense. The issue of cost overrun in development projects is exceptionally predominant in both created and developing countries yet this pattern is extremely serious in developing countries where these overwhelms at times surpass 100% of the foreseen cost as stated by the study of Azhar et al. (2008). Frimpong et al. (2003) in their worldwide investigation of development projects execution presumed that cost overwhelm is a noteworthy issue in the development business where 9 of 10 projects are confronted by these invades which regularly go between 50 and 100%.

The (IF) affects the project to delivery with the satisfaction of the stakeholder of the project is ranked as the 3rd consequences. However, there is a full agreement between the respondent groups. Contractors, the owner and consultant placed this factor as 3rd ranked. Various distinctive interests can be influenced, contrarily, over the span of a major construction project. Neglecting to address and meet the worries and desires of the stakeholders included has brought about numerous projects disappointments and failure. Construction development projects include various stakeholders, and their fulfillment could straightforwardly impact the execution of subsequent projects. Driven by a yearning to enhance project achievement successfully, the basic fulfillment components relevant to the development administration procedure ought to be recognized. In all actuality stakeholder fulfillment is the basic analysis of worth creation yet we have almost no direction not to mention apparatuses and strategy to help us measure stakeholder gratefulness (Heravi 2014). A project completion can be measured customarily by three components, which are cost, time and quality.

The (IF), negatively affects the project to delivery with fulfillment of the technical specification of the construction project is ranked as the 4th consequences. However, there is a full agreement between the respondent groups. Contractors, owner and consultant placed this factor as 4th ranked. Specifications, an essential segment of construction development documentation, diagram the levels of quality and the standards to be met in construction development of the project. Specifications characterize the subjective prerequisites of materials and items to guarantee that everybody comprehends the item necessities. Whether you are a planner, engineer, architect or some other outline advisor in the field of construction development projects, the most vital part of any projects past the drawings is the specifications. A complete very much archived detail is a protection to both the outline group and the proprietors to guarantee a complete and utilitarian project. In most all jurisdictions the determinations (project specification manual) holds more legitimateness than the real drawings.

The (IF) negatively affects the project to deliver with meeting all the project objectives/requirements is ranked as the 4th consequences. However, there is a full agreement between the respondent groups. Contractors, owner and consultant placed this factor as 5th ranked. A project is a one of a kind, transient attempt, embraced to accomplish arranged targets, which could be characterized as far as yields, results or advantages. A project is generally considered to be a win in the event that it accomplishes the targets as per their acknowledgment criteria, inside a concurred timescale and spending plan. Interest in powerful project administration will have various advantages to both the host association and the general population required in conveying the project. Analyse extent of every project, highlight risks and suppositions, dole out obligations and possession, characterize project destinations and basic achievement components, devise a conveyance plan, illuminate all significant gatherings and screen/guarantee project conveyance. It will give a more noteworthy probability of accomplishing the fancied result, guarantee productive and best esteem utilization of assets and fulfill the contrasting needs of the project's stakeholders.

84.4.3 Research Limitations

Despite the fact that best endeavors were placed in this research and findings do make a huge commitment for construction industries projects, this research has a few limitations. The remaining influential factors related to internal stakeholders include supplier, subcontractor and labour not stated in this study. All different reasons of variables that negatively affect project successful completion related to internal stakeholders and its effect on general project completion must be nitty gritty further which is the author's expected future for evaluating the effects of these factors identified with internal stakeholder of construction projects.

84.5 Conclusion

The result of analysis from this study can be said to be of awesome importance to the construction development projects. The dominant part of the respondents are completely required in the construction industry with at least years of construction experience, implying that the respondents have an abundance of learning and could supply the vital data on the inquiry conveyed in the surveys. Construction industries projects are to a great degree variable and affected by huge factors. An influential factor (IF) which negatively affects project success completion was created. The questionnaire was developed with the 37 factors perceived from literature review. Going before honest to goodness survey outline, pilot study was coordinated to check variables that influentially affecting project completion which identified from literature review in relevance with construction industry of Yemen. The pilot study resulted in the identifying of 33 significant factors which were considered for further study in Yemen construction industry. Modified questionnaire sets were distributed amongst owner, the consultant and contractor organization, this resulted in collecting 283 valid samples. Collected samples were analysed. As a results four groups as Consultant Related Factors (CONSRF) consisting of 9 causes, Contractor Related Factors (CONTRF) consisting of 9 causes, Owner Related Factors (CONTRF) consisting of 8 causes, Designer Related Factors (DESRF) consisting of 7 causes. The samples were analysed with average index method to assess the ranking of factors that influentially affecting project successfully completion. The top five significant factors include the money cash flow during construction, the conflict between owners and other parties, delay in running bill payments for the contractor, poor project management, and slow decisions from owner. The effect of (IF) negatively influences to project successful completion as regard to time overrun, cost overrun, negatively affect to satisfaction of the stakeholder, negatively affect to technical specification and not fulfillment all meeting all the project objectives/requirements.

Acknowledgements This work was supported in part by Universiti Tun Hussein Onn Malaysia under Grant No. 1322 to Dr. Ng Kim Soon.

References

Abdullah, M. R. (2010). *Significant causes and effects of construction delay*. Master thesis, University Tun Hussein Onn Malaysia

Ahmed SA (2014) Evaluation of Risk Factors affecting Time And cost Of Construction Projects in Yemen. International journal of management 4(5):168–178

Al-Ansi NA (2012) Evaluating sites and services policy as approach to afford housing for low-income people in Yemen: case study. Journal of Science & Technology. 17(2):1–10

Ali AS, Kamaruzzaman SN (2010) Cost performance for building construction projects in Klang valley. Journal of Building Performance 1(1):110–118

Al-Sabahi, M. H., Al-Hamidi, A. A., Ramly, A. & Rejab, K. M (2014). Exploring Criteria and Critical Factors for Governmental Projects Implementation in Yemen: A Case Study. *Journal of Surveying, Construction and Property (JSCP)*, 5(2). Pp.1–17

Assaf SA, Al-Hejji S (2006) Causes of delay in large construction projects. Int J Project Manage 24(4):349–357

Atkin B, Skitmore M (2008) Editorial: stakeholder management in construction. Construction Management and Economics 26(6):549–552

Azhar, N., Farooqui, R. U., & Ahmed, S. M. (2008). Cost Overrun Factors In Construction Industry of Pakistan. Paper presented at the *First International Conference on Construction,* In Developing Countries (ICCIDC–I) “Advancing and Integrating Construction Education, Research & Practice”

Briner W, Hastings C, Geddes M (1997) Project Leadership. Long Range Plan 30(1):142

Cleland DI, Ireland LR (1999) Project management: strategic design and implementation, vol 4. McGraw-Hill, Singapore

Doloi, H. (2013). Cost overruns and failure in project management: understanding the roles of key stakeholders in construction projects. *Journal of construction engineering and management*. Vol. 139, No.,pp. 267–279

Doloi H, Iyer KC, Sawhney A (2011) Structural equation model for assessing impacts of contractor’s performance on project success. Int J Project Manage 29(6):687–695

Doloi H, Sawhney A, Iyer KC, Rentala S (2012) Analysing factors affecting delays in Indian construction projects. Int J Project Manage 30(4):479–489

Fallahnejad MH (2013) Delay causes in Iran gas pipeline projects. Int J Project Manage 31 (1):136–146

Freeman, R. (1984). *Strategic management: a stakeholder approach*. Cambridge University Press

Frimpong Y, Oluwoye J, Crawford L (2003) Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study. Int J Project Manage 21:321–326

Haseeb, A. T. D. (2011). Causes and Effects of Delays in Large Construction Projects of Pakistan. Kuwait Chapter of Arabian. *Journal of Business and Management Review*. 1(4), pp. 18–42

Heravi Torbati, A. H. (2014). *Improving construction management: an investigation into the influences of effective stakeholder involvement on project quality outcomes.* Queensland University of Technology: Ph.D. Thesis

Kikwasi, G. (2013, February). Causes and effects of delays and disruptions in construction projects in Tanzania. *Australasian Journal of Construction Economics and Building* - Conference Series (Vol. 1, No. 2, pp. 52–59)

Li TH, Ng ST, Skitmore M (2013) Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: a fuzzy approach. Automation in construction 29:123–135

Memon, A. H., Rahman, I. A., & Azis, A. A. A. (2011). Preliminary study on causative factors leading to construction cost overrun. *International Journal of Sustainable Construction Engineering and Technology*, 2(1)

Meng X (2012) The effect of relationship management on project performance in construction. Int J Project Manage 30(2):188–198

Odeh AM, Battaineh HT (2002) Causes of construction delay: traditional contracts. Int J Project Manage 20(1):67–73

Olander, S. (2006). *External stakeholder analysis in construction project management.* Lund University, UK: PhD Thesis

Olander S (2007) Stakeholder impact analysis in construction project management. Construction Management and Economics 25(3):277–287

Olatunji, O. A. (2008). A comparative analysis of tender sums and final costs of public construction and supply projects in Nigeria. *Journal of Financial Management of Property and Construction*, 13(1)

PMI (2013) A guide to the project management body of knowledge (PMBOK). Fifth Edition, Project Management Institute (PMI)

Salazar-Aramayo JL, Rodrigues-da-Silveira R, Rodrigues-de-Almeida M, de Castro-Dantas TN (2013) A conceptual model for project management of exploration and production in the oil and gas industry: The case of a Brazilian company. Int J Project Manage 31(4):589–601

Stoney C, Winstanley D (2001) Stakeholding: confusion or utopia? Mapping the conceptual terrain. J Manage Stud 38(5):603–626

Sultan, B. M. (2005). *The construction industry in Yemen: Towards economic sustainability*. Queensland University of Technology: Ph.D. Thesis

Tumi, S. A. H., Omran, A., & Pakir, A. H. K. (2009, November). Causes of delay in construction industry in Libya. *The International Conference on Economics and Administration* (pp. 265–272)

Verbeke A, Tung V (2013) The future of stakeholder management theory: A temporal perspective. J Bus Ethics 112(3):529–543

Chapter 85
Investigating the Relationship Between Student Characteristics and Progression: An Archive Study

Josua Pienaar, Xianbo Zhao and Nadine Adams

85.1 Introduction

In Australia, the revised Higher Education Standards Framework focuses attention on Student Participation and Attainment which covers the education-related experiences of students from admission through to attainment of a certified qualification (s) (or part thereof). Within Standard 1.3, it is explicit that higher education institutions must focus on aspects of retention, progression and completion: "Trends in rates of retention, progression and completion of student cohorts through subjects of study are monitored to enable review and improvement", and "Students have equivalent opportunities for successful transition into and progression through their subject of study, irrespective of their educational background, entry pathway, mode or place of study" (Department of Education and Training 2014).

To satisfy Australian Government reporting requirements, the Student Progression Unit (SPU) is used to report progression to government departments (McInnis 2000; Dobson and Sharma 1993). Using the SPU as an organisational efficiency measure, it is possible to compare institutional performance. However, it is oversimplified to analyse student progression without consideration into student characteristics. This is because different students usually hold different characteristics, which are likely to influence their progression. Therefore, this study attempts

J. Pienaar
School of Engineering and Technology, Central Queensland University,
Wayville 5034, SA, Australia

X. Zhao (✉)
School of Engineering and Technology, Central Queensland University,
Sydney 2000, NSW, Australia
e-mail: b.zhao@cqu.edu.au

N. Adams
Academic Learning Services Unit, Central Queensland University,
Rockhampton 4702, QLD, Australia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_85

to determine the relationship between students' characteristics and progression through an archive study of Built Environment student records at Central Queensland University (CQUniversity). As few studies have investigated the effect of students' characteristics on their progression, this study can contribute to the literature relating to student progression.

85.2 Literature Review

85.2.1 Built Environment Education in Australia

Historically, the Built Environment consisted of blue collar occupations, relying on tradespeople and the development of apprentices as part of succession planning (Gimesy 1992). The shift of Built Environment training into higher education has come about as a result of increased technical requirements and professionalisation. The increased technical requirements are encapsulated in the development of building codes (Building Code of Australia now known as the National Construction Code), various Australian Standards (more than 4000 standards exist in Australia) as well as more stringent enforcement of local building regulations. Consequently, a technical skill, while necessary, is not sufficient to satisfy the requirement of the modern industry. More than anything, the introduction of Built Environment academic programs in 1958 signalled that the industry recognised the need for both technical and management skillsets (Gimesy 1992; Tyler 2001). In terms of disciplines within higher education, the Built Environment is relatively young (Du Toit and Mouton 2012; Savage et al. 2010; Hughes 2010; Knight and Ruddock 2009; Griffiths 2004). It has been seen as an applied science (Knight and Ruddock 2009); as a discipline it is more focused on the application of existing knowledge and on the training of professionals rather than research (Du Toit and Mouton 2012). Research into the Built Environment discipline is produced less frequently than in other related disciplines including Engineering (Pienaar et al. 2013). The research-teaching nexus in the discipline appears out of balance with a steady influx of 'pure academic researching' lecturers while industry practitioners and industry-aligned learning outcomes are sidelined. Many areas that must be targeted for research and improvement in the Built Environment in Australia have been identified as the further development of research, of academic-industry linkages and the improvement of the student experience (Sher 2010).

From 2000 onwards the Built Environment education and the industry had to react to many changes in political, educational and economic policy in response to events such as the global financial crisis (De Valence and Runeson 2011; McGrath-Champ et al. 2011; Yorston and Chileshe 2014). In this period, Built Environment education underwent changes in the development and delivery of programs (Pienaar et al. 2013; Davis and Savage 2009). In an attempt to reduce the geographical isolation felt by distance education Built Environment students (Croft et al. 2010), universities and delivery methods have become increasingly technology oriented and students are being required to partake in growing numbers of online engagement activities both synchronous and asynchronous.

While some research has been conducted in male dominated fields such as engineering and architecture programs in a face-to-face environment (McLaughlin and Mills 2010; Wall et al. 2006; Williams and Sher 2008), it is evident that the issue of progression specifically relating to the Built Environment, as a discipline area which is predominantly male and distance education, is under-researched and under-theorised and necessitates further investigation. Therefore, this study will focus on the issue of progression of the Built Environment students in a distance education environment.

85.2.2 Progression, Attrition and Retention

Generally speaking, progression is defined as a measure and indicator of a student's academic development (Hayward and Hoelscher 2011; Jeffreys 2007; Mooney et al. 2010). The Australian Government defines retention as 'students enrolled in an award (graduating) program in the following year, and not having graduated or taken an exit award in the first year of enrolment' (Department of Education and Training 2013). Attrition is defined as 'students not enrolled in an award (graduating) program in the following year, and not having graduated or taken an exit award in the first year of enrolment' (Department of Education and Training 2013).

Previous research highlights that there are contextual and background factors that serve as motivators for students (Chileshe et al. 2007; Kember et al. 2010). With Australia's former federal government's aim to equip 40% of all Australian 25–35 year-olds with bachelor degrees by 2025 (Gillard 2010), student attrition, retention and progression has come to the forefront of tertiary education discussions (Andres and Carpenter 1997; Carroll et al. 2009; Lowis and Castley 2008; Lui 2008). Student progression, attrition and retention are important for all educational institutions, and universities have been struggling to reduce student attrition for the last 40 years (Tinto 1975; Willcoxson et al. 2011; Godfrey et al. 2011; Moller-Wong and Eide 1997; Olsen 2008). Over the past two decades research in attrition and retention has emphasized the importance of identifying factors impacting progression and how to manage those factors (McInnis 2000; Jeffreys 2007; Thomas 2002; Lau 2003; Scott 2005; Robinson 2004; Berge and Huang 2004).

Student performance and institutional throughput influences reputation and funding and while research is a driver for educational institutions, the production of industry-ready graduates is a key requirement (Gonski 2011; David 2013; Love et al. 2001). Producing industry-ready graduates is a long standing aim of academic providers and professional organisations (Mitchell and Allen 2014; Kivunja 2014). With changes to how universities and educational institutions are funded and supported by governments, and the ways in which content is delivered nationally and internationally, it is more critical than ever for higher education to establish accessible contemporary academic programs, grow market share and retain students as part of operational survival (Porter 2015). Progression is an important component in higher education and training and it is in institutions' interest to promote progression (Hayward and Hoelscher 2011; Jeffreys 2007; Carroll et al. 2009; Burns 2011; Ewell et al. 2003; Kelly and Marshall 2012).

The Student Progression Unit (SPU) is a standardised measure recorded by all Australian Universities for each student. The SPU is calculated by comparing the Effective Full-time Student Load (EFTSL) passed with the percentage EFTSL assessed (Dobson and Sharma 1993; Powell 2002; Department of Education and Training 2014). EFTSL is a measure that indicates the notional proportion of the workload which would be applicable to a standard annual program for a student undertaking a full year of study in a particular year. An EFTSL constitutes the equivalent of one year of full-time study. For undergraduate students at CQUniversity, this equates to eight subjects (i.e. 8×6 units of credit = 48 units of credit). CQUniversity (2011) and the Australian Department of Education (Department of Education and Training 2014) define SPU as:

SPU = EFTSL Passed/EFTSL Assessed (excluding results not finalised)

The SPU is automatically calculated, cannot be recalculated and does not take academic workload or term of study into account. Specifically, a student who passed one of two subjects has the same SPU as a student that passed three of six subjects (provided that the subjects were equal in credit point value). Incomplete subject results do not affect the SPU, as only finalised results are used for the calculation of the SPU.

85.3 Methodology

The research on student progression has been overwhelmingly based on the analysis of teaching institution archive data, originally collected to enable reporting to funding bodies, most typically government departments of education (Sher 2010; Moodie 2007; Moodie and Wheelahan 2009; Wheelahan 2009). Hence, archive study was also performed in this study. The archive data, obtained through the CQUniversity Student Admissions and Management System and spanning a ten year period, were analysed in order to explore the relationships between student characteristics recorded in the database and the SPU for Built Environment students at CQUniversity. The data covered all students studying Built Environment programs from the start of Term 1 2000 to the end of Term 3 2010.

Baradwaj and Pal (2012) found that before knowledge could be extracted from archived data through data mining, it has to be prepared. Specifically, after removing of personal identifiers to retain individual anonymity, 13,751 lines of data were reduced to a single data line for each of the 1547 students. A total of 74 data fields were identified and 44 of them were required to satisfy the reporting requirements of government and other funding bodies. Finally, the clusters of variables that essentially repeated the same information were replaced by a single

Table 85.1 Demographic characteristics of the archive data population

Demographic characteristics	N	%	Demographic characteristics	N	%
Gender			*Academic program*		
Male	1198	77	Associate degree of building surveying	440	28
Female	349	23	Bachelor of building surveying and certification	131	8
Age (in years)			Bachelor of construction management	395	26
15–24	619	40	Associate degree of building design	139	9
25–34	502	32	Bachelor of building design	442	29
35–44	276	18	*Nationality*		
45–54	139	9	Australian	1317	85
55–74	11	1	Other	230	15
Language spoken at home					
English	1469	95			
Other	78	5			

variable, which reduced the final data set for analysis to 17 variables and one anonymous identifying number for each student. These variables can represent the individual characteristics of students and their effects on SPU were analysed. However, because of the word limit, only part of the results is reported here. Table 85.1 shows the demographics and the academic program characteristics of the archive data population. The population comprised 1547 students in different stages of academic study.

85.4 Results and Discussion

One-way analysis of variance (ANOVA), followed by post hoc tests of Tukey HSD and Dunnett T3, was used to test for statistical significance at the 0.10 level. The results are shown in Table 85.2.

Built Environment academic programs are typically male dominated (David 2009; Hackett et al. 1992; Perrone et al. 2001). The male to female percentage in the archive records is higher than the national average for the Built Environment. A one-way ANOVA between subjects (an ANOVA with only two groups is mathematically equivalent to independent sample t-test) was conducted to compare the effect of gender on the SPU. The results indicated that gender had no significant effect on SPU [$F(1, 1545) = 0.031$, $p = 0.859$].

CQUniversity's main campus is located in Rockhampton, Queensland, on the Tropic of Capricorn, about halfway between Brisbane and Cairns. The students were all distance students independent of their home location, as CQUniversity does not deliver these programs on a face-to-face basis. The majority of students

Table 85.2 Student characteristics and SPU

Category	SPU	N	p-value
Gender			
Male	0.586	1198	0.859
Female	0.580	349	
Location			
Metropolitan	0.568	811	0.066
Regional	0.61	500	
Socioeconomic status			
High	0.559	241	0.304
Medium	0.576	856	
Low	0.607	375	
Academic credit transfer			
No credit transfer	0.496	1086	0.000
Internal credit transfer	0.738	51	
External credit transfer	0.782	380	
Both internal & external	0.81	30	
Country of birth			
Australia	0.575	1317	0.238
Other	0.608	230	
Academic program			
Associate degree of building surveying	0.678	440	0.000
Bachelor of building surveying and certification	0.723	131	
Bachelor of construction management	0.523	395	
Associate degree of building design	0.543	139	
Bachelor of building design	0.503	442	

(62%) resided in metropolitan areas. The mean score for those in metropolitan areas was different from those in the regional areas. The p-value of a one-way ANOVA was 0.066 and significant at the 0.10 level. Thus, the results showed that geographical location had a significant impact on the SPU and that students in regional areas perform better than those in metropolitan areas.

An individual's socioeconomic status (SES) depends on a combination of variables including employment or occupation, education, wealth, income, and place of residence (Australian Bureau of Statistics 2013). The majority of students were classified as Medium SES (58%) followed by 26% classified Low SES and 16% as High SES. A one-way ANOVA between subjects was conducted and the results implied that there was no significant difference between the SES groups at the 0.10 level [$F(2, 1469) = 1.192$, $p = 0.304$].

Within the two categories of internal (CQUniversity) and external (from another university) transfers, there are four main groups: (1) those students with no credit transfer; (2) those students with internal credit transfer; (3) those students with external credit transfer; and (4) those students who have both internal and external credit transfers. The majority of students (70%) have no credit transfer, and 25% of the students successfully applied for external credit transfer. There was a highly significant difference between groups [F (3, 1543) = 58.801, p = 0.000]. Post hoc comparisons using the Dunnett T3 test indicated that students with no credit transfers had a significantly lower SPU score than those with either an internal or external credit transfer. Those students transferring previous academic experience and credibility may do so with a specific goal in mind i.e. achieving the qualification. Those with academic credits enrolled in staged industry licensed programs (specifically in Bachelor of Building Surveying and Certification) achieve higher SPUs than those without credit or in other programs. Although transferred credit is not included in the determination of SPU, it indicates a level of determination and experience not encountered in those students without it.

In terms of country of birth, students born in 47 different countries were represented in the archive study. Australian born students represented 85% of the population. Students who were born overseas attained higher mean SPU scores than those who were born in Australia. However, the one-way ANOVA results suggested that country of birth had no significant effect on the SPU.

There are five academic programs in the Built Environment at CQUniversity focusing on three main disciplines: Building Design, Construction Management and Building Surveying. Students in the Building Surveying programs outperform those in the other degrees. A one-way ANOVA between subjects was conducted to compare the impact of the academic program on the SPU for the five qualifications. There was a significant impact of the academic program on the SPU at the 0.05 level [F (4, 1542) = 17.547, p = 0.000]. Post hoc comparisons using the Dunnett T3 test indicated that the mean SPU score for the Bachelor of Building Surveying program was significantly higher than those for the Bachelor of Construction Management, Associate degree of Building Design and Bachelor of Building Design programs. This finding may be because of the incentive to acquire the valuable staged professional licences, related to the Diploma, Associate degree and Bachelor levels, which gave the students the impetus and desire to complete the programs quickly. This finding may strongly suggest that how quickly a student wants to complete a program is likely to impact on SPU. However, the willingness to complete a qualification in order to open up additional employment opportunities is not the only motivation to progress more or less efficiently. For some students the need to earn an income whilst studying and, for others, the need to provide family care or support may have a greater priority than the efficiency level of their study progress. In addition, it could be that the content of subjects necessary to gain licences matches better to students' work experience or that legislatively linked subjects are taught or examined somewhat differently from other subjects, which may provide a better explanation of why students choosing these courses and subjects secure higher SPU scores.

85.5 Conclusions and Recommendations

By analysing the archive of 1547 Built Environment student records at CQUniversity, this study investigates the relationship between students' characteristics and progression. The SPU was used to measure the students' progression. The analysis results indicated that the students with academic credit transfers performed better in terms of SPU than those without, and that the students who were in the Bachelor of Building Surveying and Certification program received significantly higher SPU scores than those in other programs. In addition, geographical location had a significant impact on the SPU and that students in regional areas perform better than those in metropolitan areas. Furthermore, it was found that the students' gender, geographical location, socioeconomic status, and countries of birth did not significantly affect their SPU scores.

Despite achievement of objectives, this study involves some limitations. Firstly, the measurement of student progression is simply single dimensional and holding an institutional perspective. Also, the selection of student characteristics may not be exhaustive. Therefore, future research may take a multi-dimensional view of student progression that can really consider what students seek and achieve from vocationally-relevant programs in higher education. In addition, based on such a view, a new measurement of student progression could be developed, and the effect of student characteristics on it would be still worth investigation.

References

Andres L, Carpenter S (1997) Today's higher education students: issues of admission, retention, transfer, and attrition in relation to changing student demographics. Centre for Policy Studies in Education—University of British Columbia, Canada, p 58

Australian Bureau of Statistics (2013) Australian demographic statistics, A.B.o. Statistics, Editor. Australian Government, Canberra, Australia, p 56

Baradwaj BK, Pal S (2012) Mining educational data to analyze students' performance. Int J Adv Comput Sci Appl 2(6):63–69

Berge ZL, Huang Y (2004) A model for sustainable student retention: a holistic perspective on the student dropout problem with special attention to e-learning. Deosnews 13(5):1–26

Burns SM (2011) Predicting academic progression for student registered nurse anesthetists. Am Assoc Nurse Anesth J 79(3):193–201

Carroll D, Ng E, Birch D (2009) Retention and progression of postgraduate business students: an Australian perspective. Open Learn 24(3):197–209

Chileshe N, Haupt T, Fester F (2007) Assessing the readiness of building diplomates for the South African construction industry. J Edu Built Environ 2(1):31–59

Croft N, Dalton A, Grant M (2010) Overcoming isolation in distance learning: building a learning community through time and space. J Edu Built Environ 5(1):27–64

CQUniversity (2011) CQUniversity academic dashboard. https://radar.cqu.edu.au/ibmcognos/cgi-bin/cognosisapi.dll?b_action=xts.run&m=portal/main.xts&startwel=yes

David ME (2009) Diversity, gender and widening participation in global higher education: a feminist perspective. Int Stud Sociol Edu 19(1):1–17

David G (2013) Funding cuts a concern for all, in the Australian. News Corp Australia, Canberra, Australia, p 1

Davis R, Savage S (2009) Built environment and design in Australia: challenges and opportunities for professional education. In: 20th annual conference for the australasian association for engineering education. Engineers Australia, Adelaide, Australia p 795

De Valence G, Runeson G (2011) On the state of the building industry after the GFC and the Euro crisis. Australas J Constr Econ Buil 11(4):102–113

Department of Education and Training (2013). 2013 Appendix 4—Attrition, success and retention. http://docs.education.gov.au/documents/2013-appendix-4-attrition-success-and-retention

Department of Education and Training (2014) Higher education student—elements by file. http://heimshelp.education.gov.au/sites/heimshelp/2015_data_requirements/pages/highereducationstudent_elementsbyfile

Department of Education and Training (2014) Higher education standards framework, education, editor. Australian Government, Canberra, Australia p 40

Dobson I, Sharma R (1993) Student progress: a study of the experience in Victorian tertiary institutions. J Tert Educ Adm 15(2):203–211

Du Toit JL, Mouton J (2012) A typology of designs for social research in the built environment. Int J Soc Res Methodol 16(2):125–140

Ewell PT, Schild PR, Paulson K (2003) Following the mobile student—can we develop the capacity for a comprehensive database to assess student progression. National Centre for Higher Education Management Systems, Indianapolis, USA, p 140

Gillard J (2010) Julia Gillard national press club address. Australian Commonwealth, GovernmentCanberra, Australia

Gimesy O (1992) Built from nothing: a history of the building industry in Australia. Building Careers Resource Centre of Australia, Carlton, Australia p 257

Godfrey E, Aubrey T, King R (2011) Who leaves and who stays? retention and attrition in engineering education. Eng Edu J High Edu Acad Eng Subj Centre 5(2):26–40

Gonski D. et al. (2011) Review of funding for schooling. Department of Education (DET), Canberra, Australia, p 319

Griffiths R (2004) Knowledge production and the research–teaching nexus: The case of the built environment disciplines. Stud High Educ 29(6):709–726

Hayward G, Hoelscher M (2011) The use of large-scale administrative data sets to monitor progression from vocational education and training into higher education in the UK: possibilities and methodological challenges. Res Comp Int Edu 6(3):316–329

Hackett G et al (1992) Gender, ethnicity, and social cognitive factors predicting the academic achievement of students in engineering. J Couns Psychol 39(4):527–538

Hughes W (2010) Built environment education, research and practice: integrating diverse interests to make an impact. West Africa built environment research (WABER) conference. University of Reading, Accra, Ghana, pp 1–8

Jeffreys MR (2007) Tracking students through program entry, progression, graduation, and licensure: assessing undergraduate nursing student retention and success. Nurse Educ Today 27 (5):406–419

Kelly K, Marshall C (2012) Prediction of engineering student progression from entrance data. In: 29th international manufacturing conference. University of Ulster, Belfast, Northern Ireland, United Kingdom p 9

Kember D, Ho A, Hong C (2010) Initial motivational orientation of students enrolling in undergraduate degrees. Stud High Educ 35(3):263–276

Kivunja C (2014) Do you want your students to be job-ready with 21st century skills? change pedagogies: a pedagogical paradigm shift from Vygotskyian social constructivism to critical thinking, problem solving and siemens' digital connectivism. Int J High Edu 3(3):81–92

Knight A, Ruddock L (2009) Advanced research methods in the built environment. Wiley, London, United Kingdom p 256

Lau LK (2003) Institutional factors affecting student retention. J Edu 124(1):126–136

Love PED, Haynes NS, Irani Z (2001) Construction managers' expectations and observations of graduates. J Manag Psychol 16(8):579–593

Lowis M, Castley A (2008) Factors affecting student progression and achievement: prediction and intervention. A two-year study. Innovations Edu Teach Int 45(4):333–343

Lui S (2008) Student interaction experiences in distance learning courses: a phenomenological study. Online J Distance Learn Adm 11

McInnis C. et al. (2000) Non-completion in vocational education and training in higher education: a literature review commissioned by the Department of Education, Training and Youth Affairs. Research and Evaluation Branch report. Canberra, Australia. Australian Government, Department of Education, Training and Youth Affairs p 90

McGrath-Champ S, Rosewarne S, Rittau Y (2011) From one skill shortage to the next: the Australian construction industry and geographies of a global labour market. J Ind Relat 53 (4):467–485

McLaughlin P, Mills A (2010) The best of both worlds—how vocational education can enhance university studies in construction management. Res Post-Compulsory Edu 15(1):117–126

Mitchell AM, Allen S (2014) A qualitative analysis of the curriculum for career-ready graduates from the perspective of academics and business professionals: China, Europe and the United States. J High Edu Theory Pract 14(1):100–117

Moller-Wong C, Eide A (1997) An engineering student retention study. J Eng Educ 86(1):7–15

Mooney O et al (2010) A study of progression in Irish higher education—a report by the higher education authority. Dublin, United Kingdom, p 92

Moodie G (2007) Regulating 'university' and degree-granting authority: Changing of the guard. J High Edu Policy Manage 29(1):103–117

Moodie G, Wheelahan L (2009) The significance of Australian vocational education institutions in opening access to higher education. High Edu Q 63(4):356–370

Olsen A (2008) Staying the course: retention and attrition in Australian universities. Australian Universities International Directors' Forum, Hong Kong, China, p 16

Perrone KM, Sedlacek WE, Alexander CM (2001) Gender and ethnic differences in career goal attainment. Career Dev Q 50(2):168–178

Porter S (2015) To MOOC or Not to MOOC: how can online learning help to build the future of higher education? First edn. Chandos Publishing, London, United Kingom p 156

Powell TC (2002) The philosophy of strategy. Strateg Manag J 23(9):873–880

Pienaar J, Adams N, Dekkers A (2013) Building a sturdy foundation–creating an engaging first year course that prepares a diverse student demographic for an undergraduate built environment programme. In: 16th international first year in higher education conference. First Year in Higher Education, Wellington, New Zealand

Robinson R (2004) Pathways to completion: patterns of progression through a university degree. High Educ 47(1):1–20

Savage SM, Davis RM, Miller E (2010) Professional education in built environment and design—a report prepared for the Australian learning and teaching council (ALTC). Australian Learning and Teaching Council, Strawberry Hills, Australia, p 151

Scott D (2005) Retention, completion and progression in tertiary education in New Zealand. J High Edu Policy Manage 27(1):3–17

Sher W et al. (2010) Opportunities and challenges for construction education in Australia. In: 18th Conseil International du Bâtiment (CIB) World Building Congress Conseil International du Bâtiment (CIB), Salford, United Kingdom, p 118

Thomas L (2002) Student retention in higher education: the role of institutional habitus. J Edu Policy 17(4):423–442

Tinto V (1975) Dropout from higher education: a theoretical synthesis of recent research. Rev Edu Res 45(1):89–125

Tyler PJ (2001) To provide a joint conscience: a jubilee history of the Australian institute of building, first edn. The Australian Institute of Building, Canberra, Australia p 152

Wall J, Ahmed V, Smit D (2006) Addressing the lifelong learning needs of construction professionals using technology facilitated learning. J Edu Built Environ 1(2):57–69

Wheelahan L et al (2009) Higher Education in TAFE. NCVER Monograph Series 01/2009. In: *N*CVER Monograph Series. National Centre for Vocational Education Research (NCVER), Adelaide, Australia, p 60

Willcoxson L, Cotter J, Joy S (2011) Beyond the first-year experience: the impact on attrition of student experiences throughout undergraduate degree studies in six diverse universities. Stud High Educ 36(3):331–352

Williams A, Sher W (2008) An intervention strategy to support first year Engineering and Built Environment students through remote mentoring strategies. In: IADIS international conference e-Learning 2008. Amsterdam, Netherlands, pp 76–82

Yorston N, Chileshe N (2014) Lessons learned from building the education revolution (BER) program by the South Australia construction firms. In: 30th annual association of researchers in construction management (ARCOM) conference. Association of Researchers for Construction Management, Portsmouth, United Kingdom, p 10

Chapter 86
Key Parameters on Financial Loss of Construction Accidents in Hong Kong Construction Industry

Kai-Chi Ying, Guomin Zhang and Sujeeva Setunge

86.1 Introduction

Recently, construction could be regarded as a booming industry in Hong Kong. Continuous investment has been flown into the construction market since the commencement of various infrastructure projects and residential projects launched by the HKSAR (2007–2014). The Gross Domestic Product (GDP) attributed to the construction industry is steadily increasing (Census and Statistics Department, Hong Kong Special Administrative Region 2013). Expenses on construction safety and employing safety personnel have been increased as well. Despite this effort, the number of construction accident was still high.

Loss due to construction accidents may simply be classified as direct and indirect losses (Elias et al. 2012; Haupt and Pillay 2016). By reviewing the direct and indirect expenses caused by the construction accidents, previous researchers gained valuable achievement in knowledge and analysis about construction accidents in different aspects. This paper aims at presenting financial loss due to construction accidents. It formulates measures of construction industry from year 2007–2012 in Hong Kong.

K.-C. Ying (✉) · G. Zhang · S. Setunge
School of Engineering, RMIT University, Melbourne, Australia
e-mail: kc_ying@vtc.edu.hk; s3361735@student.rmit.edu.au

G. Zhang
e-mail: kevin.zhang@rmit.edu.au

S. Setunge
e-mail: sujeeva.setunge@rmit.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_86

86.1.1 Background of the Study

Construction accidents not only affect the progress of construction projects, but also result in cost implications such as delay claims, compensation claims from the accident victims and overtime cost claim owing to extra time spent and administrative work from the crew. As construction site is a place crowded with labour, machine plant and various building materials, accident lead to not only injuries or death of victim but also much more consequences following. Injuries or deaths of the workers result in unavoidable statutory compensation according to the Labour Ordinance. Besides, accidents may also lead to a reduction of morale and available labour force. For death case, it means a loss of life which implies a direct and permanent loss of manpower and also affects the family of victim; for the injury case, it means a temporary loss of manpower as the victims may need to take long sick leave for recovery. The reduced workforce may in turn affect the project progress. Furthermore, as accident often leads to suspension of works or even cease of work due to investigation and administrative work from the government task-force, such as the Labour Department, Police and rescue force, cost implication due to the suspension should not be overlooked. There are various kinds of financial loss caused by construction accident including personnel loss, equipment loss, plant loss, material loss and idle of machine and equipment. In short, accident has induced costs in different aspects.

This paper is going to investigate the key parameter of financial loss caused by construction accidents in Hong Kong based on the information collected through a series of structured interviews conducted from June to December 2013. 949 accident cases have been collected from 117 projects for analysis. The findings, the regression model and its validation assessment will be presented in this paper.

86.1.2 Literature Review—Costs in Accident

Accident induces costs no matter direct or indirect cost. Researchers investigated costs induced by construction accidents. As one of the pioneers in accident cost studies, Heinrich indicated that the ratio between indirect and direct costs is 4:1 (Coble et al. 2000). Researchers further explained about cost of safety and cost of injuries. They explained that costs of safety include all types of training, testing, safety incentive, staffing for safety, personal protective equipment and safety programs where some researchers are classified as safety investment. They also pinpointed that cost of injuries include costs associated directly and indirectly. Indirect costs are related to medical case injuries and restricted work/lost in workday. Researchers elaborated what is direct cost and indirect cost. They have discovered that at least 19 types of indirect costs could be raised by an accident. The following sections are going to discuss different costs caused by accidents (Hinze and Appelgate 1991).

86.1.2.1 Financial Cost

The UK Health and Safety Executive reported and presented the costs of workplace fatalities and injuries in Britain (Health and Safety Executive 2015) defined that financial costs, which are equal to direct costs, are the summation of all payments that have to be made or income/production that is lost including productivity costs, health and rehabilitation costs, administrative and legal costs and compensation.

86.1.2.2 Insured and Un-Insured Cost

Rowlinson (2003) explained about insured and un-insured cost in construction accidents. Insured cost means that the contractor bought insurance for the project. The insured cost includes employers' liability, public or third party liability and contractor's all risk policies. In Hong Kong, according to the Employee's Compensation Ordinance, Chapter 282, an employer is liable to pay compensation in respect of injuries sustained by his employees as a result of an accident arising out of and in the course of employment; or in respect of occupational diseases specified in the Ordinance suffered by the employees. An employer must be in possession of a valid insurance policy to cover his liabilities both under the Employees' Compensation Ordinance and at common law for the work injuries for his employees. This Ordinance covered workers from all industry. Workers have been protected by the Ordinance as it is compulsory for all contractor companies to pay for that Insured cost. Once accident happened, insurance company needs to pay for the injury compensation. If the contractor does not buy the insurance for the worker, then the contractor will become the one to bear all liability and uninsured cost.

In Hong Kong, the contractors are responsible for the work insurance and third party insurance (HKSAR 1999). Workers are sheltered under the insurance scheme. In case of an accident or injury happened, the insurance company will settle the claims. If a contractor does not possess a valid insurance policy to cover its liabilities for the work injuries for its workers, it is illegal and the contractor needs to pay directly to the victims. Therefore, the payment claims are either paid by the insurance companies or the contractors themselves. It is the contractor's obligation to insure according to the General Condition of Contract (HKSAR 1999). It is believed that all construction projects in Hong Kong should be insured.

86.1.2.3 Direct and Indirect Cost

Accident induces direct and indirect costs. Direct costs of accidents include sick leave payments, employee's compensation payments, personal injury claims, public liability claim, repair of damage to buildings, repair of damage to plant and equipment, replacement of products and overtime payment (Rowlinson 2003). Hinze and Appelgate (1991) pinpointed and listed out 5 main items of the direct cost of construction accident, namely medical cost, indemnity, general liability, miscellaneous and other.

Henrich listed out 11 items in indirect costs of accident (Heinrich 1980), which include: cost of time lost of injured employee, cost of time lost of other employees who stop work, cost of time lost by foremen, supervisors or other executives, cost of time spent on the case by first-aid attendant and other staff, cost due to the damage of machinery, tools, property and materials, incidental cost due to interference with production, cost to continue paying the wages of the injured worker, loss in profit due to reduced worker productivity, loss in profit due to idle equipment, cost incurred because of subsequent injuries partially caused by the incident and cost of overheads. Coble et al. (2000) listed out indirect costs due to medical case injuries and costs related to restricted work/lost workday injuries.

Hinze J. and Appelgate L. also listed out 19 items about indirect costs of construction accident. These 19 items are: injured worker (Loss of productivity on day of injury, follow-up treatment and resuming work), crew of injured worker (Assisting injured worker, completing additional work due to accident, loss of productivity due to accident and inspection), crew in vicinity of accident due to watching events and discussing accident, replacement worker (Reduced productivity of the replacement worker, training of the replacement worker, cost of transporting injured worker), supervisory and administrative (other staff need to spend time on assisting the injured worker, investigating the accident, preparing the reports, time with the media and the project owner, time with the regulatory inspector), damaged property (repairing damage and material damage), and impact cost. Researchers did not argue about concept raised by accidents (Hinze and Appelgate 1991).

Teo and Feng (2011) have summarized the factors illustrated by scholars in previous accident cost researches. Feng (2011) further reviewed the factors affecting the workplace accident costs of building projects. According to Feng et al. (2015), there were 13 possible components in Singaporean practice which will lead to loss in productivity. These 13 possible components are: (1) the injured worker; (2) crew of injured worker; (3) other workers in vicinity of accidents; (4) investigation or inspections as a result of the injury; (6) replacement of injured worker; (7) damaged equipment or plant; (8) Stop Work Orders (SWO); (9) cost of supervisory or staff effort; (10) transportation of injured worker; (11) additional work required; (12) consumption of the first-aid materials and (13) additional benefits to the injured worker beyond the Work Compensation Act (WCA). The consumption of the first-aid materials can be regarded as replacement or renewal of materials where sometimes will be defined as “other cost items”. In Hong Kong, as there is no similar requirement of additional benefit from the WCA, this point will not be referred in this study.

Tang et al. (2004, 2007), and Nadeem et al. (2009) investigated accident cost on contractor for construction projects in the Hong Kong construction industry. These include day loss of injured person and his/her percentage of disability, any amount of compensation for sympathy money, equivalent loss after resuming work, medical services and expenses, fines & legal expenses, time lost of other employees such as site agent, engineer, foreman, other labour, loss in plant and equipment, damaged material or finished work, idle plant or machinery and other costs items. Tang's concept is going to be further elaborated in this paper.

86.1.2.4 Other Costs

Apart from safety management cost, preventive cost for safety, researcher introduced pain, suffering and loss of amenities (PLSA) as social costs in construction accident by De Saram and Tang (2005) (Rowlinson 2003).

In summary, costs of safety should be read as "safety investment" and "financial loss of accident" to prevent discrepancy or misunderstanding. There is no argument among various researchers in terms of direct cost or indirect cost except the interpretation of various cost items; some researches have more interpretation but others get less. Therefore, financial loss of accident can be expressed as {Day loss, Sympathy payment, equivalent loss after resuming work, Hospitalization expenses, medical expenses, fines & legal expenses, lost time of other employees, loss in plant & equipment, damaged material or finished work, idle plant & machinery and other costs items}.

86.2 Methodology (Data Collection)

Accident costs are the summation of all accident expenses after accident happened. Accident costs have been suffered by contractors as well as insurance companies. As it is compulsory for the contractor to insure for the project and their employee (HKSAR 2012), it is believed that the cost expenses on contractor are mainly borne by insurance companies. The costs that induced by accident and used for survey study are listed out as follows:

Salary loss (C1): Loss is estimated by day of absence (C1a) x salary of victim (C1b). For example, if the daily salary of victim is HK$1000 and number of absence day is 10, the salary loss can be easily calculated as HK$10,000.

Loss from injured person after resuming work (C2): The effective and workdone of victim is believed to be reduced after his resuming work. The equivalent loss is estimated by (Day loss * 1/20 + % of Disability) * (Wage per day) (Tang et al. 1997).

Hospitalization Expenses (C3): Hospitalization expenses (C3a) is depended on number of day that the victim stayed at hospital. In Hong Kong, Hong Kong resident costed HK$100 per night.

Medical Expenses other than hospitalization (C4): Medical expenses (excluding hospitalization expenses) (C3b) and others (transportation costs to clinic) (C3c) are expected to be recorded to find out the real costs on medical services & expenses.

Fines & Legal Expenses (C5) including fine by court (C5a), solicitor Fees (C5b) and Others cost on legal expenses (C5c) are expected to be recorded to find out the total expenses on compensation for the victim or relative output in legal expenses.

Time Lost of other employees (C6): When an accident happened, time has been spent by other employees in assisting the injured person. After the accident, additional administrative works or investigation may be required and it induces time and costs expenses. The cost was estimated by the cost expenses, monthly wages * time incurred of relevant staff such as site agent, site engineer, foreman and other laborers. (Nadeem et al. 2009; Tang et al. 1997, 2004, 2007).

Equipment or Plant loss (C7): It is the cost expenses if the accident induces damaged/replacement cost of plant, repairing cost or others this might easily understandable as repair cost or loss after accident.

Damaged material or finished work (C8): It is the cost expenses if the accident induces damage to material, and finished work or others. Similar to (C7), the damaged material or finished work can be estimated as repair or undo cost.

Idle machinery/equipment (C9): It is the cost expenses if the accident induces machinery or equipment idle in time. The cost is estimated by the daily hired wage of plant * number of idle time. The cost expenses are provided by the interviewee.

Other costs items (C10): It is the cost expenses if the accident induces other expenses which have not yet been counted under other previous items. For example, first-aid treatment, assessing/rescheduling work activities, cleaning up site, resume work up to standard, reassuring clients or others (Haupt and Pillay 2016).

According to Feng et al. (2015), 13 components have been considered in his Singaporean study. Additional benefits to the injured worker beyond the Work Compensation Act (WCA) is unique in Singapore, these two components have been extracted away from this study. Furthermore, consumption of the first-aid materials has been usually considered in safety investment as replacement which has been put into other cost items. In Hong Kong, there is no Stop Work Orders (SWO) but similar item named Ceased Work Orders issued by the Labour Department. The Ceased Works Orders indeed reduce the site productivity, lower morale of workers and other issues are counted as other costs items (C10). There are 10 components used in the Hong Kong study. Financial loss is the summation of all cost components.

86.2.1 Survey Samples

Comprehensive structured interviews were conducted from Jun–Dec 2013. The interviewees are all experienced construction expects. 38 constructions experts were invited for interview. All interviewees get at least Higher Diploma qualification and at least five years' working experience in the construction industry.

This is recommended that the more the sample number, the more accurate of regression model can be drawn. In Feng (2011) research study, 39 of total 234 contractor companies were used to determine the safety performance of building projects in Singapore. This is meaningless to query the number of sampled project since the contract sum of project varies between projects. Else, this is understandable to use the percentage of contract sum of total construction output as reference. The study summarized about 10% of construction projects from Apr 2007 to Mar 2012 which is representable to overall construction market (Tang et al. 2004).

86.2.2 Data Findings and Analysis

117 projects and 949 accident cases have been recorded in the survey study. These projects contributed to about 10% of the total contract sum of construction projects from April 2007 to March 2012. Respondents are not necessary to disclose their company and project name as some confidential information, accident number, company safety scheme or strategy may not be feasible to be disclosed. Besides, as some accident cases might involve personal information or some cases are under legal or prosecution process, these are not possible to be shown. Confidentiality was assured to the respondents verbally and confirmed by the RMIT University ethic committee.

Contract sum of sampled project are varied with the scale of project, type of project, difficulties and duration of the project. The projects including civil engineering project, structural building construction project, foundation project, Alteration and Addition (A&A) project, demolition project, buildings works, rehabilitation project and roadwork project. The variation type of project is good to represent the real situation in Hong Kong industry.

86.2.3 Research Findings

About 10% of the contract sum of construction projects from Apr 2007 to Mar 2012 has been studied. Researcher agreed that 10% of contract sum of construction projects is good enough to represent a significant sample for studies (Tang et al. 2004). Ratio of sampled accident is 5–8% of actual reported accident (Ying et al. 2015). The amount of financial loss of accident has been recorded. The samples are consistent and reliable to present the real construction situation in Hong Kong.

According to sampled project, mean age of victim is 40 and standard deviation is 8 respectively. It reflected that the victim in Hong Kong construction market is mainly middle-aged. Their mean salary is around HK$600. Most victims are semi-skilled workers.

In Hong Kong, hospital payment of Hong Kong resident is only HK$100 per night. It includes all medical expenses and surgery charge. It is understandable that injury of victim in each accident is different and hard to predict the day of hospitality. It provided at least the concept of social expenses in medical service of construction accident for further study. Daily salary of site agent, engineer, foreman and other labor are used as reference for determining the total loss of other staff. The estimated formula is reference with (Tang et al. 1997).

Variation of equipment loss, materials loss, loss due to idle time and other loss are huge as the cost implication is often depended on different type and scenario of accident, as sometimes accident involve neither equipment nor materials or other losses.

86.2.4 Regression Model

Total 939 valid data has been used for regression model. Computer programme, Statistical Package for the Social Sciences (SPSS) version 24 was used for analyzing the data.

After scatterplot studying and correlationship checking, the model is in a linear pattern. Financial loss has significant relationship between independent variable: salary loss of victim, hopsititation expenses, other expense, idle cost of site, materials loss, equipment loss due to accident and salary of other workforce. The linear regression is known as below:

$$\begin{aligned} Y = \underset{\text{(Salary loss)}}{0.817X_1} + \underset{\text{(hospitalization)}}{61.672X_2} + \underset{\text{(Others loss)}}{1.007X_3} + \underset{\text{(Idle loss)}}{1.014X_4} \\ + \underset{\text{(Material loss)}}{0.94X_5} + \underset{\text{(Equipment loss)}}{0.905X_6} + \underset{\text{(Salary of Others)}}{70.68X_7} + \underset{\text{(Constant)}}{583.61} \end{aligned}$$

From the regression model produced an estimate of financial loss of accident. The results indicated adjusted R^2 value is 0.776 and p-value is less than 0.05 respectively. The regression model showed a good-fit and robust model with strong relationship between the data set (Chan and Chan 2004). The corresponding analysis of variance (ANOVA) result showed that the regression model is good fit. The tolerance and VIF of collinearity statistics are less than 1 and 2 respectively that no collinearity relationship between data was found.

Several common regression models have also been tried and linear regression model was found the best fit and the most representable for analyzing the financial loss in construction accident.

86.3 Validation

With reference to (Chan and Chan 2004), the performance of survey respondents and predicted values from the model can be compared by percentage error (PE) where:

$$\text{Percentage Error(PE)} = \text{Predicted value} - \text{actual value}/\text{actual value} \times 100\%.$$

$$\text{Mean absolute percentage error(MAPE)} = \sum |\text{PE}|/\text{n}$$

Totally 949 accident cases are sorted out according to the financial loss ranging from the largest amount value to the smallest one. 10 independent cases have been extracted out for validating the regression model. These are the 30th, 130th, 230th, 330th, 430th, 530th, 630th, 730th, 830th and 930th case to ensure a uniform distribution in validation (This includes samples which sorted from large to low amount in financial loss). Percentage error and absolute percentage error were found as 1.1 and 7.7% respectively. This validation method has been adopted by Chan and Chan (2004).

Almost all the overall value prediction (i.e. 939 cases) have been put into the model and compared with the regression result. Percentage error and absolute percentage error were found as 1.1 and 15.0% respectively. In general, the actual values and predicted values by the model are consistent. It can be concluded that the regression model performed good with minor difference between actual and predicted values in predicting the financial loss in accident case.

Based on the validation result, it is proven that findings from the regression model are verifiable and reliable. By putting some real cost items into the regression model, financial loss per each accident might be estimated as HK$28,010. According to previous accident records, average accident number in the past ten year is 3621 (from Apr 2002 to Mar 2002). Financial loss due to construction accident is about HK$845,000 per month (without fine$) (Direct & Indirect cost).

86.4 Discussion and Conclusion

Review of relevant literature sought a set of independent variables which might affect financial loss. A series of structural interviews has been conducted from June to December 2013 to investigate the real situation and real data in Hong Kong construction market. 117 projects and 949 accident case have been recorded. These 117 projects represented around 10% of total contract sum of project from year 2007 to 2012.

According to the survey findings, the mean victim age is 40 year old, accident happened in this middle-aged worker group (40–56 year old) is a potential problem in Hong Kong construction industry. Also, the mean salary of victim is found in about HK$620. It represented that the majority of victims are semi-skilled labor (<HK$1000 per day). The government and stakeholders should put more effort on safeguarding the construction safety of this specific group of high-risk worker. Mean day loss per accident is found at 17 days. It evaluated direct and indirect cost should be counted and be further eliminated. An accident indeed implicated cost expenses in hospitalization system, medical services, direct and indirect expenses in site operation such as equipment loss, materials loss, loss due to idle time and others. The findings are in line with previous literature. Financial loss has been estimated as HK$28,000 per accident case (including direct and indirect cost).

Numerical analysis has been done to investigate how each independent variable affects the financial loss. Seven key independent variables are generated. These are (1) salary loss of victim, (2) hospitalization expenses, (3) other expense, and (4) idle cost of site, (5) materials loss, (6) equipment loss due to accident and (7) salary of other workforce. Validation has been done by comparing the predicted values with the actual values reported by the contractors. It was confirmed that the model and its prediction are reliable. It is estimated that the average financial loss of each accident is about HK$28,000 and the financial loss per month according to year 2002–2012 accident number is about HK$845,000. Indeed, it showed that the contractors and stakeholders are suffered from huge financial loss in construction accident and the loss will be then transferred to social cost and government burden.

References

Census and Statistics Department, Hong Kong Special Administrative Region (2013) "Hong Kong Annual Digest of Statistics", http://www.censtatd.gov.hk/hkstat/

Chan PCA, Chan WMD (2004) Developing a benchmark model for project construction time performance in Hong Kong. Build Environ 39:339–349

Coble RJ, Hinze J, Haupt TC (2000) "Construction Safety and Health Management", HD7269 B89. C66-200 (UST Lib)

De Saram DD, Tang SL (2005) Pain and suffering costs of persons in construction accidents: Hong Kong. J Constr Manag Econ 23(6):645–658

Elias I, Felix H, David O (2012 Aug) Cost-benefit analysis for accident prevention in construction projects. J Constr Eng Manag 138(8):991–998

Feng YB (2011) Optimizing safety investments for building projects in Singapore. Ph.D. thesis, National University of Singapore

Feng YB, Zhang S, Peng Wu (2015) Factors influencing workplace accident costs of building projects. Saf Sci 72:97–104

Haupt TC, Pillay K (2016) Investigating the true costs of construction accidents. J Eng Design Technol 14(2):373–419

Health and Safety Executive (2015) Costs to Britain of workplace fatalities and self-reported injuries and ill health, 2012/13

Heinrich HW (1980) Industrial accident prevention: a safety management approach. McGraw-Hill, NY

Hinze J, Appelgate LL (1991) Costs of construction injuries. J Constr Eng Manag 117(3):537–550

HKSAR (1999) General condition of contract for civil works

HKSAR (2007–2014) The policy address. The Hong Kong Special Administrative Government

HKSAR (2012) Factory and industrial undertaking (safety management) regulations. The Hong Kong Special Administrative Government

Nadeem A, Tang SL, Lee HK (2009) Social costs of construction accidents and safety investments in Hong Kong. In: Fifth international conference on construction in the 21st century (CITC-V), May 20–22, 2009, Istanbul, Turkey

Rowlinson S (2003) Hong Kong construction–safety management & the law. Sweet & Maxwell Asia

Tang SL, Lee HK, Wong K (1997) Safety cost optimization of building projects in Hong Kong. J Constr Manag Econ 15:177–186

Tang SL, Ying KC, Chan WY, Chan YL (2004) Impact of social safety investments on social costs of construction accidents. J Constr Manag Econ 22(9):937–946

Tang SL, Chan SSK, De Saram DD, Lee HK (2007) Costs of construction accidents in the social and humanity context—a case study in Hong Kong. HKIE Trans 14(2):35–42

Teo ALE, Feng YB (2011) Costs of construction accidents to Singapore contractors. Int J Constr Manag 11(3):79–92

Ying KC, Zhang KGM, Setunge S (2015) Numerical framework for accident cost estimation—research concepts and data findings. In: the 3rd international conference on civil engineering, architecture and sustainable infrastructure (ICCEASI 2015), 1–3 July 2015, Hong Kong

Chapter 87
Knowledge Transfer Between R&D Projects and Commercial Projects: A Conceptual Framework

Eric Too and Stewart Bird

87.1 Introduction

Research and development (R&D) activities are far from a rare sight in today's competitive corporate environment. Since the concept of corporate R&D was first introduced in the German chemical industry in the 1880s, research has shown significant value to be gained from organisation's R&D investment (Arora 2016; Hirschey et al. 2012; Griliches 1986). One particular area of study is R&D's impact on organisation share price valuation (Chan et al. 2015; Wang and Fan 2014) as share price provides a clear indictor in the measurement of R&D benefits. Specifically, R&D brings intangible benefits to the organisation through areas such as brand perception, process improvement and innovation, which, in turn, is reflected in the organisations share price (Sougiannis 1994).

Another strand of research takes a more inward look on R&D's contribution to firm efficiency. For example, Subal et al. (2012) suggested that R&D investment can have a positive effect on processes, procedures and tools within an organisation that lead to efficiency gains. The continual investigation into process and tool improvements through R&D activities not only promotes greater productivity and efficiency within a firm but is also linked to innovation (Mairesse and Pierre 2004; McGuirk et al. 2015).

Although the benefits that flow from R&D activities seem to be evident, there are countless different approaches taken by organizations to achieve these potential benefits. Financial considerations are a major factor influencing how organizations approach R&D (Lazonick and Oner 2011). Being seen as an unessential expense,

E. Too (✉)
School of Property, Construction & Project Management, RMIT University, Melbourne, Australia
e-mail: eric.too@rmit.edu.au

S. Bird
Aurecon Group, Docklands, Australia

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_87

R&D operations are often cut particularly in times of financial stress (Cincera et al. 2012). As a result, a significant number of organizations have avoided the costs and uncertainties associated with internal R&D activities by either outsourcing to external companies or entering into partnerships and alliances with research institutions and academia (Martinez-Noya et al. 2012). These contractual agreements between sponsor organizations and those that conduct the research raises the argument of whether the full value of the research is being realized by the sponsor organizations (Carpay et al. 2007). Many argue that the knowledge developed through close participation in R&D activities holds significant value (Martinez-Noya et al. 2012). Significant amount of knowledge and experience generated through the R&D activities is lost when the project findings are transferred back to the sponsor organization. What the sponsor organization receives is the explicit knowledge gained from the research. However, the tacit knowledge, which is more difficult to transfer, often remains with the external organization who undertook the research.

Realizing the importance of gaining both the explicit and tacit knowledge, many organizations have shifted the pendulum back to in-house R&D activities. With in-house R&D, the organization assumes the risks associated with managing, funding and disseminating the research. The added advantage of such approach, however, is that they retain both explicit and tacit knowledge gained from the R&D activities thus bringing a greater likelihood of it translating into commercial benefits. In a project based organisation, this means utilizing R&D knowledge to better deliver commercial projects.

The primary aim of this paper is to determine the mechanism for successful knowledge transfer between in-house R&D and commercial projects (known as embedded R&D) i.e. how a project based organization utilize in-house R&D knowledge to better deliver commercial projects. The next section will examine the role of R&D and project success and how the concept of embeddedness can facilitate knowledge transfer. Using the concept of embeddedness, a conceptual framework on how knowledge generated from R&D can be transfer to commercial applications in a project environment is next proposed. Finally, the paper ends with some concluding remarks.

87.2 Literature Background

87.2.1 Embedded R&D and Project Success

A project manager aims to meet or exceed the objectives of a project (El-Sabaa 2001). In order to understand how R&D activities can be beneficial to them, it is essential to determine what project objectives are and what meeting them looks like. This area of project management has been thoroughly explored in academic literature under project success theory. It is widely agreed that all projects are unique in nature and therefore all projects aim to achieve something that has not be done previously (Cleland and King 1983). Therefore, project success will take on different meaning in different contexts. For this reason, project success has not been well-defined in project management literature. Atkinson (1999) points out that traditional project management literature often focuses on measuring the success of projects from the point of view of the project manager and they were inextricably linked to cost, time and quality or the "Iron Triangle". More recently the literature has explored more broad definitions of project success. They take into greater account the breadth of project outcomes and attempt to take into account more qualitative measures (Dvir et al. 1998; Shenhar et al. 2002).

Key factors that contribute to project success have also been widely studied. For example, a number of studies take a macro view on the success factors starting with factors such as organisational strategy (Cooke-Davies 2002). Most tend to focus on the processes and operations of a project and attempt to identify trends in planning and procedure that can be used as a framework on other projects (Shenhar et al. 2002). An idea that is gaining more attention is the role of knowledge as an influencer of project success (Koskinen and Vanharanta 2002; Todorović et al. 2015). The majority of these studies categorise knowledge into two categories, tacit and explicit knowledge. Explicit knowledge is generally seen in a project context in the form of processes, procedures and guidelines (Anand et al. 2010). Tacit knowledge, on the other hand, is defined as "intuition and commitment, both of which are obtained through the experience of the individual and the mental models formed through this experience" (Anand et al. 2010). Due to the nature of tacit knowledge, this knowledge often remains with an individual until they undergo an experience in close proximity with another individual (Koskinen and Vanharanta 2002). Tacit knowledge, therefore, cannot be codified and transferred easily from one project to another and has a significant impact on project success (Koskinen 2000) and is the most difficult to manage for a project manager.

The difficulty in which tacit knowledge is transferred has attracted a number of research that delve deeper into project-based knowledge development and sharing. Bakker et al. (2011) explored how the learning and knowledge from one project can be transferred and used to benefit the outcomes of another. They argued that although project context changes each time a project team is assembled and disbanded, inter-project knowledge transfer can have a significant impact on the success of future projects if it can be better understood.

In examining the critical success factors in the transfer of R&D knowledge, Cummings and Teng (2003) provided empirical evidence to support the theory of embeddedness and knowledge transfer. Geographic distance between participants in knowledge networks and spatial embeddedness were found to be a critical factor in successful knowledge transfer (Argote and Ingram 2000; Boekema and Roel 2004). Schamp et al. (2004) examined tacit knowledge and found that social interaction was essential for successful knowledge transfer. Other studies have taken a different approach to embeddedness and considered it not from a physical point of view, but from a more abstract point of view. For example, Argote and Ingram (2000) measure how intertwined knowledge is in processes, systems and people. Bakker et al. (2011) distinguishes between a number of different forms of embeddedness; relational, cognitive and temporal.

Relational embeddedness is defined as the "strength of the relation between two or more organizational actors" (Bakker et al. 2011; Uzzi 1996). Coleman (1990) describes the concept in terms of the "quality of dyadic exchanges, including the degree to which parties consider one another's needs and goals as well as the behaviours that they exhibit toward one another, such as trust, norms, reputation, sanctions, and obligations". The stronger the relationship in terms of proximity, frequency of contact and level of trust, the greater the chance of knowledge transfer between the two parties (Coleman 1990). Cognitive embeddedness refers to similarity in the representations, interpretations, and systems of meaning among firms (Nahapiet and Ghoshal 1998). Cognitive embeddedness is defined as the extent to which the two parties share "representations, interpretations, and systems of meaning" (Van Wijk et al. 2008). The research suggests that two parties that share complimentary knowledge bases are more likely to experience successful knowledge transfer (Nooteboom 2000). Temporal embeddedness relates to the extent to which two parties have worked together before recoupling to undertake a new project (Bakker et al. 2011). A greater level of temporal embeddedness supports higher levels of relational and cognitive embeddedness and supports knowledge transfers between parties.

Another sub-category of embeddedness that has been widely studied is the concept of structural embeddedness. Simsek et al. (2003) describes structural embeddedness as the nature and composition of a knowledge network. They also highlight the importance of acknowledging the actors within the network and their objectives and motivations. The concept of structural embeddedness is therefore, significant to R&D knowledge transfer as participant's can play multiple roles with an individual network. From example, a participant may hold one role on an R&D project and a different role when working on commercial projects. The position of the participant in the knowledge network is also significant as it will impact upon his ability to apply the knowledge from R&D for commercial project success.

The literature on embeddedness strongly focus on the embeddedness of actors across projects that are similar nature, between actors in different organizations and between actors that play individual roles in a particular knowledge network. However, there is limited literature that examines the role of embeddedness between projects that are of a distinctly different nature, between projects with significantly different objectives and how the concept relates to a single individual within multiple knowledge networks. This suggests that there is an opportunity to provide new and meaningful research into the area of knowledge transfer from R&D to commercial projects in an embedded R&D situation. To address this, next section will propose a conceptual framework to address knowledge transfer between projects of these nature using the concepts of embeddedness.

87.3 Conceptual Framework

From the literature a number of concepts and theories have been identified that support the connections between corporate R&D acquired knowledge and its transfer to commercial application. This is developed into a conceptual framework to facilitate knowledge transfer between R&D project and commercial project as exhibited in Fig. 87.1

A key factor that is acknowledged in almost all studies in the area of knowledge transfer is the proximity of the entity to the knowledge that their ability to transfer it to another. This concept is explored in a number of different ways including spatial proximity, relational proximity and temporal proximity. Each of these concepts aim to determine where the entity is positioned in a particular knowledge network. The position of the entity within a knowledge network will influence their access to knowledge and the means available to them to transfer that knowledge. These concepts and frameworks, specifically, the frameworks proposed by Bakker et al. (2011) in relation to cognitive embeddedness and Simsek et al. (2003) in relation to structural embeddedness are augmented and logically connected in our proposed framework to enable the transfer of knowledge in an embedded R&D situation.

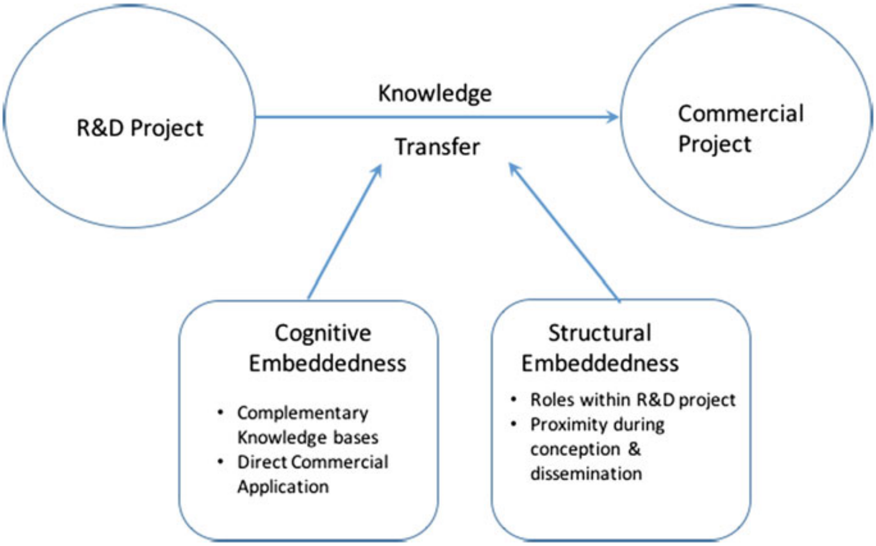


Fig. 87.1 Conceptual framework for R&D knowledge transfer

87.3.1 Cognitive Embeddedness

Bakker et al. (2011) distinguishes between three types of embeddedness; relational embeddedness, temporal embeddedness and cognitive embeddedness. Relational embeddedness refers to the strength and quality of connections between two parties and temporal embeddedness refers to the length and frequency of their interactions. In the context of R&D in project organizations, there are multiple participants involves. Therefore, relational and temporal embeddedness are unimportant and will be omitted. Cognitive embeddedness, on the other hand, will determine how similar the knowledge bases are of the R&D projects and commercial projects. This will determine whether the participant was able to apply the R&D knowledge to commercial projects. Two aspects of cognitive embeddedness are conceptualized to be important in knowledge transfer. They are complementary knowledge bases and direct commercial application.

87.3.1.1 Complementary Knowledge Bases

An important aspect of our model is the proximity of the R&D project to the commercial project in terms of knowledge base. This is important because it establishes mutual understanding and will influence the factors involved in the transfer of knowledge from one to another. In the case of project organizations, the level of cognitive embeddedness can be assessed by examining the similarities in knowledge bases between the participant's R&D project and the commercial projects they work on a day-to-day basis.

To assess the knowledge bases of both R&D and commercial projects, it is necessary to assess their area of work and whether the R&D undertaken is aligned with the commercial project. In other words, the R&D project and commercial projects must hold "shared representations, interpretations, and systems of meaning" (Van Wijk et al., 2008). If the R&D project and the commercial projects shared a similar subject matter and similar technical objectives they are said to have a high level of cognitive embeddedness. More specifically, R&D project is related to the commercial work of the participant, in relation to knowledge, tools or processes that are used in their day-to-day work. However, if the project differed in their subject matter and their objectives then they are said to have a low level of cognitive embeddedness. In line with Bakker et al. (2011) this model assumes that a certain level of cognitive embeddedness between the R&D and commercial project will positively assist the participant in aligning the goals and outcomes of both projects and assist the transfer of knowledge.

Proposition 1 *The knowledge base of the R&D and commercial project need to be similar to successful transfer knowledge from one to the other.*

87.3.1.2 Direct Commercial Application

Further to understanding the similarity in knowledge bases between projects, it is important to assess whether the R&D project was conceived and designed with a direct commercial application in mind. One determinate of cognitive embeddedness is how the R&D project was conceived and designed. If the R&D project is undertaken in order to address an existing commercial opportunity, then there is a high level of cognitive embeddedness between the two projects and is more likely to experience successful knowledge transfer. There is little or no cognitive embeddedness between projects in situation where there is no direct commercial application that the R&D is designed to address or when the area of the R&D itself can differ completely to the commercial project's topic area.

Proposition 2 *R&D project must be conceived and designed with a direct commercial application in order for successful transfer of knowledge from one to the other.*

87.3.2 Structural Embeddedness

Structural embeddedness is perceived to be important in our model because it determines the participant's positions in the knowledge network (Van Wijk et al. 2008), their proximity to knowledge in the R&D project and their ability to apply knowledge to the commercial and influence its outcomes. When there is a high level of cognitive embeddedness between projects the reasons and benefits of knowledge transfer in such situations are clearer. For this reason, our model uses Simsek et al. (2003) concept of structural embeddedness to determine the participant's position in the knowledge network and therefore their proximity to both the R&D generated knowledge and their ability to apply the knowledge in a commercial situation. Specifically, our model examines the participants' role in both the R&D and commercial projects, their proximity to the knowledge, and their ability to apply knowledge. If the participant's position within the knowledge network holds them in close proximity to the knowledge generated through R&D and in a position that allows them to apply the knowledge to a commercial situation, then the participant will be said to have a high level of structural embeddedness and a is therefore more likely to transfer knowledge from one project to another.

87.3.2.1 Participant Role Within R&D Team

Evaluating the role of participant can determine their proximity to the knowledge generated during the R&D project and determine the detail in which they understood the knowledge. In R&D projects, participants that takes on a more technical/hands-on role within the team or assume a leadership, management or coordination role. Participants in leadership positions on R&D projects can experience knowledge transfer by freeing up the individual, both to focus on the main objectives of the R&D and to 'sell' or disseminate the research outcomes around the rest of team and externally. Similarly, when participants take on more hands-on roles in R&D, these participants are likely to be undertaking the vast majority of the technical work required to complete the R&D project. In such situation, since they are the ones undertaking the R&D work, they are more likely to apply the knowledge to commercial projects that they worked on. Participation undertaking a more hands-on role within the R&D team would also be more likely to experience or contribute to knowledge transfer because they were in closer proximity to the finer details of the R&D. In determining the nature and quality of their participation and exposure to knowledge generated through the research and the opportunities for them to transfer it to a commercial situation. This highlights that the role the participant plays within the R&D team can influence the success of knowledge transfer.

Proposition 3 *Participant's role and level of involvement in both the R&D and commercial project influence successful knowledge transfer.*

87.3.2.2 Proximity to R&D Generated Knowledge

Participant's proximity to the R&D generated knowledge had an influence on knowledge transfer. Participant's position in two separate knowledge networks, the R&D network and the commercial project network has an important bearing on structural embeddedness. The position within the R&D network helped determine factors influencing the participant's ability to consume knowledge (the first part of the knowledge transfer process) and their position in the commercial project network helped determine factors influencing the participant's ability to apply the knowledge to a commercial situation (the second part of the knowledge transfer process). It looked at proximity during conception and dissemination to determine their position with the knowledge network and their ability to adequately consume the R&D knowledge in order to initiate the knowledge transfer process. The participant present during the conception of the R&D project and their involvement in the formulation and design of the R&D project can lead to greater ownership of the R&D knowledge, a greater understanding of the objectives and therefore influence knowledge transfer. The participant's proximity during the R&D project dissemination can affect an individual's understanding of the final outcomes of the R&D project in order to transfer the knowledge successfully to commercial application. Specifically, participant's presence and involvement in closing out the project and analyzing and documenting the research findings can have strong influence.

Proposition 4 *Proximity to conception and dissemination of R&D knowledge influence successful knowledge transfer.*

87.4 Conclusion

For project based organizations that rely on the intellectual capital of their employees to deliver successful projects, it is essential that they develop the means to ensure the effectiveness of their in-house R&D spending. Many of these organizations do not have the valuation mechanisms that publicly listed or manufacturing organizations have. The mechanisms that are available to them focus heavily on macro indicators that are intangible and difficult to measure.

For these organizations, commercial survival means being able to deliver projects successfully and each investment they make should be focused on this objective. As the literature indicates, there is an increasing trend for organizations to participate in R&D activities less directly. Organizations are trading the in-house approach for less risky approaches such as outsourcing or partnership agreements. Therefore, having the ability to measure how R&D activities directly influence project success factors is a critical to the validation of in-house R&D expenditure for organizations.

The proposed conceptual framework serves as a valuable asset to organizations that wish to better design their R&D activities to ensure they are realizing tangible commercial outcomes from their in-house R&D investments. Specifically, it suggests that organizations must consider the complementary knowledge bases and potential of direct commercial application of their R&D project in order to strengthen their cognitive embeddedness. Similarly, the roles and involvement of participants in the R&D projects as well as their proximity during the conception and dissemination of the R&D projects are necessary to strengthen their structural embeddedness. Together, both the cognitive and structural embeddedness are critical factors influencing the successful transfer of R&D knowledge for commercial application.

References

Anand G, Ward PT, Tatikonda MV (2010) Role of explicit and tacit knowledge in six sigma projects: an empirical examination of differential project success. J Oper Manag 28(4):303–315

Argote L, Ingram P (2000) Knowledge transfer: a basis for competitive advantage in firms. Organ Behav Hum Decis Process 82(1):150–169

Arora S (2016) Investment decision making in the upstream oil industry: an analysis. J Bus Strategy 12(1):40–52

Atkinson R (1999) Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. Int J Project Manag 17(6):337–342
Bakker RM, Cambré B, Korlaar L, Raab J (2011) Managing the project learning paradox: a set-theoretic approach toward project knowledge transfer. Int J Project Manag 29(5):494–503
Boekema F, Roel R (2004) Knowledge, networks and proximity: an embeddedness perspective. Eur Plan Stud 12(5):603–605
Carpay F, Chieh HC, Dan Y (2007) Management of outsourcing R&D in the era of open innovation. In: The fifth international symposium on management of technology-managing total innovation and open innovation in the 21st century, Zhejiang University, Hangzhou, China, 252–256
Chan K, Chen H, Hong L, Wang Y (2015) Stock market valuation of R&D expenditures: the role of corporate governance. Pacific-Basin Financ J 31:78–93
Cincera M, Cozza C, Tübke A, Voigt P (2012) Doing R&D or not (in a crisis), that is the question. Eur Plan Stud 20(9):1525–1547
Cleland D, King WR (1983) Systems analysis and project management. McGraw Hill, New York
Coleman JS (1990) Rational action, social networks, and the emergence of norms. In: Calhoun C, Meyer MW, Scott WR (eds) Structures of power and constraint. Cambridge University Press, New York
Cooke-Davies T (2002) The "Real" success factors on projects. Int J Project Manag 20(3):185–190
Cummings JL, Teng BS (2003) Transferring R&D knowledge: the key factors affecting knowledge transfer success. J Eng Tech Manage 20(1–2):39–68
Dvir D, Lipovetsky S, Shenhar A, Tishler A (1998) In search of project classification: a non-universal approach to project success factors. Res Policy 27(9):915–935
El-Sabaa S (2001) The skills and career path of an effective project manager. Int J Project Manag 19(1):1–7
Griliches Z (1986) Productivity, R&D, and basic research at the firm level in the 1970's. Am Econ Rev 76(1):141
Hirschey M, Skiba H, Wintoki MB (2012) The size, concentration and evolution of corporate R&D spending is U.S. firms from 1976 to 2010: evidence and implications. J Corp Financ 18(3):496–518
Koskinen KU (2000) Tacit knowledge as a promoter of project success. Eur J Purch Supply Manag 6(1):41–47
Koskinen KU, Vanharanta H (2002) The role of tacit knowledge in innovation processes of small technology companies. Int J Prod Econ 80(1):57–64
Lazonick W, Oner T (2011) US biopharmaceutical finance and the sustainability of the biotech business model. Res Policy 40(9):1170–1187
Mairesse J, Pierre M (2004) The importance of R&D for innovation: a reassessment using French survey data. J Technol Transfer 30(1–2):183–197
Martinez-Noya A, Esteban G, Mauro FG (2012) R&D outsourcing and the effectiveness of intangible investments: is proprietary core knowledge walking out of the door? J Manag Stud 50(1):67–91
McGuirk H, Lenihan H, Hart M (2015) Measuring the impact of innovative human capital on small firms' propensity to innovate. Res Policy 44(4):965–976
Nahapiet J, Ghoshal S (1998) Social capital, intellectual capital, and the organizational advantage. Acad Manag Rev 23(1):242–266
Nooteboom B (2000) Learning by interaction: absorptive capacity, cognitive distance and governance. J Manag Governance 4(1):69–92
Schamp EW, Bernd R, Lo V (2004) Dimensions of proximity in knowledge-based networks: the cases of investment banking and automobile design. Eur Plan Stud 12(5):607–624
Shenhar AJ, Tishler A, Dvir D, Lipovetsky S, Lechler T (2002) Refining the search for project success factors: a multivariate, typological approach. R&D Manag 32(2):111–126
Simsek Z, Lubatkin MH, Floyd SW (2003) Inter-firm networks and entrepreneurial behavior: a structural embeddedness perspective. J Manag 29(3):427–442

Sougiannis T (1994) The accounting based-valuation of corporate R&D. Account Rev 69(1): 44–68

Subal K, Ortega-Argilés R, Potters L, Vivarelli M, Voigt P (2012) Corporate R&D and firm efficiency: evidence from Europe's top R&D investors. J Prod Anal 37(2):125–140

Todorović ML, Petrović DC, Mihić MM, Obradović VL, Bushuyev SD (2015) Project success analysis framework: a knowledge-based approach in project management. Int J Project Manag 33(4):772–783

Uzzi B (1996) The sources and consequences of embeddedness for the economic performance of organizations: the network effect. Am Sociol Rev 61(1):674–698

Van Wijk R, Jansen JJP, Lyles MA (2008) Inter- and intra-organizational knowledge transfer: a meta-analytic review and assessment of its antecedents and consequences. J Manag Stud 45(1):830–853

Wang Y, Fan WG (2014) R&D reporting methods and firm value: evidence from China. Chin Manag Stud 8(3):375–396

Chapter 88
Life Cycle Costing for Insulated Pitched Roof Structures

I.M. Chethana S. Illankoon, Vivian W.Y. Tam and Khoa N. Le

88.1 Introduction

Energy efficiency is one of the significant areas of discussion in building construction. However, there are many factors affecting energy efficiency of buildings. A sound thermal insulation is considered as a crucial step to reduce the energy use of buildings (Roels and Langmans 2016). Building components such as walls, floor and roof play an important role in the overall heat losses in wintertime and heat gains in summertime. Therefore it is necessary to use insulation to for these building components.

To reduce solar irradiation and high heat gains through the roof in hot climates, insulation and coatings are often used to cover the exterior side of the roof component, leading to a significant effect on reducing the unwanted heat gains in summer conditions (Roels 2011). However, the heat transmission and thermal insulation depends on the thermal resistance which is known as the R-Value (Jankovic 2013).

Green Building Council Australia (2015), identified the significance of the thermal insulation in energy efficiency in buildings and allocated credit points in the green star rating tool. In obtaining green star rating, up to 5 credits out of 20 for energy efficiency in green buildings are allocated for thermal insulation (2015). This itself signifies the importance of thermal insulation of buildings. Further, in green buildings it is required to increase up to 15% of total R-Value of roof insulation compared to the national standards in Australia. According to the

I.M.C.S. Illankoon · K.N. Le
School of Computing Engineering and Mathematics, Western Sydney University, Sydney, Australia

V.W.Y. Tam (✉)
College of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: vivianwytam@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_88

Table 88.1 Minimum total R-Value for climate zone

Climate zone	1, 2, 3, 4, and 5	6	7	8
Direction of heat flow	Downwards		Upwards	
Minimum total R-Value for s roof or ceiling with roof upper surface solar absorptance value of not more than 0.4	3.2	3.2	3.7	4.8
Minimum total R-Value for s roof or ceiling with roof upper surface solar absorptance value of more than 0.4 but not more than 0.6	3.7	3.2	3.7	4.8
Minimum total R-Value for s roof or ceiling with roof upper surface solar absorptance value of more than 0.6	4.2	3.2	3.7	4.8

Adapted from Australia Building Codes Board (2016)

building code of Australia, it is necessary for the buildings to achieve the minimum R-Value given for each climate zone (Australia Building Codes Board 2016).

Australia Building Codes Board (2016) clearly specifies two types of roofs, namely the pitched roof structures and flat roof structures. However, pitched roofs structures are commonly used. Further, depending on the climate zone there are certain R-Values to be achieved as reported in Table 88.1.

There are many options available for the developers to obtain the required total R-Value with the use of different insulation material and different types of sarking. The cost of each of these options varies drastically with the choice of material used. Further to that, roof and ceiling structures require regular maintenance which is considerable proportion compared to the longer life cycle of the buildings. However, there is a clear lack of life cycle cost information and analysis regarding the lifecycle cost for these different types of roof to achieve different insulation requirements. Therefore, this research calculates the life cycle cost for different roofing solutions and ceilings together with the total R-Value.

88.1.1 Pitched Roof Structures

Pitched roofs are widely used in Australia. There are many types of pitched roofs available. According to Insulation Council of Australia and New Zealand (2014), there six types of pitched roof structures. The classification depends on the roof covering material and the type of ceiling. Based on those parameters, main six types of pitched roof structures are classified in Table 88.2.

Each of these roof types has a 22.5° pitch (Table 88.2). Solid materials, air layers and insulation layer are considered for insulation purposes of pitched roof. Usually there is sarking material in the roof structure. Single sided foils, Double sided anti-glare foils, vapour permeable membrane and bubble/foal foils are the popular sarking materials.

Table 88.2 Types of pitched roof structures

Code	Type of roof	Description
R0100	Pitched tiled roof with flat ceiling	Tiled roof at 22.5° pitch, 25 mm battens with or without a sarking membrane under the battens, attic space, ceiling insulation laid on a horizontal 10 mm plasterboard ceiling
R0200	Pitched metal roof with flat ceiling	Metal sheet roof at 22.5° pitch, 40 mm battens with or without a sarking membrane under the battens, attic space, ceiling insulation laid on a horizontal 10 mm plasterboard ceiling
R0300	Pitched tiled roof with cathedral ceiling below rafters (concealed rafters)	Tiled roof at 22.5° pitch, 25 mm battens over 190 mm rafters with a sarking membrane, 10 mm plasterboard raked ceiling fixed under the rafters
R0400	Pitched metal roof with cathedral ceiling below rafters (concealed rafters)	Metal roof cladding at 22.5° pitch, 40 mm battens over 190 mm rafters with a sarking membrane between, min. 75 mm high noggins between rafter, 10 mm plasterboard raked ceiling fixed under the rafters
R0500	Pitched tiled roof with cathedral ceiling above rafters (exposed rafters)	Tiled roof at 22.5° pitch, 25 mm battens over 190 mm rafters with a sarking membrane and 10 mm plasterboard raked ceiling with exposed rafters. Minimum 75 mm noggins between rafters positioned to allow 20 mm clearance below sagged sarking membrane, and a 10 mm plasterboard ceiling lining pushed up between the rafters and fixed to the nogging
R0500	Pitched metal roof with cathedral ceiling above rafters (exposed rafters)	Metal roof cladding at 22.5° pitch, 40 mm battens over rafters with a sarking membrane between, min. 75 mm high noggins between rafter and 10 mm plasterboard raked ceiling with exposed rafters

Adapted from Insulation Council of Australia and New Zealand (2014)

The insulation of the roof significantly varies based on the R-Vale of the ceiling insulation material (Insulation Council of Australia and New Zealand 2014). The total R-Value of the roof structure is the summation of the indoor and outdoor air films, air gaps, roof covering, sarking material, attic space (if available), ceiling insulation and type of ceiling material. If the total R-Value is increased, the roof provides better insulation standards.

Different materials with varying R-values are used as ceiling insulation to achieve required level of insulation. Glass wool batts, glass wool blankets, polyester and wool batts are the commonly used insulation material. The R-Value of these insulation materials depends on the thickness of the material layer also (Zhang 2011).

88.2 Life Cycle Cost Calculation for Pitched Roof Structures

Life cycle cost is identified as a tool for assessing the total cost performance of an asset over time, including the acquisition, operating, maintenance, and disposal costs (Goussous and Al-Refaie 2014). Australian National Audit Office (2001) identified that the process of LCC fundamentally involves assessing costs arising from an asset over its life cycle and evaluating alternatives that have an impact on this cost of ownership. For the pitched roof structures the life cycle cost varies depending the on the different types of material used for covering, structure and insulation. Further, there are many options available to achieve the required level of insulation with different materials. Therefore, this research focused on the life cycle cost calculation of the pitched roof structures for the selection of the most suitable pitched roof structures.

According to Australian National Audit Office (2001), there are five main phases which triggers different types of costs which are design, purchase and construction, operation costs, maintenance costs, development costs and disposal costs. In order to calculate the life cycle cost all these types of costs must be captured and discounted into present day values. This is similar to the life cycle cost calculation of pitched roof structures as well. The life cycle costs of pitched roofs include the initial cost of construction, maintenance costs, cost of demolition of the structure and reuse of material if applicable. Therefore, all these types of cost components were considered in the calculation.

88.2.1 Determination of Initial Cost

The initial cost included three components, namely the roof covering including the sarking material, roof structure and the ceiling and ceiling insulation. According to Table 88.2, there are two types of roof coverings, metal covering and tile covering. In this research, tiled roofs consisted of two options, concrete tiles or terracotta tiles. Further the metal roof covering included Aluminium covering with 0.7 and 0.9 mm thickness separately. Further it also included copper roof covering. The roofs included 10 mm plasterboard ceiling. For Roofs R0100 and R0200 with flat ceiling included a prefabricated roof truss with attic space. For other roofs with cathedral ceiling included rafters.

For all the roofs, ceiling is a 10 mm plasterboard ceiling which included necessary ceiling structure with ceiling joists. Further, the ceiling insulation used are according to the Insulation handbook by Insulation Council of Australia and New Zealand (2014). Each type of insulation material used for each roof and the R-Values are reported in Table 88.3.

There are four types of sarking material included in the study, namely; single sided foils, vapour permeable membranes, double sided antiglare foil. The composite costs

Table 88.3 Ceiling insulation materials used

Type of roof	R-Value	Type of material
R0100 and R0200	R3.5	Glass wool batts, Polyester batts, Wool batts
	R4.0	Glass wool batts, Polyester batts
	R5.0	Glass wool batts, Polyester batts
R0300 and R0400	R2.0	Glass wool batts, Glass wool blanket with light weight foil, Polyester batts
	R2.5	Glass wool batts, Glass wool blanket with light weight foil, Polyester batts
	R3.0	Glass wool batts, Polyester batts, Wool batts
	R4.0	Glass wool batts, Polyester batts
R0500	R2.0	Glass wool batts, Glass wool blanket with light weight foil, Polyester batts
	R2.5	Glass wool batts, Glass wool blanket with light weight foil, Polyester batts
	R3.0	Glass wool batts, Polyester batts, Wool batts
	R4.0	Glass wool batts, Polyester batts
	R5.0	Glass wool batts

are taken from the Rawlinson cost database (Rawlinsons 2015) and for material prices current market prices were obtained. Prices are collected in six main cities in Australia; Adelaide, Brisbane, Melbourne, Perth, Hobart and Sydney.

88.2.2 Determination of Maintenance Costs

Usually roofs require proactive maintenance to prevent costly repairs and full replacement. The tiled roofs require careful maintenance strategies compared to metal roofs. However in general regular maintenance of a roof is 2% from the full replacement cost of the roof (Roofing Contractor 2016). A period of 20 years considered in this research. Further a discounting rate of 3% is also used to discount the maintenance cost over the period of 20 years. However, in this calculation gutter replacements, gutter guard fitting, gutter and downpipe cleaning and flashing replacements and not considered.

88.2.3 Determination of Disposal and Other Costs

At the end of the life time the roof components are disposed. However, extra cost is added for is care in demolition including stacking and setting aside for reuse of roof covering when possible and the timber framing. Further, costs for preparing timber framing for re-use is also added for the life cycle cost calculation. The plasterboard ceiling and ceiling insulation will be disposed. The debris is assumed to be transported 15 km away from the site.

Disposal of these items incur at the end of the life cycle cost. Therefore all the future costs are discounted to the present values using the discounting rate, which is 3% for this research. Finally the life cycle cost is calculated, which is the sum of all the categories of costs.

88.3 Life Cycle Costs for Insulated Pitched Roofs

In Table 88.4, life cycle cost for each roof type is given. Further the total R-Value of each roof is also provided considering the sarking material, air films and the ceiling insulation. The research is carried out for six capital cities in Australia. However the life cycle costs given in Table 88.4 represent the cost data of Sydney. There are slight changes in life cycle costing due to the price changes available in difference cities in Australia.

According to Table 88.4, when the types of pitched roof are compared, R500 and R600 roof types are higher in life cycle cost. This main reason is the increase in initial cost. These two types of roofs have exposed rafter ceiling and therefore, it has higher finishing costs for ceiling. Further the maintenance cost is slightly higher because of the exposed rafters. When tiled roofs are considered, the life cycle cost is almost similar for both terracotta tiles roofs and concrete tiled roofs. Further, the maintenance cost of tiles roofs amounted around 18–20% of the life cycle cost. The cost of demolition also amounted around 18–20% of the life cycle cost. In metal roof covering, the copper roof covering had a significant higher life cycle cost. The reason is the higher initial cost compared to the Aluminium roof covering. However, in metal roof covering, maintenance cost varies from 20 to 22% compared to the life cost. Further, the cost of demolition varies from 12 to 13% of the life cycle cost.

The life cycle cost of the roof slightly increases with the increase in the insulation. If the insulation is higher, the life cycle cost also increases. The initial market price for R2.0 type insulation is usually half the price of R5.0 insulation type in general. Therefore, it directly affects the life cycle cost of the pitched roof structure.

In this research, there are many options considered for these types of roofs. The changes in roof structures are also considered. As an example, life cycle cost is calculated for the changes in rafter laying (rafter laid in 450 mm center to center and 600 mm center to center). However, these changes did not directly affect the life cycle cost of pitched roof structures.

Table 88.4 Life cycle costs and the total R-Values for different types of roofs

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
R0100								
Concrete roof covering								
R3.5 Glass wool	4.1	328.28	4.9	337.89	5.1	327.29	5.3	316.48
R3.5 Polyester		330.78		340.40		329.79		318.79
R3.5 Wool		346.47		356.08		345.48		333.29
R4.0 Glass wool	4.6	329.03	5.4	338.65	5.6	328.04	5.8	317.17
R4.0 Polyester		333.29		342.90		332.30		321.10
R5.0 Glass wool	5.5	332.77	6.3	342.38	6.5	331.78	6.7	320.62
Terracotta roof covering								
R3.5 Glass wool	4.1	381.27	4.9	390.88	5.1	378.02	5.3	363.36
R3.5 Polyester		383.77		393.39		380.52		365.67
R3.5 Wool		399.46		409.07		396.21		380.17
R4.0 Glass wool	4.6	382.02	5.4	391.64	5.6	378.77	5.8	364.05
R4.0 Polyester		386.28		395.89		383.02		367.99
R5.0 Glass wool	5.5	385.76	6.3	395.37	6.5	382.51	6.7	367.50
R0200								
Aluminium roof covering								
R3.5 Glass wool	4.1	332.11	4.9	341.72	5.4	331.12	5.5	318.05
R3.5 Polyester		334.61		344.23		333.62		320.36
R3.5 Wool		350.30		359.91		349.31		334.86
R4.0 Glass wool	4.5	332.87	5.4	342.48	5.8	331.88	6.0	318.75
R4.0 Polyester		337.12		346.73		336.13		322.68
R5.0 Glass wool	5.5	336.60	6.3	346.21	6.8	335.61	7.0	322.20

(continued)

Table 88.4 (continued)

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
Copper roof covering								
R3.5 Glass wool	4.1	911.98	4.9	921.60	5.4	910.99	5.5	853.95
R3.5 Polyester		914.49		924.10		913.50		856.26
R3.5 Wool		930.18		939.79		929.19		870.76
R4.0 Glass wool	4.5	912.74	5.4	922.35	5.8	911.75	6.0	854.65
R4.0 Polyester		916.99		926.61		916.00		858.58
R5.0 Glass wool	5.5	916.47	6.3	926.09	6.8	915.48	7.0	858.10
R0300								
Concrete roof covering								
R2.0 Glass wool batts	2.5	412.78	3.6	422.39	3.8	411.79	3.8	394.57
R2.0 Glass wool blanket		413.00		422.61		412.01		394.77
R2.0 Polyester		412.02		421.64		411.03		393.87
R2.5 Glass wool batts	3.0	413.48	4.1	423.10	4.3	412.49	4.4	395.22
R2.5 Glass wool blanket		415.92		425.53		414.93		397.47
R2.5 Polyester		414.02		423.64		413.03		395.72
R3.0 Glass wool batts	3.5	415.59	4.4	425.21	4.6	414.60	4.7	397.17
R3.0 Polyester		416.13		425.75		415.14		397.67
R3.0 Wool batts		429.34		438.95		428.35		409.87
R4.0 Glass wool batts	4.4	417.60	5.0	427.21	5.2	416.61		399.02
R4.0 Polyester		422.46		432.08		421.47		403.52

(continued)

Table 88.4 (continued)

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
Terracotta roof covering								
R2.0 Glass wool batts	2.5	465.59	3.6	475.20	3.8	462.34	3.8	441.28
R2.0 Glass wool blanket		465.80		475.42		462.55		441.48
R2.0 Polyester		464.83		474.44		461.58		440.58
R2.5 Glass wool batts	3.0	466.29	4.1	475.90	4.3	463.04	4.4	441.93
R2.5 Glass wool blanket		468.73		478.34		465.47		444.18
R2.5 Polyester		466.83		476.45		463.58		442.43
R3.0 Glass wool batts	3.5	468.40	4.4	478.01	4.6	465.15	4.7	443.88
R3.0 Polyester		468.94		478.56		465.69		444.38
R3.0 Wool batts		482.14		491.76		478.89		456.58
R4.0 Glass wool batts	4.4	470.40	5.0	480.02	5.2	467.15		445.73
R4.0 Polyester		475.27		484.89		472.02		450.23
R0400								
Aluminium roof covering								
R2.0 Glass wool batts	2.3	418.24	2.5	427.86	3.6	417.25	4.1	397.65
R2.0 Glass wool blanket		418.46		428.07		417.47		397.85
R2.0 Polyester		417.49		427.10		416.50		396.95
R2.5 Glass wool batts	2.8	418.95	3.0	428.56	4.1	417.96	4.6	398.30
R2.5 Glass wool blanket		421.38		431.00		420.39		400.55
R2.5 Polyester		419.49		429.10		418.50		398.80
R3.0 Glass wool batts	3.3	421.06	3.5	430.67	4.5	420.07	5.0	400.25
R3.0 Polyester		421.60		431.21		420.61		400.75
R3.0 Wool batts		434.80		444.41		433.81		412.95
R4.0 Glass wool batts	4.2	423.06	4.4	432.67	5.3	422.07	5.8	402.10
R4.0 Polyester		427.93		437.54		426.94		406.60

(continued)

Table 88.4 (continued)

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
Copper roof covering								
R2.0 Glass wool batts	2.3	996.30	2.5	1005.92	3.6	995.32	4.1	931.87
R2.0 Glass wool blanket		996.52		1006.13		995.53		932.07
R2.0 Polyester		995.55		1005.16		994.56		931.17
R2.5 Glass wool batts	2.8	997.01	3.0	1006.62	4.1	996.02	4.6	932.52
R2.5 Glass wool blanket		999.44		1009.06		998.45		934.77
R2.5 Polyester		997.55		1007.16		996.56		933.02
R3.0 Glass wool batts	3.3	999.12	3.5	1008.73	4.5	998.13	5.0	934.47
R3.0 Polyester		999.66		1009.27		998.67		934.97
R3.0 Wool batts		1012.86		1022.47		1011.87		947.17
R4.0 Glass wool batts	4.2	1001.12	4.4	1010.73	5.3	1000.13	5.8	936.32
R4.0 Polyester		1005.99		1015.60		1005.00		940.82
R0500								
Copper roof covering								
R2.0 Glass wool batts	2.3	457.82	2.5	432.39	3.0	470.47	3.2	404.65
R2.0 Glass wool blanket		458.04		432.60		470.69		404.85
R2.0 Polyester		457.06		431.63		469.71		403.95
R2.5 Glass wool batts	2.8	458.52	3.0	433.09	3.5	471.17	3.7	405.30
R2.5 Glass wool blanket		460.96		435.52		473.61		407.55
R2.5 Polyester		459.06		433.63		471.72		405.80
R3.0 Glass wool batts	3.3	460.63	3.5	435.20	3.9	473.28	4.1	407.25
R3.0 Polyester		461.17		435.74		473.83		407.75
R3.0 Wool batts		474.37		448.94		487.03		419.95
R4.0 Glass wool batts	4.2	462.63	4.4	437.20	4.9	475.29	5.1	409.10
R4.0 Polyester		467.50		442.07		480.16		413.60

(continued)

Table 88.4 (continued)

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
Terracotta roof covering								
R2.0 Glass wool batts	2.3	363.41	2.5	363.62	3.0	355.95	3.2	333.57
R2.0 Glass wool blanket		363.62		363.84		356.16		333.77
R2.0 Polyester		362.65		362.86		355.19		332.87
R2.5 Glass wool batts	2.8	364.11	3.0	364.32	3.5	356.65	3.7	334.22
R2.5 Glass wool blanket		366.55		366.76		359.09		336.47
R2.5 Polyester		364.65		364.86		357.19		334.72
R3.0 Glass wool batts	3.3	366.22	3.5	366.43	3.9	358.76	4.1	336.17
R3.0 Polyester		366.76		366.97		359.30		336.67
R3.0 Wool batts		379.96		380.17		372.50		348.87
R4.0 Glass wool batts	4.2	368.22	4.4	368.43	4.9	360.76	5.1	338.02
R4.0 Polyester		373.09		373.30		365.63		342.52
R0600								
Aluminium roof covering								
R2.0 Glass wool batts	2.5	427.52	3.0	437.14	3.4	426.53	3.6	406.23
R2.0 Glass wool blanket		427.74		437.35		426.75		406.43
R2.0 Polyester		426.77		436.38		425.78		405.53
R2.5 Glass wool batts	3.0	428.23	3.4	437.84	3.9	427.24	4.1	406.88
R2.5 Glass wool blanket		430.66		440.27		429.67		409.13
R2.5 Polyester		428.77		438.38		427.78		407.38
R3.0 Glass wool batts	3.4	430.34	3.9	439.95	4.4	429.35	4.5	408.83
R3.0 Polyester		430.88		440.49		429.89		409.33
R3.0 Wool batts		444.08		453.69		443.09		421.53
R4.0 Glass wool batts	4.4	432.34	4.9	441.95	5.4	431.35	5.5	410.68
R4.0 Polyester		437.21		446.82		436.22		415.18

(continued)

Table 88.4 (continued)

Type of roof	Vapour permeable membrane		Single sided foil		Double sided antiglare foil		Double sided bubble/Foam foil	
	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)	Total R-Value	LCC (AUD)
Copper roof covering								
R2.0 Glass wool batts	2.5	1007.40	3.0	1017.01	3.4	1006.41	3.4	942.13
R2.0 Glass wool blanket		1007.61		1017.23		1006.62		942.33
R2.0 Polyester		1006.64		1016.25		1005.65		941.43
R2.5 Glass wool batts	3.0	1008.10	3.4	1017.71	3.9	1007.11	3.9	942.78
R2.5 Glass wool blanket		1010.54		1020.15		1009.55		945.03
R2.5 Polyester		1008.64		1018.26		1007.65		943.28
R3.0 Glass wool batts	3.4	1010.21	3.9	1019.82	4.4	1009.22	4.4	944.73
R3.0 Polyester		1010.75		1020.37		1009.76		945.23
R3.0 Wool batts		1023.95		1033.57		1022.96		957.43
R4.0 Glass wool batts	4.4	1012.21	4.9	1021.83	5.4	1011.22	5.4	946.58
R4.0 Polyester		1017.08		1026.70		1016.09		951.08

88.4 Conclusions and Recommendations

This research identified the insulation requirements for the pitched roof structures in Australia and calculated the life cycle cost for each of these roof structures. In conclusion, the life cycle cost depends highly on the roof covering and the type of insulation used. The maintenance and end of life cost for tiled roof coverings are comparatively higher due to the extra care required in handling, maintaining and stacking and setting aside for reusing. Life cycle cost for copper roof covering is higher due to the higher initial costs. Further, the life cycle cost is higher for highly insulated roofs with higher total R-Values. Usually the cost of maintenance for insulated pitched roofs amount to 20% of the life cycle cost. In this research, only the life cycle cost for pitched roof with insulation is calculated. However, there are direct energy savings with the changes in the thermal insulation which is not included in this research. Therefore, further research can be carried out even focusing on the impact of energy in the lifecycle cost for pitched roof structures with necessary insulation.

Acknowledgements The authors wish to acknowledge the financial support from the Australian Research Council (ARC) Discovery Project under grant number DP150101015.

References

Australia Building Codes Board (2016) National construction code 2016; Building code of Australia. The Australian Building Codes Board, Canberra

Australian National Audit Office, "Life cycle costing—better practice guide," 2001

Goussous J, Al-Refaie A (2014) Evaluation of a green building design using LCC and AHP techniques. Life Sci J 11

Green Building Council Australia, "Green Star-Design & as built v1.1," 2015

Insulation Council of Australia and New Zealand (2014) Insulation handbook, in Part 1: Thermal performance. Insulation Council of Australia and New Zealand

Jankovic L (2013) Designing zero carbon buildings using dynamic simulation methods: Taylor and Francis, London

Rawlinsons (2015) Rawlinson construction cost guide, vol 33. Rawlinson Publishing, Perth, Western Australia

Roels SM (2011) The effect of a reflective underlay on the global thermal behaviour of pitched roofs. Build Environ 46:134–143, 1/2011

Roels S, Langmans J (2016) Highly insulated pitched roofs resilient to air flow patterns: guidelines based on a literature review. Energy Build 120:10–18, 5/15/2016

Roofing Contractor (2016 Aug 15). Available: http://www.roofingcontractor.com/articles/89106-making-a-case-for-roof-maintenance

Zhang H (2011) Building materials in civil engineering, 1st edn. Woodhead Publishing Limited, Cambridge, UK

Chapter 89
Life-Cycle Cost Assessment of Durable Repair of Concrete Structures Based on Environmental Costs

X.M. Mi, C.Y. Liu, D.W. Li, N.X. Han and F. Xing

89.1 Introduction

The failure of concrete structures, which is primarily caused by environmental corrosion, involves changes in the appearance of the concrete and reduction of its load capacity and affects the security of entire structures (Durham and Rens 2010). The durability of life-cost forecasting is of significant importance in theory and practice. Life-cycle economic analysis, which is dependent on the accuracy of statistical and economic information as well as past and present economic phenomena, applies scientific methods to analyze the entire life cycle to determine the economics of future growth prospects (David Trejo and Kenneth Reinschmidt. 2007a).

Most studies of life-cycle costs focus only on economic analyses, which do not consider all economic variables and social costs (David Trejo and Kenneth Reinschmidt. 2007b). The history of human economic development indicates that there is a close relationship between economic development and environmental quality. On average, approximately one ton of concrete is produced each year for every human being on Earth (Lippiatt and Ahmad 2004). Direct and indirect activities associated with the use of concrete have a significant impact on the global environment, emphasizing the need to correctly assess the environmental impact (Van den Heede and De Belie 2012). In the United States, approximately 2.58% of carbon emissions are from direct concrete activities, including cement manufacturing and construction (U.S. Energy Information Administration (EIA) 2013). Manufacturing industries and construction are the fourth largest source of CO_2

X.M. Mi (✉) · C.Y. Liu
College of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: mixm@szu.edu.cn

D.W. Li · N.X. Han · F. Xing
Guangdong Provincial Key Laboratory of Durability for Marine Civil Engineering, College of Civil Engineering, Shenzhen University, Shenzhen, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_89

emissions in the 15 countries of Europe and were responsible for 13% of total GHG emissions in 2011 (Europe Environment Agence (EEA) 2013).

Simultaneously, concrete structures inevitably exhibit durability problems due to the characteristics of the materials and the influence of the environment. Change in structural performance due to changes in the durability of concrete ultimately affects the safety of structures. Significant maintenance costs must be incurred to improve the durability of many concrete structures. Nowadays, studies have increasingly focused on life-cycle assessments of buildings, including environmental and economic costs (Roh et al. 2014).

Carbon emissions are a general term for GHG emissions. According to the fifth assessment report (hereinafter referred to as the "Report") of the Intergovernmental Panel on Climate Change, carbon emissions from fossil fuel combustion and cement production increased more rapidly during the 2000–2011 period than the 1990–1999 period (Intergovernmental Panel on Climate Change (IPCC) 2013). The amount of CO_2 originating from the construction industry is particularly significant. According to a report released by the Department for Business, Innovation & Skills of the United Kingdom, CO_2 emissions related to the construction industry represent nearly 47% of total CO_2 emissions in the UK. In addition, manufacturing (of construction products and materials) produces the greatest amount of emissions within the construction process (Department for Business, Innovation & Skills of UK 2010).

Therefore, this paper discusses the life-cycle cost assessment of concrete structures on the basis of durable repair technology from an environmental impact perspective. We analyze the five stages of concrete durability development, as well as appraise the repair solutions for a degraded concrete structure based on a case study. It is found that environmental cost has a significant influence on the selection of repair solutions.

89.2 Literature Review and Research Model

Extensive engineering practice and experience have demonstrated that durable repair technology for concrete structures in coastal regions involves a large number of experimental projects and specific techniques. The different interactions between technology and materials have a substantial impact on the economic externalities of the ultimate concrete durability.

The concepts and ideas of architectural design should consider project construction costs and operation and maintenance costs (Orshan 1980). Life-cycle cost analysis practices changed over the course of two decades, revealing a gap between the state-of-the-practice and the state-of-the-art (Ozbay et al. 2004). Paya-Zaforteza et al. (2009) simulated and optimized the carbon emissions of a reinforced concrete frame structure design scheme. The authors concluded that two goals, carbon emissions and life-cycle cost, must be emphasized in the concrete structure durability assessment. Simulations and a case study revealed that the carbon emissions of the optimal economic cost scheme were 3.8% higher, while the economic costs of the scheme with minimal carbon emissions were 2.77% higher (Paya-Zaforteza et al. 2009). Oliver-Solà et al. (2011) exploited the GWP diagram method as an environmental tool to guide the design of concrete sidewalks to ultimately reduce carbon emissions (Oliver-SolÀ et al. 2011). They noted that the GWP diagram method is characterized by accuracy, adaptability and ease of interpretability, and thus a life-cycle assessment of carbon emissions from concrete pavement can be performed.

Nässén et al. (2012) studied carbon emissions and the economic cost difference between concrete structures and wooden structures during their life cycle (NässÉN et al. 2012). The results revealed that wooden structures emit less carbon dioxide when wood incineration treatment during waste processing is not considered. However, the analysis of life-cycle carbon emissions reveals that the carbon emissions from concrete and wood-structure buildings are almost equal when the incineration treatment is considered. Furthermore, the carbon emissions from wood-structure buildings are significantly smaller compared to the construction of concrete structure if carbon-capture technologies are used, while wood structures have no advantages with respect to cost.

Polder et al. (2013) predicted the life-cycle cost of maintaining a cathodic protection system based on data from 150 concrete structures in the Netherlands. They also used statistical techniques to analyze the data (Polder et al. 2013). Roh et al. (2014) conducted a life-cycle CO_2 assessment of an apartment house in Korea but did not convert the environmental impact into economic costs (Roh et al. 2014).

Extensive engineering practice and research data indicate that coastal concrete durability studies involve a large number of pilot projects and specific techniques and that the system is influenced by the various interactions between technology and materials. Thus, a life-cycle cost analysis is required to analyze the durability of the components. Research in this field remains sparse and has mainly been concentrated in other disciplines, such as marine analysis, mechanical engineering and other aspects of economic analysis. Scholars have conducted a variety of modeling studies of marine economic forecasts using traditional modeling methods to obtain growth curves, extrapolate trends, and establish a recursive discrete model. Others have applied time-series methods to develop cost models to forecast sensitive factors. However, these models are not well matched to the research objects, focus only on the fitting process and have poor predictive ability. Therefore, it is difficult to conduct a comprehensive life-cycle cost analysis of the whole process and make long-term forecasts.

Based on the concrete structure durability deterioration characteristics of coastal regions, we select major infrastructure and buildings as a case study. The inspection and repair program is studied and determined based on the structure failure probability. Moreover, this paper analyses problems in relevant factor costs including construction costs, routine testing costs, repair costs and failure losses. Emphasis is placed on the development of a life-cycle assessment method by which durability technologies of concrete structures can be evaluated (Table 89.1).

Table 89.1 The framework of the life-cycle cost analysis

Construction stage	Use stage		Demolition and disposal stage
Material prices, production costs, costs of ancillary activities	Testing costs	Repair costs	Demolition and disposal costs
Cost variables input and prediction			
The analysis of reliability and failure probability			
The cost of materials, relevant concrete, components and parts, the cost of ancillary activities in construction stage, other indirect costs	Cost allocation between testing equipment and instrument application, indirect costs resulting from testing activities	Direct cost of repair: materials, construction machinery, labor etc. Indirect production and transportation costs caused by repair activities	Field costs of concrete structure blasting and demolition, costs caused by concrete structure demolition and waste disposal

Table 89.2 The framework of life-cycle cost analysis

Construction stage		Use stage		Demolition and disposal stage
Materials production and transportation	Construction	Testing activities	Rehabilitation activities	Demolition and disposal
Carbon emission characteristics and carbon footprint				
Carbon emissions from concrete-related material production, manufacture, processing and handling	Carbon emissions generated by construction equipment and production of auxiliary materials	Carbon emissions generated by testing equipment and instruments. Carbon emissions caused by testing activities	Carbon emissions resulting from repair material production and transportation. Carbon emissions caused by repair machinery and other ancillary activities	Carbon emissions caused by demolition of concrete structures such as blasting. Carbon emissions generated by construction waste disposal

According to the life-cycle stages, carbon emissions related to materials and activities are defined in Table 89.2. The activities include transportation, construction, testing activities, rehabilitation activities, demolition and disposal. The complexity of defining and calculating these activities is readily apparent.

Life-cycle costs include initial costs and future costs. The initial costs of construction projects are the construction costs, and the future cost is the delivery of construction projects completed during the period after removal, including energy, operating, maintenance, repair, and replacement costs as well as residual values.

Therefore, the life-cycle cost model is constructed as follows:

$$C = C_0 + \sum_{j=1}^{n} C_j(1+i)^{-j} - S(1+i)^{-n},$$

Where C denotes the life-cycle cost, C_0 denotes the construction costs, C_j denotes the repair costs at year j, and S is the residual values of the project.

89.3 Case Studies

89.3.1 Project Introduction

Project A, located in Shenzhen city, is a large seaside exhibition hall that is 100 m north of the Mirs Bay Sea. Project A includes a two-story public building, five sea basins and various types of ornamental pools (marine animal show pools). The public building's area is 7460 m^2, the five sea basins' volume is 7000 m^3, and the ornamental pools' volume is greater than 2000 m^3. Apart from some office space within a brick structure, the structures are concrete-framed structures with cast-in-place reinforced concrete floors. In addition, the water in the pools and basins is seawater directly obtained by pipelines from the sea. The temperature of the sea water is approximately 29° centigrade in the summer and 16° centigrade in the winter. Moreover, the water's salinity is approximately 30. The project was designed in 1996, and construction began in the same year. Project A, which was once the largest aquarium in China was completed and came into service in 1998.

In 2001, repair engineering was performed because of water leakage from a deformation between the seawater pool and the main building joints. In 2004, a structural component degradation phenomenon was identified. In addition, a deformation of 300 mm in the sea water pools appeared to again be causing serious water leakage after being repaired. The aim of this study is to determine the reason why the concrete components deteriorated in six years. Furthermore, we provide a comprehensive approach for building restoration based on a life-cycle cost analysis.

The structural engineering institute of Shenzhen University conducted a detailed investigation of the structure in 2005. A maintenance strategy centered on durability was then proposed. The repair engineering was completed in November 2007.

The field survey showed that the corridor areas of the concrete structures, whether on the surface or the interior, exhibited relatively severe structural degradation; partial salting was even apparent on the walls of the pools. Moreover, some areas exhibited more serious reinforcement corrosion problems.

Based on the <Concrete Structures Durability Design and Construction Guide> (CCES01-2004, China), we can conclude that this level of environmental effects is not the result of a normal indoor environment. We made a judgment that it is similar to an offshore heavy salt fog area environment III-E.

The basis for evaluation was 《Concrete-part 1: Specification, performance, production and conformity》 (EUROPEAN STANDARD, EN206-1: 2000). The design thickness of the protective layer for the main concrete components is as follows: the beam and column are approximately 25 mm, and the floor is 15 mm.

Based on the action principles and techniques applied for reinforcement corrosion destruction worldwide, concrete repair methods include patch repair, film coating, sealing and protection, cathodic protection and electrochemical chloride extraction and alkaline and rust inhibitors.

Technical solution one is electrochemical chloride extraction, and technical solution two is patch repair and coating.

The specific analysis object: a total of six middle columns in a pipe gallery with number XBZ3. Protective layer thickness: 25 mm. Repair height: 5.7 m. Total repair area: 54.7 m^2. Marine chloride environmental conditions: splash zone, rating F.

Assuming that the random variables obey a normal distribution, the model is as follows:

$$E\{C_{cap}\} = S + \sum_{j=1}^{t_G} \frac{V_j}{(1+r)^j} + \sum_{j=1}^{t_G} \frac{P\{F_j\}D_j}{(1+r)^j},$$

Where

$E\{C_{cap}\}$	structure whole life-cost expectation,
S	direct investment,
V_j	the j-th year's cost of maintenance and management,
$P\{F_j\}$	failure probability of structural performance in the j-th year,
D_j	loss due to structural performance failure in the j-th year,
r	real interest rate, and
t_G	service life of the structural objects.

Demolition original surface course: thickness of 20 mm, total maintenance area of 54.7 m^2, and engineering quantity of 1.095 m^3.

Demolition original concrete protective layer: thickness 25, total maintenance area 54.7 m^2,engineering quantity of 1.368 m^3.

C30 concrete with gentle volume expansion: 75 mm, total maintenance area 54.7 m^2, engineering quantity of 4.104 m^3.

Polypropylene ester emulsion mortar: 10 mm, total maintenance area 54.7 m^2, 0.547 m^3.

Demolition original concrete protective layer (100 m^2) (Table 89.3).

Table 89.3 Life-cycle cost analysis results

Content	Cost (USD)
Demolition of the protective layer of reinforced concrete—manual	91.50
Demolition of the reinforced concrete cover—mechanical demolition	129.71
C30 concrete rectangular column production (within 3 m^3)	38.68
Total cost of the construction stage	930.28
Electrochemical cost	3970.16
Cost of maintenance and management	1632.25
Cost of losses based on reliability	18.97
Total cost of the first scheme (30 years, from 2007 to 2026)	5621.39
Total cost of the second scheme (30 years, from 2007 to 2026)	4508.88

89.3.2 Life-Cycle Cost Analysis with Carbon Emission Variables

Electrochemistry scheme: Constant voltage current regulator 10, where the device is powered for four weeks; the voltage is 200 mV direct current; the electrolyte is water; the desalination density is 2.5 A/m^2; the quantity of electricity is 1800 A/h; and the area of desalination is 500 m^2.

Sand: 1.85 t/m^3; Stone: 2.0 t/m^3; Timber: 0.5 t/m^3; Steel: 8 t/m^3; Plastics: 0.9 t/m^3; Mortars: 2.2 t/m^3; Cement: 1.5 t/m^3.

The first scheme's carbon emissions are 11 tons, while the second scheme's carbon emissions are 36 tons.

The EU ETS has been established since 2005. Carbon trading prices have been volatile, and the highest price reached was 32 Euros per ton in 2008, which decreased to 8 Euros per ton in 2009. The price was 18 Euros per ton in 2011.

According to trade data from the China Shenzhen Emission Rights Exchange, the average price of carbon emissions per ton was 10.75 USD in 2013. The gap between the two schemes becomes small when carbon emission costs are considered.

89.3.3 Prediction Analysis

Prediction analyses can be performed based on the above results. Without considering environmental variables, the life-cycle costs of the two schemes become equal in 38.5 years when we extend the analysis time setting. When carbon emissions are considered, this time moves forward approximately 3 years. Therefore, environmental affects must be considered during the life-cycle cost analysis and technique selection.

These results demonstrate that the environmental cost has a great influence on the solution selection. The solution selection will change significantly when the carbon emission trading price reaches 30 dollars. Moreover, if we add a more variable carbon tax, the two solutions' results will change much sooner.

89.4 Conclusions

This paper discusses a life-cycle cost analysis of coastal concrete structures' durability by incorporating carbon emission variables to develop and analyze two solutions for the concrete durability of Project A in China. It is found that the first scheme's cost is much more than the second scheme's without consideration of carbon emissions. The second scheme will cause the more carbon emissions. Therefore, the first scheme will be the better choice if the carbon emission cost is considered and the lifespan is more than 36 years. In fact, the Concrete Structures' lifespan are usually more than 50 years. So the results reveal that carbon emissions have a substantial influence on the solution selections. Due to global warming, it is imperative for governments to impose effective policy instruments to promote energy savings and carbon emission reductions. The methods for reducing carbon emissions have become a focus of international politics and economic concern as well as academic research. The analysis results reveal that the life-cycle cost for coastal concrete is a complex and dynamic system and is influenced by many factors. Changes in each factor will inevitably affect the selection of technology. The increasing importance of environmental costs compared to other influential factors must be considered.

Acknowledgements This research was supported by the National Natural Science Foundation of China (No.: 51520105012).

References

David Trejo PE, Kenneth Reinschmidt M (2007a) Justifying materials selection for reinforced concrete structures I: sensitivity analysis. J Bridge Eng 12(1):31–37

David Trejo PE, Kenneth Reinschmidt M (2007b) Justifying materials selection for reinforced concrete structures II: economic analysis. J Bridge Eng 12(1):38–44

Department for Business, Innovation & Skills of UK (2010) CO_2 emissions influenced by the construction industry. Low Carbon Construction IGT Report, 29 November

Europe Environment Agence (EEA) (2013) Annual European Union Greenhouse Gas Inventory 1990–2011 and inventory report 2013 submission to the UNFCCC secretariat

Intergovernmental Panel on Climate Change (IPCC) (2013) Climate change 2013 the fifth assessment report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland

Lippiatt B, Ahmad S (2004) Measuring the life-cycle environmental and economic performance of concrete: the BEES approach, international workshop on sustainable development and concrete technology. Iowa State University, Ames, pp 213–230

Liu R, Durham SA, Rens KL (2010) Durability of sustainable concrete mixtures. Green Streets and Highways, pp 248–257

NässÉN J, Hedenus F, Karlsson S, Holmberg J (2012) Concrete versus wood in buildings: an energy system approach. Build Environ 51:361–369

Oliver-SolÀ J, Josa A, Arena A, Gabarrell X, Rieradevall J (2011) The GWP-chart: an environmental tool for guiding urban planning processes: application to concrete sidewalks. Cities 28:245–250

Orshan O (1980) Life cycle cost: a tool for comparing building alternative. Proc Symp Qual Cost Build 1(3):63–71

Ozbay K, Jawad D, Parker NA (2004) Life cycle cost analysis: state-of the practice versus state-of-the art. In: Proceedings of the 83rd annual meeting of the transportation research board. Transportation Research Board, Washington DC, US

Paya-Zaforteza I, Yepes V, Hospitaler A, GonzÁLez-Vidosa F (2009) CO_2-optimization of reinforced concrete frames by simulated annealing. Eng Struct 31:1501–1508

Polder R, Leegwater G, Worma D, Courage W (2013) Service life and life cycle cost modelling of cathodic protection systems for concrete structures. Cem Concr Compos 47:69–75

Roh Seungjun, Tae Sungho, Shin Sungwoo, Woo Jeehwan (2014) Development of an optimum design program (SUSB-OPTIMUM) for the life cycle CO_2 assessment of an apartment house in Korea. Build Environ 73:40–54

U.S. Energy Information Administration (EIA) (2013) Annual energy outlook 2013 with projections to 2040. Washington, DC 20585

Van den Heede P, De Belie N (2012) Environmental impact and life cycle assessment (LCA) of traditional and "green" concretes: literature review and theoretical calculations. Cem Concr Compos. doi:10.1016/j.cemconcomp,01.004

Chapter 90
Literature Review on the Research Discipline of Low Carbon Cities in China

X.Y. Du, T.K. Li, Z.H. G and L.Y. Shen

90.1 Introduction

Low carbon city is a concept accompanied by low carbon economy, which was mentioned first time by the British government in 2003 in its "energy white paper" in 2003. From then on, scholars begin to pay close attention to research of low carbon city (Li and Zhang 2011). Six ministries in China jointly issued the first "National Assessment Report on Climate Change" in 2007, and it was the first official document to low carbon policy in China; President Jintao Hu explicitly advocated the low carbon economy development in September 2007; The Ministry of Construction launched the "Low-Carbon City" in ShangHai and BaoDing as pilot cities in the early 2008. Since then low carbon city become one of strategic target in chinese cities. Academic circles has devoted good efforts to the discussions on low carbon city.

The research area of low carbon city is relatively broad, involving ecology, sociology, ethics and so on. The research topics on low carbon city combine urban planning, development path and policy suggestions and so on. These research topics are nevertheless fragmental, which have limited effectiveness in providing reference value. It is very important yo gain a holistic picture on these studies that their reference values can be utilized effectively.

There are some studies on the current status of the research about low carbon city in China. The results of this kind of study can be divided into two main classes: one kind focuses mainly through literature reading, to summarize and sum up the

X.Y. Du (✉) · T.K. Li · Z.H. G · L.Y. Shen
School of Construction Management & Real Estate,
Chongqing University, Chongqing, China
e-mail: 1101714844@qq.com

X.Y. Du · Z.H. G · L.Y. Shen
International Research Centre for Sustainable Built Environment,
Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_90

research on the theory and experience (Li and Zhang 2011; Fan 2011). For example: Jiping Fan, Zigong Zhang and so on overview the research of the low carbon city from the perspectives of object, content and methods

Another existing study is based on objective data, using the methods of literature metrology and the empirical research, for example: Yu, C.H and so on analyzed the keywords, authors, organizations, journals of the literature in China National Knowledge Infrastructure Database (CNKI) about low carbon research during the period of 2003–2011, which presents a knowledge map using Citespce (Hui et al. 2012). For example: Li, X.B constructed a co-occurrence clustering tree and a co-occurrence network on the literature about the low carbon research in CNKI during the period of 1980–2010. They concluded that the macro research takes the dominant position, the middle—level research is becoming popular and the micro research has yet to start (Li and Tang. 2012). Chengcheng Wang draw a knowledge map for demonstrating the research status and development contexts on the subject of the low carbon city (Wang et al. 2013). Their conclusion shows that the research field on low carbon mainly concerns seven specific directions such as: low carbon economy, low carbon city, energy-saving emission reduction, sustainable development and others.

The research on low carbon city has been developing gradually. This can be evidenced by the number of academic research articles about low carbon city, as shown in Table 90.1. The studies for reviewing the research status of low carbon city research appeared mostly in 2011, and they are considered n not effective to reflect the most updated status of the research in the discipline of low carbon city. Therefore it is necessary to examine the current research situation about the low carbon city. There are a few studies with focus on analysis of the status, but they do not provide an overall profile to map the status.

The research data used in this paper are collated from the articles on the low carbon city in 198 journals which are Chinese core and the CSSCI journals. The high frequency keywords (HFK) in there research articles are identified from these 198 journals. These HFKs are further examined by using. By using EXCEL software, the co-word matrix, similar matrix and dissimilarity matrix; Furthermore, by using SPSS software, HFKs are classified into 14 clusters of low carbon city in china. These clusters show the status of the existing studies on low carbon cities in china; By mapping the strategic coordinates, we know the location of different classes.

Table 90.1 The number of research on articles on low carbon cities (Lv et al. 2011)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number	4	13	14	68	347	3809	2873	2434	2844	3026	2727	388

90.2 The Research Process and Research Method

Firstly, In this paper, the co-word analysis method and strategic diagram are applied to analyze the research status about low carbon city within the context of China. Co-word analysis can display a hot topic in the field cluster analysis is used to reflect on low carbon city the through classification, and display research status. Strategy coordinate method is used to reveal low carbon city research by group.

Secondly, Word analysis is a method of content analysis, which was introduced firstly by French literature metrologists in the late 1970s.

The method counts the group of words that appear in the same paper, to analyze the affinities of these words by cluster method and reflect visually the structure of research fields which are represented by these words (Zhong and Li 2008a, b).

Thirdly, those processed keywords are further classified into high frequency keywords (HFK) and non-HFK, HFKs are chosen by considering both the frequency of their appearance and the number of HFKs, so that the total number of HFKs are not too many.

In 1988, Law John, for the first time, proposed the use of two-dimensional coordinates, the density within a specific field and the centrality for which are related to the mentioned field. This relationship which is composed with various fields. The density and the degree of centrality are calculated according to the following formulas.

$$\text{Density} = \sum_{i,j \in \Phi s (i \neq j)} Eij/(n-1) \tag{1}$$

$$\text{Centrality} = \sum_{i \notin \Phi s, j \in (\Phi - \Phi s)} Eij/(N-n) \tag{2}$$

N is the number of the total keywords; n is the number of keywords within the cluster; i and j represent different keywords; Φ represents all the keyword; Φs represents a group of keywords within a cluster.

Eij denotes Equivalent index, which can reflect the correlation between i and j, the formula are as the following (Wang et al. 2013):

$$Eij = Fij/FiFj = Fij^2/FiFj \tag{3}$$

F_{ij} is the number of co-occurrence of i and j.F_i represents the occurrence number of i and F_j represents the occurrence number of i.

90.3 Data Collection

This paper search literature about low carbon city from the CNKI database, chosen CSSCI and core journals published on the relevant literature, a total of 198 journals has been screened, and a total of paper 1092 are collated.

Keywords processing: firstly, all the keywords quoted in all those 1092 papers are collected and those keywords without relations to low carbon city are considered invalid for this study and eliminated. Such as Low carbon steel, symbiosis between fish food and so on.

Secondly, keywords will be merged by considering two situations: one situation is that keywords have similar meaning, such as “low carbon eco-city” and “ecological city”; Another situation is that keywords have subordinating relationship (Lv et al. 2011), such as “the way of traffic” and “the way of travel”, “Beijing” and “city of Beijing”. As a result, 1574 keywords are identified. Depend on the researchers’ experience and high balance between number and frequency, 48 words, which frequency of emerging in papers more than ten times, was selected as the high frequency keywords. Occurrence of these keywords account for 45% of the total number of keywords. Consequently, 49HFKs are identified, all of the which have appeared more than ten times in various papers and the numbers of these 48HFKs accounts for 45% of the total number of occurrences of all the 1574 keywords. The 48HFKs are listed in Table 90.2.

90.4 Data Processing

The 48 valid HFKs will be processed in this section through establishing their co-word matrix, similar matrix and dissimilarity matrix.

Co-word matrix is established by examining the number of co-occurrence of the co-word matrix of HFKs. It can be seen that the HFKs co-words matrix is a 48 * 48 matrix, as shown in Table 90.3 (H.1 is short for HFK.1).

The Ochiia coefficient is used to convert the co-word matrix to the similarity matrix.

$$\text{Ochiai} = F\text{ij}/\sqrt{Fi \times Fj} \tag{4}$$

By applying the data in Table 90.2 to model (4), the similarity matrix can be obtained.

Table 90.2 HFKs of the low carbon city in China

HFK.	Keyword	Frequency
A		
HFK.1	Low carbon city	313
HFK.2	Low carbon economy	240
HFK.3	Carbon emissions	174
HFK.4	Index system	87
HFK.5	Policy	70
HFK.6	Representative city of low carbon	53
HFK.7	Consumer behavior	52
HFK.8	Development path	52
HFK.9	Urban planning	48
HFK.10	Travel model	46
HFK.11	Sustainable development	45
HFK.12	Low carbon development	37
HFK.13	Energy conservation and emission reduction	34
HFK.14	Energy	34
HFK.15	Urban transportation	32
HFK.16	Climate change	32

HFK	Keyword	HFK.	Keyword	Frequency
B				
HFK.17	Low carbon transportation	HFK.33	Green building	13
HFK.18	Urbanization	HFK.34	Scenario analysis	13
HFK.19	Eco-city	HFK.35	Influencing factors	13
HFK.20	Urbanization	HFK.36	Low carbon Tourism City	12
HFK.22	Ecological civilization	HFK.37	Greenhouse gas inventory	12
HFK.22	Resource city	HFK.38	Factor analysis	12
HFK.23	Employment of land	HFK.39	Low carbon community	12
HFK.24	Urban spatial structure	HFK.40	Low carbon industry	11
HFK.25	Technical methods	HFK.41	Architecture of landscape	11
HFK.26	The principle of decoupling	HFK.42	Carbon finance	11
HFK.27	Development model	HFK.43	Detailed control planning;	11
HFK.28	Analytic hierarchy process	HFK.44	DPSIR model	10
HFK.29	Industrial structure	HFK.45	Economic growth	10
HFK.30	Urban residents	HFK.46	Carbon sink	10
HFK.31	Two type society	HFK.47	Research progress	10
HFK.32	Carbon footprint	HFK.48	Low carbon competitiveness	10

Table 90.3 Co-word matrix of the 48 HKFs on low carbon city in China

	H.1	H.2	H.3	H.4	H.5	H.6	H.7	H.8	H.9	H.10	H.11	H.12	H.13	H.14	H.15	H.16
A																
H.1	313	77	38	42	35	12	7	13	12	3	10	8	10	24	2	14
H.2	77	240	22	13	25	13	8	15	5	3	14	0	13	13	5	9
H.3	38	22	174	3	4	22	13	4	6	8	0	6	0	15	3	12
H.4	42	13	3	87	0	4	0	0	1	1	2	3	0	2	0	0
H.5	35	25	4	0	70	1	0	0	1	0	2	0	0	1	3	1
H.6	12	13	22	4	1	53	1	1	3	2	2	5	0	0	2	3
H.7	7	8	13	0	0	1	52	0	0	0	0	3	0	0	0	1
H.8	13	15	4	0	0	1	0	52	0	0	1	0	0	2	1	1
H.9	12	5	6	1	1	3	0	0	1	2	2	1	1	1	6	0
H.10	3	3	8	1	0	2	0	0	1	46	1	0	0	2	4	0
H.11	10	14	0	2	2	2	0	1	2	1	45	1	2	0	0	3
H.12	8	0	6	3	0	5	3	0	2	0	1	37	1	2	1	1
H.13	10	13	0	0	0	0	0	0	1	0	2	1	34	1	0	1
H.14	24	13	15	2	1	0	0	2	1	2	0	2	1	34	1	0
H.15	2	5	3	0	3	2	0	1	1	4	0	1	0	1	32	0
H.16	14	9	12	0	1	3	1	1	6	0	3	1	1	0	0	32
	H.17	H.18	H.19	H.20	H.21	H.22	H.23	H.24	H.25	H.26	H.27	H.28	H.29	H.30	H.31	H.32
B																
H.1	4	4	6	1	7	2	0	3	7	5	10	2	2	2	0	2
H.2	3	4	6	0	4	8	2	0	3	2	6	4	10	0	0	5
H.3	5	12	3	3	0	1	3	7	5	5	0	0	2	2	0	2
H.4	0	0	7	1	3	0	0	0	2	1	0	5	0	0	0	0
H.5	4	2	7	2	0	3	0	0	0	1	4	0	0	0	0	0

(continued)

Table 90.3 (continued)

	H.17	H.18	H.19	H.20	H.21	H.22	H.23	H.24	H.25	H.26	H.27	H.28	H.29	H.30	H.31	H.32
H.6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
H.7	1	3	0	0	1	0	0	0	0	2	0	0	3	1	0	0
H.8	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
H.9	0	3	1	0	0	1	0	3	1	0	0	0	0	0	2	0
H.10	8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
H.11	0	4	1	0	2	2	0	0	0	0	3	0	0	0	0	0
H.12	0	1	1	2	1	1	0	0	1	0	0	0	0	1	0	0
H.13	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0
H.14	3	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1
H.15	3	1		0	0	0	1	0	0	0	0	0	0	0	0	0
H.16	0	4	1	0	1	0	0	0	0	0	0	0	2	1	0	0
	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48
C																
H.1	3	5	3	3	6	3	4	3	3	5	3	9	3	4	5	1
H.2	0	2	0	1	0	4	1	1	0	5	0	1	2	4	0	1
H.3	1	3	6	2	2	1	3	0	0	1	3	0	6	1	3	0
H.4	1	0	0	0	0	4	1	1	1	0	1	8	0	2	0	1
H.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
H.6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
H.7	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
H.8	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0
H.9	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	
H.10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
H.11	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0

(continued)

Table 90.3 (continued)

	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48
H.12	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
H.13	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
H.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
H.16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
	H.1	H.2	H.3	H.4	H.5	H.6	H.7	H.8	H.9	H.10	H.11	H.12	H.13	H.14	H.15	H.16
D																
H.17	4	3	5	0	4	1	1	1	0	8	0	0	0	3	3	0
H.18	4	4	12	0	2	0	3	0	0	0	4	1	0	0	1	4
H.19	6	6	3	7	7	1	0	0	3	0	1	1	3	0		1
H.20	1	0	3	1	2	0	0	0	1	0	0	2	0	0	0	0
H.21	7	4	0	3	0	0	1	0	0	0	2	1	0	0	0	1
H.22	2	8	1	0	3	0	0	0	0	0	2	1	0	1	0	0
H.23	0	2	3	0	0	0	0	0	1	0	0	0	0	0	1	0
H.24	3	0	7	0	0	0	0	0	0	1	0	0	0	0	0	0
H.25	7	3	5	2	0	0	0	0	3	0	0	1	0	0	0	0
H.26	5	2	5	1	1	0	2	1	1	0	0	0	1	0	0	0
H.27	10	6	0	0	4	0	0	0	0	0	3	0	0	0	0	0
H.28	2	4	0	5	0	0	0	0	0	1	0	0	0	0	0	0
H.29	2	10	2	0	0	0	3	0	0	0	0	0	0	1	0	2
H.30	2	0	2	0	0	0	1	0	0	0	0	1	0	1	0	1
H.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.32	2	5	2	0	0	0	0	1	2	0	0	0	0	0	0	0
	H.17	H.18	H.19	H.20	H.21	H.22	H.23	H.24	H.25	H.26	H.27	H.28	H.29	H.30	H.31	H.32

(continued)

Table 90.3 (continued)

	H.17	H.18	H.19	H.20	H.21	H.22	H.23	H.24	H.25	H.26	H.27	H.28	H.29	H.30	H.31	H.32
E																
H.17	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
H.18	0	27	1	0	0	0	0	0	1	0	0	2	1	0	0	0
H.19	0	1	26	1	2	0	1	0	0	0	2	0	0	0	0	0
H.20	0	0	1	25	3	0	0	0	0	0	0	0	0	0	0	0
H.21	0	0	2	3	21	0	0	0	0	0	0	0	0	0	0	0
H.22	0	0	0	0	0	20	1	0	0	0	1	0	0	0	0	0
H.23	0	0	1	0	0	0	20	0	0	0	0	0	0	0	0	0
H.24	1	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0
H.25	0	1	0	0	0	0	0	0	17	0	0	0	1	0	0	0
H.26	0	0	0	0	0	0	0	0	1	15	0	0	1	0	1	0
H.27	0	0	2	0	0	0	0	0	0	0	15	0	0	0	0	0
H.28	0	2	0	0	0	0	0	0	0	0	0	14	0	0	0	0
H.29	0	1	0	0	0	0	0	0	0	1	0	0	14	0	0	0
H.30	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
H.31	0	0	0	0	0	0	0	1	0	1	0	1	1	0	14	0
H.32	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14
	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48
F																
H.17	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.18	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
H.19	4	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
H.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 90.3 (continued)

	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48
H.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.24	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
H.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.26	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0
H.27	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0
H.28	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
H.29	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
H.30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
H.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.32	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0
	H.1	H.2	H.3	H.4	H.5	H.6	H.7	H.8	H.9	H.10	H.11	H.12	H.13	H.14	H.15	H.16
G																
H.33	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
H.34	5	2	3	0	0	0	0	1	0	0	0	0	1	0	0	0
H.35	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
H.36	3	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0
H.37	6	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0
H.38	3	4	1	4	0	0	0	0	0	0	0	1	0	0	0	0
H.39	4	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0
H.40	3	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0
H.41	3	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0
H.42	5	5	1	0	0	0	0	0	0	0	0	0	0	0	1	0
H.43	3	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 90.3 (continued)

	H.1	H.2	H.3	H.4	H.5	H.6	H.7	H.8	H.9	H.10	H.11	H.12	H.13	H.14	H.15	H.16
H.44	9	1	0	8	0	0	0	0	0	0	1	0	0	0	0	0
H.45	3	2	6	0	0	0	2	0	0	0	0	0	0	0	0	1
H.46	4	4	1	2	0	0	0	0	1	0	0	0	0	0	0	0
H.47	5	0	3	0	0	0	0	0	2	0	0	0	0	0	0	1
H.48	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	H.17	H.18	H.19	H.20	H.21	H.22	H.23	H.24	H.25	H.26	H.27	H.28	H.29	H.30	H.31	H.32
H																
H.33	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
H.34	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1
H.35	0	1	0	0	0	0	0	0	2	0	0	0	1	0	0	0
H.36	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
H.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.39	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.40	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
H.41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.43	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
H.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.45	0	1	0	0	0	0	0	0	1	4	0	3	1	0	0	0
H.46	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
H.47	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48

(continued)

Table 90.3 (continued)

	H.33	H.34	H.35	H.36	H.37	H.38	H.39	H.40	H.41	H.42	H.43	H.44	H.45	H.46	H.47	H.48
I																
H.33	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.34	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.35	0	0	13	0	0	0	0	0	0	0	0	0	0	0	1	0
H.36	0	0	0	12	0	0	0	0	0	0	0	0	0	0	2	0
H.37	0	0	0	0	12	0	0	0	0	0	0	0	0	0	1	0
H.38	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0
H.39	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
H.40	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0
H.41	0	0	0	0	0	0	0	0	11	0	0	0	0	2	0	0
H.42	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0
H.43	0	0	0	0	0	0	0	0	0	0	11	0	0	1	0	0
H.44	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
H.45	0	1	0	0	0	0	0	0	0	0	0	0	10	1	0	0
H.46	1	0	0	0	0	0	1	0	0	0	0	0	0	10	0	0
H.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
H.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10

Table 90.4 The clusters of the HFKs about low carbon city in China

Clusters	HFKS	Clusters	HFKS
Cluster.1	HFK.26; HFK.45; HFK.29; HFK.7	Cluster.9	HFK.25; HFK.35
Cluster.2	HFK.1; HFK.1; HFK.5; HFK.14	Cluster.10	HFK.39; HFK.24; HFK.28; HFK.31; HFK.22; HFK.23; HFK.42; HFK.48; HFK.37; HFK.43
Cluster.3	HFK.3; HFK.6		
Cluster.4	HFK.9; HFK.16; HFK.11; HFK.20		
Cluster.5	HFK.10; HFK.15; HFK.17	Cluster.11	HFK.42; HFK.46
Cluster.6	HFK.27; HFK.40	Cluster.12	HFK.13; HFK.34; HFK.8; HFK.32;
Cluster.7	HFK.12; HFK.21; HFK.18	Cluster.13	HFK.4; HFK.44
Cluster.8	HFK.36; HFK.47; HFK.30	Cluster.14	HFK.19; HFK.34

90.5 Data Analysis

90.5.1 Cluster Analysis on HFKs

Clusters analysis method is used to identify the grouping behaviors of these HFKs. In using analysis, similarity matrix need to convert to dissimilarity matrix through: Dissimilarity Matrix = 1 − Similarity Matrix.

By inputting the data of Dissimilarity Matrix into SPSS22, using Euclidean distance and ward connection, the cluster analysis results can been shown in Table 90.4 (Fig. 90.1).

90.5.2 Strategic Analysis of HFKs About the Low Carbon City Research in China

For establishing the strategic coordinate of the HFKs clusters, the values of density and centripetal for each cluster need to be calculated according to (1) and (2). Then mean density and centrality of each cluster are calculated. The result is that: the mean density of each cluster is 0.02 and the centrality of each cluster is 0.00457. The X and Y values of clusters in the strategic coordinates are got by the density and centrality of each clusters being subtracted from the mean value of density and

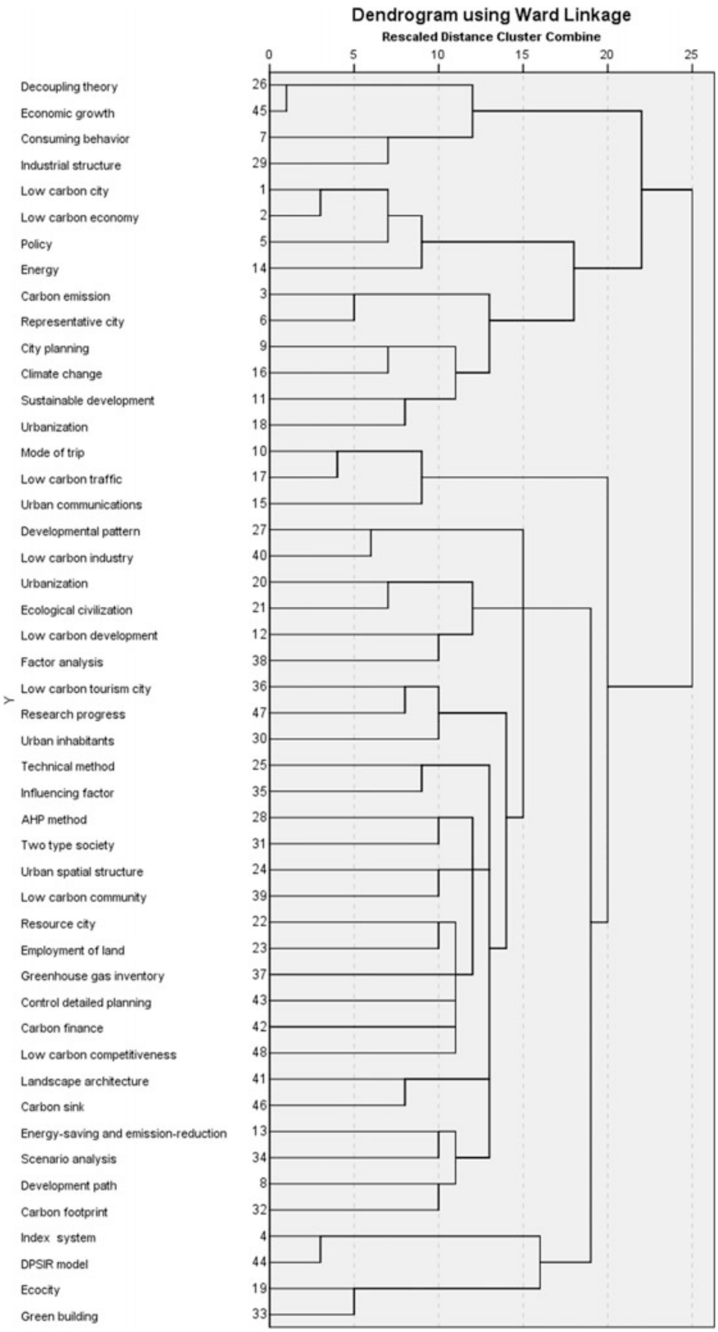


Fig. 90.1 Cluster analysis of HFKs about low carbon city in China

Table 90.5 :The strategic coordinate of the clusters about low carbon city in China

Cluster	Density	Centrality	X	Y
Cluster.1	0.048	0.006	0.027	0.002
Cluster.2	0.063	0.014	0.043	0.009
Cluster.3	0.052	0.007	0.032	0.003
Cluster.4	0.011	0.008	−0.009	0.003
Cluster.5	0.033	0.002	0.013	−0.002
Cluster.6	0.024	0.002	0.004	−0.003
Cluster.7	0.002	0.004	−0.019	−0.001
Cluster.8	0	0.002	−0.02	−0.002
Cluster.9	0	0.002	−0.02	−0.003
Cluster.10	0.001	0.004	−0.019	−0.001
Cluster.11	0	0.002	−0.02	−0.003
Cluster.12	0.004	0.004	−0.017	−0.001
Cluster.13	0	0.006	−0.02	0.001
Cluster.14	0.047	0.001	0.027	−0.004

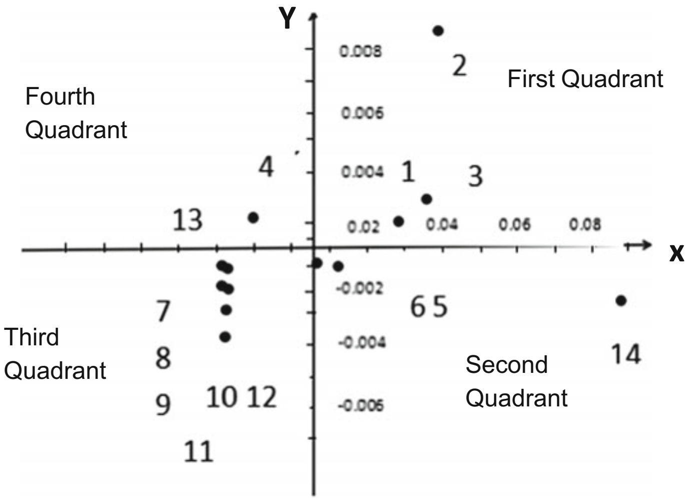


Fig. 90.2 Strategic coordinates of HFKs about low carbon city in China

centrality. The calculation of strategic coordinate data as shown in Table 90.5, the strategic coordinate chart as shown in Fig. 90.2.

It can be seen that the 14 clusters are located in four different quadrants. The Cluster 1, 2, and 3 positions in the first quadrant of the strategic coordinates. These three clusters have the following characteristics: first, they have higher density values indicating that the individual HFKs, within the clusters have close relation. Secondly, these three clusters have higher centripetal values, meaning that these clusters have close relationship with other clusters. It is shown that Cluster 5, 6, and 14 are positioned in the second quadrant of the strategic coordinates. The characteristics of these three clusters are the following: first, they have lower density values indicating that the individual HFKs within the clusters do not have a close relationship. Secondly, these three clusters have higher centripetal, meaning that these clusters relate closely with other clusters. It can be seen that Cluster 7, 8, 9, 10, 11, and 12, are positioned in the third quadrant of the strategic coordinates. These six clusters have the following characteristics: first, they have lower density values indicating that the individual HFKs within the clusters are not close. Secondly, these six clusters have lower centripetal values, meaning that these clusters do not have close relationship with other clusters. It is shown that Cluster 4 and 13 are positioned in the fourth quadrant of the strategic coordinates. These two clusters have the following characteristics: first, they have higher density values indicating that the individual HFKs, within the clusters have close relation. Secondly, these two clusters have lower centripetal values, meaning that these clusters do not have close relationship with other clusters.

90.6 Discussion and Conclusion

The analysis results in the above section demonstrate that the research issues on Low-Carbon city in China are fragmental, as many clusters of these HFKs are not associated closely, evidenced by the fact that many clusters positioned in quadrants 2 and 3. Since clusters include a number of HFKs, but these keywords are not related within the clusters, as indicated in quadrant 4.

These findings indicate that the research achievement in the discipline of low carbon city in China need to be coordinated in a way that researchers should communicate more and pursue more joint research works.

The research findings from this study are considered effective as the data are collected by screening 198 Journals published in China, during the period of 2002–2016. The total keywords of 4323 relating to the discipline of low carbon city in China are identified of which 1547 are valid keywords.

The findings provide important reference to researchers who wish to gain a holistic picture about the frontier topic of further study. To practice, this study provide a map for searching the relevant solution for specific problem relating to low carbon city.

This study will lead to further research on a holistic literature review about low carbon city at global level.

Acknowledgements This study is part of the research project sponsored by the Chinese National Social Science Program Fund, entitled “Assessment indicators for low-carbon city (15AZD025)”.

Appendix

The list of five of the 198 journals which have been screened.

	Name of the journals	The number of valid articles
1	Chinese Journal of Population Resources and Environment	86
2	Urban Studies	91
3	Urban Planning International	25
4	Statistics and Decision	7
5	Science & Technology Progress and Policy	27

References

Fan J (2011) Review of research on low carbon city. China Popul Resour Environ S1:478–481

http://baike.so.com/doc/6425169-6638841.html

http://baike.so.com/doc/881418-931692.html

http://ss.zhizhen.com/s.do?go=q&sw=%E4%BD%8E%E7%A2%B3%E5%9F%8E%E5%B8%82&Submit=

Hui L, Caihua Y, Liu J (2012) Knowledge map of low carbon research analysis in China. Resour Sci 10:1959–1964

Li JB, Tang F (2012) Co-word network visualization analysis in low carbon city. Sci Technol Manage Res 08:40–44

Li B, Zhang G (2011) Low carbon city: a review of domestic literature. J Capital Univ Econ Bus 01:107–120

Lv Y, Cheng L, Su J (2011) The present condition and trend of small company management research in China based on the co-word network analysis. Sci Technol Manage 32(2):10–1 116

Wang C, Jiang H, Ting W, Li M (2013) Knowledge map of China's low carbon research field: based on co-word network. China Popul Resour Environ 09:19–27

Zhong W, Li J (2008a) A study on co-word analysis (A)—the process and mode of co-word analysis. Inf J 05:70–72

Zhong W, Li J (2008b) A study on word analysis (B)—cluster analysis. Intell J 06:141–143

Chapter 91
Management Strategies for 5D-BIM Adoption in Hong Kong

I.Y.S. Chan, A.M.M. Liu and B. Chen

91.1 Introduction

Construction industry has long been regarded as a sector with low innovation and poor performance (Dulaimi et al. 2005; Hampson and Manley 2001). In recent decade, the advent of building information modeling (BIM) becomes the pioneer as a conspicuous innovation sweeping the construction industry on a global scale. The awareness of applying BIM for quantity surveying (QS), i.e., 5D-BIM (integrating data of 3D-BIM with 4th D: time and 5th D: cost) has been increasing sharply in Hong Kong. While there is high awareness of 5D-BIM adoption and recognition of benefits that 5D-BIM brings about (e.g., improved estimation efficiency (Azhar 2011) and enhanced information processing capacity (Grilo and Jardim-Goncalves 2010), its adoption is still limited and in its early stage in Hong Kong. Such hindered innovation (5D-BIM) adoption in construction is attributed to various factors, including the stickiness to the old ways, fear of failure in adoption, perceived high financial investment needed in innovation, lack of time and resources, and so on (Australian Expert Group in Industry Studies 1999).

To promote 5D-BIM in the construction sector, it's necessary to foster innovation adoption in the sector. Hence, the research aims at investigating how 5D-BIM (a well-recognized innovation in construction) can be fostered in construction. To fulfill this aim, the following objectives are to be achieved:

1. Provide an overview of innovation in Hong Kong quantity surveying;
2. Explore the impacts of various management strategies, including innovation climate and learning transfer climate on innovation adoption;

I.Y.S. Chan · A.M.M. Liu · B. Chen (✉)
Department of Real Estate and Construction, The University of Hong Kong,
Hong Kong, China
e-mail: bingchen923@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_91

3. Developing BIM implementation strategies for quantity surveying in Hong Kong.

91.2 Management Strategies and Innovation

91.2.1 Innovation in Construction

Although there is no all-agreed definition of innovation, similarities among various definitions given by different researchers can be identified and innovation can generally be regarded as—a *process* of "generation, development and implementation of ideas" (Dulaimi et al. 2005) in different *forms*, such as product, business process, and management innovation (Pedersen 1996; Higgins 1994). There are two main characteristics of innovation: novelty to institution (Slaughter 1998) and value creation (e.g., "time and cost savings in project delivery and improved quality of the product") (Kissi et al. 2012). It's believed that innovation is of paramount importance for coping with the challenges and changes (Green 2011).

In construction practices, the increasing complexity, faster pace, growing expectation on project productivity, accuracy, quality and safety all call for innovation in the sector. BIM, as the most distinct innovation in construction in recent decade, emerges and develops in face of such challenges and changes. BIM not only overcomes the challenges resulted from the increasing project complexity but also plays an indispensable role in changing the established fragmented work practices in architecture, engineering and construction (AEC) industry in accordance with its evolution from 3D, to 4D and now 5D BIM. Thus, the evolution of BIM is an innovative *process* of generating, developing and implementing information gathering, processing and exchange tools/platforms (*form*) for construction project management which are *novel* to the construction sector and are expected to create some positive *values*, such as enhanced accuracy (Kubba 2012), improved quality and collaboration (Gao et al. 2005) and so on.

Research on innovation dominantly uses exposed production and expenditure on research and development (R&D) in an organization as indicators of innovation (Lazzarotti et al. 2011; Birchall et al. 2011; Hu 2003). However, these indicators fail to take latent innovation into account, such as new management and business models, creative combinations of existing technologies and processes (NESTA 2008). For instance, according to the traditional indicators of innovation, the investment on developing and updating BIM software (i.e., R&D process) can be measured to represent the innovation level. However, the adoption of BIM and its consequences, such as the change of established project management practices from fragmentation to integration, belongs to latent innovation which can hardly be measured via traditional innovation indicators. Since this study focuses on the adoption of BIM in construction (i.e., actors' actions and reactions to innovation), a proxy, innovation competency (i.e., the root source of innovation) is more appropriate to be employed to measure innovation in this context. The definition of innovation competency is "the disposition of individuals to act and react in an innovative manner in order to deal with different critical incidents, problems or tasks that demand innovative thinking and reactions, and which can occur in a certain context" (Cerinšek and Dolinšek 2009). In this specific context of 5D-BIM adoption, innovation competency refers to the ability of employees in an organization to generate, develop, adopt, or implement novel ideas and knowledge in different forms to enhance organizational effectiveness and performance.

91.2.2 Innovation Climate

Previous research on impacts of organizational factors impinging on innovation has focused on organizational characteristics, such as firm size (Subramanian and Nilakanta 1996), degree of centralization, degree of formalization, degree of specialization (Damanpour 1991) and etc. However, such factors provide limited explanation of why employees in the organization are motivated to adopt innovation. Based on psychological climate theory (James and Sells 1981), this research identifies two factors of management strategies, which can encourage employees' adoption of innovation, namely innovation climate and learning transfer climate.

According to Jams and Sells's psychological climate theory (James and Sells 1981), individuals are prone to respond to their subjective cognitive perceptions of their surroundings rather than reacting to an objective environment. That means an employee's innovative behaviors are more easily affected by their subjective perception of the environment where encourage innovation. Hence, innovation can be fostered by an innovation climate. *Innovation climate* refers to individuals' perception about the extent to which their organization provides support for them, and encourages them to take the initiative and seek novel ideas that stimulate innovation in the organization (Martins and Terblanche 2003; Mumford and Gustafson 1988; Ahire and Ravichandran 2001).

According to Scott and Bruce (Scott and Bruce 1994), there are two dimensions of innovation climate, including *support for innovation* and *supply of resources*. Support for innovation means that an organization encourages its employees to grow creative ideas as well as tolerates diversity within the organization (Siegel and Kaemmerer 1978). Although diversity among employees may result in intragroup conflicts and reduced work efficiency, it is still indispensable to organizational innovation (Scott and Bruce 1994). It is because only organizations with tolerance of diversity can be open-minded to embrace innovative ideas at work which has the potential to improve the organization effectiveness and performance (Hair et al. 1998). On the other hand, to develop the innovative ability of employees, it's necessary for organizations to offer adequate resources supply, e.g., time, training, material, and other management support, for the employees to allow them to adopt innovation at work (Kesting and Ulhoi 2010). The innovative ability of employees is the source where organizational innovation derives from, while a supportive innovation climate is critical to the development of employees' creativity (Gumusluoglu and Ilsev 2009).

91.2.3 Learning Transfer Climate

Learning has long been acknowledged as the key drive for innovation and organizational success (Armstrong and Foley 2003). Learning transfer, which refers to "the effective and continuing application, by trainees to their jobs, of the knowledge and skills gained in training both on and off the job" (Broad and Newstrom 1992), is a broader concept compared with "learning" since learning transfer incorporates the process of applying, integrating and maintaining new knowledge and skills in addition to acquiring knowledge and skills. To facilitate learning transfer, a learning transfer climate is imperative.

Based on the learning transfer system inventory model proposed by Holton et al. (Holton et al. 2000), learning transfer-climate is a construct of three levels, including personal, training and organizational levels. As for training in the learning transfer system, there are five primary factors underpinning learning transfer in the system, namely openness to change, performance feedback, performance self-efficacy, transfer effort-performance expectation, and performance-outcome expectations. The first two factors in the system can be grouped into *task support* related elements (Bates and Khasawneh 2005). *Openness to change* means individuals' subjective perceptions about the attitude of the group they belong to towards change. The operational definition of openness to change is reflected by the extent to which the group are willing to invest resource in change and the degree of support individuals gained during the learning transfer process. *Performance feedback* refers to the extent to which individuals receive constructive feedback about their performance in the learning transfer process. Latter three factors belong to *individual cognitive* states group. *Performance self-efficacy* can be defined as the degree to which individuals believe that they are capable to apply the learnt knowledge and skills to their work. *Transfer effort-performance* expectation refers to individuals' perception about whether learning transfer can improve performance. *Performance-outcome expectation* refers to individuals' perception about whether the improved performance brings about the outcomes they treasure (Bates and Khasawneh 2005).

Learning transfer climate, in forms of organizational openness to change, constructive feedback on performance and subjective perception of one's self-efficacy in learning transfers and expectations of transferring efforts to performance and transferring performance to outcomes, is identified as an important antecedent of innovation (Holton et al. 2000; Bates and Khasawneh 2005).

91.2.4 Relationships Between Innovation and Management Strategies

In the light of abovementioned theoretical perspectives on factors predicting innovation in organization, management strategies, including innovation climate

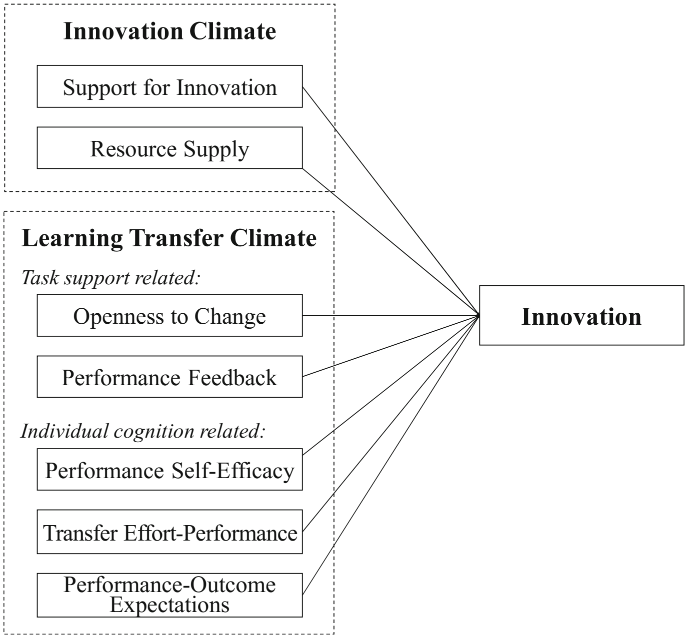


Fig. 91.1 Relationships between innovation and management strategies

and learning transfer climate are found to be important antecedents of innovation (as shown in Fig. 91.1). That is to say if the positive correlations of innovation climate-innovation and learning transfer climate-innovation exist, to promote innovation (5D-BIM) adoption in construction means to make and implement corresponding management strategies of stimulating innovation climate and learning transfer climate in organizations in construction. Thus, it's important to test the relationships between factors of innovation climate and learning transfer climate and innovation to see whether these factors predict innovation and which factor influences innovation the most in different types of organizations in construction sector. Next section will introduce the research method to test the relationships and present and analyze the results.

91.3 Questionnaire Survey and Case Studies

As mentioned before, BIM has long been recognized as a significant innovation in construction. Innovation, in itself, evolves and re-innovates, so does the evolution of BIM (i.e., from 3D, to 4D, and to 5D BIM). An appropriate way to study the adoption of BIM in construction is to raise the research to the level of innovation adoption (i.e., an overview), followed by grounded studies for 5D-BIM adoption in

Hong Kong construction sector (i.e., case examples). Hence, quantitative method based on questionnaire survey is firstly employed to have a view of innovation in Hong Kong quantity surveying and test the relationships between factors of management strategies, including innovation climate and learning transfer climate, and innovation as hypothesized in the conceptual model (as shown in Fig. 91.1). Then some case examples are provided to elaborate the result of questionnaire survey study, laying foundation for recommendation of suggestions on management strategies for 5D-BIM adoption in Hong Kong construction sector.

91.3.1 The Questionnaire Survey

91.3.1.1 Sample

The questionnaires were delivered via email, fax and in person to 500 quantity surveyors who have (i) worked in main construction parties, including client developers, contractor firms or consultant firms, (ii) first-hand experience in quantity surveying in construction projects in Hong Kong, and (iii) more than one year working experience in his/her current organization at the time the questionnaires were released to the respondents. After conducting the survey, 147 were received (the response rate is 29.4%). Among the respondents, 29% of them worked in client developers, 37% served in contractor firms and 31% work in consultant firms.

91.3.1.2 Measurement Instrument

There are three scales incorporated in the survey, namely innovation climate, learning transfer climate and innovation. A well-validated innovation climate scale developed by Siegel and Kaemmerer (1978) and modified by Scott and Bruce (1994) is applied to measure support for innovation and supply resource. Sample items could be "Creativity is encouraged in my current organization" and "The reward system in my current organization encourages innovation". To measure learning transfer climate, the learning transfer system inventory (LTSI) (only adopting the domain of training-in-general of LTSI) developed by Holton and Bates (2002) is employed. Sample items include "I never doubt my ability to use newly learned skills" and "Training usually helps me increase mu productivity". Lastly, the innovation scale developed by Kaiser and Holton (1998) is adopted to measure the innovation competency of an organization as perceived by respondents. Sample items include "We have improved the quality of our products/services by continuously looking for new and better ways to do things". Respondents are asked to judge their level of agreement with the statements in a 5 point Likert measurement format.

91.3.1.3 Results

Reliability of Factors

The reliability levels of the factors of innovation (INN), innovation climate (i.e., support for innovation (IC1) and resource supply (IC2)), learning transfer climate (i.e., performance self-efficacy (LCT1), openness to change (LCT2), performance-outcome expectation (LCT3), performance feedback(LCT4) and transfer effort-performance expectation (LCT5)) are determined by Cronbach's alpha values (a commonly used indicator). Since the alpha values of these 8 variables are all higher than 0.6, the variables are considered reliable for further analysis.

Innovation in Construction

The mean score of innovation for all respondents in general is 3.29. While it's higher than the neutral point of 5-point Likert scale, i.e., 3, there is room to enhance overall innovation competency of organizations in construction sector. In addition, the mean scores of innovation for different types of organizations, including client developers, contractor firms and consultant firms in constructions varies: 3.32, 3.21 and 3.37 respectively (as shown in Fig. 91.2). It's worth mentioning that contractors are found to be of lowest innovation level, while the consultants rank first.

Innovation Climate

The mean scores of two variables of innovation climate construction, i.e., support for innovation and resource support for respondents in general are found to be 3.06 and 3.02 respectively (as shown in Fig. 91.3). The results are above the neutral point of 3 in the 5-point Likert response format but still have room to be enhanced.

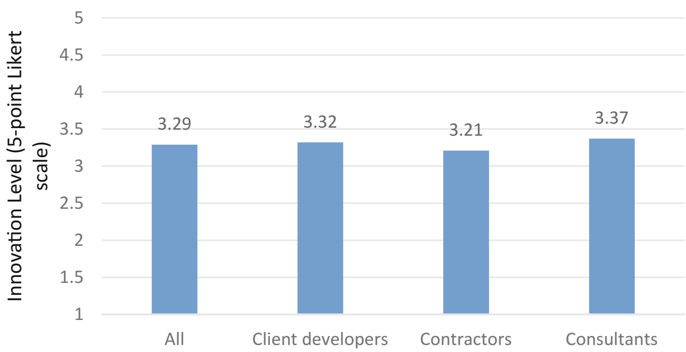


Fig. 91.2 Innovation of various respondent groups

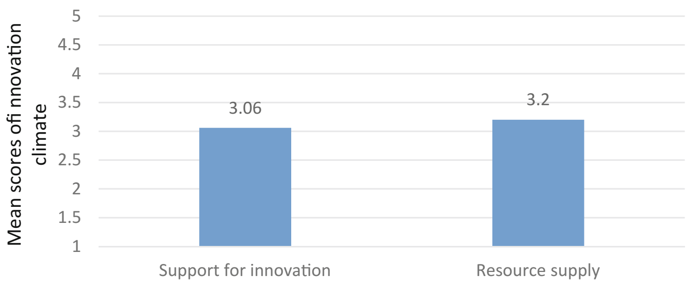


Fig. 91.3 Innovation climate of all respondents

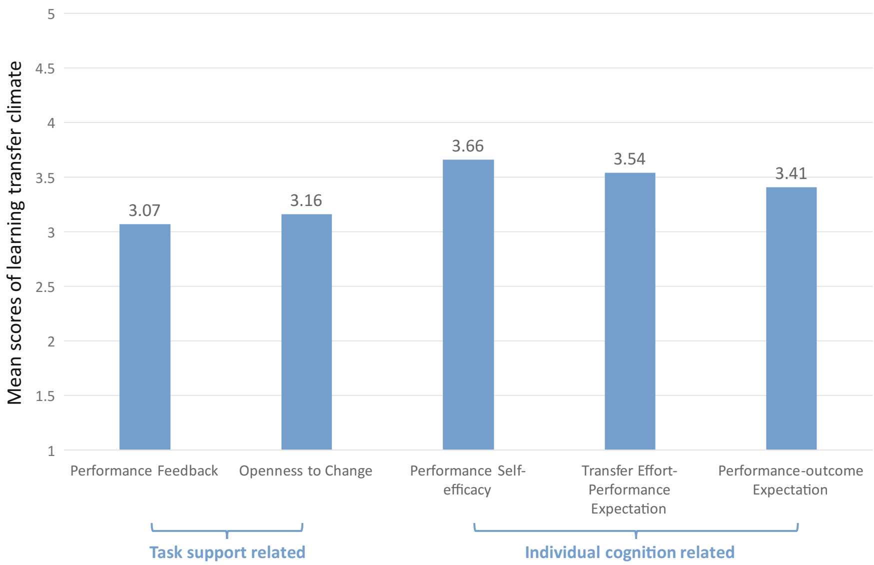


Fig. 91.4 Learning transfer climate of all respondents

Learning Transfer Climate

There are five variables in the construct of learning transfer climate. The mean scores of performance feedback, openness to change, performance self-efficacy, transfer effort-performance expectation and performance-outcome expectation for all respondents are 3.07, 3.16, 3.66, 3.54 and 3.41 respectively (as shown in Fig. 91.4). It's noteworthy that the mean scores of task support related variables, (i.e., performance feedback and openness to change) are both lower than the other three individual cognition related variables of performance self-efficacy, transfer effort-performance expectation and performance-outcome expectation.

Relationships Between Various Management Strategies and Innovation

The relationships between innovation climate, learning transfer climate and innovation is firstly tested via correlation analysis and followed by regression modelling. The positive correlation coefficients between all innovation climate variables, i.e. support for innovation (IC1), resource supply (IC2), and the variable of innovation are at $p < 0.01$ significance. As for learning transfer climate variables of performance self-efficacy (LTC1), openness to change (LTC2), performance-outcome expectation (LCT3), the positive correlation coefficients are at $p < 0.01$ significance, while another two variables of performance feedback (LCT4) and transfer effort-performance expectation (LCT5) were found to have non-significant correlation coefficients.

Multiple regression analysis with forward selection method is further applied to scrutinize the innovation-innovation climate, innovation-learning transfer climate associations of the total sample and different groups of respondents respectively.

1. Modelling for the associations between innovation climate and innovation

Since the result of Pearson correlation reveals that the strength of correlation between IC1 and innovation is the highest, IC1 is chosen as the first independent variable. Other independent variables are added to the regression model subsequently. A variable could remain in the final regression model if the significant value of the variable is lower than 0.05, and if adding it can reduce the standard error or increase the R square values of the model estimate. The model development stops after variable of IC2 is added to the regression model and its significant value is lower than 0.05. The final regression model reveals that the association relationships between innovation climate factors: support for innovation and resource supply and innovation are positive and significant. The same analysis is employed to investigate the three groups of client developers, construction consultants and contractors (as shown in Fig. 91.5). The results show that support for innovation has positive and significant associations with innovation in client developers and contractors, while in consultants, resource supply has positive and significant associations with innovation.

2. Modelling for the associations between learning transfer climate and innovation

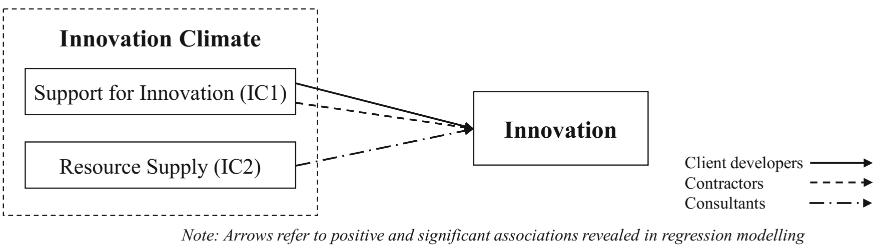


Fig. 91.5 Associations between innovation climate and innovation

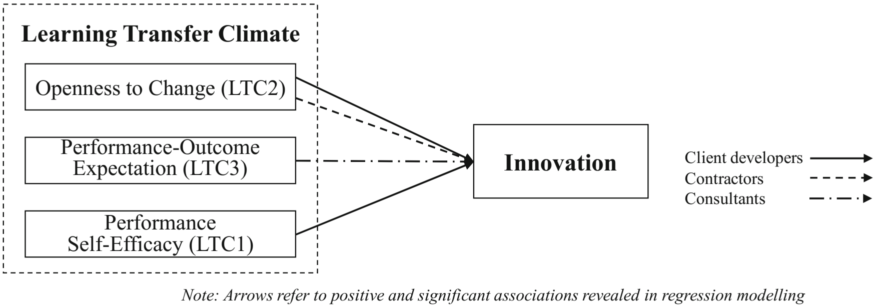


Fig. 91.6 Associations between learning transfer climate and innovation

Similar to modelling for the associations between innovation climate and innovation, the method of multiple regression analysis with forward selection is employed to probe the associations between learning transfer climate factors and innovation, beginning with the total sample and move forward to investigate the association relationships of three groups of client developers, contractors, and consultants (the results are shown in Fig. 91.6). The final regression model reveals that in general innovation is positively influenced by openness to change (LTC2), performance-outcome expectation (LTC3) and performance self-efficacy (LTC1), innovation in client developers is positively predicted by LCT2 and LCT1, innovation in contractor firms is positively predicted by LTC2, and innovation in consultant firms is positively predicted by LTC3.

91.3.1.4 Discussion of Questionnaire Survey Result

The survey results in this research shed light on the 5D-BIM adoption in construction. Firstly, the results are consistent with the previous literature that innovation climate and learning transfer climate are two important antecedents of innovation in general. As for innovation climate, both support for innovation and resource supply are found to positively predict innovation in construction. Whereas, it's noteworthy that although both task support related factor (i.e., openness to change) and individual cognition related factors (i.e., performance-outcome expectation and performance self-efficacy) under the construct of learning transfer climate have positive and significant association with innovation in construction, another two factors of performance feedback and transfer effort-performance are excluded. Comparing with individual cognition related learning transfer climate, task support related climate in construction is relatively lower. That means even if quantity surveyors are confident in adopting 5D-BIM in their work after training and have positive expectation that improved job performance can result in valued outcomes, 5D-BIM adoption can still be hampered by conservative group climate that discourage innovative technology and working manner. Hence, to foster 5D-BIM adoption, the climate of openness to change in construction organizations should not be overlooked.

In addition, the survey results also reveal that 5D-BIM adoption in construction sector can be propelled by heterogeneous construction parties. To foster innovation in construction, the client developers and contractors play a pulling role, while consultants play a pushing role.

In accordance with the survey results, openness to change and support for innovation are key driving forces to innovation for both client developers and contractors. A case study provided by Boland shows that the climate of openness to change and support for innovation in client developers' organization allows the development of an innovative design, which will encourage the contractors to create new construction method and adopt new tools to overcome the challenges (Boland et al. 2007). Similarly, the climate of openness to change and support for innovation in contractors' firms can stimulate their employees to create new construction method and adopt new tools to carry out the innovative design for the client developers. Besides, as client developers are originator and sponsor of a construction project, their performance self-efficacy determines whether to adopt 5D-BIM in the project. In this case, consultant can help the client develop to guarantee efficacy of a proposed innovation by applying their specialist expertise. On the other hand, as consultants are at the downstream of the supply chain in construction sector, they tend to be motivated by extrinsic stimulation mechanism, such as resource supply and performance-outcome expectations (e.g., incentives provided by client developers or contractors).

Therefore, the results of this research contribute to the theories of innovation by proposing the sequence and interaction of different construction parties in the innovation process, including client developers, contractors and consultants (as shown in Fig. 91.7).

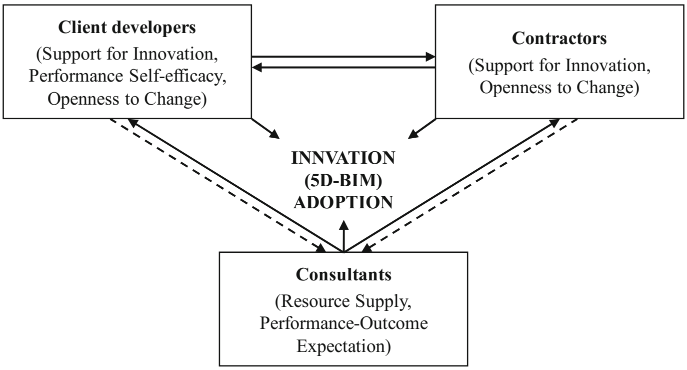


Fig. 91.7 The postulated interactive roles of construction parties in fostering innovation (5D-BIM) adoption

91.3.2 Case Studies

In order to validate and elaborate the above questionnaire survey findings, case examples of 5D-BIM adoption are provided in this section. In addition, based on the case examples, suggestions on management strategies of promoting 5D-BIM adoption in different construction parties, including client developers, contractors and consultants will be proposed accordingly.

91.3.2.1 Overview of 3 Cases

Case 1: Public rental housing project in Shui Chuen O

Case 1 is a new public rental housing project in Shui Chuen O Phase 1 in Shatin of Hong Kong. The client developer of this project is Hong Kong Housing Authority (HKHA), which is the main supplier of public housing in Hong Kong. HKHA has introduced BIM in their projects for cover 3D visualization, clash detection and 4D simulation since 2006. Quantity surveying section in HKHA started to explore how to adopt 5D-BIM in this project. A particular work team is established to use quantities extracted from BIM to carry out cash flow simulation and interim payment assessment. The general contractor (GC) in this project, China State Construction Engineering (Hong Kong) Ltd, is required by HKHA to use BIM data and carry out cash flow forecast and payment simulation. HKHA issued a variation order to the GC to compensate their extra effort and cost of adopting 5D-BIM in the project. The BIM consultant, BIM Limited, is employed by the GC to create the building models and assist with the tasks of BIM-based quantity takeoff and cost estimation.

Case 2: Anderson Road Project

Case 2 is about Anderson Road Project Phases A and B, which are delivered by Integrated Procurement Approach (IPA) contract, in which the contractor, China State Construction Engineering (Hong Kong) Ltd, are responsible for conducting 5D model-based quantity takeoff and schedule optimization. The contractor adopts BIM in this project because of the requirements listed in the contract as well as the complexity of the structural design. The 5D-BIM team in this project, which is set up by the contractor, has done lots of work to facilitate the 5D-BIM adoption, including developing and implementing integrated 5D BIM workflow, BIM execution plan and BIM modeling guidelines.

Case 3: BIM consultant—Glodon Software co., Ltd

Glodon is a leading AEC IT company in China, offering software product and solutions to the entire lifecycle of construction projects, whose main business market is in mainland China and Hong Kong. Glodon have developed 5D-BIM software such as architecture and structure software TAS 2016 as well as mechanical and electrical software TME 2016. As a BIM consultant, Glodon provides not only 5D-BIM software but also consultation services, such as giving advice on how to build the model for the purpose of 5D-BIM. In current practice, BIM-based detailed quantity takeoff and cost estimation occurred in the construction stage after the model has been created in design stage. Such BIM models seldom take the requirements of quantity surveying into consideration. BIM consultants have to adopt a "half measure" of 5D-BIM that exporting a building model from modelling software to existing Glodon cost management system instead of using the information stored in the building model directly.

91.3.2.2 Discussion of 3 Cases

1. 5D-BIM adoption from the perspective of client developers

According to the results of questionnaire survey, support for innovation, performance self-efficacy, openness to change are key drivers for innovation in client developers' organizations. In both case 1 and case 2, the adoption of 5D-BIM in the projects is required and paid by the client developers, which shows high awareness of innovation and openness to change of the client developers in Hong Kong, especially the public ones, such as HKHA. As for support for innovation, case 2 adopts IPA procurement approach to deliver the project, through which the contractor participates in the early stage and can give suggestions on the design and 5D-BIM adoption. That means the client developer start to aware that support for innovation which encourages innovative ideas and allows different voices within the project team is important to fostering 5D-BIM adoption. However, such awareness and application range is limited since commonly-used project procurement method is still traditional design-bid-build (DBB) in Hong Kong at this stage, which calls for more awareness and attempts of integrated project delivery (IPD) in construction practices.

Based on above cross-case analysis, we know that public client developers in Hong Kong welcome and embrace changes and innovation. They are open to change and start to provide support for innovation. And there are already preliminary results of 5D-BIM adoption achieved, including enhanced accuracy, efficiency and productivity of quantity surveying.

A frequently-mentioned challenge of 5D-BIM adoption in these cases is the lack of professionals, who are competent in both BIM and QS. Often, QS professionals do not have experiences in modeling and experience difficulties in understanding BIM software. Meanwhile, architects who can design with BIM are few in Hong Kong. Most architects produce 2D drawings instead of BIM. In addition, architects know little about QS. Hence, they have difficulties in taking requirements of Hong Kong Standard Method of Measurement of Building Works (HKSMM) into consideration when creating BIM. In terms of the questionnaire survey results, personnel in client developer's organization believe if they are confident in applying their new skills to their work (i.e., performance self-efficacy), the adoption of 5D-BIM will be fostered and promoted. Thus, the lack of professional knowledge and practical skills of the personnel will seriously hinder 5D-BIM adoption, which implies that training of 5D-BIM for AEC professionals is very important to success 5D-BIM adoption.

2. 5D-BIM adoption from the perspective of contractors

The questionnaire survey study shows that support for innovation and openness to change are essential to adoption of 5D-BIM in contractors' organizations. Compared with public client developers in Hong Kong, contractors' attitudes towards change and innovation is relatively passive and conservative since contractors are requested to implement 5D-BIM in case 1 and case 2. The openness to change of the contractors is lower than that of client developers since contractors are not sure about whether adopting 5D-BIM would bring them actual benefits. The perceived passive attitude of openness to change in their organization will discourage the employees to use their newly-learned skills to their works. As mentioned by a contractor's employee in Case 1 project, even though the quantity is ready in BIM model, they still followed their old working practices and checked quantities from BIM measurement, instead of checking the model. Hence, a learning transfer conducive climate is important fostering professionals' adoption of an innovative technology. The hesitation to change of the personnel also revealed the inadequate support for innovation within contractors' organizations. Thus, an innovation climate of encouraging creative and diversified perspectives should be cultivated to support employees to adopt 5D-BIM in their work. Through managing changes in organization's policy, working procedures and even changes of fundamental organizational assumptions, such as vision and core values, the innovation adoption can be pushed forward by all the employees in contractors' organization.

3. 5D-BIM adoption from the perspective of BIM consultants

As mentioned in Sect. 3.1.4, consultants locate at lower stream of the supply chain in construction sector, their innovation relies much on external resources provided by the industry or other parties in the project and extrinsic reward mechanism which means they value performance-outcome expectations. The above cases study unveiled two general types of resource supply in need, namely the hard and soft resource.

For the hard resource supply, a standard approach of modelling (SAM) is important to generating a specification-compliant quantity takeoff which meets the requirement of HKSMM. Different modelers often create BIM models in their own way. Different modelling methods will lead to discrepancies in quantity takeoff. To guarantee a reliable BIM-based quantity takeoff that can be used in actual practices, a SAM is needed to ensure: (a) consistent modeling approach; (b) identifiable building components; and (c) sufficient object information to fit current QS measurement practices in different regions (e.g., HKSMM4 in Hong Kong). Although the development of a SAM has to be led by client developers, authorities or other professional industry associations, BIM consultants can still contribute to and push forward this issue by giving their ideas learned from their modelling and first-hand BIM-based quantity takeoff experience.

Soft resource supply, e.g., management resource supply is also necessary for conflict resolution between quantity surveyors in consultants' or contractors' firms and upstream parties, such as client developers and designers. Due to the established fragmented work practices in AEC industry, designers and modelers rarely consider quantity surveyors' advice and comments when they start BIM and it's also difficult and time-consuming for quantity surveyors to extract and to link data among fragmented data sources to do quantity takeoff and cost estimation. Thus, the status of "downstream" party of consultants and low effectiveness of their works demonstrate the importance of IPD, only through which adopting 5D-BIM can achieve its greatest potential and create the greatest value.

91.4 Conclusion and Suggestions

5D-BIM is an inevitable trend in the construction sector. The questionnaire survey study on impacts of various management strategies on innovation (5D-BIM) adoption shows that innovation climate and learning transfer climate are important antecedents of innovation in construction sector in general. The further analysis of different parties in construction indicates that innovation in client developers is positively predicted by factors of support for innovation, performance self-efficacy and openness to change, innovation in contractors is positively affected by factors of support for innovation and openness to change, and innovation in consultants is positively influenced by resource supply and performance-outcome expectation. The cases of 5D-BIM adoption in Hong Kong has validated the results of questionnaire survey study. Based on results of two studies and the international trends and practices worldwide, management strategies of adopting 5D-BIM for three major parties in construction are proposed. From the perspective of client developers, suggestions for them incorporate promoting and adopting integrated procurement delivery in their projects, improving their employees' knowledge and skills of both BIM and quantity survey through pertinent training to develop in-house BIM capability, and leading the establishment of standard approach of modelling. From the perspective of contractors, suggestion for them is to nurture the learning transfer climate of openness to change and the innovation climate of encouraging creative and diversified perspectives among the organization. For the consultants, they are encouraged to push forward and contribute to the establishment of standard approach of modelling by providing their professional knowledge and first-hand experience.

Acknowledgements This work was supported by the Research Grants Council under the General Research Fund (Project No. HKU 715111).

References

Ahire SL, Ravichandran T (2001) An innovation diffusion model of TQM implementation. IEEE Trans Eng Manage 48(4):445–464

Armstrong A, Foley P (2003) Foundations for a learning organization: organization learning mechanisms. Learn Organ 10(2):74–82

Australian Expert Group in Industry Studies (1999) Mapping the building and construction product system in Australia. ISR, Canberra

Azhar S (2011) Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry. Leadersh Manage Eng 11(3):241–252

Bates R, Khasawneh S (2005) Organizational learning culture, learning transfer climate and perceived innovation in Jordanian organizations. Int J Training Dev 9(2):96–109

Birchall D, Chanaron JJ, Tovstiga G, Hillenbrand C (2011) Innovation performance measurement: current practices, issues and management challenges. Int J Technol Manage 56(1):1–20

Boland RJ Jr, Lyytinen K, Yoo Y (2007) Wakes of innovation in project networks: the case of digital 3-D representations in architecture, engineering, and construction. Organ Sci 18(4): 631–647

Broad ML, Newstrom JW (1992) Transfer of training: action-packed strategies to ensure high payoff from training investments. Addison-Wesley, Reading, MA

Cerinšek G, Dolinšek S (2009) Identifying employees' innovation competency in organisations. Int J Innov Learn 6(2):164–177

Damanpour F (1991) Organizational innovation: a meta-analysis of effects of determinants and moderators. Acad Manag J 34(3):555–590

Dulaimi MF, Nepal MP, Park M (2005) A hierarchical structural model of assessing innovation and project performance. Constr Manage Econ 23(6):565–577

Gao J, Fischer M, Tollefsen T, Haugen T (2005) Experiences with 3D and 4D CAD on building construction projects: benefits for project success and controllable implementation factors. Construction Informatics Digital Library, w78

Green S (2011) Making sense of construction improvement. Wiley-Blackwell Publications, Oxford, p 148

Grilo A, Jardim-Goncalves R (2010) Value proposition on interoperability of BIM and collaborative working environments. Autom Constr 19(5):522–530

Gumusluoglu L, Ilsev A (2009) Transformational leadership, creativity, and organizational innovation. J Bus Res 62(4):461–473

Hair JFJ, Anderson RE, Tatham RL, Black WC (1998) Multivariate data analysis (5th edn), New Jersey, Prentice Hall

Hampson KD, Manley K (2001) Construction innovation and public policy in Australia. Innovation in construction: an international review of public policies pp 31–57

Higgins JM (1994) Innovate or evaporate: test and improve your organization's IQ. New Management Publishing Company Inc, Winter Park, FL

Holton EF, Bates RA (2002) The learning transfer systems inventory, Louisiana State University, Office of HRD Research

Holton EF, Bates RA, Ruona WEA (2000) Development of a generalized learning transfer system inventory. Human Resour Dev Q 11(4):333–360

Hu AG (2003) R&D organization, monitoring intensity, and innovation performance in Chinese industry. Econ Innov New Technol 12(2):117–144

James LR, Sells SB (1981) Psychological climate: theoretical perspectives and empirical research. Toward a psychology of situations: an interactional perspective pp 275–295

Kaiser S, Holton E (1998) The learning organization as a performance improvement strategy. In: R. Torraco (ed), Proceedings of the Academy of Human Resource Development Conference pp 75–82

Kesting P, Ulhoi JP (2010) Employee-driven innovation: extending the license to foster innovation. Manag Decis 48(1):65–84

Kissi J, Dainty A, Liu A (2012) Examining middle managers' influence on innovation in construction professional services firms: a tale of three innovations. Constr Innov: Inf, Process, Manage 12(1):11–28

Kubba S (2012) Building information modelling, Handbook of Green Building Design and Construction: LEED, BREE and Green Globes, in S Kubba edn, Butterworth-Heinemann

Lazzarotti V, Manzini R, Mari L (2011) A model for R&D performance measurement. Int J Prod Econ 134(1):212–223

Martins EC, Terblanche F (2003) Building organisational culture that stimulates creativity and innovation. Eur J Innov Manage 6(1):64–74

Mumford MD, Gustafson SB (1988) Creativity syndrome: integration, application, and innovation. Psychol Bull 103(1):27

NESTA (2008) Total innovation. NESTA, National Endowment for Science, Technology and the Arts. Retrieved at http://www.nesta.org.uk/publications/reports/assets/features/total_innovation , on 24 August 2010

Pedersen DO (1996) The economics of innovation in construction. In: Katavic M (ed) Economics management of innovation, productivity and quality in construction: CIB W55 building economics 7th international symposium, Zagreb, Croatia, 4–7 September, pp 158–184

Scott SG, Bruce RA (1994) Determinants of innovative behavior: a path model of individual innovation in the workplace. Acad Manag J 37(3):580–607

Siegel S, Kaemmerer W (1978) Measuring the perceived support for innovation in organizations. J Appl Psychol 63:553–562

Slaughter ES (1998) Models of construction innovation. J Constr Eng Manage 124(3):226–231

Subramanian A, Nilakanta S (1996) Organizational innovativeness: exploring the relationship between organizational determinants of innovation, types of innovations, and measures of organizational performance. Omega 24(6):631–647

Chapter 92
Method for Urban Rail Transit Project Financing Decision-Making Based on Triangular Fuzzy Number

L.L. Yuan, Y.S. Wang and Y. Sun

92.1 Introduction

Urban rail transit has remarkable influences on overall social growth as modern public transport infrastructure. It features many advantages such as: safety, fast speed, large freight volume and less pollution. It has huge benefit influences. Rail transit construction is conductive to the development of public transport facilities and plays an irreplaceable role in comprehensive development of whole society. China's urban rail transit construction enters rapid development phase during the period of "the 11th Five-year Plan". It is further evolved into the infrastructure investment priority. Along with the accelerated urbanization, rail transit accounts for 50–60% of residents' transportation in modern urban transit system. In consequence, the development of urban trail transit becomes the key to solving the problem about urban traffic jam. However, there is huge fund demand for transit construction. The total investment in urban planning across China in 2009 amounted to 88.2 billion Yuan, which was increased to 1156.8 billion Yuan. By the end of 2020, the traffic mileage of metro in rail transit network across China will arrive at 6.1 thousand km. it will be the golden period of the rapid development of China's urban rail transit construction in the coming thirty years. The innovations will be made in urban rail transit project investment and financing model gradually along with the study on financing tools. At the present, the investment in urban rail transit project around the world is mainly concentrated on traditional financing modes such as: government investment, national debt, special fund, bank loan and modern new-type financing models including BOT (Build Operate Transfer), TOT

L.L. Yuan (✉) · Y.S. Wang
School of Civil and Transportation, South China University of Technology, Guangzhou, China
e-mail: yuanliangliang1978@163.com

Y. Sun
Construction Department, Guangzhou Metro Corporation, Guangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_92

(Transfer Operate Transfer), PEI (Private Finance Initiatives) and ABS (Assets Backed Security). Some scholars have carried a lot of studies on financing model of urban rail transit project (Peter 1989; Bowes and Ihlanfeldt 2001; Wang 2009; Tian 2014). However, How to select best financing model for rail transit construction project? How to make decision over financing model? In actual decision making, it is often necessary for the numerous experts to evaluate and compare different properties of alternative schemes to make final decision. For there are many experts participating in decision making, the attribute of decision-making problem is fuzzy and uncertain. In this paper, the characteristics of decision-making properties during decision making of urban rail transit project financing are integrated and the decision-making model for financing mode, which provides reference for rail transit construction project.

92.2 Related Theories

92.2.1 Triangular Fuzzy Number

Fuzziness indicates the uncertainty of things or ambiguity and uncertainty of attitude. Fuzzy number refers to the concept corresponding to the precision number. As one kind of fuzzy number, triangular fuzzy number is used to narrate the numerical interval occurring to the things and the value most possibly emerging within the interval (Li and Wang 2011; Hu et al. 2011; Yuan et al. 2015). The triangular fuzzy number is as defined as below:

Definition 1
Assuming $\tilde{a} = (a^l, a^m, a^u)$ and it satisfies $0 < a^l < a^m < a^u$, then $\tilde{a}$ is a triangular fuzzy number, whose membership function can be indicated as:

$$\mu_{\tilde{a}}(\chi) = \begin{cases} \frac{x-a^l}{a^m-a^l} & a^l \leq x < a^u \\ \frac{x-a^u}{a^m-a^u} & a^m \leq x < a^u \\ 0 & x < a^l or, x > a^u \end{cases} \tag{92.1}$$

There are any triangular fuzzy numbers $\tilde{a} = (a^l, a^m, a^u), \tilde{b} = (b^l, b^m, b^u)$. According to the extension principle, the corresponding operational rules are as below:

$$\begin{aligned} \tilde{a} \oplus \tilde{b} &= (a^l + b^l, a^m + b^m, a^u + b^u) \\ \tilde{a} \otimes \tilde{b} &= (a^l \times b^l, a^m \times b^m, a^u \times b^u) \\ \lambda \otimes \tilde{a} &= (\lambda a^l, \lambda a^m, \lambda a^u), \lambda > 0, \lambda \in R \\ 1/ \otimes \tilde{a} &= (1/a^l, 1/a^m, 1/a^u) \end{aligned} \tag{92.2}$$

In which: $\oplus\otimes$ means the addition and multiplication symbols of triangular fuzzy number; λ is a constant.

Definition 2
If $\tilde{a} = (a^l, a^m, a^u), \tilde{b} = (b^l, b^m, b^u)$ are any two triangular fuzzy numbers, the distance between $\tilde{a}$ and $\tilde{b}$ can be indicated as:

$$d = (\tilde{a}, \tilde{b}) = \sqrt{\frac{|a^l - b^l|^2 + 4|a^m - b^m|^2 + |a^u - b^u|^2}{6}} \quad (92.3)$$

Definition 3
There are any two triangular fuzzy numbers $\tilde{a} = (a^l, a^m, a^u), \tilde{b} = (b^l, b^m, b^u)$, then

$$S = (\tilde{a}, \tilde{b}) = 1 - \frac{|a^l - b^l| + |a^m - b^m| + |a^u - b^u|}{3} \quad (92.4)$$

Indicates the similarity of triangular fuzzy numbers $\tilde{a}$ and $\tilde{b}$. Obviously, the larger $S(\tilde{a}, \tilde{b})$ the more similar $\tilde{a}$ and $\tilde{b}$. When $\tilde{a}$ and $\tilde{b}$ are completely the same, $S(\tilde{a}, \tilde{b}) = 1$.

92.2.2 Attribute of Project Financing Decision-Making

Urban rail transit project financing model decision-making process is a complicated process for the decision maker should not only give considerations to some attribute characteristics of project financing model but also have to think about the demands and preferences of financing decision making subject namely the government (or owner), for which the government (or owner) can serve as the investor and decision making supervising subject of urban rail transit project in most cases (Yuan et al. 2015). By combining project characteristics, the consideration should be mainly given to the attributes of following three aspects when making decision over financing model of urban rail transit project as it is believed so in this paper:

(1) Project attribute: it indicates the characteristics of urban rail transit project, including investment composition and economic intensity. Due to the difference in project composition, there are different guarantee extents for project risk. Economic intensity of the project decides ability of the project to attract the fund. The higher the economic intensity the smoother the financing channel.
(2) Demands and preferences of the government (or owner). Urban rail transit project belongs to infrastructure project. To select financing model, it is an imperative to choose corresponding financing model according to the demands and preferences of the government (or owner), which include preferences in financing structure and financing cost. According to the fiscal strength, demands & preferences of the government, the government (owner) can choose

traditional financing models (fiscal appropriation) including PPP, BOT and TOT to raise funds for the project when coping with urban rail transit project construction.

(3) Financing model characteristic. There are different characteristics and scopes of application for different financing models. Financing model characteristic indicates extent, scale of financing, financing procedure and speed, participation degree of the government (or owner) and financing risk distribution degree. There are different financing channels for different financing models. Meanwhile, there is difference in financing procedure of different financing models and the time for raising large-scale of funds. Therefore, it is an imperative to choose financing model according to the urgency degree of the project and scale of required funds. With different financing models selected, different financing risks are brought to the related parties of the project. When selecting financing model, it is the significant basis for decision making to rationally allocate and evade risks.

92.3 Multi-attribute Decision Making Model for Project Financing Fuzzy Group

MADM (Multi-attribute Decision Making) indicates MADM subject holds discussions and makes decision over attribute characteristics of certain problem (Su and Huang 2006; Huang and Li 2011; Liu and Re 2015). For example, expert group constituted by K experts gives evaluation on and makes decision over multiple attributes of many alternative schemes. Then, it refers to a problem about multi-attribute decision making of a group. Fuzzy multi-attribute decision making indicates clustering and integrating fuzzy suggestions of expert group and the process of transforming the group decision making problem into personal comprehensive decision making problem. During integrating expert opinion, the consideration should be given to the authority of expert individual, the consistency in expert group opinion and type characteristics of attribute.

When there is expert set $E = (e_1, e_2, \ldots, e_k)$, evaluation attribute set $U = (u_1, u_2, \ldots, u_n)$ and alternative scheme set $X = (x_1, x_2, \ldots, x_m)$, in which $K, m, n \in N$. If the assignment that expert $e_k = (k = 1, 2, \ldots K)$ gives to evaluation attribute $u_j \in U(j = 1.2, \ldots, n)$ of alternative scheme $x_i \in X(i = 1.2, \ldots, m)$ is $\tilde{a}_{ij}^k = \left[a_{ij}^{kl}, a_{ij}^{km}, a_{ij}^{ku}\right]$, the composition of value under evaluation attribute of alternative scheme given by each expert forms a fuzzy decision making matrix $A^k = (\tilde{a}_{ij}^k)_{m \times n}$. If there are K experts in expert group, there are K fuzzy decision making matrixes. K fuzzy decision making matrixes are integrated into a comprehensive decision making matrix of expert group through certain combined approach. Then, according to the experience and preferences of decision maker, the different evaluation attributes are endowed with corresponding weighted value and comprehensive weight of alternative scheme are calculated.

92.3.1 Evaluation Attribute Classification and Expert Weight Calculation

Type classification in evaluation attribute set U is generally divided into benefit type, cost type and fixed type. Generally speaking, the large evaluation value of benefit type attribute the better and the smaller that of cost type one the better. Furthermore, the fixed type attribute has small influence on decision making result. There are small changes in its decision making and weight value, only for reference for decision making. The consideration is mainly given to the benefit and cost type attributes. For different experts in the expert group have different importance degrees in participating in decision making in different fields. For example, the financing experts have more authority for financing channels and ways of the project. The construction management experts have more authority for project attribute evaluation. The investment management and control experts and representatives have better understandings about the preference of the government (or owner) in investment. Therefore, is a corresponding expert weight vector $\varpi^j = (\varpi_1^j.\varpi_2^j, \ldots, \varpi_k^j)$ for each subjective evaluation attribute $u_j \in U(j = 1.2, \ldots, n)$, in which $0 \leq \varpi_k^j \leq 1$ and $\sum_{k=1}^{k} \varpi_k^j = 1$. Expert weight vector manifests the importance degree of expert decision making opinion in expert group.

92.3.2 Standardization of Fuzzy Decision Making Matrix

According to the fuzzy evaluation for al attributes of alternative scheme by the expert, each expert MADM matrix is built. As there are different evaluation index attributes during decision making, set benefit type attribute set as I_1 and cost type one as I_2, "dimension" for attribute of different types might be different. To eliminate the influences of different physical dimension, the decision making matrix should be standardized according to the following formulas.

$$r_{ij}^k = a_{ij}^k / \left\| a_j^k \right\| = a_{ij}^k / \sum_{i=1}^{m} a_{ij}^k, j \in I_1 \tag{92.5}$$

$$r_{ij}^k = (1/a_{ij}^k) / \left\| (1/a_j^k) \right\| = (1/a_{ij}^k) / \sum_{i=1}^{m} (1/a_{ij}^k), j \in I_2 \tag{92.6}$$

92.3.3 Expert Comprehensive Weight Determination and Opinion Integration

According to the different importance degrees of expert in participating in decision making in different fields, the expert evaluates different attributes of the alternative schemes. However, during practical decision making, the consideration should be given to the authority of expert opinion and consistence in it, for which the expert performs evaluations according to his preference when giving decision making evaluation. Therefore, it is necessary to give consideration to the similarity degree of attribute evaluation value when integrating expert opinion to measure the consistency of expert opinion by taking similarity as the standard.

(a) As for any two experts e_p and e_q, the similarity $S_{ij}(p,q)$ of evaluation values under same attributes of same scheme can be calculated according to the formula (92.4).

$$S_{ij}(p,q) = 1 - \frac{\left|r_{ij}^{pl} - r_{ij}^{ql}\right| + \left|r_{ij}^{pm} - r_{ij}^{qm}\right| + \left|r_{ij}^{pu} - r_{ij}^{qu}\right|}{3} \quad (92.7)$$

(b) Calculate the degree of similarity of each expert in same attribute evaluation opinion of other experts about same scheme, and take average value of similarity as that of expert personal and group opinion, namely average degree of similarity $AS_{ij}(e_k), e_k \in E$, and calculate relative similarity $RS_{ij}(e_k)$ according to average one.

$$AS_{ij}(e_k) = \frac{1}{k-1} \sum_{l=1, l \neq k}^{k} S_{ij}(k,l) \quad (92.8)$$

$$RS_{ij}(e_k) = AS_{ij}(e_k) / \sum_{l=1}^{k} S_{ij}(e_I) \quad (92.9)$$

(c) By combining the authority and consistency of expert opinion, determine the comprehensive importance degree of expert individual under corresponding evaluation attributes in all alternative schemes, namely comprehensive weight of expert opinion $\varpi_{ij}(e_k)$.

$$\varpi_{ij}(e_k) = \alpha \varpi_k^j + (1-\alpha) \times RS_{ij}(e_k) \quad (92.10)$$

In which: α refers to weight coefficient, which indicates the final preference in comprehensive weight of expert opinion, and $0 \leq \alpha \leq 1$. The larger α the more partial the final expert weight to the expert individual authority and the smaller α the more partial that to the expert group opinion (Yue and Huang 2016).

(d) Integration of expert opinion. The comprehensive weight value of each expert is calculated according to the evaluation standard of attributes of alternative schemes of expert individual. If the expert group opinions are integrated, the integration is the evaluation value of all attributes of alternative scheme given by the expert group and constitutes the standard fuzzy decision making matrix of expert group. That is, according to formula (92.11), expert group standard can be calculated as comprehensive fuzzy decision making matrix $B = (b_{ij})_{m \times n}$, in which:

$$b_{ij} = \sum_{k=1}^{k} (\varpi_{ij}(e_k) \times r_{ij}^{l}) \tag{92.11}$$

92.3.4 Comprehensive Weight Calculation and Sequencing of Alternative Schemes

After expert group opinion is integrated as comprehensive fuzzy decision making matrix, due to the fuzziness and complexity of decision making problem, the decision maker should give corresponding weights to evaluation attributes according to the preference and importance degree of all attributes to obtain weight vector of all attributes $w = (\varpi_j)$, in which $\varpi_j = (\varpi_j^l, \varpi_j^m, \varpi_j^n)$. The weight vectors are normalized according to the formula (92.12) to obtain standard weight vector $\bar{\varpi} = (\bar{\varpi}_j), \bar{\varpi}_j = (\bar{\varpi}_j^l, \bar{\varpi}_j^m, \bar{\varpi}_j^n)$.

$$\bar{\varpi}_j = \varpi_j / \varpi_j^{\max} = \begin{cases} \bar{\varpi}_j^l = \varpi_j^l / \varpi^{l^{\max}} \\ \bar{\varpi}_j^m = \varpi_j^m / \varpi^{m^{\max}} \\ \bar{\varpi}_j^n = (\varpi_j^n / \varpi^{n^{\max}}) \wedge 1 \end{cases} \tag{92.12}$$

In which, $\varpi^{l^{\max}} = \max(\varpi_j^l / \varpi_j^l \in \varpi_j), \varpi^{m^{\max}} = \max(\varpi_j^m / \varpi_j^m \in \varpi_j), \varpi^{u^{\max}} = \max(\varpi_j^u / \varpi_j^u \in \varpi_j)$, indicates obtaining the smallest operational symbol.

According to standard comprehensive fuzzy decision making matrix B and standard attribute weight vector w, the fuzzy comprehensive evaluation value of all alternative schemes can be calculated.

$$v_i = \sum_{j=1}^{n} (b_{ij} \otimes \bar{\varpi}^T) \tag{92.13}$$

For it could be known that v_i is triangular fuzzy number according to the calculation result of formula (92.13), namely $v_i = (v_i^l, v_i^m, v_i^n)$. For it is hard to directly compare the size of triangular fuzzy number or sequence it, the desired value of triangular fuzzy number will be calculated according to the membership function characteristic of triangular fuzzy number in this paper. Then, the fuzzy evaluation values will be sequenced according to the size of expected value. The left expected value of v_i is $E_L(v_i) = (v_i^l + v_i^m)/2$ while the right one of v_i is $E_R(v_i) = (v_i^n + v_i^m)/2$. By integrating left and right expected values, the expected value of v_i that could be obtained is

$$E(v_i) = \eta E_L(v_i) + (1 - \eta)E_R(v_i) \tag{92.14}$$

In which, $0 \le \eta \le 1$ refers to optimism-pessimism coefficient. When $\eta > 0.5$, it indicates the decision maker is pessimistic. When $\eta < 0.5$, it indicates the decision maker is optimistic. Here, $\eta = 0.5$, it indicates the decision maker is neutral. If it is substituted into the formula (92.14), the expected value of selected evaluation value that could be calculated is

$$E(v_i) = (v_i^l + 2v_i^m + v_i^n)/4 \tag{92.15}$$

If the expected value is larger, it indicates the corresponding fuzzy evaluation value v_i of the alternative scheme is larger. Therefore, the alternative scheme can be sequenced and decision over advantages and disadvantages can be made.

92.4 Case Inspection

Guangzhou urban rail transit project metro line 11 is 44.2 km long, there are total 32 stations (including 19 transfer stations). The total investment is approximately 42 billion Yuan. 8-car type-A train is adopted. The passenger flow volume at initial stage will exceed 1.2 million people/time after opened. Metro line 11 is loop line, passing through main city areas of Guangzhou, connecting many districts of Guangzhou, like Tianhe, Baiyun, Yuexiu, Liwan and Haizhu and connecting large-scale transportation junctions such as: Guangzhou train station and Guangzhou east railway station. The urban rail transit project features huge investment. The line passes through five districts. With many pipelines along the line, the workload of dismantle is very large. Some lines are underneath pass and close to sensitive area. Guangzhou municipal government preliminarily adopts traditional financing models such as: PPP, BOT and ABS during argument over the project and organized in convening seminar. The final argument over project is carried out. The financing model is determined by combining the specific practical situation of the project. There are more than 40 experts participating in the seminar, including financial, governmental, investment consulting and intermediary experts and representatives from Guangzhou Metro Group Co., Ltd. To simplify calculation and guarantee objectiveness, the experts and representatives are divided into five groups, each of which evaluates project attribute, investor's demand and preference

Table 92.1 Fuzzy number representation methods of linguistic variable

Language	Superb	Good	Better	Ordinary
Fuzzy number	(0.8, 0.9, 1)	(0.6, 0.7, 0.8)	(0.5, 0.6, 0.7)	(0.4, 0.5, 0.6)
Language	Worse	Bad	Worst	
Fuzzy number	(0.3, 0.4, 0.5)	(0.1, 0.2, 0.3)	(0, 0.1, 0.2)	

attribute and financing model characteristic of the alternative schemes through fuzzy linguisticvariable. The linguistic variable in Table 92.1 is transformed into triangular fuzzy number and its average value is taken as the final evaluation value of the group. Ultimately, the expert MADM matrix is built. Besides, the decision over alternative financing model is made through MADM model.

Alternative scheme set $X = \{\text{BOT, PEI, ABS and TOT}\}$, indicated with x_1, x_2, x_3, x_4 respectively, decision attribute $U = \{$project attribute u_1, investor's demand and preference u_2 and financing model characteristic $u_3\}$. Expert group set $E = \{$financial expert e_1, governmental expert e_2, Guangzhou metro expert e_3, investment consulting expert e_4 and intermediary expert $e_5\}$. The corresponding attributes of alternative schemes are endowed with marks according to the expert group. The higher the value the higher the evaluation. By taking the average value of comprehensive expert group opinion, the fuzzy evaluation decision making matrix of all expert groups for the alternative schemes is $A^1, A^2, \ldots, A^5$.

$$A^1 = \begin{bmatrix} (0.64 & 0.72 & 0.76) & (0.54 & 0.70 & 0.75) & (0.68 & 0.72 & 0.70) \\ (0.60 & 0.75 & 0.84) & (0.62 & 0.74 & 0.52) & (0.56 & 0.70 & 0.65) \\ (0.74 & 0.60 & 0.55) & (0.58 & 0.78 & 0.65) & (0.82 & 0.60 & 0.65) \\ (0.54 & 0.72 & 0.65) & (0.72 & 0.60 & 0.72) & (0.65 & 0.80 & 0.56) \end{bmatrix}$$

$$A^2 = \begin{bmatrix} (0.64 & 0.70 & 0.66) & (0.58 & 0.62 & 0.75) & (0.68 & 0.62 & 0.70) \\ (0.56 & 0.85 & 0.68) & (0.72 & 0.64 & 0.56) & (0.56 & 0.80 & 0.63) \\ (0.72 & 0.66 & 0.56) & (0.68 & 0.76 & 0.67) & (0.80 & 0.68 & 0.56) \\ (0.58 & 0.62 & 0.62) & (0.82 & 0.60 & 0.62) & (0.68 & 0.81 & 0.76) \end{bmatrix}$$

$$A^3 = \begin{bmatrix} (0.62 & 0.72 & 0.76) & (0.56 & 0.76 & 0.72) & (0.58 & 0.72 & 0.74) \\ (0.58 & 0.85 & 0.64) & (0.65 & 0.73 & 0.62) & (0.54 & 0.76 & 0.85) \\ (0.72 & 0.80 & 0.65) & (0.63 & 0.78 & 0.68) & (0.80 & 0.70 & 0.75) \\ (0.58 & 0.82 & 0.66) & (0.74 & 0.68 & 0.56) & (0.68 & 0.82 & 0.57) \end{bmatrix}$$

$$A^4 = \begin{bmatrix} (0.72 & 0.62 & 0.66) & (0.64 & 0.60 & 0.72) & (0.78 & 0.52 & 0.60) \\ (0.64 & 0.76 & 0.80) & (0.63 & 0.84 & 0.62) & (0.58 & 0.80 & 0.68) \\ (0.83 & 0.70 & 0.58) & (0.59 & 0.74 & 0.75) & (0.80 & 0.60 & 0.73) \\ (0.56 & 0.76 & 0.65) & (0.77 & 0.66 & 0.82) & (0.68 & 0.70 & 0.59) \end{bmatrix}$$

$$A^5 = \begin{bmatrix} (0.65 & 0.70 & 0.73) & (0.55 & 0.80 & 0.65) & (0.78 & 0.62 & 0.74) \\ (0.72 & 0.76 & 0.82) & (0.66 & 0.74 & 0.62) & (0.58 & 0.80 & 0.64) \\ (0.75 & 0.67 & 0.58) & (0.68 & 0.78 & 0.68) & (0.85 & 0.70 & 0.60) \\ (0.64 & 0.78 & 0.68) & (0.73 & 0.68 & 0.70) & (0.68 & 0.83 & 0.56) \end{bmatrix}$$

By transforming A^k standardly according to formula (92.5) or (92.6), the standard decision making matrix $R^k, k = 1, 2, \ldots, 5$ will be obtained. Then, the expert opinions are integrated through formulas (92.7)–(92.9), the relative similarity $RS_{ij}(e_k)$ of each group of expert opinion will be obtained. The calculation result is as below:

$$RS_{ij}(e_1) = \begin{bmatrix} 0.2036 & 0.1880 & 0.2045 \\ 0.2106 & 0.1940 & 0.2160 \\ 0.1937 & 0.1840 & 0.1906 \\ 0.2112 & 0.2080 & 0.2004 \end{bmatrix}, \quad RS_{ij}(e_2) = \begin{bmatrix} 0.2018 & 0.1984 & 0.2035 \\ 0.2106 & 0.1840 & 0.2062 \\ 0.1026 & 0.1945 & 0.1809 \\ 0.2108 & 0.2183 & 0.1886 \end{bmatrix}$$

$$RS_{ij}(e_3) = \begin{bmatrix} 0.1916 & 0.1980 & 0.2045 \\ 0.2003 & 0.1940 & 0.2060 \\ 0.1835 & 0.2048 & 0.1906 \\ 0.2006 & 0.2066 & 0.2008 \end{bmatrix}, \quad RS_{ij}(e_4) = \begin{bmatrix} 0.1938 & 0.1982 & 0.2056 \\ 0.1806 & 0.2046 & 0.1962 \\ 0.2054 & 0.1844 & 0.1967 \\ 0.2002 & 0.1886 & 0.2118 \end{bmatrix}$$

$$RS_{ij}(e_5) = \begin{bmatrix} 0.2026 & 0.1980 & 0.2130 \\ 0.1806 & 0.2042 & 0.1860 \\ 0.1837 & 0.1949 & 0.1809 \\ 0.2018 & 0.2070 & 0.2020 \end{bmatrix}$$

For corresponding weights of known financing model decision making attribute of expert group, please refer to Table 92.2.

According to the formula (92.10), the value of α in this paper is 0.4. it indicates the decision maker is more partial to the group decision making opinion. For the comprehensive weights of each attribute of corresponding alternative schemes given by the expert, please refer to Table 92.3. Further, according to the formula (92.11), the standard fuzzy decision making matrix B of expert group can be calculated.

$$B = \begin{bmatrix} (0.2406 & 0.2720 & 0.2760) & (0.2058 & 0.3076 & 0.2085) & (0.2018 & 0.2872 & 0.3070) \\ (0.2260 & 0.3075 & 0.1984) & (0.1968 & 0.2734 & 0.3056) & (0.2659 & 0.3070 & 0.1905) \\ (0.2270 & 0.3260 & 0.2055) & (0.2257 & 0.2176 & 0.3005) & (0.1882 & 0.1968 & 0.2013) \\ (0.1956 & 0.2073 & 0.3060) & (0.1982 & 0.2100 & 0.3274) & (0.2045 & 0.2080 & 0.3016) \end{bmatrix}$$

According to the former experience and preference, the triangular fuzzy empowerment value is used for the importance of decision maker in decision

Table 92.2 Weight of evaluation attributes in expert group

ϖ_j^k	$u_2/\%$	$u_3/\%$	$u_4/\%$
e_1	20	35	25
e_2	35	15	30
e_3	20	15	20
e_4	15	20	15
e_5	20	25	10

Table 92.3 Comprehensive weights of attributes of corresponding alternative schemes by each expert

	u_1	u_2	u_3	u_1	u_2	u_3	u_1	u_2	u_3	u_1	u_2	u_3	u_1	u_2	u_3
x_1	0.201	0.242	0.261	0.180	0.167	0.186	0.221	0.194	0.190	0.178	0.180	0.186	0.206	0.226	0.208
x_2	0.212	0.182	0.166	0.170	0.234	0.250	0.223	0.188	0.194	0.267	0.290	0.236	0.186	0.209	0.184
x_3	0.223	0.238	0.193	0.243	0.280	0.256	0.206	0.180	0.198	0.228	0.209	0.188	0.178	0.202	0.226
x_4	0.234	0.240	0.186	0.223	0.264	0.168	0.188	0.235	0.222	0.176	0.208	0.188	0.190	0.245	0.260

Table 92.4 Fuzzy comprehensive evaluation and expected values of alternative schemes

Options	v_i^l	v_i^m	v_i^n	$E(v_i)$
PPP	0.5206	0.7642	0.8216	0.8607
Traditional model	0.6250	0.4615	0.8094	0.8432
ABS	0.6055	0.4327	0.6237	0.7045
BOT	0.6592	0.5078	0.8670	0.6238

making with regard to project attribute, investor's demand and preference and financing model characteristic, the decision making attribute weight vector $w = (\varpi_1, \varpi_2, \varpi_3)$ will be obtained, in which.$\varpi_1 = (0.38, 0.46, 0.32)$,$\varpi_1 = (0.35, 0.46, 0.42)$, and $\varpi_1 = (0.24, 0.32, 0.36)$. By standardizing the attribute weight value through formula (92.12), the standard weight vectors of all attributes are obtained $\bar{\varpi} = (\,(0.68, 0.90, 1.00) \quad (0.80, 1.00, 0.96) \quad (0.65, 1.00, 1.00)\,)$.

Calculate the fuzzy comprehensive evaluation value of all alternative schemes through formula (92.13). For the comprehensive evaluation value is triangular fuzzy number. The comparison and judgment cannot be made directly. Therefore, for the expected value of comprehensive evaluation value of all alternative schemes is calculated through formula (92.15), please refer to the Table 92.4. It could be obtained from Table 92.4 the corresponding expected value of all alternative schemes reaches 0.8607 > 0.8432 > 0.7045 > 0.6238. That is, the good and bad sequences of alternative schemes are PPP > traditional model > ABS > BOT. That is, PPP financing model is the best, followed by the traditional model. Financing model BOT is the worst, which is basically the same with the actual situation of the project. The urban rail transit project investment is so huge. PPP financing model is good for mitigating the government finance input and evading certain construction risks.

92.5 Conclusions

Based on triangular fuzzy number group multi-attribute theory, the financing decision making model is built for urban rail transit project in this paper. It provides decision making references for urban rail transit project investor government (or individual) by selecting appropriate financing model according to the specific situation of the project. However, speaking of urban rail transit project decision making, it is necessary to make decision over its applicability and scheme. In addition, it is also necessary to have corresponding guarantee measures. For example, PPP financing model can be used for Guangzhou rail transit project metro 11. However, to ensure the project PPP financing is smoothly carried out, it is also necessary for the capital partners to make choice and have incentive mechanism for the participation of social capital. The governmental departments should be based on principle of the advantage over core energy, priority to honor and advantage over experience during the process that the partners make choices. From the perspectives such as: financial strength, technical ability, management ability and experience, the consideration can be given to many contents such as: contribution proportion, period of franchise rights and benefit distribution.

Acknowledgements This work is supported by the foundation of research program of Guangzhou Metro Corporation. The authors would like to thank the editor-in-chief, and the two anonymous reviewers for their insightful comments and suggestions that have significantly improved the paper.

References

Bowes DR, Ihlanfeldt KR (2001) Identifying the impacts of rail transit stations on residential property values. J Urban Econ 50(1):1–25

Hu LF, Guang X, Deng Y (2011) Approach for fuzzy multi-attribute decision making. Control Decis 26(12):1877–1880

Huang ZL, Li MQ (2011) Method for triangular fuzzy number multi-attribute group decision-making based on group's ideal solution. J Xiamen Univ (Natural Science) 50 (5):817–822

Li XH, Wang MJ (2011) Project financing decision making model based on fuzzy group multiple attributes. Appl Res Comput 28(11):4228–4231

Liu MF, Re HP (2015) A study of multi-attribute decision-making based on a new intuitionistic fuzzy entropy measure. Syst Eng Theory Pract 35(11):2909–2916

Peter N (1989) Project financing. Sweet & Maxwell, London

Su SB, Huang RH (2006) Attribute hierarchical mode based on triangular fuzzy number. Syst Eng Theory Pract 26(12):115–119

Tian H (2014) A research in financing mode of chinese urban rail transit construction—based on the perspective of state-owned commercial banks. Ph.D. thesis of Southwestern University of Finance and Economics

Wang M (2009) Research on the BT mode for project financing for urban mass transit. J Railway Eng Soc 9:98–102

Yuan LL, Wang YS, Yao C, Sun Y (2015) Analyzing influencing factors of financing decision for urban rail transit projects using DEMATEL approach. Open Constr Build Technol J 9:255–261

Yue YD, Huang HY (2016) Financing structure selecting model for PPP mode of the government financing platform existing projects based on FMADM. J Soc Sci Hunan Normal Univ 2:109–115

Chapter 93
On Territorial Planning Reconfiguration in China: A Critical Review of the Existing Planning System

Liping Shan, Yuzhe Wu and Sheng Zheng

93.1 Introduction

At present, China has more than 80 types of planning promulgated by the government, including more than 20 kinds of the statutory planning, thus there are lots of contradictions, conflicts and overlaps among China's diverse plans, which makes the planning meaningless. In the process of planning and management, there exist more problems, such as the shortage of the management requirements collaboration, difficulties in planning departments convergence and unclear tube body (Su and Chen 2015). One of the most noticed topics is how to get a kind of coordination among so many types of plans, including the "multiple-plan coordination" from theory to practice.

The national development and reform commission, the ministry of land and resources, the ministry of environmental protection, housing and urban construction department and other ministries jointly issued "Notices about carrying out counties "multiple-plan coordination" pilot work" (Development and Reform Plan No. [2014]1971), explored for the fusion problem of spatial planning, such as land use planning, urban planning, economic and social development planning and the ecological environment protection planning (Yuan and Tang 2015). In the year of 2016, the fourteenth session of the national people's congress committee meeting of Xiamen has adopted "Several provisions of multi-planning coordination in Xiamen special economic zone". Article 2 pointed out that multiple plans integration refers

L. Shan · Y. Wu (✉) · S. Zheng
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

L. Shan
e-mail: shanliping@zju.edu.cn

S. Zheng
e-mail: shengzheng@zju.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_93

to the establishment of its strategic space planning as a guide, the coordination of national economy and social development planning, the overall urban planning, land use overall planning, environmental protection planning and other spatial planning, the structure of approval and management information platform for business and project collaboration, improving the examination and approval system for construction projects, and to realize a good system for urban governance system and modern governance capacity.

93.2 Different Kinds of Problems from Multiple Types of Plans in China

Planning means a series of arrangements and prospects of certain social and economic conditions for the future development arrangements. For a long time, there are many types of planning in China, such as the macro planning at the national level, the micro planning of the local level and the special planning of the various functional departments. On the one hand, those plans play an important role in the national and local economic and social development, on the other hand, different types of planning also caused some problems, the planning contents are mutually staggered, lack of effective interface between the various types of planning (Zhang and Zhao 2015).

(1) Different planning period and legal basis. When using the China's national economic and social development planning, the overall urban planning and the land use planning for the example, the national economic and social development planning is an overall outline of a national or regional economic and social development, organized by the government in the level, with the generally five years of planning period. The overall urban planning is the comprehensive deployment and implementation measures for the character of the city, development goals, development scale, land use, spatial layout and the construction in a certain period of time, organized by the local governments, generally the planning period is 20 years. Land use planning is always in a certain region, makes the overall layout arrangement for land development, utilization, management and protection in space and time, according to the national economic and social sustainable development and the local natural, economic and social conditions, with generally 15 years planning period (Li 2015). However, ecological environment protection planning has the 5 years planning period, due to the differences in the time, there will be different targets between short and long term planning, as a short-term planning, national economic and social development planning and the ecological environmental protection planning will not be able to guide the overall urban planning and land use planning reasonably. The differences of the legal basis result in the differentiation of the regulation and management. In the legal level, urban planning and land use planning should be based on the plan for national

economic and social development, at the same time, the urban planning should dovetail with the land use planning. "Urban and Rural Planning Law of the PRC" fifth items stipulates: "the city, town and village planning shall be based on the national economic and social development planning, and engaged with the overall land use planning"; "Land Administration Law of the PRC" 22 item stipulates: "the city, town and village overall planning, should be in line with the overall land use planning, the construction scale in the city, town and village overall planning shall not exceed which determined in the overall land use planning" (Li 2014).

(2) The differences of planning technology and target makes the spatial layout is unreasonable, which is difficult to connect. Planning technical standards are different from others, take the land classification standards for example, land use planning adopts to the "Land use planning preparation procedures in city, county and township", the classification for land nature contains 3 major categories, with the whole 29 categories; urban planning adopts to "Standard for urban land classification and planning construction" (GB50137-2011), in which the construction land contains eight categories, and 42 whole small class (Su and Chen 2015). Planning from different departments will have different tasks, which leads to different emphases. Urban planning established by the Departments of Planning and Construction explores the reasonable use of national land use from the view of social economic development; Departments of National Development and Reform Commission establish the main functional zoning according to different regional carrying capacity of resources and environment, existing development density and development potential, put forward the optimized development, key development, restricted development and development zoning from the policy level; Departments of National Land establish land use planning from the aspects of basic farmland protection, focusing on the non construction land protection and control of the construction index; And the ecological function zoning are established by the Departments of Environmental Protection, from the angle of city ecological zoning restrictions to ecological service function.

In addition, there are social and economic development planning, put forward the strategies and objectives in the next five years from the social and economic development point, in which the economic, demographic and social development indicators are payed more attention to compared with land space (Yang et al. 2015). Production, life and ecology space boundary has not been delineated, nor those has been designated to fully demonstrate. The ecological planning land boundaries delineated in the overall urban planning and land use planning has big differences, and there always occur that the construction projects determined by the Departments of Development and Reform touch ecological boundaries, ecological protection zones lack co-ordination, affecting the city's ecological security (Jin et al. 2015).

(3) From the perspective of planning approval authority, the social and economic development planning are approval by the people's Congress at the same level, the local governments have greater right, the approval is relatively easy, and have strong timeliness. However, the urban planning and land use planning are approval by the authority at the superior level, due to the lengthy legal audit process, sometimes planning will tarted to embark upon a new revision at the end of the approval of the previous. In the implementation of planning, the land use planning are required for information technology and indicators management, planning implementation has strong rigid; as for urban planning, as a result of local development strategy adjustment or market development needs, often need to be adjusted (Zhang and Luo 2015).

93.3 From the Multiple Plans to Coordination-Studies

Since the reform and opening policy, with the development of China's urbanization, planning plays a more and more obvious role for the guidance of spatial development process, it began to cause the attention of many scholars, since the last round of planning in the year of 1996, China has seen increased problems in the planning coordination. Xiao (1998) proposed that the overall urban planning and land use planning are important contents to do a macro guidance for a regional urban construction and optimization of land use structure, both of them are related, while have differences from the planning contents, classification and other aspects, he also proposed that the coordination, convergence and improvement of planning knowledge, planning contents, classification and planning statistics. Lv (1998) analyzed differences between the two planning.

Zhu (1999) analyzed the conflicts between the urban planning and land use planning from the more specific aspects, the relationship between the two are of mutual restriction and included, the urban planning provide the land use planning with the guidance and coordination in the urban system planning, determine regional structure of land use. Land use planning should provide as sufficient land as possible to guarantee for the development of the city, to promote the regional economic and social development. At the same time, he discussed the basic strategies for the two planning coordination from the relationship, work mode, city spatial structure, land classification, spatial planning system, planning management system of the two types of planning. After that, there are a lot of researches for the coordination, integration of the two types of the planning, both from the theory and practice. Since the middle 1990s, the "two planning" coordination has been an integral part of the overall urban planning and land use planning researches. In 2008, China's "Urban and Rural Planning Law of the PRC" implemented and proposed the to realize the "three compliance", the article 5 of Chapter 1 clearly stipulates: preparation of the overall urban planning, town planning and planning of township and village shall be in accordance with the national economic and social development planning and connected with land use planning.

As for academic research, researches of three compliance focus in theoretical analysis and technology convergence, in the theoretical construction, the majority stressed construction of a scientific planning system for multi-goal mutual integration, and learned from foreign space planning system; and on the analysis of the problem, from the department duties, planning contents and emphasis to analyzed differences from three gauge; in the technical coordination, population index requirements, urban land demand and planning content system of convergence are the specific research directions (Zhang and Luo 2015). As for practice, in 2004, the National Development and Reform Commission put forward to carry out "three compliance" pilot work in the six counties such as Suzhou City, Anxi County, Yibin City which actually has not been fully implemented (Qi et al. 2015). In the early 2014, the Ministry of housing and urban rural development put forward the work requirements for "three compliance" and "multiple plans integration", to promote the development of new type of urbanization and strengthen the urban management.

And also in the year of 2014, the National Development and Reform Commission, the Ministry of land and resources, the Ministry of environmental protection and the Ministry of housing and urban rural construction jointly issued to determine the 28 cities and counties including Xiamen as the "multiple plans integration" pilot cities and counties, wished that in the counties spatial units, China would explore the way for "a city a plan" and "a blueprint for continuous eternal development", to explore the experience for the establishment of a unified system of spatial planning (He 2015). Other discussions about the "multiple plans integration" are from technology integration model (Yuan and Tang 2015); theory analysis (Jin et al. 2015); and practice (Wang and Wei 2015).

93.4 Spatial Planning System in China

Regardless of two planning coordination, three compliance or multiple plans integration, the aim are to adjust China's existing space planning situation, combined with the pilot work in the cities and counties, which will mix all kinds of space planning into the city or county region with a control fir spatially explicit border, to achieve regional coordination in all kinds of spatial planning and management, a city a plan, a blueprint, an effective solution to all kinds of traditional spatial planning guide differences, self systems, conflicts, lack of cohesion of contradictions, and provide the basis for the establishment of a unified interface, coordination spatial planning system (Lin et al. 2015). Zhang and Fang (2016) put forward that the existing research showing a context as "untangle the spatial planning system form-sum up the relationship and conflict between planning-seek multi-planning conflict root—have regulatory coordination test/practice (explore multiple plans integration techniques/methods)—for further study of the spatial planning system structure and system innovation".

Zhu et al. (2015) thought that construction of the spatial planning system first need to explore the scope of duties on all kinds of spatial planning, also means to solve the problems of planning "fight", by planning "one" all kinds of spatial planning will achieve the space coordination in the aims and requirements, and then the discussion of ways for feasibility of "a space a plan and establishment of the same spatial planning system will be come up with. Planning coordination is basis for the establishment of a unified system of spatial planning, in recent years, Shanghai, Shenzhen, Wuhan, Guangzhou, Xiamen and other cities, based on local conditions, carried out a variety of exploration for spatial planning system integration, from the aspects of system innovation, advocating the concept, technology integration and urban governance, gained some experience. China's four kinds of spatial planning including urban and rural planning, land use planning, major function oriented zoning and ecological functional have their own characteristics in the aspects of legal and institutional arrangements, but space control is their common development trend, while facing all kinds of difficult coordination problems.

As for the division of functions, urban and rural planning focuses on construction management, while land use planning puts more emphasis on resource conservation, development priority zoning is about regional coordination, and ecological priority zoning is dedicated to eco-environment protection, all of which are space control methods in regard to land development rights (Lin and Xu 2014).

In the practice of spatial planning, taking Chongqing city as an example, Yu and Yi (2009) has combed the city's process of implementing the plan of "three compliance" and "four compliance", which explored integration and coordination but still needed support from law, policy and techniques.

In preparation of the comprehensive spatial planning, it is requested to make sure overall space resources development pattern, and take development restrictions and prohibition areas into the red line of development spatial resources, and take them with the development of the region into spatial planning system, make the various projects arranged in an orderly manner under the space control elements such as strong degree, nature, direction and scale, solve problem of project random landing, achieve the target of planning to drive the implementation of the project; arrange urban and rural space unified, to avoid duplication construction, resource allocation and facilities resolving conflicts, arrange the overall urban and rural development (Yu and Yi 2009).

The consistency of the types of planning in space is of great importance for planning coordination. Wu (2015) Put forward that from the perspective of resource allocation, different types of planning on the same national spatial area cause the conflicts. Planning can be divided into control planning and development planning, in classification from the development. Planning control is designed to control regional development, such as in order to protect the ecological environment, ecological environment protection zone is delineated; to the areas harming to economic and social development and human habitation, the forbidden areas are delimited; the aim of development planning is to have planning arrangements to the time and strength within the region, in order to obtain greater benefits as far as possible.

However, for the same land space, the two attributes of the control planning and the development planning will cause the greater overlap and conflict in the same space unit. In China, the situation occurs from time to time, for example, the ecological and environmental protection planning in the preparation from Department of environmental protection has the main part-the ecological and environmental protection zoning, which often overlaps with the optimization development areas and key development areas in major function oriented zoning compiled by the development and Reform Commission, urban development areas in urban and rural planning and the allowable construction areas and conditional construction areas in the land use planning compiled by the Land and Resources Bureau. And the cultivated land protection zoning determined by Departments of cultivated land protection often deviates from the development requirements of other planning. Development or control is the embodiment of different resource allocation means for the same space unit, and the most important one is the requirements of the "one map" to a region, which also means the determination of the nature of the two types of regional space planning.

However, planning is a deployment for the future uncertainty, the future is in the presence of uncertainty, if the whole spatial region are allocated the control and development planning, which will lose flexibility to the future development, because we are unable to accurately forecast the future development. It is unable to accurately estimate the direction, the nature, the population and demand of urban development, or environmental changes. Therefore, there should exists considerable scope between the development and control planning, where the market is the most direct means of allocating resources. In space, it means that control and development planning do not occupy the whole region.

As for implementation, to the perspective of landscape ecology, control and development planning and market allocation means in the region can be implemented from the point, line, surface. From the point of view, the combination of scenic spots and historical sites protection with the optimization development plots; the landscape characteristics of the line mainly include the river, transportation, ecological corridors and so on. Conduits, rivers, high-speed rail, highways and rivers serve as transportation lines are carried out development planning, while key ecological conservation, ecological corridors are control planning; and the planning in surface, mainly divided into control planning for the protection of arable land, ecological sensitive areas, water source protection areas, historical and cultural protection areas and development planning of city optimization development district and development zone (Wu 2015).

93.5 Conclusions

China has a large number of planning, and the competent authorities are different, resulting in a lot of planning problems, overlapping and conflicts. In this context, the Chinese government and scholars have carried out different explorations. Researches on the theory and practice from two planning coordination to three compliance in recent years have laid the foundation for China's regulation and coordination.

"One map" planning requires for the spatial planning coordination of multiple plans integration, and main source of the conflicts between spatial planning the differences of the allocation of land resources (space), from the different spatial planning made in the same unit based on environmental protection from the point of view of restrictions on development, or the thought to encourage the development of urban economic growth, and so on.

Therefore, based on the literature review, whether "one map" planning, "multiple plans integration" or a unified spatial planning system, the most important is to determine the nature and spatial scope of the control planning and development planning. In addition, the control planning and development planning can not cover the whole area, there should be space left to the market as "invisible hand" to control, to select the control or development planning. Control planning is protection and forbidden to the area which need protection related to the sustainable development at the long-term, the development planning is the planing for the existing or future development region and the direction, scientific and rational planning, make the development of the region in the political, economic, cultural and social aspects. From the point of view of point, line and plane, the selection of spatial planning system is based on the evaluation of land suitability.

Acknowledgements The work is supported by the National Natural Science Foundation in China (Grant No. 71373231), Scientific Research Project of Education Department of Zhejiang Province (Grant No. Y201636214), the National Social Science Foundation of China (Grant No. 14ZDA039) and the Fundamental Research Funds for the Central Universities.

References

Daily G (1997) Nature's services: society dependence on natural ecosystems. Island Press, Washington, D.C

Davidoff P (1965) Advocacy and pluralism in planning. J Am Inst Planners 31:331–338

Gong L, Yang M, Zhang PC (2015) Study and implementation of "multiple planning in one" assistant decision system based on GIS. Urban Geotech Invest Surveying (6):11–14

He ZZ (2015) Study on the one of multiple plans integration: reflection on the practices of Xiamen. Urban Dev Stud 22(6):52–58

Ji RK (2014) The land ministry pushing land planning legislation pilots of the "three plan coordination". 21 Century Business Herald 15(6)

Jin LX, Zhu HM, Chen YX (2015) A framework of territorial spatial development planning based on multiple-planning integration. Territory Nat Resour Study (6):29–33

Li DQ (2014) Local government three plans integration efforts and innovation. Planners 30(9): 65–69
Li RR (2015) The cognition to “multi regulation unification” and its reform suggestions. Shangxi Archit 41(21):7–9
Lin J, Xu CY (2014) Land development rights, space control and synergetic planning. City Plann Rev 38(1):26–34
Lin J, Chen S, H, Xu CY, Wang C (2015) Came analysis of spatial planning. Urban Plann Forum (1):10–14
Lv WJ (1998) Similarities and differences between urban overall planing and land use overall planing. Urban Plann Forum 1:34–36
National People’s Congress (2008) Urban and Rural Planning Law of the People’s Republic of China
Qi Y, Du Y, Li QJ et al. (2015) “Three plans integration” oriented urban-rural master plan coordination. Planners 31(2):5–11
Su H, Chen H (2015) The essence “multiple plans integration” and planning compilation. Planners 31(2):57–62
Wang Y (2008) Urban planning system in international vision-comparative studies based on governance theory. China Architecture & Building Press
Wang WS, Wei LJ (2015) The practice and reflection of Xiamen “multiple plans integration”. Planners (2):46–51
Wu YZ (2015) A framework of “multiple planning integration” based on control planning and development planning [EB/OL]. https://wenku.baidu.com/view/8adce8dedc88d0d233d4b14e852458fb770b38d0.html
Wu YZ, Discussion on “3 in 1” planning in China
Xiao CD (1998) The discussion of urban planning and land use planning. Urban Plann Forum 1:29–33
Yang ZX, Wu HT, Qi Y (2015) From the “two rules integration” and “multiple planing integration” into the urban and rural planning ideas. Annual meeting of China’s urban planning
Yu J, Yi Z (2009) Comprehensive spatial planning compilation: Chongqing urban-rural planning experiment. Planners 25(10):90–93
Yuan L, Tang Y (2015) Technology integration mode with regard to “multiple planning integration” province. Nat Resour Econ China 8:47–51
Zhang W, Xu HX (2005) Analysis on coordination of urban and rural planning. City Plann Rev (11):75–79
Zhang JX, Chen H (2014) Spatial governance: political economy of China’s urban and rural planning transformation. City Plann Rev (11): 9–15
Zhang SK, Luo Y (2015) Comprehensive path of realizing “three plans integration”: experimental cities in Guangdong province. Planners 31(2):39–45
Zhang, YJ, Fang CL (2016) A review on spatial planning coordination and China’s “coordinated planning”. Urban Plann Forum (2):78–87
Zhang JJ, Guo X, Zhao XM (2015) Discussion and outlook about integration of multiple plans under new normal. Acta Agric Jiangxi 7(10):125–128
Zhu, CB (1999) The coordinating mechanism for urban planning and land use planning. Urban Plann Forum 4:10–13
Zhu J, Deng ML, Pan A (2015) Three planning in one: exploring the order and regulation capacity of spatial planning. City Plann Rev 39(1): 41–47

Chapter 94
On the Garbage Classification Mechanism Based on Repeated Games in Urban Network Organization

Teng Su and Yuzhe Wu

94.1 Introduction

With Chinese urbanization, garbage has become an urban disease. The amount of garbage grew at an average annual rate of 5.44%, from 0.31 million tons in 1980 to 1.71 million tons in 2012 (Han et al. 2016), which severely restricted urban development and residents' life. Garbage classification is the basis to realize Harmless integrated treatment, which is very important to increase garbage resources' recycling and comprehensive utilization (Min et al. 2002).

In this context, the State Council promulgated the "State Council approved the Ministry of Housing and Urban-Rural Development and other Departments' the Notice of Opinions to Further Strengthen the Municipal Solid Waste Work" (State Council Promulgated [2011] No. 9), followed by provinces' opinions one after another. Zhejiang Province promulgated "Opinions on Further Strengthening the Municipal Solid Waste Work" in July 2012, and Hangzhou has established special website for garbage classification and put a series of implementation rules and regulations system such as garbage classification' methods, identification and standards, implementation of the program, assessing the implementation rules. The urban garbage classification mechanism has been carried out in full swing.

Urban garbage classification is complex system project. At macro-level, it involves the enhances of environmental protection awareness, the development of policies and regulations, the innovation of management system, public participation, technical support and so on; at micro-level, it requires the participation of multi-stakeholder whose demands and behavior are different, and moreover will and behavior of the same stakeholders also have a big difference (Chen et al. 2015).

T. Su · Y. Wu (✉)
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_94

This article looked at the multi-stakeholder in urban garbage classification, starting from management organization types based on hierarchical organization minimum authorized theory and repeated games theory. The paper compared the different management organization types' role in urban garbage classification for constructing more optimized urban garbage classification mechanism.

94.2 Theoretical Basis and Literature Review

94.2.1 Literature Review on Chinese Urban Garbage Classification

Developed countries' experience of urban garbage classification has been quite mature, while China is still in development. Chinese scholars have made the following study: Summarized the approach of developed countries such as Japan, the United States, Germany and so on, and proposed citizen participation, education and publicity, legal constraints, government incentives, multi-agent cooperative governance and several other experiences for China (Lv and Du 2016); Proposed urban garbage classification model "government involvement and guidance, business executive, consumer making decision" at the system design level (Chen and Nie 2010); Probed the necessity and feasibility of the environmental education to urban garbage classification at the level of government involvement and guidance (Chen et al. 2011); Studied the characteristics of relevant stakeholders' willingness and behavioral at level of public participation (Chen et al. 2015), focusing on the social capital of urban garbage classification, with social networks, social norms and social trust as elements (Han et al. 2016); Researched garbage incineration, landfill, composting, integrated processing technology, and pointed out the development direction of China's urban garbage classification at the technical level (Zhang et al. 2011). Research methods had not only macro-level system construction, but also micro-level focus analysis; not only theoretical research such as lessons learned, model design and technology contrast (Chen and Nie 2010; Zhang et al. 2011), but also empirical research based on data and investigation (Han et al. 2016; Chen et al. 2015; Lv and Du 2016; Chen et al. 2011).

On public participation, some scholars studied the behavioral characteristics of public participants as rational economic men in the framework of collective action from on economic perspective (Chen et al. 2015), and others studied the feasibility and path of garbage classification with public participants as social men under standard constraints on psychology and sociology perspective (Han et al. 2016). Based on this, some suggests have been proposed such as building market-oriented operation mechanism, improving the garbage mechanism fee system, strengthening publicity and education to raise the environmental awareness, and realizing the constraints specification of public participation and interaction. As a public issue, urban garbage classification is inevitably accompanied by the logic of collective action and the market failure because of too large supervision costs (Olson 2009), education and social norms just provide a "soft" constraint. Therefore, it is necessary to analyze the psychological characteristics and action logic of various participants on the perspective of organization management and game theory to make useful discussion on urban garbage classification.

94.2.2 Theoretical Basis: The Hierarchical Organization Minimum Authorized Theory and Repeated Fames Theory

Because of market failures, hierarchical organization came into being. However, with the social division and high specialization, hierarchical organization must rely on lower-level's efforts and information to get things done and achieve social (Hayek 1948). When supervision costs are too large, or subordinates have monopolistic information, it needs to set up independent activists with a certain degree of authorization (Bendor 1985). However, it will lead to inconsistent behavior or inefficient combination in any hierarchical organization as long as the decision-making power was given to more than one sub-unit, in other words, every hierarchical organization with decentralization must violate Pareto optimality, transitive or global (Sen 1983). To break this dilemma, in the premise of ensuring Pareto optimality, transitive (Nash equilibrium exists) and the minimum authorization, we only violate global conditions by affecting (ignoring or changing) the preference of certain sub-unit to control their centrifugal tendencies. However, any social decision rules are steerable if it depended on more than one participant (Gibbard 1973; Satterthwaite 1975).

Relying on market forces can ease hierarchical organizational failures, although not Pareto optimality, but also to ensure the Pareto suboptimal with minimize loss of efficiency (Jensen and Meckling 1976). However, agency costs are unavoidable, and market forces may only provide a rough limit to hierarchical organization (Grossman and Hart 1986). Network organizations based on repeated games can solve hierarchical organizational failures effectively. In the repeated games of prisoner's dilemma in which individual rationality leads to collective irrationality, players can obtain Pareto optimality by tit for tat strategy (Axelrod and Hamilton 1981). In a small, clear-boundary network organization, spontaneous order would be formed if the communication with each other is long-lasting (Ostrom 2014). Repeated games are not only the key to solve the Prisoner's Dilemma problem, but also the key to establish spontaneous order in network organization.

94.3 Stakeholder Analysis

Currently, although governments take active strategy in urban garbage classification, such as strengthening propaganda and guidance, formulating rules and regulations, and encouraging property companies or garbage collection company to involve, but it's ultimately depended on community residents' actions which is more based on the social norms and economic interests of themselves' utility. When force and (or) selective excitation don't work well because of pick-up and "tragedy of the commons" due to the large supervision costs in community residents' garbage classification, it's necessary to examine various stakeholders' demands and behavior from the perspective of the organization management. Otherwise, no matter how government brag the significance of garbage classification, community residents have on action without social norms constraint or economic interests driven, and property companies or garbage collection company based on profit maximization couldn't take the initiative and dedication, either. As a result, urban garbage classification could only become bright future, but not fully implemented.

All in all, urban garbage classification relates to multi-stakeholder, and we need to consider a variety of factors. For analytical purposes, this paper abstracts the following important participants: residents, Residents committee, garbage collection company and local government, and summarizes their characteristics of powers and aspirations as follows (Table 94.1) based on their roles in garbage classification:

(1) Residents: the first body of urban garbage classification, hold on the power to decide garbage classification or not directly. Their appeal is the maximum benefit with the minimum cost. If costs outweigh benefits, they wouldn't take action;
(2) Residents Committee: get authorization from the residents who desired garbage classification, coordinate residents' contradiction, communicate with Garbage Collection Company and decide the profit distribution. Its appeal was ensuring residents to take action and optimizing community environment.

Table 94.1 Comparison of the powers and appeal of urban garbage classification stakeholders

Participants	Powers (examples)	Appeal (examples)
Residents	Decide garbage classification or not directly	The maximum benefit with the minimum cost
Residents committee	Coordinate residents' contradiction and decide the profit distribution	Ensure residents to take action and optimize the community
Garbage collection company	Provide financial and technical support and determine market coverage	Maximize profits in garbage collection
Local government	Formulate rules and provide policy support	Optimize and solve urban garbage problem effectively

(3) Garbage Collection Company: provide financial and technical support for urban garbage classification, and hold on the power to determine the market coverage. Its appeal is to maximize profits in garbage collection;
(4) Local Government: formulate rules and provide policy support for company and Residents committee. Its appeal is to optimize and solve the urban garbage problem effectively.

94.4 Hierarchical Organization Authorization: Necessity and Problems

94.4.1 Authorization Necessity: Complexity of Urban Garbage Classification

Since multi-stakeholder's demands and behavior are different, and moreover the will and behavior of the same stakeholders also have a big difference, urban garbage classification is highly complex. Under the premise to consider cost, local government couldn't achieve to supervise all residents' action, garbage collection company wouldn't put much costs into the supervision and education of residents considering its maximizing profits, and residents committee also have no much space to supervise because the behavior to dispose garbage may happen at any time and it has resistance to predetermined the disposing garbage time in short time.

Because of complexity, all sectors of garbage classification have some external, and the hierarchical organization based on simple force couldn't run or worth due to the large supervision costs with information asymmetry. Therefore, to build urban garbage classification mechanism, we have to consider residents' appeal, and authorize the residents who can decide garbage classification or not directly, such as giving the power to decide initial garbage classification or the power of suggestions or veto when they communicate with garbage collection company about pricing remuneration and profit distribution. Only authorizing could ease incentive hitchhiking caused by information asymmetry and external resistance to a certain extent.

94.4.2 Authorization Problems: Hierarchical Organizational Failures

Authorization could ease residents' incentive hitchhiking to some extent. However, as long as decision-making power is given to more than one sub-unit, there would violate the Pareto optimal, transfer or global in any hierarchical organization. The more authorized, the greater the likelihood and severity of dilemma are.

Table 94.2 Resident I and residents committee's preference rankings of different programs

		Residents committee: decide profit distribution program	
		Program ①	Program ②
Resident I: decide initial garbage classification program	Program A	Program x	Program y
	Program B	Program z	Program w

Resident I: has powers to make preference rankings about Program x and Program z
Suppose its preference ranking is Program y > Program z > Program x > Program w
Residents committee: has powers to make preference rankings about other Program
Suppose its preference ranking is Program x > Program w > Program y > Program z

For analytical purposes, the followings are assumed: in the community garbage classification, there are two programs (A and B) of initial garbage classification, and two programs (① and ②) with profit distribution of garbage collection. Residents I has the authority to make decision on the former, for example, when residents committee decide profit distribution of garbage collection to take program ①, Residents I has the power to decide to take program B rather than program A. Then, we have two different preference rankings about different programs (Table 94.2).

As shown in Table 94.2, residents committee hold Program w is better than Program y; according to Pareto principle, Resident I and residents committee both hold Program y is better than Program z and Program x is better than Program w; according to authority principle, Resident I determined Program z is better than Program x. Then, we get an undeliverable preference ranking: Program y is better than Program z, Program z is better than Program x, Program x is better than Program w, Program w is better than Program y.

Visibly, if Resident I has the authority of initial garbage classification, hierarchical organization would appear dilemma. Selecting Program z or Program w isn't in line with Pareto optimal, because Resident I and residents committee both hold Program y or Program x is better. Selecting Program x is equivalent to take Resident I's decision-making authority back, and the hitchhiking problems brought by complexity couldn't be solved still. If selecting Program y, it is clear that residents committee hold Program w is better.

When hierarchical organization encounter dilemma, we try to ignore the global conditions, and ignore or change Resident I's preferences that Program y is better than Program x, so that Program w become the "relatively optimal" program to achieve Pareto suboptimal.

94.4.3 Resident I's Strategies: Distorting the Preference Information

In hierarchical organizations, even if they can influence (ignore or change) a sub-unit's preference, as long as organizations need to rely on sub-unit's advice or action, results would be manipulated by distorting private information. In other words, Resident I could provide false information, so that residents committee would make the decision which is better for Resident I, but departing from Pareto suboptimal.

For analytical purposes, the followings are assumed: Resident II is fully honest and wouldn't hide his preference information of different programs. There are three programs (A, B, C) about garbage classification. Residents committee, Resident I and Resident II all have their own preference rankings (Table 94.3), and the final program is determined by residents committee accordance with the views of the tripartite opinion comprehensively.

Assuming taking several rounds of voting under majority rule, which is to vote on two of the programs first and then the winner is voted with the third program. When information is complete, no matter which two programs are the first round of voting, Program B are the final winner as a result. However, when information asymmetry, if the first round of voting is between Program A and Program B, Resident I could distort his private preference information. Resident I could put Program B behind Program A in the first round of voting, accordance with true preferences in the second round, and the final winner would be Program C. In other words, Resident I could achieve his private purposes by exaggerated the harm of Program B highly, but the cost is the expense of overall efficiency.

Due to the complexity of garbage classification, hierarchical organizations need to authorize, while due to information asymmetry and external resistance, authorization would inevitably lead to dilemma and failures. So how to avoid Resident I providing false information that Program A is better than Program B? And how to make Resident I provide true information with friendly and cooperative attitude?

94.5 Solution One: Market Forces

Urban garbage classification and collection is not only social behavior, but also market behavior. Relying on market forces could ease hierarchical organizational failures, so that each unit has a pressure to reduce hitchhiking and uncooperative. However, because of the dislocation between personal interests and organization interests, market forces could only provide a rough restriction on hierarchical organization. Due to the possibility of the breakdown negotiating with garbage collection companies, market pressure could make Resident II hope Resident I to adopt cooperative attitude and not to provide false information that Program A is better than Program B. However, each individual of Resident II all hopes others to

Table 94.3 Residents committee, Resident I and II's preference rankings of different programs

Preference rankings	Residents committee	Resident I	Resident II
First	Program B	Program C	Program A
Second	Program C	Program B	Program B
Tried	Program A	Program A	Program C

supervise and punish Resident I, supervision itself also has serious hitchhiking. Results show that self-interested behavior leads the supervisory role of Resident II difficult to give full play.

Therefore, if we would like to use market forces, we must start from reducing the supervision cost of every resident. First is to make the communication lines open among residents, residents committee and local government to reduce the direct supervision costs. Second is to protect the privacy information of discloser to reduce the risk supervision costs. Third is to explore the establishment of effective discloser incentives to reduce the supervision costs by raising their earnings. Fourth is to develop community volunteer organizations to reduce the hitchhiking of supervision by organizing action.

94.6 Solution Two: Repeated Dames and Network Organizations

94.6.1 Single Game Model of Residents Committee and Resident I

In the game to determine garbage classification program, if both of residents committee and Resident I take cooperation strategy and express truthful information, the efficiency loss of decision-making would minimize, although could not achieve Pareto optimality. But if one of them (such as Resident I) hold self-serving and take uncooperative strategy, the results would be hierarchical organizational failures.

Suppose in the game, if residents committee and Resident I both take the cooperation strategy, their benefits would be 3; if one take cooperation strategy and the other one not, the benefits of uncooperative one would be 4, and cooperation one 1; if both sides do not take cooperation strategy, their benefits would be 2 (and if the non-cooperation of both sides lead the negotiations with garbage collection company flawed, their benefits would be 0). This is a typical prisoner's dilemma game, and the dominant strategy of residents committee and Resident I are both uncooperative, which leads the garbage classification mechanism failure in hierarchical organization mode (Table 94.4).

Table 94.4 Single game model of residents committee and Resident I in garbage classification

		Resident I's strategy	
		Cooperation	Non-cooperation
Residents committee's strategy	Cooperation	Residents committee's benefit: 3 Resident I's benefit: 3	Residents committee's benefit: 1 Resident I's benefit: 4
	Non-cooperation	Residents committee's benefit: 4 Resident I's benefit: 1	Residents committee's benefit: 2 Resident I's benefit: 2

94.6.2 Repeated Game Model of Residents Committee and Resident I

When the cooperation between residents committee and Resident I is not limited to the garbage classification or not limited to one time, the game relation would be changed. In addition to garbage classification, suppose the probability of further cooperation is w, and the probability of k-th cooperation is wk-1. If residents committee hold on "Tit for Tat" strategy, that means if Resident I take uncooperative strategy, residents committee would be also uncooperative in the next, then the dominant strategy of both sides would be different.

In repeated games, if residents committee and Resident I all take uncooperative strategy in each community including garbage classification, both of their expected total benefits would be $EB = 2 \times (1 + w1 + w2 + \cdots) = 2/(1 - w)$; if residents committee hold on the "Tit for Tat" strategy, the Resident I's expected total benefits would be $EV = 3/(1 - w)$ when he takes the "Tit for Tat" strategy, and be $EB = 4 + 2/(1 - w)$ when he takes uncooperative strategy (Table 94.5).

Obviously, the probability (w) of further cooperation is very important: if $w < 3/4$, $3/(1 - w) < 4 + 2/(1 - w)$, that means the expected total benefits by taking "Tit for Tat" strategy are always less than taking uncooperative strategy. While, if $w > 3/4$, $3/(1 - w) > 4 + 2/(1 - w)$, which means the expected total benefits by taking "Tit for Tat" strategy are always more than taking uncooperative strategy. In other words, as long as the possibility of further cooperation between residents committee and Resident I is large enough, the uncooperative strategy would not be dominant at all.

Therefore, in order to let both sides act with cooperative attitude consciously, it is necessary to increase the chance or probability of further cooperation. On one hand, establish and improve cooperation mechanism of community garbage classification, so that the cooperation between residents and residents committee become norm. We could set up the Garbage Classification Committee, for example, and make the cooperation institutionalized. On the other hand, enhance communication among residents through community cultural activities etc., so that residents could expect to mutually beneficial cooperation with each other. For example, make Resident I realize residents committee desire to and would cooperate with in every collaborative work.

94.6.3 Network Organization

Constructing an organizational model to ensure repeated games could develop towards the direction of cooperation is the basic way to Pareto optimal in urban garbage classification. In a small and clear-boundary network organization, spontaneous order would be formed if the communication with each other is long-lasting.

Table 94.5 Repeated game model in garbage classification and other communities life and work

		Resident I's strategy	
		Tit for tat	Non-cooperation
Residents committee's strategy	Tit for tat	Residents committee's *EB*: 3/(1 − w) Resident I's *EB*: 3/(1 − w)	Residents committee's *EB*: 1 + 2/(1 − w) Resident I's *EB*: 4 + 2/(1 − w)
	Non-cooperation	Residents committee' s *EB*: 4 + 2/(1 − w) Resident I's *EB*: 1 + 2/(1 − w)	Residents committee's *EB*: 2/(1 − w) Resident I's *EB*: 2/(1 − w)

First, supervision could be carried on by the group itself when small scale. Therefore, a residential area or one building would better be a unit for urban garbage classification, so that downsizing makes every resident "bow to see the rise" with each other and always in the midst of others' supervision. Then, every resident's non-cooperation could be effectively alleviated, and garbage classification would be more efficient.

Second, clear-boundary could effectively prevent residents' hitchhiking. Therefore, urban garbage classification would better to be put into practice in owner-occupied residential areas first, where every resident could not choose to participate or not in community garbage classification freely. When hitchhiking and non-cooperation were under control, at every step, other leased residential areas could be incrementally put into practice.

Third, long-lasting communication is the key to play continue roles in network organization. Therefore, setting up the Garbage Classification Committee would make cooperation institutionalized, and enhance communication among residents through community cultural activities etc. Then, mutually beneficial cooperation would become a kind of institution and culture, and optimal efficiency would be achieved in garbage classification as well as other community life and work, finally.

In summary, when hierarchical organization failure could not be completely corrected by market forces, network organizations would effectively solve residents' shirking and hitchhiking in community garbage classification as a complex work. Repeated Games provides theoretical support to play the role of network organization, and a path for the construction of urban garbage classification mechanism.

94.7 Conclusion

Due to the complexity of urban garbage classification, it is necessary to authorize in hierarchical organization. However, authorization would most likely bring residents' hitchhiking and distorting information who directly involve in garbage classification, which leads to a dilemma in hierarchical organization.

From the external constraints level, relying on market forces could ease hierarchical organizational failures, so that each unit has a pressure to reduce hitch-hiking and uncooperative. The key is reducing supervision cost. In this regard, we propose the following recommendations: First is to make the communication lines open among residents, residents committee and local government. Second is to protect the privacy information of discloser. Third is to explore the establishment of effective discloser incentives. Fourth is to develop community volunteer organizations.

From the internal mechanism level, network organizations based on repeated games offers another solution for hierarchical organization failure. In repeated games, cooperative strategy would be a dominant strategy when game time is large enough. Network organization provides a model to ensure repeated game develop towards the direction of cooperation. In this regard, we propose the following recommendations: First is to downsize garbage classification to avoid supervision costs in large organization. Second is to be put into practice in owner-occupied residential areas first, and then other leased residential areas. Third is to set up the Garbage Classification Committee to make cooperation institutionalized, mutually beneficial cooperation become a kind of institution and culture.

However, network organizations with small, clear-boundary and repeated communication isn't the sufficient condition of urban garbage classification, culture and convention are another key constraint. Only if residents all have recognized everyone else hope cooperation and would be continue to cooperate, the cooperation in network organizations would be achieved. Therefore, we had better to pay attention to public education and enhance the communication among residents, so that mutually beneficial cooperation would be common willingness. Only under the guidance of fully healthy culture and convention, network organizations could play its unique advantages in urban garbage classification to achieve social benefits.

Acknowledgements The authors appreciate the financial support by the National Natural Science Foundation of China (Grant No. 71373231), and the helpful work from the organizing committee of CRIOCM2016 International Symposium on Advancement of Construction Management and Real Estate.

References

Axelrod R, Hamilton WD (1981) The evolution of cooperation. Science 211(4489):1390–1396

Bendor JB (1985) Parallel systems: Redundancy in government. University of California Press, Berkeley and Los Angeles, pp 46–48

Chen F, Nie Y (2010) A governance model under cyclic economic conditions MSW. Spec Zone Econ 2:303–304

Chen H, Hu Y, Liu F et al (2011) Some thoughts on environmental education in education for all on the separate collection of municipal solid waste. China Popul Resour Environ (S1):75–78

Chen S, Li R, Ma Y (2015) Paradox between willingness and behavior: classification mechanism of urban residents on household waste. China Popul Resour Environ 25(9):168–176

Gibbard A (1973) Manipulation of voting programs: a general result. Econometrica J Econometric Soc 587–601

Grossman SJ, Hart OD (1986) The costs and benefits of ownership: a theory of vertical and lateral integration. J Polit Econ 94:691–719

Han H, Zhang Z, Peng W (2016) An analysis of the influence mechanism of social capital on households' waste separation. J Zhejiang Univ (Humanities and Social Sciences) 03:164–179

Hayek FA (1948) Individualism and economic order. University of Chicago Press, Chicago, pp 77–84

Jensen MC, Meckling WH (1976) Theory of the firm: managerial behavior, agency costs and ownership structure. J Financ Econ 3(4):305–360

Lv W, Du J (2016) Japan's waste classification management experience and its inspiration to China. J Central China Normal Univ (Humanities and Social Sciences) 01:39–53

Min QW, Pei XF, Yu WD (2002) Status, problems and countermeasures of municipal solid wastes and their treatment in China. Urban Environ Urban Ecol 15(6):51

Olson M (2009) The logic of collective action. Harvard University Press, pp 6–32

Ostrom E (2014) Collective action and the evolution of social norms. J Nat Resour Policy Res 6 (4):235–252

Satterthwaite MA (1975) Strategy-proofness and arrow's conditions: existence and correspondence theorems for voting procedures and social welfare functions. J Econ Theory 10(2): 187–217

Sen A (1983) Liberty and social choice. J Philos 80(1):5–28

Zhang Y, Shang X, Li K et al (2011) Technologies status and management strategies of municipal solid waste disposal in China. Ecol Environ Sci 20(2):389–396

Chapter 95
Optimizing Life-Cycle Carbon Emissions for Achieving Concrete Credits in Australia

Vivian W.Y. Tam, Khoa N. Le and Cuong N.N. Tran

95.1 Introduction

The catastrophe of climate change requires immediate crucial elucidations (Müller and Harnisch 2008). One fundamental issue for the building and construction industry is to address the global climate change challenge by developing credible carbon labelling schemes for building material (Wu et al. 2014). It is also acknowledged that concrete is the most-widely used construction material (i) whose demand cannot be met by the world's cement production and (ii) currently contributes to about 5% of the annual global anthropogenic carbon dioxide (CO_2) emissions (Kline and Kline 2015; Flower and Sanjayan 2007).

Nowadays, the construction trend tends to move toward sustainable building design such as "green building", which is defined as "the ability to fulfil the needs of the future" (ASHRAE 2006) and covers the entire building life-cycle from raw material extraction to design, construction, operation and demolition (Wang et al. 2011; Zimmermann et al. 2005). In relation to these, the promotion of green strategies in a building's life-cycle plays a significant role in achieving sustainability (Zhang et al. 2011).

Concrete is considered as friendly to the environment in all stages of its usage, production and demolition making it a natural choice for sustainable home construction (The Concrete Network 2016). Contributions of concrete to sustainability come from its components such as cement, aggregate and even water. Concrete should desirably be strong, durable and preferably can withstand the toughness of its surroundings with minimal damage and deterioration (Sabnis 2015). In this

V.W.Y. Tam (✉) · K.N. Le · C.N.N. Tran
School of Computing, Engineering and Mathematics, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia
e-mail: vivianwytam@gmail.com

V.W.Y. Tam
College of Civil Engineering, Shenzhen University, Hangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_95

simulated model, concrete has mainly been categorised into two types: conventional and high-strength. Concrete made with normal aggregate with compressive strengths greater than 40 MPa ($\sim$6000 psi) is considered as high-strength concrete (Mamlouk and Zaniewski 2011).

A sustainable industry should be marked by a minimal environmental impact not merely during the manufacturing process, but also during the entire life-cycle of the product (Sabnis 2015). To promote design and construction practices that reduce the negative environmental impacts on buildings and to improve their occupant health and well-being, many green building rating systems have been developed such as: (1) the Leadership in Energy and Environmental Design (LEED®) by the United States Green Building Council (USGBC) (Farham and Gholian 2014); (2) Building Research Establishment Environmental Assessment Method (BREEAM) by the Building Research Establishment (Malley et al. 2014); (3) the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) by the Japan Sustainable Building Consortium (Wong and Abe 2014); and (4) the Green Star Environmental Rating System by the Green Building Council of Australia (Sabnis 2015).

The purpose of the Green Star Environmental Rating System is to support the building industry in its evolution to sustainable and environmental-friendly development. This Green Star Environmental Rating System is designed to (GBCA 2005): (1) establish a common benchmark and standard of measurement for green buildings; (2) promote integrated -building design; (3) identify building life-cycle impacts; (4) raise awareness of green-building benefits; (5) recognize environmental leadership; and (6) transform the built environment to reduce impact on the environment.

It is indisputable that green-building implementation which has been encouraged by the Green Building Council of Australia through the means of the Green Star Environmental Rating System can help improve companies 'image and recognition on fighting environment change'. Nevertheless, there are common thoughts among investors that the implementation of environmental-friendly methods to achieve specific Green Star status will significantly alter their project's budget. They will only achieve minimal points required for a particular Green Star status, therefore, green-building design should be widely encouraged and reinforced in the industry.

Life-cycle, life-cycle energy and life-cycle carbon-emission assessments form three streams of life-cycle studies which have been applied to evaluate environmental impacts of building construction (Chau et al. 2015; Aïtcin and Mindess 2011). The carbon-emission life-cycle assessment of building material, including concrete, follows three internationally-recognized standards: PAS 2050:2011 (BSI 2011), ISO 14040:2006 (ISO 2006) and greenhouse-gas protocol (Flower and Sanjayan 2007; The Concrete Network 2016; Chau et al. 2015). It should be noted life-cycle assessment is a lengthy calculation process which can be tedious which have deterred companies, industry partners and designers to implement green-building. As such, for the industry to achieve a specific Green-Star credit seems difficult because the process has not been well-prepared and user-friendly.

Life-cycle carbon-emission analyses may be divided into three stages following the entire building's life from the perspective of material and energy flow: (1) a materialization stage: incorporating material preparation, transportation and on-site production; (2) an operational stage: daily usage, daily routine and engineering renovation; and (3) a disposal stage: incorporating building demolition, waste transportation and material recycling (Zhang and Wang 2015).

The total embodied CO_2 from concrete production is directly proportional to the cement content used in the concrete mix (Sabnis 2015). It is also well-known that among the principal material used for concrete manufacturing, carbon emissions are typically attributable to Portland clinker production from cement kilns. Most cements contain approximately 5% of gypsum, 12% of supplementary cementitious material (SCM) including fly ash (or pulverized fuel ash), superfine fly ash, ground-granulated blast-furnace slag, rice husk ash, natural pozzolans, colloidal silica, metakaolin, superfine Calcium Carbonate (pure limestone) and 83% of Portland clinker.

The primary objective of this paper is to develop a computer-aided model to examine life-cycle carbon emissions in concrete implementation and explore adequate calculations and results to successfully achieve full credit points for Credit 19B.1: Life-cycle impacts—Concrete in the Green Star—Design & As Built in the Green Star Environmental Rating System. From this point onward, Credit 19B.1 is addressed as "the credit" for brevity. This paper presents a systematic approach to the credit and addresses all concrete used in a project including structural and non-structural elements as well as the appropriate proportions of SCM used in concrete (GBCA 2015). Different SCM types are commonly incorporated into cement mixture as substitute for fly ash, silica fume or blast furnace slag and this method is particularly attractive from both economic and environmental perspectives. The researched mix designs include various concrete strengths of 20, 25, 32, 40, 50, 65, 80 and 100 MPa which are mainly used in the construction industry for various applications (American Concrete Institute 2008). Achieving extra credits by incorporating recaptured/reclaimed water and the use of alternative fine aggregate within the mix has also been explored (GBCA 2015). The benefits of conducting this research can enable business and developers access to various concrete mix designs that can achieve full credits in Credit 19B.1: Life-cycle impacts—Concrete.

95.2 Research Methodologies

Credit 19B.1: Life-cycle impacts—Concrete in the Green Star Design & As Built in Australia is employed to encourage and recognize the reduction of greenhouse-gas emissions, resource usage and wastage associated with concrete usage (GBCA 2015). The credit addresses all concrete used in a project including structural and non-structural elements, but excluding concrete masonry. Up to two points are available where the Portland cement content in all concrete used in the project has been reduced by replacing it with SCM. Fly ash, blast-furnace slag, silica fume are selected as SCM as recommended by the Green Building Council of Australia.

One or two points can further be awarded if Portland cement content is reduced by 30% or 40% respectively, measured by the total mass across all concrete used in the project compared to the reference case.

An extra half a point is available if the water mix for all concrete used in the project contains at least 50% of captured or reclaimed water (measured across all concrete mixes in the project), and the remaining half a point may be obtained if the following criteria are met: (1) at least 40% of coarse aggregate in the concrete is crushed slag aggregate or another alternative material (measured by mass across all concrete mixes in the project), provided that the use of such material does not increase the use of Portland cement by over five kilograms per cubic meter of concrete; and (2) at least 25% of fine aggregate (sand) inputs in the concrete are manufactured sand or other alternative material (measured by mass across all concrete mixes in the project), provided that the use of such material does not increase the use of Portland cement by over five kilograms per cubic meter of concrete.

Carbon emissions are primarily related to material and energy flow within the boundary of the building life-cycle (Zhang and Wang 2015), mainly during the following processes: extraction, manufacturing, on site, operation, demolition, recycling, disposal and transportation. Emission estimates are developed using an emission-factor approach, as shown in Eq. 95.1.

$$\textbf{Emission rate} = \textbf{Emission factor} \times \textbf{Activity data} \tag{95.1}$$

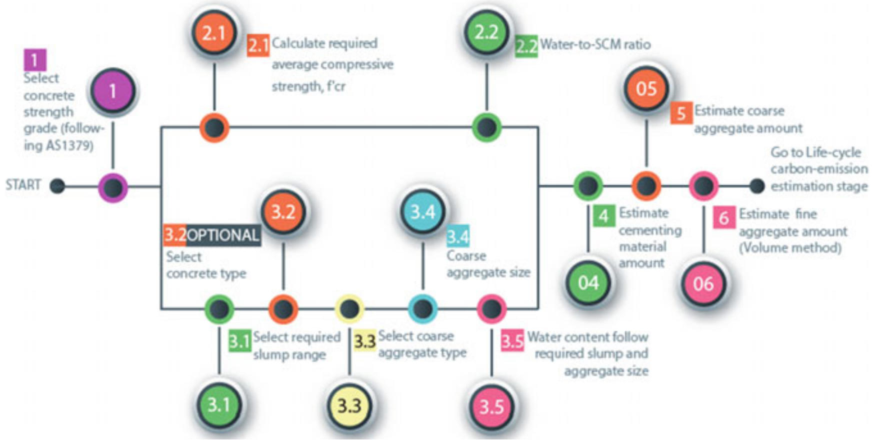
The life-cycle carbon emission analysis takes into account all carbon emissions intensive outputs resultant due to a building structure going through different phases of its life-cycle. The subsequent amount of embodied CO_2 released during these phases can mathematically be calculated using Eq. 95.2 (Chau et al. 2015):

$$\begin{aligned} ECO_2 = {} & CO_{2_{\{Extraction/Production\}}} + CO_{2_{Transportation}} + CO_{2_{On\text{-}Site/Operation}} \\ & + CO_{2_{Demolition}} + CO_{2_{Recycling}} + CO_{2_{Disposal}} \end{aligned} \tag{95.2}$$

where ECO_2 is the embodied carbon (EC) emissions released during the concrete life-cycle, CO_{2j} represents the carbon emissions during the jth phase of concrete's life-cycle. The estimation for each CO_{2j} is explained in the followings.

After estimating the life-cycle carbon emissions for different concrete types under different SCM replacement percentages, a computer-aided model is developed. The model is developed on Microsoft Excel and Visual Basic platforms and has been proposed as a solution to reducing repeated calculations on the life-cycle carbon emissions for various concrete types under different SCM replacement percentages.

The input data of material requirements have been entered following the procedure in Fig. 95.1 to design concrete mix proportions for non-air-entrained concrete with: (1) strengths within the of 20–100 MPa range; (2) aggregate types



(3.1): Slump range is assumed from 30-50mm.
(3.2): Concrete type in the paper is non-air entrained concrete.
(3.3): The maximum size of aggregates is assumed as 12.5mm.

Fig. 95.1 Flow chart representation of the concrete mixture calculation

among angular coarse (crushed stone), sub-angular aggregate, gravel with some crushed particles, and rounded gravel; and (3) exposure environmental condition of concrete. After achieving optimal concrete mix proportions, the life-cycle carbon emissions can be automatically estimated to obtain different Green Star points in the Credit 19B.1 in the Green Star Design & As Built.

The model interface is the gateway to (i) enter required data, (ii) estimate concrete mix proportions and (iii) summarise the life-cycle carbon emissions. Using the proposed model, data can be input, sorted and stored automatically according to preset conditions. Two sample interfaces from the developed model are shown: data-entry template (Fig. 95.2) and data-output template (Fig. 95.3).

After selecting options in the data-entry template, the user may obtain results as shown in Fig. 95.3 by pressing the Export button. Data-output results including concrete mixture design and the life-cycle carbon emissions amount will be automatically calculated and exported to a new Excel sheet which can be conveniently used by designers.

95.3 Life-Cycle Carbon Emissions for Different Concrete Types

95.3.1 100% Ordinary Portland Cement Concrete

Table 95.1 and Fig. 95.4 show an example of how the total embodied CO_2 are generated from the model. The EC emissions generated from concrete in the

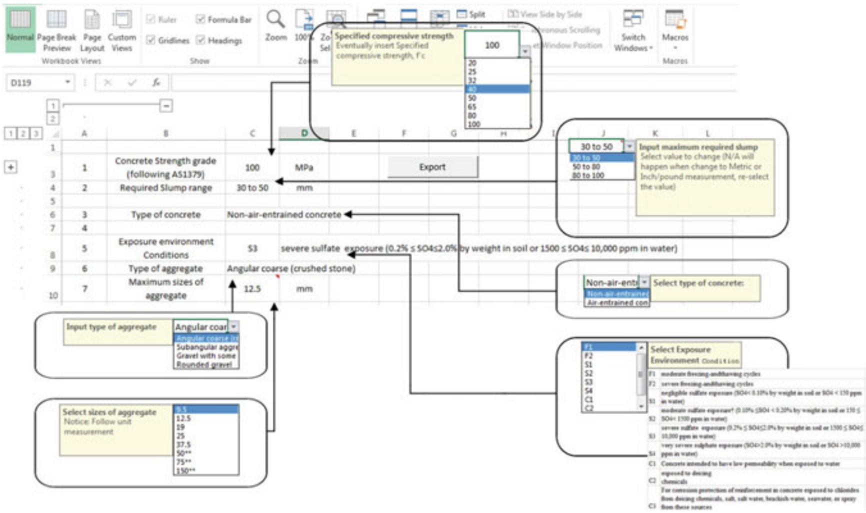
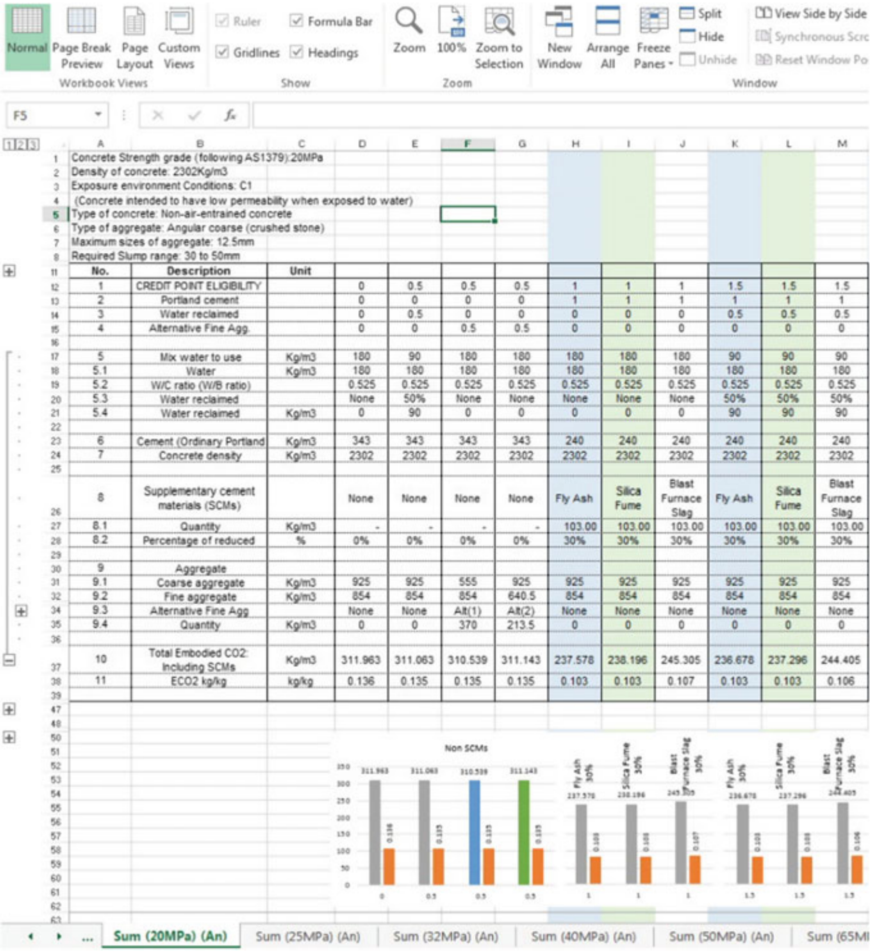


Fig. 95.2 Entry data template in the model

20–100 MPa range with 100% ordinary Portland cement in non-air-entrained concrete. Aggregate types can be changed as angular coarse (crushed stone), sub-angular aggregate, gravel with some crushed particles, rounded gravel, with the maximum aggregate size of 12.5 mm and the required slump range within 30–50 mm.

The estimated data reveal that concrete's life-cycle carbon emissions typically has non-linear relationship with the concrete strength. For instance, the total EC emissions from 100-MPa concrete with angular coarse, and the maximum aggregate size of 12.5 mm (535.66 kg/m^3) is approximately 1.49 times more than that of 20-MPa concrete with the same aggregate type (359.28 kg/m^3). In material composition for concrete production, the required cement amount of 100–MPa concrete (648 kg/m^3) is about 1.59 times more than that of concrete with a 25-MPa (408 kg/m^3) strength, while considering in the concrete strength is increased 5 times.

The selection of appropriate aggregate is also important for all structural concrete and is independent of concrete strength. Changing aggregate types affects concrete sustainability. Using the proposed model, it has been found that the life-cycle carbon emissions generated from angular coarse concrete is higher than that of concrete using the remaining three aggregate types. For example, for 32-MPa concrete, the life-cycle carbon emissions of angular coarse concrete, sub-angular aggregate concrete, gravel with some crushed particles concrete, rounded gravel concrete are 376.1, 360.52, 345.72 and 338.65 kg/m^3 respectively. This is because the cement amount used in angular-coarse-concrete is higher than in concrete from using the remaining three aggregate types, causing higher life-cycle carbon emissions. For a given water-to-cement ratio, compared with other



Concrete Strength grade (following AS1379):20MPa
Density of concrete: 2302Kg/m3
Exposure environment Conditions: C1
(Concrete intended to have low permeability when exposed to water)
Type of concrete: Non-air-entrained concrete
Type of aggregate: Angular coarse (crushed stone)
Maximum sizes of aggregate: 12.5mm
Required Slump range: 30 to 50mm

No.	Description	Unit	D	E	F	G	H	I	J	K	L	M
1	CREDIT POINT ELIGIBILITY		0	0.5	0.5	0.5	1	1	1	1.5	1.5	1.5
2	Portland cement		0	0	0	0	1	1	1	1	1	1
3	Water reclaimed		0	0.5	0	0	0	0	0	0.5	0.5	0.5
4	Alternative Fine Agg.		0	0	0.5	0.5	0	0	0	0	0	0
5	Mix water to use	Kg/m3	180	90	180	180	180	180	180	90	90	90
5.1	Water	Kg/m3	180	180	180	180	180	180	180	180	180	180
5.2	W/C ratio (W/B ratio)		0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525
5.3	Water reclaimed		None	50%	None	None	None	None	None	50%	50%	50%
5.4	Water reclaimed	Kg/m3	0	90	0	0	0	0	0	90	90	90
6	Cement (Ordinary Portland	Kg/m3	343	343	343	343	240	240	240	240	240	240
7	Concrete density	Kg/m3	2302	2302	2302	2302	2302	2302	2302	2302	2302	2302
8	Supplementary cement materials (SCMs)		None	None	None	None	Fly Ash	Silica Fume	Blast Furnace Slag	Fly Ash	Silica Fume	Blast Furnace Slag
8.1	Quantity	Kg/m3	-	-	-	-	103.00	103.00	103.00	103.00	103.00	103.00
8.2	Percentage of reduced	%	0%	0%	0%	0%	30%	30%	30%	30%	30%	30%
9	Aggregate											
9.1	Coarse aggregate	Kg/m3	925	925	555	925	925	925	925	925	925	925
9.2	Fine aggregate	Kg/m3	854	854	854	640.5	854	854	854	854	854	854
9.3	Alternative Fine Agg		None	None	Alt(1)	Alt(2)	None	None	None	None	None	None
9.4	Quantity	Kg/m3	0	0	370	213.5	0	0	0	0	0	0
10	Total Embodied CO2 Including SCMs	Kg/m3	311.963	311.063	310.539	311.143	237.578	238.196	245.305	236.678	237.296	244.405
11	ECO2 kg/kg	kg/kg	0.136	0.135	0.135	0.135	0.103	0.103	0.107	0.103	0.103	0.106

Fig. 95.3 Output data template including concrete mixture proportion and the life-cycle carbon emissions

aggregate, rounded aggregate demands lower cement content because of its smaller surface area for a given volume which is called "specific surface area".

Rough-textured and angular-coarse aggregate provide stronger mechanical bonding and are generally more appropriate for high-strength concrete than smooth-textured aggregate. It is observed that for concrete produced using identical material and alike proportions, crushed-coarse aggregate from fine-grained diabase and limestone likely yields the highest concrete strength. Hence, this class of aggregate should be considered as "green" and is a preferred aggregate type for concrete production.

Table 95.1 Total embodied CO_2 which generated from concrete with 100% ordinary Portland cement, concrete type is non-air-entrained concrete, aggregate type is angular coarse (crushed stone), maximum sizes of aggregate is 12.5 mm, required slump range is 30–50 mm

Description	Unit	Concrete strength grade (following AS1379)-MPa							
		20	25	32	40	50	65	80	100
Mix water to use	kg/m^3	180	180	180	180	149	149	149	149
Water-to-cement ratio/water-to-binder ratio		0.441	0.428	0.418	0.35	0.319	0.277	0.247	0.23
Ordinary Portland cement	kg/m^3	408	421	431	515	467	537	603	648
Concrete density	kg/m^3	2308	2310	2312	2325	2364	2373	2381	2385
Aggregate									
Coarse aggregate	kg/m^3	925	925	925	925	1295	1295	1295	1295
Fine aggregate	kg/m^3	795	784	776	705	453	392	334	293
Total Embodied CO_2	**kg/m^3**	**359.28**	**368.77**	**376.1**	**437.37**	**403.78**	**454.81**	**502.9**	**535.66**
ECO_2 kg/kg	**kg/kg**	**0.156**	**0.16**	**0.163**	**0.188**	**0.171**	**0.192**	**0.211**	**0.225**

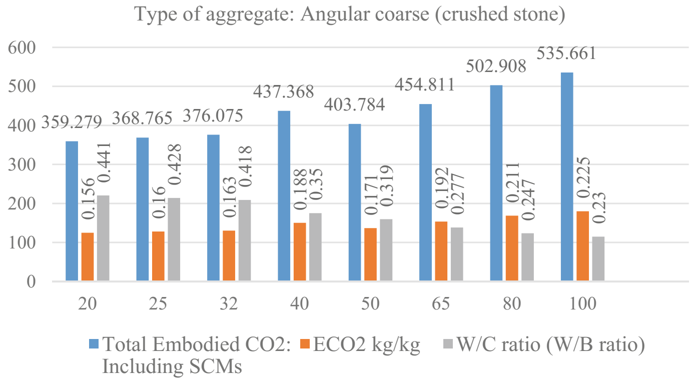


Fig. 95.4 Total embodied CO_2 which generated from concrete with 100% ordinary Portland cement, concrete type is non-air-entrained concrete, aggregate type is angular coarse (crushed stone), maximum sizes of aggregate is 12.5 mm, required slump range is 30–50 mm

95.3.2 Concrete Replacing Ordinary Portland Cement with SCM

The model developed so that the concrete mixture proportion and its life-cycle carbon emissions can be automatically estimated when any one variable or a combination of more than one variable are changed: concrete strength grade, aggregate type or maximum sizes of aggregate, exposure environment conditions.

The use of fly-ash is significant in reducing life-cycle carbon emissions. The 80 MPa concrete produces 502.9 kg/m^3 total embodied CO_2 in 100% ordinary Portland cement concrete while concrete with 30% fly-ash replacement generates 372.19 kg/m^3 life-cycle carbon emissions. Silica fume and blast furnace slag concrete with identical strength have slightly higher total embodied CO_2 at 373.28 and 385.77 kg/m^3 respectively. According to our model, the life-cycle carbon emissions of fly-ash concrete are always less than those from the remaining two SCM concrete types for both desired point levels in the Credit 19B.1.

Using the developed model, the total embodied CO_2 can be estimated under various conditions for different SCM using different replacement percentages as well as claiming about 50% water or using alternative fine aggregate. It has been found that although these options achieve two points for the credit, the life-cycle carbon emission results of SCM combination using reclaiming water or alternative fine aggregate are higher than using solitary SCM.

Based on the above analysis, it has been found that high-strength concrete is more sustainable than normal strength concrete (Aïtcin and Mindess 2011). The water-to-binder ratio plays an effective role in designing compressive-strength concrete but also controlling the concrete life-cycle carbon emissions. Our model shows that concrete life-cycle carbon emissions are increased about 1.5 times for

5-time concrete strength increase from 367 kg/m^3 (20 MPa) to 562 kg/m^3 (100 MPa). This means that it is crucial to lower the water-to-binder ratio in concrete and this ratio should be carefully monitored as precisely as possible so that it can be used to build a durable and sustainable concrete structure (Aïtcin and Mindess 2011).

Choosing the coarse-aggregate type for concrete strength improvement or producing the "green" concrete depends on particle types and shapes. The rough-and angular-coarse aggregate types produce stronger concrete but higher life-cycle carbon emissions because of the higher cement content.

According to our model, fly-ash is found to be the optimum SCM that can be used to reduce concrete life-cycle carbon emissions among the three SCM studied. It may be suggested that not only material cost, but fly-ash should be the preferred material for "green" concrete mixing to ensure minimal life-cycle carbon emissions from concrete production.

95.4 Conclusion

This paper has developed the computer-aided model using Microsoft Excel and Visual Basic platforms to calculate life-cycle carbon emissions for conventional and high-strength concrete in numerically achieving optimal points in Credit 19B.1: Life-cycle impacts - Concrete in the Green Star Design & As Built in the Green Star Environmental Rating System developed by Green Building Council of Australia. Different aspects of concrete mixing and various scenarios can be varied in our model including concrete strength, aggregate type and exposure condition to better-fit individual organizations and designers. The model can be used to automatically calculate life-cycle carbon emissions of concrete per unit volume after entering the required cement quantity, fine aggregate, coarse aggregate and water. The model is designed to be flexible and is one of the simplest ways in estimating the optimal proportion for specific concrete mixing and the life-cycle carbon emissions to achieve the Green Star's concrete credit. The model can provide insights and effective methods for designers to achieve Credit 19B.1 for various concrete types, aggregate types the amount of reclaimed water and alternative fine aggregate utilizing.

Acknowledgements The authors wish to acknowledge the financial support from the Australian Research Council (ARC) Discovery Project under grant number DP150101015.

References

Aïtcin P-C, Mindess S (2011) Sustainability of concrete. Spon Press

American Concrete Institute (2008) ACI 211.4R-08. Guide for Selecting Proportions for High-Strength Concrete Using Portland Cement and Other Cementitious Materials

ASHRAE (2006) ASHRAE greenguide: the design, construction, and operation of sustainable buildings. Butterworth-Heinemann

BSI (2011) PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services

Chau CK, Leung W, Ng TM (2015) A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. Appl Energy 143: 395–413

Farham MR, Gholian MM (2014) Leadership in Energy and Environmental Design. Eur Online J Nat Soc Sci 3:112

Flower DJ, Sanjayan JG (2007) Green house gas emissions due to concrete manufacture. Int J Life Cycle Assess 12:282–288

GBCA (2005) GBCA Environmental rating system for buildings

GBCA (2015) Green Star—Design & As Built, 1st edn. Green Building Council of Australia, Sydney

ISO (2006) ISO 14040:2006 Environmental management—life cycle assessment—principles and framework

Kline J, Kline C (2015) Cement and CO_2: what is happening. IEEE Trans Ind Appl 51:1289–1294

Mamlouk MS, Zaniewski JP (2011) Materials for civil and construction engineers. Pearson Higher Education

Müller N, Harnisch J (2008) A blueprint for a climate friendly cement industry. Report for the WWF–Lafarge Conservation Partnership. Gland, Switzerland, WWF

O'Malley C, Piroozfar PAE, Farr ERP, Gates J (2014) Evaluating the efficacy of BREEAM code for sustainable homes (CSH): a cross-sectional study. Energy Proc 62:210–219

Sabnis GM (2015) Green building with concrete: sustainable design and construction. CRC Press, Boca Raton, FL

The Concrete Network (2016) What makes concrete a sustainable building material?, http://www.concretenetwork.com/concrete/greenbuildinginformation/what_makes.html

Wang Zz, Fan Lc, Mark H (2011) Life-cycle assessment of CO_2 emissions of buildings. In: 2011 International conference on remote sensing, environment and transportation engineering (RSETE), pp 438–441

Wong S-C, Abe N (2014) Stakeholders' perspectives of a building environmental assessment method: the case of CASBEE. Build Environ 82:502–516, 12//2014

Wu P, Xia B, Zhao X (2014) The importance of use and end-of-life phases to the life cycle greenhouse gas (GHG) emissions of concrete—a review. Renew Sustain Energy Rev 37: 360–369

Zhang X, Wang F (2015) Life-cycle assessment and control measures for carbon emissions of typical buildings in China. Build Environ 86:89–97

Zhang X, Shen L, Wu Y (2011) Green strategy for gaining competitive advantage in housing development: a China study. J Clean Prod 19:157–167

Zimmermann M, Althaus HJ, Haas A (2005) Benchmarks for sustainable construction: a contribution to develop a standard. Energy Build 37:1147–1157, 11//2005

Chapter 96
Paradigm Shift Towards Green Industry Restructuring: A Review of Industrial Land in China

Jiaojiao Luo, Yuzhe Wu and Xiaoling Zhang

96.1 Introduction

Financial crisis and industrial technological revolution have become the newly developing powers sweeping across the globe since the new century. Many countries are undergoing a veritable energy revolution with the use of natural gas production and unconventional oil techniques as well as industrial restructuring. For instance, the U.S. attempts to adopt technology revolution, including striving to support new technology industries and promote industrial "green" transformation, to match the coordination between real economy and virtual economy as well as realize the economic recovery. Specifically, the U.S. government put forward a series of programs and plans recent years for the sake of promoting industrial transformation, or rather reindustrialization, such as "Framework for revitalizing American manufacturing", "A national strategic plan for advanced manufacturing", and "A strategy for American innovation" (Zhao 2015). Meanwhile, Germany, UK, and countries alike, also come on strategic plans focusing on the transition of energy utilization from barbaric, extensive use to diversified exploitation and international supply. Germany, suffered from bi-directional compression of reindustrialization and manufacturing transition, raises industrial strategy 4.0 (Posada et al. 2015), namely intelligent production based on information physical system, to strengthen international competitiveness of manufacturing industry. UK got great

J. Luo · Y. Wu (✉)
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

J. Luo
e-mail: luojiaojiao@zju.edu.cn

X. Zhang
Department of Public Policy, City University of Hong Kong, Kowloon Tong
Hong Kong, China
e-mail: xiaoling.zhang@cityu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_96

hurt in domestic economy and manufacturing during financial crisis in 2008, later government issued "The UK low carbon transition plan: national strategy for climate & energy", "The UK renewable energy strategy" and "National infrastructure plan" (Longo et al. 2008). All these files are committed to build new economic growth point through low carbon and digital strategy. In other words, authorities hold the sincere wish on upgrading traditional industries by means of low-carbon and high-tech. In the trend of global energy technology innovation, industrial revolution with the feature of green, smart and sustainable will certainly turn into another worldwide revolution, following the first, the second industrial revolution.

As for China, its original energy policy gave priority to extensive supply for the main goal at that time was economic growth. Early industrial expansion was incidental to the increasing scale costs, namely additional units of output need more raw materials. At this point, the State decides to increase energy supply to meet fast-growing demand for resource. Since around the middle and late period of industrialization, government began to pay highly attention on environmental issues and energy security issues brought by excessive power consumption. As is known to all, industrial land has become an important carrier for economic development. Reasonable industrial structure and location can save urban land effectively and reduce the cost of land as well as environmental governance. However, Chinese extensive industrial land use pattern leads to severe ecological problems during land use process, like stubbornly high proportion of industrial land to urban construction land always limits ecological land boost. In addition, productive pollution caused by industrial land has had a serious impact on urban ecological environment and residents' health. Therefore, considering dual pressures from both domestic and foreign countries, unstainable industrial land use pattern and full swing of energy transformation, it is imperative that China ought to find a way to launch paradigm shift towards green industry restructuring.

This study explores the paradigm shift towards Chinese green industrial restructuring. In so doing, the paper not only contributes to the prevalent reindustrialization literature, it also responds to ponder over the ways and means for industrial transformation, which are based on a review/assessment of domestic industrial land policy. This article is organized as follows: in Sect. 96.2, we discuss recent development state of industrial revolution and introduce Chinese industrial land policy development history in Sect. 96.3. We then discuss micro dilemmas during industrial land use process (Sect. 96.4). Section 96.5 presents the article with three consideration suggestions for future green industrial restructuring of China and Sect. 96.6 concludes.

96.2 Literature Review

The relationship between energy system and social spatial organization is filled with complexity, dynamics and not yet fully understood, but in outline its main features are clear that the availability of energy resources has always influenced economic environment (Owens 1990). Likewise, related industrial land debate raised two central issues about economic change, including older industries tend to show a retardation in output and employment growth and industry aging erodes national competitiveness (Norton 1986). The decline of many industrial agglomeration in Western countries could be observed as they were confronted with severe competition (Boschma and Lambooy 1999) due to the poor ability to upgrade and innovate. Innovation both in the creation of new technology, land use allocation, environment governance, and industrial land policy is of great importance in the increasing competitive global markets. For many firms, the shift to proactive environmental management, or rather the shift towards green industry is driven by pressures from governments, customers, employees, and competitors (Berry and Rondinelli 1998). Recent years, some scholars concentrate on digging out whether it is worthy to upgrade industrial pattern into green industries and green goods innovation. Shapira et al. (2014) put forward using search term combination and text mining to discern green goods sector companies and King and Lenox (2001) use longitudinal data and statistical methods which reduce the potential for unobserved differences among firms to support "pays to be green" hypothesis.

National studies on green industrial restructuring are still at an early stage. It happens that there is a similar case that the relevant research often combines environment with energy and land use. Some focus more on the relationship between land use and carbon footprint. For example, Han et al. (2012) utilize actual land use change and land net primary productivity to improve footprint accounting method and apply to the research on mutual relationship between energy and economic development. Zhao and Huang (2010) set up energy consumption model for the sake of doing various land use pattern carbon emissions quantitative analysis. You et al. (2010) attempt to seek for new path to achieve low-carbon and measures relevancy degree of land use structure and carbon emissions. Other scholars are inclined to study from the perspective of land use ecological environment. Regional land use is strongly linked to environmental pollution. Low urban land use efficiency, grievous contradiction between land supply and demand, together with something alike, really aggravate pollution and traffic congestion phenomenon (He and Fu 2008; Zhao and Pu 2006). Of course, intensive land use also is written topic because it is the key element during environment-friendly and resource-saving society construction (Wang 2006; Cao 2005). In general, although specific idea varies, all literatures affirm the importance of sustainable development and energy revolution directly or indirectly. But, how to realize future green industrial transformation in China has not been interpreted in detail. The paper tries to put forward some reasonable advice on paradigm shift towards green reconstruction on the basic of thorough analyzing on Chinese industrial land policy.

96.3 Introduction on Industrial Park Policy

Industrial park refers to a certain scope of the land which is designated with exclusive use of industrial facilities. Generally, its establishment is to promote local economic development. China's industrial park history has gone through three stages.

Preparatory stage: 1983–1991. In the mid-1980s, Shenzhen took the lead in the decision of "implementing an open policy, establishing special economic zones". Subsequently, nation proposed related documents and gradually set up economic and technological development zone plans. At that time, the basis of industrial park was so weak that most of them were away from mother town and lack of primary production condition, nor could they obtain positive effects of industrial foundation in the mother town.

Boom growth stage: 1992–2002. In 1992, China formally entered the stage named market economy. A nationwide industrial park construction spring up, especially in coastal areas. Many well-known companies rushed into industrial park and brought advanced technology as well as massive funds.

Consolidation and redevelopment stage: 2003–now. Since 2003, government has realized that industrial development occupied plenty of land resource. Problems such as dispersed industrial land park, extensive land use, and resources waste always exists. Thus, the State Council carried out "deepening the reform of strict land management decision" which stipulates no industrial park is allowed to build if goes against land use planning and urban master planning (Gao et al. 2013).

96.4 Macro Dilemmas of Industrial Land Use: Industrial Park

96.4.1 Wantonly Spread of Industrial Park Construction

According to the statistical data, there only has 18 industrial parks, including Ningbo economic and technological development zone (ETDZ), Qinhuangdao ETDZ, Qingdao ETDZ, and so on (see Table 96.1) before 1992 when the central government hasn't established special economic zones and open coastal cities. Clustered together in coastal areas, ETDZs always belong to specific areas for industries, especially knowledge-and technology-intensive industries. Then, during the boom growth stage of industrial park, a nationwide industrial park construction was spread and even more than 200 national-level parks sprung up in just ten years while the total of all parks up to 6024. Industrial park consolidation activity was carried out in 2003, covering 35,400 km^2. Totally 2046 parks were withdrawing and merging. In accordance with Chinese urban planning, take per capita land area 100 m^2 to be standard, 10,000 km^2 can accommodate 100 million people, thus the inventory acreages of development zone equals to the size of built-up areas for urban population in 2003 was 340 million.

However, the new round land use planning shows neither developed regions nor developing regions perform well in quitting industrial park construction. For example, Ningbo (see Fig. 96.1), a city in Zhejiang Province, is basking in an economic boom and holds strong purchasing power. In 2003, there is only one industrial park located in Zhenhai district, Ningbo city, named Zhenhai economic development zone with 746.9 ha planning area. Whereas, new round land use planning (2006–2020) adds two new economic development zones in the corner of northeast and southwest, Ningbo chemical industry with 1700 ha planning area and Ningbo mechanical-electrical industrial park with 1200 ha planning area, respectively. Obviously, government in developed regions still maintains a certain industrial scale increase and take park construction to be active force to attract capital. At the same time, such situation at developing regions is more alarming. On the one hand, developing areas, generally speaking, have a strong appeal to the industrial enterprise because they are relatively rich in natural resources and material, labor supply exceeds demand while in addition, the cost is relatively low. On the other hand, less developed areas need industrial parks to advance regional economic development since their economic output is comparatively small as well as industrial scale. Figure 96.2 presents an undeveloped counties' area planning during 2006–2020 in Zhejiang Province, which the yellow area means reserved region for basic farmland, the blue stands for areas used for basic farmland transferring in and the red denotes areas used for basic farmland transferring out. We can see from the figure that in this county, a number of basic farmland is programmed to

Table 96.1 The list of 18 industrial parks constructed before 1992

Industrial parks	The time of project construction
Ningbo ETDZ	1984.10
Qinhuangdao ETDZ	1984.10
Qingdao ETDZ	1984.10
Yantai ETDZ	1984.10
Zhanjiang ETDZ	1984.11
Guangzhou ETDZ	1984.12
Lianyungang ETDZ	1984.12
Nantong ETDZ	1984.12
Tianjin ETDZ	1984.12
Fuzhou ETDZ	1985.01
Hongqiao ETDZ	1986.08
Minxing ETDZ	1986.08
Caohejing ETDZ	1988.06
HCTIZ	1989.05
Shanghaijinqiao EPZ	1990
Hainanpuyang ETDZ	1992.03
Wenzhou ETDZ	1992.03

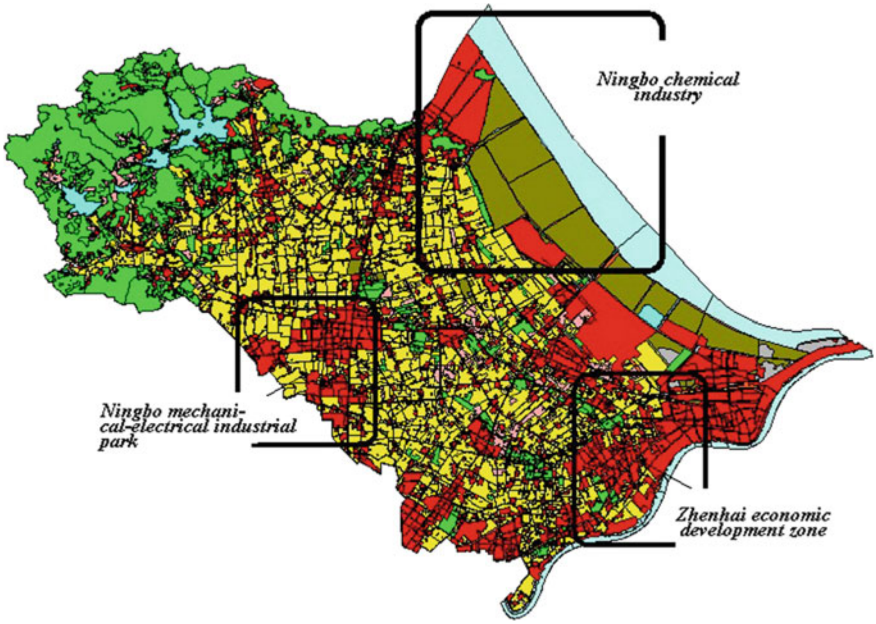


Fig. 96.1 Land use planning in Ningbo

be transferred out and the total areas is larger than original construction region (reddish-brown areas in the southwest in figure). It is thus fairly easy to infer developing districts authorities get ready for bringing in industry on account of mass arable land transferred into construction land. But, can it profit less developed districts? Probably not. Economy in such areas is in a imitate stage, meaning that market economic system is imperfect and lack of technical support. Therefore, it is a wrong choose for government begins large-scale industrial park construction while the outcome will exhibit asset inefficiency as well as resource waste.

96.4.2 Energy Consumption in Industrial Land Use

In 20 years of accelerated industrialization, China's position in the international trade market has risen steadily to become an industry trade power in the supply of primary and labor-intensive products (Yang 2008). Total global GDP in 2004 is \$77.3 trillion, including 10.39 of China, occupying 13.4% of global share. Of course, community gratifies GDP high growth, but how much have the society paid for such achievement. No one can deny that the fact that GDP growth is often accompanied by environmental pollution and energy consumption. Digitized boom tends to mask resources waste and environmental degradation problem, which is identified as stumbling block to sustainable development.

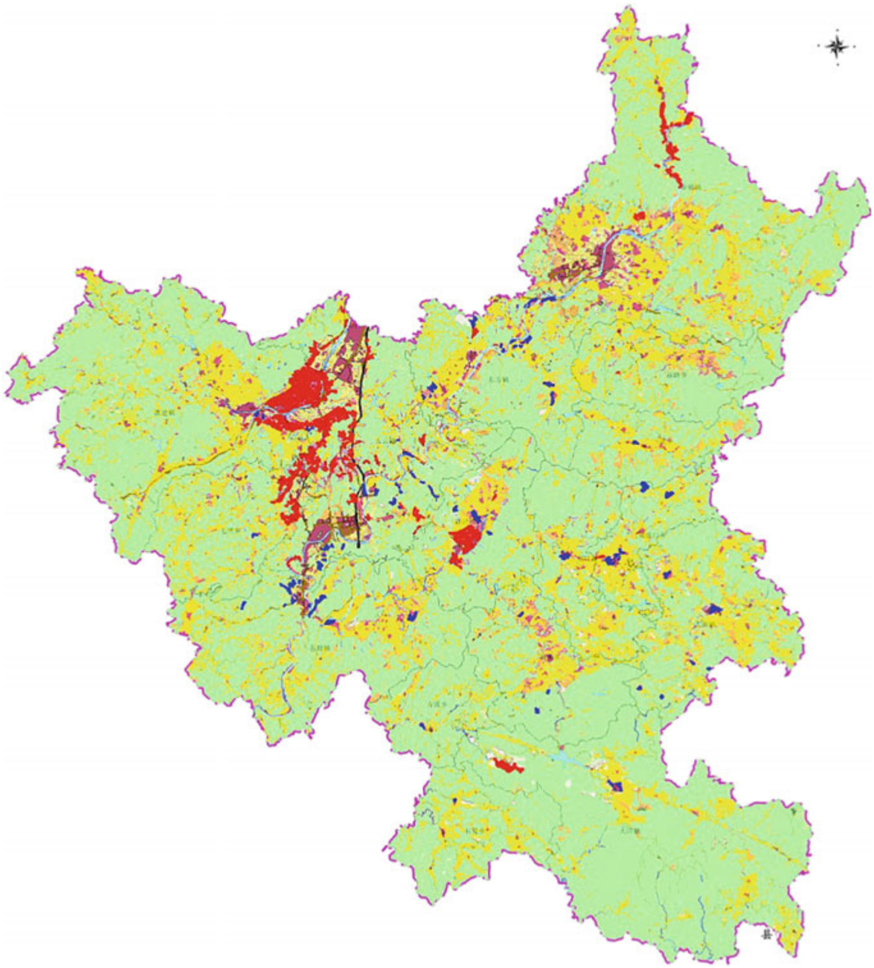


Fig. 96.2 Land use planning in a developing region

Since 1978, China's entire energy consumption has always been on the rise, especially in the new century, energy consumption growth rate soars and the standard coal consumption comes to surpass 3 billion tons in 2010. Recent data shows, in 2014, China produces 2476 billion tons cement, 60% of world production; 822.7 million tons steel, 50% of world production; 3.87 billion tons of coal, 50% of world production. As for energy consumption, China has consumed 6.6 billion tons of cement from 2011 to 2013, just three years, more than that in United States expended throughout the 20th century. What's worse? The U.S. constructed skyscrapers, interstate, Hoover Dam, and so on during 1901–2000 while the cement consumption is only 4.5 billion tons. Apparently, China is required to improve efficiency in the use of material. Based on statistics, most domestic depletion of resources are project construction, in which industrial energy consumption accounted for about 70%.

96.4.3 Environmental Press Appeals to Green Industry Restructuring

The correct use of industry restructuring can promote sustainable development to realize green society so that community goals of credibility, environmental quality and equity are attained most efficiently. Exact pressure put on restructuring comes from both internal and external, that is cost of environmental degradation and carbon tariffs covered in American Clean Energy and Security Act (ACELA) respectively.

Cost of environmental degradation refers to the price resulting from utilizing environmental service during economic process (Guo and Fan 2007), or we can say it is the part that natural assets liquidated as economic assets so as to provide support for economic behavior with a loss in natural resources as well as environment. China has leaped to first place in the world for its 9% proportion that environmental degradation and energy cost occupy among GDP. India locates in second place by a tiny margin while the values in developed countries like Japan, Korea, and Germany are no more than 1%, even the proportion in America also are less than 3% (Bank 2010). Regions in Midwest China lacks in advanced technology and industrial development pattern there is relatively backward. Moreover, per unit output causes more pollution emission than the east coast. But now, more industrial enterprises move from east to west which means large numbers of pollution will spread to the Midwest. This is a bad phenomenon because Midwest regions situate in the upstream, thus pollution can easily diffuse to the east through water migration.

As for external pressure, United States House of Representatives passed ACELA in 2009. The bill proposed a cap and trade system, under which the government would set a limit (cap) on the total amount of greenhouse gases that can be emitted nationally. Companies then buy or sell permits to emit these gases, primarily carbon dioxide CO_2. Carbon tariff levied major focus on developing countries which are undergoing rapid urbanization, including China. World Bank ever estimated that China could face an average tariff of 26% and exports is expected to drop by 21% if carbon tariff is fully implemented.

Danger of internal and external pressures tell us that blindly pursuing economic growth will not only lead to the exhaustion of natural resources, but also could result in ecological crisis. Therefore, vigorously develop green economy requires industry restructuring.

96.5 Paradigm Shift Towards Green Industry Restructuring

Population and economy are considered to be two major factors that affect energy. According to "UN world population prospects: The 2012 revision", population growth will occur mainly in Africa in next 30 years, India goes to overtake China as the world's most populous nation in the year 2028 and China's population reaches its peak in 2030, then gradually declines. Prospects further points out that in 2030, China is expected to add 310 million urban residents and achieve 70% urbanization rate. By then, total urban population in nation will exceed 1 billion. As for economy, generally speaking, when a country's urbanization rate is between 30 and 70%, we call it is in the accelerating urbanization period and society at that time needs more resources, populations, and capital transfer as material support (Liu et al. 2005). Until 2030, the stage of rapid development of urbanization in China is coming to an end and stable development period will turn up. It is absolutely not sustainable development to achieve economic prosperity at the expense of the natural environment. In this way, China should be sensitive to national situation and hold a clear understand of industry restructuring to deepening industry green reform and push sustainable development to a new stage since Chinese traditional economic boom mode takes up quantities of natural resource.

96.5.1 Energy Structure Change

Countries' energy consumption is composed of multiple energy. What we call energy structure refers to the proportion that various energy, like coal, oil, natural gas, and solar energy, accounts for of total energy. In accordance with BP world energy statistical data, China has hit a record of 14 years' consecutive growth in energy consumption and in 2014, its primary energy consumption reaches 2972.1 million tons, ranking first in the world energy growth market with 2.6% amplification. However, energy consumption structure in China is extremely unreasonable, for instance, in 2014, world's average coal share of primary energy consumption downs to 30% while China coal consumption is 1962.4 ton with 66%. Figure 96.3 records all energy consumption and coal proportion since 1978, among which yellow line means the data collected from 2011 statistical yearbook and red line stands for the data gathered from 2014 statistical yearbook. The data during 1978–1999 are completely coincide in both yellow line and red line, but when goes into new century, two lines appears different trend. Specifically, yellow line indicates the value that coal consumption in primary consumption maintains at a stable level of 70%, while the red line show constantly decline of that value and by 2013, the proportion of coal is below 60%. Considering world energy statistical data, the paper finds yellow line would be better to reflect China's energy consumption structure reality.

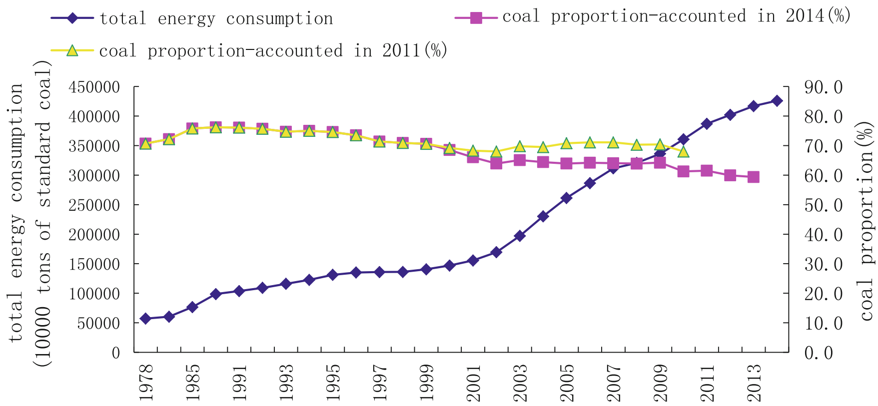


Fig. 96.3 Total energy consumption and coal proportion in China

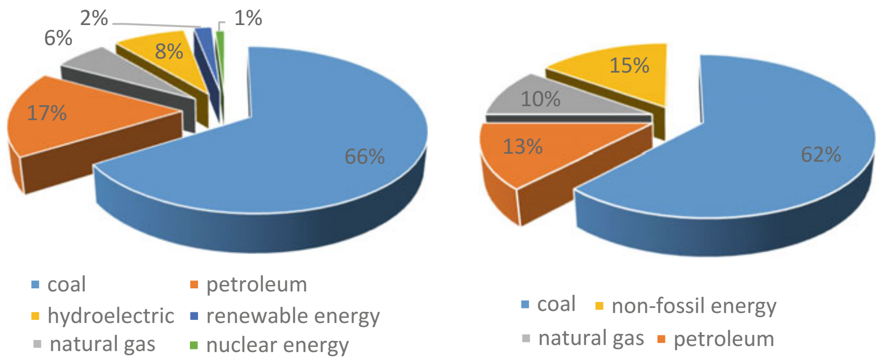


Fig. 96.4 Ratio on different types of primary energy consumption in 2014, 2020

In the world, energy optimization always focus on three major fields, namely reducing coal consumption proportion, improving coal conversion capabilities and perfecting terminal energy-use. Energy development strategic action planning was come out by government in 2014, which proposes energy security system will be formed by 2020, controlling coal consumption to 62%, increasing gas share to 10%, enhancing non-fossil energy proportion to 15% (Fig. 96.4). Given the truth that in 2014, coal consumption accounts for 66% with only 2% fell in 4 years, more rigorous control must be done to realize the target of 62% in 2020.

96.5.2 Local Financial Revenue Mechanism Reform

Although mass industrial park construction cannot bring considerable land transfer fee in the short term, it is able to create a long-term stable tax revenues (sales tax and corporate income tax), thus governments enjoy selling industrial land at a low price to attract industrial enterprise. Cheap industrial land sales behavior shift financial pressure to housing market. In other words, local governments have to raise commercial and residential land price to make up for financial losses of industrial land so that they can achieve win-win target of economic growth and fiscal revenue.

In that way, how to persuade local government to give up “low, small, scatter, chaotic” industrial park construction and move to green industry restructuring when in the repressive atmosphere of sustainable development? How to realize robust revenues without industrial park? The paper endorses levying “property tax”, a local government stable income source, can provide financial support for sustainable urbanization. Also, in most developed countries, property tax is usually based on actual sale prices and commodity market price assessment, especially in the United States and Europe where land and property tax is a cornerstone of city revenue. Of course, for better property tax implementation, authorities should start this policy from ones who possess high-end property firstly while stabilizing housing price by means of media so as to curb speculative excesses.

96.6 Conclusion

The paper reviews industrial park policy evolution from the 1980s and analyzes dilemmas of industrial land as well as industrial park construction firstly. Combining the phenomena of wantonly spread industrial park, mass energy consumption, and environment stress, recommendations from the perspective of energy structure and local financial revenue are present for green transformation. Main conclusions are as follows:

(1) Chinese industrial park policy has undergone several changes since 1980s, and government gradually addict to park construction for the aim of attracting foreign businesses and investment, especially at the time after 1992 when China moves into market economy.
(2) More than 20 years’ reform and opening up doesn’t turn down the heat of industrial park construction, nowadays issues including wantonly spread of industrial park construction, unhealthy competition among zones, ow input and output rate, and unreasonable planning layout have become more serious, even can be described as the impediments to social sustainable development.

(3) In the trend of global energy technology innovation, industrial revolution with the feature of green, smart and sustainable will certainly turn into another worldwide revolution, following the first, the second industrial revolution. The paper recommends governments to make some reform in energy structure and local financial revenue mechanism. In practical terms, these means authorities can devote to reduce coal consumption proportion and promote clean energy while turn present tax pattern into a new pattern focusing on property tax.

Acknowledgements The authors appreciate the kind financial support from the Fundamental Research Funds for the Central Universities and the National Natural Science Foundation of China (Grant No. 71373231).

References

Bank W (2010) World development indicators. World Bank
Berry MA, Rondinelli DA (1998) Proactive corporate environmental management: a new industrial revolution. Acad Manag Exec 12(2):38–50
Boschma R, Lambooy J (1999) The prospects of an adjustment policy based on collective learning in old industrial regions. GeoJournal 49(4):391–399
Cao J (2005) The basic ideas of land intensive and economical use in China. China Land 10:19–21
Gao W, Ma K, Liu H (2013) Policy evolution of the economical and intensive utilization of industrial land in china since 1978. China Land Sci 10:37–43
Guo H, Fan F (2007) Research on accounting environmental costs of green GDP. Econ Probl 7:50–52
Han Z, Meng Y, Liu L, Liu L, Zhou Z (2012) Modified method of energy carbon footprint and application based on regional land use change. Trans Chin Soc Agric Eng 28(9):190–195
He Y, Fu B (2008) Effects of land use changes on the environment in Yuxi city. Res Soil Water Conserv 15(4):200–203
King AA, Lenox MJ (2001) Does it really pay to be green? An empirical study of firm environmental and financial performance: an empirical study of firm environmental and financial performance. J Ind Ecol 5(1):105–116
Liu Y, Li R, Song X (2005) Analysis of coupling degrees of urbanization and ecological environment in China. J Nat Resour 20(1):105–112
Longo A, Markandya A, Petrucci M (2008) The internalization of externalities in the production of electricity: willingness to pay for the attributes of a policy for renewable energy. Ecol Econ 67 (1):140–152
Norton RD (1986) Industrial policy and American renewal. J Econ Lit 24(1):1–40
Owens SE (1990) Land use planning for energy efficiency. Transaction Publishers, New Brunswick, NJ, USA
Posada J, Toro C, Barandiaran I, Oyarzun D, Stricker D, De Amicis R … Vallarino I (2015) Visual computing as a key enabling technology for industrie 4.0 and industrial internet. Comput Graph Appl IEEE 35(2):26–40
Shapira P, Gök A, Klochikhin E, Sensier M (2014) Probing “green” industry enterprises in the UK: a new identification approach. Technol Forecast Soc Chang 85:93–104
Wang Y (2006) Study on indictors for the assessment of land saving and intensive use. China Land Sci 20(3):24–31

Yang D (2008) International influences of China's becoming "World Factory". China Ind Econ (9):42–49
You H, Wu C, Shen P (2010) Correlation degree measurement and characteristic explanation between land use structure and carbon emission from energy consumption. China Land Sci 24 (11):4–9
Zhao L (2015) The experience and enlightenment of USA and Japanese industrial transformation and upgrading. Rev Ind Econ 1:100–104
Zhao R, Huang X (2010) Carbon emission and carbon footprint of different land use types based on energy consumption of Jiangsu Province. Geogr Res 29(9):1639–1649
Zhao C, Pu L (2006) Issue in land use during urbanization-A case study in Jiangsu Province. Resour Environ Yangtze Basin 15(2):169–173

Chapter 97
Pilot Case Study of New Engineering Contracts (NECs) in Hong Kong—Joy or Tears?

D.W.M. Chan and J.H.L. Chan

97.1 Introduction

Procurement and contracting strategies are crucial to the success of every construction project as they establish the basis for co-operation between the client and the contractor. Nevertheless, due to the increasing complexity and uncertainty of projects nowadays, high level of co-ordination and co-operation amongst project participants is required (Pesamaa et al. 2009). The conventional project delivery approaches have attracted numerous criticisms for causing disputes and adversarial working relationships, which in turn lead to time and cost overruns and poor quality of work. Novel contracting strategies have therefore emerged worldwide to facilitate proactive problem solving, to establish common goals of various contracting parties and to encourage greater collaboration between the contracting parties (Construction Industry Review Committee 2001). In recent years, a multitude of employers have selected NEC3 (New Engineering Contract Version 3) ECC (Engineering and Construction Contract) which is specially designed for partnering or collaborative working, and positive responses have been reported by early users (e.g. Wright and Fergusson 2009; Bryant 2012; Chan et al. 2014; NEC Users' Group 2015).

NEC3 ECC has gained wide popularity within the construction industry of the United Kingdom over the past two decades with its intended purpose of achieving more favourable project outcomes. It is now in use in over 20 countries and regions

D.W.M. Chan (✉)
Department of Building and Real Estate, The Hong Kong Polytechnic University,
Hung Hom, Kowloon, Hong Kong
e-mail: daniel.w.m.chan@polyu.edu.hk

J.H.L. Chan
School of Professional Education and Executive Development (SPEED),
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
e-mail: hljchan@speed-polyu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_97

including the United Kingdom, France, the Netherlands, Sweden, New Zealand, Australia, South Africa, United Arab Emirates, India and the Philippines (Chan et al. 2014). As a result of the lessons learned from these successful cases overseas, the relevant works departments under the Development Bureau of the Hong Kong Special Administrative Region (SAR) Government have adopted NEC3 for a series of over 30 “pilot/trial” construction projects since August 2009 to test its applicability and to encourage more collaboration from the different contracting parties within the project team. An extensive desktop literature review has revealed that although the perceived benefits (Wright and Fergusson 2009), key operational principles (Broome 2012), and perceptions towards NEC3 (Sun and Oza 2006), have been documented in previous literature, yet there is a scarity of research publications about the application of NEC3 ECC in the East. This paper serves as an attempt to report on the project performance of the first trial of NEC3 ECC in Hong Kong.

97.2 Overview of New Engineering Contract Version 3 (NEC3)

The New Engineering Contract (NEC) is a modern family of standard contracts which facilitates the implementation of sound project management principles and practices based on a spirit of mutual trust and co-operation, which also defines the legal relationships between different contracting parties (NEC 2005). The third version of NEC (i.e. NEC3) was published in June 2005, and the Engineering and Construction Contract (ECC) is the main contract for a typical construction project between an employer and a contractor. According to Broome (2012) and Wright and Fergusson (2009), there are 23 interlocking contract documents and guidance books in addition to the third edition of ECC including:

- Engineering and Construction Contract (between an Employer and a Contractor)
- Engineering and Construction Subcontract (between a Contractor and a Subcontractor)
- Professional Services Contract (between an Employer or a Contractor and a Consultant)
- Adjudicator’s Contract (between two contracting parties and an Adjudicator)
- Engineering and Construction Short Contract (for “simple” work)
- Engineering and Construction Short Subcontract (for use with the ECC or EC Short Contract)
- Term Services Contract (where the contract is for a period of time rather than a single project)
- Framework Contract
- Guidance Notes and Procurement and Contract Strategies Guide (including flowcharts).

Amongst the contracts listed above, NEC3 ECC (i.e. the main contract) has captured much attention of researchers worldwide in recent years. Sun and Oza (2006) surveyed 85 clients, contractors and consultants based in the United Kingdom, of which 97% had used the NEC ECC contracts, and 88% of all parties rated the contract as excellent or good. Wright and Fergusson (2009), via a case study in New Zealand, found that NEC3 ECC provides a structured project management framework, flexibility in terms and conditions of contract, well-defined contractual procedures, clear plain language, together with a proactive and forward looking environment.

Lord et al. (2008) compared the development of construction contracts in Mainland China and the United Kingdom. They opined that relational contracting (NEC being one of the standard forms used in this field) could be effective in the construction market, provided that appropriate counter-measures are adopted to eliminate the obstacles of such form of contracting.

Heaphy (2013) drew a comprehensive comparison between two popular international construction contracts namely NEC3 ECC and FIDIC. He was of the view that both forms of contract are designed to be used for all kinds of construction works on an international basis. NEC3 ECC attempts to encourage collaborative behaviours, proactive risk management and good project management. Employers are advised when making decision on whether to adopt NEC3 ECC or FIDIC to decide how much they want to operate the contract and approach they wish to take in engaging the supply chain in the projects concerned.

Mickovski et al. (2013) reported on a case study of infrastructure project in Scotland procured with NEC3 ECC Option A (Priced Contract with Activity Schedule). Their study reflected that all parties to the contract have to be motivated and engaged in identifying opportunities for value engineering and sustainability benefits in order to achieve the overall goals of the project. Rooney and Allan (2013) advocated that those highways projects procured with NEC3 ECC performed better than those with the Institution of Civil Engineers (ICE) Standard Form of Contract located in the United Kingdom in terms of time and cost predictability. Judging from a desktop review of previous research studies, most of them put emphasis on the application of NEC3 ECC in the West, not much has been done in analysis of cases in the East, especially in the Hong Kong context. This finding from literature review further reinforces the aim of this study (i.e. to report on a case study in Hong Kong and serve as a foundation for further research in NEC3 ECC in Hong Kong).

97.3 Case Study Methodology

Case study is considered as a research method in which one case will be scrutinized in depth, adopting whatever methods are deemed suitable. The main thrust is to establish a full understanding of that case as far as possible (Silverman 2005). The purpose of carrying out a case study is to explore the particularity and the uniqueness of a single case (Simons 2009). This research method is particularly relevant to the construction industry which is project driven and made up with many different kinds of organizations (e.g. employers, main contractors, consultants, subcontractors, etc.). Fellows and Liu (2015) considered that case study is a research method used to investigate experimental theory or topics using set procedures, usually with different combinations of data collection (e.g. interview and documentary analysis) where the emphasis is towards exploring a phenomenon within a context. Yin (2009) also concurred "case study" as an empirical inquiry which probes a contemporary phenomenon and context that are not clearly evident and comprises a bundle of sources of evidence. Case study is an appropriate research method in this study as this should be used for studying new phenomena where quantitative research methodologies are not possible or appropriate.

Qualitative information was derived from relevant archives through documentary analysis, participants' observations in regular project meetings and partnering workshops, and in-depth interviews which are considered to be typical and effective ways in case study research (Eisenhardt 1989; Yin 2009). The personal observations and recommendations of the NEC advisors were included as well in this study to offer important insights and valuable lessons learned for further improvement of contract administration of future similar NEC3 cases in Hong Kong. In addition, the various key performance data of the case study were measured and analyzed throughout the course of the project.

97.4 Highlights of Case Study Project

The name of the case study project is the "Improvement of Fuk Man Road Nullah Project in Sai Kung" with the Employer being the Drainage Services Department (DSD) of the Hong Kong SAR Government, the Project Manager being the Chief Engineer (Drainage Projects) from DSD, the Supervisor being Black & Veatch, the Contractor being Chun Wo Construction & Engineering Company Limited, together with the NEC Advisor and Partnering Workshop Facilitator (JCP Consultancy International Limited). It was the first Hong Kong SAR Government's pilot project to try out the New Engineering Contract (NEC) to foster a partnering and collaborative working relationship between the employer and the contractor, and the form of main contract chosen was the Engineering and Construction Contract (ECC) Option C: Target Cost with Activity Schedule. Figure 97.1 indicates the scope of works for the case study project. The scope of works included the decking over an existing about 180 m long and 12 m wide open nullah at Fuk Man Road in Sai Kung, constructing a 4000 m^2 urban park over the top and upgrading an adjacent roundabout improvement works (Chan et al. 2014). The construction work commenced in August 2009 and was completed in May 2012 at a final project cost of about HK$72.9 million.

Fig. 97.1 Outline scope of works for the NEC pilot case study project

97.5 Final Out-Turn Performance of Case Study Project

A first partnering workshop was organized for the representatives of the Employer, Project Manager, Supervisor and Main Contractor to get familiar with the contractual procedures and key features of NEC3 ECC. In the same workshop, they developed a set of mutually agreed project objectives and target project outcomes. All of them agreed on how they needed to work together in order to achieve these stated common objectives and expected outcomes upon project completion. The project team including the representatives from the client (government) departments, the consultant team and the main contractor jointly established a set of five Key Performance Indicators (KPIs) for measuring these objectives throughout the construction stage of the case study which is the first NEC3 construction project in Hong Kong.

With reference to Table 97.1, the overall performance of the case project is satisfactory since the final out-turn performance could meet or even exceed the target outcomes. As Takim and Akintoye (2002) suggested, user satisfaction is one of the important performance indicators for effectiveness of a project. It is also incorporated in the web-based construction project performance monitoring system proposed by Cheung et al. (2004). Under the performance measure of user satisfactions, the two client departments (i.e. the Leisure and Cultural Services Department and the Drainage Services Department) jointly rated 8 out of 10 marks.

Table 97.1 Final out-turn performance of the case study project

Key performance indicator	Final out-turn performance	Target outcome	Final out-turn performance exceeds/matches with target outcomes?
1. User satisfactions	➢ 8 out of 10 by the Leisure and Cultural Services Department (LCSD) and the Drainage Services Department (DSD) ➢ 8 letters of commendation received	➢ 7 out of 10(Note: Score in range of 1–10, where 1 = totally dissatisfactory and 10 = totally satisfactory)	➢ Yes
2. Time performance	➢ Completed in 141 weeks against an extended contract period of 165 weeks (i.e. completed ahead of schedule by 24 weeks or 6 months)	➢ 24 weeks of early completion (i.e. completed ahead of schedule by 14.5% or 6 months)	➢ Yes
3. Cost performance	➢ Agreed final target cost of HK$76.7 million less actual project cost of HK $72.9 million at completion = gain share of HK$3.8 million (i.e. actual project cost reduced by HK$3.8 million equivalent to about 4.95% of cost saving from the agreed final target cost)	➢ 5% of cost saving for gain share between the employer and the contractor	➢ Yes
4. Quality performance	➢ Minor defects found on non-critical items. Handover to LCSD within 10 days of completion of works	➢ No major rework required	➢ Yes
5. Safety and environmental performance	➢ No recorded incidents of safety or environmental infringements, and 4 valid public complaints ➢ 3 industry safety awards obtained	➢ Zero reportable site accident	➢ Yes

This finding has evidently manifested the overall project performance to be outstanding. Perhaps, the performance of the project under other performance measures may generate more evidences to support this notion.

The project was delivered in 141 weeks against an extended contract period of 165 weeks (i.e. completed ahead of schedule by 24 weeks or 6 months). It outperformed amongst many other completed construction projects in Hong Kong against the measure of time performance. When compared with other construction projects, for example, Chan et al. (2010) reported that the modification and extension works of an underground railway station project procured by the target cost contracting model was successfully completed by 7 months earlier than the contract completion date conducive to a time saving of about 20%. Thus, the case project reported herein is adjudicated as satisfactory in respect of time performance.

Cost performance is perceived to be the most important success factor in the projects procured by target cost contracts that Hughes et al. (2012) advocated. The case project was completed with a cost saving of HK$3.8 million which is equivalent to about 4.95% of the agreed final target cost, in comparison with the modification and extension works of an underground railway station project procured by the target cost contracting model mentioned above with 5% cost saving upon completion (Chan et al. 2010). It can be concluded that cost performance is generally favourable due to cost saving behind.

Pertaining to quality performance, which is a significant aspect of performance indicator for construction projects in general (Cheung et al. 2004), the project team targeted at project commencement that there would be no major rework. This target was finally accomplished as there were only minor defects identified on non-critical items. Moreover, the whole completed project was transferred to the end-user client department (i.e. Leisure and Cultural Services Department) within 10 days of completion of works.

In terms of safety and environmental performance, the project also met the target outcome agreed at the start of the project and no reportable site accidents were recorded during construction. What's more, three industry safety awards were received as a result of the outstanding safety management of the project team.

Early settlement of final project account was also achieved with 80% of the compensation events (CEs) agreed at project completion in May 2012, and 100% agreed at end of November 2012. With the early warning mechanism in place under NEC3, a total of 15 early warnings were issued and the unexpected issues were resolved jointly and promptly via the partnering teamwork approach.

97.6 Conclusions

Construction employers are recommended to adopt the target cost contracting method which ties the individual objectives of the employer and the contractor together with the purpose of establishing some common goals or objectives for a project and improving the traditional confrontational working atmosphere within the project team. However, the application of this alternative integrated form of contractual arrangement is rather new and remains at a infant stage of development in Hong Kong. This paper has reported on the first trial case of applying NEC3 ECC (Option C: Target Cost with Activity Schedule) in Hong Kong. The actual out-turn performance of this pilot case was found satisfactory as a whole when compared with the target outcomes jointly developed by the representatives of different contracting parties during the first partnering workshop. Under the effective operational mechanism of NEC3 by the project team members, the project was completed with high user satisfactions, ahead of schedule, with cost saving, no major rework, no recordable site accidents, and several industry safety awards conferred. While a basket of pilot projects are still on-going in town, it may be premature to conclude that the application of NEC3 ECC is successful in Hong Kong. Nevertheless, this paper has served as a stepping stone for further study and comparison of project performance of NEC3 ECC in both local and international contexts.

Acknowledgements The authors wishes to extend their heartfelt thanks to the key project stakeholders and interviewees who have kindly participated in the interviews and provided their valuable feedback and required project information to document this pilot case study. Part of the contents included in this paper was extracted from another published journal article by the same authors, Chan et al. (2014).

References

Broome J (2012) NEC3: a user's guide. ICE Publishing Limited, London

Bryant M (2012) London 2012 Olympic Park delivered on time and within budget using NEC3 contracts. NEC Users' Group Newsletter, UK, Issue No. 58, London 2012 Special Issue, Apr, p 1

Chan DWM, Lam PTI, Chan APC, Wong JMW (2010) Achieving better performance through target cost contracts—the tale of an underground railway station modification project. Facilities Spec Issue Perform Meas Manage Facilities Manage 28(5/6):261–277

Chan JHL, Chan DWM, Clifford B (2014) New Engineering Contracts (NECs) in practice—empirical evidence from a pilot case study in Hong Kong. Constr Law J 30(4):217–235

Cheung SO, Suen HCH, Wong KKW (2004) PPMS: a web-based construction project performance monitoring system. Autom Constr 13(3):361–376

Construction Industry Review Committee (2001) Construct for excellence. Report of the Construction Industry Review Committee, Hong Kong Special Administrative Region, Jan, 207 p

Eisenhardt KM (1989) Building theories from case study research. Acad Manag Rev 14(4): 532–550

Fellows R, Liu A. (2015) Research methods for construction, 4th edn. Wiley

Heaphy I (2013) NEC versus FIDIC. In: Proceedings of the Institution of Civil Engineers (ICE)—management, procurement and law, vol 166, issues 1, pp 21–30

Hughes D, Trefor W, Ren Z (2012) Is incentivisation significant in ensuring successful partnered projects? Eng Constr Archit Manage 19(3):306–319

Lord WE, Zhang S, Liu A (2008) Towards a modern construction contracts: parallel development in the UK and China. In: Proceedings of the international conference on multi-national

construction projects—securing high performance through cultural awareness and dispute avoidance, 21–23 Nov 2008, Shanghai, China
Mickovski SB, Black JD, Smith MJ (2013) Innovative use of ECC (NEC3) for procurement and management of infrastructure projects with limited funding: Bervie Braes case study. In: Proceedings of the 29th Annual ARCOM conference, 2–4 Sept 2013, University of Reading, UK, 799–808, Association of researchers in construction management
NEC (2005). NEC3 engineering and construction contract. Thomas Telford Publishing Ltd, June, 80 p. ISBN 978-0-7277-3359-7
NEC Users' Group (2015). Mt Mercer wind farm—the first NEC project in Australia. Available from URL: https://www.neccontract.com/NEC-in-Action/Case-Studies/Mt-Mercer-Wind-Farm. Accessed on 26 Feb 2015
Pesamaa O, Eriksson PE, Hair JF (2009) Validating a model of cooperative procurement in the construction industry. Int J Project Manage 27(6):552–559
Rooney P, Allan R (2013) A case study of changing procurement practices on delivery of highways project. In: Proceedings of the 29th annual ARCOM conference, 2–4 Sept 2013, University of Reading, UK, 779–788, Association of researchers in construction management
Silverman D (2005) Doing qualitative research, 2nd edn. Sage Publications, London
Simons H (2009) Case study research in practice. Sage Publications, London
Sun M, Oza T (2006) Collaboration support realises business process benefits for NEC/ECC projects. In: Report of the construction and property research centre. Faculty of the Built Environment, University of the West of England, Bristol, UK
Takim R, Akintoye A (2002) Performance indicators for successful construction project performance In: Proceedings of the 18th annual ARCOM conference, 2–4 Sept 2002, Northumbria University, UK, vol 2, 545–555, Association of researchers in construction management
Wright JN, Fergusson W (2009) Benefits of the NEC ECC form of contract: a New Zealand case study. Int J Project Manage 27(3):243–249
Yin RK (2009) Case study research: design and methods, 4th edn. Sage Publications, London

Chapter 98
Potentials of TDR for Balancing Built Heritage Conservation and Compact Development in Hong Kong

Jun Hou and Edwin H.W. Chan

98.1 Introduction

Due to articulated land shortage, acute topography, increasing population growth, and shortage of time, Hong Kong government and planners have few options left but to adopt vertical development, resulted in a densely and mixed use urban habitat packed with closely built high-rise residences and commercial buildings (Fig. 98.1). In order to in accordance with the requirement of vertical and high density, many old buildings were demolished to make room for new compact development. Built heritage plays an important role in the city as it reflects the history and social changes, becoming a matter of increasing public interest. It provides a deep sense of connection to the past and to lived experiences, and sustains our values and communities and allows us to share a collective history.

In Hong Kong, there were 101 declared monuments, of which 43 were privately owned. The total number of 1444 graded historic buildings, of which 1059 were privately owned. These statistics present that privately owned built heritage plays an important role in Hong Kong. However, with the rapid urban development and increasing growth population, the buildable lands become fewer and fewer, which leads to the city even more dense, and the land price and housing price even much higher. Facing the high maintenance cost of the built heritage and the profit-making pursue, owners are prone to demolish the historic buildings and redeveloped the site. Transfer of development rights (TDR) has been provided as one of the

J. Hou (✉)
Department of Urban and Rural planning, Hefei University of Technology, Hefei, China
e-mail: jun.hou@connect.polyu.hk

E.H.W. Chan
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, China
e-mail: edwin.chan@polyu.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_98

Fig. 98.1 Overview of Hong Kong. *Source* http://image.baidu.com/

economic incentives by Hong Kong government to encourage the private owner to conserve the built heritage since 2008. It is considered as a good method that balancing the conservation and development, which achieves compact development and at the same time conserves the built heritage. The paper aims to explore the potentials of using TDR to preserve built heritage in Hong Kong. The research based on the success framework developed by Chan and Hou (2015) carried out interviews to explore the difficulties and possibilities to implement TDR.

98.2 TDR Mechanism

Transfer development rights (TDR) is a market-based tool to help implementing a jurisdiction's growth policies (McConnell and Walls 2009). TDR uses the "economic engine" of new growth to accommodate pressures for growth and development and at the same time preserve essential resources such as working lands (farms and forests), environmentally sensitive areas, and important features such as land marks, heritage buildings (Pizor 1978). TDR programs allow landowners to sever development rights from properties (Kaplowitz et al. 2008) that communities identified for preservation such as farmland, forest and historic buildings (known as "sending area"), and sell them to purchasers who want to increase the density of development in areas that can accommodate additional growth (known as "receiving area") (Johnson and Madison 1997).

Four fundamental components of TDR are identified, that are: (1) sending area; (2) receiving area; (3) a transfer system which facilitates the valuation and transfer of development potential from one parcel to another; and (4) an overseeing body that develops and maintains the principles of the program and use of the tool" (Greenaway and Good 2008). TDR has been most extensively used in the United States, with about 191 TDR programs, covering over 142,000 ha of farmland, natural areas and open space (McConnell and Walls 2009). Other countries like Australia (Pruetz 2003), Canada (Pruetz 2003), Japan (Spaans et al. 2010), France (Renard 2007), Germany (Henger and Brizer 2010), China (Wang et al. 2010) have also carried out TDR programs. Sheehan (2007) identified five aspects of TDR limitations, including (1) TDR cannot work alone; (2) it is a complicated program need a good deal of research; (3) it is not the right tool for all communities; (4) municipalities do not have the same level of control over as they do with zoning; (5) TDR has not consistently been successful in changing the development patterns in town center.

98.3 Methodology

Ten in-depth interviews were carried out with academic, government committee members and people work in the industry about the problems and difficulties to implement TDR in Hong Kong according to the framework of success factors for built heritage conservation developed by Chan and Hou (2015) (Table 98.1). The questions are categorized into seven groups based on the seven criteria in the framework. In each group, questions are based on each determinants. Questions like "do you think it is feasible for TDR legislation? What are the difficulties? Do you have any suggestions about how to implement TDR legislation?" were designed as open-ended questionnaire.

In addition, three important aspects—social, economic, and environmental of sustainable development theory are used to analyze the contribution of TDR in Hong Kong.

98.4 Contribution of TDR to Sustainable Compact Development in Hong Kong

98.4.1 From the Social Aspect

In Hong Kong, many private property are the residence of the celebrity, which is important to educate the generations and understand the history. However, if the private owner's redevelopment plan does not violate the regulation of urban planning, the government cannot prevent them. The only ways is to negotiation with the private owner. TDR is such an incentive for the private owner. First, TDR is voluntary. The landowners have the right to develop as permitted by current zoning without participating in the TDR. If the developers have no demand for additional density or height, they don't need to care about the TDR. They can choose to participate freely according to their own needs. Unlike zoning, that every related stakeholders should obey it. Second, TDR compensates landowners fairly (Pizor 1978; Li 2008). Unlike zoning which sometimes causes unfairness since it benefits some landowners and limits others. So, TDR makes rigid land use

Table 98.1 Framework for appraising the critical success factors of TDR Chan and Hou (2015)

Criteria	Determinants
Political acceptability	D1, Enabling legislation for TDR
	D2, Minimal zoning changes and variances
	D3, TDR should be included in the built heritage conservation mechanisms
TDR leadership	D1, The authority of the administering agency
	D2, The local government support
	D3, Set up review mechanisms and protocols for updating TDR values over time
	D4, The approval process will be not delayed
Public support	D1, Good information about TDR and TDR
	D2, Neighbors of the receiving site do not oppose the higher density
	D3, Timely key participant involvement
	D4, Community monitor mechanism
Social equity	D1, The value of the building after re-use to the public
	D2, Using a list of criteria to evaluate the credits transfer ratio
Simplicity	D1, Developers and sending area landowners understand the programme
	D2, Easy for the government departmental staff to administer
Market incentive	D1, Offer sufficient compensation to the sending area owners
	D2, Low transaction and administrative costs
	D3, The maximum development potential of the receiving site and the sending site
	D4, Incentives aimed at motivating the operators to operate the re-use program, such as monetary support at the beginning of the project
Environment	D1, Compatible with the master plan, zoning plan and design standards
	D2, Minimal disturbance to the existing environment
	D3, Physical capability to handle increased density

regulations more politically feasible and easier to implement (Barrese 1983). TDR makes the private owner not resist the conservation. Third, compared with zoning which can change over time and with new administrations, TDR is more predictable. Instead of incurring the cost and risks of negotiating with government approving authorities for variances, owner/developer can exceed additional density by purchasing development rights.

98.4.2 From the Economic Aspect

Conservation programs for built heritage have great differences with those conservation programs such as forest, farm. Built heritage often located in the city centre and the land price is expensive. The government faces huge economic burden for conservation. For example, in the case of Ho Tung Garden, the private owner charged the government 7 billion. It is impossible for the government to buy all of the heritage. TDR is market—based and unlike the PDR programs that the government uses the limited public funding to compensate the owners. TDR relies on the private market (developer of the receiving sites who acquire greater development potential) and do not require government funding (Kaplowitz et al. 2008). TDR allows the market to decide what parcels to be preserved without reducing total growth. The developer will gain more density or height than that in zoning law. Additional, the income of related departments will increase from receiving the transaction fee etc. (Chan and Lee 2008). In addition, the property owner undertake the maintenance fee. It encourages using the private fund to conserve the land.

98.4.3 From the Environmental and Cultural Aspect

In compact development of Hong Kong, conservation works promote the spiritual aspect of quality life by preserving church and other valuable buildings to the public. TDR aims to balance the built heritage conservation and high-rise and high density development, which provide the recreation in the city center. Before the transfer, environmental capacity assessment should be carried out to check how much additional density could be transferred to the receiving area. Built heritage with low density and building height. Existing TDR cases in Hong Kong use the vacant land or green area as the receiving area. TDR is more permanent which uses deed restrictions or conservation easement for permanent protection of parcel (Pizor 1978). Once the development right has been transferred, the owner should obey the easement strictly. TDR can be used to protect land or buildings that are under threat of development or any other resources that a community wants to preserve (Pruetz et al. 2007). According to Pruez et al. (2007), in the US, about 191 TDR programs targeted towards environmental and farmland conservation 15 programs are oriented towards historic preservation and 12 focus on infrastructure and urban design.

98.5 Evaluation of Implementation of TDR in Hong Kong

From the literature, Li (2008) examined whether TDR can be adopted effectively in Hong Kong by reviewing the current control on property development and its effects on heritage buildings and conditions for applying the TDR in Hong Kong. After examining the available TDR cases, the author concluded that the future looks promising for TDR applications in Hong Kong. Although there is general support for allocating greater resources to built heritage conservation efforts through the provision of economic incentives, some authors suggest that TDR may not be the appropriate incentive because its implementation requires legislative amendments that would be difficult to implement, given the land scarcity in Hong Kong (LCP 2007). TDR gives the owners of historic buildings strong power to redevelop and makes the compensation far more expensive.

From the practice, TDR is the only method dealing with the situation that the private owner wants to demolish the historic building and do not accept the monetary compensation. There are several TDR cases that have been implemented in Hong Kong. Before 2007, the government has attempted to use this concept to conserve the private built heritage. The completed cases are the conservation of monument “Tai Fu Tai” and “Morrison Hall”, and the graded one building “Ohel Leah Synagaue”. After 2007, the government finished conserving “King Yin Lei” and “Sheng Kung Hui” by using TDR. However, there are some controversial to these cases. For example, the receiving site the owner expected are against by the public (e.g. Ho Dung Garden in Hong Kong); the value of the built heritage is doubt by the public; the value after re-use is difficult to realize (e.g. King Yin Lei). The development rights of Sheng Kung Hui compound and CLP Power Hong Kong Administration Building (Head Office Building) were successfully transferred just because in the front case, the owner owned another land with the same land use category in zoning plan, and in the latter one, the development rights transferred within the site, which makes the case relatively simple and less controversial.

From our interview, all of the interviewees assured TDR is a proper method to conserve the privately built heritage. No other better methods than TDR so far. The interviewees identified some difficulties of TDR and propose some ideas to improve TDR. Firstly, Interviews with the professionals in Hong Kong show the government support is the basis to success TDR program. But all of the interviewees said government support is far from enough. The government gives less support to TDR and it is passive administration. The evidence presents like no clear TDR policy, few researches, most of the public do not know what is TDR, TDR moves not fast in Hong Kong. They proposed the government should give highly attention to TDR, develop TDR policy and supporting policies, give support to legislation, develop most feasible strategies to promote effective public support. Secondly, the interviewees ensure the willingness of the owner to participate the TDR projects is critical. They all consider public support to TDR in Hong Kong is far from enough. So far, few people in Hong Kong understand clearly about what is TDR and what kind of benefits can bring to the participants. Educating the public and give the public power to make decision are the major strategies. Thirdly, TDR face some institutional challenges, due to lack of consistency with planning mechanism. No agency in charge of all the things of TDR, which result in some cooperation problems when implementing TDR. Fourthly, transfer systems should be developed to guide the transfer process such as transfer ratio, record the transfer situation and supervision the heritage maintenance.

98.6 Conclusion

TDR is the proper method to preserve the privately owned built heritage in Hong Kong, no other alternatives so far. Case by case approach is flexible but not sustainable. The experts have many ideas and suggestions to promote TDR. The key point is that in order to make public participate positively, government support on the clear conservation objective, proper arrangement of institutions and effective transfer system is necessary.

References

Chan EH, Hou J (2015) Developing a framework to appraise the critical success factors of transfer development rights (TDRs) for built heritage conservation. Habitat Int 46:35–43

Chan EHW, Lee GKL (2008) Contribution of urban design to economic sustainability of urban renewal projects in Hong Kong. Sustain Dev 16(6):353–364

Greenaway G, Good K (2008) Transfer of development credits in Alberta: a feasibility review. Miistakis Institute

Hong Kong. Legislative Council Panel on Home Affairs (LCP) (2007) Views and suggestions received from the public on the review of built heritage conservation policy. LC Paper No. CB (2) 1559/06-07(01)

Johnston R, Madison M (1997) From landmarks to landscapes: a review of current practices in the transfer of development rights. J Am Plan Assoc 63:365–378

Kaplowitz M, Machemer P, Pruetz R (2008) Planners' experiences in managing growth using transferable development rights (TDR) in the United States. Land Use Policy 25(3):378–387

Li LH (2008) Applicability of partnership and transfer of development rights (TDRs). In: Urban regeneration in HK

Machemer PL, Kaplowitz MD (2002) A framework for evaluating transferable development rights programmes. J Environ Plan Manage 45(6):773–795

McConnell V, Walls M (2009) U.S. experience with transferable development rights. Rev Environ Econ Policy 3(2):288–303

Pizor PJ (1978) A review of transfer development rights. Appraisal J 46(3):386–396

Pruetz R (2003) Beyond takings and givings: saving natural areas, farmland and historic landmarks with transfer of development rights and density transfer charges. Arje Press

Renard V (2007). Property rights and the 'transfer of development rights'–Questions of efficiency and equity. Town Plann Rev 78(1):41–60

Sheehan M (2007) Transfer of development rights: a study of its use in other states and the potential for use in Rhode Island

Spaans M, Veen MVD, Janssen-Jansen L (2010) The concept of non-financial compensation: what is it, which forms can be distinguished and what can it mean in spatial terms? Eur J Plan, Jan 2010

Wang H, Tao R, Wang LL, Su FB (2010) Farmland preservation and land development rights trading in Zhejiang, China. Habitat Int 34(4):454–463

Chapter 99
Prioritizing Best Value Contributing Factors for Contractor Selection: An AHP Approach

Muhammad Hasnain, Fahim Ullah, Muhammad Jamaluddin Thaheem and Samad M.E. Sepasgozar

99.1 Introduction and Background

The traditional procurement has served the construction industry for rather too long and offered its benefits (Odeh and Battaineh 2002). However, in the face of increasing awareness and regulatory requirements on sustainability, and raising demand of quality from key stakeholders, traditional low-cost procurement seems incapacitated (El Wardani et al. 2006). This drives the stakeholders to explore alternative procurement strategies, especially the ones attempting to fulfill current and futuristic demands. As a response, Best Value (BV) has come up as a candidate procurement approach. It is an efficient and effective system that minimizes unnecessary communication, generates a win-win-win situation, and guarantees maximum value at lowest cost, high profit and minimal project cost (Kashiwagi et al. 2010). BV procurement process considers price and other key factors for evaluation and selection for enhancing the long-term value of construction and performance (Scott 2006). It aims at maximizing transaction outcome, increasing value for money, emphasizing efficiency and enhancing performance standards. Public sector organizations need to establish best practice, develop demonstrable

M. Hasnain · F. Ullah (✉) · M.J. Thaheem
Department of Construction Engineering and Management (CE&M),
School of Civil and Environmental Engineering (SCEE),
National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
e-mail: fahimullah@nit.nust.edu.pk; f.ullah@student.unsw.edu.au

M. Hasnain
e-mail: hasnain.cem5@nit.nust.edu.pk

M.J. Thaheem
e-mail: jamal.thaheem@nit.nust.edu.pk

S.M.E. Sepasgozar
Faculty of the Built Environment, University of New South Wales, Sydney, Australia
e-mail: samad.sepasgozar@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_99

standards and formulate appropriate contractual provisions for procuring public works and services (Akintoye et al. 2003). For motivation, there are useful BV case studies (Kashiwagi 2011; Walker et al. 2002; Van de Rijt et al. 2011).

Performance Information Procurement System (PIPS) is developed by Performance Based Studies Research Group at Arizona State University for risk management in procurement process. It is based on the deductive logic that expert vendors have low risks and can deliver desired quality at lowest possible cost. It requires pre-planning and proactive risk management to mitigate risk before it occurs (Kashiwagi et al. 2010). It has three major phases: identification of potential BV, clarification, and contract award and performance measurement (Little and Kashiwagi 2012). In 1st phase, vendors are evaluated based on their cost, schedule, ability to identify and mitigate project risks, past performance of team and interviews of key personnel. Although similar criteria are used in other selection processes, the underlining difference is in method of data collection and analysis. In 2nd phase, sufficient duration is allocated to carefully pre-plan and clarify the project and services. During this period, the vendor primarily performs project review for understanding intent of owner, outlines scope and responds to owner's questions. After clarification, owner awards the contract in 3rd phase. Then onwards, the vendor submits a weekly risk report for tracking all project deviations in terms of its schedule and cost. Kashiwagi (2011) identified service delivery as main problem of construction industry and classified services into four quadrants: price-based, best-value, negotiated-bid and unstable. The research further highlighted five major components of BV PIPS: information management theory, Kashiwagi solution models, construction industry structure, PIPS and performance information risk management system. Decision making comes with intrinsic risks and BV method aims at lowering the impact of these risks by selecting the best option based upon offered value. BV vendor provides more value by ensuring lesser risks, enhancing project success, and addressing needs and concerns of client. By using performance information, expert vendors highlight their better progress on similar projects. If BV PIPS overall scores are equal, then owner can select lowest price option and in case if BV vendor becomes more expensive, clear justifications must be provided.

In an attempt to identify and group the key elements contributing to quantification and assessment of BV contractor selection, literature is reviewed extensively and CFs of BV process are identified. Further, Analytical Hierarchy Process (AHP) is applied to highlight the most significant contributing factors influencing key decision making. It is aimed at moving towards the more efficient and new system based upon the holistic value offered which will capture more value based offerings instead of only cost saving and compromising on other aspects leading to failures of projects. Based upon the results, discussion and conclusions are drawn in order to pave the path for moving from traditional low bid system to BV based contractor selection. The findings of this paper will help in selection of BV contractor for clients, BV supplier for contractor and BV team for consultants. Hence a win-win-win scenario can be achieved by capturing the holistic essence of BV process.

99.2 Methodology

In order to identify BV factors, a systematic literature review was conducted. The result of the analysis provides 15 BV CFs. To do so, five scholarly papers for each CF were searched using literature databases of ASCE Library, Science Direct, Google Scholar, Taylor & Francis Online, CIB W117, Emerald Insight and Scopus. Keywords such as 'best value', 'PIPS', 'BV factors' and 'BV procurement' were used. In total, 62 research publications from different journals of project management, and construction engineering and management published from 2000 to 2015 have been studied. A spreadsheet was prepared and papers were arranged chronologically and alphabetically to avoid duplication. Further, 36 construction professionals having a minimum experience of 5 years were involved in a questionnaire survey to assign values to factors for developing the priority matrices for AHP. The experts were contacted through official emails. The values assigned by the professionals are averaged as shown in Tables 99.2 99.3, 99.4 and 99.5.

99.2.1 Grouping of BV Factors

Upon further scrutiny, assessment of literature, and inspiration from previous studies, identified factors are grouped into five main criteria: cost, performance, quality control, health and safety, and project control. As a result, the factors mentioned in Table 99.1 are referred to as sub-criteria and their hierarchal grouping is shown in Fig. 99.1.

99.2.2 Analytical Hierarchy Process (AHP)

AHP is a mathematical multi-criteria decision-making (MCDM) technique (Saaty 2008) to solve complex and ambiguous decision-making problems (Chin and Pun 2002). It involves both qualitative and quantitative components to establish various decision models. It helps in decomposing decision problems from an overall project goal to more manageable groups and sub-groups, and eventually to scenarios or alternatives. These clusters or sub-clusters include attributes, forces, activities, criteria, objectives, etc. (Saaty 1994). AHP uses pair-wise comparison for assigning quantitative weights to elements at both cluster and sub-cluster levels. At the final level of assessment, it calculates 'global' weights of elements. One of its main functions is to calculate the consistency ratio that ascertains the suitability of matrices for analysis (Cheng et al. 2005). Nevertheless, AHP models assume unidirectional relationships between clusters of different decision levels along the hierarchy and uncorrelated elements within and between clusters. Hence, it is not appropriate for models that specify interdependent relationships (Saaty and Vargas 2012).

Table 99.1 Best value contributing factors

S. No	Factors	Ref	s#	factors	Ref
1	Proposed tender price (PTP)	Gajjar et al. (2014)	9	Quality control measures (QCM)	Flyvbjerg (2013)
2	Low project life cycle cost (LPCC)	Kashiwagi et al. (2014)	10	Meeting design requirements (MDR)	Flyvbjerg (2013)
3	Financial capability (FC)	Xia et al. (2014)	11	User expectations and satisfaction (UES)	Flyvbjerg (2013)
4	Additional financial resources for priority projects (FRP)	Gajjar et al. (2014)	12	Actual schedule achieved for similar works (SAW)	Odeh and Battaineh (2002)
5	Past performance and expertise of the company (PPEC)	Kim and Huynh (2008)	13	Project control and monitoring process (PCM)	Vanhoucke (2012)
6	Number of key personnel (NKP)	Dainty et al. (2005)	14	Environmental impact (EI)	El Wardani et al. (2006)
7	Optimized resource utilization (ORU)	Gajjar et al. (2014)	15	Health and safety performance (HSP)	Pan et al. (2012)
8	Training and skill level of project team (TSP)	Dainty et al. (2005)			

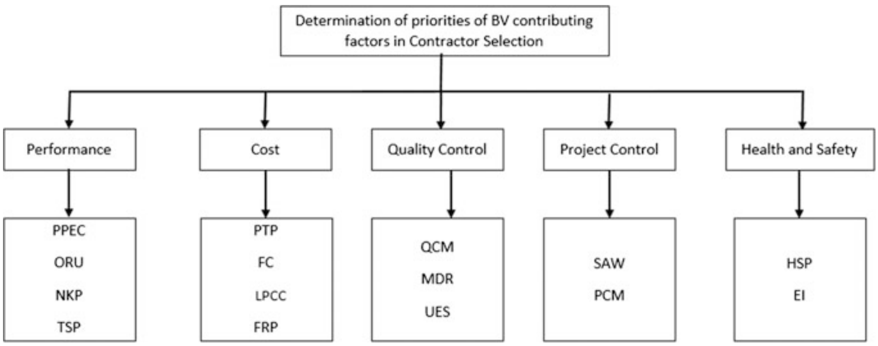


Fig. 99.1 An AHP based model for determination of priorities of BVCFs in contractor selection

The main objective of this study is to prioritize the studied factors in decision making of BV contractor selection. Because decision making issues related to contractor selection are becoming more complex, it is challenging to handle all of them in a single set of processes. Current literature provides an idea about the use of AHP particularly in ranking and prioritizing of different criteria and sub-criteria

(Chin and Pun 2002). As per standard process, in 1st step of AHP, objectives of the complex and ambiguous problem are defined and stated clearly using charts. An overall system is drafted for problem and possible ways to achieve the objectives. In 2nd step, the problem is decomposed into a multi-level hierarchal assembly using group decisions or surveys by involving field experts. The top level hierarchy, representing the problem goal, is sub-divided into several criteria in next level to highlight their details. In 3rd step, a pairwise comparison is made through decision matrix for illustrating the relative importance of factors. Using a scale of 1–9, the factors are ranked and matrix based pairwise comparisons are made using Saaty's (1994) scale. The comparison in hierarchal structure are made in such a way that the elements underling common nodes are compared with other elements of the same node. In 4th step, priority weights of elements are identified with the help of maximum eigenvectors and eigenvalues calculated using Saaty's (1994) formula. These are special elements associated with a matrix equation. In 5th step, consistency of pairwise comparisons and data sets are checked with help of consistency index, and consistency ratio with a maximum acceptance limit of 0.1. Any value greater than 0.1, highlights inconsistency leading to its discarding. In 6th step, the global weights of all elements are identified as per the goals defined in AHP model. Lastly, in 7th step, in accordance to global prioritization, all the elements are reorganized in declining order after calculating their global weights.

Super Decisions® software implements AHP for decision making with dependence and feedback developed by Saaty (1994). Its work is based on two main MCDM methods: AHP and ANP. Both methods use the fundamental concepts of prioritization by deriving priorities and judgments made on element pairs. The software uses same prioritization techniques, or obtains priorities by normalizing direct measurements. It has been widely used in both research and practical fields (Adams and Saaty 2003).

99.3 Results and Discussions

A hierarchy can be developed using stakeholder perception, recollection and creative thinking. According to Zahedi (1986), due to dependence upon managerial decisions of number and structure of criteria levels, decision making becomes complex. The hierarchal structure starting at top with the goal, and various criteria and sub-criteria in subsequent levels is designed after setting out the study goal. Thus, an AHP framework is constituted to accomplish study goal as shown in Fig. 99.1.

99.3.1 Pairwise Comparison of Criteria

In pairwise comparison, entities in pairs are compared to judge the preferred entity among all or find similarities between them. The pairwise comparison of all five criteria of this study with respect to the goal of determining the priorities of BV CFs in contractor selection is carried out. It highlights the relative importance of each criterion against study goal. The synthesized matrix is shown in Table 99.2.

99.3.2 Pairwise Comparison of Factors

Similar to pairwise comparison of criteria, pairwise comparison of CFs is also done. In the pairwise comparison factors PPEC, NKP, ORU and TSP have been compared with respect to "Performance" criteria; PTP, LPCC, FC and FRPC with respect to "Cost" criteria; HSP and EI with respect to "Health and Safety" criteria; PCM and SAW with respect to "Project control" criteria and factors QCM, MDR and UES have been compared with respect to "Quality control" criteria as shown in Table 99.3.

99.3.3 Normalized Matrix

Normalization is a method of computing numbers that takes into account the overall values. Normalized matrix is unitarily similar to its diagonal matrix ($AA^* = A * A$). The normalized matrix of criteria, and factors of performance, cost, health and safety, quality control and project control is shown in Table 99.4.

99.3.4 Calculation of Local Weights and Global Weights

After normalization, the next step is calculating each criterion/sub-criterion's local weights to represent the relative value of elements in regards to the element placed

Table 99.2 Pairwise comparison of criteria

Consistency ratio (0.03018)	Performance	Cost	Health and safety	Proj Ctrl	Quality Ctrl
Performance	1	2	5	4	2
Cost	½	1	7	4	2
Health and safety	1/5	1/7	1	1/3	1/4
Project control	¼	1/4	3	1	1/2
Quality control	½	1/2	4	2	1

Table 99.3 Pairwise comparison matrix of factors

Consistency ratio (0.0303)	PPEC	NKP	ORU	TSP	Consistency ratio (0.00)	HSP	EI	
PPEC	1	3	3	5	HSP	1	2	
NKP	1/3	1	2	4	EI	1/2	1	
ORU	1/3	1/2	1	2	Consistency ratio (0.00)	PCM	SAW	
TSP	1/5	1/4	1/2	1	PCM	1	1/2	
Consistency ratio (0.0211)	PTP	LPCC	FC	FRP	SAW	2	1	
PTP	1	3	2	5	Consistency ratio (0.0088)	QCM	MDR	UES
LPCC	1/3	1	1/3	2	QCM	1	2	3
FC	1/2	3	1	4	MDR	1/2	1	2
FRP	1/5	1/2	1/4	1	UES	1/3	1/2	1

immediately above it in the hierarchal arrangement. After doing this, decision makers mainly focus on identifying the relative value of each element in terms of main objective of the hierarchal arrangement i.e. global weights. Both weights of the goal are 1 each. Weighing local priorities by global priorities (i.e. at preceding level) for any hierarchical element gives global weight, known as their parents (Saaty and Vargas 2012).

99.3.5 Ranking the Criteria and Sub-criteria

For clear identification of impact of all CFs on goals of the hierarchal model, they must be arranged in decreasing order. It makes the identification of key factors easy for decision makers. The priority weights of factors for current study are shown in Table 99.5 and graphically represented in Fig. 99.2. In AHP, the pairwise comparison of criteria and factors are done as shown in Table 99.4, and local and global weights of all factors are determined as shown in Table 99.5.

The second column displays local weights of criteria showing that performance criteria with overall weight of 38.0% stands at top position and its weightage is approximately nine times more than that of health and safety (4.7%). The results reveal that despite cost and quality control, contractors are primarily evaluated on basis of their past performance incorporating resources (labor and non-labor), and number and size of projects previously carried out. The factor "past performance and expertise of company" possesses maximum weight (19.72%) showing that though contract is awarded to lowest bidder normally, still contractors are evaluated on basis of their past performance.

Figure 99.2 portrays the priority levels of CFs in BV procurement which will assist the decision makers in making comprehensive decisions for awarding

Table 99.4 Normalized matrix of criteria and factors

Consistency ratio (0.032)	Performance	Cost	H&S	Proj Ctrl	Qlty Ctrl	Priority vector
Performance	2/5	1/2	1/4	1/3	1/3	0.380
Cost	1/5	1/4	1/4	1/3	1/3	0.302
Health and safety	4/49	3/82	1/20	1/34	1/23	0.047
Project control	1/9	2/31	1/7	3/34	2/23	0.096
Quality control	1/5	1/8	1/5	1/6	1/6	0.174
Consistency ratio (0.0303)	PPEC	NKP	ORU	TSP	Priority vector	
PPEC	½	5/8	1/2	3/7	0.519	
NKP	1/6	1/5	1/3	1/3	0.254	
ORU	1/6	1/9	1/6	1/6	0.148	
TSP	1/9	1/19	1/13	1/12	0.078	
Consistency ratio (0.0211)	PTP	LPCC	FC	FRP	Priority vector	
PTP	½	2/5	5/9	3/7	0.470	
LPCC	1/6	1/7	4/43	1/6	0.137	
FC	¼	2/5	2/7	1/3	0.317	
FRP	6/61	1/15	3/43	1/12	0.078	
Consistency ratio (0.00)	HSP		EI		Priority vector	
HSP	2/3		2/3		0.667	
EI	1/3		1/5		0.333	
Consistency ratio (0.00)	PCM		SAW		Priority vector	
PCM	1/3		1/3		0.333	
SAW	2/3		2/3		0.667	
Consistency ratio (0.008)	QCM	MDR	UES		Priority vector	
QCM	5/9	4/7	½		0.539	
MDR	2/7	2/7	1/3		0.270	
UES	1/5	1/7	1/6		0.163	

contract. The factors "proposed tender price (0.1419)", "number of key personnel (0.0965)", "financial capability (0.0957)" and "quality control measures (0.0937)" acquire distinctively higher weights than other mentioned factors and are very close to each other. The second most significant factor is "proposed tender price" that enables client to compare the tenders and cost plan, and assess their inherent value ensuring value for money. It is used to identify the negotiable areas of savings during tender evaluation and award. In public procurement, cost is the most dominant factor, so price proposed by bidders will set a fine line for the client in BV based contract award decisions. The least rated factor is "environmental impact" which is often ignored in construction as highlighted by Shen (2004) leading to environmental degradation and narrowing of green land.

Table 99.5 Composite priority weights for criteria and factors

Criteria	Local criteria weights	Factors	Local factor weights	Global weights
Performance	0.380	PPEC	0.519	0.1972
		NKP	0.254	0.0965
		ORU	0.148	0.0562
		TSP	0.078	0.0296
Cost	0.302	PTP	0.470	0.1419
		LPCC	0.137	0.0413
		FC	0.317	0.0957
		FRP	0.078	0.0235
Health and safety	0.047	HSP	0.667	0.0313
		EI	0.333	0.0156
Project control	0.096	PCM	0.333	0.0319
		SAW	0.667	0.0640
Quality control	0.174	QCM	0.539	0.0937
		MDR	0.270	0.0469
		UES	0.163	0.0283

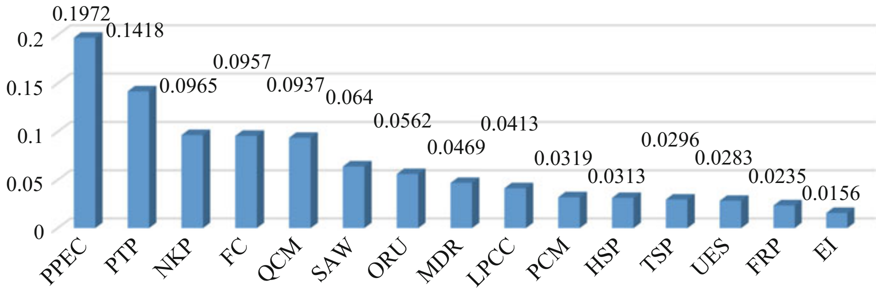


Fig. 99.2 Bar chart of prioritization of factors

99.4 Conclusions

The aim of this study was to identify BV CFs for contractor selection and help the decision makers by highlighting factors critical to successful procurement. It employed AHP methodology for identification and prioritization of CFs affecting the decision making of contractor selection process. A total of 15 factors have been identified from literature published from 2000 to 2015. Using AHP, relative importance and impacts of these factors in contractor selection have been identified. Results indicate that performance and cost criteria occupy top positions in hierarchy of factors indicating their significance in decision making. The other factors have relatively low scores showing their minimal importance in decision making process. AHP methodology is proposed due to its established application in various complex real-world problems and their solution, and its simplistic methodology and hierarchical structure. Further, not only it deals with both tangible and intangible variables but also maintains transparency in decisions by decomposing complex issues into simple hierarchical structure. AHP assists decision makers to identify the complex relationship among elements of concerned problem. Therefore, it is adopted for prioritizing the BV CFs according to the specific objective of current study. Based on the findings of this study, decision makers can identify necessary resources and required capabilities of contractors to manage and endure their competitive advantage. The relative significance of factors can be very helpful for procurement personnel in contract award decisions. The proposed AHP model is simplistic and its computations can be made using available software like Super Decisions® or spread sheets. The hierarchal structure allows the user to readily determine the relative contribution and significance of identified factors in accurate decision making. It provides a win-win-win situation regardless of stakeholder association. The client can select BV offering contractor, the contractor can select BV supplier whereas the consultant can select his BV team through different decisions. The proposed model reflects the owners' needs and preferences as the relative weights of factors are assigned according to their requirements. Hence, the existing selection mechanism can be improved ultimately paving ways for switching from traditional low bid system to the more reliable and better performing BV system. The findings are all the more relevant to developing countries where cost is still valued more than the value offered.

A limitation of the current study is intertwined with poor change management in construction industry which results into limited availability of specific data useful for in depth evaluation, and lack of innovation and adoptability of construction industry. The field professionals tend to stick to the traditional low bid methods and value the previous dealings and cost saving attributes highly. This not only limits the innovation but also discourages the new entrants in the field. In this regards, the current study is a stepping stone for moving away from the inefficient traditional system to more innovative and adoptive BV approach. The current study can be extended to include all stakeholders of the contract: contractor, consultant and client for ensuring a win-win-win contract model. Also, in addition to 15 BVCF presented, other satisficing considerations such as contractor suitability, cooperation and availability for the project could also be incorporated in current framework.

References

Adams WJ, Saaty R (2003) Super decisions software guide. Super Decisions 9

Akintoye A, Hardcastle C, Beck M, Chinyio E, Asenova D (2003) Achieving best value in private finance initiative project procurement. Constr Manage Econ 21:461–470

Cheng EW, Li H, Yu L (2005) The analytic network process (ANP) approach to location selection: a shopping mall illustration. Constr Innovation 5:83–97

Chin K-S, Pun K-F (2002) A proposed framework for implementing TQM in Chinese organizations. Int J Qual Reliab Manage 19:272–294

Dainty AR, Cheng M-I, Moore DR (2005) Competency-based model for predicting construction project managers' performance. J Manage Eng 21(1):2–9
El Wardani MA, Messner JI, Horman MJ (2006) Comparing procurement methods for design-build projects. J Constr Eng Manage 132(3):230–238
Flyvbjerg B (2013) Quality control and due diligence in project management: getting decisions right by taking the outside view. Int J Project Manage 31:760–774
Gajjar D, Kashiwagi D, Kashiwagi J, Sullivan K (2014) Best value case study: cold storage facility in Miami, Florida. J Adv Perform Inf Value 6(1)
Kashiwagi D (2011) Case study: Best value procurement/performance information procurement system development. J Adv Perform Inf Value 3(1)
Kashiwagi J, Sullivan K, Kashiwagi D (2010) New contract model for project management. PM-05 Advancing Project Management for the 21st Century, pp 228–335
Kashiwagi D, Kashiwagi J, Child G (2014) Price based environment of design and engineering services. J Adv Perform Inf Value 6(1)
Kim S-Y, Huynh T-A (2008) Improving project management performance of large contractors using benchmarking approach. Int J Project Manage 26:758–769
Little M, Kashiwagi D (2012) State of Idaho procurement of it services. In: 5th international public procurement conference (IPPC5), proposed paper, Seattle, WA, US
Odeh AM, Battaineh HT (2002) Causes of construction delay: traditional contracts. Int J Project Manage 20:67–73
Pan W, Dainty AR, Gibb AG (2012) Establishing and weighting decision criteria for building system selection in housing construction. J Constr Eng Manage 138:1239–1250
Saaty TL (1994) How to make a decision: the analytic hierarchy process. Interfaces 24:19–43
Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1:83–98
Saaty TL, Vargas LG (2012) Models, methods, concepts & applications of the analytic hierarchy process, vol 175. Springer Science & Business Media, US
Scott S (2006) Best-value procurement methods for highway construction projects. Transportation Research Board, vol 561, US
Shen J (2004) Population growth, ecological degradation and construction in the western region of China. J Contemp China 13(41):637–661
Van de Rijt J, Witteveen W, Vis C, Santema S (2011) Best value at the directorate-general for public works and water management in The Netherlands: a case study of the procurement of infrastructure projects worth $1,200 M. J Adv Perform Inf Value 3(1)
Vanhoucke M (2012) Measuring the efficiency of project control using fictitious and empirical project data. Int J Project Manage 30:252–263
Walker DH, Hampson K, Peters R (2002) Project alliancing vs project partnering: a case study of the Australian National Museum Project. Supply Chain Manage Int J 7(2):83–91
Xia B, Chen Q, Xu Y, Li M, Jin X (2014) Design-build contractor selection for public sustainable buildings. J Manage Eng 31(5):04014070
Zahedi F (1986) The analytic hierarchy process—a survey of the method and its applications. Interfaces 16:96–108

Chapter 100
Recycled Aggregate in Concrete Production: A New Approach

Vivian W.Y. Tam, Anthony Butera and Khoa N. Le

100.1 Introduction

Construction and demolition waste is attributed with a large portion of landfill space around the world (Pacheco-Torgal et al. 2013). Recycling construction and demolition waste has been heavily researched in order to discover solutions for reducing landfill space. The use of crushed concrete waste as recycled aggregate serves as a solution with outstanding potential for reducing landfill volume. Conversely, recycled concrete, as it is known, is characterised by a large physical and mechanical shortcomings (Li et al. 2008).

The deficiency of strength exhibited by recycled concrete does not permit it to surpass natural concrete in terms of mainstream practical usage (Kou et al. 2012). To achieve recycled concrete which challenges natural concrete, it must undertake additional strengthening processes. However, supplementary procedures required for improving recycled concrete quality must closely equal practicality and monetary expenditure of natural concrete.

Review on the effects of incorporating recycled aggregate, sourced from construction and demolition waste, on the carbonation behaviour of concrete was conducted (Silva et al. 2015). Various influencing aspects related to the use of recycled aggregate, such as replacement level, size and origin, as well as the influence of curing conditions, use of chemical admixtures and additions on carbonation over a long period of time were identified.

Modification of recycled aggregate by calcium carbonate biodeposition was examined (Qiu et al. 2014; Grabiec et al. 2012). Calcium carbonate was used for

V.W.Y. Tam (✉) · A. Butera · K.N. Le
School of Computing, Engineering and Mathematics,
Western Sydney University, Sydney, Australia
e-mail: vivianwytam@gmail.com

V.W.Y. Tam
College of Civil Engineering, Shenzhen University, Shenzhen, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_100

precipitation of calcium carbonate, while culture medium consisting of beef extract, peptone and urea was used for cultivation of microorganisms. It was found that the microbial carbonate precipitation peaks at pH 9.5 and increases with higher temperature, bacteria concentration or calcium concentration.

Experiments was also carried out for investigating the possibilities of producing carbonated granulated steel slag concrete in replacing common natural aggregate (Pang et al. 2015). Test results showed that carbonation treatment can significantly improve the strength and volume stability of steel slag aggregate and reduce water absorption, porosity and free calcium oxide.

The process of carbon-conditioning recycled aggregate and recycled concrete thus proposals an abundance of potential. There are different approaches in carbon-conditioning, for either recycled aggregate or recycled concrete. For carbon-conditioning recycled aggregate, recycled aggregate is first placed in a sealed chamber and at that juncture; it is exposed to carbon dioxide at pressure for a given amount of time. The exposer produces a recycled aggregate which is denser, less porous with a reduced amount of water absorbency (Zhan et al. 2014; Vahid et al. 2012). The discharge of an amount of CO_2 from the conditioned recycled aggregate also generates a superior bond matrix as a result of an enhanced chemical reaction and a great filling of space within the matrix (Kou et al. 2014). Carbon conditioning improves recycled aggregate quality and as a consequence, generates a resilient recycled concrete (Zhan et al. 2014). Properties of carbon-conditioned recycled aggregate and its mortar were also studied (Zhang et al. 2015). It was found that the carbonation increased the apparent density and reduced both water absorption and crushing value of recycled aggregate. The flowability and compressive strength of the recycled aggregate mortar were lower than those of natural sand mortar. However, the properties of mortar made with CO_2 treated recycled aggregate were very similar to those of natural sand mortar.

An alternative approach is carbon curing of recycled concrete (Zhan et al. 2013). A CO_2 curing process was adopted to cure concrete blocks made with recycled aggregate. Non-load and load-bearing blocks were prepared and placed in a pressurized 100% CO_2 curing chamber for 6, 12 and 24 h. It was found that the CO_2 cured blocks attaining higher compressive strength and lower drying shrinkage than the corresponding moist cured blocks. It was also found that curing time and amount of recycled aggregate present in the blocks had insignificant effects on the strength gain and CO_2 curing degree.

Carbon-conditioning recycled aggregate is not yet used in the mainstream concrete production. Carbonation is cheaper than other recycling alternatives, seems to generate an appropriate physical and mechanical quality and is practical for commercial use. However, additional research must be conducted. This paper investigates the use of carbon-conditioned recycled aggregate (RA^{CO_2}) by varying chamber pressure (0, 75 and 150 kPa), chamber duration (0, 30 and 90 min) and RA^{CO_2} replacement ratio (0, 30 and 100%) in concrete production. Results on compressive, tensile and flexible strength and modulus of elasticity at 28 curing days are compared.

100.2 Material

Recycled aggregate samples collected from a south-eastern Australia centralised recycling plant was adopted for the production of concrete. Particle size distribution is of importance as it affects workability and strength (Neville 1995). As regards the sample collected was fulfilling the particle size distribution of 10 mm and 20 mm aggregate as stated in Australian standard (AS 1141.11 2014).

The water absorption of the recycled aggregate sample is about 5.02% for 10 mm and 5.63% for 20 mm with particle density on oven-dried basis of about 1.44 t/m^3 for 10 mm and 1.30 t/m^3 for 20 mm, particle density on saturated and surface-dried basis of about 1.51 t/m^3 for 10 mm and 1.37 t/m^3 for 20 mm, apparent particle density of about 1.55 t/m^3 for 10 mm and 1.40 t/m^3 for 20 mm, aggregate crushing value of about 34%, about 2% contaminant, flakiness index of about 15.12 for 10 mm and 9.78 for 20 mm, and misshapen particle of about 0.88%. The properties of natural aggregate are also compared with the recycled aggregate.

100.2.1 Carbonation Chamber

For carbon-conditioning recycled aggregate, a carbonation chamber was designed and built, including a translucent polyvinyl chloride pressure pipe with a screw top lid connecting to a CO_2 tank, brandishing a regulator in controlling pressure. CO_2 was introduced to the chamber for the experimented pressure and duration. Figure 100.1 illustrates the carbonation chamber used.

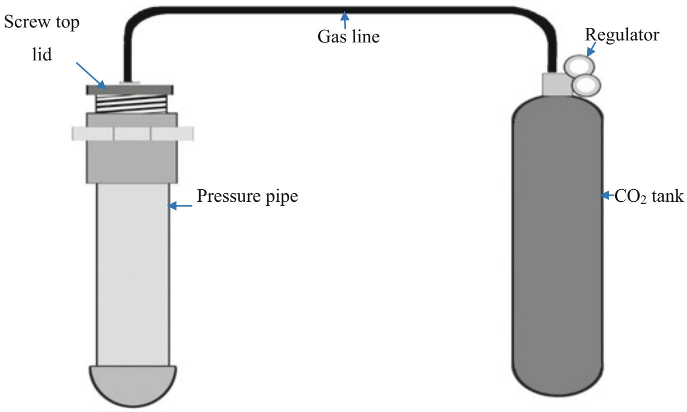


Fig. 100.1 Carbonation chamber

100.3 Experimental Design

Ordinary Portland cement, designated Type GP (General Portland) was used for the experimental work. The RA^{CO_2} replacement ratios were used at 0, 30 and 100%, water-to-cement ratios were used at 0.4. The process of carbon-conditioning is a new experimental and prototype process. Pressure on 75 and 150 kPa was nominated. The duration was selected to observe the change in two different duration lower than that of Kou's studies (Kou et al. 2014) for gaining knowledge on the effects of carbon-conditioning in a manageable commercial timeframe.

The mixing procedure conducted in this paper is based on Australian Standard 1012 (1993). The RAC mixing was first charged with about half of natural and recycled coarse aggregate, then with natural fine aggregate, then with cement, and finally with the remaining coarse aggregate. Water was then immediately added after starting the operation for 2 min (AS 1012 1993). It needs to be emphasized that no superplastizer or additive was added to any concrete mixes in the experimental work. This can ensure that the actual results from the RA^{CO_2} replacement percentages, chamber pressure and chamber duration are recorded and analysed.

Three 100 mm-diameter and 200 mm-high concrete cylinders for each mixing proportion were used for conducting compressive strength (AS 1012.9 2014) at 28 curing days.

The concrete samples were demoulded after 24 h of mixing and immediately placed in a room with controlled environmental conditions at temperature of 22 ± 2 °C and relative humidity level of 70 ± 2%.

100.4 Results and Discussions

The process of carbon-conditioning for the recycled aggregate generates compressive strength improvement. Figure 100.2 illustrates a superior performance of the recycled concrete with 30% RA^{CO_2} replacement percentage compared to the natural concrete while the recycled concrete with 100% RA^{CO_2} replacement percentage deteriorates when contrasted against the natural concrete. The recycled concrete with 30% recycled aggregate replacement percentage (30–0–0 mix) supplies a notable result, bettering the natural concrete (0–0–0 mix). Standard recycled concrete typically features about 12 and 36% losses in 30 and 100% recycled aggregate replacement percentages respectively (Batayneh et al. 2007; Behera et al. 2014). However, the results in this experiment display a 30% loss for the recycled concrete with 100% recycled aggregate replacement percentage (100–0–0 mix) and a 4% gain for the recycled concrete with 30% recycled aggregate replacement percentage (30–0–0 mix). The recycled concrete attains a slightly enriched quality when rivaled to the standard.

Another observation is that the recycled concrete with 30% RA^{CO_2} replacement percentage exposed to lower chamber pressures (30–90–75 and 30–30–75 mixes)

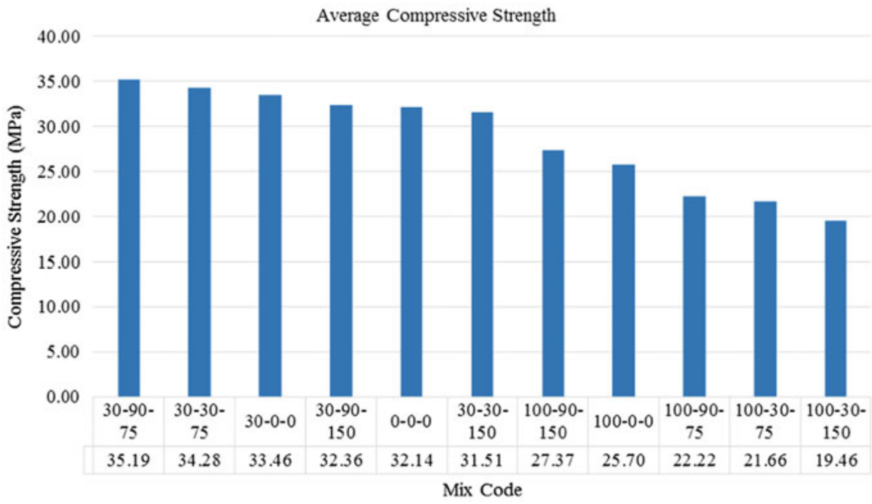


Fig. 100.2 Experimental results on compressive strength

characterises the highest compressive strength results of about 35.19 and 34.28 MPa respectively. The 30–90–75 mix, with RA^{CO_2} exposed to the CO_2 for a lengthier duration of 90 min attains a slightly higher compressive strength result of about 35.19 MPa than that of the 30 min mix of about 34.28 MPa (30–30–75 mix). The experimental results indicate that the RA^{CO_2} gains heightened properties at lower chamber pressures and longer chamber duration. In agreement with Kou et al.'s results (2014), it is postulated that a longer CO_2 exposure period permits the RA^{CO_2} to uptake additional CO_2 and thus, manufacturing a less pores, less absorbent, denser aggregate and generating a desirable chemical reaction during hydration, leading to a superior and denser bond matrix.

A greater performance of the 75 kPa chamber pressure mixes (30–90–75 and 30–30–75 mixes) when paralleled to the 150 kPa chamber pressure mixes (30–90–150 and 30–30–150 mixes) are slightly counterintuitive. The higher chamber pressures are believed to push the CO_2 into the RA^{CO_2} at a quicker rate, consequently upgrading the aggregate properties in a shorter duration. The high chamber pressure mixes instead lower the compression strength of the final concrete of which it even past the 30–0–0 mix for the 30–90–150 mix and 0–0–0 mix for the 30–30–150 mix. The theorised rational behind this result is that the pressure is actually too high, breaking down some of the soft recycled aggregate in place of carbon. It is thus unveiled that high chamber pressures, contrastingly to intuition, have a degeneration effect on recycled concrete with RA^{CO_2}.

The recycled concrete with 30% RA^{CO_2} results provides a trend. The chamber duration as the largest contributing factor to an improved RA^{CO_2}, has a greater outcome upon a longer chamber exposure time. In addition, the higher the chamber pressure, the less compressive strength is gained by the recycled concrete. The high chamber pressure supersedes a longer chamber duration. These trends are indicated by the order of the 30–90–75 mix, the strongest followed by 30–30–75, 30–90–150 and 30–30–150 mixes.

The recycled concrete with 100% RA^{CO_2} replacement percentage undergoes great loss even when likened to the 100–0–0 mix. As of mentioned, the recycled concrete with 100% RA^{CO_2} replacement percentage was visibly and provided considerably additional saturation during mixing. The calculated and constant water to cement ratio of 0.4 appeared to be exceeded. The overly saturated concrete was a result of the amount of CO_2 absorbed by the recycled aggregate, subsequently, reducing the water absorption and leaving excess water in the cement. The excess water devastated the compression strength results. Unlike the 30% carbonated recycled aggregate concrete, longer chamber duration seizes precedence over the chamber pressure. Both the 100–90–150 and 100–90–75 mixes perform superiorly to the 100–30–75 and 100–30–150 mixes. The 100–30–150 mix acquires the worst compressive strength result. The poor compressive strength results succumb to the undesirable high chamber pressure of 150 kPa with low chamber duration of 30 min.

100.5 Conclusion

The paper examined that the process of carbon-conditioning recycled aggregate provides an improvement to the physical and mechanical properties of the recycled concrete. Experimental work was conducted for the use of RA^{CO_2} with varying chamber pressure (0, 75 and 150 kPa), chamber duration (0, 30 and 90 min) and RA^{CO_2} replacement percentages (0, 30 and 100%) for concrete production. It was found that RA^{CO_2} on low chamber pressure and/or long chamber duration creating the highest quality recycled concrete. The recycled concrete with 30% RA^{CO_2} replacement percentages achieved better physical and mechanical performance than the natural concrete while the recycled concrete with 100% RA^{CO_2} replacement percentages generated large amount of free water in concrete mixing. Carbon-conditioning exhibits further potential based upon the experimental results. The supplementary process, when compared to others, produces a robust recycled concrete in an inexpensive and practical manner. This paper provides insights and generates new information for further research. Carbon-conditioning is an effective means of enhancing recycled concrete performance.

References

AS 1141.11 (2014) Methods for sampling and testing aggregates—particle size distribution by sieving. Australian Standards, Australian Government

AS 1012 (1993) Methods of testing concrete. Australian Standard

AS 1012.9 (2014) Methods of testing concrete—determination of the compressive strength of concrete specimens. Australian Standards, Australian Government

Batayneh M, Marie I, Asi I (2007) Use of selected waste materials in concrete mixes. Waste Manag 27(12):1870–1876

Behera M, Bhattacharyya SK, Minocha AK, Deoliya R, Maiti S (2014) Recycled aggregate from C&D waste & its use in concrete—a breakthrough towards sustainability in construction sector: a review. Constr Build Mater 65(1):501–516

Grabiec AM, Klama J, Zawal D, Krupa D (2012) Modification of recycled concrete aggregate by calcium carbonate biodeposition. Constr Build Mater 34(9):145–150

Kou S, Zhan B, Poon CS (2012) Feasibility study of using recycled fresh concrete waste as coarse aggregates in concrete. Constr Build Mater 28(1):549–556

Kou SC, Zhan BJ, Poon CS (2014) Use of a CO_2 curing step to improve the properties of concrete prepared with recycled aggregates. Cement Concr Compos 45(1):22–28

Li J, Xiao H, Zhou Y (2008) Influence of coating recycled aggregate surface with pozzolanic powder on properties of recycled aggregate concrete. Constr Build Mater 23(3):1278–1291

Neville AM (1995) Properties of concrete. Burnt Mill, Harlow, Essex; New York, Longman

Pacheco-Torgal F, Tam V, Labrincha J, Ding Y, de Brito J (2013) Handbook of recycled concrete and demolition waste. Woodhead Publishing Limited, Cambridge

Pang B, Zhou Z, Xu HX (2015) Utilization of carbonated and granulated steel slag aggregate in concrete. Constr Build Mater 84(6):454–467

Qiu J, Qin D, Tng S, Yang EH (2014) Surface treatment of recycled concrete aggregates through microbial carbonate precipitation. Constr Build Mater 57(4):144–150

Silva RV, Neves R, de Brito J, Dhir RK (2015) Carbonation behaviour of recycled aggregate concrete. Cement Concr Compos 62(9):22–32

Vahid R, Yixin S, Boyd A (2012) Carbonation curing versus steam curing for precast concrete production. J Mater Civ Eng 24(9):1221–1229

Zhan BJ, Poon CS, Shi CJ (2013) CO_2 curing for improving the properties of concrete blocks containing recycled aggregates. Cement Concr Compos 42(9):1–8

Zhan B, Poon CS, Liu Q, Kou S, Shi C (2014) Experimental study on CO_2 curing for enhancement of recycled aggregate properties. Constr Build Mater 67(4):3–7

Zhang J, Shi C, Li Y, Pan X, Poon CS, Xie ZB (2015) Influence of carboanted recycled concrete aggregate on properties of cement mortar. Constr Build Mater 98(11):1–7

Chapter 101
Recycled Ceramic Fine Aggregate for Masonry Mortar Production

A.C.J. Evangelista, Vivian W.Y. Tam and J. Santos

101.1 Introduction

Producing recycled coarse aggregate is a clear valid option, since various researches has proved that their viable incorporation (Tam 2009; Pacheco-Torgal and Jalali 2010; Zong et al. 2014; Bravo et al. 2015). Bogas et al. (2015) concluded that recycled coarse lightweight aggregate concrete is a potential competitive alternative product to conventional lightweight concrete. Soutsos et al. (2004) stated that recycled aggregates can be used to replace quarried limestone aggregate, usually used in coarse (6 mm) and fine (4 mm-to-dust) gradings to produce concrete building blocks and other precast concrete units. However, the use of recycled fine aggregate from construction and demolition waste has mostly been limitedly used for sub-base in transport infrastructure and the recovery of former quarries by landscaping.

For the reason of limited supply on natural fine aggregate and the saturation of landfill to take the fine fraction of construction and demolition waste, the study of recycled fine aggregate has been conducted by researchers with satisfactory results when they are used in concrete and mortars production (Medina et al. 2014; Saiz Martínez et al. 2016). Ulsen et al. (2013) stated that studies about the use of recycled fine aggregate are still rare even though this fraction represents about half of the weight in construction and demolition waste. In large Brazilian centres,

A.C.J. Evangelista
Civil Engineering Department, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

V.W.Y. Tam (✉)
School of Computing, Engineering and Mathematics, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia
e-mail: vivianwytam@gmail.com

J. Santos
College of Civil Engineering, Shenzhen University, Hangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_101

shortage of sand deposits and the increasing prices by 100% over the last 4 years in the city of Sao Paulo due to long transportation distances is significant. In addition, the production of high fraction in recycled fine aggregate from construction and demolition waste is encouraging technology development for the production of high quality recycled sand for cement-based material.

The production of recycled fine aggregate from the comminution of the entire construction and demolition waste by tertiary crushing influences recycled fine aggregate properties in term of shape, texture, particle size distribution, water absorption and porosity. The masonry mortars manufactured with recycled fine aggregate obtained high absorption capacity, porosity, sorptivity and shrinkage than conventional masonry mortars. This is due to high water absorption capacity of the aggregate, whereas, water content differed greatly from plant to plant. Some researchers reported the difference between oven-dried density and saturated surface-dried density that defines water-retaining capacity of the particles and therefore their water absorption (Rodrigues et al. 2013; Martínez et al. 2013).

Therefore, this paper aims to analyze the influence of recycled fine aggregate for masonry mortar production. Five levels of sand replacement by ceramic waste are investigated, including 0, 20, 30, 50 and 100%. Mortar fresh properties are investigated: consistency, density and entrained air content. Hardened properties are also investigated including density (at 28 days), compressive strength (at 3 days, 7 days and 28 days) and tensile strength (at 3 days, 7 days and 28 days).

101.2 Research Methodologies

101.2.1 Material

Material used in this research includes cement, natural sand, recycled fine aggregate from ceramic waste and water. The recycled fine aggregate is a ceramic waste crushed material used at the renovation of the Materials Laboratory of the Federal University of Rio de Janeiro in Brazil and consists only of ceramic tile waste.

Cement

The binder used in the study is Brazilian type CPV ARI Portland cement (similar to ASTM Type III—high early strength).

Aggregate

Properties of the natural sand and the ceramic waste used are summarized in Table 101.2 according to Brazilian Standards (Brazilian Association of Technical Standards-ABNT) (ABNT 2001, 2003a, b, 2009):

The recycled fine aggregate used in this study is obtained by employing a commercial jaw crusher (model—Queixada 200). The ceramic waste presents an elongated shape, which produces elongate fine aggregate.

The particle density of recycled fine aggregate is 2.38 k/cm^3. Penteado et al. (2016) reported similar results using samples of three different waste, including porcelain tile, porous tile and stoneware tile with densities of 2.35, 2.60 and 2.24 g/cm^3 respectively.

The particle size distribution of natural sand and recycled fine aggregate acquired according to ABNT NBR NM 248 (ABNT 2003). The particle size distribution of directly influences the performance of mortar fresh properties, including workability, consumption of water and binders content.

Water

The water used in the production of mortars came from the supply system of the city of Rio de Janeiro in Brazil. The pH measured from five samples during the experimental period showed consistent values between 6.5 and 6.7.

101.2.2 Mortar Mix Proportions

This study investigates five different recycled fine aggregate replacement percentages including 0, 20, 30, 50 and 100%. For this experimental program, it is taken into consideration requirements of British Standard BS 4551 (BS 2005a) a 1:3 ratio on cement: sand by weight due to the recycled fine aggregate's density is close to the natural fine aggregate's density. This mortar composition is widespread used in Brazil. It is adopted consistency index of 270 ± 10 mm to conserve the water-to-cement ratio for all the mortars production equal to 0.55.

101.2.3 Properties Testing

The experimental program includes tests performed according to ABNT (Brazilian Association of Technical Standards) to evaluate mortars of both fresh and hardened properties. Mortar consistency and workability are evaluated according to ABNT NBR 13276 (ABNT 2005a), the flow table test is conducted for each mixture. Fresh density and air content are also measured according to ABNT NBR 13278 (ABNT 2005b). Regarding the hardened properties, determination of the specific gravity is evaluated according to NBR 13280 (ABNT 2005c), whereas measurements are carried out at the age of 28 days using four cylindrical specimens of 50 mm × 100 mm. Compressive strength is measured at the ages of 3, 7 and 28 days by four cylindrical specimens of 50 mm × 100 mm for each day using a EMIC compressive testing machine with a maximum capacity of 100 ton and a compression load rate of 0.45 ± 0.15 MPa/s (ABNT 2007). Split tensile strength is tested at 3, 7 and 28 days (ABNT 2011) by means of four cylindrical specimens of 50 mm × 100 mm for each day.

101.3 Results and Discussions

Table 101.1 presents the consistency results for each mortar mixture. The results analysis shows that the higher the recycled fine aggregate replacement, the lower is the workability.

The recycled fine aggregate retains more water than natural fine aggregate due to their high absorption rate, which tends to decrease the amount of free water in the mixture. The absorption rate of the recycled fine aggregate is not compensated; however the 50% recycled fine aggregate replacement percentage provides an acceptable workability to masonry mortar application. It is important to notice that this property is according to the ABNT NBR 13276 (ABNT 2005a)—260 ± 5 mm. Other studies (Matias et al. 2014; Silva et al. 2016) reported a mean value of 175 ± 10 mm to mortar consistency.

Moreover, the high recycled fine aggregate replacement percentage contributes for packaging purpose, which leads to a more cohesive mortar with fewer tendencies to segregation between aggregate and cement paste. Importantly, absorption rate for recycled material is not compensated, which contributes to the decrease in the fluidity of fresh mortar. Similar results were reported by Torkittikul and Chaipanich (2010), whereas the results showed that the flow of mortar significantly decreased with the increase of ceramic waste aggregate content. This was due to the angular shape of ceramic waste aggregate, which caused a reduction in the mortar workability and thus was more difficult to compact. Jiménez et al. (2013) also explained the bulk density of fresh mortar decreased with an increase in the replacement percentage when using recycled fine aggregate from ceramic walls because the dry density of recycled fine aggregate was lower than that of the natural fine aggregate used as a reference mortar. On the contrary was observed by Farinha et al. (2015) using sanitary ware waste, whereas was necessary to decreased the mix water content to maintain the consistency at 175 ± 10 mm and the mortar cohesion.

The results of density and entrained air content tests are presented at Table 101.2. It can be seen that the higher the recycled fine aggregate replacement percentage, the lower is the specific gravity of mortar. As density decreases, the amount of air in the mortar increases. These two properties influence the workability of the mortar. Silva et al. (2009) showed similar results and explained those results due to the lower apparent bulk density of ceramic bricks compared to sand.

Table 101.1 Consistency index

Mixture	Consistency (mm)
M1 (100% NFA; 0% RFA)	280
M2 (80% NFA; 20% RFA)	258
M3 (70% NFA; 30% RFA)	253
M4 (50% NFA; 50% RFA)	243
M5 (0% NFA; 100% RFA)	162

Table 101.2 Density and entrained air content test results in the fresh state

Mixture	Density (g/cm^3)	Entrained air (%)
M1 (100% NFA; 0% RFA)	2.17	3.98
M2 (80% NFA; 20% RFA)	2.15	4.02
M3 (70% NFA; 30% RFA	2.13	4.05
M4 (50% NFA; 50% RFA)	2.11	4.09
M5 (0% NFA; 100% RFA)	2.04	4.22

Table 101.3 Results of compressive strength

Mixture	3 days (MPa)	7 days (MPa)	28 days (MPa)
M1 (100% NFA; 0% RFA)	23.5	29.6	36.4
M2 (80% NFA; 20% RFA)	25.5	32.0	39.6
M3 (70% NFA; 30% RFA)	26.8	33.4	43.7
M4 (50% NFA; 50% RFA)	28.4	33.5	45.0
M5 (0% NFA; 100% RFA)	17.8	23.3	28.0

Note NFA is natural fine aggregate; and RFA is recycled fine aggregate

The Brazilian Standard ABNT 13281 (ABNT 2005d) reports a classification gap from 1.40 g/cm^3 to 2.20 g/cm^3 or density >2.00 to masonry mortar.

The entertained air presented a slightly increase (maximum of 6% at M5), as the density decreases. Similar performance were obtained by other researchers (Jiménez et al. 2013; Oliveira et al. 2013) obtained 14% of air content in their tested mortars whit ceramic waste as recycled fine aggregate, reporting that fill within the range of 7–18% recommended by British Standard BS 4721 (BS 2005b).

The compressive strength results averaged by three obtained for each mixture are shown in Table 101.3. It can be seen that increasing the recycled fine aggregate replacement percentage tends to increase the compressive strength. M4 (50% recycled fine aggregate replacement percentage) presents a 20% increase in compressive strength compared with the result without any recycled fine aggregate replacement. The more continuous grain size distribution and the largest amount of recycled fine aggregate presents the enhancement on the particle packing effect and contributes to the a better compaction of the mixtures. Besides that, as the recycled fine aggregate has higher absorption index than natural fine aggregate, there can also occurred an internal curing process resulting in an increase of adherence at the aggregate/paste interface. However, the total recycled fine aggregate replacement percentage shows great damage to the mortar strength, probably a consequence of increased porosity of the mixture by the difficulty of densification fresh, caused by high absorption of recycled fine aggregate. Mixture M5 clearly presents the pieces of recycled fine aggregate with less cohesive mixture.

101.4 Conclusion

In order to contribute to the increased knowledge about the characteristics of recycled fine aggregate on the behavior of mortars, this research contributed to establish that the use of ceramic tile waste as recycled fine aggregate for masonry mortar production as technically feasible. The conclusion of using recycled fine aggregate in masonry mortars in this study were:

- The recycled fine aggregate replacement percentage by up to 50% presented results according to recommended by the ABNT NBR 13276 (ABNT 2005a)—260 ± 5. mm. Considering the workability and homogeneity of the mortar, it is not viable the 100% replacement percentage of the natural sand by recycled fine aggregate.
- Density in the fresh state from 2.00 to 2.22 g/cm^3 was according to NBR 13278 (ABNT 2005). Being classified as mortar "D6" (>2.00 g/cm^3). The entrained air content of 4–6% fills within the range of 7–18% recommended by fill within the range of 7–18% recommended by British Standard BS 4721 (BS 2005b) and ABNT NBR 13278 (ABNT 2005b).
- Apparent density in the hardened state results run into ABNT NBR 13281 (ABNT 2005d). It is classified as mortar "M6" (>1800 kg/m^3).
- Masonry mortar with all percentages of recycled fine aggregate for sand replacement meet the Brazilian Standard requirements of 8 MPa at a curing age of 28 days.

Ceramic tile waste may be used as unconventional materials, replacing sand in masonry mortar production. This study suggested future investigation, considering the complemental data concerning economic benefits for the construction industry. The technical evaluation proved the viability of the reuse of ceramic tile waste without the necessity of sophisticated treatment to the mortar production. Regarding the environmental impact, the results may contribute to motivate a significant reduction of ceramic waste at landfills.

References

ABNT (2001) NBR NM 49: fine aggregate—determination of the organic impurities. ABNT, São Paulo, Brazil

ABNT (2003a) NBR NM 46: Determination of material finer than 75 um sieve by washing. ABNT, São Paulo, Brazil

ABNT (2003b) NBR NM 248: aggregates—Sieve analysis of fine and coarse aggregates. ABNT, São Paulo, Brazil

ABNT (2005a) NBR 13276: mortars applied on walls and ceilings—preparation of mortar for unit masonry and rendering with standard consistence index. ABNT, São Paulo, Brazil

ABNT (2005b) NBR 13278: mortars applied on walls and ceilings—determination of the specific gravity and the air entrained content in the fresh stage. ABNT, São Paulo, Brazil

ABNT (2005c) NBR 13280: mortars applied on walls and ceilings—determination of the specific gravity in the hardened stage. ABNT, São Paulo, Brazil
ABNT (2005d) NBR 13281: mortars applied on walls and ceilings—requirements. ABNT, São Paulo, Brazil
ABNT (2007) NBR 5739: concrete—compression test of cylindrical specimens—method of test. ABNT, São Paulo, Brazil
ABNT (2009) NBR NM 52: fine aggregate—determination of the bulk specific gravity and apparent specific gravity. ABNT, São Paulo, Brazil
ABNT (2011) NBR 7222: concrete and mortar—determination of the tension strength by diametrical compression of cylindrical test specimens. ABNT, São Paulo, Brazil
Bogas JA, de Brito J, Figueiredo JM (2015) Mechanical characterization of concrete produced with recycled lightweight expanded clay aggregate concrete. J Clean Prod 89:187–195. doi: http://doi.org/10.1016/j.jclepro.2014.11.015
Bravo M, de Brito J, Pontes J, Evangelista L (2015) Mechanical performance of concrete made with aggregates from construction and demolition waste recycling plants. J Clean Prod 99:59–74. doi:http://doi.org/10.1016/j.jclepro.2015.03.012
BS 4551:2005 (2005a) Methods of testing mortar screeds and plasters. BSI, London, UK
BS 4721:2005 (2005b) Specification for ready-mixed building mortars. BSI, London, UK
Farinha C, de Brito J, Veiga R (2015) Incorporation of fine sanitary ware aggregates in coating mortars. Constr Build Mater 83:194–206. doi:http://doi.org/10.1016/j.conbuildmat.2015.03.028
Jiménez JR, Ayuso J, López M, Fernández JM, de Brito J (2013) Use of fine recycled aggregates from ceramic waste in masonry mortar manufacturing. Constr Build Mater 40:679–690. doi: http://doi.org/10.1016/j.conbuildmat.2012.11.036
Martínez I, Etxeberria M, Pavón E, Díaz N (2013) A comparative analysis of the properties of recycled and natural aggregate in masonry mortars. Constr Build Mater 49:384–392. doi:10.1016/j.conbuildmat.2013.08.049
Matias G, Faria P, Torres I (2014) Lime mortars with heat treated clays and ceramic waste: areview. Constr Build Mater 73:125–136. doi:http://doi.org/10.1016/j.conbuildmat.2014.09.028
Medina C, Frías M, Sánchez de Rojas MI (2014) Leaching in concretes containing recycled ceramic aggregate from the sanitary ware industry. J Clean Prod 66:85–91. doi:http://doi.org/10.1016/j.jclepro.2013.10.029
Oliveira R, de Brito J, Veiga R (2013) Incorporation of fine glass aggregates in renderings. Constr Build Mater 44:329–341. doi:http://doi.org/10.1016/j.conbuildmat.2013.03.042
Pacheco-Torgal F, Jalali S (2010) Reusing ceramic wastes in concrete. Constr Build Mater 24(5):832–838. doi:10.1016/j.conbuildmat.2009.10.023
Penteado CSG, Viviani de Carvalho E, Lintz RCC (2016) Reusing ceramic tile polishing waste in paving block manufacturing. J Clean Prod 112:514–520. doi:http://doi.org/10.1016/j.jclepro.2015.06.142
Rodrigues F, Carvalho MT, Evangelista L, de Brito J (2013) Physical–chemical and mineralogical characterization of fine aggregates from construction and demolition waste recycling plants. J Clean Prod 52:438–445. doi:http://doi.org/10.1016/j.jclepro.2013.02.023
Saiz Martínez P, González Cortina M, Fernández Martínez F, Rodríguez Sánchez A (2016) Comparative study of three types of fine recycled aggregates from construction and demolition waste (CDW), and their use in masonry mortar fabrication. J Clean Prod. doi:http://doi.org/10.1016/j.jclepro.2016.01.059
Silva J, de Brito J, Veiga R (2009) Incorporation of fine ceramics in mortars. Constr Build Mater 23(1):556–564. doi:http://doi.org/10.1016/j.conbuildmat.2007.10.014
Silva RV, de Brito J, Dhir RK (2016) Performance of cementitious renderings and masonry mortars containing recycled aggregates from construction and demolition wastes. Constr Build Mater 105:400–415. doi:http://doi.org/10.1016/j.conbuildmat.2015.12.171

Soutsos MN, Millard SG, Bungey JH, Jones N, Tickell RG, Gradwell J (2004) Using recycled demolition waste in concrete building blocks. Eng Sustain Proc Inst Civil Eng 157(3):139–148. http://dx.doi.org/10.1680/ensu.2004.157.3.139

Tam VWY (2009) Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. J Clean Prod 17(7):688–702. doi:http://doi.org/10.1016/j.jclepro.2008.11.015

Torkittikul P, Chaipanich A (2010) Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes. Cement Concr Compos 32(6):440–449. doi:http://doi.org/10.1016/j.cemconcomp.2010.02.004

Ulsen C, Kahn H, Hawlitschek G, Masini EA, Angulo SC (2013) Separability studies of construction and demolition waste recycled sand. Waste Manag (New York, N.Y.) 33(3):656–662. http://doi.org/10.1016/j.wasman.2012.06.018

Zong L, Fei Z, Zhang S (2014) Permeability of recycled aggregate concrete containing fly ash and clay brick waste. J Clean Prod 70:175–182. doi:http://doi.org/10.1016/j.jclepro.2014.02.040

Chapter 102
Remaking the Physical Disability Inclusion Score (PDIS) and the Visual Impairment Inclusion Score (VIIS) to Assess the Disability Inclusiveness of Commercial Facilities: A Pilot Study

W.K. Lau, T.Y.M. Lam, W.M. Ho and W.K. Wu

102.1 Introduction

Laid down in Article 9 of the Convention on the Rights of Persons with Disabilities, ratified states are bound to take appropriate measures to ensure persons with disabilities (PWDs) to have equal access to physical environment of different indoor and outdoor facilities (UN 2006). When it comes to regional and local levels, laws against disability discrimination such as Disability Discrimination Ordinance (DDO, Cap 487 of *Hong Kong Laws*) in Hong Kong are enacted to make discrimination against PWDs unlawful. Under the DDO, two examples of discrimination relating to commercial facilities are discrimination against PWDs as a result of unequal access to premises, and discrimination by employers who failed to provide their employees equal access to facilities. Despite the legislative requirements, facilities managers, facility owners, tenants, etc. have yet or just started to realise the importance and value of being disability inclusive and thus failed to make commercial facilities inclusive proactively. If no action is taken to rectify the situation, it means loss of business and talents.

To make built environment more disability inclusive by first being able to tell accessibility of buildings, two tools namely Physical Disability Inclusion Score (PDIS) and Visual Impairment Inclusion Score (VIIS) were previously developed. In contrast with access audit and access appraisal, the PDIS and the VIIS were simple, quantitative and more objective tools to assess respectively the physical disability and the visual impairment inclusiveness of higher education buildings. No

W.K. Lau (✉) · T.Y.M. Lam · W.M. Ho · W.K. Wu
Department of Construction Technology and Engineering, Faculty of Science and Technology, Technological and Higher, Education Institute of Hong Kong (THEi), Tsing Yi, Hong Kong, China
e-mail: wkelau@vtc.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_102

matter whether or not PWDs have received higher education, they will graduate (graduated) from schools, (will) work in different industries and shop in commercial facilities. Meanwhile, disability confidence has more been advocated by governments (e.g. the UK and the Australian governments) and caught attention of multinational corporations (MNCs), facilities managers should put removal of barriers to access and use facilities and management for inclusion on agenda. They are the reasons the PDIS and the VIIS are further developed and applied in commercial facilities.

This paper is organised as follows. First earlier works in building disability inclusiveness assessment will be reviewed in brief. Then research design and components of this study will be described and explained. Followed by this preliminary findings from the pilot study which is made of Non-Structural Fuzzy Decision Support System (NSFDSS) workshops and on-site assessments will be presented. This paper ends with a discussion and conclusions.

102.2 Earlier Works in Building Disability Inclusiveness Assessment

The move to make not only built facilities but also the society as a whole to be disability inclusive founded on the biopsychosocial model which accepts disability to be neither an intrinsic problem of PWDs nor an extrinsic problem of the society alone (Lau 2014). Barrier-free and universal design, as their name suggests, centred on design and physical aspects to include PWDs. Perhaps universal design is the ideal and ultimate design solution to all disability excluding and ageing societies, on the other hand, management actions to include PWDs have largely been ignored and are just budding. Including PWDs by accessible and usable design together with appropriate management actions will be the first step and way out to remove disability exclusion.

In the past and now access audit and appraisal are undertaken to check compliance or to establish the level of accessibility of buildings and environments. Appeared in literature in the past were quite some access audit studies (e.g. McClain et al. 1993; Chard and Couch 1998) that investigated wheelchair accessibility in public buildings. Ormerod (2005) compared the process of two methods and detailed the audit process. Things such as equipment for and areas to be analysed in access audit are described in detail. Wu et al. (2007) adopted the Analytic Hierarchy Process (AHP) to develop a quantitative assessment model to assess building accessibility. Lau (2014) and Lau et al. (2016) used the NSFDSS to develop the PDIS and the VIIS to assess respectively the physical disability and the visual impairment inclusiveness of university buildings in Hong Kong. As disability inclusiveness of a facility depends on its design and the way it is managed, and that management may have inadequately been considered in accessibility assessment, Yau and Lau (2015) pioneered a study in Hong Kong to survey the disability awareness of both practitioners and companies in the property management sector. Input from that study did give hint to the parts management can play to make buildings and environments disability inclusive.

102.3 Research Design

At centre of this research, questions like "what makes commercial facilities disability inclusive", "how to assess the level of disability inclusiveness of commercial facilities" and "what part management can play for commercial facilities to be disability inclusive" are raised. The remaking began with an update of literature review in disability inclusion in built environment, particularly those relating to commercial facilities. Reviewed also is facilities and property management for disability inclusion which is a relatively new topic in the area.

With input from literature review, the PDIS and the VIIS assessment frameworks published in Lau (2014) and Lau et al. (2016) are refined. The refined frameworks were circulated among the pilot respondents for comments. In the discussion with the respondents where those having physical disability were asked about the PDIS (Commercial) framework and those having visual impairment were asked about the VIIS (Commercial) framework, they generally agreed with the frameworks and did not add to the frameworks. They were then asked to weight various assessment attributes in the framework concerned and the weightings were generated by the NSFDSS.

In the main-round study, it is targeted to have at least 80 respondents who are persons with physical disability or visual impairment, building professionals or those without any disability and not working in the building, construction and real estate sectors. In the following, research components of this pilot study under headings of (1) Assessment Hierarchies of PDIS (Commercial) and VIIS (Commercial); (2) Weighting by NSFDSS; and (3) On-site Assessments will be discussed one after one.

102.3.1 Assessment Hierarchies of PDIS (Commercial) and VIIS (Commercial)

Modified from and very much similar to the PDIS and the VIIS, assessment hierarchies of PDIS (Commercial) and VIIS (Commercial) are organised into two separate, five-level hierarchies (Figs. 102.1 and 102.2). The top level is the goal, which is to show the overall physical disability or visual impairment inclusiveness of commercial facilities in a score. The second level is the branch level, which is split into *Design* and *Management* to reflect disability inclusiveness of commercial facilities is determined by both elements. The third level is the category level, and it

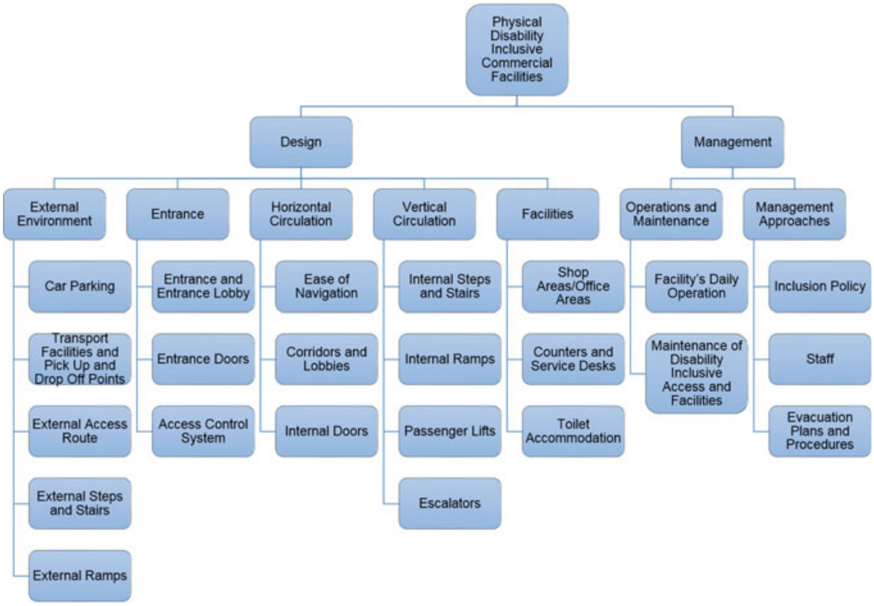


Fig. 102.1 PDIS (Commercial) hierarchy of assessment attributes

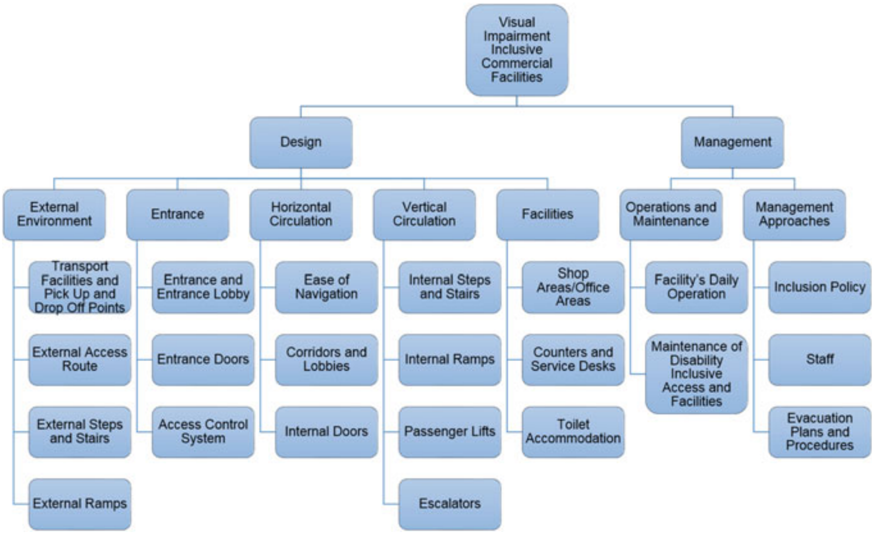


Fig. 102.2 VIIS (Commercial) hierarchy of assessment attributes

consists of *External Environment*, *Entrance*, *Horizontal Circulation*, *Vertical Circulation* and *Facilities* under *Design*, and *Operations and Maintenance* and *Management Approaches* under *Management*. The forth and the bottom level are respectively the attribute and the parameter levels in which individual parameters of a certain attribute are defined and determined by observable items. To give readers a clearer picture of the elements in the assessment hierarchies, items at category, attribute and parameter levels of the hierarchies are presented in Table 102.1.

Table 102.1 Assessment attributes at category, attribute and parameter levels (PDIS (Commercial) as example)

PDIS (Commercial)—design		
Categories	Attributes	Parameters
External environment	Car parking	Provision of Accessible Parking Space
		Design of Accessible Parking Space
	Public Transport Facilities and Pick Up and Drop Off Point	Design of Public Transport Facilities and Pick Up and Drop Off Point
	External Access Route	Design of External Access Route
		Surface of External Access Route
	External Steps and Stairs	Design of External Steps and Stairs
		Handrails of External Steps and Stairs
		Surface of External Steps and Stairs
	External Ramps	Design of External Ramps
		Handrails of External Ramps
		Surface of External Ramps
Entrance	Entrance and Entrance Lobby	Design of Entrance and Entrance Lobby
		Surface of Entrance and Entrance Lobby
	Entrance Doors	Design of Entrance Doors
		Fittings of Entrance Doors
		Operations of Entrance Doors
	Access Control System	Design of Access Control System
Horizontal Circulation	Ease of Navigation	Ease of Navigation
	Corridors and Lobbies	Design of Corridors and Lobbies
		Surface of Corridors and Lobbies
	Internal Doors	Design of Internal Doors
		Fittings of Internal Doors
		Operations of Internal Doors
	Internal Steps and Stairs	Design of Internal Steps and Stairs
		Handrails of Internal Steps and Stairs
		Surface of Internal Steps and Stairs
	Internal Ramps	Design of Internal Ramps
		Surface of Internal Ramps
		Handrails of Internal Ramps

(continued)

Table 102.1 (continued)

PDIS (Commercial)—design		
Categories	Attributes	Parameters
	Passenger Lifts	Provision of Lifts for PWDs
		Design of Lifts (for PWDs)
		Lift Door Operations
		Lift Control Buttons
		Emergency Equipment
	Escalators	Design of Escalators
	Shop Areas/Office Areas	Design of Shop Areas/Office Areas
	Counters and Service Desks	Design of Counters and Service Desks
	Toilet Accommodation	Provision of Accessible Toilets
		Design of Accessible Toilets
		Emergency Call Bell
PDIS (Commercial)—Management		
Categories	Attribute	Parameters
Operations and Maintenance	Facility's Daily Operation	Facility's Daily Operation for Physical Disability Inclusion
	Maintenance of Disability Inclusive Access and Facilities	Maintenance of Physical Disability Inclusive Access and Facilities
	Inclusion Policy	Inclusion Policy
	Staff	Staff
	Evacuation Plans and Procedures	Evacuation Plans and Procedures

Being able to summarise the physical disability and the visual impairment inclusiveness in a score, the Building Inclusiveness Assessment Score (BIAS) was proposed as the prototype of the PDIS and the VIIS family. It is a single, aggregate figure of the ratings (*F*) and weightings (*w*) of all attributes that affect the disability inclusiveness of built facilities:

$$\text{BIAS} = g(w_1, w_2, \ldots, w_n; F_1, F_2, \ldots, F_n) \tag{102.1}$$

where BIAS is the Building Inclusiveness Assessment Score;

w_i (i = 1, 2, …, n) denotes the non-negative weighting of the *i*th inclusion attribute and all w_i's sum to unity;

F_i denotes the (standardised) rating of the *i*th inclusion attribute;

n is the total number of inclusion attributes; and

g(.) is a continuous or discrete function that combines all w_is and F_is.

The merits of presenting the disability inclusiveness of a built facility include convenience and simplicity in use. However, it was later realised that assessing and presenting the overall disability inclusiveness may not convey useful information as persons with physical disability and persons with visual impairment access and use built facilities differently (Lau 2014). Subsequently the BIAS is split into two sub-scores, i.e. the PDIS and the VIIS (later sub-score was renamed to score), and below shows the mathematical representation of PDIS (Commercial):

$$PDIS(Commercial) = \sum_{i=1}^{n} w_i F_i \tag{102.2}$$

As can be seen in (102.2), PDIS (Commercial) [and VIIS (Commercial)] positively correlates with w_i and F_i given w_i and F_i are all positive. So next the computation of w_i by NSFDSS and F_i through on-site assessments will be explained.

102.3.2 Weighting by NSFDSS

To weight the w_is, NSFDSS instead of AHP is used to generate objective and consistent results. In short, the work flow of the NSFDSS is summarised in Fig. 102.3. Since the problem has been identified and broken down into independent elements, and the elements have been grouped into PDIS (Commercial) and VIIS (Commercial) hierarchies, data are to be collected in NSFDSS workshops where respondents will do pair-wise comparisons and assign percentile to each element. Once all the steps in the NSFDSS process are done, both the priority and the weight of categories, attributes and parameters will be generated.

102.3.3 On-Site Assessments

Similar but not the same as before, on-site assessment by PDIS (Commercial) and VIIS (Commercial) begin with a desk study where documents such as site layout and building plans are studied. What follows are on-site evaluations during which visual inspections and measurements of the subject commercial facility will be carried out. Since one of the goals in this remaking is to explore fast-track means to assess building disability inclusiveness, action camera as well as other electronic measuring devices will be used. Once the on-site evaluation is done, structured interviews with management personnel of the visited commercial facilities will be arranged. Relevant information and data will then be extracted from the videos and the collected materials, and will subsequently be verified.

For the ratings F_is, the rating scale of the individual parameters sets the rules to govern the rating process. In most of the cases, a scale of 0–2 is used, where 0 is given to disability excluding design or practices and 2 is given to fully inclusive design or practices. As Lau et al. (2011) added, this scale is different from previous studies where the rating began with the legal minimum, the rating for meeting legal minimum in the PDIS and the VIIS family is 1. In practice, the actual condition may

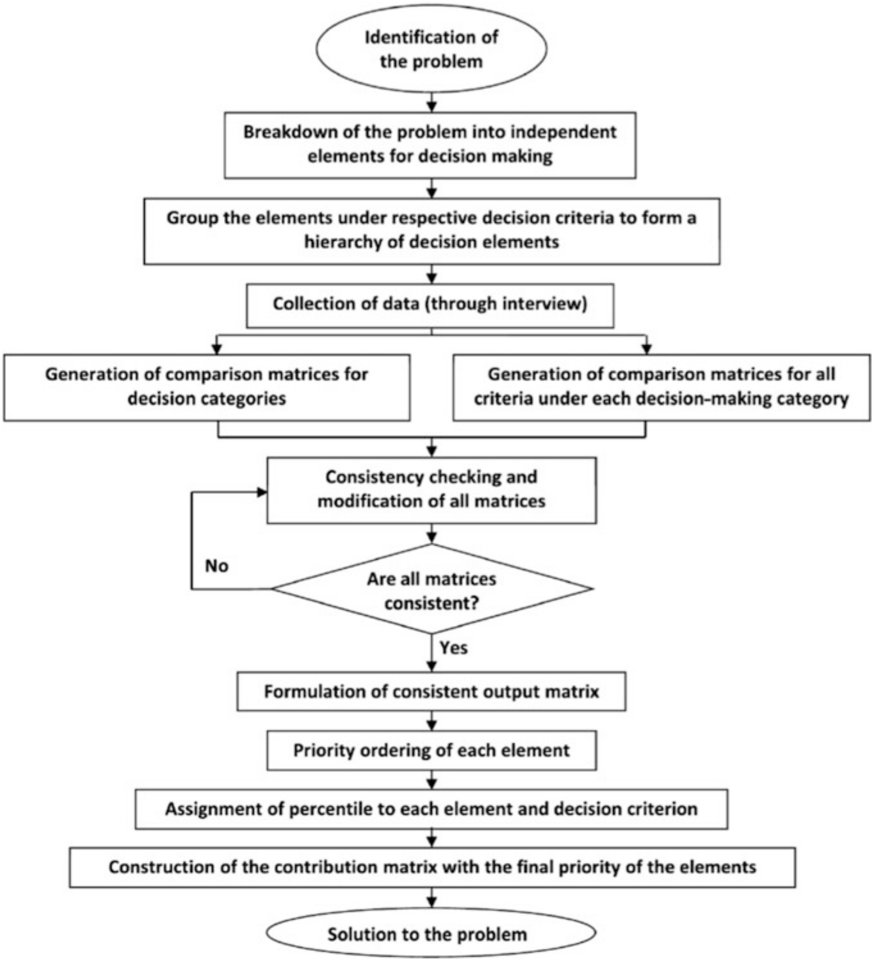


Fig. 102.3 Workflow of the NSFDSS (adapted from Yau 2012)

not follow the rating scale and linear interpolation will be used to calculate the rating. Where an inclusion attribute is qualitative in nature, either dichotomous or multinomial classification will be adopted to decide a rating.

102.4 The Pilot Study and Preliminary Findings

In this pilot study, 4 who are physically impaired (all are wheelchair users) and 2 who are visually impaired were invited to comment on the PDIS (Commercial) or the VIIS (Commercial) framework and weight the assessment attributes. Visits were also made to 6 commercial facilities where quick on-site assessments applying the principles of PDIS (Commercial) and VIIS (Commercial) were done to test the tools. Reported below are the findings from the NSFDSS workshops and the selected non-inclusive areas identified from the on-site assessments.

102.4.1 From NSFDSS Workshops

Similar to the past results where respondents were asked to weight the relative importance of design and management to physical disability and visual impairment inclusive higher education buildings, respondents in this pilot study all view that *Design* is more important than *Management* for commercial facilities to be disability inclusive.

Under *Design*, *Vertical Circulation* and *Entrance* are considered by the physically impaired as more important categories, and the visually impaired see *Facilities* as more important category, that affect the inclusiveness of their respective disability in commercial facilities. Under *Management*, both *Operations and Maintenance* and *Management Approaches* are important from the results, and the physically impaired choose *Operations and Maintenance*, while the visually impaired choose *Management Approaches*, to be more important.

Once a person with physical disability traveled to and entered a commercial facility, *External Ramps* and *Transport Facilities and Pick Up and Drop Off Point* under *External Environment*, and *Entrance Doors* under *Entrance*, are *Design* attributes thought to be more important. When he or she travels around, *Internal Doors* under *Horizontal Circulation*, and *Passenger Lifts* and *Internal Ramps* under *Vertical Circulation*, are the more important *Design* attributes. Among *Shop Areas/Office Areas*, *Counters and Service Desks* and *Toilet Accommodation* of *Facilities*, the result is diverse and it can tell which one is more important only after the main-round study.

Apparently, the way persons with visual impairment access and use commercial facilities is different from that of persons with physical disability, and so do the relative weights given to the attributes. For the visually impaired, *Transport Facilities and Pick Up and Drop Off Point* but not *External Ramps* is the most important *Design* attribute under *External Environment*. To travel around commercial facilities, the visually impaired consider *Ease of Navigation* of *Horizontal Circulation* and *Passenger Lifts* of *Vertical Circulation* to be more important. For *Design* attributes under *Entrance* and *Facilities*, further study is needed to find out the more important ones.

As for *Management* attributes under *Operations and Maintenance*, the physically impaired think both operations and maintenance are important for them to be included in commercial facilities, while the visually impaired pick operations. For *Management Approaches*, once again, further study is needed to find out the more important attributes among *Inclusion Policy*, *Staff* and *Evacuation Plans and Procedures*.

To make things simple and short, the weightings of various assessment attributes at different levels generated by NSFDSS are summarised in Tables 102.2, 102.3, 102.4, 102.5, and 102.6.

102.4.2 From On-Site Assessments

Possibly a common sight in older commercial buildings, steps are present at the entrance of a commercial building and wheelchair users are kept from accessing the building independently. Without an accessible entrance, the property management company of this building provided temporary ramps that may be steep and unsafe for wheelchair users to access the building. Rarely seen is the provision of tactile guide paths and tactile warning strips in both exterior and interior of commercial facilities. In one visited shopping mall, a tactile guide path is provided on the ground floor guiding the visually impaired to walk from the entrance to the passenger lifts. Such tactile guide path, however, is made of raised parts whose shapes are different from the local standard. The visually impaired may be confused when they walk on the path the first time.

For ease of navigation, a finding is that room and shop numbers are often assigned inconsistently. Users no matter with or without disability may sometimes find it hard to navigate around. Directories and signs to provide directional information may be located at places too high for wheelchair users to read, or designed and printed with visually similar colours and small shapes, symbols and fonts that the visually impaired hard to see.

Lifts for PWDs, or accessible lifts as called locally, is another issue that warrants attention. What prevented persons with physical disability to use lifts in commercial facilities without hassle include small size of lift cars and inappropriately located call and control buttons. Very often lift car doors are wide enough to allow a wheelchair to pass through, but small size of lift cars makes manoeuver of wheelchair impossible. Inside lift cars especially those small-sized ones, provision of control panel on one single side and use of overspilled floor buttons posing challenges to those on wheelchair are common. Outside lifts, the locations of some call buttons are too high or objects such as litter bin are present obstructing wheelchair users to press. As voiced by the visually impaired and confirmed in this pilot study, lifts in commercial facilities seldom have full set of audible signals to indicate direction of travel and closing of doors, but merely indication of arrival without specifying the floor level. Besides, the visually impaired may find it hard to press the correct floor button, as in some lifts Braille is not provided next to lift control buttons.

In some visited commercial facilities, there is no provision of accessible toilets for PWDs, or such toilets are not provided on every floor. Where they are provided, they are not up to the latest design standard without sufficient space for wheelchair users to manoeuver and not provided with folding grab rail. In other toilets where persons with ambulant disability or visual impairment usually use, they are seldom

Table 102.2 Weighting of *Design* and *Management* branches

	PDIS (Commercial)			VIIS (Commercial)		
Branches	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6
Design(%)	70	60	60	50	70	70
Management (%)	30	40	40	50	30	30
Total (%)	100					

Table 102.3 Weighting of *Design* attributes generated by NSFDSS

	PDIS (Commercial)				VIIS (Commercial)	
Design categories	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6
External Environment	11.48% (3rd)	10.73% (3rd)	10.53% (4th)	8.93% (4th)	16.82% (1st)	11.17% (4th)
Entrance	14.23% (2nd)	12.02% (2nd)	14.25% (1st)	10.93% (2nd)	11.22% (3rd)	8.90% (5th)
Horizontal Circulation	11.48% (3rd)	10.73% (3rd)	12.89% (2nd)	8.06% (5th)	13.93% (2nd)	13.84% (3rd)
Vertical Circulation	21.33% (1st)	14.51% (1st)	11.80% (3rd)	10.00% (3rd)	11.22% (3rd)	20.75% (1st)
Facilities	11.48% (3rd)	12.02% (2nd)	10.53% (4th)	12.08% (1st)	16.82% (1st)	15.34% (2nd)
Total	70%	60%	60%	50%	70%	70%

Table 102.4 Weighting of *Management* categories generated by NSFDSS

	PDIS (Commercial)				VIIS (Commercial)	
Management categories	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6
Operations and Maintenance	19.51% (1st)	20.00% (1st)	21.00% (1st)	25.00% (1st)	12.75% (2nd)	12.75% (2nd)
Management Approaches	10.49% (2nd)	20.00% (1st)	19.00% (2nd)	25.00% (1st)	17.25% (1st)	17.25% (1st)
Total	30%	40%	40%	50%	30%	30%

Table 102.5 Weighting of *Design* attributes generated by NSFDSS

	PDIS (Commercial)				VIIS (Commercial)	
Design attributes	Respondent 1 (%)	Respondent 2 (%)	Respondent 3 (%)	Respondent 4 (%)	Respondent 5 (%)	Respondent 6 (%)
Car Parking	0.70	1.58	1.27	1.30	–	–
Transport Facilities and Pick Up and Drop Off Point	3.96	2.38	2.35	1.77	5.93	3.82
External Access Route	2.64	2.38	2.59	1.95	4.38	2.55
External Steps and Stairs	0.21	1.75	1.73	1.95	3.96	3.16
External Ramps	3.96	2.63	2.59	1.95	2.55	1.64
Sub-total of “External Environment”	11.48	10.73	10.53	8.93	16.82	11.17
Entrance and Entrance Lobby	7.72	3.18	5.04	3.74	2.65	2.03
Entrance Doors	5.15	5.30	5.04	4.13	3.64	4.13
Access Control System	1.36	3.54	4.17	3.06	4.93	2.75
Sub-total of “Entrance”	14.23	12.02	14.25	10.93	11.22	8.90
Ease of Navigation	1.50	2.89	4.02	2.44	6.12	6.21
Corridors and Lobbies	3.99	3.92	4.44	2.67	4.52	3.05
Internal Doors	5.99	3.92	4.44	2.95	3.29	4.59
Sub-total of “Horizontal Circulation”	11.48	10.73	12.89	8.06	13.93	13.84
Internal Steps and Stairs	1.54	2.54	2.04	2.33	2.07	5.29
Internal Ramps	7.26	4.72	3.43	2.33	1.81	3.52
Passenger Lifts	8.77	4.72	3.79	2.81	3.12	7.16
Escalators	3.76	2.54	2.53	2.54	4.22	4.78
Sub-total of “Vertical Circulation”	21.33	14.51	11.80	10.00	11.22	20.75
Shop Areas/Office Areas	6.46	3.98	3.10	4.27	3.95	4.85
Counters and Service Desks	4.31	3.64	4.09	3.53	8.04	3.93
Toilet Accommodation	0.72	4.40	2.73	4.27	4.83	6.56
Sub-total of “Facilities”	11.48	12.02	3.70	12.08	16.82	15.34

Table 102.6 Weighting of *Management* attributes generated by NSFDSS

	PDIS (Commercial)				VIIS (Commercial)	
Management attributes	Respondent 1 (%)	Respondent 2 (%)	Respondent 3 (%)	Respondent 4 (%)	Respondent 5 (%)	Respondent 6 (%)
Facility's Daily Operation	7.80	10.00	10.50	12.50	7.97	8.92
Maintenance of Disability Inclusive Access and Facilities	11.70	10.00	10.50	12.50	4.78	3.83
Sub-total of Operations and Maintenance	19.51	20.00	21.00	25.00	12.75	12.75
Inclusion Policy	5.34	6.06	5.92	8.05	4.43	4.26
Staff	2.87	7.32	6.54	8.89	7.38	5.88
Evacuation Plans and Procedures	2.29	6.62	6.54	8.05	5.45	7.11
Sub-total of Management Approaches	10.49	20.00	19.00	25.00	17.25	17.25

provided with accessible urinal and constructed with visually contrasting sanitary fitments and finishes. In the meanwhile, counters, or concierges, in commercial facilities are not accessible to wheelchair users as they are often built without a lowered portion.

102.5 Discussion and Conclusions

This study and the things presented in this paper are essentially a continuation of earlier works. The PDIS and the VIIS were endeavours to fill the gap of a simple, quantitative and more objective tool(s) to assess disability inclusiveness of higher education buildings. Being moved forward in this study is to extend the application of the tools to commercial facilities. PDIS (Commercial) and VIIS (Commercial) are remade from the PDIS and the VIIS to indicate the extent to which commercial facilities include persons with physical disability or visual impairment.

Though there are better ways to study the way the physical impaired and the visually impaired access and use commercial facilities, the relative weights generated by NSFDSS did provide useful information to facilities managers, facility owners, etc., at macro level to prioritise the resources in making sensible adjustments and improvements to commercial facilities to include PWDs and to create value. Perhaps this study is still at the pilot stage, the relative weights to be collected in the main-round study can be used to compare with the baseline values in 2012 to tell whether the perceived importance placed by different groups of respondents to inclusion attributes remained the same after years, and whether the perceived importance of inclusion attributes stayed the same in different building type.

As presented in this paper, PDIS (Commercial) and VIIS (Commercial) are comprehensive disability inclusiveness assessment tools that can uncover both non-inclusive areas and management malpractice in commercial facilities. As time goes by when the two tools are more applied, a database recording the non-inclusive areas and management malpractice can be developed. It will not only add knowledge to this area but also serve as practical guide for those engaging in planning, design, construction and management of buildings. The findings in the main-round will also pave way for further study in building management for disability inclusion. Not yet reported but also part of this study, fast-track means to assess building disability inclusiveness using electronic devices such as action camera will be explored. In company with simplified assessment proforma, extensive but quick assessment of physical disability and visual impairment inclusiveness of built facilities using PDIS (Commercial), VIIS (Commercial), or other future tools in the PDIS and the VIIS family, will be made possible.

Acknowledgements The authors gratefully acknowledge the financial support provided by THEi seed grant (project no. 1516119) that made this study possible.

References

Chard G, Couch R (1998) Access to higher education for the disabled student: a building survey at the University of Liverpool. Disabil Soc 13(4):603–623

Lau WK (2014) Assessing the disability inclusiveness of buildings, unpublished Ph.D. thesis, Department of Real Estate and Construction, the University of Hong Kong, Hong Kong

Lau WK, Ho DCW, Yau Y (2011) Assessing the inclusiveness of built facilities: a case study of higher education facilities. In: 18th annual European Real Estate Society conference, 15–18 June 2011, Eindhoven University of Technology, European Real Estate Society

Lau WK, Ho DCW, Yau Y (2016) Assessing the disability inclusiveness of university buildings in Hong Kong. Int J Strategic Prop Manags 20(2):184–197

McClain L, Beringer D, Kuhnert H, Priest J, Wilkes E, Wilkinson S, Wyrick L (1993) Restaurant wheelchair accessibility. Am J Occup Therapy 47(7):619–623

Ormerod M (2005) Undertaking access audits and appraisals: an inclusive design approach. J Build Apprais 1(2):140–152

United Nations (UN) (2006) Convention on the rights of persons with disabilities and its optional protocol, available at, retrieved on 6/7/2016

Wu S, Lee A, Tah JHM, Aouad G (2007) The use of a multi-attribute tool for evaluating accessibility in buildings: the AHP approach. Facilities 25(9/10):375–389

Yau Y (2012) Multicriteria decision making for homeowners' participation in building maintenance. J Urban Plan Dev 138(2):110–120

Yau Y, Lau WK (2015) Disability awareness: a baseline study in the property management sector. Equal Opportunities Commission, Hong Kong

Chapter 103
Research of Housing Price Based on Bid-Rent Theory

Donglang Yang, Zhongfei Cui and Luyao Zhao

103.1 Introduction

103.1.1 General Situation of Kenli County

Kenli County in Shandong Province located in the Yellow River estuary, the hinterland of Shengli Oilfield. At the end of 2007, Kenli County has a total area of 2204 km^2, and a total population of 215,000 people (Li et al. 2007; Tian 2008; Yuan et al. 2010). In recent years, along with the advance of urbanization, the urban area of Kenli County expands unceasingly, which attracts a large number of rural population into the city for work. At the same time, those population stimulated the development of the Kenli County, and promote the demand for housing, which lead to a large number of real estate projects to be build.

Based on the Bid-rent Theory, this study discussed the relationship between the housing price and the distance from the city center of Kenli County to the house, to offer references to developers and residents for houses. Due to the small size, Kenli County conforms to the Monocentric City Assumption. To improve the administrative ability, Kenli County remove the People's Government building and construct a centralized administrative area, among which, banks, schools, shopping malls, hospitals and other facilities are also constructed. Under such a background, this study selected People's Government building as the city center.

D. Yang (✉) · Z. Cui · L. Zhao
Real Estate Institute of Xi'an Jiaotong University, Xi'an, China
e-mail: 570362978@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_103

103.1.2 Bid-Rent Theory (Zhou 2007; Kang 2008)

Bid-rent theory is often used in Urban Economics. The main idea is that land price and demand will change along with the change of its distance to city center. The rent means the fees paid for the use of land in a certain period of time, and bidding rent refers to the biggest cost that buyers would pay for the different location of the land.

Bid-rent Theory was first put forward by David Ricardo, which studied the bid-rent in Agriculture. He thought that the most productive land based on the advantage of the minimum relative productivity of land, and the competition ensures the full advantage of the landlord appears in the form of rent.

William Alonso's bid-rent model is the milestone of neoclassical regional theory. He thought, various activities in land use are rivals to others, the location determinant of these economic activities is the rent they can pay. And through bid-rent, different activities get their location. In urban area, commercial has the highest competition ability and can pay the highest land rent, so commercial land is usually close to the city center. Secondly locates the industrial land, and then the residential areas, finally the agriculture areas. Then the city shows a concentric rings pattern of urban geographical distribution. Referring to Classic bid-rent model of W. Alonso, considering utility function of residents' choices and economic principles, this paper construct the regression model of the relationship between second-hand housing price and its distance to the city center.

103.2 Data and Model

103.2.1 Data

This study selected 550 ordinary second-hand housing (excluding villas, attics, and house with yard) trading information from a real estate transaction platform, on May 24, 2016. We divided these statistics into groups by communities the house belongs to, and counted the housing price (per square meter) in each group. Considering the actual situation of Kenli County, we cut the data groups in which the communities were built before 2003. To ensure the data reflect the actual situation of community effectively, we deleted groups whose sample size is less than 5. We chose Auto Navi Map to measure linear distance from the community to Kenli County People's Government and record the distance. We count 438 samples of 25 communities in total. As Table 103.1 shows.

Table 103.1 Data summary

Community	Floor price (yuan per aquare)	Top price (yuan per aquare)	Mean price (yuan per aquare)	Distance (km)	Sample size
Shengxing	4166	6055	5337.18	0.380	34
Chenxing	2333	5230	4479.31	0.536	15
Yucai	4732	5922	5257.46	0.664	14
Kangju	3750	6190	5164.14	0.680	27
Mingzhu	3968	5714	5165.50	0.840	5
Shui'an	4149	5507	4790.00	1.000	23
Shuxiang	3205	5600	4523.53	1.100	20
Huifeng	4000	6000	5259.88	1.260	33
Xindongfang	3539	5116	4323.13	1.300	31
Kangli	3117	6480	5035.30	1.310	18
Ruichen	3218	5500	4851.64	1.320	22
Yihe	4477	5187	4807.00	1.430	6
Junyuan	3826	5225	4141.36	1.610	11
Xinglong	3000	4230	3819.90	2.000	12
Yongfeng	3396	5538	4222.77	2.200	15
Caifu	3875	5769	4797.88	2.500	25
Shengqiao	3292	5192	4355.00	2.510	18
Heli	2745	4500	3536.13	2.520	22
Tianyi	3723	4909	4117.00	2.600	12
Yixin	4188	5000	4734.00	2.690	10
Shengli	4117	5367	4615.08	2.700	17
Lijing	3821	5238	4568.09	3.140	13
Heping	3000	5000	3829.92	3.200	17
Lihe	3571	4901	4135.67	3.260	12
Jinxia	3986	4632	4338.83	3.480	6
Summarizing	2333	6480	/	/	438

103.2.2 Model

In bid-rent model, we assume that residents pursue the highest total utility among distance from the city center, dwelling area and the consumption (Chen 2014). Assume that distance to city center is t, and the transportation cost is k(t), the land rent is p(t), the using quantity of the land is q, the commodity price is p (constant), and the consumption of commodity is z. Thus, for a family whose income is y, we can get the budget constraint equation as following:

$$y = k(t) + p(t) * q + p * z \tag{103.1}$$

Then we can get the bid-rent model:

$$p(t) = [y - k(t) - p * z]/q \quad (103.2)$$

In bid-rent model, on the same utility level, the residents will choose the lowest rent place. On condition of perfect competition, the highest bidder will get the land renting right (Kang 2008). Finally the housing price and the distance from the city center will be in correlation as shown in Fig. 103.1.

In Fig. 103.1, different lines represent different families' housing choosing bid-rent, on condition of perfect competition, price is determined by the highest bidder, thus it tends to be a lower convex curve.

Due to construction conditions, facilities, personnel composition, floors, interior decoration and other reasons, housing price of different communities with the same distance from the city center could be different. But in combination with following scatter diagram drawn from the statistics, it can be seen that there is a negative correlation between the housing price and the distance. At the same time, as you can see in the scatter diagram, Kenli County's second-hand housing mainly distribute in the position of the 0.6–3 km from the government building.

As shown in Fig. 103.2.

In order to meet the utility function of bid-rent theory, this study determined to use the Asymptotic Regression Model (Deng 2015), model expression is as follows:

$$y = b_0 + b_1 e^{tx} \quad (103.3)$$

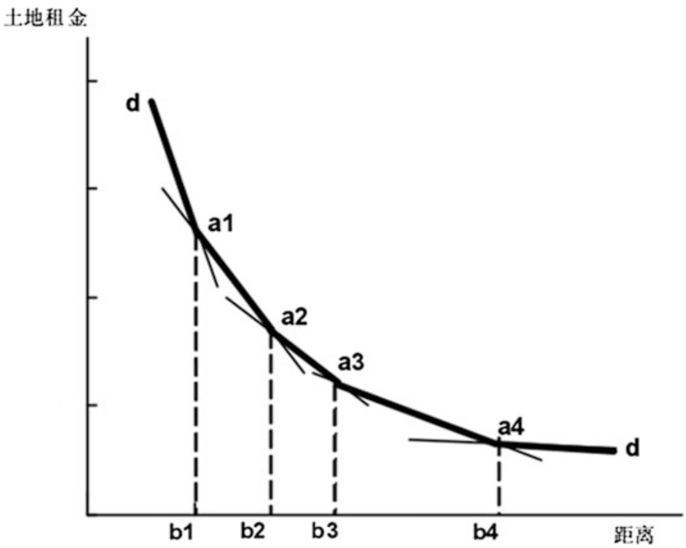


Fig. 103.1 Relationship between housing price and the distance from the city center

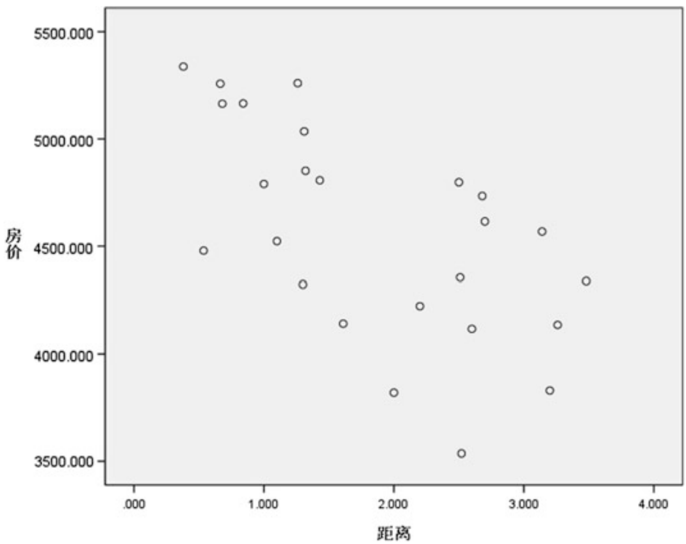


Fig. 103.2 Scatter diagram

Table 103.2 The regression result

Regression coefficient	Regression coefficient value	Standard error
b_0	4057.06	453.487
b_1	1565.95	399.179
t	−0.72	0.693

$R^2 = 0.45$

In the expression, y represents housing price, the unit is yuan per square meters; x represents the distance from the city center, the unit is kilometer; $b_0/b_1/t$ are parameters, e represent the natural logarithm.

103.3 Result

Using SPSS to calculate parameter value, we got the result as follows (Table 103.2).

We can get the regression model of Kenli County's second-hand housing price and its distance from the city center as following equation:

$$y = 4057.06 + 1565.95 * e^{-0.72x}$$

With the help of this model, real estate developers can estimate project investment situation, and determine whether they can gain profit: when the project cost is higher than the estimated value of housing price, the profit tend to be negative, and they should stop investment; when the project cost is lower than the estimated value of housing price, the profit probability tend to be bigger, they can go on with the investment. At the same time, residents can buy houses with the help of the model. When the house is less than the price we estimate, there is high possibility that residents buy cost-effective house, and vice versa.

103.4 Conclusions and Outlook

103.4.1 Main Conclusions

This paper studied Kenli County's second-hand housing price with the change of distance from the city center, referring to bid-rent theory. Through the 438 valid samples of 25 communities, the statistics showed the distribution of Kenli County's community housing. And then we constructed the regression model of housing price variation with distance. The main conclusions show as follows:

(1) Kenli County residential area mainly distributes in the range of 0.6–3 km from the county government. The range of area less than 0.6 km are mainly occupied by county administrative departments, the range of more than 3 km are mainly gardens, factories and rural areas. The lowest housing price is 2333 yuan per square meter, the highest housing price is 6480 yuan per square meter.
(2) Except the relationship between housing price and distance from the city center, the factors such as community management, construction conditions, facilities, personnel composition, floors, interior decoration also play a great role in house price.
(3) The model can provide reference for residents to purchase houses and developers to build houses.

103.4.2 Outlook

The main problems of this study are that the sample size is relatively small, and that using network data, there is certain deviation in samples. In the further study, we can improve it by improving means of gathering data and expanding sample size.

(1) Improve the means of gathering data. In order to ensure the veracity of statistics, we can use field research to collect first-hand statistics, and use transaction value to replace bid price. At the same time, the distance from a community to the city center should be measured precisely.
(2) Expand the samples. We can extend category from residential land to the industrial land and commercial land; we can enlarge the sample size, using the

original data rather than the average value to ensure the accuracy of the model; we can select more factors such as floor, decoration, community construction situation to increase the number of the independent variables and to construct a more accurate model.

References

Chen HW (2014) Urban land use and transport integration model based on bid rent theory. South China University of Technology

Deng Y (2015) Discussion on spatial pattern and rent-law of the land price in Beijing. Nat Resour Rep 02:218–225

Kang QX (2008) Western bid rent theory and its latest development process development. Econ Surv 6:12–14+46

Li XJ, Fang YD, Tian SF, Zhang WW, Zhong WJ (2007) Analysis of obstacles in the Yellow River Delta sustainable land use of Kenli County. Agric Eng 7:71–75

Tian YH (2008) Skills quality training of farmers in new countryside construction. Shandong Agricultural University

Yuan WT, Wang YY, Xiu HM, Huang YF, Hu JT (2010) Environmental sensitivity evaluation at Yellow River Delta. Water Conserv 06:214–218

Zhou JK (2007) Urban land economics. Peking University Press, pp 30–37

Chapter 104
Research on Cost Risks for EPC Project Using Entropy-Weight Evaluation Method

Jiali Liu, Jinjin Chen and Liyin Shen

104.1 Introduction

With the development of global economic integration, construction industry faces increasingly fierce market competition, which can be seen from the increasingly higher requirements for the construction engineering (Pícha et al. 2015). More and more complex and large-scale projects and high-rise buildings are required to be built within an extremely short period (Hao and Lin 2010). Different contracting tasks in different stage, such as design, materials and equipment procurement, project construction. etc., are assigned to different contractors in the traditional contracting mode, which is proven to the reason for the disconnection of management interface, frequent engineering changes, and eventually the delay of project and cost overrun. In order to ensure the quick and efficient completion of the project, general contracting mode for the EPC project emerges accordingly.

General contracting mode for EPC project means that the general contractor selected by the owner takes full charge of the design, procurement, construction and completion of the project (Hong 2014). Owner has only contractual relation with general contractor, therefore its contract management is simple. The general contractor can give full play to the advantages of integration management, shorten the construction period and reduce cost by implementing overlapping activities occurred in different stages at the same time. However, EPC project engages a long process of construction, requesting for complicated engineering techniques and enormous financial investment. Various factors may come up to affect project costs in construction process, so the general contractor faces huge cost risk. Therefore, effective cost risk management become the key to the success of the EPC project.

J. Liu (✉) · J. Chen · L. Shen
Faculty of Construction Management and Real Estate, Chongqing University, Chongqing, China
e-mail: glily0626@163.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_104

This paper is devoted to determine the weight of cost risk factors in implementing EPC project, based on entropy-weight method, evaluate the significant of individual cost risks and the degree that EPC project cost is influenced.

104.2 Research Method

Cost risk management of EPC project aims to achieve planned target project cost. The effect of cost risk management directly determines whether the EPC project can be successfully implemented from economic perspective (Jintao 2013). Because the EPC project is characterized with long process of construction period, large scale and wide scope, the factors which affect the project cost are various, in large quantities and in complex relationship. In order to establish an evaluation index that can comprehensively reflect cost risks of EPC project, a comprehensive research method of combining the checklist method, expert investigation method, expert scoring method, entropy-weight calculation method with ABC classification method is adopted. This integrated method can help analyze the cost risks from both subjective and objective perspectives. The management process of cost risks in EPC project can be divided into three parts, namely risk identification, risk evaluation, and risk response and monitoring (Kerur and Marshall 2012). This study is divided into the following three parts.

Cost risk identification of EPC project is the first and crucial step of the cost risk management. Because the EPC project has long process of construction and cost risk factors change along with the proceeding of the project, cost risk identification of EPC project is a complex and continuous process. The methods of checklist and expert investigation are adopted in combination in identifying cost risks in this paper.

After an extensive literature search, the checklist of cost risks in EPC project is established, as shown in Table 104.1

After establishing risk checklist, the expert investigation method is adopted to comment on and revise the factors in the checklist. Five experts were randomly selected from Expert Library of related fields of EPC project. As a result, a revised checklist is obtained, which is structured in two layers, as shown in Table 104.2.

The evaluation on cost risks for EPC project is followed, providing the link between the identification of cost risks and the response and monitoring of cost risks (Qiang 2014). In order to conduct the risk evaluation, entropy-weight method is adopted. In applying this method, there are three procedures to follow, which are described as follows:

1 Experts in related fields of EPC project construction are invited to rate by score the effect of each risk factor on project cost, including the possibility of occurrence of cost risk and loss severity. The scoring scales are defined in Table 104.3. Score indicates the relative importance of cost risk factors which are at the same level.

Table 104.1 Preliminary checklist of cost risks in EPC project

Cost risk categories	Cost risk factors
Economy risk	The impact of inflation
	Adjustment of relevant monetary policy
	Interest rate rise
Organization risk	Inefficiency of owners coordination management
	Supervision engineer lack of professional quality, especially organization and coordination ability
	The backward management methods that a contractor use
	Supplier or subcontractor fails to fulfill the contractual obligations
Technology risk	Design is unreasonable, with defects
	Application of new technology is not mature, causing rework
	The construction scheme is not consistent with the design proposal
Contract risk	Significant unfair terms in contract
	The ambiguous division of rights and responsibilities among all parties involved
	Terms of the contract is not comprehensive
Nature risk	Harsh climate conditions
	Influence of force majeure such as earthquake
	Unfavorable geological condition
Other risk	Workers in site are of poor professional quality, lacking of safety awareness
	Owner's poor payment ability cause of poor credit
	Budgeters' negligence of duty, resulting in cost estimations or settlements errors
	Equipment's installation and operation are not in accordance with the specification

It is supposed that there exist n risk factors at an index level and m experts. The evaluation result x_{ij} represents the score that the expert i ranks the relative importance of the cost risk factor j. The evaluation matrix can be established accordingly, as shown in formula (104.1).

$$X = (x_{ij})_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{104.1}$$

2 Assign weight for each expert by entropy-weight calculation method. The entropy in information theory indicates the degree of disorder of information (Shengguo 2013). If more information is carried by one factor, the higher certainty, smaller entropy and larger entropy-weight this factor will have. In other

Table 104.2 The revised checklist of cost risks in EPC project

Risk categories (level C)	Risk factors (level F)
Economy risk C_1	Price rise under the fixed price contract F_1
	Foreign exchange control and foreign exchange fluctuation F_2
	The general contractor's financing interest rate rise F_3
Technology risk C_2	Ineffective control of the design progress F_4
	Design defects F_5
	The estimated deviation of the quantities F_6
	Supplier fails to fulfill obligations F_7
	General contractor's poor ability of procurement, organization and management F_8
	Transportation risk of machinery, equipment, and materials F_9
	Sub-contractor fails to fulfill obligations F_{10}
	Construction units ineffectively control the quality, schedule and safety of construction F_{11}
Nature risk C_3	Harsh climate conditions F_{12}
	Unfavorable geological condition F_{13}
Organization risk C_4	Owner's poor payment ability cause of poor credit F_{14}
	The general contractor's financing risk (mainly mean the financing channels and line, etc.) F_{15}
	Poor general contractor's ability of capital optimization F_{16}
	Contract terms are not complete, even have omissions F_{17}
	The ambiguous responsibility definition of claim, change and force majeure F_{18}
	Understanding ambiguity of contract items among all partiesF_{19}
	Cooperation with the owner F_{20}
	Cooperation with the supervision engineer F_{21}
	Cooperation with the sub-contractor F_{22}
	Cooperation with supplier F_{23}
	Cooperation with local authorities F_{24}

Table 104.3 Scoring scales of cost risk factors

Relative importance	Extremely low	Very low	Low	Less low	Middle	Less high	High	Very high	Extremely high
score	1	2	3	4	5	6	7	8	9

words, this factor has the greater influence on decision making. Entropy can be used not only to determine the weight of each index, but also to assign weight to each expert (Shaokuan et al. 2010).

The entropy value of expert *i* is defined as:

$$H_i = -k \sum_{j=1}^{n} f_{ij} \ln f_{ij}, \quad (i = 1, 2, \ldots, m) \tag{104.2}$$

In the formula, $f_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}$, $k = \frac{1}{\ln n}$.

On the other hand, the entropy-weight value of the expert i is defined as:

$$\lambda_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{104.3}$$

In the formula, $0 \leq \lambda_i \leq 1, \sum_{i=1}^{n} \lambda_i = 1$.

(3) Calculate the relative importance of risk factors and rank them. By multiplying the entropy-weight vector ($\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_m)$) of m experts with the evaluation matrix X of relative importance of the cost risk factors in EPC project, the score of each cost risk factor can be derived by the vector:

$$Y = \lambda \cdot X = (y_1, y_2, \ldots, y_n) \tag{104.4}$$

In the formula (104.4), y_j represents the importance of the cost risk factor j.

Because the sum of weight value of y_j at the same level may not equal to one, the relative importance of the factor j needs to be normalized by the following method:

$$\omega_j = \frac{y_i}{\sum_{j=1}^{n} y_i} \tag{104.5}$$

ω_j represents the normalized relative importance of risk factor j.

$\omega_p^{(C)}$ represents the relative importance of the risks at the level C, $\omega_{p,q}^{(F)}$ represents the relative importance of the risks at the level F. So the comprehensive importance of risk factor l is:

$$\omega_l = \omega_{p,q} = \omega_p^{(C)} \omega_{p,q}^{(F)}, \quad (l = 1, 2, \ldots, 24) \tag{6}$$

Based on the evaluation results, risk response and monitoring of cost risk need to be identified. The cost risk factors are ranked according to their relative importance. Then use ABC classification method, also known as primary and secondary factors analysis, to determine main risk factors and secondary risk factors that influence target cost, pertinently taking cost risk response strategy and increasing the probability to achieve the target cost of EPC project cost. Commonly response strategies against risk include risk avoidance, risk mitigation, risk transfer and risk retention (Yin 2010).

104.3 Research Data and Analysis

By using above research methods, the following discussions will be conducted by using the data collected from interviewing five experts. The five experts were invited to rank the relative importance of level-C factors in Table 104.2. The evaluation matrix of relative importance of all risk factors at level C is reached.

$$X = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \left| \begin{array}{cccc} 9 & 8 & 9 & 6 \\ 8 & 7 & 8 & 5 \\ 9 & 7 & 8 & 5 \\ 9 & 8 & 9 & 5 \\ 8 & 8 & 9 & 6 \end{array} \right| \end{array}$$

Using formulas (104.2) and (104.3), the entropy value H_i and entropy-weight value of each expert $\lambda_i^{(A)}$ can be calculated. The calculation results are shown in Table 104.4.

The weight of relative importance of each level-C risk can be calculated based on formulas (104.4) and (104.5):

$$\omega^{(C)} = \left(\omega_1^{(C)}, \omega_2^{(C)}, \omega_3^{(C)}, \omega_4^{(C)}\right) = (0.2890, 0.2513, 0.2845, 0.1752)$$

Similarly, relative importance of level-F risk factors in Table 104.2 can be calculated. The evaluation results are shown in Table 104.5

According to Table 104.5, the ABC classification method is adopted to determine the main cost risks that affect project target cost. The main cost risks can be listed in descending order according to their importance, and the ranking result is: F_{12}, F_1, F_{13}, F_2, F_3, F_7, F_{11}, F_5, F_{10}, F_6, F_8, F_4 and F_9. The cumulative weight of the above thirteen risk factors take up to 82.48% of the total weighting value.

The secondary cost risk factors are identified as F_{14}, F_{15}, F_{19}, F_{17}, F_{18}, F_{20}, F_{16}, F_{22}, F_{21}, F_{23} and F_{24}, in descending order.

Considering the specific cost risk factors which may occur in EPC project, the cost risks can be controlled at an acceptable range by taking active response strategies. Specific response measures include:

Table 104.4 Evaluation result of the relative importance of all risk factors at level C

Experts	H_i	$\lambda_i^{(C)}$
E_1	0.9911	0.1452
E_2	0.9883	0.1909
E_3	0.9843	0.2561
E_4	0.9824	0.2871
E_5	0.9926	0.1207

Table 104.5 Comprehensive evaluation results of cost risk of EPC project

Level C		Level F		Comprehensive weight ω_l	Rank of importance
Risk categories	Relative importance	Risk factors	Relative importance		
C_1	0.2890	F_1	0.4507	0.13025	2
		F_2	0.3077	0.08893	4
		F_3	0.2416	0.06982	5
C_2	0.2513	F_4	0.1110	0.02789	12
		F_5	0.1327	0.03335	8
		F_6	0.1202	0.03021	10
		F_7	0.1440	0.03619	6
		F_8	0.1201	0.03018	11
		F_9	0.1089	0.02737	13
		F_{10}	0.1258	0.03161	9
		F_{11}	0.1373	0.03450	7
C_3	0.2845	F_{12}	0.5696	0.16205	1
		F_{13}	0.4304	0.12245	3
C_4	0.1752	F_{14}	0.1092	0.01913	14
		F_{15}	0.1084	0.01899	15
		F_{16}	0.0912	0.01598	20
		F_{17}	0.0967	0.01694	17
		F_{18}	0.0925	0.01620	18
		F_{19}	0.0988	0.01731	16
		F_{20}	0.0924	0.01619	19
		F_{21}	0.0743	0.01302	22
		F_{22}	0.0879	0.01540	21
		F_{23}	0.0743	0.01302	23
		F_{24}	0.0743	0.01302	24

(1) Risk avoidance. If the probability of occurrence of a cost risk is extremely high and the loss of that risk is extremely serious, such as F_{13}, yet there is no better measure to against that risk or the profit from the taken measure is unable to cover the cost, risk avoidance is adopted by abandoning the project or changing the action plan. Generally, it is not advocated to adopt risk avoidance (Guojiang 2013).

(2) Risk mitigation. If the cost risk is more likely to occur but the loss due to the risk is less, such as F_{11}, F_{10}, F_6 and F_7, cost risk managers should consider take measures of risk mitigation to reduce the negative impact of risk factors, by improving the sense of responsibility of constructors, suppliers and subcontractors and reducing the errors made by staff. The specific circumstances of the EPC project, the risk tolerance of concerned parties and cost management objectives should be taken into consideration when making decision on whether adopt risk mitigation or not.

(3) Risk transfer. When the cost risk is unlikely to occur but the loss it may bring is serious, such as F_1, F_{12}, F_2 and F_3, consideration should be given to transfer the cost risks to an involved or third party by subcontracting, contract or agreement before cost risks occur. This way can effectively prevent loss caused by cost changes. Nevertheless, risk transfer can't eliminate cost risks, but transfer partial or all cost risks to the party who is able to accept more risks.
(4) Risk retention. When the cost risk has low probability of occurrence, slight loss and less threat to target cost, such as F_{20}, F_{21}, F_{22}, F_{23} and F_{24}, the risk managers should consider to absorb the adverse consequences of cost risk events by making use of risk retention measures, such as planning risk retention in advance. If the risk managers are not aware of risk factors that may threaten cost stability, such as F_{17} and F_{18}, they can only accept passively the loss of cost risk, so called non-planned risk retention. Non-planned risk retention is considered the results of mistakes by risk managers and it should be avoided.

Cost risks monitoring is to take measures to monitor and control the cost risks of EPC project (Hanhan and Jie 2010). Because the cost risk factors of EPC project are enormous and the project changes are continuous, the cost risks monitoring and control is a dynamic process including on identification, evaluation and response strategy. The practice of this dynamic risk management process can help identify problems and take corrective measures timely. Thus the aim of cost control for EPC project can be achieved with acceptable level of variation.

104.4 Discussion and Conclusion

The increased cost risks to general contractor are embodied in the fixed-price contract which has taken into account the risk allowance during the process of contract implementation. It is difficult to revise the terms or charge claims once a contract is signed, so higher expectations on contractor's managerial ability for controlling cost risks is imposed. This paper presents a comprehensive evaluation index by using entropy-weight calculation method, checklist method, expert investigation method and ABC classification method. This integrated method can improve the quality of risks evaluation.

However, the evaluation of cost risks in this paper only considers the impacts of individual risks on cost of EPC project. It does not give the evaluation results when individual risks are considered in combination. The internal connection between the risk factors has not be examined. The issues will be investigated in the future study of this research team.

References

Guojiang J (2013) Research on risk management of EPC general contracting project. Tianjin University, Tianjin

Hanhan L, Jie Y (2010) Case analysis of risk management international in EPC project bidding stage. J Int Econ Cooperation 12:53–57

Hao T, Lin P. (2010) The risk management analysis and countermeasures of the EPC general contracting project. J Chongqing Univ Sci Technol Nat Sci Ed 12(1):177–179

Hong Y (2014) Research on economic analysis and cost control strategies of EPC project. Sci Technol Econ Market 6:135–140

Jintao J (2013) Research on the general contractor project risk management under EPC mode. Sci Technol Inf 25:429–432

Kerur S, Marshall W (2012) Identifying and managing risk in international construction projects. Int Rev Law 1:1–14

Pícha J, Tomek A, Löwitt H (2015) Application of EPC contracts in international power projects. Procedia Eng 123:397–404

Qiang C (2014) Research on risk management of international construction projects under EPC mode. World Entrepreneurs: Half-month Ed 1:94–95

Shaokuan C, Denghua Z, Donghai L (2010) General contracting project management theory and practice of hydropower project under EPC mode. China Water Power Press, Beijing, pp 13–15

Shengguo H (2013) Risk prevention under EPC mode. Bus Manage 8:65–67

Yin W (2010) EPC general contracting project risk analysis and management control. Popular Sci Technol 4:87–89

Chapter 105
Research on Dynamic Fuzzy Multi-objective Optimization of Engineering Projects Considering Risk Factors

R.X. Ding, X.Q. Wang, T.T. Han, M.X. Li and N.N. Xia

105.1 Introduction

Management confusion brought by conflicts among project objectives is one of the essential problems in current project management field. It will result in serious loss for project stakeholders, such as lacking explicit control objectives for schedule, quality and cost, unreasonable project implementation planning, quality deficiencies caused by extremely compressed time or low cost. Taking account of the effects multi-objective optimization exerts on cost, schedule and quality, how to resolve the conflicts among multiple objectives in projects and improve the coordination and management of multiple objectives have been attached importance by researchers and practitioners (Mitchell 2007; Tareghian 2007). In addition, nowadays, engineering projects are becoming huge in investment scale, long in period and filled with risks, having more strict requirements in the management of coordination among multiple objectives.

Krettek (2010) believed that multi-objective optimization in engineering projects would affect managers' decision-making behaviours to some extent. When

R.X. Ding · X.Q. Wang · M.X. Li (✉) · N.N. Xia
College of Management and Economics, Tianjin University, Tianjin, China
e-mail: lmx_everyday@163.com

R.X. Ding
e-mail: dingruxi@tju.edu.cn

X.Q. Wang
e-mail: wxq@tju.edu.cn

N.N. Xia
e-mail: ninixia@tju.edu.cn

T.T. Han
China Development Bank Tianjin Branch, Tianjin, China
e-mail: hantaotao@126.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_105

optimizing objectives, risks are one of the key factors that need to be considered. Otherwise, it would be hard for projects to progress as planned and loss would be caused. Therefore, it is necessary to take risks into account. Researchers have done plenty of related studies (Mokhtari 2011; Zhang 2010; Hapke 2000; Liang 2010). In addition, multi-objective sequencing of project participants will change during the life cycle of projects. Thus, when optimizing multiple objectives, it is essential to manage projects from a dynamic perspective. Moreover, analysis and optimization of multiple objectives in engineering projects is fundamental to realize the coordination and equilibrium of these objectives. To sum up, considering the risks and dynamism in projects can make multi-objective optimization more realistic, which will be more meaningful for practice guidance.

In conclusion, on the basis of traditional multi-objective optimization research, this paper will take risks and dynamic environment of projects into account, and in the meanwhile, cost, schedule and quality, the triangle of project management objectives will be optimized. Founded on Fuzzy Set Theory, Utilization Theory, Dynamic Optimization Theory, this paper will propose time-cost and time-quality equilibrium-optimization functions, and thereby build a dynamic fuzzy multi-objective optimization (RDMO) model of engineering projects considering risk factors. Then, the paper will solve the model through a kind of Particle Swarm Optimization algorithm. Finally, the paper gives an example, which can verify the feasibility and reasonability of the model built by this paper.

105.2 The Risk Considered Dynamic Multi-objective Optimal Model (RDMO Model)

In engineering project, the overall goal generally is spending the shortest time with the lowest cost to achieve the highest quality. Cost, schedule and quality, these three basic objects are interrelated in the limited resources as a unified whole. Generally speaking, the quality of engineering projects can be improved to some extent with the increased cost and schedule in the execution stage. However, the relationship among the three objects is not monotonous, as showed in Fig. 105.1.

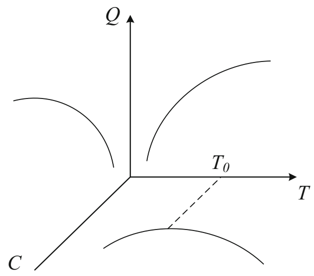


Fig. 105.1 The relationship of cost (C), schedule (T) and quality (Q) in an engineering project

The establishment of RDMO model is based on the following assumptions:

1. An engineering project can be decomposed into a plurality of processes.
2. The critical path of a project and the relationship between the project processes do not change in the execution.
3. Each process has the shortest schedule, the normal schedule and the longest schedule with the corresponding cost and achievable quality, respectively. The schedule of the whole project is the summation of each process in the critical path.
4. The relative quality of each process can be represented by a real number q_i ($q_i \in [0,1]$). The overall quality of the project can be assembled by the weighted average quality of each process.

105.2.1 The Relationship of Cost, Schedule and Quality

105.2.1.1 The Relationship Between Cost and Schedule

Let A be the set of all processes/activities in the critical path of an engineering project, which contains n processes. For each process i ($i = 1, 2, \ldots, n$), we divide the cost c into direct cost c_d (e.g. material fee) and indirect cost c_m (e.g. management fee); t_0 is the normal schedule, t_s is the shortest schedule and t_l is the longest schedule. Correspondingly, c_{d0}, c_{ds} and c_{dl} represent the direct cost of the process i with the normal schedule, the shortest schedule and the longest schedule, respectively. The same symbol meaning for c_{m0}, c_{ms} and c_{ml}. Let c_0 be the total cost of process i under the normal schedule, which is a specific value. Thus, the relationship between the cost and the schedule can be characterized in Fig. 105.2.

As showed in Fig. 105.2, the association between the direct cost c_d and the process schedule is curvilinear. The association between the indirect cost c_m and the process schedule as a liner function. As the total cost c is the summation of c_d and c_m, the relationship between c and the schedule of process i is as a quadratic

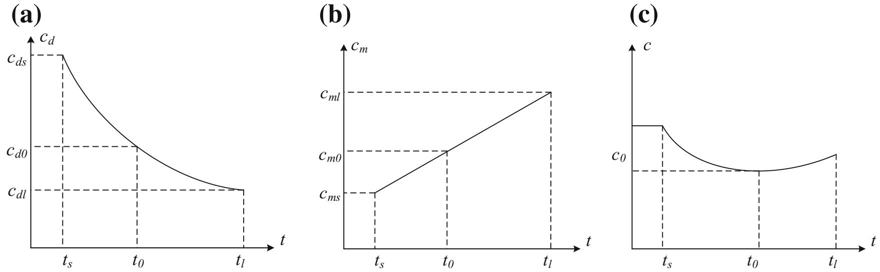


Fig. 105.2 The relationship between the cost and schedule for a process. **a–c** Represent the change of the direct cost c_d, indirect cost c_m and total cost c during the shortest schedule t_s to the long schedule t_l

function. Therefore, for any process i ($\forall\ i \in A$), the relationship between the total cost c_i and schedule t_i can be defined as:

$$c_i = c_{i0} + \beta_{ai}(t_i - t_{i0})^2 + \beta_b(t_i - t_{i0}) \quad (105.1)$$

where c_i represents the actual total cost of the process i, c_{i0} represents the total cost under the optimal schedule t_{i0}. The actual schedule of the process i is represented by t_i. β_{ai} is the marginal direct cost, and β_b is the marginal indirect cost.

Thus, the cost-schedule equilibrium-optimization can be defined as:

$$\begin{aligned} &\min C = \sum_{i=1}^{n} \left[c_{i0} + \beta_{ai}(t_i - t_{io})^2 + \beta_b(t_i - t_{i0})\right] \\ &\min T = \sum_{i \in A} t_i \\ &s.t. \quad \beta_{ai} > 0, \beta_b > 0 \\ &\qquad\quad t_{is} \le t_i \le t_{il} \end{aligned}$$

C and T represent the cost and schedule of the entire engineering project, respectively.

105.2.1.2 The Relationship Between Quality and Schedule

In this paper, we adopt a more commonly used method of quality quantification. Compared with the achievable quality level under the normal schedule, in general, the actual quality level will be respectively reduced and increased along with the shortening and adding of the construction time. However, when making an execution plan for an engineering project, actually, the best quality can be achieved in the normal schedule. In other words, when extending the execution schedule within limit, the increase of the quality is indistinctively; and when compressing the schedule, the decrease of the quality is significant, as showed in Fig. 105.3.

For each process, the same relationship between quality and schedule also consist in. The quantitative relation of quality and schedule for each process can be matched into the following function:

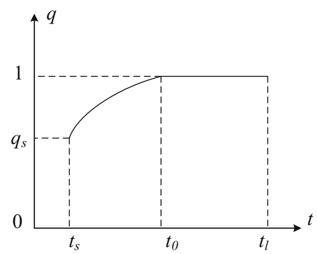


Fig. 105.3 The relationship between the quality (q) and schedule (t) in each process

$$q_i = \begin{cases} \beta_{qi} t_i^{1/2} & t_{is} \le t_i \le t_{i0} \\ 1 & t_{i0} \le t_i \le t_{il} \end{cases}$$

β_{qi} is the marginal quality factor, and $\beta_{qi} = t_{i0}^{-1/2}$.

Thus, the quality-schedule equilibrium-optimization can be defined as:

$$\begin{aligned} &\min -Q = \sum_{i=1}^{n} -\omega_i q_i \\ &\min T = \sum_{i \in A} t_i \\ &s.t. \quad q_i = \begin{cases} \beta_{qi} t_i^{1/2} & t_{is} \le t_i \le t_{i0} \\ 1 & t_{i0} \le t_i \le t_{il} \end{cases} \\ &\qquad \beta_{qi} = t_{i0}^{-1/2} \\ &\qquad t_{is} \le t_i \le t_{il} \end{aligned}$$

Q represents the quality of the entire engineering project.

105.2.1.3 The Cost-Quality-Schedule Equilibrium-Optimization

Based on the analysis of cost-schedule and quality-schedule, the cost-quality-schedule equilibrium-optimization can be summarised as:

$$\begin{aligned} &\min C = \sum_{i=1}^{n} \left[c_{i0} + \beta_{ai}(t_i - t_{i0})^2 + \beta_b (t_i - t_{i0}) \right] \\ &\min -Q = \sum_{i=1}^{n} -\omega_i q_i \\ &\min T = \sum_{i \in A} t_i \\ &s.t. \quad q_i = \begin{cases} \beta_{qi} t_i^{1/2} & t_{is} \le t_i \le t_{i0} \\ 1 & t_{i0} \le t_i \le t_{il} \end{cases} \\ &\qquad \beta_{ai} > 0, \beta_b > 0, \beta_{qi} = t_{i0}^{-1/2} \\ &\qquad t_{is} \le t_i \le t_{il} \end{aligned} \tag{105.2}$$

It need to emphasize that: the total cost is the summation of all processes cost and the overall quality of the project can be assembled by the weighted average quality of each process. Different with the cost and quality, the schedule of the whole project is the summation of each process in the critical path.

105.2.2 The Description of Risk Factors in Engineering Projects

There are various risk factors in the dynamic multi-objective management. In general, the risk situations of an engineering project can be classified into two categories: the uncertain risk factors of the project itself (e.g. the changes of the execution environment, the unstable resource and so on); and the decision-making risks of decision makers (e.g. the risk preferences and risk attitudes of decision makers). Therefore, it is of great importance to consider the risk factors in to the dynamic multi-objective management processing of engineering project.

105.2.2.1 The Description of the Uncertainty Risk Factors

The changeable environment and unstable resource of the engineering project make it uncontainable for the cost, schedule and quality. The Fuzzy Set Theory is widely used in management science, which was proposed by Zadeh (1965) to describe the uncertain situations. In this paper, we use the Triangular Fuzzy Numbers (TFNs) to describe the uncertainty and use the related confidence level theory to describe the decision-making risk.

Definition 1
Let $a = (a^L, a^M, a^U)$ be a triangular fuzzy number (TFN), where $0 < a^L \leq a^M \leq a^U$. The membership function of a is defined as following function $\mu_a(x)$.

$$\mu_a(x) = \begin{cases} \frac{x-a^L}{a^M-a^L}, & x \in [a^L, a^M] \\ \frac{x-a^U}{a^M-a^U}, & x \in [a^M, a^U] \\ 0, & x \in (-\infty, a^M) \cup (a^U, +\infty) \end{cases}$$

According to the definition function $\mu_a(x)$, an example of TFN has been showed in Fig. 105.4.

In order to well describe the uncertainty of the engineering project, for each cost, quality and schedule, we use TFNs to represent the uncertainty of the project. For example, the quality of process i can be represented by $\tilde{q}_i = (q_i^L, q_i^M, q_i^U)$.

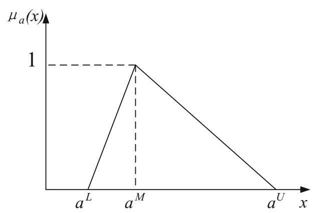


Fig. 105.4 The membership function of a TFN

105.2.2.2 The Description of the Decision-Making Risk Factors

Expect the uncertain risk environment, the risk preferences of decision makers also impact on the project management. We use the confidence level λ to describe the different risk preferences.

Definition 2
For a fuzzy set A, which is defined on U, and a real number λ ($\lambda \in [0, 1]$), the level cut A_λ is satisfied as:

$$A_\lambda = \{x \in U | \mu_{\underset{\sim}{A}}(x) \geq \lambda\}.$$

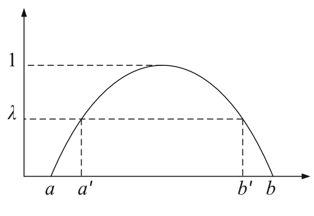
In which, λ is the confidence level and A_λ is the level cut of A with λ. As showed in Fig. 105.5, when take the confidence level be λ, the corresponding level cut is $A_\lambda = [a', b']$.

From the definition of λ-confidence level we can know that, the range of the TFN is getting shrink when λ approaches to 1, which means the higher λ represents the higher accuracy representation of the objects. The more accuracy representation of project objectives, the more optimal results can be got. In other words, different λ-confidence levels can well represent the different risk preferences of decision makers in the management of engineering projects.

Thus, combined with the optimization problem (105.2), take the uncertainty of the engineering project and the risk preferences of decision makers into consideration, the risk considered multi-objective optimization problem can be de denoted as:

$$\begin{aligned}
&\min \tilde{C}^{(\lambda)} = \sum_{i=1}^{n} \left[\tilde{c}_{i0}^{(\lambda)} + \beta_{ai} \left(\tilde{t}_i - \tilde{t}_{i0}^{(\lambda)} \right)^2 + \beta_b \left(\tilde{t}_i - \tilde{t}_{i0}^{(\lambda)} \right) \right] \\
&\min - \tilde{Q}^{(\lambda)} = \sum_{i=1}^{n} -\omega_i \tilde{q}_i^{(\lambda)} \\
&\min \tilde{T}^{(\lambda)} = \sum_{i \in A} \tilde{t}_i^{(\lambda)} \\
&s.t. \quad \tilde{q}_i^{(\lambda)} = \begin{cases} \tilde{\beta}_q \sqrt{\tilde{t}_i^{(\lambda)}} & \tilde{t}_{is}^{(\lambda)} \leq \tilde{t}_i^{(\lambda)} \leq \tilde{t}_{i0}^{(\lambda)} \\ 1 & \tilde{t}_{i0}^{(\lambda)} \leq \tilde{t}_i^{(\lambda)} \leq \tilde{t}_{il}^{(\lambda)} \end{cases} \\
&\qquad \beta_{ai} > 0,\ \beta_b > 0,\ \tilde{\beta}_q = 1/\sqrt{\tilde{t}_{i0}^{(\lambda)}} \\
&\qquad \tilde{t}_{is}^{(\lambda)} \leq \tilde{t}_i^{(\lambda)} \leq \tilde{t}_{il}^{(\lambda)}
\end{aligned} \tag{105.3}$$

Fig. 105.5 The λ-confidence level



105.2.2.3 The Risk Considered Dynamic Multi-objective Optimization (RDMO) Model

As the long-term is one characteristic of engineering projects, the objective management is a dynamic and changeable process with the changeable environment. Thus, multi objective optimization model in dynamic environment is more in line with engineering practice. In a continuous short period, the characteristics of the engineering project are very similar. Therefore, the entire process can be divided into multiple time zones. Hence, the management process can be regard as a combination of a series of multi-objective optimization under a specific environment, which is determined by the different time zones. In this paper, we divide the entire engineering project into *m* stages. For any stage S_k ($k = 1,2,\ldots,m$), the risk considered dynamic multi-objective optimization (RDMO) model is denoted as:

$$
\begin{aligned}
&\min(\tilde{C}^{(\lambda)}, S_k) = \sum_{i=1}^{n} \left[\tilde{c}_{i0}^{(\lambda)} + \beta_{ai}\left(\tilde{t}_i - \tilde{t}_{i0}^{(\lambda)}\right)^2 + \beta_b\left(\tilde{t}_i - \tilde{t}_{i0}^{(\lambda)}\right) \right] \\
&\min(-\tilde{Q}^{(\lambda)}, S_k) = \sum_{i=1}^{n} -\omega_i \tilde{q}_i^{(\lambda)} \\
&\min(\tilde{T}^{(\lambda)}, S_k) = \sum_{i \in A} \tilde{t}_i^{(\lambda)} \\
&s.t. \quad \tilde{q}_i^{(\lambda)} = \begin{cases} \tilde{\beta}_q \sqrt{\tilde{t}_i^{(\lambda)}} & \tilde{t}_{is}^{(\lambda)} \le \tilde{t}_i^{(\lambda)} \le \tilde{t}_{i0}^{(\lambda)} \\ 1 & \tilde{t}_{i0}^{(\lambda)} \le \tilde{t}_i^{(\lambda)} \le \tilde{t}_{il}^{(\lambda)} \end{cases} \\
&\qquad \beta_{ai} > 0,\ \beta_b > 0,\ \tilde{\beta}_q = 1/\sqrt{\tilde{t}_{i0}^{(\lambda)}} \\
&\qquad \tilde{t}_{is}^{(\lambda)} \le \tilde{t}_i^{(\lambda)} \le \tilde{t}_{il}^{(\lambda)}
\end{aligned} \tag{105.4}
$$

For ideally, each stage contains only one process. Thus, in order to facilitate, we regard the execution processes as the multiple stages of the entire engineering project in the following analysis and numerical experiment.

105.2.3 The Description of the Risk Preference of Decision Makers in the RDMO Model

The risk attitude of decision maker is also an important factor to affect the management of engineering projects. The utility theory is a classical theory, which describes the decision-making process under the uncertain risk conditions. In traditional economics theory, the decision makers need to consider the benefits and costs, and use the utility maximization principle to make decision. Therefore, decision maker's risk attitude can be measured by the utility function, and the different risk attitudes can bring different effects, even though they have the same management target. The difference is reflected the utility curve.

Taking the risk attitude of decision makers into account, this paper uses the multi-attribute utility function $u(\tilde{C}, \tilde{T}, \tilde{Q})(u(\tilde{C}, \tilde{T}, \tilde{Q}) \in [0, 1])$ to evaluate the utility. The utility function should satisfy the following actual disciplines: the shorter the schedule is, the bigger the utility is; the lower the cost is, the bigger the utility is; and the higher the quality level is, the bigger the utility is. In addition, because the project management faces many risk factors and uncertainties, the decision makers are inclined to risk aversion, so the total utility function should be a concave function, that is, diminishing marginal utility. Those analyses can be summarised as the following equations:

$$\begin{cases} \frac{\partial u}{\partial C} \leq 0, \frac{\partial^2 u}{\partial C^2} \leq 0 \\ \frac{\partial u}{\partial T} \leq 0, \frac{\partial^2 u}{\partial T^2} \leq 0 \\ \frac{\partial u}{\partial Q} \geq 0, \frac{\partial^2 u}{\partial Q^2} \leq 0 \end{cases} \quad (105.5)$$

To solve the multi-attribute utility function Eq. (105.5), we need to first decompose the three properties of the function as:

$$u(\tilde{C}, \tilde{T}, \tilde{Q}) = u[u(\tilde{C}), u(\tilde{T}), u(\tilde{Q})]$$

Multi attribute utility function can be obtained by multiplicative or additive for decomposition. In this paper, we use the additive approach to decompose $u[u(\tilde{C}), u(\tilde{T}), u(\tilde{Q})]$ into three single-attribute utility functions. After that, a comprehensive evaluation based on multi-attribute utility function will be carried out, which uses each single-attribute utility value. As showed in the following:

$$u[u(\tilde{C}), u(\tilde{T}), u(\tilde{Q})] = \tilde{\omega}_{\tilde{C}} \otimes u(\tilde{C}) + \tilde{\omega}_{\tilde{T}} \otimes u(\tilde{T}) + \tilde{\omega}_{\tilde{Q}} \otimes u(\tilde{Q}),$$

$\tilde{\omega}_{\tilde{C}}$, $\tilde{\omega}_{\tilde{T}}$ and $\tilde{\omega}_{\tilde{Q}}$ is the importance coefficient, which is the emphasis of decision makers on the objectives. The decision makers through the fuzzy language, which can be transformed into the fuzzy importance coefficient, can evaluate the importance coefficient. For example, in the case of 7-scale fuzzy linguistic evaluation information, the relationship between the fuzzy number and the fuzzy number is shown in Table 105.1.

Decision makers generally have averse-risk attitude. For the reason that, after the decomposition, the single attribute utility function should still is a convex function. Therefore, we use the form of convex quadratic function to represent the single attribute utility function as the followings.

Table 105.1 Fuzzy evaluation language with reference to the importance coefficient

Evaluation language	The related TFNs
Not at all important	(0, 0, 0.17)
Fairly unimportant	(0, 0.17, 0.33)
Slightly unimportant	(0.17, 0.33, 0.5)
Neutral	(0.33, 0.5, 0.67)
Slightly important	(0.5, 0.67, 0.83)
Fairly important	(0.67, 0.83, 1)
Very important	(0.83, 1, 1)

$$\begin{cases} u(\tilde{C}) = [\dfrac{D(\tilde{C}^+ - \tilde{C})}{D(\tilde{C}^+ - \tilde{C}) + D(\tilde{C} - \tilde{C}_-)}]^{1/2} \\ u(\tilde{T}) = [\dfrac{D(\tilde{T}^+ - \tilde{T})}{D(\tilde{T}^+ - \tilde{T}) + D(\tilde{T} - \tilde{T}_-)}]^{1/2} \\ u(\tilde{Q}) = [\dfrac{D(\tilde{Q} - \tilde{Q}_-)}{D(\tilde{Q}^+ - \tilde{Q}) + D(\tilde{Q} - \tilde{Q}_-)}]^{1/2} \end{cases} \tag{105.6}$$

In Eq. (105.6) $\tilde{C}^+, \tilde{C}_-, \tilde{T}^+, \tilde{T}_-, \tilde{Q}^+$ and $\tilde{Q}_-$ represent the maximum and minimum of the cost, schedule and quality, respectively.

In this paper we use TOPSIS (Technique for order Preference by Similarity to an Ideal Solution) method to solve the utility functions. The steps are summarised in the Algorithm 1.

Algorithm 1

1. Let $u_+ = u[u_+(\tilde{C}), u_+(\tilde{T}), u_+(\tilde{Q})]$ be the positive ideal solution, and $u_- = u[u_-(\tilde{C}), u_-(\tilde{T}), u_-(\tilde{Q})]$ be the negative ideal solution. In which, e.g., $u_+(\tilde{C})$ and $u_-(\tilde{C})$ means the maximum and the minimum utility value of cost, respectively.
2. Normalize for all $u_j = u[u(\tilde{C}), u(\tilde{T}), u(\tilde{Q})]$, then $u_+ = 1$ and $u_- = 1$.
3. For $\forall u_j = u[u(\tilde{C}), u(\tilde{T}), u(\tilde{Q})]$, compute the distance between positive and negative ideal solutions, $D(u_j, u_+)$ and $D(u_j, u_-)$, respectively.
4. Compute the related similarity degree:

$$R_j = \frac{D(u_j, u_+)}{D(u_j, u_+) + D(u_j, u_-)}. \tag{105.7}$$

5. Then the RDMO model Eq. (105.5) equals to the following optimal function:

$$\max R_j = \frac{D(u_j, u_+)}{D(u_j, u_+) + D(u_j, u_-)}.$$

105.3 An Illustrative Example

We implement the RDMO model into a small-scale single engineering project to verify the effectiveness of the proposed RDMO model. Let P be the project, which has 11 activities/processes, as showed in Fig. 105.6.

The indirect cost of all activities is set as $\beta_b = 0.1$ (as $\beta_b = 1000\$/\text{day}$). The relationship between each activity of project P and other information are listed in Table 105.2. The importance coefficients of the objects are $\tilde{\omega}_{\tilde{C}} = (0.2, 0.3, 0.4), \tilde{\omega}_{\tilde{T}} = (0.4, 0.5, 0.6), \tilde{\omega}_{\tilde{Q}} = (0.1, 0.2, 0.3)$, which are counted by decision makers.

105.3.1 Some Basic Computations

As an illustrative example, we implement RDMO model with the confidence level $\lambda = 0$ in Sects. 3.1.1 and 3.1.2.

105.3.1.1 Computations for Cost, Schedule and Quality

Through the analysis of Table 105.2, the critical path of the project P is: $1 \rightarrow 2$ $3 \rightarrow 5 \rightarrow 6 \rightarrow 8 \rightarrow 10 \rightarrow 11$. Besides, by combining the engineering network planning diagram and the parameters of each activity, the fuzzy time, cost and quality level of the project can be calculated.

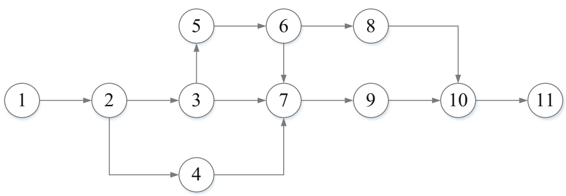


Fig. 105.6 The activity-on-node network diagram of project P

Table 105.2 The relationship between each other activity and the coefficients

Process	Preceding activities	The shortest schedule (t_{is}, day)	Normal schedule (t_{i0}, day)	The longest schedule (t_{il}, day)	Importance (ω_i)	Coefficient of direct cost (β_{ai}, 10,000$/d)	Activity total cost (c_{i0}, 10000$)
1	–	(25, 26, 27)	(28, 30, 32)	(33, 34, 35)	0.05	0.1	(18, 20, 22)
2	1	(45, 46, 47)	(50, 54, 58)	(60, 61, 62)	0.08	0.15	(30, 33, 36)
3	2	(56, 57, 58)	(60, 65, 70)	(72, 73, 74)	0.12	0.07	(38, 40, 42)
4	2	(22, 24, 26)	(28, 35, 42)	(44, 45, 46)	0.06	0.06	(22, 25, 28)
5	3	(35, 37, 39)	(40, 44, 48)	(50, 51, 52)	0.08	0.05	(28, 30, 32)
6	5	(45, 47, 49)	(52, 58, 64)	(66, 67, 68)	0.06	0.08	(36, 38, 40)
7	3, 4, 6	(32, 33, 34)	(35, 38, 41)	(42, 43, 44)	0.06	0.03	(23, 25, 27)
8	6	(65, 66, 67)	(70, 80, 90)	(92, 93, 94)	0.20	0.1	(44, 46, 48)
9	7	(22, 23, 24)	(25, 30, 35)	(36, 37, 38)	0.04	0.08	(19, 21, 23)
10	8, 9	(53, 54, 55)	(58, 64, 70)	(72, 73, 74)	0.10	0.09	(37, 40, 43)
11	10	(60, 62, 64)	(65, 70, 75)	(76, 77, 78)	0.15	0.05	(42, 44, 46)

$$\tilde{T}_{\max} = \sum_{i \in A} \tilde{t}_{il} = (521, 529, 537),$$
$$\tilde{T}_0 = \sum_{i \in A} \tilde{t}_{i0} = (423, 465, 507),$$
$$\tilde{T}_{\min} = \sum_{i \in A} \tilde{t}_{is} = (384, 395, 406).$$

Combined with Eq. (105.1), the total cost of the entire project can be computed by:

$$\begin{aligned} \tilde{C}_{0\max} &= \sum_{i \in A} \tilde{c}_{i(T_{\max})}, \tilde{C}_0 = \sum_{i \in A} \tilde{c}_{i0}, \tilde{C}_{0\min} = \sum_{i \in A} \tilde{c}_{i(T_{\min})}, \\ \tilde{C}_{\max} &= \max(\tilde{C}_{0\max}, \tilde{C}_0, \tilde{C}_{0\min}), \\ \tilde{C}_{\min} &= \min(\tilde{C}_{0\max}, \tilde{C}_0, \tilde{C}_{0\min}). \end{aligned} \tag{105.8}$$

Using Eq. (105.8) and the data in Table 105.2, we can get, under the longest fuzzy schedule, the total cost $\tilde{C}_{0\max}$ is (341.5, 430.3, 594.8); under the shortest fuzzy schedule, the total cost $\tilde{C}_{0\min}$ is (343.7, 442.8, 624.5); and under the normal fuzzy schedule, the total cost $\tilde{C}_0$ is (337, 362, 387). Therefore, the maximum fuzzy total cost $\tilde{C}_{\max}$ is (343.7, 442.8, 624.5), and the minimum total cost $\tilde{C}_{\min}$ is (337, 362, 387).

Otherwise, according to the quality functions showed in Sect. 2.1.2, the lowest fuzzy quality level is (0.860, 0.915, 0.980), and the highest fuzzy quality level is 1.

These numerical results are proved the correctness of the analysis for the relationships of the cost, the schedule and the quality showed in Sect. 2.1 and will be used in the next section.

105.3.1.2 Computations for Utilities

According to Eq. (105.6) and Algorithm 1, the utilities of cost $\tilde{C}$, schedule $\tilde{T}$ and quality $\tilde{Q}$ can be rewritten into Eq. (105.9).

$$\begin{cases} u(\tilde{C}) = \left[\dfrac{D[(343.7, 442.8, 624.5) - \tilde{C}]}{D[(343.7, 442.8, 624.5)^{+} - \tilde{C}] + D[\tilde{C} - (337, 362, 387)]} \right]^{1/2} \\ u(\tilde{T}) = \left[\dfrac{D[(521,529,537) - \tilde{T}]}{D[(521,529,537) - \tilde{T}] + D[\tilde{T} - (384,395,406)]} \right]^{1/2} \\ u(\tilde{Q}) = \left[\dfrac{D[\tilde{Q} - (0.860, 0.915, 0.980)]}{D[\tilde{Q} - (0.860, 0.915, 0.980) + D[(1,1,1) - \tilde{Q}]} \right]^{1/2} \end{cases} \tag{105.9}$$

Then we can get the total utility function of project P, by combine the importance coefficients of the objects, as Eq (105.10):

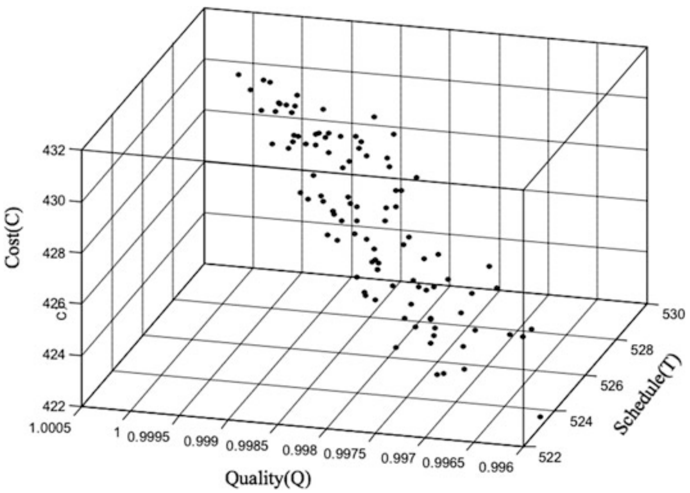


Fig. 105.7 The Pareto optimal solutions with confidence level λ = 0

$$u_j = \tilde{\omega}_{(\tilde{C})} \otimes u(\tilde{C}) + \tilde{\omega}_{(\tilde{T})} u(\tilde{T}) + \tilde{\omega}_{(\tilde{Q})} u(\tilde{Q}). \quad (105.10)$$

105.3.2 The Static Illustrative Example

According to Eq. (105.7) and Algorithm 1, we implement POS algorithm on Matlab to get the optimal solution. The results are showed in Fig. 105.7.

The results showed in Fig. 105.7 indicate the schedule for project P n Pareto solution is focused around in 524–529 days, which is closed to the fuzzy longest schedule. Moreover, in this interval, the cost and quality are increased with the extension of schedule. In conclusion, the distribution of schedule is rounded to the longest schedule, which is related to the preference, that the decision makers are more emphasis on the quality and cost of the project.

105.3.3 The Dynamic Illustrative Example

In this sub-section, we give a dynamic illustrative example for RDMO model with the confidence level $\lambda = 0$. We divide the project P into early (S_1), intermediate (S_2) and late (S_3) three stages, respectively. We suppose that the differences between the three stages is the importance of objects to decision makers. In the early stage S_1 of the project, we assume that quality is the most important object for decision makers. However, in the late stage S_3 of the project, schedule is the most prior object to be

Table 105.3 The weights of each object in each stage

	$\tilde{\omega}_{\tilde{C}}$	$\tilde{\omega}_{\tilde{T}}$	$\tilde{\omega}_{\tilde{Q}}$
S_1	(0.2, 0.3, 0.4)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)
S_2	(0.3,0.4, 0.5)	(0.2, 0.3, 0.4)	(0.2, 0.3, 0.4)
S_3	(0.2, 0.3, 0.4)	(0.4, 0.5, 0.6)	(0.1, 0.2, 0.3)

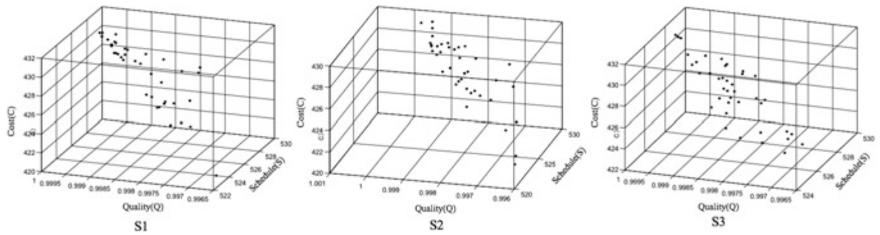


Fig. 105.8 The Pareto optimal solutions of three stages

Table 105.4 The Pareto optimal solutions and the optimal value in each stage

		S_1	S_2	S_3
The serial number of the process	1	(32, 34, 36)	(31.29, 33.29, 35.29)	(32, 34, 36)
	2	(55.86, 59.86, 63.86)	(54.53, 58.53, 62.53)	(56.06, 60.06, 64.06)
	3	(68, 73, 78)	(67.71, 72.71, 77.71)	(66.51, 71.51, 76.51)
	4	(37.73, 44.73, 51.73)	(38, 45, 52)	(38, 45, 52)
	5	(46.95, 50.95, 54.95)	(47, 51, 55)	(47, 51, 55)
	6	(58.23, 64.23, 70.23)	(61, 67, 73)	(56.87, 62.87, 68.87)
	7	(39.98, 42.98, 45.98)	(38.86, 41.86, 44.86)	(40, 43, 46)
	8	(83, 93, 103)	(83, 93, 103)	(83, 93, 103)
	9	(30.76, 35.76, 40.76)	(32, 37, 42)	(32, 37, 42)
	10	(67, 73, 79)	(67, 73, 79)	(67, 73, 79)
	11	(72, 77, 82)	(72, 77, 82)	(72, 77, 82)
Cost		(383.20, 422.53, 520.81)	(389.31, 426.45, 531.83)	(385.22, 421.68, 528.21)
Schedule		(483.05, 525.05, 567.05)	(482.57, 524.57, 566.57)	(480.44, 522.44, 564.44)
Quality		(0.9853, 0.9971, 0.9982)	(0.9832, 0.9962, 0.9980)	(0.9791, 0.9933, 0.9967)

taken into consideration. Therefore, we assign the weights of each object in different stages as showed in Table 105.3. Other parameters are the same with those in static condition. In dynamic condition, the solution process is mainly based on the improved PSO algorithm.

The operation is simulated for 40 times, accordingly, there are 40 Pareto optimal results for each stage. The distribution diagrams of the 40 Pareto optimal results are showed in Fig. 105.8. In addition, we randomly chose a Pareto optimal solution in each stage, the processes combination and the corresponding cost, schedule and quality are showed as Table 105.4.

From the distribution of Pareto optimal results in Fig. 105.8 and Table 105.4, we can know that although the fuzzy degree of results remains the same, the frontier of Pareto optimal results have an apparently change because of the different preference of decision makers. In the early stage of project P, improving quality will bring more utility to decision makers, therefore, quality is comparatively in a high degree; in the late stage of project, the value of schedule is controlled in a low level.

105.4 Conclusions

As the long-term is one characteristic of engineering projects, it is necessary to manage the objects from the perspective of dynamism. Therefore, the paper focuses on the triangle of projects and builds a RDMO model fit for engineering projects with the consideration of dynamism and risk factors, which comprise of both objective risk factors of projects and subjective risk factors from decision-makers. The paper proved the validity of the model through an illustrative example. The results demonstrated that the optimal solution region did not show obvious change while the degree of distribution and ambiguity decreased apparently, when improving the confidence interval. The narrowed ambiguity arranges caused by the decline of uncertainty faced by projects could account for the phenomenon. In addition, the results of example indicated that the Pareto optimal solutions were distinct in various periods. That was because the change of decision-makers' preference could change the object function of the optimization problem. These results stressed the importance of decision-makers' subjectivity.

The further study can focus on the scope of risk factors and dynamic environment. Although the paper considered the objective and subjective risk factors, the impact of those risk factors on engineering projects is complex, which needs further research. The paper divided projects into various periods and assumed that the constraint condition and target function were different in those periods. However, the change of project environment, both inside and outside, is gradual rather than sudden, which also need improving in future studies.

Acknowledgements We appreciate the financial support of the National Natural Science Foundation of China (Grant No. 71172148 and No. 71231006).

References

Hapke M (2000) Pareto Simulated Annealing for Fuzzy Multi-objective Combinatorial Optimization. J Heuristics 6(3):329–345
Krettek J (2010) Preference modeling and model management for interactive multi-objective evolutionary optimization. In: Proceedings of computational intelligence for knowledge-based systems design, Springer, Berlin Heidelberg, pp 574–583
Liang TF (2010) Applying fuzzy goal programming to project management decisions with multiple goals in uncertain environments. Expert Syst Appl 37(12):8499–8507
Mitchell G (2007) An effective methodology for the stochastic project compression problem. IIE Trans 39:957–969
Mokhtari H (2011) Time-cost trade-off analysis in project management: an ant system approach. IEEE Trans Eng Manage 58(1):36–43
Tareghian HR (2007) A solution procedure for the discrete time, cost and quality trade off problem using electromagnetic scatter search. Appl Math Comput 90:1136–1145
Zadeh LA (1965) Fuzzy sets. Inf Control 8(3):338–353
Zhang H (2010) Fuzzy-multi-objective particle swarm optimization for time–cost–quality trade off in construction. Autom Constr 19(8):1067–1075

Chapter 106
Research on Evaluation of Xi'an Shantytown Renovation Projects' Social Benefit

Yang Donglang, Zhao Luyao and Cui Zhongfei

106.1 Introduction

Shantytown made a significant contribution to the economic development in China in the middle and later periods of 20th century. However, with the advancement of urbanization, due to the lack of management, complexity of residents' structure, imperfection of infrastructure, and low utilization efficiency of land resources, shantytown has become a big obstacle to urban planning and economic development (Sun 2007). Therefore, in the 1990s, China has gradually started the shantytown renovation work. Since 2003, Xi'an has accumulated rich experience and reconstruction results in renovation work. However, at present, among those renovation projects, the department in charge tend to focus on project planning and economic benefit can obtain, while renovation projects' social benefit are ignored. At the same time, in the current academia, studies of shantytown's renovation projects' social benefit evaluation are rare and evaluation method is relatively single.

To evaluate the social benefit of shantytown renovation projects, first social benefit should be clearly defined. In recent years, there are a lot of study on social benefit, but different subjects have its own definition, thus there is no uniform definition in academia (Yan 2004). Defined social benefit as "the benefit of the public welfare services that occurrence of something, some kind of behaviour or some engineering program can provide, the specific performance is in improving the environment, providing employment opportunities, promoting the construction of spiritual civilization, regional's coordinating development, economic prosperity,

Y. Donglang · C. Zhongfei
School of Public Policy and Administration, Xi'an Jiao Tong University, Xi'an, China

Z. Luyao (✉)
School of Public Policy and Management, Xi'an Jiao Tong University, Xi'an, China
e-mail: 124853307@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_106

and increasing revenues, facilitating people's life, improving the quality of people's life". (Zhang 2007) considered that "social benefit is a measurement that how human activities meet the needs of public, the social benefit analysis of this activity is the social evaluation of the activity, or social benefit evaluation". (Fu and Li 2008) from the perspective of social reproduction put forward that the connotation of social benefit including three parts, "improving people's welfare level, improving the social civilization and improving people's own reasonable reproduction". China National Committee for Terms in Sciences and Technologies (CNCTST) put forward, "Social benefit refers to a general term of various contributions that a project has made on employment, increasing income, improving the quality of life and other social welfare aspects" (Du 2012).

Sum up above-mentioned points of view, we think that the definition of social benefit should be considered from two aspects, one is its subject is "the shantytown renovation projects", the other one is social benefit should refers to improvements that a project can bring to the environment, employment, economics and people's welfare, etc. Therefore, in this paper, the social benefit of shantytown renovation projects is defined as: in a certain area, the improvement degree of regional economy, coordinated development of urban and rural areas, ecological and cultural environment, dwellers employment level and quality of life that is brought by the shantytown renovation projects.

106.2 Data Gathering and Evaluation Indexes Selecting

106.2.1 Description of Shantytown Renovation Project

Xi'an began shantytown renovation projects in 2003. By the end of 2015, there are 247 shantytown renovation projects, which involving 184,600 households, 636,400 people and total investment of 10.2 billion Dollars. Among these projects, concerning to location and whether the project is accomplished, we selected two projects as our investigation objects. One is a village of 940 households called Ba Fu village, and it began moving back work (after the renovation work is finished, the dwellers will move back to the new apartment) in April, 2012. The other is a community of 1700 households called Yuan Feng, and it began moving back work in November, 2011. Both the two projects are in the area within the second ring road of Xi'an, and the renovation work has accomplished and dwellers have been lived here for three to four years.

106.2.2 Data Gathering

The data used in this study was from an April 2016 investigation of renovation projects' social benefit. This investigation was based on the questionnaire which we designed according to experience of related research and evaluation indexes we selected, the questionnaire included two parts, respondents' basic information and the social benefit evaluation. We selected two typical renovation shantytown as investigation objects, issued questionnaires by means of random sampling, and ultimately recycled 126 questionnaires, after deleting unsatisfactory ones, we kept 121 valid questionnaires, and effective rate is 96.03%.

106.2.3 Evaluation Indexes Selecting

When selecting the evaluation indexes of Xi'an shantytown renovation projects' social benefit, we consulted a large number of literatures, with reference of relative studies and other benefit (economic, land consolidation, etc.) of shantytown renovation (Shen and Qin 2008; Sun 2014), combined with our definition of shantytown renovation projects' social benefit, which is, **"in a certain area, the improvement degree of regional economy, coordinated development of urban and rural areas, ecological and cultural environment, residents employment level and quality of life that is brought by the shantytown renovation projects"**, finally we selected 21 evaluation indexes, and variable name, variable definition, variable measurement are as listed in Appendix 106.1.

In this study, since there are many observed variables and these variables are all associated with a latent variable, in order to get a group of variables which is more concise, we choose factor analysis to analyse. Besides, we can calculate a comprehensive score of the effect of renovation project—social benefit score through using the methodology of factor analysis.

To ensure that the indexes we selected are suitable for factor analysis, we did KMO test and Bartlett Test of Sphericity. KMO (Kaiser-Meyer-Olkin) value is used to compare simple correlation coefficient and partial correlation coefficient between variables, it is generally believed that if KMO value is bigger than 0.6, factor analysis can be performed. Bartlett Test of Sphericity is used to test whether correlation matrix is a unit matrix, in other words all variables are independent. In this study, SPSS software returned a KMO value of 0.736, more than 0.6; and significance of Bartlett Test of Sphericity is 0.000, which is to say we may reject the null hypothesis. Therefore, we think the selected 21 variables are suitable for factor analysis.

To make sure the highest extraction rate of the original variables, this study chose principal component method to extract factors. According to the principle that eigenvalue should be bigger than 1 and referring to scree plot (Fig. 106.1), we extracted 6 common factors from the 21 original variables, the total variance

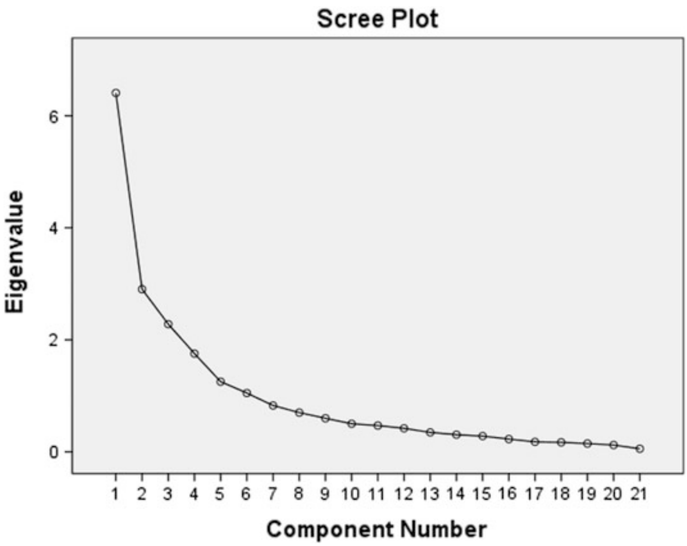


Fig. 106.1 Scree plot

explained is 74.516% (as listed in Table 106.1), which has reached an acceptable level.

Through Extracting factors, we obtained a component matrix, as in Table 106.2. For convenience, we cancel displaying the factor loading whose value is below 0.5. Using the component matrix, we can express every variable in the shape of factors, take variable x1 Family per capita income as an example:

$$x_1 = 0.418F_1 + 0.614F_2 - 0.264F_3 - 0.113F_4 + 0.004F_5 + 0.360F_6 \quad (106.1)$$

The component matrix is the basis of naming factors. Take social range and means variable and social sites and environment variable as an example, this two variables have relatively high load on the fourth factor, shows that the two variables are mainly composed by the fourth factor, and we need to take this into consideration when naming factors. Observing the component matrix, we found it difficult to explain the meaning of each factor, to get factors that have clear meaning and easier to analyse, we try to rotate the component matrix.

To avoid multiple load and improve the explaining ability of factors, and ensure the independence between each factors, this study chose to use Varimax method to rotate the initial component matrix. For convenience, we cancel displaying the factor loading whose value is below 0.5. The result is shown in Table 106.3.

Now we can see relatively clear meanings of each factors. According to the factor loading in Table 106.3, we can name the 6 factors as in Table 106.4.

Table 106.1 Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	6.408	30.516	30.516	6.408	30.516	30.516
2	2.903	13.824	44.340	2.903	13.824	44.340
3	2.280	10.858	55.197	2.280	10.858	55.197
4	1.754	8.354	63.551	1.754	8.354	63.551
5	1.253	5.966	69.517	1.253	5.966	69.517
6	1.050	5.000	74.516	1.050	5.000	74.516
7	0.828	3.941	78.457			
…	…	…	…			
21	0.055	0.263	100.000			

Table 106.2 Component matrix

	1	2	3	4	5	6
Water, power, gas supply	0.729					
Old-age care faculty and service	0.722					
Hygiene condition	0.710					
Popularization of digital TV and Internet	0.680					
Public security situation	0.663					
Heating condition	0.658					
Greening environment	0.647	−0.525				
Convenience of transportation	0.645					
Per capita dwelling area	0.622					
Overall satisfaction with life	0.607					
Opportunity to attend cultural recreational activities	0.545					
Dwelling living comfort	0.525					
Pollution treatment						
Neighbourhood harmony		0.693				
Family per capita income		0.614				
Family employment status			0.731			
Renovation Region economic development			0.639			
Family consumption level			−0.600			
Social sites and environment				0.715		
Social range and means				0.600		
Education condition of children					0.566	
Extraction method: Principal component analysis						
a. 6 components extracted						

Table 106.3 Rotated component matrix

	1	2	3	4	5	6
Greening environment	0.920					
Hygiene condition	0.867					
Pollution treatment	0.751					
Old-age care faculty and service	0.742					
Water, power, gas supply	0.659					
Heating condition	0.647					
Family employment status		0.878				
Renovation Region economic development		0.868				
Convenience of transportation		0.606				
Popularization of digital TV and Internet		0.517				
Neighbourhood harmony			0.784			
Family per capita income			0.657			0.515
Overall satisfaction with life			0.656			
Public security situation	0.521		0.588			
Social range and means				0.858		
Social sites and environment				0.826		
Per capita dwelling area				0.509		
Dwelling living comfort					0.695	
Opportunity to attend cultural recreational activities					0.689	
Family consumption level					0.543	
Education condition of children						0.872

Use regression method provided by SPSS and put out component score coefficient matrix, as shown in Table 106.5. According to Table 106.5, we can set up standardized factor score model, which is:

$$Z(F_1) = -0.042x_1 + 0.069x_2 + \cdots + 0.129x_{21} \tag{106.2}$$

$$Z(F_6) = 0.318x_1 + 0.030x_2 + \cdots - 0.063x_{21} \tag{106.3}$$

To get non-standardized factor score model, multiply each coefficient on the right side of above equation by the square root of the corresponding factor eigenvalues (Zhang 2007), which is:

$$F_1 = \sqrt{4.405}(-0.039x_1 + 0.066x_2 + \cdots + 0.128x_{21}) \tag{106.4}$$

……

Table 106.4 Factors' naming

Factor symbol	Factor name	Main variables composed	Factor loading
F1	Infrastructure construction	Greening environment	0.920
		Hygiene condition	0.867
		Pollution treatment	0.751
		Old-age care faculty and service	0.742
		Water, power, gas supply	0.659
		Heating condition	0.647
		Public security situation	0.521
F2	Regional development	Family employment status	0.878
		Renovation Region economic development	0.868
		Convenience of transportation	0.606
		Popularization of digital TV and Internet	0.517
F3	Life harmony	Neighbourhood harmony	0.784
		Family per capita income	0.657
		Overall satisfaction with life	0.656
		Public security situation	0.588
F4	Social activities	Social range and means	0.858
		Social sites and environment	0.826
F5	Life quality	Dwelling living comfort	0.695
		Opportunity to attend cultural recreational activities	0.689
		Family consumption level	0.543
F6	Education development	Education condition of children	0.872
		Family per capita income	0.515

$$F_6 = \sqrt{1.481}(0.376x_1 + 0.028x_2 + \cdots + 0.016x_{21}) \tag{106.5}$$

Finally, we can set up comprehensive score model as:

$$\begin{aligned} F &= \frac{20.975\%F_1 + 13.312\%F_2 + 12.649\%F_3 + 10.462\%F_4 + 10.067\%F_5 + 7.050\%F_6}{74.516\%} \\ &= 0.281F_1 + 0.176F_2 + 0.170F_3 + 0.140F_4 + 0.135F_5 + 0.095F_6 \end{aligned} \tag{106.6}$$

Table 106.5 Component score coefficient matrix

	1	2	3	4	5	6
Family per capita income	−0.042	−0.039	0.257	0.006	−0.116	0.318
Family consumption level	0.069	−0.193	0.045	−0.162	0.284	0.03
Per capita dwelling area	−0.05	0.123	0.102	0.187	−0.06	0.128
Dwelling living comfort	−0.05	−0.045	−0.154	0.194	0.436	−0.122
Education condition of children	−0.015	0.049	−0.097	0.002	−0.045	0.644
Social range and means	−0.039	0.017	−0.139	0.437	0.063	−0.037
Social sites and environment	0.037	−0.135	0.026	0.408	−0.113	0.023
Neighbourhood harmony	−0.06	−0.079	0.363	0.009	−0.004	−0.189
Overall satisfaction with life	−0.063	0.098	0.246	−0.122	0.101	−0.013
Opportunity to attend cultural recreational activities	−0.077	0.018	0.008	−0.057	0.343	0.092
Pollution treatment	0.206	−0.058	−0.17	0.095	−0.041	0.095
Greening environment	0.258	−0.07	−0.018	−0.018	−0.097	−0.02
Hygiene condition	0.228	−0.013	0.076	−0.059	−0.172	0.052
Water, power, gas supply	0.147	−0.057	0.141	−0.147	0.06	−0.044
Heating condition	0.146	−0.049	−0.088	0.045	0.205	−0.216
Convenience of transportation	0.007	0.197	−0.176	0.022	0.209	0.054
Old−age care faculty and service	0.162	0.022	−0.106	0.028	0.064	0.026
Popularization of digital TV and Internet	0.063	0.131	0.12	−0.07	0.069	−0.268
Family employment status	−0.054	0.355	0.008	−0.085	−0.031	−0.074
Renovation Region economic development	−0.053	0.367	0	0.01	−0.157	0.199
Public security situation	0.129	0.027	0.309	0.055	−0.325	−0.063

106.3 Evaluation Results

In case of scores of each index, which equal to sample mean of each variable, there are 12 indexes have a score above 3 points, among them, the three highest indexes are Popularization of digital TV and Internet (3.74), Water, power, gas supply (3.41), Family consumption level (3.40), which is to say, these three indexes achieve relatively large improvement. The three lowest indexes are Social range and means (2.41), Heating condition (2.48), per capita dwelling area (2.69), suggesting that these three indexes all decreased to some extent.

In case of scores of each factor, in the order from high to low, they are infrastructure construction (85.75), life harmony (77.17), regional development (63.44), life quality (62.26), education development (58.49), and social activities (49.74).

In case of comprehensive score, after calculating, it is 69.35 points, suggesting that from the subjective viewpoint of the residents who live in the shantytown and participate the renovation projects, the projects gained certain social benefit on the whole, but the benefit are not satisfying.

106.4 Conclusion and Suggestion

This study takes two shantytown renovation projects as study objects, uses factor analysis to evaluate its social benefit, and we can draw following conclusions:

(1) In aspects of infrastructure construction, regional development, life harmony, life quality, there are relatively good social benefit.

The evaluation shows, infrastructure construction of shantytown renovation projects obtained an evaluation score of 85.75 points, suggesting that shantytown renovation projects have made considerable improvement in community infrastructure construction, which is mainly represented by green environment, health, pollution control, endowment facilities and services, water supply, power supply, gas supply, heating, and public security situation indexes. Regional development obtained an evaluation score of 63.44, indicating shantytown renovation projects have made some certain improvement in regional economic and society development, which is mainly represented by family employment status, renovation region economic development, Convenience of transportation, popularization of digital TV and Internet indexes. Life harmony obtained an evaluation score of 77.17 points, suggesting that renovation communities are better than before in neighbourhood harmony, family per capita income, overall satisfaction with life and public security situation aspects. Residents' life quality obtained an evaluation score of 62.26 points, indicating shantytown renovation projects also brought improvement to renovation communities in dwelling living comfort, opportunity to attend cultural recreational activities and family consumption level these three aspects.

(2) In aspects of residents' social activities and education development, there are relatively poor social benefit.

Social activity obtained an evaluation score of 49.74 points, suggesting that, residents feel worse in social range, means, sites, environment after the renovation projects, the social benefit is negative. Analyse the reasons, we think it's mainly because shantytown renovation projects have broken the traditional social network and mode among residents in original shantytown, while the residents can't blend in the modern urban social networks. Education development obtained an evaluation score of 58.49 points, it's mainly because this factor includes two variables, family per capita income and education condition of children, and most of the investigated residents believe that, after renovation projects, they lost the income of house renting, the general income is reduced. And therefore family per capita income index is relatively low in score, which lead to the low score of education development of children factor.

Taken together, the social benefit are not bad. The comprehensive evaluation score of shantytown renovation projects is 69.35, belongs to a superior intermediate level. Which is to say shantytown renovation projects have gained obvious benefit.

Shantytown renovation is an important means to complete city functions, improve urban landscape, optimize the allocation of land resources and promote the adjustment of regional industrial structure, meanwhile, it's of great significance to effectively solve the problem of the housing difficulties in low-income families. Research conclusions of this article also provide a revelation about how to proceed with Xi'an city's shantytown renovation work.

Firstly, shantytown renovation projects should ensure that various infrastructure be complete. Shantytown renovation projects should make communities gain improvements in green environment, hygiene condition, pollution control, endowment facilities and services, water supply, power supply, gas supply, heating and other infrastructures, at the same time, the government should pay attention to synchronization of municipal and surrounding public facilities, strive to do so for residents' convenient living.

Secondly, shantytown renovation projects should pay attention to social activities of residents. Shantytown renovation projects should not only consider the project planning, the project Implementation, or the moving back of residents, the residents' development after the project implementation should also be valued. Department in charge should establish and complete community's management organization like committees as soon as possible, provide leisure activity platforms for the residents, often organize cultural and recreational activities within the community, to promote association between the residents.

Thirdly, shantytown renovation projects should be "people oriented". In future's projects planning, department in charge of shantytown renovation work should pay attention to communicate with residents deeply, listen to advice of residents about the renovation project planning and specific scheme. In project implementation, the department in charge should ensure the renovation speed, and more importantly, ensure the quality of housing, let people live at ease. Meanwhile, urbanization is not only about land and residence registration, but also about people, when renovation projects shift land's property right and residents' residence registration type, it should push the residents actively blend into city life as well.

Appendix Social Benefit Evaluation Indexes Table

Variable symbol	Variable name	Variable definition	Much worse than before	A little worse than before	Almost like before	A little better than before	Much better than before
x_1	Family per capita income	family income/family size	1	2	3	4	5
x_2	Family consumption level	Consuming ability	1	2	3	4	5
x_3	Per capita dwelling area	House area/ family size	1	2	3	4	5
x_4	Dwelling living comfort	Degree of comfort	1	2	3	4	5
x_5	Education condition of children	Quality of school and convenience of access to school	1	2	3	4	5
x_6	Social range and means	Interpersonal range and diverse means of social activities	1	2	3	4	5
x_7	Social sites and environment	The environment of the social sites	1	2	3	4	5
x_8	Neighbourhood harmony	Do you get on well with your neighbour	1	2	3	4	5
x_9	Overall satisfaction with life	Subjective sensation of life satisfaction	1	2	3	4	5
x_{10}	Opportunity to attend cultural recreational activities	Access to cultural recreational activities	1	2	3	4	5
x_{11}	Pollution treatment	Treatment of effluent	1	2	3	4	5
x_{12}	Greening environment	Greening of the community	1	2	3	4	5
x_{13}	Hygiene condition	Treatment of rubbish	1	2	3	4	5
x_{14}	Water, power, gas supply		1	2	3	4	5

(continued)

(continued)

Variable symbol	Variable name	Variable definition	Much worse than before	A little worse than before	Almost like before	A little better than before	Much better than before
x_{15}	Heating condition		1	2	3	4	5
x_{16}	Convenience of transportation		1	2	3	4	5
x_{17}	Old-age care faculty and service	Are there any old-age care faculty and service in community	1	2	3	4	5
x_{18}	Popularization of digital TV and Internet	Do you install digital TV and Internet	1	2	3	4	5
x_{19}	Family employment status	How many your family members are employed	1	2	3	4	5
x_{20}	Renovation Region economic development	Do you think economic development turns up	1	2	3	4	5
x_{21}	Public security situation		1	2	3	4	5

References

Du Y (2012) A study of social benefit of community education. Mod Distance Educ Res (In Chinese) 06:3–9

Fu H, Li J (2008) Social benefit analysis of construction projects. Mod Manag Sci (In Chinese) 04:25–26

Shen J, Qin M (2008) An exploration of how to analyse comprehensive benefit and construct evaluation indexes system of urban village renovation. Rural Econ Sci-Technol (In Chinese) 01:37–38

Sun X (2007) Study on rebuilding the squatter settlements in Jinan City (In Chinese). Shandong Normal University, Master

Sun Z (2014) Evaluation of Shantytown land consolidation benefit research (In Chinese). Master, Central China Normal University, Wuhan

Yan L (2004) A study on social benefit evaluation of railway acceleration (In Chinese). Master, North China University of Technology, Beijing

Zhang M (2007) A exploration research on social benefit: theory, indicator system, method (In Chinese). Master, Lanzhou University

Chapter 107
Research on Performance of Construction Enterprises Based on Informatization and Contract Management

Bing Zhang and Sujie Hu

107.1 Introduction

Globally, construction industry informatization is very low, its informatization rate is 0.3%, however, compared with other countries, China's construction industry informatization rate is only about 0.03%, which is one tenth of the international informatization rate (Tan et al. 2016), what's worse, most construction enterprises' informatization in China is still in a backward state (Zhu and Ren 2006). Under this circumstance, the State Council proposed construction enterprises should take active measures to push the development of information technology and pay more attention to its informatization for which could enhance their vitality and competitiveness.

Furthermore, informatization is associated with management modernization. Promoting informatization could improve the condition of contract management level in construction enterprises. In addition, contract management is the center of all the works in construction industry. The development of contract management informatization in construction industry is moving to use modern information

Foundation This research was funded by Jiangsu College of Philosophy and Social Science Funds (Grant Nos. 2016SJB630101), and Yangzhou University Funds (Grant Nos. FFCL15B04).

B. Zhang
College of Civil Science and Engineering of Yangzhou University, Yangzhou, China

B. Zhang
School of Economics and Management of Tongji University, Shanghai, China

S. Hu (✉)
Master of School Management, Expert in Construction Management,
Wuhan University of Technology, Wuhan, China
e-mail: 18801923577@126.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_107

technology to track and integrate contract information, then realize effectual allocation of resource and improve enterprise benefits.

Thus, in order to optimize and realize the innovation of construction industry, construction enterprises should combine contract management with information technology to enhance their competitiveness and performance. Considering there is lack of analysis of relationship between informatization, contract management and performance in construction industry, this research would fill the gap by examining the relationship of informatization, contract management and enterprise performance via structural equitation model. The rest of this article is structured as follows. In Sect. 107.2 we discuss the literature and theory model of the paper. Section 107.3 conducts our empirical study via questionnaire survey and structural equation. The last section would conclude the article.

107.2 Theoretical Model and Research Hypothesis

107.2.1 Theoretical Model

Kluver (2010) defined informatization as a process whereby information and communication technologies transform economic and social relationships to minimize cultural and economic barriers. Information technology have greatly improved productivity in all sectors of industry, which could replace labor-intensive actions and is a key corporate resource. Similarly, informatization is widely recognized as facilitating not only effective project management but also automation in construction industry (Jung et al. 2004). In addition, informatization is often associated with management modernization, which is often viewed as a modernization process, and the relationship between informatization and modernization is complex and ambiguous (Frissen 1992).

Contract management of construction is a dynamics progress, which has the characteristics of great information volume, rapidly changing information and complicated factors. Thus informatization has a great potential value on contract management in construction industry (Yan et al. 2015). Incidentally, informatization could improve performance of construction enterprises. Yu et al. (2007) pointed out level of informatization is one of the most important factors influencing performance. And information technology degree of use is the five key performance outcome (Thomas et al. 2001). Furthermore, project success has been influenced by contract management, and essentially contract management had a positive correlation with project performance, which could accounted for almost 66% variation in project performance (Mutua et al. 2014).

Thus, we could find that enterprise informatization do help to improve the efficiency of contract management, which could maximize the benefit of construction engineering and its performance. To this end, this research put forward a hypothesis model that enterprise informatization produces an effect on enterprise performance by affecting enterprise contract management. The relationship of the three concepts shows in Fig. 107.1.

107.2.2 Index Construction

According to the principle of constructing index based on interviews of top managers from five large construction enterprises in Yangzhou city, this paper establishes measurement indicators of enterprise informatization, enterprise contract management and enterprise performance. The three parts contain eight latent variables, which correspond to eight second-class indexes: awareness of informatization, information appliance, and application level of informatization, contract organizing and management system, quality of management staff, application level of contract management, behavior performance and outcome performance, which would be discussed in more details below.

The index system of enterprise informatization concludes three modules: awareness of informatization, information appliance and application level of informatization. The index system of contract management is divided into 3 dimensions: contract organizing and management system, quality of management staff and application level of contract management, and enterprise performance is divided into behavior performance and outcome performance. Table 107.1 shows the details.

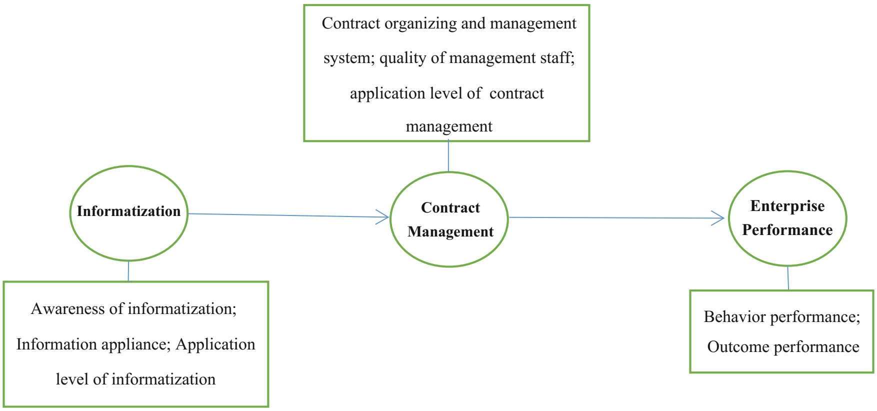


Fig. 107.1 Theoretical model

Table 107.1 Index system

First class index	Second class index	Code
Enterprise informatization	Awareness of informatization	AI
	Information appliance	IA
	Application level of informatization	ALI
Enterprise contract management	Contract organizing and management system	COMS
	Quality of management staff	QMS
	Application level of contract management	ALCM
Enterprise performance	Behavior performance	BP
	Outcome performance	OP

107.2.3 Research Hypothesis

There are many literatures discussed the three factors, and lots of papers have begun to discuss the relationship of those factors, Table 107.2 gives some literatures which are representational.

Based on the above analysis and summary of theories and the index system, this paper establishes the hypothesis model of contract management of construction industry in information mode, and puts forward the following hypothesis:

H1: Awareness of informatization has a significant effect on contract organizing and management system.
H2: Awareness of informatization has a significant effect on quality of management staff.
H3: Awareness of informatization has a significant effect on application level of contract management.

Table 107.2 Research summary for hypothesis

Scholar	Research content
Liu (2015)	Awareness of modern management plays an increasingly important role in establishing a stable management institution and organization
Zhan (2012)	Improving the awareness of informatization to cultivate excellent leaders, which can promote enterprise contract management
Ma (2015)	Strengthening construction of information is the basis and guarantee of contract management
Yan (2013)	Applying information technology to management promotes contract management
Sun et al. (2008)	Organizing and management system of contract management have a positive impact on enterprise performance
Zhao and Guo (2012)	Quality of management staff is the basis and guarantee of improving enterprise performance
Zhao and Chen (2006)	There is no essential difference between the performance of contract management and enterprise performance

H4: Information appliance has a significant effect on application level of contract management.
H5: Application level of informatization has a significant effect on application level of contract management.

107.3 Research Method and Empirical Analysis

The research process consists of three types. First, a thorough literature review to identify three constructs. Second, the use of literature review and interviews with experienced practitioners to establish theory model, eight second-class indexes and hypotheses. Third, a questionnaire survey method was used to verify and investigate the model.

107.3.1 Data Collection and Verification

The questionnaire survey was developed based on the eight second-class indexes with 5-point Likert-type scale (1 = significant unimportant, 5 = significant important). In order to maximize the number of respondents, help was sought from Yangzhou Construction Association. A total of 240 questionnaires were distributed, 225 were returned, of which 18 were discarded due to incomplete information, the remaining 207 valid were recorded and used for the analysis. Tests of validity and reliability showed the minimum Cronbach'α of eight latent variables is 0.784 and KMO of the scale is 0.901, the value of significance level is close to 0, which meets the requirement of 0.05, indicating the data is qualified.

107.3.2 Model Building and Verification

This research established an original model based on the theory model shown in Fig. 107.2, which contains three exogenous latent variables: awareness of informatization, information appliance and application level of informatization, among these are 17 observational variables whose residual errors named e11–e35. Then endogenous variables consist of contract organizing and management system, quality of management staff, application level of contract management, behavior performance and outcome performance, their residual errors are e41–e85. Residual errors of eight latent variables are z1–z8.

After establishing the original model, the survey results were conducted by SPSS Amos 18.0, the results are shown in Table 107.3.

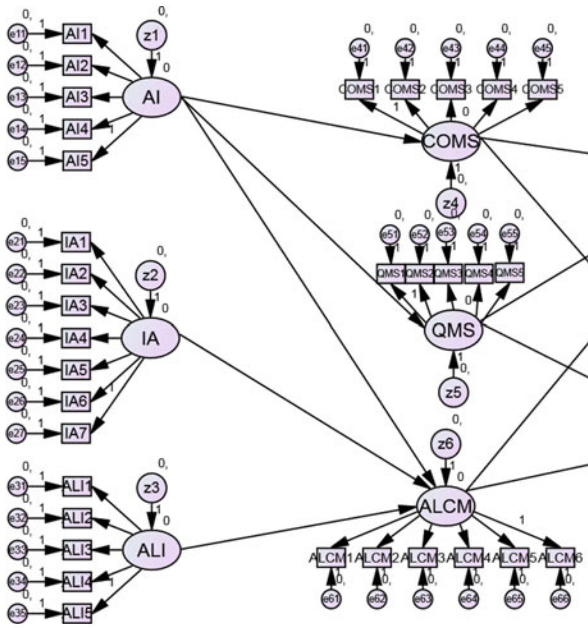


Fig. 107.2 Path model of the research

Table 107.3 Fit indices of the model

Fit indices	Chi-square/degrees of freedom	RMSEA	CFI	IFI
Original	5	0.140	0.693	0.695
Current	4.41	0.103	0.857	0.876

Fit refers to the ability of a model to reproduce the data, a good-fitting model is one that is reasonably consistent with the data and so does not necessarily require respecification (Kenny and McCoach 2003). It is better that the value of chi-square/degrees of freedom and IFI should be small, smaller is better. While the value of CFI and IFI should be from 0 and 1, and bigger is better. Table 107.3 shows that, after model updating, the results of those indexes are more desirable than the original model, which means the modified model is much better.

107.3.3 Path Analysis

Path analysis is used to describe the directed dependencies among a set of variables, which is a causal modelling approach to exploring the correlations and determining whether a multivariate set of non-experimental data fits well with a particular causal model. This research uses standardized partial regression to measure the path coefficients, the results shows in Table 107.4. In addition, the standardized coefficient of path analysis could be used in examining the possible causal linkage between statistical variables, especially could be compared the relative effects of the variables within the fitted regression model.

Table 107.4 shows that all the unstandardized regression coefficients are positive, and all P values are less than 0.05, indicating significance level of all paths meet the requirement, which testify all the hypothesizes. Then a further path influence is discussed, according to standardized regression coefficient, its value is widely dispersed from 0.160 to 0.949. To better measure the degree of the path influence, a simple classification is necessary.

Considering classification is a general process related to categorization, in which ideas and objects are recognized and understood, then the path influence is divided into three types, that are low level influence, moderate level influence and high level influence. The type of low-level influence means its path coefficient is small; its value is from 0 to 0.33. There are five paths belong to the low level influence type, including 'Application level of contract management to Behavior performance', 'Quality of management staff to Behavior performance', 'Quality of management staff to Outcome performance', 'Application level of informatization to Application

Table 107.4 Regression coefficient of the model

Path	Unstandardized regression coefficient	S.E.	C.R.	P	Label	Standardized regression coefficient
COMS <— AI	1.134	0.112	10.127	***	par_37	0.949
ALCM <— AI	0.942	0.118	7.987	***	par_38	0.891
ALCM <— IA	0.168	0.074	2.275	0.023	par_39	0.160
ALCM <— ALI	0.348	0.123	2.833	0.005	par_40	0.216
QMS <— AI	1.212	0.127	9.544	***	par_46	0.942
BP <— COMS	0.446	0.106	4.194	***	par_41	0.467
OP <— COMS	0.321	0.125	2.565	0.010	par_42	0.332
OP <— QMS	0.310	0.112	2.778	0.005	par_43	0.346
BP <— ALCM	0.279	0.102	2.723	0.006	par_44	0.258
OP <— ALCM	0.264	0.120	2.196	0.028	par_45	0.242
BP <— QMS	0.218	0.091	2.394	0.017	par_47	0.246

Notes "***"shows that the significance level is lower than 0.001

level of contract management' and 'Information appliance to Application level of contract management', the values are 0.258, 0.246, 0.242, 0.216 and 0.160 respectively. It is concluded that except the path 'Quality of management staff to Behavior performance', the remaining four paths are related to Application level of contract management (ALCM), indicating that ALCM has little influence on neither behavior nor outcome performance.

The type of moderate level influence means its path coefficient is neither very large nor very small; its value is from 0.33 to 0.66. There are three paths belong to the moderate level influence type, including 'Contract and management system to Behavior Performance', 'Quality of management staff to Outcome performance' and 'Contract organizing and management system to Outcome performance', the values are 0.467, 0.346 and 0.332 respectively, it could see that there are two variables involved, that are Contract organizing and management system (COMS) and Behavior performance (BP), showing that COMS has some influence on performance, that are behavior performance and outcome performance, while outcome performance has been influenced by Quality of management staff (QMS) and Contract organizing and management system (COMS).

The type of high-level influence means its path coefficient is much large; its value is from 0.66 to 1. There are three paths belong to the high level influence type, including 'Awareness of informatization to Contract organizing and management system', 'Awareness of informatization to Quality of management staff' and 'Awareness of informatization to Application level of contract management', the influence values are 0.949, 0.942 and 0.891 respectively. It could see that Awareness of informatization (AI) was related to the other three contract management factors, showing that AI could influence the level of contract management.

107.4 Conclusion

This research focus on the relationship of informatization, contract management and its performance using structural equation modeling. This paper indicates that informatization could influence contract management and enterprise performance while contract influence performance as well. Furthermore, according to the analysis, the results could be summarized into three aspects:

First, the construction enterprise should pay more attention to cultivating the awareness of information in construction project implementation, that is the emphasis given to conduct training on its employee and managers of understanding the information knowledge about construction engineering, which could make the employees especially their top managers understand the importance of the informatization on the construction engineering. Under the circumstances, the construction enterprises could take advantage of information technology and get informatization via information method advantageously, which could enhance the level of decision-making and work efficiency, and ultimately meet the requirements of information era.

Second, considering contract management is the center of all complex management work, especially compared with other industry sectors, construction industry has a large amount of contract documents. Successful contract management could prevent risks effectively and improve enterprise performance; Furthermore, contract management is a mediator factor that is essential to the relationship between enterprise informatization and its performance. The evaluation of contract management reflects enterprise performance, indicating the significance of applying contract management.

Third, both informatization and contract management could influence construction enterprise performance, considering the complexity of the content and procedure of contract management, and the difficulties of collecting and dealing with a large number of contracts and other related engineering files in practice as well, merely relying on manual work could not meet the challenge. Thus, in order to deal with those works conveniently and comply with demands of information era, it is essential to resort to informatization to improve the contract management level and its performance via information network and management platform to realize the reasonable allocation of resources, which could improve the level of enterprise management and project management.

With the development of information technology, managers tend to pay more attention to informatization management. In order to enhance the vitality and competitiveness, it is indispensable to combine information technology with management for construction enterprises. Therefore, this paper probes in contract management of construction industry in information era via quantitative analysis. According to the analysis of structural equation model, this paper constructs the influence chain of contact management of construction industry in the mode of information to manifest the hypothesis. Then the results show that contract management is an indispensable mediator factor of the relationship between enterprise informatization and its performance, which contribute to the advice that suitable informatization and management platform should be established to promote enterprise performance. This research provide ideas to further researches.

References

Frissen P (1992) Informalization and administrative modernization: a comparative analysis. Eur Public Adm Informatization: Comp Res Proj Policies, Syst, Infrastruct Proj 2:479

Jung Y, Chin S, Kim K (2004) Informatization index for the construction industry. J Comput Civ Eng 18(3):267–276

Kenny DA, McCoach DB (2003) Effect of the number of variables on measures of fit in structural equation modeling. Struct Equ Model 10(3):333–351

Kluver R (2010) Globalization, informatization, and intercultural communication

Liu J (2015) Advices of enterprises' financial management information. Chin Manag Informationization 18(13):53–55

Ma Z (2015) Study on the project legal person responsibility organization of government investment project. Chang'an University

Mutua JM, Waiganjo E, Oteyo IN (2014) The influence of contract management on performance of outsourced projects in medium manufacturing enterprises in Nairobi County, Kenya. Int J Bus Soc Sci 5(9)

Sun L, Li J, Lan H (2008) Empirical analysis of labor. Bus Times (21):34–35

Tan X-L, Guan C-S, Lu Y-W, Xiong S-K, He X-W (2016) The single factor influence model and BIM fusion technology research of construction progress foundation item: project (2015GK3031) supported by science and technology department of Hunan province, China Foundation item: project (KY201209, KY201418) supported by construction department of Hunan province, China

Thomas SR, Macken CL, Lee S-H (2001) Impacts of design/information technology on building and industrial projects. A Report submitted to NIST, Construction Industry Institute, University of Texas, Austin, TX

Yan M (2013) Enterprise contract management information law and economics analysis. Electron Test (24):158–159

Yan P, Liu T, Huang S (2015) General contract management based on BIM5D. ICCREM 2015 187–196

Yu I, Kim K, Jung Y, Chin S (2007) Comparable performance measurement system for construction companies. J Manag Eng 23(3):131–139

Zhan Y (2012) Improving contract management by contract management informatization. Mod Econ Inf (8)

Zhao B, Chen Z (2006) Research on the performance evaluation on the construction project contract management. Optim Capital Constr 27(5):35–37

Zhao J, Guo J (2012) Performance evaluation system on coal enterprises in the low-carbon transition and development. Chin Min Mag 21(11):34–38

Zhu LB, Ren H (2006) Informationization: the key to improvement of construction enterprises' core competence. J Chongqing Univ

Chapter 108
Research on the Comprehensive Economic Strength of Macro Regional Distribution in Urbanization

Min Tian, Na Tang and Jie Han

108.1 Introduction

Urban agglomeration is the main form of urbanization, which is an important form of spatial organization of social economic activities and a new form of the distribution of productive force. According to <*National Plan on New Urbanization (*2014–2020*)*>, each region should optimize its macro spatial distribution and micro spatial form of urbanization according to its own natural endowment of resources and environmental capacity, and should develop urban agglomerations, which have high efficiency in agglomeration, great radiation function, superior urban system and functional complementation, based on the principle of making a mater plan, distributing rationally, cooperating and larger cities leading smaller ones, thus making itself an important platform for national economic development, regional development and international competition and cooperation. Therefore, urban agglomeration is the aim of regional development and the main form of urbanization. It is also the kernel of the centralizing and diffusing in the process of functioning of social economy. Cities and towns are parts of urban agglomeration, so they must first integrate into the macro regional area, namely urban

M. Tian (✉)
School of Business Administration, Xihua University, Chendu, China
e-mail: mt83@163.com

M. Tian
Department of City and Regional Planning, University of North Carolina, Chapel Hill, USA

N. Tang
Secretary of Administrating Office, Chengdu No. 18 Middle School, Chengdu, China
e-mail: tang_mcmug@qq.com

J. Han
Cashier and Secretary of Financial Office, Sichuan Mineral Investment Group Co. Ltd, Sichuan, China
e-mail: hanke008@126.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_108

agglomeration, in which cities and towns could seek their respective functions and orientations, making themselves necessary function nodes in the essential construction of urban clusters, thus further more promoting the transformation of the regional pattern from single center drive into multi-center developing and the economic development from non-balanced and incoordinated into non-balanced but coordinated. Cities and towns should also play the roles of “supporting points” and “growth poles” in the development of urban agglomeration.

108.2 The Macro Distribution of Regional Area Requires Cities and Towns to Integrate into the Urban Agglomeration

Tony Garnier (1869–1948, French architect), in his work <*An Industrial City: Study for the construction of the cities*> (1918), mentioned the idea of “functional separation”, that is, the separation of spaces by function through zoning into several categories: industrial, civic, residential, health related, and entertainment. He thought that the organization of urban space should concentrate more on the demands for various facilities and the relationship with the outside.

Milton Santos (1926–2001, Brazilian geographer) came up with the theory of divided space in his work <*The Divided Space: the two circuits of the urban economy*> (1979). He thought that the process of modernization is the process of the diffusion of innovation in time (from preceding phase to following phase) and space (from central area to outer area). In such cases, overall growth in economy can be seen in underdeveloped countries. However, due to the tendency to invest in capital-intensive enterprises, the demand of local market is restricted by the monopoly price, and the government is lacking in capital. Therefore, people in these countries cannot get full employment in large enterprises, but engaged in the business of small commodities. In this way, the economic structure of “divided space” in underdeveloped countries is formed, which means the economy in these countries includes two circuits—Upper Circuit and Lower Circuit. The former looks for cooperation outside the urban areas, while the latter looks for cooperation in the urban and suburban areas. That is the early form of urban agglomeration. As can be seen, smaller cities and towns involved more in the lower circuit are closely related with the rural areas in input and output, and they are also the connection of large cities and rural areas. Therefore, smaller cities and towns help to connect the industries in large cities with those in rural areas and also help the out-diffusion of the resources in large cities. They are essential in the development of regional economy and a necessary part of the urban agglomeration.

The planning and arrangement of the production and living factors of cities and towns should not be restricted within one city or town, but on a macro regional level in the urban agglomeration. The flowing of the production and living factors should be well-organized and cooperative. Urban agglomeration is a multiple nuclei urban system. The interactions of the factors of population, information, funds, technology, culture, etc. between cities are the base of this system. Meanwhile, as an important spatial organization form of social and economic activity, urban agglomeration has become a new form of distribution of productive forces. It reflects the economic mobility in space and the law of economy developing in the direction with low resistance.

108.3 The Indicator System of Economic Strength of Urban Agglomeration

The following is an indicator system of economic strength of urban agglomeration, including six aspects and sixteen indicators—economic development level, the quality of economic development, industrial structure, three key demands, the level of urbanization, and the income of urban and rural residents etc.

108.3.1 Indicators

The economic strength of urban agglomeration should be measured with six first-class indicators and sixteen second-class indicators, including:

- economic development level: GDP, the growth of GDP, and GDP per Capita
- the quality of economic development: workforce productivity, local public revenue *(LPR)* and the proportion of local public revenue *(LPR)* in GDP
- industrial structure: rate of industrialization, the proportion of employees in the secondary and tertiary industries, the proportion of value added of tertiary industries in GDP
- three key demands: the amount of total fixed assets investment, the total amount of retail sales and the amount of import and export
- the level of urbanization: urban population and rate of urbanization
- the income of urban and rural residents: average disposable income of urban residents and net income of rural residents.

The data of indicators are referred to (Statistic Yearbook of Sichuan 2015). In this indicator system, the weights of indicators are chosen according to assignment by experts and Research on the Economy Capacity of Four Urban Agglomerations in Sichuan (Jan, 2014, Sichuan Provincial Bureau of Statistics http://www.sc.stats.gov.cn/tjxx/zxfb/201401/t20140107_15110.html), as is shown in Table 108.1.

Table 108.1 Evaluation system of economic strength of urban agglomeration

	First class indicators		Second class indicators	
	Designation	Weight	Designation	Weight
Economic strength (100)	Economic development level	18	GDP [0.1 billion *yuan*]	6
			Growth of GDP [%]	3
			GDP per Capita [*yuan*]	9
	Quality of economic development	20	Workforce productivity [*yuan* per capita]	4
			LPR [0.1 billion *yuan*]	8
			Proportion of LPR in GDP [%]	8
	Industrial structure	20	Rate of industrialization [%]	5
			Proportion of employees in the secondary and tertiary industries	6
			Proportion of value added of tertiary industries in GDP [%]	9
	Three key demands	14	Amount of total fixed assets investment [0.1 billion *yuan*]	5
			Total amount of retail sales [0.1 billion *yuan*]	5
			Amount of import and export [10,000 US dollars]	4
	Level of urbanization	13	Urban population [10,000 persons]	5
			Rate of urbanization [%]	8
	Income of Urban and rural residents	15	Average disposable income of urban residents [*yuan*]	7
			Net income of rural residents [*yuan*]	8

Source Research on the Economy Capacity of Four Urban Agglomerations in Sichuan (Jan, 2014, Sichuan Provincial Bureau of Statistics) http://www.sc.stats.gov.cn/tjxx/zxfb/201401/t20140107_15110.html

108.3.2 Evaluation Methods

108.3.2.1 Convert Indicators with Dimensionless Method

The differences in unit and order of magnitude between the indicators can make it impossible to evaluate directly. In order to avoid this kind of problems, each indicator should be converted with dimensionless method. In practice, the most common dimensionless methods include standardization, normalization, efficacy coefficient method, index method and segmented scoring method. Efficacy coefficient method is used in this research, as in the following formula:

$$Z_i = \frac{X_i - X_{\min}^i}{X_{\max}^i - X_{\min}^i}$$

108.3.2.2 Synthesizing Indicators

At present, the most common methods of synthesizing include total synthesizing, product synthesizing and mixed synthesizing. Total synthesizing can help make up the differences between the numerical values of the indicators, so it is used in this research, as follows:

$$\int (x) = \sum_i w_i \times z_i$$

z_i is the normalized value of x_i; w_i is the weight of x_i.

108.3.3 Selection of Indicators

According to China's Central City Work Conference and the documents of *National Plan on Main Functional Zones* and *The 12th Five-Year Plan on Urbanization in Sichuan*, the macro distribution of the construction of small cities and towns in Sichuan should take urban agglomeration as the main form. The four urban agglomerations in Sichuan include the Chengdu Plain, South Sichuan, Northeast Sichuan and the Panzhihua-Xichang Region *(Pan-Xi Region)*. These four urban agglomerations, to some extent, reflect the pattern of economic development of the Sichuan Province in the process of urbanization. Therefore, this research is carried out by taking these urban agglomerations as the spatial form of the macro regional distribution.

108.4 Evaluation and Analysis of the Economic Strength of Four Urban Agglomerations in Sichuan Province

108.4.1 Results

By collecting, sorting and converting with dimensionless method the data of cities and towns of the four urban agglomerations in 2014, with the efficacy coefficient method, the comprehensive economic strength of the four urban agglomerations in Sichuan in 2013 can be seen in the following figures (Figs. 108.1 and 108.2).

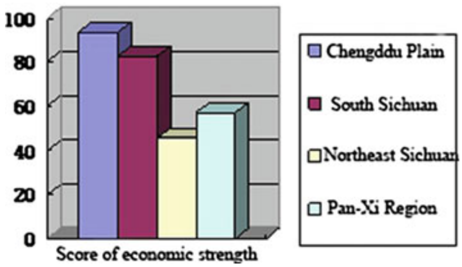


Fig. 108.1 Comparison of comprehensive economic strength of four urban agglomerations in Sichuan, 2014

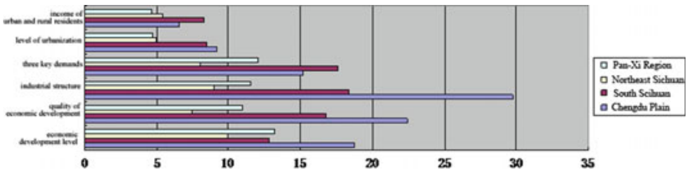


Fig. 108.2 Classified index of economic strength of four urban agglomerations in Sichuan, 2014

As can be seen in chart 1, there are obvious gaps in economic strength between the four urban agglomerations. Chengdu Plain ranked first, with a score of 93.08; South Sichuan ranked second, with 82.329; Pan-Xi Region ranked third, with 57.14; Northeast Sichuan was at the bottom, with 44.99.

As is shown in chart 2, Chengdu Plain was the strongest in economy, ranking first in four first-class indicators—economic development level, the quality of economic development, industrial structure and the level of urbanization—at the top of the four urban agglomerations. South Sichuan made great progress, with a higher score than that of 2013. Pan-Xi Region and Northeast Sichuan were close in economic strength, but Pan-Xi Region had obvious advantage over Northeast Sichuan.

108.4.2 Analysis

108.4.2.1 Economic Development Level

The economic development level is evaluated by GDP, growth of GDP and GDP per Capita. South Sichuan ranked first, with a score of 23.8; Chengdu Plain ranked second, with 18.76, Pan-Xi Region ranked third, with 13.2; Northeast Sichuan was at the bottom, with 9.998 (See Fig. 108.3).

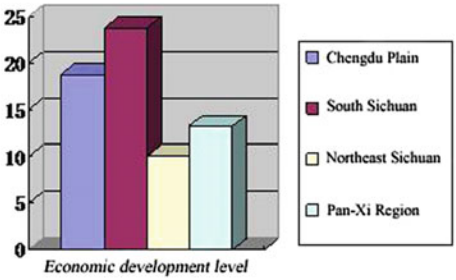


Fig. 108.3 Economic development level of four urban agglomerations in Sichuan, 2014

In 2014, the four urban agglomerations all had a GDP of over 200,000,000,000 yuan, but there were obvious gaps between the urban agglomerations. Chengdu Plain had a GDP of 1504,714,000,000 yuan, more than the total amount of the other three agglomerations, for Chengdu is a primate city and it includes two "100 billion(GDP) cities"—Deyang (139,594,000,000 yuan) and Mianyang (145,512,000,000 yuan). Northeast Sichuan, with the leading of two "100 billion (GDP) cities"—Nanchong (132,855,000,000 yuan) and Dazhou (124,541,000,000 yuan), achieved a GPD of 508,040,000,000 *yuan*, ranking second. South Sichuan, including cities of Zigong, Luzhou, Neijiang and Yibin which are close in GDP, achieved a GPD of 455,431,000,000 *yuan*, ranking third. Pan-Xi Region, for it includes the smallest number of cities (only Panzhihua, Liangshan Autonomous Prefecture and part of Ya'an), ranked last, with a GPD of 214,208,000,000 *yuan*.

In terms of the growth of GDP, the four urban agglomerations kept a rapid growth in 2014. All had a growth of over 10%, except South Sichuan. Pan-Xi Region had the rapidest growth of 11.2%, 1.2% more than the average growth of Sichuan Province, making itself the No. 1 growth pole in Sichuan Province. The growth of Northeast Sichuan was 10.8%.

In 2014, the GDP per Capita of Chengdu Plain was 38,183, though below the national average (43,300 yuan), above the average of Sichuan (32,600 yuan). It was 1.2 times that of South Sichuan, 1.8 times that of Northeast Sichuan, and 1.2 times that of Pan-Xi region. According to the income classification by World Bank in 2010,[1] converted by the exchange rate of RMB to US dollar,[2] the GDP per Capita of Chengdu Plain, South Sichuan and Pan-Xi Region were respectively $6070.7, $4865.9 and $5055.4, which reached above the level of the middle-income. Only Northeast Sichuan was still at the level of lower-middle income, with a GDP per Capita of $3316.1.

[1]The income classification (2010) by World Bank classifies e.

[2]The exchange rate of RMB to US dollar in 2013 is 6.2897.

Table 108.2 Evaluation of the quality of economic development of the four agglomerations in Sichuan, 2014

			Quality of economic development					
			Workforce productivity [*yuan* per Capita]		LPR [0.1 billion *yuan*]		Proportion of LPR in GDP [%]	
	Score	Rank	Absolute number	Rank	Absolute number	Rank	Actual performance	Rank
Chengdu plain	22.45	1	1521.39	1	1256.64	1	6.71	2
South Sichuan	18.8	2	855.25	3	287.28	2	6.64	3
Northeast Sichuan	7.52	4	915.49	2	255.87	3	5.23	4
Pan-Xi region	11	3	674.68	4	253.56	4	7.75	1

108.4.2.2 Quality of Economic Development

The quality of economic development is evaluated by workforce productivity, local public revenue *(LPR)* and the proportion of local public revenue *(LPR)* in GDP. The results are: Chengdu Plain ranked first, with a score of 22.45; South Sichuan ranked second, with 18.8; Pan-Xi Region ranked third, with 11; Northeast Sichuan ranked fourth, with 7.52 (See Table 108.3 for more details).

Workforce productivity is an important measure of competitiveness, depending on technical efficiency, technical progress and capital deepening. Through calculation, in 2014, Chegndu Plain had the highest workforce productivity of 1521.39 yuan per capita; Northeast Sichuan ranked the second, with 915.49 yuan per capita; South Sichuan ranked the third, with 855.25 yuan per capita; Pan-Xi was at the bottom, with 674.68 yuan per capita (See Table 108.2).

In absolute amount, there are obviour gaps between the urban agglomerations in the local public revenue (LPR). Chengdu Plain was far ahead, with 125,664,000,000 yuan, which was 4.4 times that of South Sichuan, 4.9 times that of Northeast Sichuan and 4.95 times that of Pan-Xi Region. South Sichuan was more substantial in LPR, because of the two Liquor-industry cities—Yibin and Luzhou, even surpassing the Heavy Industry city, Deyang, and the technological city, Mianyang. The per Capita LPR of the six cities in Northeast Sichuan clusters were not high, between 2.5 and 6.5 billion yuan. For Pan-Xi Region, because the number of the cities it governs is small, its financial strength is not as good as the other three agglomerations, although the LPR of Liangshan Autonomous Prefecture (10.001 billion yuan) ranked third in Sichuan Province.

In terms of proportion of LPR in GDP, Pan-Xi Region was at the top, with 7.75%, proving its financial power with more resource-based industries, while Chengdu Plain 6.71%, South Sichuan 6.64% and Northeast Sichuan 5.23%. International experience shows that the proportion of LPR in GDP is in positive

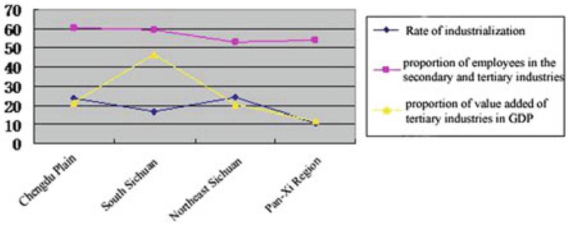


Fig. 108.4 Industrial structure of four urban agglomerations in Sichuan, 2014

correlation with the development of economy, that is, the better economy develops, the higher proportion LPR has in GDP. Pan-Xi Region and Chengdu Plain had higher proportion of LPR in GDP, which shows that they are better in economic development and the governments are better at financial functions and macro-control.

108.4.2.3 Industrial Structure

Industrial structure is evaluated by rate of industrialization, the proportion of employees in the secondary and tertiary industries, the proportion of value added of tertiary industries in GDP. The results are: Chengdu Plain ranked first, with a score of 17.31; South Sichuan ranked second, with 13.18; Pan-Xi Region ranked third, with 10.47; Northeast Sichuan ranked fourth, with 10.33.

As can be seen in Fig. 108.4, Chengdu Plain and Northeast Sichuan were close in rate of industrialization, respectively 23.71 and 24.07%, higher than that of South Sichuan and Pan-Xi Region.

The proportion of employees in the secondary and tertiary industries of Chengdu Plain reached 60.2%, while that of South Sichuan ranked second, with 59.4%, proving that with the speeding of industrialization and adjustment of industrial structure, more and more people are employed in the tertiary industries like service, financial and tourism sectors, etc., the secondary and tertiary industries have become the most important part of employment. The proportions of employees in the secondary and tertiary industries in Northeast Sichuan and Pan-Xi Region were close, respectively 52.8 and 53.8%, showing that through adjust the industrial structure, the structures of the two urban agglomerations have become more reasonable.

The proportion of value added of tertiary industries in GDP of Chengdu Plain reached 21.5%, showing that the adjustment of industrial structure in Chengdu Plain has begun to flatten, and that it has turned into an urban agglomeration with service sector as a main industry. The proportion of value added of tertiary industries in GDP of South Sichuan reached 46.37%, showing that South Sichuan is turning from an urban agglomeration with manufacture as a main industry into one with service sector as a main industry. Northeast Sichuan and Pan-Xi Region were low in roportion of value added of tertiary industries in GDP, which, to some extent, shows that they still have difficulty in improving industrial structure and

Table 108.3 Index of level of urbanization of four urban agglomerations in Sichuan, 2014

	Level of urbanization			
	Urban population [10,000 persons]		Rate of urbanization [%]	
	Absolute number	Rank	Actual performance	Rank
Chengdu plain	3230	1	46.79	1
South Sichuan	1517	3	43.48	2
Northeast Sichuan	2419	2	38.11	4
Pan-Xi region	642	4	42.5	3

depend much on resources in economy growing. Therefore, it is necessary for the two agglomerations to speed up the transforming of economic structure and development mode.

108.4.2.4 Level of Urbanization

The level of urbanization is evaluated by urban population and rate of urbanization. The results are: Chengdu Plain ranked first, with a score of 9.23; South Sichuan ranked second, with 8.53; Northeast Sichuan ranked third, with 4.96; Pan-Xi Region ranked fourth, with 4.73.

Urban population reflects the agglomeration effect and the economy of scale of the cities and towns, and, to some extent, shows the level of industrialization of the urban agglomeration. Rate of urbanization is an important measure of the economic development, systematization and management of a country or region.

In terms of urban population, the four agglomerations gather 99.9% of the population in Sichuan Province. The population of Chengdu Plain was 32,300,000, accounting for 41.3% of the total urban population of Sichuan Province, which means nearly half of urban population of Sichuan Province are in Chengdu Plain. The population of Northeast Sichuan was 24,190,000, and that of South Sichuan was 15,170,000. Only about 6,420,000 people were living in Pan-Xi Region, making it the agglomeration with the smallest population density (See Table 108.3).

The rate of urbanization of Chengdu Plain was the highest, which was 46.8%, making it the only urban agglomeration in Sichuan that has more urban permanent residents than rural permanent residents. In terms of urbanization of population, there have been historic changes in the population and social structure of Chengdu Plain. It is entering an era of Urban Society. According to the international classification of stages of urbanization, South Sichuan and Pan-Xi Region have just entered the stage of fast-accelerating development, while Northeast Sichuan has entered the stage of steady-accelerating development.

108.5 Enhance the Comprehensive Economic Strength of the Urban Agglomeration

108.5.1 Make More Explicit the Overall Developing Strategy, with Entire-Region Scheme and Top-Level Design

The common structures of the industrial divisions inside the urban agglomeration, on one hand, cause resource wasting and, on the other hand, restrict the improving of the overall competitiveness of the agglomeration. In order to solve this problem and realize the regional economic integration, the intervention and guidance of the government is necessary, with entire-region scheme and top-level design at the provincial level. Cities, urban agglomerations and major economic zones are diverse in its location, resources and Eco-environment, with no common development mode. Therefore, they must, based on its own situation, plan scientifically and carry out different regional policies, in this way, urging each urban agglomeration to reconsider its functional position and industrial distribution, according to its own resources, location and industrial specialization.

By improving the industrial structures, the development of industries among the urban agglomerations will transform from vertical division to vertical combining horizontal division, from production element complementing to structured cooperation, from labor intensive to capital and technology intensive, therefore, leading to dislocation development and complementary advantages. Among the four urban agglomerations of Sichuan Province, if the modern service industry of Chengdu Plain and the manufacturing of South Sichuan and Northeast Sichuan can be powerfully combined, and the resources of Pan-Xi Region can be take full advantage of, the competitive advantages of the four agglomerations will be greatly improved among the Chengdu-Chongqing Economic Zone and even on a nationwide scale.

108.5.2 Cultivate Economic Growth Points Based on Cities and Towns as Spatial Carrier

With the gradient promotion of national economic from north to west and the global industries transferring from coast to inland, the western regions, connecting the eastern and the western provinces, are of vitality for the eastern provinces to seek for development and also the open-up forefront of the western provinces. Therefore, the four urban agglomerations should grasp the opportunity of a new round of Western Development and the construction of Chengdu-Chongqing Economic Zone, and take full advantage of the traffic condition of Sichuan Province, Meanwhile, they should optimize and adjust their spatial distribution among the agglomerations and make the best of their own resources, advantages and existing achievements, so as to find their own functional positions in the development of Sichuan Province based on the multi-point and multi-pole supporting strategy. In this way, they can cultivate a group of economic growth points based on cities and towns as spatial carriers and find their own way of coordinated development with characteristics of the western regions.

They should insist on classified guidance and advancing on the whole, increasing the radiation function of the central economic undertaking cities in the counties, improving their abilities of industrial transferring inside the agglomerations, industrial division-cooperation and expanding employment, and accelerating the development of relatively developed counties (towns) into medium-sized cities. They should continue with the project of "One industry for each county; One product for each village", which enrich people with technology, and cultivate their characteristic economy, strengthening their industrial support and the construction of public facilities, promoting the centralizing of population and industries and accelerating the developing of under-developed counties into small cities. For the counties of the minority ethnics, it is important to improve the transfer payment system, optimize basic facilities and cultivate new economic growth points.

108.5.3 Promote Industrial Disposition and Spatial Planning; Realize Compact, Intensive, Efficient and Green Development

In the strategy of multi-point and multi-pole supporting, it is of vitality to realize the development "from point to area and from point to pole". In order to realize it, the industrial disposition and spatial planning must be combined. Each city should take advantage of its own resources and location, be clear with its leading industries and characteristic industries, and promote the industrial cooperation of cities and towns, forming the development pattern of dislocation development and division-cooperation. They should focus on cultivating industrial clusters in the process of urbanization, and improve supporting facilities in the process of developing industrial clusters. They should scientifically plan the spatial distribution and realize compact, intensive, efficient and green development.

108.5.4 Strengthen Industrial Support and Guide Differentiation Competition

Industries are the support of "points and poles". Take the four agglomerations of Sichuan Province for example. The primate city, Chengdu, aimed at constructing modernized and international metropolis and focusing on the construction of

"Three Centers", strive to develop its modern service industry and high-tech industry and lead the high-end orientation and servitization of the industrial structure of Sichuan Province, therefore, promoting the ranking of its service industry in the western regions. Cities like Luzhou, Deyang, Mianyang, Panzhihua, etc., should cultivate clusters of characteristic industries, such as the industrial cluster of major equipment in Deyang, the industrial cluster of electronic information in Mianyang, the industrial clusters of rolling stock in Ziyang and Meishan, the industrial cluster of engineering machinery in Luzhou, the industrial cluster of numerically-controlled machine tool in Zigong and the industrial cluster of vanadium-titanium industry in Panzhihua. They should develop characteristic industries based on its own conditions, especially the rich resources of agricultural products and eco-environment, developing processing industry of agricultural products and eco-tourism. Meanwhile, they should promote the interactive development of the primary industries and the secondary and tertiary industries, and undertake the industrial transfer in order.

108.6 Conclusion

The development of a city is the process of the migration of suburban population to urban areas and the transforming of farming land into city construction land. The development of a city should be on the basis of its capacity of environment and resources. The urban space should be distributed scientifically, so as to realize compact, intensive, efficient and green development. Urban agglomeration is the main form of urbanization, which is an important form of spatial organization of social economic activities and a new form of the distribution of productive force. It reflects the economic mobility in space and the law of economy developing in the direction with low resistance.

Each city should take advantage of its own resources and location, be clear with its leading industries and characteristic industries. Each city and town plays respective roles in the agglomerations. There should be a net structure of dislocation development and division of labor. Generally speaking, large urban agglomerations are in the form of "Central cities—Sub-central cities—Backbone cities—cities and counties—towns"; medium-sized urban agglomerations are in the form of "Central cities—cities—towns—market towns"; small urban agglomerations are in the form of "Central cities—towns—market towns". To improve the division of labor, functional complementation and synergetic development of different cities and towns, promote the industrial cooperation of cities and towns, achieve dislocation development and cooperative development is the most important for the economic development of the region and cities.

This article only discusses the comprehensive economic strength of urban agglomerations. The development of economy in cities requires not only the strategies of macro regional distribution, but also the industrial support and city constructions like ecological civilization construction etc. How to promote the urbanization in China with the idea of New Urbanism, how to develop cities intensively with limited land resource, how to promote the harmonious development of society, and how to improve living standard through infrastructure construction and the improvement of the material and social environment are what need to be discussed.

Fund projects This study was supported by the National Scholarship Fund (CSC NO.201408515155); Raise Funds Project of Academic and Technical Leaders in Sichuan Province, 2014 "Study on the construction of the key small towns in Sichuan province with the interaction between urbanization and new type industrialization, urban and rural overall planning". (Chuan Education Plan (2014) No.35,w14215264); Soft Science Project of Sichuan Science and Technology Department in 2015 (2015ZR0165).

References

Armstrong H, Taylor J (1985) Regional economics & policy. Philip Allan Publishers Limited

Lambe W (2008) Small towns big ideas—case studies in small town community economic development. Community & Economic Development Program. School of Government, University of North Carolina at Chapel Hill. UNC School of government N.C. Rural Economic Development Center. December 2008

Planning of National New Urbanization (2014–2020). 3/16/2014. Central government portal. http://www.gov.cn/zhengce/2014-03/16/content_2640075.htm

Research on the Economy Capacity of Four Urban Agglomerations in Sichuan (2014). Sichuan Provincial Bureau of Statistics. Jan, 2014. http://www.sc.stats.gov.cn/tjxx/zxfb/201401/t20140107_15110.html

Working Conference of the Central City. 12/23/2015. http://news.xinhuanet.com/ziliao/2015-12/23/c_128559296.htm

Chapter 109
Research on the Housing Affordability of University Graduates in Guangzhou

Fan Wu, Linghin Li, Mingjie Dai, Yiming Gao, Ruoshi Tang, Kaihang Lin, Kaijian Li and Haoqi Huang

109.1 The Research on Housing Affordability

109.1.1 Housing Affordability—Research Background

Housing affordability is the analysis of the relationship between such variables as household's incomes, household's housing expenditure; and other housing allowance entitlement as well as housing standards (Chaplin and Freeman 1999). While most of the studies in housing affordability started with an angle of analyzing the impact of marketization of housing assistance on lower-income groups (Whitehead 1991), examination of housing affordability should not only be linked to the study of housing poverty in any society. Recently, due to the rising house prices in most emerging and mature economies, housing affordability of young people, especially the recent university graduates, has attracted more and more research as well as policy interest. The study of housing affordability of this particular demographic group is interesting because they are the sector who initially have minimal financial resources but will subsequently and quickly change as they progress in their own career and personal development. When young people with university education have garnered enough working experience, especially in professional fields such as finance, real estate and urban planning, medical or legal work, their income will increase exponentially. Moreover, when young people get married and form their

F. Wu (✉)
Department of Construction Management, South China University of Technology, Guangzhou, China
e-mail: ctfanwu@scut.edu.cn

L. Li
Department of Real Estate and Construction, Faculty of Architecture, The University of Hong Kong, Pok Fu Lam, Hong Kong

M. Dai · Y. Gao · R. Tang · K. Lin · K. Li · H. Huang
South China University of Technology, Guangzhou, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_109

own family, they also become two-income family which again allows a higher affordability. The analysis of housing affordability of young university graduates therefore provides more insight in this aspect than other demographic groups.

The study of housing affordability of urban residents has always been an important focus of real estate research. Nevertheless, there could still be different research foci in each study. Shen (2006) examines the current definition and connotation of House Price Income Ratio (PIR) are not clear. He explores the reasonable definition of "housing price" and "income", and the functional characteristics of PIR. Li et al. (2009) details the definition, connotation, measurement methods, and impact factors of housing affordability. He also introduces the consequence of low housing affordability and solutions to improving the affordability. Li and Zhao (2013) focuses on the relationship housing prices and fundamental income in 35 cities in China and finds that there is a significant linear relationship between housing prices and wages.

Shi and Yan (2015) construct housing affordability quadrant (HAQ) mode based on the analysis of housing affordability typical indicators, from 'Initial payment + monthly payment' dimension. Yu (2004) establishes reasonable prices evaluation system to test the residential affordability. Bogdon and Can (1997) identify the more important factors impacting housing affordability, including physical adequacy and over-crowdedness, and based on these factors, they further develop a spatial model to identity housing problems in various US cities for government action.

Zhou (2010) constructs different income family housing affordability and housing accumulation fund relationship econometric model and recommends that the government should implement income level segmentation system on provident fund system. Shen and Zhang (2011) find that the stability of the overall housing affordability is relatively weak, and heterogeneous among cities. Orr and Rivlin (2011) study impact factors of housing affordability in Washington D.C. and give advices for affordable housing policy in budget-constrained areas. Without doubt, understanding housing affordability in the society allows further examination of the poverty problem (Bramley 2012). Examination of the housing affordability level therefore allows researchers, the society and the government to understand better how much housing expenditure accounts for in the overall spending/consumption portfolio in the general or even specific household groups. From this analysis, researchers can extend into related issues such as mobility of families in search of more affordable housing (Strassmann 2000); affordable housing for younger generation (McDonald and Baxter 2005; Bujang et al. 2015); housing finance and subsidy policy (Radzimski 2014), or home-ownership rate (Bentzien et al. 2012). Housing affordability therefore accounts for a very important role in the formulation of good public policy for any responsible government, especially in the consideration of relying on market as a solution under the neoliberal ideology (Nicholls 2014).

However, little research has been devoted to the study of housing affordability of the specific demographic sector of university graduates, who are facing a lot of life-stage changes personally and financially as explained above. In this paper, we hope to contribute to this literature of housing affordability of young urban residents by examining empirically the case of Guangzhou.

Examination of housing affordability in China has also gained importance due to the rapid development of the housing market in the country (Duan 2011; Kuang and Li 2012). Among the various local markets in China, this study chooses Guangzhou as focus.

Among the first-tier cities, the housing price of Guangzhou is most approachable for potential purchasers. For the last decade, the annual growth of housing price in Guangzhou is less than 10%, while the annual growth of housing price in Shenzhen is more than 20%, and the annual growth of housing price in Beijing and Shanghai both achieved more than 17%. The trend of housing price of Guangzhou is relative temperate and rational.

109.1.2 Housing Affordability—Measurement

The measurements of housing affordability are mainly divided in two categories: one is direct comparison such as House Price Income Ratio and Housing Affordability Index; the other is residual income method in indirect form. The main indices used in the previous research are shown as follows:

(1) House Price Income Ratio (PIR)

House Price to Income Ratio generally refers to the ratio of median house price and median annual household income, which is the most common measurement of housing affordability. PIR = (house average price × house unit area) ÷ (per capita annual disposable income per household × population per household).

(2) Housing Affordability Index (HAI)

Housing Affordability Index calculation method: HAI = (monthly family income × maximum proportion of total income on housing consumption) ÷ (equal monthly loan payments). When the calculation result is equal to 1, it indicates that the maximum monthly expenditure on housing by household just meets monthly mortgage payments; when it is less than 1, it means housing price is less affordable as monthly mortgage repayment exceeds that maximum housing expenditure; when it is more than 1, it shows housing is relatively affordable.

(3) Residential Income Affordability (RIA)

Calculation method: RIA = residual income—housing costs = (household disposable income—basic non-housing living expenses)—monthly mortgage repayments (Li et al. 2009). When RIA is less than 0, monthly disposable income of the household, after meeting the basic living expenses, is not enough for mortgage loan repayment. When RIA is greater than or equal to 0, the residual income of households is able to meet mortgage loan (Duan 2011).

In this paper, Residual Income Affordability (RIA) would be applied as the measurement of housing affordability, since it considers sustainable housing affordable capacity besides basic living expenditure, which is practical. Moreover, it can be used to determine the extent of affordable housing consumption by different income levels of families, which gives the government great references on formulating housing policies.

109.2 The Housing Price and Housing Preference of University Graduates in Guangzhou

The average price of new-built housing in Guangzhou is 15,202 Yuan/m^2, while the average price of second-hand houses is 12,796 Yuan/m^2 in 2015. Since the housing price rose at express speed in the last decade in major Chinese cities, the housing policy target launched since 2007 is to stabilize the market and curb excessive rapid rise in housing prices. The measures taken to control the market have been: adjustment of credit policy, adjustment of the tax in real estate transaction, modulation of the proportion of first payment and limitation of house purchase directly, especially by non-local residents (based on Hukou registration). However, real estate price still skyrockets unchecked regardless of these suppression measures by the government. Besides the direct intervention on housing price movements, the government also tries to support low-income families by the construction of welfare housing. However, the policies of housing security can hardly cover the urban sandwich generation—the university graduates.

Young people (especially university graduates) are usually regarded as having the highest potential to improve their socio-economic status as they are in transition between different life stages with different potential opportunities to accumulate wealth for various life-span decisions. Young university graduates are living in a constantly changing environment as they are progressing through various stages of life such as education, career, family formation and expansion, mature as well as retirement. Their housing needs therefore also vary with their personal changes. However, in recent years, the salary level of these graduates has been lower than the average disposable income of the residents. Recently, the starting salary of fresh university graduates working in Guangzhou has not reached the average disposable income level of Guangzhou residents, though, as illustrated below, there is great potential on the growth of their income eventually. According to the report on 3 year post-graduation salary changes in the national and Pan-pearl River Delta regions, an average university graduate working in Guangzhou will have average 115% growth on their salary after working for 3 years. Table 109.1 shows the average starting salary of fresh university graduates and disposable income and consumption expenditure of residents in Guangzhou.

Before we analyse the affordability situation, we need to understand more about the housing preference of university graduates. We conducted a survey among

Table 109.1 Average salary of fresh university graduates and disposable income and consumption expenditure of residents in Guangzhou (Yuan/month)

Year	Average salary	Disposable income	Consumption expenditure
2007	3065	1872	1579
2008	2710	2110	1736
2009	3234	2301	1902
2010	3447	2555	2084
2011	3255[a]	2870	2351
2012	3320[a]	3171	2541
2013	3483	3504	2763
2014	3242	3816	3002
2015	3542	–	–

[a]Lack of data, generated by regression

Data source Guangdong Education Department (2016), MyCOS College Students Employment Task Force Chinese (2015)

young working population in Guangzhou. 200 valid questionnaires has been collected, 136 of which were from university graduates with a bachelor degree. Among the 136 respondents, 62% have worked for less than 3 years. 51.85% of the respondents who were not homeowners at the time of survey would like to purchase a house in 4–6 years after their graduations. This indicates that the changes in income and house price with time should be considered when measuring housing affordability because the income might increase noticeably 3–5 years after graduations.

Nearly 70% respondents choose new housing and the remainder mostly would choose second-hand housing, which indicates that the price of both types of houses should be considered. Nearly 50% of the respondents would choose 91–120 m^2, while nearly 32% choose 61–90 m^2. Hence, we would utilize the average price of houses with an area of 90 m^2 as two basic assumptions when measuring housing affordability. Furthermore, these assumptions also correspond with those of the research conducted by Yang and Shen (2008).

Based on the statistical data from this survey, we should consider the changing trends of income as well as house price and we should utilize the average price of houses with an area of 90 m^2.

109.3 Assessment of Housing Affordability Among Young University Graduates in Guangzhou—An RIA Analysis

To measure the housing affordability of Guangzhou university graduates, we firstly calculate the affordability index by residual income. The equation of residual income (RI) is:

$$RI = F^{*}I - C \tag{109.1}$$

where F is the annual disposable income of university graduates per capita; I is the number of payers; C is the non-housing expenditure of university graduates. The equation of annual reimbursement amount of university graduates is:

$$Y = 12^{*}P^{*}Q^{*}(1 - W)/(12^{*}N) + (PQ^{*}(1 - W) - K)^{*}(r/12) \tag{109.2}$$

where P is the unit housing price (including taxes); Q is floor space; W is the first payment; N is the loan period; r is the loan interest rate of housing fund; K is the accumulation amount of returned capital. Hence, the equation of the housing affordability of college graduates:

$$V = RI - Y \tag{109.3}$$

Through calculation, we can find the housing affordability of university graduates both at the graduation point and at three years after they graduated. As shown in the Fig. 109.1.

From 2007 to 2014, the variation tendency of housing affordability of university graduates at the graduation point and at three years after graduation is roughly the same, and they both rise dramatically from 2007 to 2008 and drop lately from 2008 to 2010. Between 2010 and 2011, the data also presents the rising trend, but the housing affordability three years after graduation is much more significant.

For year 2007, the housing affordability is only −46,901 Yuan (meaning that for a university graduates' household, they need 46,901 Yuan or more income every year to afford the repayment for a 90 m^2 house in Guangzhou). This year is also the only year with the figure above −40,000. For the year 2008, due to the impact of the global financial crisis, housing price was under pressure to adjust, making housing

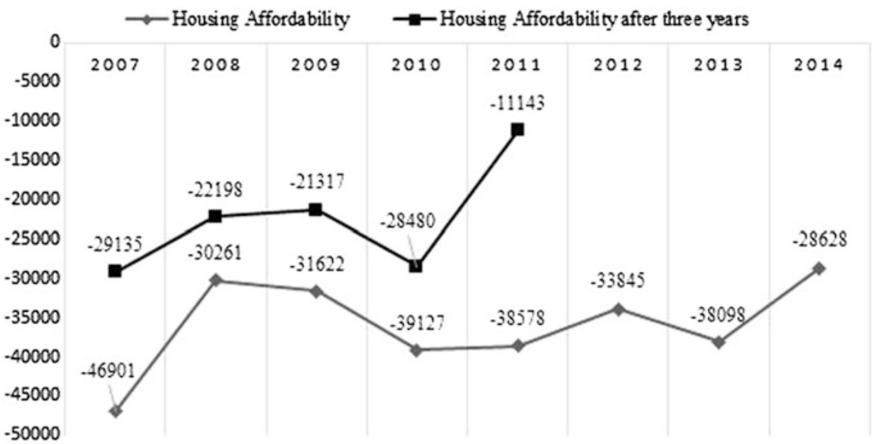


Fig. 109.1 The housing affordability of university graduates in 2007–2014 (unit: Yuan)

more affordable, and the figure reached −30,261 Yuan. From 2008 to 2011, with the recovery of the economy, housing price started to increase again, and together with the growth of non-housing expenditure, it contributed to a less favourable housing affordability situation for university graduates. The housing affordability of 2009 and 2010 was −31622 Yuan and −39,127 Yuan respectively. Year 2011 saw the highest starting salary for university graduates in our time series of 2007–2014 due to economic growth. Consequently, the housing affordability of university graduates also improved slightly, reaching −38,578 Yuan. From 2012 to 2014, housing affordability varied from −33,845, −38,098 and −28,628 Yuan respectively.

The housing affordability of university graduates after three years of graduation (G + 3) is all below −30,000 Yuan. For the reason that the salary of graduates in general increased by 115% after three years of graduation, their income begins to approach middle to high income level, and correspondingly their consumption also belongs to the higher level. For year 2007, the housing affordability of (G + 3) university graduates was −29,136 Yuan, significantly higher than the housing affordability when they first graduated. For year 2008, housing affordability increased to −22,198 Yuan, and then rose slightly to −21,317 Yuan for year 2009, but then reduced to −28,480 Yuan in 2010. For the year 2011, housing affordability rose significantly to −11,143 Yuan, twice of 2010 level. Such fluctuation in housing affordability is mainly due to high speed growth in salary in 2011 without an offset effect in general expenditure. Hence, graduates' residual income in 2011 improved significantly leading to a higher affordability.

109.3.1 Assessment of Housing Affordability Among Young University Graduates in Guangzhou—An Hat Analysis

The above analysis shows that housing affordability of university graduates is obviously influenced by their salary levels and house prices in the year when they purchase a house. Though the Residual Income Affordability shows the housing affordability of household statically at different periods from graduation, it could not show the affordability dynamically, when the salary level and housing price are changing after graduation. In order to get a better understanding of how the housing price, income, policy, and interest rate impact on the housing affordability of university graduates, this paper establishes a housing affordability time (HAT) model to simulate the process for the university graduates of purchasing housing in Guangzhou.

To show the housing affordability of university graduates more intuitively, this model defines the housing affordability time T to evaluate the ability for university graduates to purchase housing. The model evaluates the affordability by calculating the time after graduating when they can afford first payment (T_1) and the time when they can afford monthly payment (T_2) under these assumptions: Salary increases annually; Graduates are first time housing buyers, and down-payment is 20%; The payment is afforded by two adults as a household; Graduates would take out loan from housing fund for lower interest rate; The ideal size of house is 90 m^2 according to the survey above; Repayment period is 30 years. The housing affordability time T is the longer one of T_1 and T_2:

$$T = \max(T_1, T_2) \quad (109.4)$$

T_1 could be calculated when the first month t satisfies:

$$SA_t \geq P_t * SF_t * 9 \quad (109.5)$$

$$SA_t = SA_{t-1} * (1 + F_{ct}) + S_t - C_t + G_t \quad (109.6)$$

Calculation rule for T_2 could be calculated when the first month t satisfies:

$$S_t \geq MP_t * 2 \quad (109.7)$$

where T_1 is the month when saving exceeds first payment; T_2 is the month when monthly income exceeds half of the monthly payment; S_t is the salary in the *t*th month; P_t is the housing price in the *t*th month; F_{ct} is the deposit rate in the *t*th month; It is the loan rate in the *t*th month; SA_t is the sum of saving in the *t*th month; G_t is the money to repay in the *t*th month; C_t is the non-housing consumption in the *t*th month; SF_t is the proportion of first payment in the *t*th month; MP_t is the monthly payment in the *t*th month.

Figure 109.2 shows the T_1, T_2 of university graduates in Guangzhou for the graduation year 2007–2014, which means the shortest time the university graduates spend to achieve ability to pay the first payment and monthly payment. To achieve both T_1 and T_2, it costs them about 56–108 months, around 5–9 years. The result of

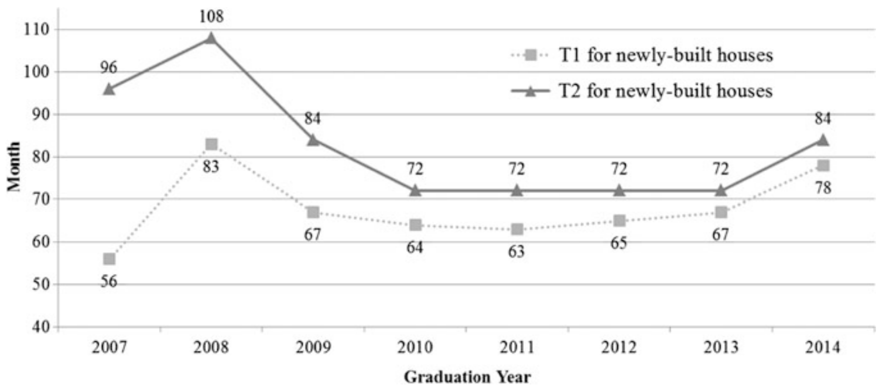


Fig. 109.2 T_1 and T_2 of university graduates in Guangzhou for year 2007–2014

HAT model is basically consistent with the actual situation of the current university graduates' financial ability.

We find that T obviously depends on T_2 since the major problem of university graduates is the lack of adequate income to pay for the high monthly house payment. Although the repayment period is 360 months, initial salary of university graduates is not enough to pay the monthly payment even with a substantial increase. It is quicker for university graduates to afford the first payment and monthly payment when they choose to purchase second-hand house. In order to find out the impact of the first payment proportion on the housing affordability of university graduates, we traverses the first payment proportion from 0 to 70%, taking graduates of 2007 as an example. When the proportion of the first payment equals to 25%, T_1 equals to T_2. At this point, it is the shortest time to reach housing affordability by only 65 months, which is shorter than any time used above. From this calculation, we can detect that the proper first payment proportion is 25%, in which the university graduates' housing affordability would be improved.

Through sensitive analysis, it's found that the income level of university graduates is the most sensitive factor to the affordability, and the second sensitive factor is housing price. So the best way that to increase housing affordability is to improve the salary level of university graduates or slow down the growth of house price.

109.4 Conclusions and Suggestions

In this paper, the Residual Income Affordability (RIA) index commonly used in academic research is applied to analyse the housing affordability of university graduates in Guangzhou. From this relatively static analysis, even with the assistance of the graduate's family funding for the down payment, there is still a more 30,000+ Yuan funding gap per year at the beginning of the graduation and about 20,000 Yuan repayment gap three years after graduation.

The static analysis is difficult to reflect the impact of rising income and housing prices several years after graduation, so this study also establishes the Housing Affordability Time (HAT) index to evaluate the housing affordability of graduates dynamically. The analysis shows that the income of university graduates rise quickly after graduation. In 5–9 years after graduation, they have the ability to pay the down payment and repay the loan, while most graduates hope to have a 'home' in 4–6 years after graduation from our pilot survey. According to our research, the income level and housing price are top 2 important impact factors of university graduates' housing affordability, while loan interest rate is the most changeable and operable factor.

Furthermore, the results above are based on the assumptions of minimum non-housing consumption, reasonably low mortgage rate, and non-urban-center locations. Even with an estimation of a reasonable affordability, it still does not mean a reasonable standard of living for this demographic group. According to our research, the income level and housing price are top 2 important impact factors of university graduates' housing affordability, while loan interest rate is the most variable and operable factor. As urban sandwich generation who could not afford the housing by their slender income or be benefited by welfare housing policy due to limited government resources, university graduates have weak housing affordability. In order to solve this problem, we have the following suggestions to the government.

The government should improve the housing policy and the housing security system should cover the low-income university fresh graduates, especially for the first 5 years after graduation. In the same time, the government should establish multi-sector supervision system to prevent misappropriation of housing provident fund. In accordance with the different income levels of graduates (Wei 2006), provide a dynamic and adjustable help in housing. For instance, provide welfare housing for low-income graduates for initial five years, then offer low-rate loan for them when they have potential capacity to purchase housing. The location of welfare housing should not be marginalized to save the commute cost of graduates and enhance their affordability.

References

Bentzien V, Rottke N, Zietz J (2012) Affordability and germany's low homeownership rate. Int J Hous Markets Anal 5(3):289–312

Bramley G (2012) Affordability, poverty and housing need: triangulating measures and standards. J Hous Built Environ 27(2):133–151

Bogdon A, Can A (1997) Indicators of local housing affordability: comparative and spatial approaches. Real Estate Econ 25:1

Bujang AA, Jiram WRA, Zarin HA, Anuar FHM (2015) Measuring the gen Y housing affordability problem. Int J Trade Econ Finan 6(1):22–26

Chaplin R, Freeman A (1999) Towards an accurate description of affordability. Urban Stud 36 (11):1949–1957

Duan M (2011) Investigation on housing affordability in Lanzhou. Int J Hous Markets Anal 2 (3):180–190

Guangdong Education Department (2016) 2015 Guangdong province college graduates' employment annual report, pp 39–54

Kuang W, Li X (2012) Does china face a housing affordability issue? Evidence from 35 cities in China. Int J Hous Markets Anal 5(3):272–288

Li B, Zhao X (2013) Relationship between house price and income fundamental. Syst Eng Theor Pract 33(12):3121–3126

Li J, Tan S, Wang W (2009) Research on foreign housing affordability. Urban Probl 5:7–13

McDonald P, Baxter J (2005) Home ownership among young people in Australia: in decline or just delayed? Aust J Soc Issues 40(4):471–487

MyCOS College Students Employment Task Force Chinese (2015) Chinese college graduate's employment annual report (2009–2014). Social Sciences Literature Press, Beijing

Nicholls S (2014) Perpetuating the problem: neoliberalism, commonwealth public policy and housing affordability in Australia. Aust J Soc Issues 49(3): 329–347, 395

Orr B, Rivlin A (2011) Affordable housing in the district—where are we now? Metropolitan Policy Program at Brookings

Radzimski A (2014) Subsidized mortgage loans and housing affordability in Poland. GeoJournal 79(4):467–494
Shen J (2006) Further discussion on definition of housing price income ratio. J Cent Univ Finan Econ 6:75–79
Shen Y, Zhang X (2011) Housing affordability stability: theory interpretation and empirical analysis. Finan Trade Econ 2:118–124
Shi J, Yan J (2015) Research on housing affordability of urban residents based on HAQ model. Syst Eng Theor Pract 35(9):2222–2231
Strassmann WP (2000) Mobility and affordability in US housing. Urban Stud 37(1):113–126
Wei J (2006) Individual housing loan pricing of commercial bank based on risk analysis study. Hunan University, 21
Whitehead C (1991) From need to affordability. Urban Stud 28(11):871–887
Yang Z, Shen Y (2008) The affordability of owner occupied housing in Beijing. J Hous Built Environ 23(4):317–335
Yu X (2004) House prices reasonable evaluation research based on residents' housing affordability, theory and practice, pp 34–35
Zhou J (2010) Analysis of public housing consumption financial system and performance evaluation. J HeBei Univ Econ Bus 31(3):40–46

Chapter 110
RFID-Enabled Management System Adoption and Use in Construction: Passing Through the Labyrinth with an Improved Technology Acceptance Model

Y.H. Niu, W.S. Lu and D.D. Liu

110.1 Introduction

In recent years, radio frequency identification technologies (RFID) have been increasingly explored. Various industries including the construction industry are managing to apply the RFID technologies to improving the working practice and utilizing their resources. The RFID-based technologies are expected to improve efficiency and cost effectiveness of project management, to tighten back-end communication, and to reduce the corresponding time of project (Wang et al. 2007). Furthermore, Lu et al. (2011) summarized three possible practical scenarios of construction management, which are management of materials, management of man and management of machinery. These scenarios are demonstrating a huge possibility of integrating RFID technologies into the construction industry. However, while attention has also been drawn to applying RFID technologies in construction, the understandings of the users' acceptance are still in an infant stage. Little is currently known about how construction practitioners adopt and use a new technology system.

The technology acceptance model (TAM) proposed by Davis (1985) offers a theoretical explanation for the user's acceptance and adoption behaviors. User's attitudes, perceived ease of use and perceived ease of use are measured against the actual use of a specific information system, so as to examine the extent and determinants of acceptance (Davis 1985, 1989). TAM shows great potentials for researchers to explore the reasons behind the user acceptance as it has been widely used in various disciplines, including the business (Ha and Stoel 2009), education (Huang et al. 2007), and healthcare research area (Melas et al. 2011).

Y.H. Niu (✉) · W.S. Lu · D.D. Liu
Department of Real Estate and Construction, University of Hong Kong, Hong Kong, China
e-mail: yuhanniu@connect.hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_110

However, when applying the TAM in the construction industry, more care should be taken because of the heterogeneous nature of the projects, silo thinking, and routine-inclined natures of construction practitioners. An exploratory study is needed to help to provide understandings of these construction practitioners' adoption and use behaviors. Therefore, taking the RFID-enabled management system as a case, the primary aim of this study is to explore the factors that can influence the users' acceptance of the system in the construction industry. The remainder of the paper comprises five sections. Section 110.2 reviews the theoretical background of TAM. Section 110.3 proposes an extended TAM, addressing the issue of dynamic changes of the acceptance levels. Guided by the extended TAM, two specific research questions are also raised in Sect. 110.3. Section 110.4 describes the research design of this study. Findings are demonstrated and analyzed in Sect. 110.5. Conclusions are drawn in Sect. 110.6.

110.2 Theoretical Background on TAM

The technology acceptance model (TAM) is firstly introduced by Davis (1985), aiming to improve the understanding of user acceptance process as well as to provide the theoretical guidelines for the new technology system. According to the original TAM model, user's attitude toward using (AT) is the major determinant toward the actual usage (AU). In turn, the user's attitude toward using, is determined by two major believes, the perceived usefulness (PU) and perceived ease of use (PEU). In addition, a set of dummy variables called external variable (EV) are included to address the characteristics of the information system, which is hypnotized to have direct impact on the perceived usefulness and perceived ease of use. Davis (1989) further developed and tested several scale items to measure the perceived usefulness and perceived ease of use in four studies as shown in Table 110.1, establishing a classical research framework that can be generalized and adopted to many application scenarios.

Built on the studies of TAM, the technology acceptance model has been widely used in different academic fields and industries. For example, for the old fusion technology, Gefen and Straub (1997) extends TAM to investigate how gender

Table 110.1 TAM constructs definitions and scale items adopted from Davis (1985) and Davis (1989)

Constructs	Definition	Scale items to measure the constructs
PU	The degree to which an individual believes that using a particular system would enhance his or her job performance	Job performance, increase in productivity, quality of work, effectiveness, useful etc.
PEU	The degree to which a person believes that using a particular system would be free of effort	Easy to learn, controllable, easy to be skilled, mental effort, clear and understandable etc.

could influence the perception and use of email. Pavlou (2003) extends the technology acceptance model by adding trust and risk as parameters to examine the consumer acceptance of electronic commerce. Besides, for the emerging technology, Liu et al. (2010) adopts the TAM to explore the user acceptance of an online learning community.

110.3 The Dynamics in the Changing Acceptance Levels

Notwithstanding the popularity of the TAM, during the three-decade development of TAM, there are a few limitations frequently appearing in many TAM studies (Lee et al. 2003). One commonly addressed limitation of TAM is that lots of TAM studies are only conducting the measurement once, when they ignore the possible changes of user's acceptance after actual usage. Karahanna et al. (1999) mention that user's acceptance is dynamic and not static, which can be observed in the construction practice. It is found that practitioners' actual use of the system could influence their attitude based on the preliminary observations in a construction project, where a RFID-enabled management system is tested on site. Practitioners acceptance toward the system subtly changed from skeptical to neutral after a period of trials and pilot testing. It is found that during the period of actual use, users' perceived ease of use and perceived usefulness are gradually increasing, demonstrated by their cooperation attitudes. Bajaj and Nidumolu (1998) have proposed the 'feedback effect', saying that the actual use would affect the perceived ease of use. Yet the effect of actual use on perceived usefulness have not been studied. Meanwhile, the actual use cannot actually influence the previous perceived usefulness and perceived ease of use. Therefore, an extended TAM is proposed in this study as shown in Fig. 110.1, where the actual use is proposed to influence the users' perceived usefulness and perceived ease of use for continued usage.

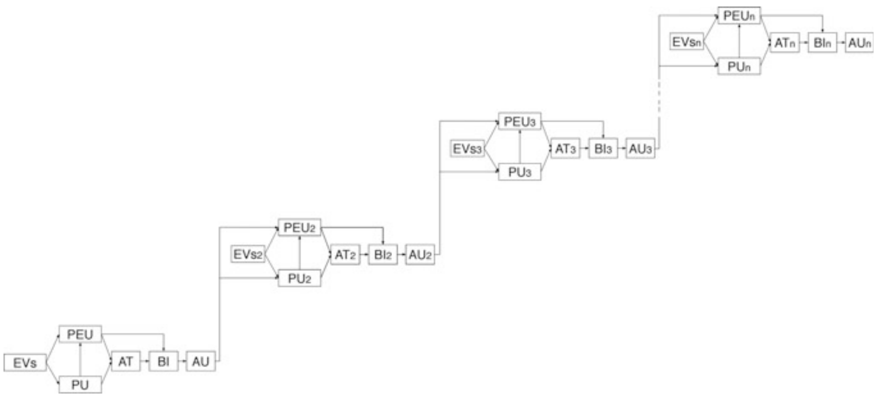


Fig. 110.1 An extended TAM with the dynamic in the changing acceptance levels

Based on the literature review and the personal experience in preliminary observations of the adoption of RFID technologies in the industry practice, the objective of this study is to explore how people working in construction adopt and view RFID technologies. To be more specific, this study aims to gain insights into the following 2 research questions:

1. What influence the user's initial acceptance of the RFID-enabled management system in the construction industry?
2. Do users' acceptance change after actual using the system and if so what influence the changing acceptance level?

110.4 Research Method

This research adopts the case study method. The case is based on the implementation of a RFID-enabled management platform to facilitate the logistics and supply chain of prefabrication housing production in Hong Kong. This platform is jointly used by the main contractor and the supplier of the prefabricated components. Semi-constructed interviews were conducted for data collection for two times, at the commencement of the platform pilot and one year after the implementation of the platform. Participants of the interview are staff with the responsibility for managing and/or executing the RFID-enabled management platform. A variety of samples are purposely chosen for the interview, aiming to include participants who have direct involvement and experience in using the platform so as to provide generalizable (Murray et al. 2011). Eight participants completed both interviews sessions, which are summarized in Table 110.1.

Interviewees were asked for a description of the implementation of the RFID-enabled management platform from their perspectives, their views about the factors which had promoted or impeded their attitude toward using the system, and their assessments of the acceptance level. The interviews were tape-recorded and transcribed into verbatim records. Interviews for participants in the supplier side were conducted in Chinese due to their language barriers. Thus the records for these participants are further translated into English.

110.5 Findings and Data Analysis

Data that are recorded and transcribed were summarized in Table 110.2. Statements are coded to constructs in the TAM model including the external variables, perceived ease of use, perceived usefulness and attitude toward using. Since the RFID-enabled management system have been implemented where all participants are involved in the implementation process, either planning or executing, the construct 'actual system use' are not measured in dummy or scale value. Instead, the differences of actual system use are distinguished by the roles taken by participants during the implementation process. Such differences have shown impacts in their changing acceptance levels, which will be further discussed as below.

110.5.1 Influences on Initial Acceptance

In the initial stage of implementing the RFID-enabled management system, the attitudes toward using vary to a large extent. Still, patterns could be found from the data and the interview. Participants who are in higher hierarchical levels and taking the roles in planning tend to hold a more positive attitude in the initial stage. The hierarchy of the participant's position and the role in implementing the system fall into the external variables in the extended TAM model. It can be found in the interview that the influences of these two factors on the initial attitudes are mediated by the perceived usefulness:

> *The moment I get to know this system; I know it will be promising. Compared with manually input, the scanned data from RFID could largely reduce human errors, thus increasing the job performance and work efficiency.* —03 building director

Table 110.2 Platform use and influences on their acceptance for participants who completed the final interview (n = 8)

Code of participants	Party	Hierarchical level	Roles in the implementation	Starting attitude toward using	Ending attitude toward using	Will you continues to use the technology?
01	Main Contractor (MC)	Executive Director	Planning	Positive	Positive	Yes
03	MC	Building Director	Planning	Positive	Positive	Yes
04	MC	Senior Project manager	Planning and executing	Neutral	Positive	Yes
07	MC	Project Manager	Executing	Negative	Positive	Yes
08	Supplier (SP)	Senior Project manager	Planning	Positive	Positive	Yes
15	SP	Production Manager	Planning and executing	Positive	Positive	Yes
09	SP	Production Engineer	Executing	Neutral	Positive	Yes
13	SP	Driver	Executing	Negative	Neutral	Maybe

On the contrary, participants who are obliged to execute the operations of the system are holding a neutral or even negative attitude toward using the system. The perceived ease of use is their major concern when they are faced with a new system:

> *We will let you know the limitation of the system once it is operated on site.* —07 project manager

> *I feel a bit frustrated since I barely know nothing about this system before. It is different from what I use to do before. I may need to take some more time to figure out how to use it before I can say I would like to use (the system).* —09 production engineer

110.5.2 Influences on Changed Acceptance

By comparing the feedbacks acquired at the two times of interviews for each participant, it is found that their attitudes toward using are not static. Some of their attitudes are overturned after the one-year experience of using the system, especially for participants who take the role of executing the system. They gain better understandings of the system through direct involvement and actual use of the system, which subsequently change their perspectives:

> *For me, I can feel that this system helps reduce a lot of errors that may occur during manual input. The right number and right code of each piece are very critical to the whole process. After using the system, I find it useful for reducing such errors… I believe using it in long term is a promising direction for our development.* —15 production manager

Belief in improved quality of work is a key feature of the perceived usefulness. When participants actually use and benefit from the system, their perceived usefulness increase. Similarly, another index of the perceived usefulness is the saving in time. After operating the system in person, participants would be able to grasp a deeper understanding of the system in respect of the saving in time and usefulness of the system:

> *Workload is a big concern to me. Compared with another management system once I used before, this RFID system make things easier. It saves my time.* —09 production engineer

Comparatively, the attitudes of participants who mainly manage and direct the system operation remain relatively stable, keeping positive as well. The expected improvements in working efficiency for the project or even the entire industry is they concerns, which fall into the feature of perceived usefulness:

> *New thought such as using RFID (technologies) can make the things difference. I hope it can generate the new era and benefit the industry.* —01 executive director

110.5.3 Influences on Continued Use

When asked about their willingness for continued use of the RFID-enabled management system at the second time of the interview, most of the participants show their willingness and interests in accepting the system. Some of them even proactively offer suggestions to improve the system from their user experience. The impact of perceived usefulness and perceived ease of use on the acceptance is still emphasized. Another significant factor in determining continued used is the system design, which is tightly associated with the ease of use. Such concerns were rarely mentioned in the first interview:

> *Sometimes the procedures are troublesome. I need to make extra efforts to log into the phone. You know the network is unstable around the border. If it I cannot log into the system, I don't want to try it again and again. This is a problem to be solved by the system developer. They need to consider it.* —13 driver

> *My colleague and I are quiet skilled in using the system. We would like to put it into use in our next project. We have more expectations on the user interface design, if it can be more user-friendly, with the functions of …* —04 senior project manager

To summarize, the data and feedbacks drawn from the interviews mesh with the relationships between the external variables, perceived usefulness, perceived ease of use, and attitude toward using in the TAM. Moreover, the dynamics in the acceptance levels and attitude toward using are demonstrated. Actual usage and implementation of the system are deemed as the enablers for participants to gain deeper understandings in the perceived usefulness and perceived ease of use, so as to affect their attitudes toward using the system.

110.6 Conclusion

With the development of RFID technologies and increasing fevers for the RFID technologies applications in construction industry, it is of interest to know the construction practitioners' adoption and use behaviors toward the RFID technologies. Guided by the extended TAM, this study initiates a qualitative study using semi-constructed interviews to explore the determinants behind the users' acceptance and behaviors. Findings indicate that in the initial stage perceived usefulness have major impacts on the acceptance of construction practitioners who are in higher hierarchical positions in the project. The findings also mesh with the proposed model, demonstrating that construction practitioners' attitudes toward using the system is not static, especially for those who take part in executing the operations in the system. The actual use and implementation process enable the practitioners to gain better understanding of the system, during which their perceived usefulness and perceived ease of use of the system gradually change. As one of the external variable, the system design account for a major determinant for practitioners' attitude toward the continued use of the system.

It is acknowledged that the limitation of this study is that participants in this study may not evenly represent all the hierarchical groups, gender groups, or RFID technologies users in the construction industry. As it is an exploratory and qualitative study, findings are not designed to be generalizable but to help establish a baseline understanding to which future study could further expand and consolidate.

References

Bajaj A, Nidumolu SR (1998) A feedback model to understand information system usage. Inf Manag 33(4):213–224

Davis FD (1985) A technology acceptance model for empirically testing new end-user information systems: theory and results. Doctoral dissertation, Massachusetts Institute of Technology

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 319–340

Gefen D, Straub DW (1997) Gender differences in the perception and use of email: an extension to the technology acceptance model. MIS Quarterly 389–400

Ha S, Stoel L (2009) Consumer e-shopping acceptance: antecedents in a technology acceptance model. J Bus Res 62(5):565–571

Huang JH, Lin YR, Chuang ST (2007) Elucidating user behavior of mobile learning: a perspective of the extended technology acceptance model. Electron Libr 25(5):585–598

Karahanna E, Straub DW, Chervany NL (1999) Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs. MIS Quarterly 23 (2):183–213

Lee Y, Kozar KA, Larsen KR (2003) The technology acceptance model: past, present, and future. Commun Assoc Inf Syst 12(1):50

Liu IF, Chen MC, Sun YS, Wible D, Kuo CH (2010) Extending the TAM model to explore the factors that affect intention to use an online learning community. Comput Educ 54(2):600–610

Lu W, Huang GQ, Li H (2011) Scenarios for applying RFID technology in construction project management. Autom Constr 20(2):101–106

Melas CD, Zampetakis LA, Dimopoulou A, Moustakis V (2011) Modeling the acceptance of clinical information systems among hospital medical staff: an extended TAM model. J Biomed Inform 44(4):553–564

Murray E, Burns J, May C, Finch T, O'Donnell C, Wallace P, Mair F (2011) Why is it difficult to implement e-health initiatives? A qualitative study. Implement Sci 6(1):1

Pavlou PA (2003) Consumer acceptance of electronic commerce: integrating trust and risk with the technology acceptance model. Int J Electron Commer 7(3):101–134

Wang LC, Lin YC, Lin PH (2007) Dynamic mobile RFID-based supply chain control and management system in construction. Adv Eng Inform 21(4):377–390

Chapter 111
Risk and Risk Factors in Brownfield Development

Hao Wu, Piyush Tiwari, Sun Sheng Han and Toong-Khuan Chan

111.1 Introduction

Brownfield development is subject to uncertainty of hidden environmental issue, legal liability, and social cost. The brownfield land market is known for its lack of transparency in communicating risk as possible cost associated information to aid decisions of market actors for brownfield development. Arguably less intense or urgent than some European and Asian countries, brownfield development has profound long-term impact in the US and Australia. The scale of brownfield land in global cities and regions has grown to affect the structural, demographical and technological aspects of the society, and has added to policy pressure. Brownfield land exhibits "special" effects that can impose significant costs on the owners and users of the site—an issue which will in turn affect asset value. The potential effects of contamination may last for years, which are costly to remediate by either landowner or government. It demands little justification that brownfield development risks need to be explicitly communicated, even though they may not be explicitly measured by market prices. It is also of practical urgency to raise the quality of brownfield valuation and decision making from risk communication, assessment, and psychological perspectives.

In consumer pricing, 'green' is regarded as valuable, whereas 'brown' is regarded as cost or risk. Valuation theory suggests such risk is measured as risk-adjusted rate of return i.e. as interest rate, discount rate or profit. In a private enterprise and property system, the power of land redevelopment lies with private actors, subject to varying yet influential government interventions. Under the theories of entrepreneurship and collaborative capability, professional (rationalised) knowledge of development risk is key to project and asset output and

H. Wu (✉) · P. Tiwari · S.S. Han · T.-K. Chan
Faculty of Architecture Building and Planning, The University of Melbourne, Melbourne, Australia
e-mail: haow@unimelb.edu.au

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_111

outcome. Valuation uncertainty is often qualitatively described where the risk of potential contamination effects is qualitatively reported. This is considered as ‘soft’ valuation advice, as the owner of the land as well as the investor do not get to understand and agree on the likelihood, scope, and importance of potential contamination and its associated costs. This study explores risk factors associate with brownfield lands and their values. It aims to develop a new way to measure brownfield redevelopment costs.

This paper is structured to develop a conceptual base of brownfield risk concerns (factors) in a professional knowledge context. It provides an intellectual basis for identifying risk factors and their preliminarily match with industry practices. This helps identify valuation communication conditions and efficiency towards possible theoretical advancement and analytic that are directly relevant to brownfield land evaluation and development (Petts 1994).

111.2 Risk to Risk Factor

The standard risk definition i.e. probability of not achieving certain objectives is more or less only a risk factor, instead of a term to capture ‘risk’ itself. It is a type of risk factor with certain degree of generalisation. Risk, in typical market economy, is ascribed to or measured by market value such as return volatility or risk premium. Mature price system does not always handle well the risk, when it is not efficiently circulated through market trade, i.e., in thin markets.

Much risk analysis and debate has been conducted in relation to risk-return trade-offs in financial economics and real estate finance. To date, the focus is on statistical modelling of historical market volatilities with or without forward-looking (Hendershott and Hendershott 2002; Wheaton 2002). There is sizeable literature on risk and valuation of brownfields or hazardous land, focused on the physical and psychological aspects of property value (Syms 2004). Syms (1996, 1999), for example, examined the perception of risk and remediation processes in the valuation of contaminated land in the UK. In the US contamination risk is captured in the measure and analysis of environmental externality in land valuation process (Wilson 1996; Case et al. 2006; Simons et al. 2008).

Risk in human decision-making is defined and measured probabilistically. But the measure also demands clear identification, classification and sorting to suit for analytic decision-making. There are two rational ways to treat uncertainty especially the “cost” side of uncertainties, i.e., the risk. One is inductive, where facts are observed, measured, analysed, and then ‘extended’ into the future. The pure form of risk-adjusted returns based on empirically observed historical returns is more or less of this nature, effectively relying on the “continuity of a similar likelihood or pattern occurring into the future”. The other is deductive, where one establishes a logical relationship e.g. sequence between quantified risk factors and an expected outcome in a “risk model”. The proposed study has features of the two approaches. It offers an indirect measure of the two-way process of inductive and deductive reasoning, which leads to valuation and investment factors to assist decision-making. It is reasonable to expect that investors continuously analyse past information and continuously alter or update their opinion and hence their predictions.

From this theoretical basis or approach, will a "risk category" emerge? How do we know that the risk category, determined a priori, will cover all possibilities of risk factors? Hutchison et al. (2005) and Gupta and Tiwari (2016) used survey method to identify principal risk factors affecting property valuation. If a priori, risk is derived from bounded rationality at individual level or human error, technology uncertainty, physical environment uncertainty, and information asymmetry, given market inefficiency.

111.3 Brownfield Risk, Markets and Risk Communication

Brownfields risk, risk factor, and market consequence are studied using case study approach, e.g., Chan et al. (1998), Chan (2000, 2009), Wu and Chen (2010a, b, 2012) and Wu et al. (2016). Bond (2001), Chan (2001) and Chan (2002) studied risk measures of consumer stigma due to existing or perceived land contamination. Winson-Geideman et al. (2016) tested the non-spatial contagion effects of brownfield sites using landfills in Australia. Their studies focused on market value and the valuation profession in Australia. The developer, as the bearer of risk associated with the development of the land, estimates (calculates) the price of the risk-return trade-of as profit, which in turn links to the 'windfall" profit and total user cost of capital. In a developer's valuation, profit is required rate of return, which is derived from broad market comparison in relation to the historic and the expected. It is interesting to ask the question: do actors in development project actively analyse and evaluate risk? To what extent is their risk evaluation, based on explicit rational expectation or rational choice behaviour?

An existing literature in property valuation has focused on the significance of and measure of risk in valuation and reporting (e.g. Mallinson and French 2000; French and Gabrielli 2004; Adair and Hutchison 2005; Hutchison et al. 2005; Joslin 2005; Lorenz et al. 2006; Meins et al. 2010; French 2011). Adair and Hutchison (2005) and Hutchison et al. (2005) concern that the UK valuation service does not explicitly address risk in pricing brownfield lands. They point to the combined risk-adjusted return measure using survey-based assessment of business risks. In particular, it is a risk-scoring system that is applicable across property markets—they developed the property risk scoring system using the Analytic Hierarchy Process (AHP). In Australia, Chan (2002) examines the measurement of stigma and assessment methods. Syms (1996, 1997) investigate perceived risks using survey approach, suggests the method is originated in the social theory of risk (Slovic 1992).

Gupta and Tiwari (2016) apply a risk-scoring model to the Indian commercial property market and find it a little difficult to link the (ranked) risk factors and valuation of the property. How would a valuer apply this method to help estimate market value? Here are some ideas. Rather than adjusting risk via the discount rate or risk adjusted returns in valuation one approach could be to focus on the direct adjustment of risk by identifying the risks, qualitatively, in terms of expected cash flow. Now these risks, which are likely to affect the quantity of the projected cash flow may be quantitatively described by ranking at the "local market" level. To explicitly communicate risk means to express the uncertainty in valuation in a way the client e.g. investor would easily understand.

However, this does not mean that the valuer has to quantitatively "price the uncertainty". Brownfield land contains specific "issues" that may impose cost upon the owner and user of the land, which will in turn affect the land's valuation. This aspect should be more explicitly expressed when it comes to the valuation, even though it may not be actually quantified as a reduction in the final value estimate. The AHP method seems to constitute a behavioural approach to human judgment and a study of behavioural economics may subsequently be employed to explore this question (Saaty 1994; Vaidya and Kumar 2006). The method of conducting a survey in order to identify valuation risks does not constitute an empirical method.

The AHP technique has some conceptual consistency with the quality point rating technique (Whipple 2006)—itself an alternative to the adjustment grid method. Gupta and Tiwari (2016) extend the AHP method to measure Indian commercial property risks. The AHP tool has also been noted in sustainable property literature (Agnieszka 2014; Lutzkendorf and Lorenz 2007), as well as in asset finance and development appraisal (Bienert and Brunauer 2007; Fisher and Robson 2006). The use of the AHP approach to assess environmental cost (esp. brownfield) however seems to be neglected. When the market is thin, valuation and rating will serve for the similar function. Adair and Hutchison (2005) argue property ratings or risk scores constitute a tool for measuring individual assets—one easily understood and communicated, and that can be applied to all property types in order to enhance decision-making. Lorenz et al. (2006) and Vaidya and Kumar (2006) discuss this method in greater detail.

Lutzkendorf and Lorenz (2007, p. 645) examine the question: "if sustainable buildings can be designed, constructed, and managed and their contribution to sustainable development described and assessed, then how can we foster such buildings' further market share and how can existing barriers be overcome?" The question is what instruments may be used to design a market for the consumer-producer. We focus on a similar question and adopt a similar research methodology in the context of brownfield lands.

A deeper concern exists in relation to the economics of rating (ranking) agency under agency theory. Choice is observed or revealed behaviour in society and choice theory is the basis of valuation. For market design, theories and hypotheses such as signalling emerge, which concerns information. Rating or ranking is a form of standardization and licensing. According to transaction cost and market design theories, this approach appears in emerging or 'thin market' scenario. For example, the analysis and evaluation of sustainable buildings demands a transaction cost approach because there is no existing market for trade. In property risk assessment for sustainability, however it is unclear what Lutzkendorf and Lorenz (2007) mean when they refer to “market transformation”. Does ‘market transformation’ occur? The differentiation of a projected product, the adaption of new technology, and consumer-producer trade preferences and policies may not indicate difference or transformation in social systems. Where might the transformation be found? Are there new market institutions and structures arising and what specific arrangements may they be described?

111.4 Brownfield Development Risk Factors: A Conceptual Frame

Valuation in its ideal state operates as the market equilibrium distribution of uncertainty where all actors’ knowledge is symmetrical. In this state, diverse individual preferences would be normally distributed. In real life, however, an asymmetric distribution of information amongst market actors is more likely the case. In a property context, this means that professional and consumer knowledge of and perceptions of the risks associated with property development also tends to be asymmetrical. This study focuses on the interplay of industry and professional knowledge. Rather than analysing consumer perceptions and/or market price, it is a factually based, project-based empirical study. The aim of the study is to better understand the specific risk factors, issues relating to the distribution of knowledge relevant to risk and the effectiveness of risk communication in the context of urban brownfield development and valuation.

Interplays have been observed between three key players in brownfield site redevelopment—namely between developer, shareholders such as lender, financier and insurer, and government e.g. planning authority. From a risk rating perspective, these interplays are likely to be asymmetrical. The asymmetry of the risk factors and rankings are conceptualised from the following three aspects.

Firstly, lender and developer differ for their ranking specific risks i.e. the priority accorded to the risk and control decision of perceived risk factors in a project. It is assumed that developers are in general project focused, whereas lenders are assumed to be more property e.g. land focused. This concept is known as asset specificity (Williamson 1985) caused by the interactions of the markets and sub-markets.

Secondly, developers differ among themselves in risk preferences due to their differing sizes and capabilities. For example, large owner-developers tend to differ from small individual house builders. They tend to rank risks differently. It is assumed that large owner-developers tend to have similar risk preferences to lenders due to their similarities in ownership value and investment risk-return trade-offs as well as their liability conditions.

Thirdly, local government planning authorities and market actors who are represented by the powerful actors of developer as active risk-taking investor and lender as passive investor also tend to differ in their ranking of risks. Given the nature of planning and control policies, both the choice set of market actors as well as their observable behaviour tends to be altered by this force—not as self-assessed incentivised risk priorities, but as compliance action due to intervention by planning policies and/or building regulations.

Thereby the effective communication of risk and project-market risk constitutes an interesting matter relating to project efficiency, with relevance to improving policy relating to the valuation process. In this study, we treat risk factors as rational models of land related uncertainty, due to different beliefs, preferences and powers, assuming the important value of private (professional) knowledge and diverse motivations, preferences, and priorities.

The conceptualisation of brownfield development risk factors demands consideration of (1) land development processes and their key components, and (2) the interests and perceptions of key stakeholder's risk factors. A risk system in the context of brownfield development should consider development as a production market and political process as well as a subjective mental process indicative of diverse tastes and psychological opinions. Through this framework we identify the principle criteria which in turn form the basis for identifying each of their sub-criteria. A holistic view of brownfield risk may focus on three categories of risk: market risk, development risk, and risk of the owner e.g. shareholder.

Considered from the perspective of costs that are associated with brownfield development, it is useful to treat risk factors as comprising: (1) a project e.g. technical, process cost, (2) a holding e.g. lending, insurance cost, and, (3) a governing e.g. social, public cost. Overall there is both a human or behavioural side to brownfield development risk, as well as a land or subject side. It helps to rearrange and classify risk factors, categories and criteria. The majority of risk factors in brownfield development are residing in public-social and transaction costs, which, along with market or private interest factors, comprise the main clustering instrument.

111.5 Exploring Risk Factor and Hierarchy

111.5.1 Rationale of Key Stakeholder Perspectives

As previous land uses, may create wide range of physical, chemical and biological hazards, a contaminated site may cause threat, i.e., risk, to human health, plants, amenity, building operation, and buildings service quality (Robertson 1999; Tedd et al. 2001). Environmental and health hazards can lead to financial loss for developer, lender, designer, constructor, owner, occupier, insurer, in addition to the general public.

According to the literature, multi-stakeholders, such as owners, governments, purchasers and lenders, have to date considered brownfield sites as economic risks with their own various and specific concerns in the redevelopment process. The study on brownfield risk aims to bring together risk factors based on the conceptual framework of lender, government and developer perceptions.

The behaviour of property owners is typically more risk averse than real estate developers (Hollander 2010). Property owners stick to keeping their contaminated sites off the real estate market out of fear of what future regulation and fiscal liabilities such sites might generate (Greenberg et al. 2003). Current owners of a brownfield site often have legal obligations to bear the clean-up costs, but are concerned the issue of contamination may result in a ruined reputation. Lack of funds to pay for the clean-up as well as a fear of revealing their identity are thus the main concerns for brownfield owners who are not concerned about the future risk of the contaminated site (Greenberg et al. 2003; Swartz 1994; Yousefi et al. 2007). The disincentives to property owners to disclose information for fear of liability and reduced property values have complicated the redevelopment of a complete inventory (Coffin and Shepherd 1998).

The following clusters of risk factor are considered and discussed, based on a broad range of literature on brownfield development and associated risk concerns: (1) valuation such as market risk, (2) planning such as public and social cost minimisation risk, (3) project such as construction and technological risk, and (4) investment such as ownership and return uncertainty risk.

111.5.2 Government e.g. Council Perspective

Public actors such as municipalities, who are only periodically present at the market, are not sensitive to either construction and land costs or housing and plot prices (Glumac et al. 2015). For municipalities, the main concern is that the resources invested by them need to be justifiable as benefits to local residents as tax payers (Yousefi et al. 2007). At the same time, the government should be concerned with the accountability of their decisions, the public visibility of potential downside risk and the possible reversion of a site to brownfield status due to newly discovered or non-remedied contamination (Yousefi et al. 2007).

111.5.3 Developer Perspective

Compared to the studies of owners and the public sector in brownfield sites, there is a relatively richer body of literature that assesses the economic concerns relating to brownfield redevelopment by the private sector—such as by developers, bankers, lenders and investors. Brownfield redevelopers use funds accumulated from investors and bankers who understand that brownfield sites may, on the average, carry a higher rate of risk than other types of redevelopment. To attract major investors, the return must be equal or greater than other real estate investment opportunities (Whitman 2006). With the risks to wealth and profit for private actors, such actors constantly evaluate the competition, seeking ways to cover the rising land and construction costs in order to gain greater profit (Glumac et al. 2015).

For developers, the cost of evaluating probability of prior pollution as well as determining the extent of actual damage via soil sample analysis are high, while such assessments of the extent of contamination may additionally result in damage to the redevelopment (Yount and Meyer 1994). Besides the costs of risk assessment, environmental mitigation, clean-up, the issue of an extension to the completion time of the redevelopment (which depends on the extent of damage), may lead the redevelopment to an uneconomical condition, thereby lowering the profit of purchasers (Bartsch, cited by Yount and Meyer 1994; Yousefi et al. 2007). The practice of competitive bidding for municipally-owned brownfield sites can restrain the incentive for brownfield development. This is due to time consuming investigation, loss of secrecy and privacy, and possibility of further costs (Meyer and Lyons 2000). Contaminated sites are at the less economically viable end of the spectrum, due to the potential for lower profit yet higher risk (Coffin and Shepherd 1998). Without strong incentives, developer will be reluctant to work on brownfield project.

111.5.4 Lender Perspective

Bankers are increasingly loath to support acquisitions of brownfield sites, out of the environmental concerns and uncertainty over the liability surrounding potential foreclosures (Yount and Meyer 1994). According to a nationwide survey of more than 7000 bankers in the U.S., more than half of the respondents refused, on at least one occasion, a loan application due to the possibility of environmental liabilities being imposed impose on the lending institution (Swartz 1994). For investors, expensive costs, an unexpectedly drawn out time frame and reduced returns all retard the motivation for brownfield redevelopment (Kinnard as cited in Yount and Meyer 1994; Alberini et al. 2005). The inability to obtain financing for brownfield projects, including the costs associated with remediation and the lack of financing for redevelopment, (Yount 1997) has received special attention in the existing literature relating to brownfield redevelopment. The hesitation of financiers to loan on brownfield acquisition it seems contributes to this situation.

In the US, the lenders' fear of "reopener"—where a brownfield site needs remediation—is common, even though the state-issued closure letters such as no further action (NFA) letters and certificated of completion (COCs), which shows closure of the remediation regulatory process, are offered (Simons et al. 2003). If a site was reopened after the construction starts, the project could be at risk, which may lead to onerous results to the investor. Lenders are disturbed by likely risk from reopened investigations and how it may affect the value of the collateral, which increases the possibility of default while concerns about reopeners and the potential negative affect the quality of lenders' interest in financing brownfield projects (Simons et al. 2003).

111.5.5 Project Delivery Perspective

For brownfield site engineering, recent studies have addressed risk factor in site remediation (Page et al. 1999; Viscusi and Hamilton 1999; Desousa 2000; Rao et al. 2001; Tam and Byer 2002; Linkov et al. 2004; Carlon et al. 2008). Carr and Tah (2001) studied construction project associated risk factors for site remediation. Weber (1997) discussed the valuation of contaminated land in the US context. Boopathy (2000) focuses on risk factors and their interactions with technology for bioremediation. Karn et al. (2009) compared site construction remediation options on their potential risks and relative benefits.

Carlon et al. (2008) developed a spatial risk assessment methodology, i.e., a spatial decision support system, to support remediation of contaminated land. They conducted a case study at Venice, Italy. Desousa (2000) studied contaminated site from private sector perspective by assessing economic costs and risks. He found that private sector fears future liability and prefer greenfield; government, on the other hand, will not remediate brownfield sites, if without assurance of private investment. Both US and Europe have developed innovative environmental and economic policies and programmes to lessen costs and risks associated with brownfield redevelopment. He argues it is important that contaminated land involves confirmed contamination, while brownfield means perceived environmental contamination due to previous land use. The study finds that residential brownfield is more profitable than others, whereas industrial brownfield in not.

Tam and Byer (2002) studied risk factors from site owners' perspective. Insurance firms are even offering products specifically for site clean-ups. Uncertainty may lead to technical, legal, clean-up costs. Performance of emerging remediation technologies may not be well understood (Freeze and McWhorter 1997). They suggest that well-established techniques may not perform as predicted. They suggest the following procedures: (1) investigate site and identify principal liability conditions—contribute to the owner's potential offsite liabilities, which is in addition to any onsite liability. (2) Identify and analyse remedial actions—advantages and limitations of various remedial approaches and provide technical guidance. Regulations can heavily influence the techniques chosen. (3) Characterise owner's liability—contaminant concentration actually exposed, the 'ability' of the contaminant to produce an adverse health effect, and being found liable in a court of law. (4) Determine net benefits to owner.

111.5.6 Further Considerations

In addition to these economic risks, research also suggests social psychological factors are also forming investors' risk concerns, which include uncertainty, lack of controllability, stigma and the social amplification of risk. Uncertainty about environmental concerns may result in an inflated assessment of the actual hazard, which can be expected to obstruct investors investment to reclaim the brownfield (Yount and Meyer 1994). The lack of environmental and redevelopment information on brownfield sites, especially with regard to potential contamination and which subsequently increase the importance of risk considerations when deciding whether and how to redevelop a site increase risk of brownfield. This also may restrain the redevelopment efforts of public sectors and also expel the investment of developers (Coffin and Shepherd 1998; Pediaditi et al. 2006).

At the same time, the ambiguities and increasing complexities in environmental policies and laws weaken the power and increase the uncontrollability of developers and bankers, which upwell the brownfield risk assessment (Yount and Meyer 1994). Different laws address different types of contamination and dictate different responses in the U.S. and the ambiguousness of legal liability surrounding brownfields obstructs the redevelopment (Coffin and Shepherd 1998). Another hindrance to municipally-owned brownfield redevelopment is development restriction. Because of ownership of the sites, the intervention of municipal government to dictate a specific use may decrease the motivation and controllability of the entrepreneurial brownfield redevelopment (Meyer and Lyons 2000).

As the bad news of legal and economic obstruction of brownfield developments are widely disseminated, lenders and entrepreneurs may retain the memory that brownfield reclamations often result in massive financial losses, which restrain the willingness to invest (Yount and Meyer 1994). At the same time, for the developers and advisers, the most uppermost factor of the decision-making process is whether or not the land has been stigmatised by its previous use (Coffin and Shepherd 1998; Syms 1999; Yousefi et al. 2007). That is to say, the stigma created by limited information or bad news that a site was contaminated may deeply block the redevelopment.

In light of the social amplification of risk, the interactions among investors shape perception of brownfield development risk (Yount and Meyer 1994). They indicate that the perception, which consider brownfield development as venture and fears of adverse responses may be exaggerated between developers and bankers, which may inflate possible negative results and decline investment opportunities. In addition, municipally-owned brownfields usually exhibit negative perception, which reduces the developers' willingness to invest (Meyer and Lyons 2000).

In addition to the economic issues and social psychological issues, there are other influential factors of successful brownfield redevelopment: community support, proposed land use, condition of the local infrastructure, support of local politicians, adverse publicity, and the number of jobs to be created (Howland 2003; Lange and McNeil 2004; Pediaditi et al. 2006; Thomas 2003). These factors have been seriously considered in whether or not to redevelop the brownfield land, researchers tend to assess the importance of a wide range of issues, which affect the process.

One German study (Grimski: cited by Syms 1999) outlines the economic aspects dominate in decisions while the social determinants considered as marginal by weighing the importance of a number of factors influencing the decision-making process. Based on the Grimski study, Syms (1999) undertook a survey of surveyors, developers and other professionals, which divided a wide range of decision-making factors into six groups. With several specific factors included in each group, Syms (1999) intends to obtain the opinions of actors who consider redevelopment of brownfield sites risky. It turns out that land developers and professionals firstly assess financial aspects of the environmental issues and then locational issues (Syms 1999). Syms (1999) nominates site-specific factors, community considerations, transport considerations, environmental factors, risk assessment factors and further considerations.

Attoh-Okine and Gibbons (2001) define brownfield remediation/redevelopment programs into a 4-step process, namely (1) site identification, (2) site assessment, (3) site remediation and (4) site redevelopment. They classify brownfield development issues under 5 categories, namely, technical, liability, financial, community concern, and future land-use concern. They use the Dempster-Shafer theory to combine evidence from various issues to determine the uncertainty in brownfield development decision-making. Based on statistical analysis of data collected from 2 national surveys, Lange and McNeil (2004) suggest, except environmental factors, a number of other factors, including time, cost, community, infrastructure, planning, cooperative banking institutions, politics, financial incentive, environmental clean-up, and jobs creation are important to the success of brownfield development.

111.6 Generic Brownfield Risk Criteria

We use our conceptual framework and past research, e.g., Syms (1997, 1999), as the working base to approach the concern of brownfield risk and risk factor, and adding to it a range of factors from the extensive study of risk factors suggested by the framework. The grouping of factors is further validated and discussed, which were passed to selected industry experts for their validation and feedback. An operational risk factor and hierarchy is shown in Table 111.1:

111.7 Discussion and Conclusion

If risk is interpreted as measurable quantity as probability for a cost to occur, risk factors and their relative importance are identified as decision aid to engage choice between various likely costs in brownfield development, even though it is likely

Table 111.1 Principal and sub risk criteria (factors)

Principal risk criteria		Sub-criteria
Site specific risk	1	Size and natural condition of the site
	2	Topography/relief
	3	High cost of social decontamination
	4	Associated environmental conditions
	5	Landscape and aesthetic effect
Political and legal risk	1	Location of the site within the settlement
	2	Image and homogeneity of the settlement
	3	Negative externality
	4	Regulatory processes and structure
	5	Fiscal risk e.g. taxation, insurance, subsidy
Socio-economic risk	1	Proximity of disposal and supply systems
	2	Accessibility to transportation systems
	3	Social amenities and quality
	4	Treatment facilities and services
	5	Crime and safety
Planning risk	1	Zoning law and regulations
	2	Long-term growth management policy
	3	Planning or other official approvals
	4	Heritage overlay and control
	5	Land development control processes
Project risk	1	Cost over-run
	2	Time delay for land remediation
	3	Technology selection to build and site treatment
	4	Disposal of project waste and contaminated soil
	5	Land development design and planning
Financial and market risk	1	Economic e.g. access to labour, job, customer
	2	Information e.g. adverse publicity, stigma,
	3	Supply and demand for development sites
	4	Project and market finance uncertainty
	5	Market liquidity and transaction cost

that these costs i.e. factors are inter-related. Subjective assessment of risk involves consumer emotion and perception e.g. stigma as demand side concern, as well as investment or control decision based risk factor identity and scoring as supply side appraisal. If brownfield development risk is cost focused, this paper suggests the entering more specifically into risk category and ranking of risk factors.

This paper develops a conceptual frame to identify and organise brownfield development risk and risk factor from experienced professional and industry perspective, not the direct consumer-driven risk perception. It looked into relevant literature and theories to bring upfront the problems of risk communication amongst key actors who are influential to identify and affect formation of risk factors and their hierarchy in brownfield development processes. The clustered risk factors, systematically formed and validated, will help the development of risk analysis tool for brownfield valuation. It has the potential to improve private decision and public policy making, in the current economic structural change driven urban land use intensification and gentrification processes.

This paper discusses what is understood as brownfield risk from professional perspective. It then compares it with survey e.g. focus group results and find out industry e.g. developer, lender, government risk preference patterns. It assumes the existence of asymmetric information and knowledge distribution between industry and in theory i.e. real estate, construction, finance and planning for brownfield development. More brownfield development projects need to be identified and studied as the carrier to analyse risk factors and compare and match theory and industry practice asymmetry. It considers the economic principle of substitution in brownfield risk analysis and decision. According to a senior development firm, land cost in countries such as Australia is approximately 6% of total development cost, whereas the figure may reach 20% in China. This may be due to high elasticity land supply, where contaminated sites become less attractive, given high uncertainty and potential on-going costs, low market transparency, poorly enforced legal environment, and strong control of public interest via media.

Since risk as stigma (Chan 2001) is understood based on the theory of exchange, this study focuses on development risk factors, as a theory of production. It assumes brownfield development or even land investment in general is preference driven of owners and developers, which is also policy-constrained. It is cost risk based. Therefore, this study focuses on the market that determines redevelopment of brownfield site. It is expected that the role of stigma is more critical in the user market of second-hand products i.e. pure trade and capital assets. Further research may build on these insights to improve risk communication in valuation by developing a rating (ranking) system to explicitly report relative risk perception in valuation of brownfield lands (Petts 1994; Hutchison et al. 2005). This paper helps establish basic ground to facilitate the development of further empirical studies, e.g., to develop a risk index to improve valuation and reporting.

References

Adair A, Hutchison N (2005) The reporting of risk in real estate appraisal property risk scoring. J Prop Invest Financ 23(3):254–268

Agnieszka Z (2014) Stated WTP and rational WTP: willingness to pay for green apartment in Sweden. Sustain Cities Soc 13(1):46–56

Alberini A, Longo A, Tonin S, Trombetta F, Turvani M (2005) The role of liability, regulation and economic incentives in brownfield remediation and redevelopment: evidence from surveys of developers. Reg Sci Urban Econ 35(4):327–351

Attoh-Okine NO, Gibbons J (2001) Use of belief function in brownfield infrastructure redevelopment decision making. J Urban Plan Dev ASCE 127(3):126–143

Bond S (2001) The use of conjoint analysis to assess the impact of environmental stigma. Pacific Rim Prop Res J 7(3):182–194
Bienert S, Brunauer W (2007) The mortgage lending value: prospects for development within Europe. J Prop Invest Financ 25(6):542–578
Boopathy R (2000) Factors limiting bioremediation technologies. Biores Technol 74(1):63–67
Carlon C, Pizzol L, Critto A, Marcomini A (2008) A spatial risk assessment methodology to support the remediation of contaminated land. Environ Int 34(3):397–411
Carr V, Tah JHM (2001) A fuzzy approach to construction project risk assessment and analysis: construction project risk management system. Adv Eng Softw 32(10):847–857
Case B, Colwell PF, Leishman C, Watkins C (2006) The impact of environmental contamination on condo prices: a hybrid repeat-sale/hedonic approach. Real Estate Econ 34(1):77–107
Chan N (2000) How Australian appraisers assess contaminated land. Apprais J 68(4):432–439
Chan N (2001) Stigma and its assessment methods. Pacific Rim Prop Res J 7(2):126–140
Chan N (2002) Stigma assessment: a multi-criteria decision-making approach. Pacific Rim Prop Res J 8(1):29–47
Chan N (2009) Reassessing the valuation of contaminated land in Australia. Pacific Rim Prop Res J 15(2):161–181
Chan N, Jefferies R, Simons R (1998) Government regulation of contaminated land—a tale of three cities. Environ Plan Law J 15(5):321–337
Coffin SL, Shepherd A (1998) Barriers to brownfield redevelopment: lessons learned from two Great Lakes states. Public Works Manag Policy 2(3):258–266
De Sousa C (2000) Brownfield redevelopment versus greenfield development: a private sector perspective on the costs and risks associated with brownfield redevelopment in the Greater Toronto Area. J Environ Plan Manag 43(6):831–853
Fisher P, Robson S (2006) The perception and management of risk in UK office property development. J Prop Res 23(1):135–161
French N (2011) Valuing in the downturn: understanding uncertainty. J Prop Invest Financ 29(3):312–322
French N, Gabrielli L (2004) The uncertainty of valuation. J Prop Invest Financ 22(6):484–500
Glumac B, Han Q, Schaefer WF (2015) Actors' preferences in the redevelopment of brownfield: latent class model. J Urban Plan Dev 141(2):1–10
Greenberg M, Downton D, Mayer H (2003) Are mothballed brownfields sites a major problem: property owners who avoid environmental clean-up costs hold back community redevelopment efforts. Public Manag Lawrence Then Wash 85(5):12–17
Gupta A, Tiwari P (2016) Investment risk scoring model for commercial properties in India. J Prop Invest Financ 34(2):156–171
Hendershott P, Hendershott R (2002) On measuring real estate risk. Real Estate Financ 18(4):35–50
Hollander J (2010) Private property owners and the remaking of brownfields. Public Works Manag Policy 15(1):32–56
Howland M (2003) Private initiative and public responsibility for the redevelopment of industrial brownfields: three Baltimore case studies. Econ Dev Q 17(4):367–381
Hutchison N, Adair A, Leheny I (2005) Communicating investment risk to clients: property risk scoring. J Prop Res 22(2–3):137–161
Joslin A (2005) An investigation into the expression of uncertainty in property valuations. J Prop Invest Financ 23(3):269–285
Karn B, Kuiken T, Otto M (2009) Nanotechnology and in situ remediation: a review of the benefits and potential risks. Environ Health Perspect, 1823–1831
Lange D, McNeil S (2004) Clean it and they will come? Defining successful brownfield development. J Urban Plan Dev 130(2):101–108
Linkov I, Varghese A, Jamil S, Seager TP, Kiker G, Bridges T (2004) Multi-criteria decision analysis: a framework for structuring remedial decisions at contaminated sites. Comp Risk Assess Environ Decis Making 38:15–54
Lorenz D, Trück S, Lützkendorf T (2006) Addressing risk and uncertainty in property valuations: a viewpoint from Germany. J Prop Invest Financ 24(5):400–433

Lutzkendorf T, Lorenz D (2007) Integrating sustainability into property risk assessments for market transformation. Build Res Inf 35(4):644–661
Mallinson M, French N (2000) Uncertainty in property valuation—the nature and relevance of uncertainty and how it might be measured and reported. J Prop Invest Financ 18(1):13–32
Meins E, Wallbaum H, Hardziewski R, Feige A (2010) Sustainability and property valuation: a risk-based approach. Build Res Inf 38(3):280–300
Meyer PB, Lyons TS (2000) Lessons from private sector brownfield redevelopers—planning public support for urban regeneration. J Am Plan Assoc 66(1):46–57
Page CA, Diamond ML, Campbell M, McKenna S (1999) Life-cycle framework for assessment of site remediation options: case study. Environ Toxicol Chem 18(4):801–810
Pediaditi K, Wehrmeyer W, Chenoweth J (2006) Sustainability evaluation for brownfield redevelopment. In: The proceedings of the institution of civil engineers-engineering sustainability, Thomas Telford Ltd
Petts J (1994) Contaminated sites: blight, public concerns and communication. Land Contam Reclam 2(4):171
Rao PSC, Jawitz JW, Enfield CG, Falta RW Jr, Annable MD, Wood AL (2001) Technology integration for contaminated site remediation: clean-up goals and performance criteria. Groundw Qual Nat Enhanc Restor Groundw Pollut 275:571–578
Robertson HG (1999) One piece of the puzzle: why state brownfields programs can't lure businesses to the urban cores without finding the missing pieces. Rutgers Law Rev 51 (5):1075–1132
Saaty T (1994) How to make a decision: the analytic hierarchy process. Interfaces 24(6):19–43
Simons RA, Pendergrass J, Winson-Geideman K (2003) Quantifying long-term environmental regulatory risk for brownfields: are reopeners really an issue. J Environ Plan Manag 46(2):257–269
Simons RA, Saginor J, Karam AH, Baloyi H (2008) Use of contingent valuation analysis in a developing country: market perceptions of contamination on Johannesburg's mine dumps. Int Real Estate Rev 11(2):75–104
Slovic P (1992) Perception of risk: reflections on the psychometric paradigm. In: Krimsky S, Golding D (ed) Social theories of risks. Praeger
Swartz RD (1994) Michigan's approach to urban redevelopment involving contaminated properties. Econ Dev Q 8(4):329–337
Syms P (1996) Perceptions of risk in the valuation of contaminated land. J Prop Valuat Invest 15 (1):27–39
Syms, P (1997) Contaminated land: the practice and economics of redevelopment. Blackwell Science
Syms P (1999) Redeveloping brownfield land: the decision-making process. J Prop Invest Financ 17(5):481–500
Syms P (2004) Previously developed land: industrial activities and contamination. Blackwell, Oxford, UK
Tam EK, Byer PH (2002) Remediation of contaminated lands: a decision methodology for site owners. J Environ Manag 64(4):387–400
Tedd P, Charles JA, Driscoll R (2001) Sustainable brownfield re-development: risk management. Eng Geol 60(1–4):333–339
Thomas MR (2003) Brownfield redevelopment: information issues and the affected public. Environ Pract 5(1):62–68
Vaidya O, Kumar S (2006) Analytic hierarchy process: an overview of applications. Eur J Oper Res 169(1):1–29
Viscusi WK, Hamilton JT (1999) Are risk regulators rational? Evidence from hazardous waste cleanup decisions. Am Econ Rev 89(4):1010–1027
Weber B (1997) The valuation of contaminated land. J Real Estate Res 14(3):379–398
Wheaton WC (2002) On measuring real estate risk: a reply. Real Estate Financ 18(4):41–42
Whipple RTM (2006) Property valuation and analysis, 2nd edn. Thomson LawBook Co

Whitman I (2006) Brownfield redevelopment by the private sector: market driven decision making, brownfield sites iii: prevention, assessment. Rehabil Dev Brownfield Sites 94:11121

Wilson AR (1996) Emerging approaches to impaired property valuation. Apprais J 21:155–170

Williamson, O (1985) The economic institutions of capitalism. Simon and Schuster

Winson-Geideman K, Krause A, Wu H, Warren-Myers G (2017) Non-spatial contagion in real estate markets: the case of Brookland Greens, Journal of Sustainable Real Estate, in press

Wu H, Chen C (2010a) A pilot case study of brownfield high-density housing development in China. Int J Hous Mark Anal 3(2):119–131

Wu H, Chen C (2010b) A pilot case study of inner-city high-density housing on brownfield in Chongqing China. In: Proceedings of the 16th PRRES annual conference, pp 1–15, 24–27 Jan, Wellington New Zealand

Wu H, Chen C (2012) Urban brownfield regeneration: an Australian perspective. In: Proceedings of 18th PRRES annual conference, 15–18 Jan, University of South Australia, Adelaide, pp 1–10

Wu H, Qin B, Yang J (2016) Regulation system and institutional design for brownfield redevelopment in Melbourne. Urban Plan Int 31(4):72–78

Yount KR (1997) The organizational contexts of decisions to invest in environmentally risky urban properties. J Econ Issues 31(2):367–373

Yount KR, Meyer PB (1994) Bankers, developers, and new investment in brownfield sites: environmental concerns and the social psychology of risk. Econ Dev Q 8(4):338–344

Yousefi S, Hipel KW, Hegazy T, Witmer JA, Gray P (2007) Negotiation characteristics in brownfield redevelopment projects. In: 2007 IEEE international conference on systems, man and cybernetics, (1–8), pp 3651–3656

Chapter 112
Risk Management in the Supply Chain of Essential Medicines

Mario M.J. Musonda, Erastus M. Mwanaumo and Didibhuku W. Thwala

112.1 Introduction

Access to quality health care is a human right and is one of the main objectives of any health care system which provides essential medicines as part of health care (Mona et al. 2013). Therefore, every Zambian citizen has right to quality health care through access to essential medicines. According to World Health Organisation (2015), essential medicines are the medicines that satisfy the needs of the population which are timely available and affordable with the right quality in adequate quantities at the right place. However, global challenges exist in ensuring that essential medicines are always available and affordable in delivering public healthcare. Essential medicines like other commodities are made available for customer (patient) through an established supply chain. Inefficiency within the supply chain brings about medicines shortages and stock outs at health facilities. These shortages are experienced globally with different causes and challenges from one country to the other. Joseph et al. (2014) asserts that shortages of essential medicines are a major issue in Tanzanian public health facilities despite increasing attention through numerous reforms and initiatives. This follows a conducted survey in 2013 which found that 41% of patients were unable to get the medicines they needed from a public health facility. In addition, Pross Nagitta et al. (2010) confirms existence of supply chain challenges and deficiencies of the Ugandan essential medicines supply chain is evidenced by the fact that there are stock outs and shortages at health facilities while the National Medical Stores would be destroying expired medicines.

M.M.J. Musonda
Department of Civil and Environmental Engineering, School of Engineering, University of Zambia, Lusaka, Zambia

E.M. Mwanaumo · D.W. Thwala (✉)
Faculty of Engineering, University of Johannesburg, Johannesburg, South Africa
e-mail: didibhukut@uj.ac.za

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_112

The study was undertaken to determine the risks that are obtaining in the public sector supply chain of essential medicines in Zambia with Lusaka District being the case study area. The study involved identifying, assessing and prioritising the risks within the supply chain that affect the efficiency of the supply chain in making the essential medicines available at public health facilities. This was done following principles of risk management process from risk identification to risk ranking.

112.2 Literature Review

Kerzner (2009) defines risk as a measure of the probability and consequence of not achieving a defined project goal and/or its objectives. This measure is purely determined by the likelihood (probability) and the consequences (impact) of the not achieving the project objectives. The above definition helps to describe and define quality risk management as a systematic process for the assessment, control, communication and review of risks to the quality of the drug (medicinal) product across the product lifecycle (Muhammad and Rehana 2014).

Mona et al. (2013) asserts that supply chain is a set of players, processes, information, and resources which transfers raw materials, and components to finished products or services and delivers them to the customers. Supply chain conceptually covers the entire physical process from ordering and obtaining the raw materials through all process steps until the finished product reaches the end consumer (Chartered Institute of Purchasing and Supply 2014). Therefore, in supply chain of health products including essential medicines, is entirely done with an objective of ensuring the essential medicines and other health products are delivered to the patient.

Figure 112.1 summarises the conceptual supply chain as a customer focused process;

Therefore, for the supply chain to function it needs coordination among participating partners and organisation. Shanmugan and Sajal (2012) stresses this that Supply Chain relationships are generally long term and require considerable strategic coordination within the organization and between the supply chain partners.

Supply Chain Management is the continuous planning, developing, controlling, informing and monitoring of actions within and between supply chain links so that an integrated supply process results which meets overall strategic goals (Chartered Institute of Purchasing and Supply 2014). Supply chain management of pharmaceuticals can be described using the cycle as indicated by the USAID Guidelines for Managing the HIV/AIDS Supply Chain (John Snow 2005; Fig. 112.2).

However, emphasis in supply chain management is made on having several processes and interested parties being involved at different stages and phases. Naude and Badenhorst-Weiss (2011) indicates that supply chain management includes the purchasing of materials, transforming them into intermediate goods and final products, and delivering a product or service to the final customers and includes all those activities involved in the flow of materials through the supply chain.

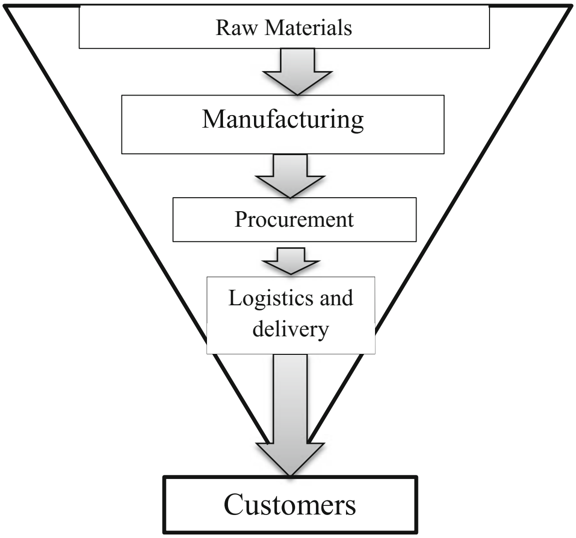


Fig. 112.1 Supply chain

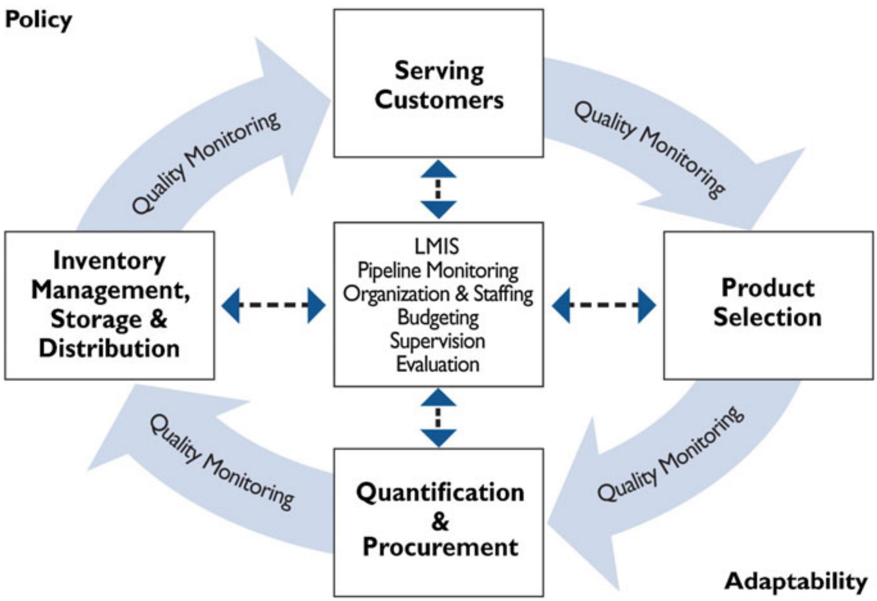


Fig. 112.2 Logistics cycle. *Source* Watson et al. (2013)

Therefore, integrating effective risk management should provide improvement in the efficiency of the supply chain in ensuring medicines availability at health facilities. It would ensure that health products are delivered at the right place in the right quality (Watson et al. 2013). However, supply chain requirements for essential medicines are different from those of health products because of the nature of medicines in general. Yadav (2007) reports that within the Zambian public sector supply chain, there are different organisations and institutions that contributes to ensuring availability of essential medicines at public health facilities. Consequently, implementation of effective risk management within the supply chain of essential medicines proved to be needed starting with the involved organisations and institutions. This is because performance of any supply chain is dependent on the performance of individual contributions of the organisations and institutions within the supply chain.

112.3 Methodology

The study was done using qualitative research methodologies as a descriptive method through case study approach. Therefore, the sample population was Lusaka District and related offices where activities and programmes are undertaken that are part of the supply chain activities. The sample size included offices that are under the Ministry of Health (MoH), Medicals Stores Limited (MSL), Zambia Medicines Regulatory Authority (ZAMRA) and Cooperating Partners (CPs). The study focused on the public sector supply chain in Lusaka District with regards to risks that reduce the efficiency of supply chain and its results through shortages and stock outs of essential medicines at public health facilities.

112.3.1 Sampling and Data Collection

The study was conducted through implementing purposive (judgmental) sampling. This method was adopted due to the nature of the research field as well as maintaining reliability and validity of data to be collected. Just as Michael et al. (2000) affirms that case study research can achieve integrity or rigour of validity through five approaches: construct validity; confirm-ability; internal validity/credibility; external validity/transferability and finally, reliability/dependability. Therefore, the sample size included individuals who have worked and/or currently working in the following identified categories of the supply chain; Selection and Quantification, Registration (Regulation), Procurement, Storage and Distribution, Quality assurance and Dispensing of essential medicines. The professions of the individuals that participated included pharmacists, procurement and other health practitioners.

Data was collected using two instruments; namely the discussions and interviews with selected experts and self-administered questionnaires to participants selected purposively. The interviews and discussions were held with selected experts by their individual professional work experience of more than ten (10) years. These sessions were used as platform to identify risks apart from literature review. A total of ten (10) experts participated in the research through interviews and discussions which were held using One-on-One approach. The sessions represented a large involvement of pharmacists (80%) in the categories of the public sector supply chain management among the experts. For the second stage, the identified risks from the reviewed literature and interview/discussions were then drafted into questionnaires for validating the identification of risks. Therefore, fifty (50) self-administered questionnaires were distributed to assist with the risk identification and analysis qualitatively and quantitatively. The questionnaires were pilot tested and corrected with the necessary changes. All questionnaires were hand delivered and collected to avoid non responsiveness from the participants. Participants were purposively selected with a view of obtaining responses/feedback that can be used with confidence.

Ethical consideration was taken into consideration in conducting the research. This was done by seeking permission from organisations and individuals while ensuring and guaranteeing that confidentiality and anonymity is preserved.

112.4 Results

All participants for this research were taken from within Lusaka district. Figure 112.3 shows the presentation of the involved professions.

Figure 112.3 shows a large involvement of total pharmacists (71%) as expected in the categories of the public sector supply chain. The majority of the total participants were with working experiences between five (5) and ten (10) years which comprises of approximately forty-six per cent (46%) and then followed by those with more than ten (10) years working experience with forty (40) per cent. This was considered to be a good contribution to the reliability and validity of the questionnaire responses/feedback in the research. However, contribution of those new in the profession (Less than five years) was vital as their responses were used to

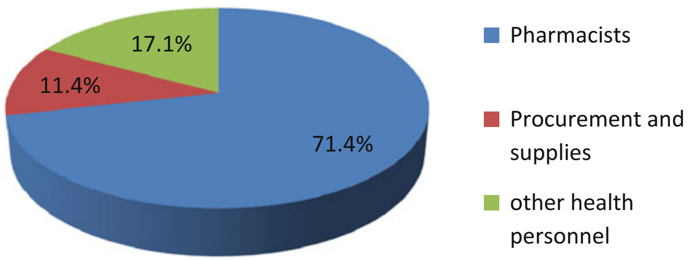


Fig. 112.3 Profession representation of participants

account for changes with professional practice due to technological advancements and also with knowledge advancements by research and developments.

After analysis of the results from both the interviews and questionnaires, the table below summarises the risks identified and assessed as the most important by the participants.

Table 112.1 confirms that despite the experts not having hands on daily experience with the activities that have an effect on the efficiency of the supply chain, certain risks have existed for a long time without being mitigated making them very repetitive and thus constantly affecting negatively the supply chain and consequently resulting in shortages and stock outs of essential medicines at public health facilities. On the other hand, it also presents an opportunity to show the variation and improvement with time of other areas where certain risks have been controlled through implementation of other activities and programmes by organisations and institutions involved in the categories of the supply chain. However, a combination of both sides reveals that there is luck of an effective risk management system that could reduce and/or avoid certain risks.

The percentage risk score (PRS) was calculated using the following formula;

Percentage Risk Score (%RS) = Priority Score * 20

The identified and assessed risks were prioritised and ranked to provide a profile that shows which risks affect the supply chain efficiency the most through contribution to shortages and stock outs of essential medicines at public health facilities. The risk ranking was based on the region of the percentage risk score of each individual risk on the risk map as shown in Table 112.2.

This formula was applied on the identified and analysed risks that were classified as the most important based on their priority scores. They were organised as described in Table 112.3.

112.5 Percentage Risk Score

Table 112.3 shows the most important risks as identified based on the study. These risks were considered to be the most important in the order they have been presented and also to channel resources that could improve the efficiency of the supply chain with the end result of reducing and/or avoiding shortages and stock outs of essential medicines at public health facilities.

Table 112.1 Identified and analysed risks in public sector supply chain of essential medicines

SN	Supply chain category	Risk from interviews/discussions	Risks from questionnaires
1	Selection and quantification	• Weak information management system • Weak coordination and transparency among stake holders • Lack of available updated EML • Inadequate capacity (specific training) • Insufficient finances	• Insufficient financial resources • Lack of technical skills/ training • Logistical and organizational • Lack of consumption information • Lack of understanding the process
2	Registration (regulation)	• Long process • Inadequate capacity (required expertise and sufficient HR) • Insufficient finances	• Long registration process • Insufficient human resources
3	Procurement	• Inadequate technical input (pharmaceutical skills) • Long lead times • Inconsistent fund disbursement • Insufficient finances	• Insufficient finances • Lack of coordination by stakeholders • Procurement lead times
4	Storage and Distribution	• Inadequate communication between MSL and health facilities • Inadequate coordination and cooperation among stakeholders • Insufficient storage spaces • Inadequate human resources • Lack of security	• Insufficient finances • Long procurement and delivery lead times • Insufficient storage infrastructure • Insufficient vehicles • Inadequate communication • Inadequate human resources
5	Quality Assurance	• Lack of infrastructure • Inadequate infrastructure • Insufficient skilled personnel • Inadequate infrastructure	• Insufficient finances • Insufficient testing facilities • Inadequate human resources • Inadequate quality management systems
6	Financial	• Lack of alternative sources of funds by GRZ • Lack of cooperation by stakeholders • Disbursement of funds delay	• Inadequate financial disbursements • Delayed and irregular disbursements

Table 112.2 Risk mapping

Risk likelihood, R(L), From 1-Low to 5-Very High	5					VH
	4				H	
	3			M		
	2		L			
	1	VL				
		1	2	3	4	5
	Risk impact, R(I), From 1-Insignificant to 5-Catastrophic					

112.6 Discussion of Results

112.6.1 Finance

It can be deduced from Table 112.3 that the most import risks in all the categories are associated with insufficient financing of the activities. The risks related to finance were calculated to having the highest percentage risks scores of ninety (90%) and hundred (100%) per cent in four of the six categories. This is a reflection of the stress the MoH is exposed to while trying to ensure availability of healthcare services to the public. This is largely contributed to the fact that MoH has to finance most of the activities to be undertaken by different institutions in the categories of the public sector supply chain of essential medicines. The level of importance by percentage score also outlines the significance of having sufficient finances for the activities in the supply chain. During the discussion and interviews, financing was observed to have been a prominent risk in almost every category which has been verified through the questionnaire survey. It further illuminates financing as the risk driver for the entire risk management process of the supply chain of essential medicines in public sector. At top level, this risk area is within the control of the law and policy makers in ensuring that guidance and oversight governance of financial management is undertaken effectively by the implementing authorities and professional personnel.

Table 112.3 Identified and analysed risks

Supply chain category	Important risks—description	Priority score	PRS (%)
1. Selection and quantification	1.1 Insufficient financial resources	5	100
	1.2 Lack of technical skills/training	4	80
	1.3 Logistical and organisational	4	80
	1.4 Lack of consumption information	4	80
	1.5 Lack of understanding the process	3.5	70
2. Registration	2.1 Long registration process	4.5	90
	2.2 Inadequate human resources	4	80
3. Procurement	3.1 Insufficient finances	4.5	90
	3.2 Lack of coordination by stakeholders	3.75	75
	3.3 Procurement lead times	3.5	70
4. Storage and distribution	4.1 Insufficient finances	4.5	90
	4.2 Long procurement and delivery lead times	4	80
	4.3 Insufficient storage infrastructure	4	80
	4.4 Insufficient vehicles	3.5	70
	4.5 Inadequate communication	3.5	70
	4.6 Inadequate human resources	3	60
5. Quality assurance	5.1 Insufficient finances	4.5	90
	5.2 Insufficient testing facilities	4	80
	5.3 Inadequate human resources	3.5	70
	5.4 Inadequate quality management systems	3.5	70
6. Finance	6.1 Inadequate financial disbursements	4	80
	6.2 Delayed and irregular disbursements	4	80

112.6.2 Selection and Quantification

Despite not having sufficient finances, certain important risks can be controlled and effectively managed if detected early and planned for within the activity action plans. Lack of technical skills/training, consumption data and understating the process under selection and quantification are some areas that effective risk management can reduce or avoid the impact of the risks on the supply chain. From the discussions and interviews, it was understood that effective implementation of continuous in-service training of personnel on selection and quantification of medicines is necessary due to the frequent transfer of trained and untrained personnel from one area of implementation to the other within and across categories of the supply chain. Therefore continuous training of personnel would be an effective mitigation measure that will ensure adequate skills are available and updated, understanding of the process is made easier and would also guarantee provision of accurate and sufficient consumption data. Henceforth, having inaccurate consumption data of essential medicines at health facilities has major impact on the efficiency of the supply chain as procurement aided by selection and quantification of essential medicines depend on consumption data from health facilities.

112.6.3 Registration

The most important risks that require priority mitigation in the risk management process under the category of registration were the length of registration process of essential medicines and inadequate human resources (HR). The two most important risks of the category are inter-related in nature because one risk can be hugely reduced and avoided by mitigation of another. The risk of having a long registration process based on a number of factors but discussions and interviews revealed that the process is lengthened by the insufficient human resources and expertise to handle the required work by ZAMRA. This is because ZAMRA personnel are also required to process the registration of other pharmaceutical and allied substances as stipulated by the Act of Parliament. Therefore, early detection and control of these most important risks of the category would increase the efficiency of the supply chain and as a result ensure timely procurement and availability of essential medicines at health facilities.

112.6.4 Procurement

The most important risks from the category were lack of coordination and cooperation by stakeholders and long procurement lead times. The risks however, had some interdependence on financing risk. This was because completion of the entire procurement process effectively required availability of sufficient funds for the activities and programmes to be successfully done. Coordination and cooperation among stakeholders relates to the integrity, ability to communicate and share information, frequent and necessary open consultations in the entire procurement process.

Information sharing and frequent communication is very important in every process that involves more than party in implementing policies and procedures. Henceforth, procurement process is not an exception from information sharing and communication practices. This has led to parallel procurement of similar medicines by MoH and CPs some years ago but has been rectified through the implementation of the National Drug Budget Line under MoH. Nevertheless, in some instances lack of coordination and cooperation has led some unnecessary multiple donations on medicines not been required urgently by health facilities leaving out addressing the need of essential medicines. Therefore, implementing risk management process under this category would ensure that there is early detection of risks and thereby plan for mitigation and control. Effective risk management process would also reduce the cost of the entire procurement process that requires emergency procurement when unforeseen risks occur and may affect the availability of essential medicines at health facilities

112.6.5 Storage and Distribution

The programmes and activities under this category are implemented by MSL as discussed and highlighted in the previous chapter. Therefore, the institution depends on being funded by GRZ through grants and support from CPs. Hence, all operations and management of activities are implemented using the GRZ grant and CPs assistance. However, as earlier discussed under financial related risks, the funding of the operations are insufficient and result in a number of risks occurring which are mitigated using emergency solutions that ultimately become costly. Failure to effectively implement risk management process in the activity plans results in costly mitigation of risks upon occurrence.

The important risks as shown in Table 112.3 are partly dependent the finances but however, they can be avoided and/or controlled to reduce the impact and consequently also reduce the percentage risk score. The length of procurement lead times had an effect on how the storage and distribution was carried out. This is because MSL plans its storage and distribution in line with the procurement plan as provided by MoH. Hence, changes in procurement process implied an equal effect of the storage and distribution plan. In addition, essential medicines are transported to various corners of the country by road. Therefore, distribution is hugely affected by limited number of vehicles to use in transporting the medicines. Insufficient vehicles for distribution imply that there is also an equivalent insufficiency of human resources to drive the vehicles and provide other related services.

Storage at national and regional level is provided by MSL while health facilities provide their own storage infrastructure. This includes providing own inventory systems, storage spaces and related management systems for ensuring quality, safety and efficacy of essential medicines are preserved before been dispensed. Insufficient storage infrastructure is experienced by many health facilities in Zambia. The lack of sufficient storage space removes the ability of health facilities to be adequately stocked with required medicines. This leads to the ordering of medicines from MSL frequently than necessary as MSL is already constrained with number of available vehicles and some health facilities are in hard to reach areas thereby leading to health facilities experiencing shortages of essential medicines. Therefore, effective implementation of risk management process in the activities would reduce or avoid the risk impact.

112.6.6 Quality Assurance

The most important risks under this category included, insufficient finances, insufficient testing facilities, inadequate human resources and quality management systems. Testing medicines for quality control purposes along the supply chain is a responsibility by MoH but delegated by the Act of Parliament to ZAMRA through regular inspections and testing using the National Drug Quality Control Laboratory. However, quality control checks were not done at every point due to the costs and necessity of the exercise. Therefore, ZAMRA ensures that the quality, safety and efficacy of essential medicines through its made by inspections and testing. Being the only public drug testing laboratory and only located in Lusaka, it meant that medicines in other areas of the country have to be taken to the laboratory for analysis and decision making which may take long. Human resource is vital for an effective quality management system. This is because a well-documented quality management system is only effective when it is implemented by personnel working in affected areas which are under the quality management system. The results of data collection show that policies, guidelines and procedures (Standard Operating Procedures—SOPs) are available but their implementation requires trained and qualified personnel with adherence to the management system.

112.7 Conclusion

The study provided a review of the effects of implementing an effective risk management system and/or luck of it. This could be observed from the study objectives of identifying, assessing and ranking of the risks which provided a risk profile of the most important risks in the supply chain. The case of supply chain management of essential medicines for the public sector in Zambia showed that integration and adoption of risk management processes could result in improved efficiency in performance of the supply chain and there by resulting in improved availability of essential medicines at public health facilities. However, achievement of improved performance also would depend on other external factors which were not part of the study. Therefore, it is recommended that another study could be conducted to ascertain and quantify other factors that could improve the availability of essential medicines at public health facilities as well as expanding the research to national wide in a quantitative research that could provide a statistical correlation between effective risk management in supply chain and availability of essential medicines at public health facilities.

References

Chartered Institute of Purchasing and Supply, CIPS (2014) CIPS positions on practice. Monthly. CIPS

John Snow Inc (2005). Guidelines for managing the HIV/AIDS supply chain. Arlington. Deliver, VA 22209 USA

Joseph W et al (2014) Stock-outs of essential medicines in Tanzania. Overseas Development Institute, London

Kerzner H (2009) Project management: a systems approach to planning, scheduling and controlling, 10th edn. Wiley, New Jersey

Michael C, Pat R, Chad P, John C (2000) Implementation of realism in case study research methodology. In: International Council for Small Business, A.C., (ed) International council for small business, annual conference, Brisbane, 2000

Mona J, Shekoufeh N, Akbar A, Rassoul D (2013) Pharmaceutical supply chain risks: a systematic review. DARU J Pharm Sci. doi: 10.1186/2008-2231-21-69

Muhammad N, Rehana B (2014) Implementation of quality risk management (QRM) in pharmaceutical manufacturing industry. IOSR J Pharm Biol Sci (IOSR-JPBS) 9(1):95–101

Naude MJ, Badenhorst-Weiss JA (2011) Supply chain management problems at South African automotive component manufacturers. South Afr Bus Rev 15(1):70–99

Pross Nagitta O, Francis S, Stephen K (2010) Tackling supply chain bottlenecks of essential drugs: a case of Uganda local government health units. In: 4th international procurement conference, Seoul

Shanmugan J, Sajal K (2012) A case study approach for understanding supply chain orientation in Indian pharmaceutical firms. Kuwait Chapter Arab J Bus Manage Rev 1(9):45–78

Watson N, Brian S, Joseph M, Andrew I (2013) Risk management for public health supply chains: toolkit for identifying, analyzing, and responding to supply chain risk in developing countries. Guide, USAID| Deliver Project, Task Order 4 USAID, Arlington, VA

World Health Organisation, WHO (2015) http://www.who.int/topics/essential_medicines/en/. [Online] (1) Available at: http://www.who.int/topics/essential_medicines/en/. Accessed 18 Mar 2015

Yadav P (2007) Analysis of the public, private and mission sector supply chains for essential drugs in Zambia. DFID Health Resource Center, META

Chapter 113
Rural Residential Land Transfer in China: Government-Driven or Market-Driven?

Zhibin Mo, Yuzhe Wu and Jianfeng Ye

113.1 Introduction

China has experienced a rapid urbanization since the introduction of reform and opening-up policies. In fact, 49.68% of China's population now live in urban areas and engage in non-agricultural industries. However, the rapid urbanization has resulted in a variety of conflicts between rural and urban areas (Yu et al. 2015), especially, the widening rural-urban economic gap. Many scholars indicated that the economic gap is partially influenced by various institutional biases, involving educational opportunity, health care, housing, political standing and other aspects, in which the unfair property rights arrangement of rural land plays a significant role.

There are two phenomenon should be taken into consideration when analyzing the reform of rural residential land system. The first one is that the amount of migrant workers from rural to urban areas has dramatically increased in recent years due to the stimulus of urbanization. Actually, over the past 30 years (up to 2012), the amount of Chinese migrant workers has been multiplied hundreds times from 6.6 million in 1982 to 236 million in 2012 (Siciliano 2012). A survey conducted in 2012 indicated that about 70% generation migrants with an average age of 23 are willing to settle down in big cities (Bo et al. 2015), which implicated that settling in cities is becoming a prevalent trend.

Meanwhile, the number of land-related legal cases has experienced a decrease from 166,042 to 61,821, but the area correlated to illegal use of land increased

Z. Mo · Y. Wu (✉)
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

Z. Mo
e-mail: 260877702@qq.com

J. Ye
Zhejiang College of Construction, Zhejiang, China
e-mail: 8626400@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_113

about 335,136 ha (Chen et al. 2015). The illegal land use, essentially, is a reflection of inefficient allocation mechanism of land resources (Chen et al. 2015). According to the current Land Management Law, the rural residential land is forbidden to be transferred outside of the original collective which is supposed to suppress the migration wave, but the trend living in cities obviously prevailed those stringent restricts, and result is that residential land left unused by the exodus of rural people has been a huge waste of land resources (Huang 2012). Paradoxically, the exorbitant housing price in China has made commodity housing unaffordable to many young people living in urban areas (Bo et al. 2015). Therefore, the informal transaction of rural residential land started to be infested in Chinese countryside with the booming demand of lower price housing from urban side and the ample supply from countryside (Chen et al. 2015), which partially explains the increase of illegal use of land in recent years.

Obviously, the current institutional arrangement of rural residential land prevents the rural residents to capitalize their rural residential land and leads to the waste of land resource. Hence, many scholars have been dedicated to explore a more rational system of the rural residential land. Some scholars support the complete privatization of rural residential land by pointing out that the property rights of rural residential land is substantially homogenous with that of state-owned construction land according to the Property Law (Cai 2005; Jiang and An 2003; Zhang 2008). However, other scholars claimed that the privatization of land in the socialistic China would be a violation of constitution, and they proposed that nationalization of rural residential land would be a way out since the land use right of urban state-owned construction land could be transacted under the modern market economy and has been proven to be successful (Xu 2005; Yan and Wang 2005; Liu and Yi 1998; Tan et al. 2006; Ma and Yang 2007). Unfortunately, a great deal of literature was focused on the alternative of nationalization or privatization from the perspective of government-driven mode, but with little consideration of the feasibility of both of them.

113.2 Comparison Between Nationalization and Privatization

The Constitution and Land Management Law of PRC clearly regulates that rural land is owned by rural collective, members of collective are only authorized to contract and manage the land from the collective they belong without the right of transaction (Rosato-Stevens 2008). Considering the success of the marketization of urban land, some scholars believe that the nationalization would be a way out for realizing the capital value of the rural residential land and the high efficiency of land use. These scholars insisted that (1) Nationalization could avoid unnecessary disputes over ideology and reduce the risks of radical reform, because it essentially conforms to the ultimate requirement of socialist public ownership. (2) Nationalization strengthens macro-control of land which is helpful curbing the land annexation. (3) Farmers' land rights are not weakened by nationalization, on the contrary, they are bestowed more practical rights from acquiring the tractable land use right though the illusory ownership has been transferred to state. (4) Nationalization of rural land could improve the use efficiency of land benefited from a set of clear property rights. (5) Nationalization is beneficial to the sustainable development of agriculture. Under the current institution, farmers are only responsible for the land they contracted from the collectives, so they are either lack of the incentive or power to take care of the management, maintaining and construction of main agricultural infrastructures. Considering how to avoid of farmers' short-term action and who should be responsible for the supply of public goods, scholars believe that nationalization would be a good choice as the responsibility transfers to a clear entity that has the capacity to undertake the public goods affairs (He 2010; Wen 2009; Tan et al. 2006; Kong 2010).

Meanwhile, scholars who hold the opposites also expressed their concerns. Firstly, how to realize the nationalization of rural land which bears millions of people with millions intricate property relationships entwined each one of them? Expropriation with low compensation, which seems an economically low cost way but actually with high social cost, the governments must answer themselves whether the opposition from land-lost people and the potential social turbulence would appear in an acceptable way. Purchasing, seems a more moderate way with less risk of opposition from the bottom. However, purchasing a huge area of rural land needs a heavy public expenditure which might be an unaffordable budget to the government at all levels. Secondly, nationalization of rural land might break the promise that CPC pledged to Chinese farmers in the early stage of PRC. Considering the political need and communist ideals, CPC devoted itself to establishing a rural society of "land to the tiller" and promised that rural land would be equally allocated to all farmers. Thirdly, the government would be the owner after the reform of nationalization, but government itself is unlikely to undertake the agricultural production, so the small-scale farming by individuals existing in the old system would not be extinct in the new system.

The privatization view is mainly held by some economists such as Posterman et al. (1996), Cai (2005) and Zhang (2008). Some of these scholars pointed out that the current land system is actually a compromise between egalitarianism and efficiency, which sacrifices the economic efficiency in the attempt of establishing an unreasonable egalitarianism. Yang (2002) indicated that the restrictions imposed on the rural land contractual management right and rural residential land use right made them extremely unstable in respect of contractual term or others. As a result, farmers are prone to take short-term actions which finally lead to the extensive utilization of land or lead to a situation similar with "the tragedy of the commons".

However, scholars who oppose privatization asserted that the privatization of rural land bears a potential risk of land annexation and is conflicted with the essence of socialism (He 2010; Wen 2009; Tan et al. 2006; Kong 2010). It is understandable that the economic value of land deserves more attention in this market-oriented society, but what we cannot ignored is the multiple roles the land plays, it is not only an asset pregnant with huge wealth but also the guarantee of people's residence rights. Benefited by privatization, it seems that the rural residents could finally acquire the right of land they should have acquired long time ago, but the reality is that the contemporary farmers are still the underprivileged, a group that is easily lost in the ferociously competitive world. Once they made wrong decisions or be coerced to relinquish their property rights of land, it is hard for them to fight against injustice. Meanwhile, the problem nationalization met shows itself in front of privatization again, how to realize the privatization? Purchasing the land with the market price or little lower of that is both exorbitant to the farmers. Gifting the land to farmers without any restitution would be unacceptable either to the state or the collectives. Therefore, most scholars hold a pessimistic attitude to the privatization of rural land due to the concerns over its feasibility.

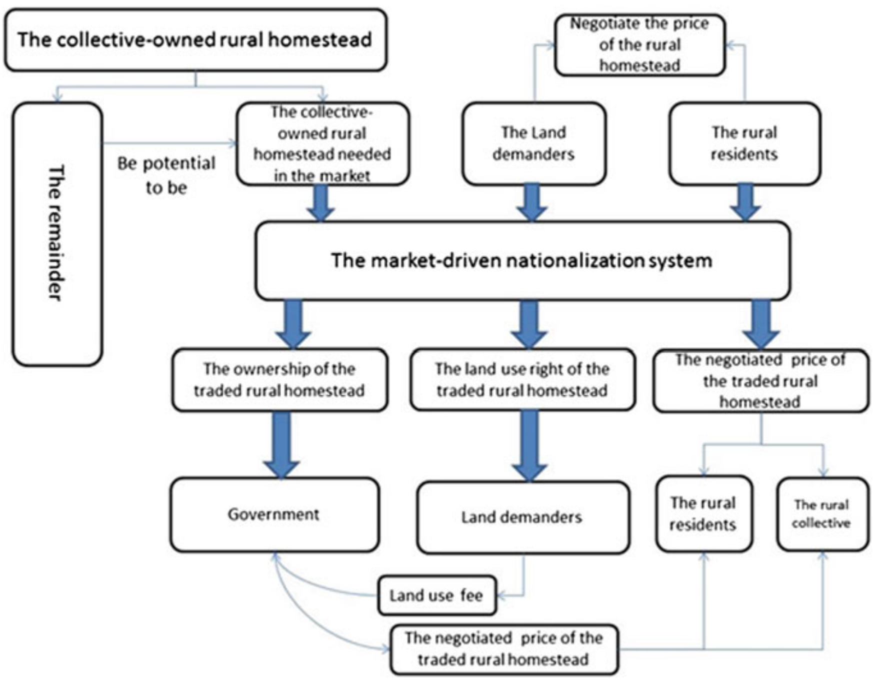


Fig. 113.1 The operational mechanism of the market-driven nationalization of rural homestead

113.3 Introduction of Market-Driven Nationalization of Rural Residential Land

Considering the success the private sector has achieved in the supply of public goods, this paper proposes a new mode, called the market-driven nationalization of rural residential land, which might help realizing the capitalization of rural residential land. The operational mechanism of this system is illustrated as Fig. 113.1.

The rural residential land transaction within the market-driven nationalization system experiences 6 steps:

(1) Step one: the establishment of a formal rural residential land market, which is supposed to be characterized as justice, fairness and openness, and the rural residents should be bestowed with the right of transacting the homestead without any violation of land planning or other relevant law.
(2) Step two: the discussion and negotiation over the details of contract should be a face-to-face process happened between the supplier and demander, which is completely conformity with the willing of both sides. Meanwhile, the supplier is required to submit a written application about the transaction and relinquishment of relevant rights of the traded homestead to the collective he/she belongs to.
(3) Step three: transaction.
(4) Step four: the ownership of rural residential land is transferred to the state and the land use right of rural residential land is transferred to the land demanders. This step happens simultaneously when the step 3 complete.
(5) The land demanders pay the land use fee to the state. The land use fee is considered higher than the negotiated price. The extra part would be budgeted into the local finance as the income of land owners, namely, the local government, and would be calculated based on a certain ratio concerning with the immediate economic factors, such as the interest rate, the location of the traded land, and the potential land use.
(6) Local government pays the original land holders (rural residents) the negotiated price. Meanwhile, the negotiated price is recommended to take a secondary allocation between farmers and collectives for 2 reasons. Firstly, as the statutory owners of the collective land under the collective rural land ownership, the rural collective ought to be compensated when its assets have been transacted. Secondly, the compensation apportioned to collectives can be used as the social security fund in case of potential market failure and living predicament falling upon the original collective members.

113.4 Assessment of the Market-Driven Nationalization Based on IAD Framework

113.4.1 Arenas, Participants and Exogenous Variables of Rural Residential Land System in the IAD Framework

According to the principles of IAD framework and the characteristics of China's rural residential land system, there are 3 arenas must be taken into account when analyzing the market-driven nationalization, they are, firstly, the central government arena which mainly consist of political pundits, secondly, the local government arena which mainly consist of various departments of local government, technocrats and civil service officials, and thirdly, the informal arena which mainly consist of social media, academic experts, interest groups, technocrats and other social departments.

Meanwhile, there 3 exogenous variables affecting each arena as well as its participants, including the attributes of resources, the attributes of participants, and the rules in use (Chen et al. 2015). In the context of rural residential land system, the three groups of exogenous variables could be defined as the attributes of rural homestead, the values of participants, and the relevant rules used in the rural residential land system, correspondently.

(1) The attributes of rural homestead. The attributes of rural residential land show themselves in 3 aspects. Firstly, the economic attribute, which means the rural residential land are closely related to the economic activities. Secondly, the social attribute. Rural residential land has a close relationship with the residence right of rural residents, of which the maintaining and improvement would be crucial in keeping the stability of rural community. Thirdly, the institutional attribute. As mentioned earlier in this paper, the marketization of rural land is always retarded due to the stringent restriction on the disposition right. Therefore, the current situation of rural residential land market presents an unfair allocation of land resources.
(2) The values of participants. The values of participants can be characterized as the aspiration for urbanism and the concerns of the preemption of various urban resources. With the impacts of industrialization and urbanization permeated into the rural areas, the number of rural migrant workers increased continuously and has been an influential social group in China. On the one hand, the new generation of migrant workers prefers to settle down in the cities. On the other hand, the exodus of migrant workers makes the rural homestead unused, which is waste of land resource.
(3) The relevant rules used in the rural residential land system. According to the Constitution and Land Management Law that land located in the rural areas, including agricultural land and rural residential land, belongs to rural collectives. Therefore, the collective members are inhibited from transacting the homestead with outsiders, and the urban housing demanders are also banned to purchase collective land.

113.4.2 The Superiorities of Market-Driven Nationalization Compared with Others

Ostrom claimed that the reform of an institution can be defined as the establishment or change of rules. The IAD framework presents six groups of rules needed to be considered when analyzing an institutional reform, including the rule of identity, the rule of boundary, the rule of choice, the rule of range, the rule of information and the rule of payment. When analyzing the reform modes of rural residential land system, such as the radical privatization, the radical nationalization, and the market-driven nationalization, we find that there are three groups of rules which would be changed in order to realize the objectives of each reform mode, including the rule of identity, the rule of choice and the rule of range.

It is worth mentioning that there is an interaction between the rule of identity and rule of choices. On the one hand, what type the identity is decides how large the collective of choices would be. On the other hand, the change of the collective of choices decides what type of identity the holders bear. In the mode of radical privatization, the collective of choices of rural residents would be enlarged because the rural residents are authorized to transact their homestead. However, the prerequisite of this change of identity is a sufficient economic power the rural residents possess for purchasing the complete ownership of their homestead. As a result, the rule of range changes correspondently, and it manifests itself in two aspects. Firstly, the gap between the rich and poor might be widened in this reform mode considering the poor who is economically unable to purchase his/her homestead. Secondly, the original rural residents liberate themselves into the market facing the risk of investment failure, which concerns the participants on the formal arena as the potential social instability caused by homeless original rural residents.

In the reform of radical nationalization, the collective of choices would be changed in a similar way with that in the reform of radical privatization since the rural residents are also allowed to transact the homestead, but what makes it different is there is only one buyer, the government, in the market. As a result, two risks emerged. The first one, the rural residential land market is in the risk of developing into a buyer's market. The government gains the power to depress the purchasing price benefited by its monopolistic position. The second one, assuming there is a fully competitive market in the context of radical privatization, the rocketing market price of real estate in China would be a heavy financial burden for the local government insomuch that the abortion of privatization seems inevitable. To conclude, the adoption of radical privatization forces the local government to face two results, which means the rule of range has been changed. However, the two results, the inefficient competitive market or the unbearable financial burden, make the change of the rule of identity and choices meaningless.

In the reform of market-driven nationalization, it is noted that rule of identity and choices for rural residents are changed by a market-oriented reform. The rural residents in the informal arena are permitted to engage in a normal land market in which their appeals could be realized by acquiring the right of negotiating and bargaining with the demanders. Meanwhile, the rule of range is changed correspondently. Firstly, the financial burden the local government faces in the radical nationalization disappearing as the purchasing fund is from the real estate developers or other demanders in the market. Secondly, the land market is a fully competitive market accessible to all eligible land demanders besides the local government which avoids the risk of buyer's market. Thirdly, the privatization of the use right of rural residential land is not disrupted by the rural residents' economic power as the identity of rural residents has been transformed from the purchaser into the supplier, which avoids the exacerbation of the social inequality. Fourthly, due to the market-driven nationalization is a gradual process and there is a special fund extracted from the transaction amount earmarked for the security insurance of lost-land rural residents, which minimizes the risks of market that the rural residents would face. Finally, the essence of the market-driven nationalization is the realization of marketization of rural homestead, but of which one of the ultimate results is the nationalization of rural homestead, which is conformity with the ideology of the socialistic China. Therefore, the political resistance the reform received would be less compared with the radical privatization.

113.5 Conclusion

The reform of land system has played a significant role in the industrialization and urbanization of China. However, compared with the flourished urban land market, the marketization of rural residential land is another story. In recent years, the rapid urbanization has attracted large amount of rural migrants working and living in urban areas, but their rural residential land were left unused in the villages due to the highly restricted rural land system. The inefficient land use and unfair arrangement of property rights have generated the academic interest, unfortunately, few scholars paid attention to the essence of the problem, the unrealized but aspired property rights for capitalizing the rural homestead, but trapped in the endless debates over privatization and nationalization. This paper dedicate to proposing a feasible plan for the capitalization of rural residential land based on the IAD framework. We find that compared with the radical privatization and nationalization, namely, the government-driven mode, the market-driven nationalization mode is prevailed in the following aspects: (1) it realizes the marketization of rural homestead; (2) it avoids the potential risk of widening the gap between rich and poor when adopting radical privatization; (3) it avoids the heavy financial burden of local government when adopting radical nationalization; (4) it avoids the ideological conflicts in the socialistic China.

Acknowledgements The authors appreciate the financial support by the National Natural Science Foundation of China (Grant No.71373231), and the helpful work from the organizing committee of CRIOCM2016 International Symposium on Advancement of Construction Management and Real Estate.

References

Bo Z, Ping L, Warren CMJ (2015) Housing prices, rural-urban migrants' decisions and their regional differences in China. Habitat Int 50:149–159

Cai JM (2005) Analysis on the reform of China's modernization, urbanization, and rural land system. Econ Frontline 1:7–10 (in Chinese)

Chen ZG, Wang Q, Huang XJ (2015) Can land market development suppress illegal land use in China. Habitat Int 49(2015):403–412

He X (2010) The logic of land property rights: where should China's rural land system go? The China University of Political Science and Law Press (in Chinese)

Huang ZH (2012) The demand of land rights, rural homestead transfer and the transfer of rural labor force. J Public Adm 9(3) (in Chinese)

Jiang YM, An YN (2003) The path dependence and the innovation of the institutional change of China's rural land system. Strategy Manage (3):54–49 (in Chinese)

Kong BB (2010) The consideration of the nationalization of rural land. Legislation Soc (8):231

Liu F, Yi Y (1998) The analysis on the collective rural land system from the perspective of law. Agric Econ (8):34–35

Ma JJ, Yang CX (2007) The target of the reform of collective rural land system. Soc Sci J Jilin Univ 3:134

Posterman R, Hanstad I, Li P (1996) Can China feed itself? Sci Am 275(5):90–96

Rosato-Sevens M (2008) Peasant and land tenure security in China's transitional economy. Boston Univ Int Law J 26:97–141

Siciliano G (2012) Urbanization strategies, rural development and land use changes in China: a multiple-level integrated assessment. Land Use Policy 29(2012):165–178

Tan QY, Wang YL, Zhao Y et al. (2006) The nationalization of collective rural land under the rapid urbanization: a case of Shenzhen. Urban Plann 161(1):98–101

Wen T (2009) Why China should not privatize land? In Chinese red flag papers (Hongqi Wengao), vol 2

Xu L (2005) The analysis on the deepening reform of China's rural land property right system. Theory Reform 5(2):89–92

Yan YQ, Wang ZH (2005) Nationalization: the reform path of the collective rural land system of China. J Xiangtan Univ 29(2):102–107

Yang XK (2002) The underlying problems of the China's reforms: the reform of land system. Strategy Manage (5):1–5

Yu TWA, Wu YZ, Shen JH, Zhang XL, Shen LY, Shan LP (2015) The key causes of urban-rural conflict in China. Habitat Int 49:65–72

Zhang HF (2008) The institutional change of PRC's rural land system: a analysis paradigm of path dependence. Agric Econ (1):95–98

Chapter 114
Scenarios for Applying Big Data in Boosting Construction: A Review

X. Chen and W.S. Lu

114.1 Introduction

The three defining characteristics of big data are volume, variety, and velocity, or the three "V"s (Zikopoulos and Eaton 2011; McAfee et al. 2012). A lot of researches dealing with big data are appearing now. Big data is used to create a new form of value in life, work, science and industry by changing markets, organizations, and relationships between people, where hidden value that could be revealed (Mayer-Schönberger and Cukier 2013). The fast development of computational resources enables sensing, capturing, collection and processing of real time data from billions of connected devices serving many different applications including environmental monitoring, industrial applications, business and human-centric pervasive applications. These activities generate a large volume of data intentionally or unintentionally, from which great values can be extracted for various purposes.

The construction industry is responsible for undertaking some of the biggest and most expensive projects where huge volume of data concerning the resources and works throughout the life cycle of a facility. Therefore, data generated from construction activities is not an exception to the pervasive digital revolution in this industry. Construction activities are mainly on-site (Mohamed 2002; Toole 2002; Ma et al. 2005; Yeh 1995; Chau et al. 2004) and off-site (Blismas et al. 2005, 2006; Tam et al. 2007). Technically, typical involvement of big data on construction activities is Building Information Modeling (BIM), which is a set of interacting policies, processes and technologies generating a methodology to manage the

X. Chen (✉) · W.S. Lu
Department of Real Estate and Construction, The University of Hong Kong, Hong Kong, China
e-mail: chenx90@hku.hk

W.S. Lu
e-mail: wilsonlu@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_114

essential building design and project data in digital format throughout the building's life cycle (Penttilä 2006). Large amounts of data are collated in federated BIM models, which are enriched gradually and persisted beyond the end-of-life of facilities, pushing the construction industry into the big data era (Eadie et al. 2013; Jiao et al. 2014; Lin et al. 2016; Bilal et al. 2016). From the perspective of public administration on construction industry, big data exists in private sectors and public sectors involving construction activities, such as the governmental departments concerning building, housing, and environmental protection. While big data has been proposed for the construction fields, there are no current studies that comprehensively reviewed the literature and status quo of employing big data in construction activities and public administration.

This study aims to review the scenarios of the applications of big data in construction activities and public administration in order to provide the status quo of the big data application in construction area. The review is divided into two sections, namely Sects. 114.2 and 114.3. Section 114.2 is for reviewing the existing and proposed scenarios that big data has been or can be applied in detailed construction activities; and in Sect. 114.3, the scenarios for public administration on construction with the use of big data are reviewed. In Sect. 114.4, the status quo of the big data applications in construction industry is discussed based on the scenarios described in Sects. 114.2 and 114.3, and other opportunities for boosting construction industry with the use of big data are suggested.

114.2 Scenarios for Construction Companies

Many considerations have been given to the labors and objects involved in construction activities, such as construction safety, productivity and efficiency, and competitive advantages.

114.2.1 Construction Safety

The safety on construction site had been heatedly studied for nearly two decades in many aspects, such as site safety responsibility (Toole 2002), strategies for improving on-site safety performance (Jaselskis et al. 1996; Lingard and Rowlinson 1998), organizational safety culture (Mohamed 2002). With the fast development of automation technology and computer technology, the construction industry has become of wide application of information and communication technologies for improving construction safety. Compared with the traditional safety planning based on analysis and causation of accidents and historical data, which are often of very small amounts, BIM allows automatic safety checking of construction models and schedules (Zhang et al. 2013). In such a checking system, the safety rules, guidelines, and best practices applied to the BIM model, the information of the building objects, the suggested safety protection methods, the checking report, collaborated software tools, and the technologies realizing the execution process put forward the application of big data in BIM system improving construction safety (Zhang et al. 2013). Location tracking and data visualization technology to advance construction ironworkers' education and training in safety in practical use, construction industry has been using big data to monitor the safety practices of workers in real time in order to boost the safety of its workforce and project operations (Hampton 2015; Financial Post 2013). An exemplary company benefiting from big data named Makro uses telematics to transfer information from on-site vehicles and equipment, where a number of variables including velocity and wind speed are measured, to a central data center; and such a data center allows the activities of crane operators constantly monitored (Hampton 2015; Shadid 2015).

114.2.2 Productivity and Efficiency

Attempts had been made to improve the productivity in construction for nearly three decades (Oglesby et al. 1989; Thomas and Yiakoumis 1987; Thomas and Završki 1999; Thomas et al. 1990). In health care, government services, retailing, and manufacturing, our research suggests, big data could improve productivity by 0.5–1% annually (Brown et al. 2011). Construction industry is no exception when it comes to improve the productivity and efficiency with the use of big data. For example, a construction company named Hansen Yuncken, has won the same level of work from fewer bids, as a result of gathering and analyzing historical internal data it has collected about factors such as sector, client, location and value, to determine which bids are more likely to win (Bleby 2015). Kim et al. (2013) proposed using the data on spatial, geometric, quantity, relationship and material layer set information stored in BIM in order to automatically create construction schedule. The data extracted from BIM is evidently big data, and automation in generating construction schedule is a scenario improving the construction productivity and efficiency. Besides, big data exists in the full big design model consisting of architectural, structural, and building services design models to improve the design efficiency (Porwal and Hewage 2013).

114.2.3 Competitive Advantages

A trend toward the delivery of projects through the adoption of innovative procurement systems that enable companies to gain competitive advantages is appearing in construction industry (Lu et al. 2012). Big data offers construction industry many opportunities. Some are general business improvements applicable to any company, while others are specifically linked to construction activities. The general business competitive advantages of using big data approach can be the company performance evaluation, more accurately targeted marketing, and improved decision-making (Thomas and Yiakoumis 1987; Thomas and Završki 1999; Thomas et al. 1990; Brown et al. 2011; Bleby 2015; Kim et al. 2013; Porwal and Hewage 2013; Lu et al. 2012; Provost and Fawcett 2013). For instance, big data is able to provide a critical new competitive advantage in information and knowledge management of construction markets (Walker and Walker 2016). Williams et al. opined big data could provide a solution to forecasting new businesses towards transforming their project management maturity (Williams et al. 2014). The competitive advantages of big data specific for construction companies include managing construction project risk by choosing partners and suppliers with better track records from the start, and offsite construction by assisting accurately prefabricate building modules of larger sizes so as to streamline the afterward onsite construction works (Burger 2016).

114.3 Scenarios for Public Administration on Construction

From the public administration perspective, social, environmental and economic impacts of construction activities should be carefully considered (Shen et al. 2016, 2017; Zhao et al. 2012; Shuai et al. 2017). Considering big data in construction management by public sectors, the scenarios beneficial from the application of big data can be construction waste minimization (CWM), and reduction of air and noise pollution given rise from construction activities.

114.3.1 Construction Waste Minimization

A significant part of waste generation is caused by construction industry, therefore CWM is a major topic for achieving sustainability performance of construction activities (Bossink and Brouwers 1996). Researchers started to explore the use of big data to achieve CWM. Recently, Lu et al. revisited the waste generation rates (WGRs) as performance indicators of CWM using big data, and benchmarks were set as a reference to evaluate the waste management performance of a construction project (Lu et al. 2015). This research group further analyzed CWM performance in the private and public sectors: big data enables stakeholders to tell that there is a notable CWM performance disparity between the public and private sectors in greater confidence (Lu et al. 2016; Chen and Lu 2017). The prediction of waste generation from a construction project is also important for the improvement of CWM. The employment of big data from public administration system also enables more accurately forecast of the waste generation at project level by contributing an S-curve model (Lu et al. 2016). Bilal et al. (2016) proposed a conceptual framework of big data architecture for construction waste analytics. Chen et al. (2017) and other environment protection agents were discussing how to develop a big data platform for CWM.

114.3.2 Air and Noise Pollution Monitoring

Air pollution is a key factor that can lead to mortality (Dockery et al. 1993; Kampa and Castanas 2008). Noise pollution is also a valid concern in cities (Zannin et al. 2002). Construction projects can result in both air and noise pollution particularly in urban areas (Zou et al. 2007). Considering the health of general publics, monitoring the surrounding air and noise pollution generated from construction sites is a necessary part of public administration. Real-time monitoring and mapping of air quality (Dutta et al. 2009) and noise (Kanjo 2010) are practicable according to the previous studies. Big data enables a real-time city and smart urbanism (Kitchin 2014). Therefore, in the urbanization process, integrating big data in monitoring air and noise pollution arose from construction activities could become reality if government actively invests on this. Such a monitoring system should import the historical data to establish benchmarks for air and noise pollution, which are used for the afterward evaluation of the air and noise pollution degree on individual construction sites. In this proposed system, data from all involved sites are collected as "new" historical data, which upgrade the benchmarks to relatively stable values eventually. It could be a strategy for reducing air and noise pollution if government demands every contractor to install the monitoring devices for the administration from governmental departments. The real-time monitoring with the use of big data can real-time reduce these pollution, and ensure the health of working labors and the general public surrounding.

114.4 Conclusions

This study comprehensively reviewed the scenarios that big data have been and can be employed in construction activities from the perspectives of construction companies and public administration. For construction companies, big data can be applied in improving construction safety, boosting the productivity and efficiency, and gaining competitive advantages. Further, BIM is the most frequently employed tool when it comes to individual construction project. Whilst for the benefits of the public, government can use big data to manage the construction waste, and monitor the air and noise pollution given rise by the construction activities. The data-driven approaches no matter for construction companies or public administration on construction activities are necessary to gain the benefits from big datasets in the raised scenarios. A data center for public administration on construction activities should be designed with existing protocols and technologies for collecting, storing and analyzing data from construction industry. Challenges, such as privacy, security, and others raised from the three “V”s should be addressed when building such a data center (Labrinidis and Jagadish 2012). This study provides stakeholders (mainly i.e. construction companies and public policy-makers with insights on the scenarios that they can improve with the use of big data.

References

Bilal M, Oyedele LO, Qadir J, Munir K, Ajayi SO, Akinade OO, Pasha M (2016) Big data in the construction industry: a review of present status, opportunities, and future trends. Adv Eng Inf 30(3):500–521

Bleby M (2015) Jan 11 2015, Big data boosts construction. Available at: http://www.afr.com/real-estate/commercial/big-data-boosts-constrcution-20150109–12l8xx

Blismas NG, Pendlebury M, Gibb A, Pasquire C (2005) Constraints to the use of off-site production on construction projects. Architectural Eng Des Manag 1(3):153–162

Blismas N, Pasquire C, Gibb A (2006) Benefit evaluation for off-site production in construction. Constr Manag Econ 24(2):121–130

Bossink BAG, Brouwers HJH (1996) Construction waste: quantification and source evaluation. J Constr Eng Manag 122(1):55–60

Brown B, Chui M, Manyika J (2011) Are you ready for the era of ‘big data’. McKinsey Q 4(1):24–35

Burger R (2016) 10 Ways commercial construction companies can use big data. Construction management, Jan 19, 2016. Available at: http://blog.capterra.com/10-ways-commercial-construction-companies-can-use-big-data/

Chau KW, Anson M, Zhang JP (2004) Four-dimensional visualization of construction scheduling and site utilization. J Constr Eng Manag 130(4):598–606

Chen X, Lu W (2017) Identifying factors influencing demolition waste generation in Hong Kong. J Clean Prod 141:799–811

Chen X, Lu W, Liao S (2017) A framework of developing a big data platform for construction waste management: a Hong Kong study. In: Proceedings of the 20th international symposium on advancement of construction management and real estate (pp 1069–1076). Springer, Singapore

Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Speizer FE (1993) An association between air pollution and mortality in six US cities. New Engl J Med 329(24):1753–1759

Dutta P, Aoki PM, Kumar N, Mainwaring A, Myers C, Willett W, Woodruff A (2009, November) Common sense: participatory urban sensing using a network of handheld air quality monitors. In: Proceedings of the 7th ACM conference on embedded networked sensor systems (pp 349–350). ACM

Eadie R, Browne M, Odeyinka H, McKeown C, McNiff S (2013) BIM implementation throughout the UK construction project lifecycle: an analysis. Autom Constr 36:145–151

Financial Post (2013) June 1, 2013. The human-safety side of big data. Available at: http://www.dataconsulting.co.uk/the-human-safety-side-of-big-data/

Hampton TV (2015) Big data boosts safety in Brazil. Available at: http://www.enr.com/articles/9640-big-data-boosts-safety-in-brazil?v=preview

Jaselskis EJ, Anderson SD, Russell JS (1996) Strategies for achieving excellence in construction safety performance. J Constr Eng Manag 122(1):61–70

Jiao Y, Zhang S, Li Y, Wang Y, Yang B, Wang L (2014, May). An augmented mapreduce framework for building information modeling applications. In: Computer Supported Cooperative Work in Design (CSCWD), proceedings of the 2014 IEEE 18th international conference on (pp 283–288). IEEE

Kampa M, Castanas E (2008) Human health effects of air pollution. Environ Pollut 151(2): 362–367

Kanjo E (2010) Noisespy: a real-time mobile phone platform for urban noise monitoring and mapping. Mob Netw Appl 15(4):562–574

Kim H, Anderson K, Lee S, Hildreth J (2013) Generating construction schedules through automatic data extraction using open BIM (building information modeling) technology. Autom Constr 35:285–295

Kitchin R (2014) The real-time city? Big data and smart urbanism. GeoJournal 79(1):1–14

Labrinidis A, Jagadish HV (2012) Challenges and opportunities with big data. Proc VLDB Endowment 5(12):2032–2033

Lin JR, Hu ZZ, Zhang JP, Yu FQ (2016) A natural-language-based approach to intelligent data retrieval and representation for cloud BIM. Comput-Aided Civ Infrastruct Eng 31(1):18–33

Lingard H, Rowlinson S (1998) Behavior-based safety management in Hong Kong's construction industry. J Saf Res 28(4):243–256

Lu W, Liu AM, Rowlinson S, Poon SW (2012) Sharpening competitive edge through procurement innovation: perspectives from Chinese international construction companies. J Constr Eng Manag 139(3):347–351

Lu W, Chen X, Peng Y, Shen L (2015) Benchmarking construction waste management performance using big data. Resour Conserv Recycl 105:49–58

Lu W, Chen X, Ho DC, Wang H (2016a) Analysis of the construction waste management performance in Hong Kong: the public and private sectors compared using big data. J Clean Prod 112:521–531

Lu W, Peng Y, Chen X, Skitmore M, Zhang X (2016) The S-curve for forecasting waste generation in construction projects. Waste Management

Ma Z, Shen Q, Zhang J (2005) Application of 4D for dynamic site layout and management of construction projects. Autom Constr 14(3):369–381

Mayer-Schönberger V, Cukier K (2013) Big data: a revolution that will transform how we live, work, and think. Houghton Mifflin Harcourt

McAfee A, Brynjolfsson E, Davenport TH, Patil DJ, Barton D (2012) Big data: the management revolution. Harvard Bus Rev 90(10):61–67

Mohamed S (2002) Safety climate in construction site environments. J Constr Eng Manag 128 (5):375–384

Oglesby CH, Parker HW, Howell GA (1989) Productivity improvement in construction. Mcgraw-Hill College

Penttilä H (2006) Describing the changes in architectural information technology to understand design complexity and free-form architectural expression

Porwal A, Hewage KN (2013) Building Information Modeling (BIM) partnering framework for public construction projects. Autom Constr 31:204–214

Provost F, Fawcett T (2013) Data science and its relationship to big data and data-driven decision making. Big Data 1(1):51–59

Shadid J (2015) Oct 14, 2015. Where construction goes to work smarter. http://blog.hcss.com/big-potential-for-big-data-in-construction-safety

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Tam VW, Tam CM, Zeng SX, Ng WC (2007) Towards adoption of prefabrication in construction. Build Environ 42(10):3642–3654

Thomas HR, Yiakoumis I (1987) Factor model of construction productivity. J Constr Eng Manag 113(4):623–639

Thomas HR, Završki I (1999) Construction baseline productivity: theory and practice. J Constr Eng Manag 125(5):295–303

Thomas HR, Maloney WF, Horner RMW, Smith GR, Handa VK, Sanders SR (1990) Modeling construction labor productivity. J Constr Eng Manag 116(4):705–726

Toole TM (2002) Construction site safety roles. J Constr Eng Manag 128(3):203–210

Walker DH, Walker DH (2016) Reflecting on 10 years of focus on innovation, organisational learning and knowledge management literature in a construction project management context. Constr Innov 16(2):114–126

Williams N, Ferdinand NP, Croft R (2014) Project management maturity in the age of big data. Int J Managing Projects Bus 7(2):311–317

Yeh IC (1995) Construction-site layout using annealed neural network. J Comput Civ Eng 9 (3):201–208

Zannin PHT, Diniz FB, Barbosa WA (2002) Environmental noise pollution in the city of Curitiba, Brazil. Appl Acoust 63(4):351–358

Zhang S, Teizer J, Lee JK, Eastman CM, Venugopal M (2013) Building information modeling (BIM) and safety: automatic safety checking of construction models and schedules. Autom Constr 29:183–195

Zhao ZY, Zhao XJ, Davidson K, Zuo J (2012) A corporate social responsibility indicator system for construction enterprises. J Clean Prod 29:277–289

Zikopoulos P, Eaton C (2011) Understanding big data: analytics for enterprise class hadoop and streaming data. McGraw-Hill Osborne Media

Zou PX, Zhang G, Wang J (2007) Understanding the key risks in construction projects in China. Int J Project Manage 25(6):601–614

Chapter 115
Smart Gateway for Bridging BIM and Building

K. Chen, W.S. Lu, F. Xue, L.Z. Zheng and D.D. Liu

115.1 Introduction

The architecture, engineering, and construction (AEC) industry has long been characterized as highly fragmented and data intensive. The inadequate provision of information in a construction project has been recognized as a factor that results in poor project performance. In order to overcome such problem, building information modeling (BIM) has emerged as a digital platform to create, exchange, and manage the project relevant information. In 2016, Timetric's Construction Intelligence Center (CIC) conducted a survey of more than 100 participants in the global construction industry. The results showed that 49% of the respondents are currently using BIM, and another 10% of the respondents plan to use BIM within one year (CIC 2016).

Across project stages, BIM should be continuously updated so that stakeholders can analyze actual against expected performance in a real-time manner (Tserng et al. 2014). Otherwise, BIM will be "blind and deaf" that cannot support decision making. Many researchers have explored methods or technologies for synchro-

K. Chen (✉) · W.S. Lu · F. Xue · L.Z. Zheng · D.D. Liu
Department of Real Estate and Construction, The University of Hong Kong, Pok Fu Lam, Hong Kong
e-mail: leochen@connect.hku.hk

W.S. Lu
e-mail: wilsonlu@hku.hk

F. Xue
e-mail: xuef@hku.hk

L.Z. Zheng
e-mail: Lizzheng@hku.hk

D.D. Liu
e-mail: liudd@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_115

nizing the BIM information with the project process. Their efforts have been conceptualized by Chen et al. (2015) as bridging BIM and building (BBB). In the conceptual framework of BBB, information about various aspects of a construction project is collected by advanced technologies including laser scanner, sensors, and Auto-ID devices. With the real-time information, BIM can support a series of project management practices, such as cost management, schedule management, and material management. Since it is not feasible to directly import the raw data in BIM, the smart gateway—the middleware between the physical project layer and the BIM layer—is of great importance to ensure information integration between the two layers.

This study aims at exploring the smart gateway for BBB. It firstly reviews previous studies on information required at construction and O&M stages. Then, based on the theoretical framework of BBB, the importance of the smart gateway is highlighted. Finally, major functions of the proposed smart gateway are described in details.

115.2 Information Requirements at Construction and O&M Stages

The management of a construction project involves using available information to make a web of decisions across the project life cycle (Flanagan and Lu 2008). The information needed by different stakeholders varies from stage to stage. Ndekugri and McCaffer (1988) summarized the contractors' inputs and outputs of information for planning, estimating, cash flow forecasting, valuations, cost control, and accounting. Ergen et al. (2007) analyzed the information flow patterns for management of prefabricated components at production, construction, and O&M stages. Becerik-Gerber et al. (2011) summarized the data requirements for facilities management. A simplified summary of information requirements at construction and O&M stages is presented in Table 115.1.

Most of the geometry and non-geometry information listed in Table 115.1 is dynamic. For example, the status of construction materials changes from "produced" to "being delivered", and then to "arrived at the construction site". Another example is the change in the dimension of building components (e.g. a wall or column) due to the design variations. Therefore, in a project where BIM is used, the original BIM developed at the design stage can be easily out-of-date. Real-time information should be timely collected to update the original BIM, based on which, stakeholders can monitor the project performance and make adjustments when it is necessary.

Table 115.1 Information requirements

Stage	Information requirements	
	Geometry information	Non-geometry information
Construction	Site information (coordinate's data and layout) Building spaces (floor, zones, rooms, openings) Utility lines Dimension of building components	Construction materials (status, quality, category, manufacturer) Precast elements (quality, category, manufacturer) Equipment attributes (ID, type, status) Financial data Location of labor, materials, and machine Project performance data Construction schedule Construction activity status Site environment
Operation and maintenance	Building services (location, relationship) Building spaces (floor, zones, rooms, openings) Utility lines Specification of exterior enclosure products Furnishing	Building services (identification number, manufacturer) Status of mechanical, electrical, and plumbing equipment Maintenance record Indoor environment Attributes of replaced components Maintenance status Maintenance schedule Operation records

115.3 Concept of Bridging BIM and Building

Bridging BIM and building (BBB) is defined as connecting the information contained in BIM with physical building processes to make BIM reflecting the actual situations (Chen et al. 2015). Here, "reflecting the actual situations" does not mean that all information about a construction project must be contained in BIM. The discussion on the usefulness of an "ever more complete/complex" BIM falls beyond the theme of this study. Technically, BIM is capable of containing nearly all types of project information, while stakeholders can determine which information should be involved and updated according to their own requirements.

Generally, BBB is performed by following procedures: (1) developing the initial BIM; (2) determining which parts of the original BIM need to be updated; (3) collecting the required information along the project process; (4) managing and processing the collected information; and (5) updating the original BIM with the processed information. Except for the first two steps, entirely relying on manual efforts to finish the remaining three steps is time-consuming and error-prone. Thanks to advanced technologies, procedures of BBB, especially for information collection and process, can be performed with considerable efficiency and effectiveness.

For geometry information, laser scanning and photogrammetry are two widely-used technologies to capture the as-built information. An example is given by Bosché et al. (2013) that a scan-vs-BIM method is proposed to integrate point clouds and BIM. The scanned point clouds are first aligned in the coordinate system of the model. Then, the comparison between point clouds and BIM helps to check variation and project process. Both laser scanners and cameras can be fixed on an unmanned aerial vehicle (UAV) to rapidly capture the construction site information from height. GIS is the computer system that has the potential for capturing, storing, checking, and displaying spatial data.

Laser scanning and photogrammetry can also be used to collect the non-geometry information such as the location of construction resources (e.g. equipment, machinery, material, building components). Besides, GPS is satellite-based for getting the position and navigation of construction objects and activities (Pradhananga and Teizer 2013). Auto-ID technologies including barcode and radio frequency identification (RFID) enable rapid tracking and tracing (Lu et al. 2011; Flanagan et al. 2014). Once being attached to a construction resource, the unique ID contained in the RFID tag or barcode can help to link the information of that construction resource to its digital representation in BIM. Sensors can capture the information about the site and indoor environment. With an integration of sensing technologies, Niu et al. (2015) even proposed smart construction objects which can automatically collect and report their own information.

115.4 Requirements for the Smart Gateway

Currently, after the real-life project information is collected, the most common methods for its integration with BIM are direct input, hyperlink, application programming interface (API) and schema extension. Goedert and Meadati (2008) added new shared parameters (e.g. specifications, RFI, shop drawings) to the components in BIM. The values of these parameters are hyperlinks that help stakeholders to find the documents of a specific component. Motamedi et al. (2016) extended the IFC schema to include the definition of RFID technology components in BIM. Standardized definitions for RFID components can be used to map the data to be stored in RFID memory to the associated entries in a BIM database. Solihin et al. (2016) introduced a concept of deferred references to the IFC schema, with which, partial models will remain integrated when they are inserted into federated models.

Using these methods, the project information can be manually or semi-automatically “placed” in BIM environment. However, they are not sufficient for the integration of BIM and real-time project information. To fully achieve BBB, a middleware between the physical project and BM is important due to the following reasons.

Firstly, raw data collected by data-acquisition technologies contains much irrelevant data and noise to be filtered, and its format can be various. Directly importing all raw data into BIM will not only make the model cumbersome, but also lead to troublesome preparation works (e.g. searching, filtering, and converting) when stakeholders would like to use BIM for decision making. Therefore, the raw data should be processed before being imported in BIM.

Secondly, some collected information is related to the entire project, while others can be related to a single space or an individual building resource. Preparatory works are needed to link the physical project and its components with the right part (s) in BIM. Without a pre-identified link, manually searching among the collected information and then selecting the corresponding part(s) of BIM for information update is very likely to be time-consuming and error-prone.

Thirdly, researchers have noted that single technologies may not able to collect all types of information required for BIM update (Akanmu et al 2014; Akanmu and Anumba 2015). Some technologies should be configured with the right set of API for information retrieve. Besides, the working status of the data-acquisition technologies should be monitored to ensure information collection.

Fourthly, the communication network may not be always available at the dynamic construction site. When a large amount of information is transferred to BIM along with the project process, a more stable channel is essential to decrease information loss.

115.5 Definition of the Smart Gateway: An Analogy

The smart gateway for BBB is inspired by gateways in many other industries. Generally, a gateway is a link between two programs or systems for information sharing. In telecommunication, gateway is a piece of hardware such as protocol translators and signal translators to provide interoperability (Chen et al. 2010). In network, gateway is a node on a TCP/IP network that serves as an access point to another network. In the field of Internet of Thing (IoT) and smart building/housing, gateway provides the bridge between devices in the physical world, the cloud, where data is collected, stored and manipulated by enterprise applications and the user equipment. In manufacturing, Huang et al. (2011) proposed a gateway as the sandwiched layer between enterprise information system (EIS) and smart object services. Their proposed gateway is used to: (1) connect and host a set of RFID-enabled objects; (2) communicate and interact with EIS and decision support system; (3) process and exchange real-time data; (4) provide facilities for service definition and configuration.

It can be seen that even though the definitions of gateways in various industries are not completely the same, the key function is to ensure the information flow among different protocols and devices. In the context of bridging BIM and building, we define the smart gateway as "the middleware platform that centrally connects the data acquisition technologies and provides mechanisms for processing the collected information to facilitate information integration between the physical project and BIM". As shown in Fig. 115.1, gateway communicates with data acquisitions technologies and the digital databases by wired or wireless networks. The smart gateway can be stationary and mobile. The stationary gateway is placed at a designated place, while the mobile gateway can be held by stakeholders to perform its function. These two types of smart gateway can be corporate with different data acquisition technologies. For example, the stationary gateway can be permanently linked with sensors placed at a fixed location; the mobile gateway is suitable to work with hand-held Auto-ID readers.

If we consider the database as a reservoir, the data/information will be the water stored in that reservoir. There are many tubes for water input/output (I/O). The role of smart gateway will be managing all the tubes and administrating the water input/output. When the water enters the reservoir through the input tube, it should be clarified and classified so that it can be stored in the right place. When the water needs to be exported, the output tube should point to the correct destination. Besides, the working status of individual tubes should also be monitored to maintain the water flow.

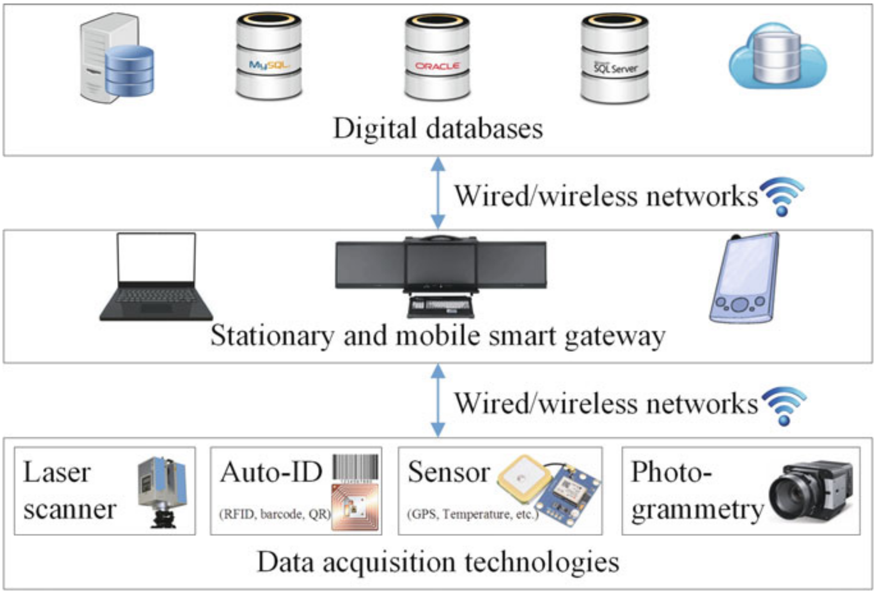


Fig. 115.1 Architecture of smart gateway

115.6 Functions of the Smart Gateway

Basically, the smart gateway has the following four functions: (1) device configuration and management; (2) data filtering and processing; (3) temporary information storage; and (4) additional information input. As shown in Fig. 115.2, some of these functions are interrelated with each other.

115.6.1 Device Configuration and Management

The Auto-ID device and sensors entail different software drivers and invoking standards/protocols provided by their vendors. Taking RFID devices as an example, the same reading function of RFID readers may require different APIs (Fang et al. 2013). The APIs of different devices are stored at the gateway, where they are grouped by their brands. When different brands of Auto-ID technologies are used in a single project, they can be connected with the smart gateway, and the right set of API will be called to enable the reading and writing functions.

When sensing devices such as the GPS sensor and the temperature sensor are fixed on construction resources or building components, they are configurated by the smart gateway for two purposes: (1) users can set the interval for each time of

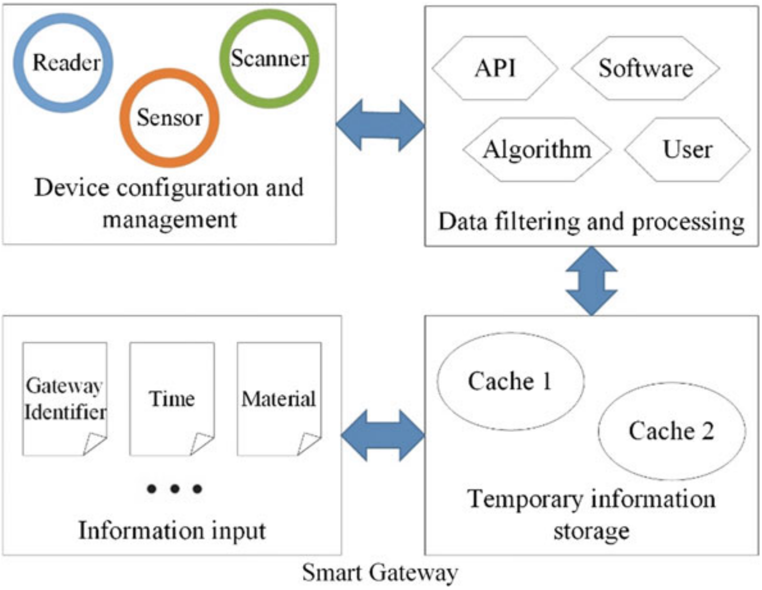


Fig. 115.2 Functions of smart gateway

data collection; (2) users can monitor their working status and check whether there is information collected.

115.6.2 Data Filtering and Processing

Even to the same type of data-acquisition devices, their collected data could have distinct messaging protocol and format if their brands are different. Before transferring the data into the database, the smart gateway will filter and process the raw data. These mechanisms guarantee that the collected data can be presented in the required form. The raw point cloud generated by laser scanning and photogrammetry can be hundred megabytes to gigabytes with many noisy data. Directly importing it into the database could be a waste of resources for transfer and storage. The raw point cloud should be filtered, and be arranged into a pre-defined coordinate system in order to keep the coordinate system of all scanned data consistent. For RFID technologies, the tag could contain diverse types of information. When a tag attached to the construction resource is scanned to record relevant information of that resource, the reader will send several types of information to the gateway. Among the retrieved data, the EPC code is usually needed since it is the unique ID for identification, while other information could be filtered to avoid information redundancy.

115.6.3 Temporary Information Storage

Regardless of being stationary or mobile, caches can be provided in the smart gateway for temporary information storage. The data-acquisition devices and smart gateway are communicated by cable, USB, and Bluetooth at a near distance. Therefore, it is relatively stable for the smart gateway to receive the collected raw data. However, it is possible that there is no communication network for the smart gateway to access the database for information upload. For example, the worker takes a RFID reader that is connected to a mobile smart gateway to check the installation of a prefabricated façade. After confirmation, installation information should be transferred to the database in order to update the status of the digital component in BIM. However, the network signal is too weak to transfer the information. The smart gateway will hold that information until the network signal becomes strong enough. The provision of temporary information storage helps to decrease the chance of information loss.

115.6.4 Information Input

As mentioned in Sect. 115.4, the collected information can be related to the whole project or individual construction resources. In the smart gateway, the received information will be virtually linked with a pre-defined ID which represents the different part(s) of BIM (e.g. individual components, space, and entire project) before it is transferred to the database. This helps to group relevant information throughout the project process.

Additionally, the smart gateway provides a user-interface for stakeholders to input supplementary information. For laser scanning and photogrammetry, information such as the time of each scan or photo-taking and the responsible person can be recorded. For Auto-ID technologies, along with the project process, the scan of Auto-ID tag will show its attached resource in the user-interface of the smart gateway where the stakeholder can input relevant information about that resource.

115.7 Conclusion

Building information modeling (BIM) would be an ideal platform to support decision making if it synchronized with the physical project to reflect the actual situation. Considerable efforts have been taken to use advanced data-acquisition technologies to collect the real-time project information and update the original BIM. This process has been conceptualized as bridging BIM and building (BBB). The BBB framework consists of physical project layer, smart gateway, database, and BIM layer. Compared with the other three layers, less attention has been paid to the smart gateway. This paper provides the concept of smart gateway, and comprehensively discusses functions of the smart gateway for BBB.

As the middleware between physical project layer and BIM layer, the smart gateway guarantees the information flow between these two layers by its four main functions, namely, configuring different data-acquisition technologies, filtering and processing the collected raw data, temporarily storing information when the communication network between the smart gateway and the database is interrupted, and allowing information input by users.

In future research, a prototype of the smart gateway will be developed and implemented in actual construction projects where multi data-acquisition devices are used. Such case study will validate the ability of smart gateway to deal with the heterogeneous BBB technologies before the information is stored in the database and transferred to BIM.

Acknowledgements This study is supported by the General Research Fund (Project No.: 17205614) of the Hong Kong Research Grant Council (RGC).

References

Akanmu A, Anumba CJ (2015) Cyber-physical systems integration of building information models and the physical construction. Eng Constr Archit Manage 22(5):516–535

Akanmu A, Anumba C, Messner J (2014) Critical review of approaches to integrating virtual models and the physical construction. Int J Constr Manage 14(4):267–282

Becerik-Gerber B, Jazizadeh F, Li N, Calis G (2011) Application areas and data requirements for BIM-enabled facilities management. J Constr Eng Manage 138(3):431–442

Bosché F, Guillemet A, Turkan Y, Haas CT, Haas R (2013) Tracking the built status of MEP works: assessing the value of a scan-vs-BIM system. J Comput Civ Eng 28(4):05014004

Chen K, Lu W, Peng Y, Rowlinson S, Huang GQ (2015) Bridging BIM and building: from a literature review to an integrated conceptual framework. Int J Proj Manage 33(6):1405–1416

Chen Y, Shen W, Huo H, Xu Y (2010) A smart gateway for health care system using wireless sensor network. In: 2010 Fourth international conference on sensor technologies and applications (SENSORCOMM), IEEE, pp 545–550

Construction Intelligence Center (CIC) (2016) Building information modeling to become future of construction industry. http://www.construction-ic.com/pressrelease/building-information-modeling-to-become-future-of-construction-industry-4941964. Accessed 16 July 2016

Ergen E, Akinci B, Sacks R (2007) Life-cycle data management of engineered-to-order components using radio frequency identification. Adv Eng Inform 21(4):356–366

Fang J, Qu T, Li Z, Xu G, Huang GQ (2013) Agent-based gateway operating system for RFID-enabled ubiquitous manufacturing enterprise. Robot Comput Integr Manuf 29(4):222–231

Flanagan R, Lu WS (2008) Making informed decisions in product-service systems. In: IMechE conference, knowledge and information management through-life, Institute of Mechanical Engineers

Flanagan R, Jewell C, Lu W, Pekericli K (2014) Auto-ID—bridging the physical and the digital on construction projects. Chartered Institute of Building. ISBN 1853800191

Goedert JD, Meadati P (2008) Integrating construction process documentation into building information modeling. J Constr Eng Manage 134(7):509–516

Huang GQ, Qu T, Fang MJ, Bramley AN (2011) RFID-enabled gateway product service system for collaborative manufacturing alliances. CIRP Ann Manuf Technol 60(1):465–468

Lu W, Huang GQ, Li H (2011) Scenarios for applying RFID technology in construction project management. Autom Constr 20(2):101–106

Motamedi A, Soltani MM, Setayeshgar S, Hammad A (2016) Extending IFC to incorporate information of RFID tags attached to building elements. Adv Eng Inform 30(1):39–53

Ndekugri IE, McCaffer R (1988) Management information flow in construction companies. Constr Manage Econ 6(4):273–294

Niu Y, Lu W, Chen K, Huang GG, Anumba C (2015) Smart construction objects. J Comput Civ Eng 04015070

Pradhananga N, Teizer J (2013) Automatic spatio-temporal analysis of construction site equipment operations using GPS data. Autom Constr 29:107–122

Solihin W, Eastman C, Lee YC (2016) A framework for fully integrated building information models in a federated environment. Adv Eng Inform 30(2):168–189

Tserng HP, Ho SP, Jan SH (2014) Developing BIM-assisted as-built schedule management system for general contractors. J Civ Eng Manage 20(1):47–58

Chapter 116
Spatial-Temporal Effects of Housing Price Caused by Metro Construction: A Perspective of Price-to-Rent Ratio

Fen Wang and Yuzhe Wu

116.1 Instructions

With the expansion of the city and the growth of population, urban metro with large passenger volume began increasingly being adopted by major cities as an effective way to improve the public transport situation fundamentally, such as Beijing, Shanghai, Wuhan, Nanjing. In recent years, Hangzhou has started to enter the "Metro Times". The initial stage planning of Hangzhou Metro amounted to 10 city lines as of 2022, and the long-term planning amounted to 13 city lines as of 2050. As of June 2016, Line 1, the first stage of Line 2 and Line 4 are already in an opening status.

Metro construction, tend to affect the characteristics of the real estate around, especially transportation convenience. So from concept planning to line selection, approval, construction, operation, the entire process more or less affects housing prices and it generally shows a sharp rise. As a result, it's likely to bring too high expectations of housing price rise caused by the metro construction to investors. Investors will take real estate as an investment commodity, which causes housing vacancy or buying in the "catch", so that the real estate market appears bubble.

Price-to-rent ratio is an important indicator of the real estate market bubble. It is the ratio between house prices per square meter of floor area and the monthly rent per square meter of floor area, also called "rental ratio". Price-to-rent ratio has been widely used in empirical research on the real estate bubble.

Based on the above background and thinking, we can't help thinking that what spatial-temporal effects of housing price can be caused by metro construction in reality, especially price-to-rent ratio, such as Hangzhou. This is a problem worthy of study.

F. Wang · Y. Wu (✉)
Department of Land Management, Zhejiang University, Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

F. Wang
e-mail: wangfen15@zju.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_116

116.2 Literature Review

There are many related researches in the field about effects of real estate price caused by urban rail transit, which can be classified as follows. First, in terms of research context, classified according to the type of rail transit, the majority is about metro and the minority is about light rail or bus rapid transit. Classified according to the type of real estate, the majority is about residence and the minority is about commercial or office properties. classified according to real estate price, the majority is about market trading price and the minority is about lease price or land premium. classified according to the impact dimension, the majority is spatial analysis and the minority is combination of special and temporal analysis. Second, in terms of research methods, there are two types of visual comparisons and quantitative analysis. Visual comparison method is relatively simple, which only reflects the real estate price changes in different location and is a simple qualitative trend analysis but can't get rid of other factors. Quantitative analysis method is mainly characterized by the application of hedonic price model, the land premium function method and GIS spatial interpolation software technology. Third, in terms of study conclusions, scholars have different specific findings about the effect of rail transit on the surrounding housing prices is positive or negative, and the specific scope. For example, Cervero and Kang made a research about the effects of rapid public transit system in Seoul, Korea on land use and land value. It was estimated that residential land price premium within 300 m from BRT stops reached up to 10, 25% higher than the premium of retail and other non-residential land (Cervero and Kang 2011). For another example, research results of Zheng Jiefen and Liu Hongyu is that the range of the most significant impact around metro sites is 500 m (Zheng and Liu 2005), and the result of Nie Chong etc. is 700 m (Nie et al. 2010), and the result of Liang Qinghuai etc. is 2000 m (Liang et al. 2007). Kan Jun etc. divided 1000 m from the metro site into five circles evenly, 0–200, 200–400, 400–600, 600–800, 800–1000 m, to conduct a qualitative study about the specific impact of Chengdu Metro Line 2 on surrounding residential housing price in Long Quan (Kan et al. 2012).

In the research field about spatial-temporal evolution law of price-rent ratio, it's mainly about spatial variation law of price-rent ratio and the majority is empirical research. It can be mainly divided into two categories. One is calculating price-to-rents in each area of the city directly by related data and analysing qualitatively through simple comparison. For example, Xie Xuan analysed price-to-rents of August 2008 in five districts of Guangzhou and worked out the characteristics of district (Xie 2009). Another is achieving more intuitive and comprehensive spatial distribution of price-to-rent by the use of GIS and spatial interpolation technology to analyse more clearly and scientifically. For example, Wu Yuzhe revealed special-temporal evolution rules of housing price by the use of GIS technology and geostatistics analysis successfully. By combining similar way above and Kriging spatial interpolation analysis, he obtained spatial distribution grid data graph of Hangzhou monthly housing rent in 2004. After doing overlay analysis between it and spatial distribution grid data graph of Hangzhou housing price in 2004, Wu Yuzhe carried out special distribution of price-to-rent of Hangzhou in 2004 finally (Wu 2005).

Looking at the above current research progress, the following two shortcomings and outlook can be found mainly: ① At present the scholars mainly researched about the effects of rail transit on housing rent or housing rent or land price around, little about the effect of rail transit on price-to-rent. So combining rail transit and price-to-rent can be tried, especially empirical study of specific areas. ② Empirical research on price-to-rent of different local regions with their spatial location by GIS technology can be tried, to better understand the health of the region's real estate market and help the government formulate a more scientific and reasonable real estate control policies.

116.3 Theoretical Basis

116.3.1 Path of Metro's Impact on Housing Price

In the study about housing price, on one hand, the housing market and housing policy are inseparable, intertwined and influence each other. On the other hand, the spatial characteristics and temporal characteristics of housing are intertwined. Theoretical framework of research on housing price is in Fig. 116.1 (Wu 2011).

Based on this theoretical framework, this paper studies the spatial-temporal impact of housing price caused by metro construction, so it is mainly focused on the

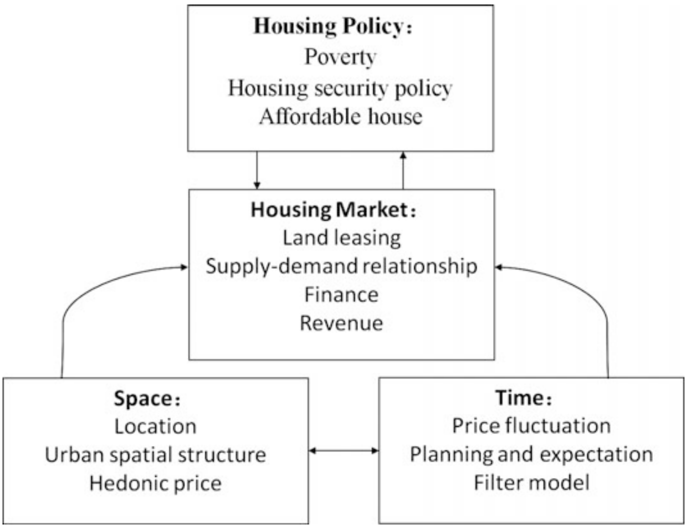


Fig. 116.1 Theoretical framework of research on housing price

following two points. Firstly, in terms of the space, metro influences convenient transportation of the surrounding real estate and affects its regional characteristics. secondly, in terms of the time, the entire process of the metro from planning, construction and opening affects people's expectations of the surrounding housing price. Through these two aspects, metro affects the supply-demand relationship of the surrounding housing market in terms of time and space, thus affecting housing price and housing bubble. Hereinafter these will be based on to analyse the phenomena in empirical research.

116.3.2 Price-to-Rent Ratio and Its Reference Value

The price-rent ratio is the ratio of the price in the residential trading market to the rent in the residential rental market, and it is one of the important indexes to measure the bubble of the real estate market.

For the reference value of price-to-rent ratio, the actual situation of different countries differs, so it can't use a unified standard or the international warning line for the judgment of a city's price-to-rent ratio of one stage in our country (Sun 2009). Many scholars discussed on how to determine the applicable price-to-rent ratio in China's real estate market. Most scholars such as Wu Yuzhe, Liu Yang, Li Hui and Yang Lichun determine the reasonable price-to-rent ratio by using income approach based on the principle that "rental costs and the cost to buy a house is equal" (Wu 2005; Liu 2010; Li and Yang 2007). Several representative reference values of price-to-rent ratio determined by Wu Yuzhe are relatively representative. It's summarized in Tables 116.1 and 116.2.

Table 116.1 Several representative reference values of price-to-rent ratio

Reference value of price-to-rent ratio	X_1 1 * 12/A	X_2 1 * 12/(A + 1%)	X_3 1 * 12/(A + 2%)	X_4 1 * 12/B
Ratio of income capitalization	A	A + 1%	A + 2%	B
Description	Calculate with the deposit interest rate directly	Calculate with sum of the deposit interest rate and risk-adjusted value (1%)	Calculate with sum of the deposit interest rate and risk-adjusted value (2%)	Calculate with annual interest rate of commercial real estate mortgage loan directly

A: The deposit interest rate (the one-year deposit interest rate published by People's Bank of China in the same period)

B: Annual interest rate of commercial real estate mortgage loan (the same period)

A and B should be determined after consulting specific number of the research area in the same period

Table 116.2 The meaning of several representative reference values of price-to-rent ratio

Price-to-rent ratio	Description
>X_1	Ratio of income capitalization is less than the deposit interest rate of bank, which indicates housing prices have obvious bubble
X_1–X_2	Ratio of income capitalization is only a little higher than the deposit interest rate of bank but risk premium is less than 1%, which indicates housing prices have bubbles
X_2–X_3	Ratio of income capitalization can meet the deposit interest rate of bank but risk premium is between 1 and 2%, which indicates housing prices have certain risk

Table 116.3 Reference values of price-to-rent ratio for April 2013

Price-to-rent ratio	Description
>400	Ratio of income capitalization is less than the deposit interest rate of bank, which indicates housing prices have obvious bubble
300–400	Ratio of income capitalization is only a little higher than the deposit interest rate of bank but risk premium is less than 1%, which indicates housing prices have bubbles
240–300	Ratio of income capitalization can meet the deposit interest rate of bank but risk premium is between 1 and 2%, which indicates housing prices have certain risk

Table 116.4 Reference values of price-to-rent ratio for June 2016

Price-to-rent ratio	Description
>800	Ratio of income capitalization is less than the deposit interest rate of bank, which indicates housing prices have obvious bubble
480–800	Ratio of income capitalization is only a little higher than the deposit interest rate of bank but risk premium is less than 1%, which indicates housing prices have bubbles
343–480	Ratio of income capitalization can meet the deposit interest rate of bank but risk premium is between 1 and 2%, which indicates housing prices have certain risk

However, Wu Yuzhe also raised shortcomings of this approach, that ratio of income capitalization just based on deposit interest rate of bank and determined risk-adjusted value by estimation instead of contacting a specific region's actual situation. So further research about reasonable price-to-rent ratio is needed (Wu 2011).

To be convenient for analysing price-to-rent ratio in later empirical research, reference values of price-to-rent ratio for 2013 and 2016 are calculated here (one-year deposit interest rate for April 2013 is 3%, which for June 2016 is 1.5%), and the results are shown in Tables 116.3 and 116.4.

116.4 Case and Methods of Empirical Research

116.4.1 The General Situation of the Study Area

Hangzhou is located in the southeast coast of China and north-western Zhejiang Province, which is the capital city of Zhejiang Province and one of the political, economic, cultural, financial and transportation centre in Zhejiang Province and is the deputy centre city of China's largest economic circle—Yangtze River Delta. Hangzhou has a total area of 16,596 km^2, thereinto urban area is 4876 km^2 and it administrates nine municipal districts, two counties and two county-level cities. Resident population of Hangzhou in 2015 is 9.018 million.

The short-term planning of Hangzhou Metro amounted to 10 city lines as of 2022, and the long-term planning amounted to 13 city lines as of 2050. Current opening situation is as shown in Table 116.5.

This article selects the total Line 1 and the first stage of Line 2 (12 stations, except the Qianjiang Road station) which have opened as the empirical research object, as shown in Fig. 116.2.

116.4.2 The Data

For the space scale of selecting residential community samples, based on the literature review about inductive research results about scope of influence about rail transit on the surrounding housing prices, this study selected residential community samples within 3 km from the metro Line 1 and the first stage of Line 2 as sample data.

According to the data sampling principle of the unit price (remove real estate area differences) and property similarity (building category and architectural features, etc.), this study selected residential community samples which had lease cases and purchase cases at the same time, and collected their second-hand housing market price (Yuan/m^2) on average and average unit rental [Yuan/m^2 (month)] from

Table 116.5 List of Hangzhou metro lines in use

Line	Construction time	Turn-on time	Number of stations	Note
The first stage of Line 1	28th March, 2007	24th November, 2012	31	Thereinto the east train station was opened in 30th June, 2013
The second stage of Line 1	28th March, 2007	24th November, 2015	3	
The first stage of Line 2	28th September, 2008	24th November, 2014	13	Thereinto Qianjiang century city station was opened in 28th April, 2016
The first stage of Line 4	May, 2012	2nd February, 2015	10	Thereinto the Xintang station was opened in 28th June, 2015

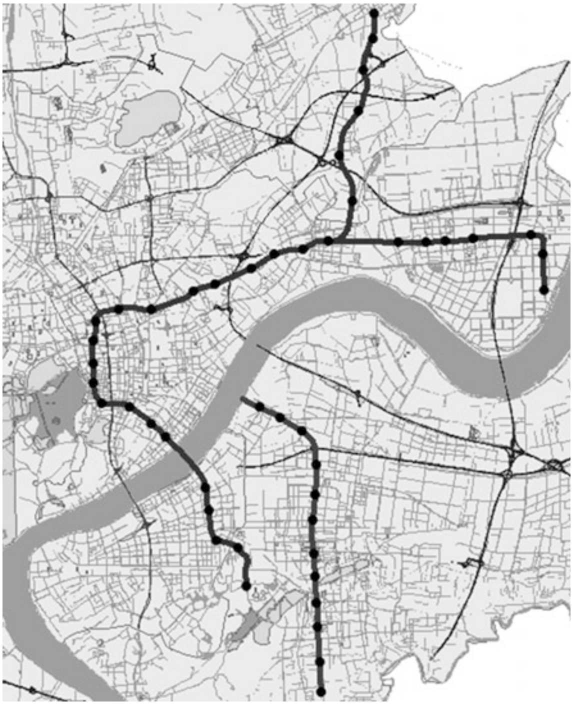


Fig. 116.2 Hangzhou metro Line 1 and southeast section of Line 2

Hangzhou SouFuncom respectively in April 2013 and June 2016 to form the sample data of housing prices and rents in the two periods. On one hand, residential community samples which have lease cases and purchase cases at the same time can meet the property similarity principle as much as possible. On the other hand, unit prices and rents data can eliminate the sample area differences to facilitate subsequent price-to-rent ratio calculation. For determination of each property's second-hand housing market price on average and average unit rental, it is gotten from taking five similar properties' second-hand housing market listed price and listed unit rental to averagely calculate.

Of course, a drawback of such data is that they are the quotation and are not necessarily the same as the price of clinching a deal really, but Wu Yuzhe confirmed that Hangzhou's second-hand housing prices in advertising media are comparable to prices of clinching a deal, through investigating the relationship between quotation and transaction price of 264 cases with different construction area at the beginning of 2004 and 2005 (Wu 2011). For this, this study thinks that it can reflect market conditions by quotation data.

Finally the effective data amount of obtained residential community samples is 568, price-to-rent data statistics of two periods as follows. As you can see from Table 116.6, the means of the data in 2013 and 2016 are both close to their median, and as can be seen from Figs. 116.3 and 116.4, data of two periods is both similar to normal distribution. In addition, because this article focuses on the effect of the

Table 116.6 Statistical data of sample points' price-to-rent ratio in 2013 and 2016

Year	Sample capacity	Average	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
2013	568	560.1706	558.4421	137.49	998.83	472.4064	649.5259	139.06812
2016	568	473.9344	457.7414	151.49	908.30	385.5710	553.3042	133.68289

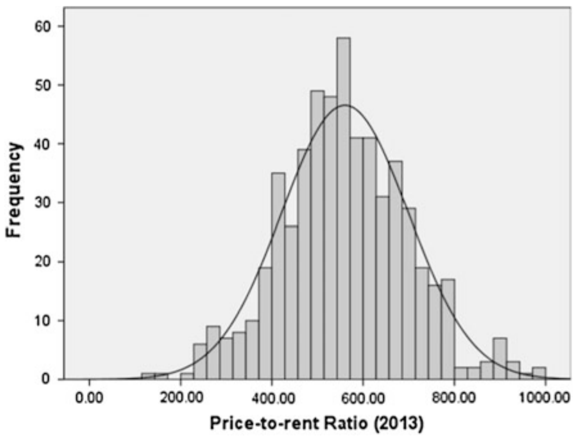


Fig. 116.3 Distribution of samples' price-to-rent ratio (2013)

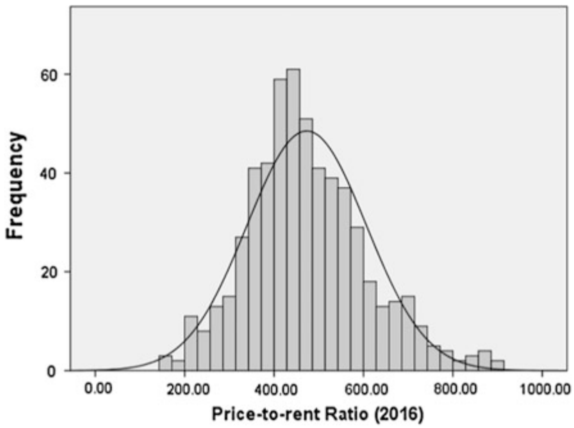


Fig. 116.4 Distribution of samples' price-to-rent ratio (2016)

metro on the spatial distribution of price-to-rent ratio, the sample distribution in different circle layers outside the metro stations was also noticed while selecting samples. As you can see from Figs. 116.5 and 116.6, the distribution is relatively reasonable, conforming to the requirements of this study. In addition, the mean value of price-to-rent ratio in 2013 is 560.17, and its in 2016 is 473.93. By comparing them to reference value of price-to-rent ratio at the front of the paper respectively it can be found that overall housing price of 2013 has a serious bubble, while bubble level of 2016 is mild.

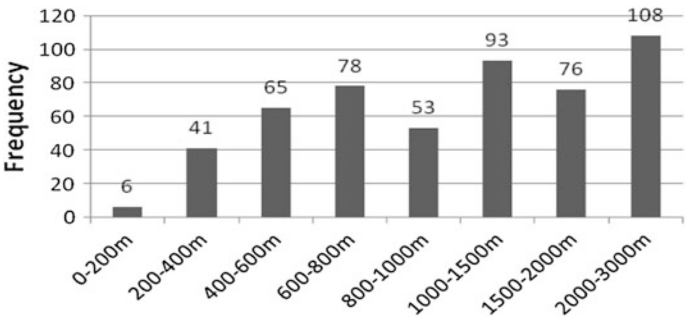


Fig. 116.5 Distribution of sample points in different circles around metro Line 1 sites

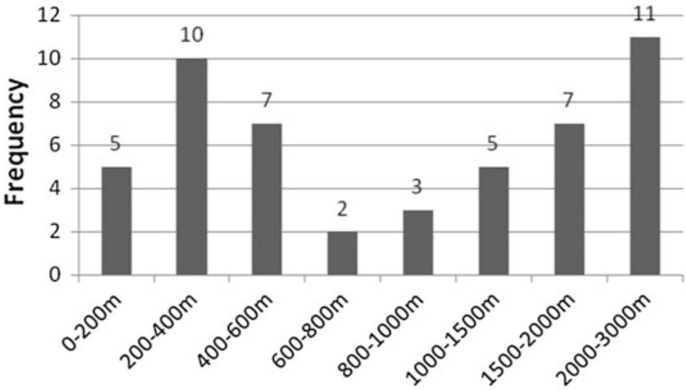


Fig. 116.6 Distribution of sample points in different circles around metro Line 2 sites (south-east section)

116.4.3 Research Methods

The main research method of this paper is GIS technology, and the supplementary method is statistical analysis. First, after vectorisation of elements in Hangzhou such as metro lines, metro sites, roads, rivers and so on with GIS, input residential community samples with their prices, rents and spatial information into system to form a spatial database. Second, use buffer analysis tools of GIS to do buffer analysis about different circle layers with different distance from metro sites. Third, use the basic statistical method to analysis price-to-rent ratio in different circle layers around metro sites.

Specific site buffer scopes are defined based on the following three aspects. The first one is the literature review about inductive research results about scope of influence about rail transit on the surrounding housing prices. The second one is the largest distance on foot which city residents can accept. Metro is directly related to travel convenience, especially for middle-aged and old people and working class families, so it also needs to consider people's largest walking distance when dividing buffer scopes. Existing research shows that the largest walking distance of urban residents can accept is usually 500–1000 m (Wu 2011). The third one is the average distance between Hangzhou metro sites. The average station spacing of Hangzhou Metro Line 1 is 1.6 km, which is too large in domestic metros, while in general metro station spacing in urban is about 1 km. Therefore, this article divided 3 km around the metro sites into eight circle layers, which is 0–200, 200–400, 400–600, 600–800, 800–1000, 1000–1500, 1500–2000 and 2000–3000 m respectively.

116.5 Results and Analysis

This article did buffer analysis about eight circle layers around metro sites of metro Line 1 and south-eastern part of Line 2 by using GIS technology and calculated the average price-to-rent of the circle layers. Based on the buffer analysis and basic statistical analysis results, quantitative and qualitative analysis from the two aspects of spatial effect and temporal effect of housing price especially price-to-rent ratio caused by metro in Hangzhou will be done next.

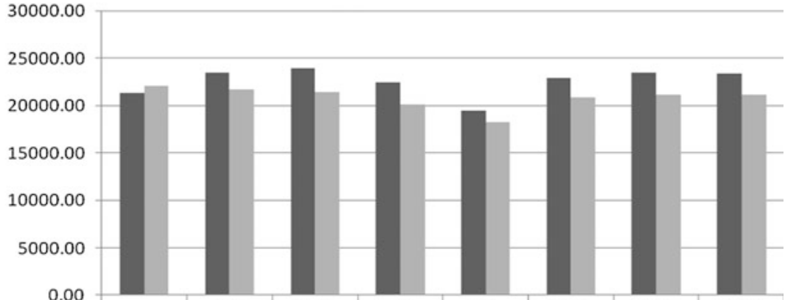
116.5.1 Spatial Effect

Figures 116.7 and 116.8 are respectively average housing prices and price-to-rent ratio of all the circle layers around metro stations of Line 1 in both 2013 and 2016. The data of 2013 represents the situation of Line 1 in early opening, and the data of 2016 represents it long after opening.

From the figure, we can see something directly that no matter for data of 2013 or data of 2016, and no matter for housing price or price-to-rent ratio, there is a boundary where is about 800 m from the stations. Within 800 m, the housing price and price-to-rent ratio tend to rise at first, and then fall down. Out of 800 m, it begins to level off gradually. To a certain extent, the effect of metro stations on the price-to-rent ratio within 800 m around is relatively obvious, and it's mainly an effect of promoting the price-to-rent ratio.

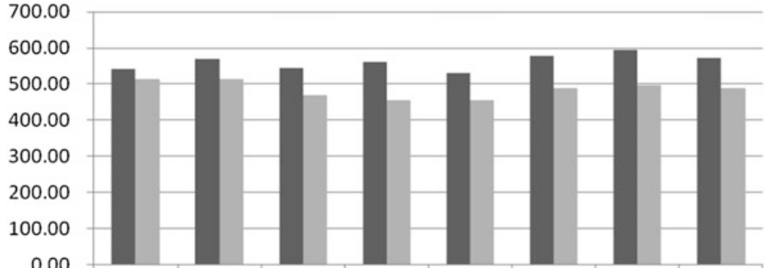
But in different periods after opening of metro, the housing price and price-to-rent in different circle layers within 800 m around the stations have little differences. In the early opening, the housing price and price-to-rent ratio within 200–800 m are little higher than those within 200 m. But after several years, the housing price and price-to-rent ratio within 200 m are little higher than those within 200–800 m, and within 800 m, the more far away from the stations, the lower of the housing price and price-to-rent ratio is.

The advantages and disadvantages of houses within 800 m around metro stations can explain this phenomenon. Within 200 m, the residents can directly walk to the



	0-200m	200-400m	400-600m	600-800m	800-1000m	1000-1500m	1500-2000m	2000-3000m
housing price(2013)	21279.33	23512.15	23977.06	22428.22	19437.43	22901.30	23423.64	23368.33
housing price(2016)	22107.67	21654.05	21429.74	20067.60	18236.58	20802.83	21091.70	21107.31

Fig. 116.7 Average housing prices in different circle layers around metro Line 1 stations in 2013 and 2016



	0-200m	200-400m	400-600m	600-800m	800-1000m	1000-1500m	1500-2000m	2000-3000m
price-to-rent(2013)	542.11	568.85	545.65	559.90	529.29	577.04	593.38	572.92
price-to-rent(2016)	512.59	513.50	468.69	454.27	455.42	490.16	498.52	489.91

Fig. 116.8 Average price-to-rent ratio in different circle layers around metro Line 1 stations in 2013 and 2016

metro station, which is very convenient and can save transportation costs greatly. In addition, the additional advertising and commercial value of the real estate along the metro line will bring a premium. But residents have to bear a series of negative influence caused by metro such as too many people, loudly noise, personnel multifarious and high crime rate. While for houses within 200–800 m, residents are pleasure to walk to the metro sites although they are not that close to metro station, without bearing a series of negative influence.

In early opening of the metro, housing consumers or investors think that in terms of general condition, houses within 200 m around metro are worse than those in 200–800 m because of the negative impact of the metro, so price and price-to-rent ratio of houses within 200 m are relatively lower. But as time goes on, people have to be forced by the traffic pressure in big cities and have to tend to houses which are much closer to the metro station, thus it slowly forms such a steady state, that within acceptable walking distance around the sites, closer from metro station, higher housing price and price-to-rent ratio.

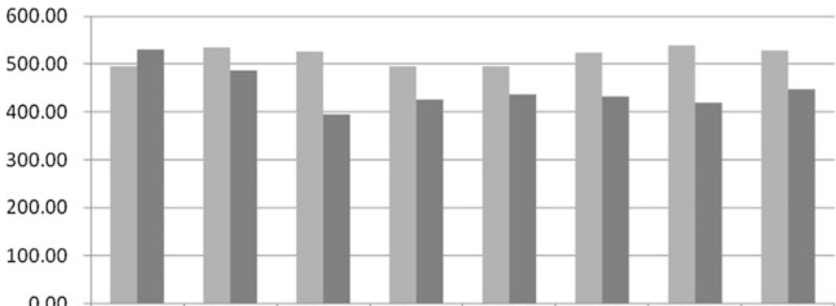
Then for metro stations in downtown and suburbs, what kind of differences are their influence scope and strength?

Figure 116.9 is price-to-rent ratio of the circle layers around Line 1 stations in downtown and suburbs in June 2016. Stations in downtown here include Chengzhan station, Ding'an Road station, Longxiangqiao station, Fengqi Road station, Wulin Square station, West Lake Culture Square station, Datieguan station, Zhalongkou station the eight sites, the rest of the stations belong to stations in suburbs.

As can be seen, the metro in downtown has effect of promotion on price-to-rent ratio within 800 m around metro stations, while the metro in suburbs has effect of promotion on price-to-rent ratio just within 400 m around metro stations. That is to say, the significant influence scope of metro stations in downtown is broader than that in suburbs.

What caused this difference may be that the service of public bicycle in downtown of Hangzhou is more perfect than that in suburbs. At present in the central area of Hangzhou, the average bus station spacing is 500–800 m and about every 300 m you will find a public bicycle service point. Public bicycle service network in downtown is more developed, which expands the significant influence scope of metro to some extent.

In addition, because of various aspects such as the politics, economy, society and so on, price-to-rent ratio in suburbs should be averagely lower than that in downtown and the difference is great in theory. But according to Fig. 116.9, the price-to-rent ratio within 400 m around metro stations in suburbs is little different



	0-200m	200-400m	400-600m	600-800m	800-1000m	1000-1500m	1500-2000m	2000-3000m
downtown	494.64	534.27	526.68	496.37	496.39	524.76	540.07	527.82
suburb	530.54	486.96	395.67	424.87	437.07	431.47	418.46	446.80

Fig. 116.9 Price-to-rent ratio of the circle layers around Line 1 stations in downtown and suburbs (2016)

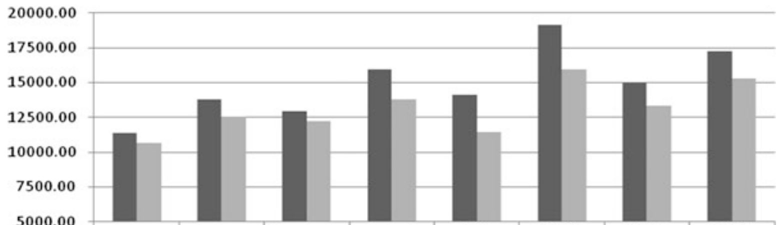
from that in downtown, and even price-to-rent ratio within 200 m is higher than that in downtown, which reaches 530.54. By comparing it to reference value of price-to-rent ratio in 2016 at the front of the paper, it has had a big bubble. That is to say, compared with urban areas, the strength of the metro pushing up price-to-rent ratio in suburbs is greater.

It is conceivable that the traffic service network in downtown is more developed and there are many other forms of transportation alternative to the metro. While the public transport service in suburbs is relatively lacking, thus dependence on the metro for suburbs is stronger than that of downtown. That is to say, the transport cost savings in suburbs caused by metro is greater than that in downtown and housing price premium effect caused by metro in suburbs is more significant, so the effect of promotion on price-to-rent ratio caused by metro in suburbs is also larger than that in downtown.

116.5.2 *Temporal Effect*

Figures 116.10 and 116.11 are respectively average housing prices and price-to-rent ratio of all the circle layers around south-eastern part stations of Line 2 in both 2013 and 2016. The data of 2013 represents the situation of south-eastern Line 2 in construction, and the data of 2016 represents it in early opening.

Through the comparison of the two stages' data of the first stage of Line 2, it can be seen as follows. First, because of the influence of housing policy as well as other factors in time and space, housing price and price-to-rent ratio of 2016 are commonly lower than those of 2013 overall, but the decline degree is different. Second, no matter before opening or in early opening, housing price and price-to-rent ratio within the scope of 200 m are lower than those within the scope of 200–800 m. It should be due to reduction life quality of the residents around caused by air pollution and noise pollution during metro construction. Third, before opening or



	0-200m	200-400m	400-600m	600-800m	800-1000m	1000-1500m	1500-2000m	2000-3000m
housing price（2013）	11352.40	13765.90	12946.86	15967.00	14096.67	19175.60	14949.00	17263.55
housing price(2016)	10687.00	12542.60	12207.71	13825.50	11482.00	15920.80	13345.00	15322.45

Fig. 116.10 Average housing prices in different circle layers around south-eastern Line 2 stations in 2013 and 2016

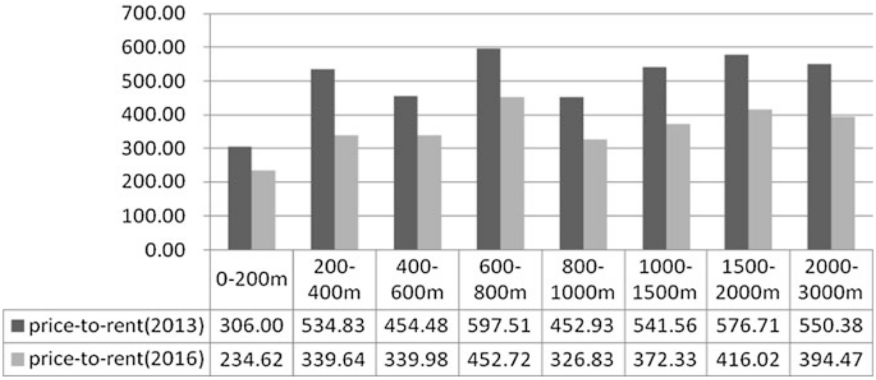


Fig. 116.11 Average price-to-rent ratio in different circle layers around south-eastern Line 2 stations in 2013 and 2016

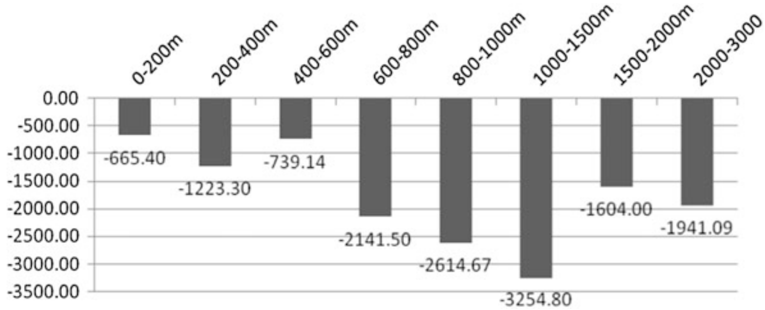


Fig. 116.12 The decline degree of housing price in different circle layers around south-eastern Line 2 stations from 2013 to 2016

during the construction period, price-to-rent ratio of 200–800 m scope was higher than the surrounding scope.

For the convenience of analysis, the decline degree of housing price and price-to-rent ratio from 2013 to 2016 are calculated. As can be seen in Figs. 116.12 and 116.13, the decline in housing prices within 0–600 m around metro stations are significantly smaller, and the decline in price-to-rent ratio within 0–200 and 400–1000 m around metro stations are significantly smaller. It shows more clearly that the construction and opening of metro have an obvious effect of promotion on the housing price and the price-to-rent ratio and they remain strongly supported the house prices and a certain degree of the housing bubble under the macro depressed housing market. In addition, by combining with analysis at the front of the paper it shows that the boosting effect was beginning to show before opening. Investors have a very keen sense of investment profits for the future. The metro before the opening, from the concept planning to line selection, approval, construction, the

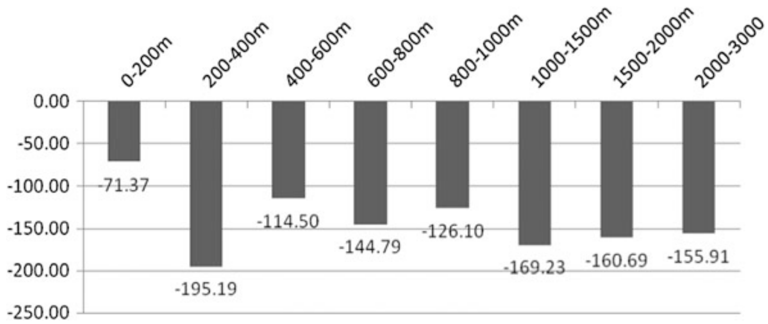


Fig. 116.13 The decline degree of price-to-rent ratio in different circle layers around south-eastern Line 2 stations from 2013 to 2016

total process causes investors' high expectations of future profits that will be brought by real estate along the metro lines and created their investment demand for the real estate around metro stations, thus it boosts housing prices and price-to-rent ratio before opening of metro.

Combining with contrast analysis of the early and later opening of Line 1 at the front of the paper, it also can be found that in the early opening housing price and price-to-rent ratio within 200 m around the site is relatively low, but when opened for a long time, people have to be forced by the traffic pressure in big cities and have to tend to houses much closer to the metro station, thus it slowly forms such a steady state, that within acceptable walking distance around the sites, closer from metro station, higher housing price and price-to-rent ratio.

116.6 Conclusion

Through above theoretical research and empirical research, the spatial-temporal effects of housing price caused by metro construction mainly from the perspective of price-to-rent ratio can be summarized as follows.

Firstly, the effect of metro stations on the price-to-rent ratio within 800 m around is relatively obvious, and it's mainly an effect of promoting the price-to-rent ratio.
Secondly, the range of metro station's effect in downtown is wider than that in suburbs, but the effect degree in suburbs is greater than that in downtown.
Thirdly, the opening of metro has an obvious effect of promoting the price-to-rent ratio, and it has begun to emerge in the planning and construction stages.
Fourthly, before opening and early after opening, within 800 m around metro stations, the price-to-rent ratio within the scope of 0–200 m is relatively the lowest, but over the subsequent years it will tend to be such a stable state, closer to metro stations, higher price-to-rent ratio.

Acknowlegements The authors appreciate the financial support by the National Natural Science Foundation of China (Grant No. 71373231), and the helpful work from the organizing committee of CRIOCM2016 International Symposium on Advancement of Construction Management and Real Estate.

References

Cervero R, Kang CD (2011) Bus rapid transit impacts on land uses and land values in Seoul, Korea. Transp Policy 18(1):102–116

Kan J, Zhang M, Guo Y et al. (2012) The effect of metro line 2 on surrounding residential house prices in Longquan based on GIS. Securities Futures China (3):184–185

Liang Q, Kong L, Deng W (2007) Impact of URT on real estate value: the case of Beijing metro line 13. China Civ Eng J 40(4):98–103

Li H, Yang L (2007) Discussion about overvalued residential housing prices—taking Shanghai as an example. Gansu Soc Sci (4):189–191

Liu Y (2010) Rationality of real estate price: a perspective of sale and rental ratio. Tech Wind 4:76

Nie C, Wen H, Fan X (2010) Temporal-spatial effects of urban rail transit on the real estate value. Geogr Res 29(5):801–810

Sun Z (2009) Change law of Chinese real estate price—an empirical study based on the substitutes between lease and purchase. Master thesis, Xiamen University, Fujian

Wu Y (2005) GIS-based exploratory data analysis on the spatial-temporal evolvement of urban housing price and its application. Ph.D. thesis, Zhejiang University, Hangzhou

Wu Y (2011) Research on temporal-spatial evolution of real estate prices—theory, method and application. Beijing Science Press, Beijing

Xie X (2009) Research on ratio of residential house prices to rents in Guangzhou. Master thesis, Guangdong University of Technology, Guangdong

Zheng J, Liu H (2005) The impact of subway construction on house prices in Shenzhen. J China Railway Soc 27(5):11–18

Chapter 117
Stakeholder Analysis of Sustainable Construction in China

Hongyang Li, S. Thomas Ng and Yahong Dong

117.1 Instruction

Sustainable construction pursues environmental protection, social well-being and economic prosperity throughout the project's life-cycle. Although green concept has attracted greater attention in China in recent years, barriers still exist which hinder its widespread adoption in the architecture, engineering and construction (AEC) industry Until now, there is yet to be a comprehensive mechanism in China to assess the sustainability of project design, construction, operation, maintenance, renovation, and demolition and the current evaluation process and outcome is still lacking credibility and acceptability. An effective way to cope with the green movement in the construction industry is through stakeholder engagement. As a result, this study aims to thoroughly analyse the perception of stakeholders towards sustainable construction in China. In this paper, the development of green con-

H. Li
School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510640, People's Republic of China

H. Li (✉)
State Key Laboratory of Subtropical Building Science,
South China University of Technology, Gungzhou 510640
People's Republic of China
e-mail: li.terryhy@yahoo.com

S. Thomas Ng
Department of Civil Engineering, University of Hong Kong,
Pok Fu Lam Road, Pok Fu Lam, Hong Kong
e-mail: tstng@hku.hk

Y. Dong
Faculty of Science and Technology,
Technological and Higher, Education Institute of Hong Kong, Tsing Yi, Hong Kong
e-mail: yadong@vtc.edu.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_117

struction in China is first presented, which is followed by a brief review of the stakeholder concept and participation theory. The interview findings are then analysed and in-depth views concerning the characteristics and respective importance of each stakeholder group involved are examined. Finally, a proposed future research agenda concludes the paper.

117.2 Literature Review

117.2.1 The Development of Sustainable Construction in China

Green construction in China can be traced back to 1994 when the State Council issued China's Agenda 21 (Shi et al. 2013). The concept of sustainability was first proposed with an emphasis on energy efficiency in the country's architecture, engineering and construction (AEC) industry. Since then, the Chinese government has been making great efforts to establish the evaluation mechanisms for sustainable buildings, e.g. the China's Eco-house Technical Evaluation Handbook (released in 2001) and the assessment system for green building of Beijing Olympic (issued in 2003). However, these early guidelines are being criticised for targeting special building types only and their applicability to other projects in general is still in question. As a result, the first version of the Evaluation Standard for Green Buildings (GBES) was adopted by the Ministry of Housing and Urban–Rural Development (MOHURD) of China in 2006 which is relevant to both residential and commercial buildings. In 2015, an updated version (i.e. the Assessment Standard for Green Building) was released with major adjustments in the scope of applicable building and the methodology of rating. The residential buildings as well as the public projects are now evaluated from both the design and operation perspectives based on criteria such as land saving and outdoor environment, energy saving and energy utilisation, water saving and water resource utilisation, material saving and material resource utilisation, indoor environment quality, construction management, operation management, promotion and innovation, etc.

Despite an increasing prosperity in sustainable construction in China, numerous issues still exist and this could hinder its further development. Of various issues, an imbalance between the design and operation of green buildings should deserve greater attention. Up to 2015, less than 10% of the labelled green design buildings in Guangdong province have obtained certificate during the operation stage. To overcome this problem necessitates a systematic framework to evaluate the life-cycle sustainability of green projects. Stakeholder engagement is a possible way to improve the credibility of assessment process and the acceptability of assessment outcome (Ng et al. 2014; Li et al. 2017).

117.2.2 The Stakeholder Concept

The stakeholder concept was first introduced by researchers at the Stanford Research Institute in the 1960s. It concerns those groups which support the organisation or else they would cease to exist (Olander 2007). The concept has gained widespread acceptance since the mid-1980s, after Freeman's (1984) book, Strategic Management: A Stakeholder Approach, which has widened the stakeholder definition to include "*any group or individual who can affect, or is affected by, the achievement of the organization's objectives*". Nowadays, references to stakeholders are commonplace both in the academic literatures as well as mainstream media and government communications.

The implementation of stakeholder theory has been far extended from its original application in strategic management to a number of fields including, more recently, construction project management (Ng et al. 2012; Li et al. 2012a, b, 2013, 2015a, b). The development of any construction project, from inception to hand over, can be controversial and may affect the many different, and sometimes discrepant, interests both positively and negatively. The representatives of these interests are referred to as the project's stakeholders who can influence the project process and/or final results, e.g. whose living environments are positively or negatively affected by a project, and/or who have received associated direct and indirect benefits or losses (Olander 2007).

117.2.3 The Theory of Stakeholder Participation

Participation is defined by Arnstein (1969) as a channel for "*the redistribution of power that enables the have-not citizens … to be deliberately included in the future*". IAPP (2007), on the other hand, reveals its core values as: (i) a right of the public to voice out their concerns about any actions that affect their lives; (ii) a promise that the input provide by the involved public will have real influence to decision making; (iii) a recognition and communication of the interests and needs of all participants; (iv) a facilitation of the involvement of those who are potentially affected by or interested in the decision; (v) an involvement of participants in designing how they would like to participate; (vi) a channel to provide all participants with the information they need; and (vii) a platform to provide feedback to participants on how their contributions have influence the decision. Public participation occurs for various reasons, including external pressures from the public and/or internal demands from decision-makers (Wang et al. 2007). Through participation, public can retain some elements of control about the decision to be made which may directly or indirectly affect them (Loh and Civic Exchange 2002). Decision-makers, on the other hand, can benefit from wider public input when deliberating, deciding and implementing a decision (OECD 2009) and hence achieving effective governance (Enserink and Koppenjan 2007).

In principle, public participation involves every person. However, it is not always possible to reach out to all individuals as some are not interested in getting involved. In view of the time and cost constraints, it is more practical to involve project stakeholders instead. Engaging project stakeholders at different stages of construction projects can be beneficial in several ways and therefore has been advocated by many researchers. However, research on stakeholders of Chinese green construction is rather limited and this may hinder the sustainable development of the AEC industry in China. On the other hand, Rowe and Frewer (2005) suggested that relevant stakeholders should be involved in different ways and at various levels. This is in line with Arnstein's (1969) eight rungs ladder for participation levels, ranging from manipulation through consultation to citizen control, according to the degree to which publics are empowered in determining the end product. Creighton (2005) agreed that participation can be best understood as a continuum with four major categories of points along the scale, including: (i) inform the public; (ii) listen to the public; (iii) engage in problem solving; and (iv) develop agreements. Various stakeholder groups should participate at the right level(s) depending upon their relative importance at each level. By doing that, stakeholder influence should help promote sustainable construction in China. Therefore, academia or practitioners shall carefully prioritise the stakeholder groups during participation and establish an effective and efficient participatory model to assess the life-cycle sustainability of green buildings in China.

117.3 Research Methodology

Interview was defined by Kahn and Cannell (1957) as a conversation with purpose between two or more individuals with highly differentiated roles, i.e. interviewer(s) asking questions while interviewee(s) answering questions. An interview is a qualitative research method aiming to gather in-depth information by harnessing facts and opinions on a particular issue as experienced by a specialist/expert. Interviews can be structured, semi-structured and unstructured and selecting the appropriate type of the three has to address the requirements of the issue being researched and the skills of the interviewer.

In this research, 15 interviews were conducted with interviewees representing a cross-section of the community, including the government officials, owners, designers, contractors, end-users, academia, and non-governmental organisations (NGOs). During the interviews, the panel experts identified the major stakeholder groups involved when delivering green projects in China. Their perspectives on the relative importance of various stakeholder groups were also solicited through a 5-point Likert scale (1 = 'least important' and 5 = 'most important').

To ensure the usefulness of the interview findings, the interviewees were selected according to a purposive sampling approach based on their knowledge and practical experience of sustainable construction in China. Table 117.1 summarises

Table 117.1 The profiles of the interviewees

Group	No.	Position	Organisation
Government Department	1	Deputy director	Municipal Department
	2	Deputy director	Provincial Department
Owner	3	Project manager	Real Estate Corporation
	4	Engineering manager	Real Estate Corporation
Designer	5	Senior architect	Design Consultants
	6	Technical director	Design Company
Contractor	7	Engineering manager	Construction Company
	8	Deputy technical manager	Construction Company
End-user	9	End-user	NA
	10	End-user	NA
Academia	11	Professor	University
	12	Senior research fellow	University
	13	Associate research fellow	Provincial Research Institution
Non-governmental Organization	14	Director	Environmental Group
	15	Member	NGO

the profiles of the interviewees. All the interviewees have ample hands-on experience in green construction, indicating that their opinions should be sufficiently relevant to this study.

117.4 Data Analysis and Results

A total of 7 stakeholder groups were identified based on the interview findings and these include: (1) government organisations; (2) owners; (3) designers; (4) contractors; (5) end-users; (6) non-governmental organisations; and (7) other relevant groups (e.g. material/technology providers, etc.). A mean score ranking technique was adopted to analyse the relative importance of various stakeholder groups involved. This technique has been applied to a number of construction management domains, for instance to delineate the common origins of delay from the client, consultant and contractor's perspective (Chan and Kumaraswamy 1996). In this study, the mean score (*MS*) regarding the respective importance of each stakeholder group can be computed by:

$$MS = \frac{\sum (f \times s)}{N}, \quad (1 \leq MS \leq 5) \tag{117.1}$$

where s represents the score given to each stakeholder group by the interviewees regarding its relative importance in sustainable construction in China, ranging from

1 to 5; *f* is the frequency of each rating (1–5) for each stakeholder group; and *N* denotes the total number of responses concerning that stakeholder group.

The mean score (*MS*) of each stakeholder group and its ranking are summarised in Table 117.2. The scale intervals are interpreted as follows: (i) "not important" ($mean\ score \leq 1.5$); (ii) "fairly important" ($1.51 \leq mean\ score \leq 2.5$); (iii) "important" ($2.51 \leq mean\ score \leq 3.5$); (iv) "very important" ($3.51 \leq mean\ score \leq 4.5$); and (v) "extremely important" ($mean\ score \geq 4.51$). As revealed in Table 117.2, all the 7 stakeholder groups are considered by the panel experts to be at least "important" to the development of sustainable construction in China. Unsurprisingly, the relative importance of government organisations ($mean\ score = 4.73$) is at the top and the group is labelled as "extremely important". Owners ($mean\ score = 4.40$) designers ($mean\ score = 3.73$), contractors ($mean\ score = 3.87$), end-users ($mean\ score = 3.93$) and other relevant groups ($mean\ score = 3.67$), on the hand, fall into the category of "very important" groups. The comments raised by the interviewees concerning the characteristics of each stakeholder group are reported as follows.

117.4.1 Government Organizations

Sustainable construction emphasises on economic, social and environmental performance throughout the building life-cycle. This is in line with the governance philosophy of the Chinese government to build a resource-saving and environmental-friendly society. The government of China, therefore, should bear the greatest responsibility in promoting the green concept to the AEC industry in the country. Relevant policies, mandates and incentives should be introduced to facilitate sustainability when delivering projects of different kinds.

117.4.2 Owners

Most of the interviewees believed that the owners in China are paying more attention to the return of investment (ROI) rather than the sustainability performance of a project, despite this phenomenon may also be relevant to other countries as well. To cope with that necessitates strong government leadership as well as market force. By raising the awareness of the general public towards green construction, owners are expected to develop projects in a more sustainable manner. Government's mandates and incentives are of equal importance during the process given the economic-social-cultural context in China.

Table 117.2 The relative importance of various stakeholder groups

Interviewee	Various stakeholder groups of sustainable construction in china						
	Government organisations	Owners	Designers	Contractors	End-users	Non-governmental organisations	Other relevant groups
1	5	5	4	4	4	3	4
2	5	4	4	4	5	4	4
3	5	5	4	4	3	2	3
4	5	4	3	3	3	3	3
5	5	5	3	3	4	3	3
6	4	5	4	4	3	3	3
7	4	5	5	5	3	2	4
8	5	4	3	4	3	2	4
9	5	4	4	4	4	4	3
10	4	5	3	3	5	4	4
11	5	5	4	4	5	5	4
12	5	4	5	5	4	4	5
13	4	4	3	4	4	3	4
14	5	4	4	4	5	4	4
15	5	3	3	3	4	5	3
Mean	4.73	4.40	3.73	3.87	3.93	3.40	3.67
Rank	1	2	5	4	3	7	6

117.4.3 Designers

Currently, sustainable residential projects and public buildings in China are evaluated based on the design as well as the operation performance. More innovation should be put to the design in order to improve the overall sustainability of the project. However, some interviewees criticised that majority of green buildings are designed with more emphasis on their façade while stakeholder concerns are usually neglected. This may go against the true spirit of the sustainability concept which strives for a balanced development among the economic, social and environmental perspectives. Besides, most of the current designs are overwhelmed by various green technologies without careful considering their applicability. This may adversely affect the project performance during the operation stage.

117.4.4 Contractors

On the contractor side, they have both technical and cost barriers to promote the green concept. The two contractors interviewed accepted they are still lacking relevant experience in adopting the new techniques required by delivering sustainable projects. They also worried that green construction may increase the cost and therefore lead to the resistance of smaller construction companies.

117.4.5 End-users

In recent years, the concept of customer satisfaction has emerged, largely in the production sector and consumer services markets, as a comparison between the customers' pre-purchase expectations and their post-purchase perceptions. In terms of the green construction industry, end-users' satisfaction can be defined as the achievement of their pre-project expectations in the actual performance during the post-occupancy stage. It is generally accepted that assessing end-users' satisfaction is the core issue of post-occupancy evaluation of sustainable buildings.

117.4.6 Non-governmental Organizations

A majority of the interviewees acknowledge the effort being put together by some environmental NGOs in promoting the sustainability concept. Their roles should help strengthen the development of green construction in China.

117.4.7 Other Relevant Groups

One should not forget about the equipment/material suppliers as the selection of construction materials may have enormous influence on energy efficiency throughout the life-cycle of a green project. The government interviewees, on the other hand, believed that more incentives should be introduced to promote production and use of green construction materials.

117.5 Conclusions

This paper has identified different stakeholder groups in relation to sustainable construction in China, and they include: (1) government organisations; (2) owners; (3) designers; (4) contractors; (5) end-users; (6) non-governmental organisations; and (7) other relevant groups (e.g. material/technology providers, etc.). The relative importance of various stakeholder groups have been evaluated and ranked using the mean score ranking technique and in-depth views have been solicited through a series of interviews.

Based on the results, the government is undoubtedly the key promoter of the green concept in the architecture, engineering and construction (AEC) industry in China. The owners, designers, contractors and equipment/material suppliers, on the other hand, should make every endeavour to assist the development of sustainable construction. The core issue is whether or not the incentives from the government or market are sufficient. A high satisfaction of end-users is one of the most important criteria for a successful green project and the non-governmental organisations may oversee the evaluation to ensure the process is credible and the outcome is acceptable. For future research, more effort should be directed to developing a participatory model to assess the life-cycle sustainability of green buildings in China.

Acknowledgements This project is supported by National Natural Science Foundation of China (Grant No. 71501074), the State Key Lab of Subtropical Building Science, South China University of Technology, China (Grant No. 2016ZB16) and the Fundamental Research Funds for the Central Universities (Approval No. 2015BS11; Project No. x2tj/D215315w).

References

Arnstein SR (1969) A ladder of citizen participation. J Am Inst Plann 35(4):216–224

Chan DW, Kumaraswamy MM (1996) An evaluation of construction time performance in the building industry. Build Environ 31(6):569–578

Creighton JL (2005) The public participation handbook: making better decisions through citizen involvement. Jossey-Bass, San Francisco

Enserink B, Koppenjan J (2007) Public participation in China: sustainable urbanization and governance. Manage Environ Qual Int J 18(4):459–474

Freeman RE (1984) Strategic management: a stakeholder approach. Pitman, Boston

IAPP (2007) IAP2 core values for public participation. International Association for Public Participation, Colorado

Kahn RL, Cannell CF (1957) The dynamics of interviewing; theory, technique, and cases. Wiley, Oxford

Li TH, Ng ST, Skitmore M (2012a) Public participation in infrastructure and construction projects in China: from an EIA-based to a whole-cycle process. Habitat Int 36(1):47–56

Li TH, Ng ST, Skitmore M (2012b) Conflict or consensus: an investigation of stakeholder concerns during the participation process of major infrastructure and construction projects in Hong Kong. Habitat Int 36(2):333–342

Li TH, Ng ST, Skitmore M (2013) Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: a fuzzy approach. Autom Constr 29:123–135

Li TH, Thomas Ng S, Skitmore M (2015a) Modeling multi-stakeholder multi-objective decisions during public participation in major infrastructure and construction projects: a decision rule approach. J Constr Eng Manage 142(3):04015087-1–04015087-13

Li TH, Ng STT, Skitmore M, Li N (2015b) Investigating stakeholder concerns during public participation. In: Proceedings of the institution of civil engineers-municipal engineer. doi:10.1680/jmuen.15.00018 (accepted and ahead of print)

Li HY, Zhang XL, Ng ST, Skitmore M (2017) Quantifying stakeholder influence in decision/evaluations relating to sustainable construction in China – A Delphi approach. J Cleaner Prod. doi:10.1016/j.jclepro.2017.04.151

Loh C, Civic Exchange (2002) Getting heard: a handbook for Hong Kong citizens. Hong Kong University Press, Hong Kong

Ng TST, Li TH, Wong JM (2012) Rethinking public participation in infrastructure projects. Proc Inst Civ Eng Municipal Eng 165(2):101–113

Ng ST, Skitmore M, Tam KY, Li TH (2014) Public engagement in major projects: the Hong Kong experience. Proc Inst Civ Eng 167(1):22–31

OECD (2009) Focus on citizens: public engagement for better policy and services. Organization for Economic Co-operation and Development, Paris

Olander S (2007) Stakeholder impact analysis in construction project management. Constr Manage Econ 25(3):277–287

Rowe G, Frewer LJ (2005) A typology of public engagement mechanisms. Sci Technol Hum Values 30(2):251–290

Shi Q, Zuo J, Huang R, Huang J, Pullen S (2013) Identifying the critical factors for green construction—an empirical study in China. Habitat Int 40:1–8

Wang WX, Li QM, Li JH, Yuan JF, Li XG (2007) Study of satisfaction evaluation model for large-scale construction project. J Chongqing Jianzhu Univ 29(4):125–128 (In Chinese)

Chapter 118
Strategic Factors Influencing Bid/No-Bid Decision of Pakistani Contractors

Ahsen Maqsoom, Malik Muhammad Farjad, Muhammad Sadaat Abbas, Muhammad Ehtesham-Ul-Haque, Muhammad Irfan and Aman Ullah Malik

118.1 Introduction

Construction industry contributes towards both economy and social betterment of the countries (Maqsoom and Charoenngam 2015). Bidding and procurement issues are long associated with construction industry and its clients. Though few scholars have tried to investigate these issues but improvements are still needed. Among the many factors affecting accomplishment of construction projects, time and cost overrun are major ones mainly caused by unmanaged bidding and bad procurement procedures. To mitigate these issues, latest and innovative bidding and procurement procedures need to be followed.

Construction industry is not only a significant factor for developed countries but also for under developed countries whose major portion of economy depends upon it. In Pakistan, there are several construction companies including national and

A. Maqsoom (✉) · M.M. Farjad · M.S. Abbas · M. Ehtesham-Ul-Haque · M. Irfan
Department of Civil Engineering, COMSATS Institute of Information and Technology, Wah Cantt, Pakistan
e-mail: ahsen.ait@gmail.com

M.M. Farjad
e-mail: student.civil.123@gmail.com

M.S. Abbas
e-mail: student.civil.123@gmail.com

M. Ehtesham-Ul-Haque
e-mail: student.civil.123@gmail.com

M. Irfan
e-mail: student.civil.123@gmail.com

A.U. Malik
Allama Iqbal Open University, Attock, Pakistan
e-mail: Amanmalik66@gmail.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_118

multinational governing the sector with high competition (Maqsoom and Charoenngam 2014; Maqsoom et al. 2014). The criterion of bid award in Pakistan is low bid or price based method where as in developed countries it is mostly the Best value procurement method that ensures high performance and quality work. The basic problem in low bid method is that it does not give value to quality and performance resulting into poor quality construction and performance. There are several short comings which need to be mitigated. Hence this research is aimed at providing factors that affect bid/no-bid decision of Pakistani contractors. The aims of this research are: (1) to identify the strategic factors considered by contractors in making bid/no-bid decision; (2) to analyze the impact and occurrence of these factors in bid/no-bid decision; and (3) to formulate a framework that will be helpful for contractors to make an efficient decision based on results.

118.2 Literature Review

Making profit and winning tender is one of the main ways for construction firms to survive in industry and achieving its aims. Making profit without entering bid and winning project is not the usual application (Egemen and Mohamed 2007). To survive in the highly competitive construction market, a firm needs to win bid. For this, bid or not to bid is one of the critical steps the company should consider, when an invitation has been received (Ma 2011). There are two ways for the construction firm to obtain the job; either by negotiation with client or competitive bidding (Dikmen et al. 2007).

Over the history, bid/no-bid decision remained the main problem for contractors around the world. Many studies have been conducted by different researchers in different countries on this topic. Problem remained the same but approaches were different for finding solution. Ahmad and Minkarah (1987) carried out study for USA and selected top 5 factors from 31 listed factors that impact bid/no-bid decision. These factors are: need for work, historic benefit, job type, owner reputation, and degree of hazards. Shash and Abdul-Hadi (1992) identified 37 factors that affecting bid/no bid decision of Saudi Arabian contractors and ranked them as per their importance. Odusote and Fellows (1992) identified 42 factors for contractors in UK. Out of these 42 factors, they ranked top 5 which are: client's ability to pay, work type, profitability, client's satisfaction, and regular client-good relationship. Chua and Li (2000) concentrated on four main groups to identify factors affecting bidding decision in Singapore that are: competition, risk, company's position in bidding, and need for work. Unlike previous studies, they assigned a resigning model on the basis of these factors to bid/no-bid decision. Egemen and Mohammad (2007) identified and grouped 50 factors into 6 categories and included 13 subcategories in total for contractors of Northern Cyprus and Turkey which are: need for a work, strength of firm, project conditions contributing to profitability, risks of project, competitions and strategic condition. Bageis and Fortune (2009) carried forward the work of Ahmad and Minkarah (1987) and identified 100 potential factors for Saudi Arabian contractors. A questionnaire survey was used to identify and rank factors affecting bidding decision and analyzed them in terms of differences between returned responses with respect to differing respondent's characteristics. Ma (2011) conducted a research in Auckland, New Zealand with a focus on factors affecting small to medium sized contractors in Auckland. Data was collected by carrying out a face to face structured interview format, incorporating a questionnaire with eight participants, experience and familiarity of firm with its specific type of work, possible contribution in building long-term relationships with other key parties and current financial capability of client.

118.3 Research Methodology

A structured questionnaire was formulated on basis of objectives of this research considering identified factors: construction market related factors, political related factors, barriers and limitations related factors, site related factors and sub-contractor related factors. All factors were further divided into sub-groups having impact on bid/no-bid decision of contractors. Questionnaire was divided into two parts: (1) open questions and (2) closed questions. In first section, respondents were asked to answer general questions related to their experience and their firms where as in second section; respondents were given 5 options based on likert scale.

The research was carried out in two steps: (1) pilot survey and (2) final questionnaire. A questionnaire was formed and pilot tested in April 2016 on 11 contractor firms. The minimum designation of respondents was Engineer ascending up to Project Manager and General Manager of particular firm. After pilot survey, improvements were made in questionnaire and final questionnaire was developed on basis of suggestions and recommendation by respondents. In questionnaire, factors were arranged and represented in a simplistic way for easy apprehension of respondents for selection of right option. Some questions were confidential and it was certain that firms will hesitate to answer these questions so they were given in percentages rather than numbers or figures for making it easier to be understood by the respondent. The final questionnaire was developed after a successful pilot survey and was sent to a population of contractor firms all over Pakistan in May 2016. Questionnaire was distributed through two ways: it was either mailed to contractor firms, or it was given in person to different firms. All contractor firms considered for the research were registered members of PEC (Pakistan Engineering Council). The Head of Administration of University and Pakistan Engineering Council (PEC) endorsed the questionnaire by a cover letter, thus providing legitimate authority to distribute questionnaire among registered contractor firms of PEC. The questionnaire was sent to 300 registered contractor firms in total, from which 167 responded to it. Thus, the response rate was 55.66%. Statistical Package for the Social Sciences software was used to analyze the data collected from these firms.

118.4 Findings

The first phase of analysis is related to the construction market related factors of Pakistani contractors. Most of these factors were taken from earlier researches on factors affecting bid/no-bid decision while some were self-developed. The respondents were asked to rate variables using Likert scale (where 1 = not important; 5 = very important). The results are shown in Fig. 118.1. 'Number of projects available in market with same size' is top ranked factor with Mean Importance Ranking (MIR) value of 3.64 for impact and 3.07 for occurrence under construction market related factors.

If there are a number of projects available in market then the selection becomes difficult. There are several factors which should be considered in such situation: profit or revenue is one of them. Every contractor wants to have more profit so they select the project with more profit. Generally large profit is earned through big projects instead of smaller ones. For this reason this factor has most influence in bid/no-bid decision for projects in Pakistani construction industry. 'Market value' is second highly ranked factor having MIR value of 3.51 for impact and 3.51 for occurrence. According to Pakistani contractors if the market is recessing, firm needs to bid for more projects. So, they even go for smaller projects available in market. Similarly, contractors want to bid for projects which have positive market value instead of the ones with negative market value. The selection is also influenced by the project fame and advertisement as contractors are more inclined to projects with more fame and profit regardless of its size. Hence this factor ended up getting more value. 'Number of competitors in market' with MIR value of 2.39 for impact and 3.54 for occurrence along with "availability of similar type of project in market" with MIR of 2.75 and 3.21 for impact and occurrence respectively were regarded as moderately important factors in bid/no-bid decision making. The prior is considered

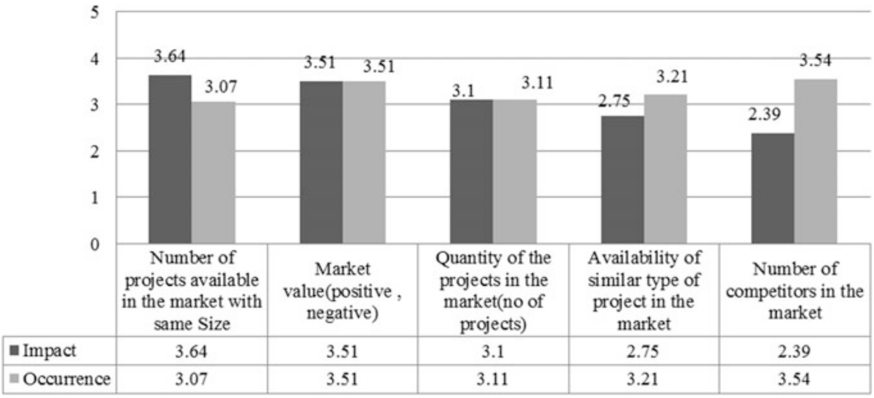


Fig. 118.1 Construction market related factors. *Note* MIR <1.49 = not important; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5 = very important

least important factor which affects bid/no-bid decision by Pakistani contractors. It is least important for a contractor to know about how and under which bidding strategy the opponents are going to bid because it is client who has to select bid document. So, bid/no-bid decision is dependent upon client's method of evaluation of bid instead of competitors in market. 'Competitors in industry' was also found less important factor affecting bid/no-bid decision according to Wanous et al. (2000), Maqsoom and Charoenngam (2014) and Ma (2011).

The second phase of analysis is related to political factors affecting bid/no-bid decision of Pakistani contractors. The respondents were asked to rate the variables using Likert scale (where 1 = not important; 5 = very important). The results for contractor related factors in bid/no-bid decision of Pakistani contractors are appended in Fig. 118.2.

'Change in government policies' with MIR value of 3.59 for impact and 3.1 for occurrence is ranked as most important factor in this research. These all political factors are self-developed for the research. This factor is regarded as most important because whenever new government arrives, it makes changes to whole structure of policies. In Pakistan, after every 5 years elections are held and new government is formed. Every political party has its own policy regarding matters of state including contracting practices. Whenever government changes, rules and policies in construction industry are also changed which affects contractors a lot. Generally, larger projects are affected by this type of factor: larger dam usually needs 7–10 years for its completion. 'Public acceptance to project' is ranked as second highest with MIR value of 3.54 for impact and 3.65 for occurrence in making bid/no bid decision. It is important for every contractor to know about the project and reaction of public to it. It is very important for any project that public or locality accepts it. They will only accept the project if the project after completion will be beneficial to them in one

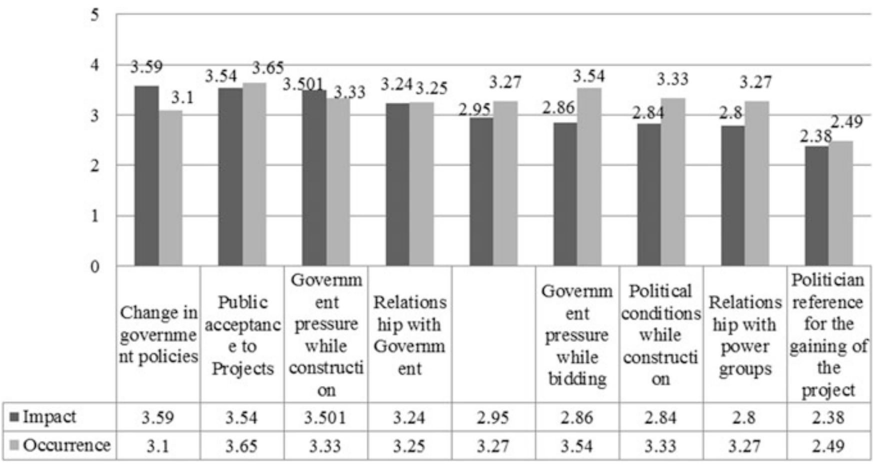
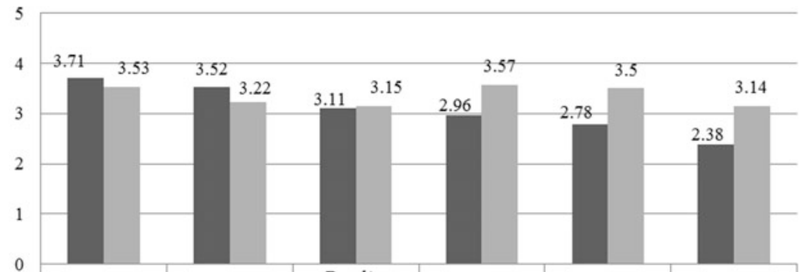


Fig. 118.2 Political related factors. *Note* MIR <1.49 = not important; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5 = very important

way or another. The success of any project is also dependent on rate at which people invest or take interest in it. If the project is not locally accepted, ultimate loss is born by the contractor in terms of money and time wastage causing delays in project. "Politician reference for gaining award of project' with MIR value of 2.38 for impact and 2.49 for occurrence is regarded as least important factor in bid/no-bid decision. Few contractors think that politician reference is essential for project award but as government is not permanent and it can be changed anytime, the factor is usually discarded. So there is always a chance of change in government or its policies which in response affect the completion of project. Using resources such as political reference to win the bid is not necessary as client demands quality product and revenue and hence often nullifies such influences.

The third phase of analysis is related to barriers and limitations influencing the bid/no-bid decisions of Pakistani contractors. The respondents were asked to rate variables using Likert scale (where 1 = not important; 5 = very important). The results for barriers and limitations related factors are appended above in Fig. 118.3.

'Allowed duration for project' with MIR value of 3.71 for impact and 3.53 for occurrence and 'Allowed duration for bid preparation' with MIR value of 3.5 for impact and 3.22 for occurrence are considered as most important factors in making bid/no-bid decision making process in Pakistani construction industry. In general, most of the projects are completed in time as prescribed by client. In contrast, if a contractor doesn't manage to complete the tasks and project in time given by the client, they face liquidated damages for both time and cost over-runs. This loss directly impacts the contractor and hence this factor is highly important for contractors. Whenever tender is opened, company might be involved in other different projects or tasks. Due to this reason, firm or contractor is not in a position of making effective bid document for securing new project as they need enough time to



	Allowed duration for project	Allowed duration for bid preparation	Penalty condition for not being able to complete the project	Completion of bid documents	Not properly managed bid documents	Technical difficulties in the project
■ Impact	3.71	3.52	3.11	2.96	2.78	2.38
■ Occurrence	3.53	3.22	3.15	3.57	3.5	3.14

Fig. 118.3 Barriers and limitation related factors. *Note* MIR < 1.49 = not important; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5 = very important

prepare their bid documents to win more projects and earn more profit. 'Technical difficulties in project' with MIR value of 2.38 for impact and 3.14 for occurrence along with 'Not properly managed bid documents' having MIR value of 2.78 for impact and 3.5 for occurrence, affect bid/no-bid decision respectively. The prior is considered as least important and lowest ranked factor because bid document is not affected by technical persons in firm as per opinion of contractors. Technical and skilled persons are required during project to manage tasks and schedule the work effectively. Skilled persons are required for operating machinery etc. but are not required in bid documentation phase. Hence, technical difficulties are not that critical factor to be worked upon on initial basis when going for bid.

Fourth phase of the analysis is related to the site related factors influencing the bid/no-bid decision of Pakistani contractors. The respondents were asked to rate variables using Likert scale (where 1 = not important; 5 = very important). The results for site related factors are appended in Fig. 118.4. 'Unforeseen site condition' with MIR value of 3.70 for impact and 3.56 for occurrence, and 'Geological conditions' with MIR value of 3.54 for impact and 3.51 for occurrence are considered as most important factors by Pakistani contractors.

Before bidding, contractor checks site condition to confirm if they are favorable for construction work or not, as unexpected damage can cause huge cost and time delays. Thus site condition plays a vital role in completion of a project. If conditions are favorable, contractor will go for a bid and can complete the project in time allocated whereas contractors refrains from bidding for project having severe conditions. 'Geological system' is ranked as second most important factor by Pakistani contractors. Geologic conditions of site are predetermined by nature. Ground characteristics influence design. The terrain, available medical facilities, as well as quick and easy access to nearest city in case of works in remote areas are some of the conditions which must be kept in mind along with geological systems. 'Uncertainty related to site condition' with MIR value of 2.45 for impact and 3.13

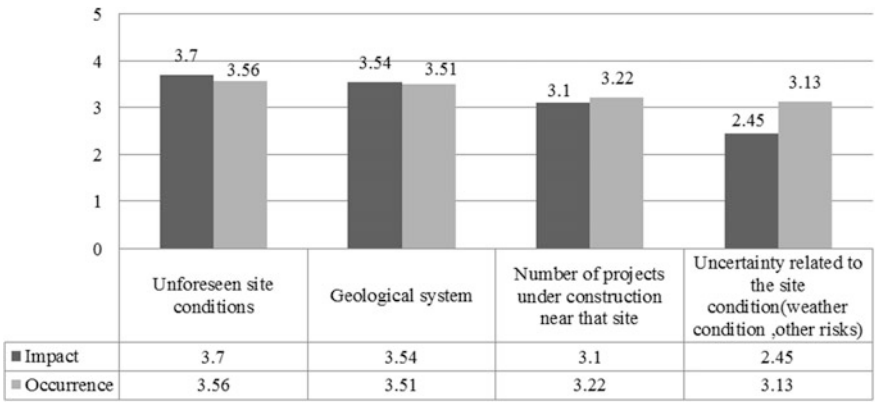


Fig. 118.4 Site related factors. *Note* MIR < 1.49 = not important; 1.5–2.49 = less important; 2.5–3.49 = moderately important; 3.5–4.49 = important; 4.5–5 = very important

for occurrence is considered as least important and lowest ranked factor. The uncertainties can not to be predicted completely but still their outcomes and hazards can be controlled by taking proper care and precautions such as risk management. By having qualified and experienced staff in firm, uncertainty or risk associated with project can easily be managed and mitigated through different plans. So, impact of this factor on bid/no-bid decision is very low due to which it has a low rank.

118.5 Conclusions

The aim of this paper is to identify the strategic factors influencing bid/no-bid decision of contractors and analyze the impact and occurrences of these factors. Construction market related and political factors are considered critical for both impact and occurrences whereas barriers and limitations related factors, site related factors are less important in terms of impacts and occurrences. Among the construction market related factors, number of projects available in market with same size is considered as highly ranked factor influencing bid/no-bid decision and market value is the second highest ranked factor. The number of competitors in market is considered the lowest impact factor in this category for making bid/no-bid decision. Among political factors, change in government policies is highly ranked and most important factor. Public acceptance to projects is second highest ranked factor and moderately important factor influencing bid/no-bid decision in Pakistani contractors whereas, politician reference for gaining project is considered as least important factor affecting bid/no-bid decision.

Among barriers and limitations related factors, allowed duration for project is highly ranked factor affecting most bid/no-bid decision and technical difficulties in project is lowest highest ranked factor. Among site related factors, unforeseen site conditions and geological conditions are highest and second highest ranked factors respectively influencing bid/no-bid decision in Pakistani construction industry whereas, uncertainty related to site condition is lowest ranked factor in this category.

The findings of the study have some limitations in form of population and sample size as it is limited to construction industry and only contractors from developing country Pakistan. In future, same study can be extended for other developing and developed countries and the results can be compared for better understanding.

Acknowledgements The authors would like to pay gratitude to Higher Education Commission (HEC), Pakistan for funding and supporting this research and Pakistan Engineering Council (PEC) for providing the list of registered contractors and for endorsing and forwarding the questionnaire to the Pakistani contractor firms.

References

Ahmad I, Minkarah IA (1987) Optimum mark-up for bidding: a preference-uncertainty trade off approach. Civil Eng Syst 4(4):170–174

Bageis AS, Fortune C (2009) Factors affecting the bid/no bid decision in the Saudi Arabian construction contractors. Constr Manag Econ 27(1):53–71

Chua DKH, Li D (2000) Key factors in bid reasoning model. J Constr Eng Manag 126(5):349–357

Dikmen I, Birgonul MT, Gur AK (2007) A case-based decision support tool for bid mark-up estimation of international construction projects. Autom Constr 17(1):30–44

Egemen M, Mohamed AN (2007) A framework for contractors to reach strategically correct bid/no bid and mark-up size decisions. Build Environ 42(3):1373–1385

Ma H (2011) Factors affecting the bid/no bid decision making process of small to medium size contractors in Auckland, Unitec Research Bank. Available online http://unitec.researchbank.ac.nz/handle/10652/1785

Maqsoom A, Charoenngam C (2014) Motives and competitive assets of Pakistani international construction contracting firms: impact of size and international experience. J Financ Manag Prop Constr 19(2):138–151

Maqsoom A, Charoenngam C (2015) The international entrepreneurial dynamics of Pakistani transnational contractors. In: Shen L, Ye K, Mao C (eds) Proceedings of the 19th international symposium on advancement of construction management and real estate. Springer, Berlin, Heidelberg

Maqsoom A, Charoenngam C, Masood R, Awais M (2014) Foreign market entry considerations of emerging economy firms: an example of Pakistani contractors. Procedia Eng 77:222–228

Odusote OO, Fellows RF (1992) An examination of the importance of resource considerations when contractors make project selection decisions. Constr Manag Econ 10(2):137–151

Shash AA, Abdul-Hadi NH (1992) Factors affecting a contractor's mark-up size decision in Saudi Arabia. Constr Manag Econ 10(5):415–429

Wanous M, Boussabaine AA, Lewis J (2000) To bid or not to bid: a parametric solution. Constr Manag Econ 18(4):457–466

Chapter 119
Study on the Affordable Housing Policy in China's Urbanization Process

Wei Wang, Zhengrong Liu and Yuzhe Wu

119.1 Introduction

As the world's second largest economy, China's urbanization has attracted the whole world's attention. From 1978 to 2015, the urbanization rate in China rose from 17.92% to 56.1%, with an average annual increase of more than 1%. According to the "world urbanization prospects" released by UN in 2014, China will add 300 million people to the cities until 2050, which is equivalent to the total population of the United States in 2014. Such a huge number of urbanization process is an enormous challenge facing China, but at the same time the new urban population to raise domestic consumption will become a new growth point of China's economic development. As an indispensable part of the rural population to urban population transfer process, the new urban population‘s housing problem, attaches great importance by the Chinese government. This is not only related to the quality of urbanization, but also a matter of social stability.

With the deepening of China's housing system reform, the price of commercial house rises continually. During the period from 1987 to 2012, the price rose from 408 to 5791 yuan per square meter. Chen et al. (2010) demonstrated that more than 85% of the urban households who need to purchase housing are unable to bear the high cost. In 1994, the State Council issued a document for the first time to establish a housing security system to meet the needs of low-income families. Since then, the

W. Wang · Y. Wu (✉)
Department of Land Management, Zhejiang University,
Hangzhou, China
e-mail: wuyuzhe@zju.edu.cn

W. Wang
e-mail: shusbs@zju.edu.cn

Z. Liu
Real Estate Management Office, Zhejiang University, Hangzhou, China
e-mail: liuzr@zju.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_119

central government has issued a series of policies to solve the housing problems of low-income families, to guide local governments to explore different types of affordable housing, and to form a combination of property insurance and leasing security framework. In the “12th Five-Year Plan” period, the State Council called for the construction of 36 million sets of affordable housing, statistically which will be over completed. The rapid development of China’s housing security system has played an important role in solving the housing difficulties of low-income families in cities and towns, and promoting a harmony society.

However, at the same time, the housing security system also exposed a lot of problems in the construction and operation process. By the end of 2015, a survey released by the National Audit Office showed that a great quantity of affordable housing have been idle in some provinces and cities. In fact, in recent years, the phenomenon of idle affordable housing appears frequently in a number of provinces and cities. Found in the audit, some affordable housing projects are only “on the paper”, the provinces and cities boast the number of affordable housing projects. In addition, in part of the areas many problems such as engineering quality shoddy, special funds idle, distribution mechanism defects etc. also more and more aroused the attention of public. In the implementation process, there is a structural difference between demand and supply: one side is unable to meet the needs of the housing; the other side is the country’s financial resources idle and waste.

Why does China’s housing security system deviate from the housing security objectives during the actual operation? What kind of operation mechanism behind? The study of these issues is conducive to improving the performance of the implementation of the housing security system, and promoting the smooth progress of the urbanization process and the economic and social development. In terms of performance, Long and Dong (2005) believe that the housing security policy not only improves the low-income housing benefits, but also improves the overall social welfare. Wei and Zhang (2008) find that, due to the defects of the system some real estate developers and a small number of medium and high income population, instead of the real target groups, obtain government’s subsidy to affordable housing construction. In terms of government’s driving force, the land transfer form in the housing security system is opposite to local government tax revenue (Li 2007), and also contrary to the overall goal of the marketization reform in land use system (Deng 2008; Jia and Liu 2007). In the study of the relationship between housing security and housing market, domestic and foreign scholars through qualitative and quantitative analysis methods to verify the existence of “causing price” interaction between commercial housing and affordable housing (Lu and Chen 2014), and commercial housing prices are affected by the significant impact of affordable housing (Ong and Sing 2002). In the protection of the object, some domestic scholars have carried out research on the middle and low income groups like sandwich layer and the floating population (Wu 2009; Zhao and Pu 2003). Other scholars in accordance with the experience of foreign housing security system, put forward the policy recommendations to improve the housing security system in China (Ba et al. 2011; Zheng and Zhang 2010). In sum, scholars from different perspectives study on housing security, and have produced a wealth of research results, to provide a way of thinking for the optimization of housing security system.

On the basis of the existing research, this paper sorts out the operating mechanism of the current affordable housing policy, and analyzes the reasons why the actual operating process is off the original intention of the system. The study found that, due to the conflict between housing security and urban economic growth target, local government carries out the “goal displacement” in the implementation process of the housing security system.

119.2 Housing Security System Operating Mechanism

The purpose of housing security system is to solve the housing difficulties of low-income families, but this does not meet the local government’s pursuit of fiscal revenue and urban economic growth. Although local government does not dare to openly violate the policies formulated by the central government, in the actual operation process, goal displacement became the rational choice of the local government. With this strategy, local government could meet the requirements of legitimacy mechanism, meanwhile without prejudice to the pursuit of efficiency mechanism.

119.2.1 Efficiency Mechanism of Housing Security System

The efficiency mechanism is the minimization of the cost or the maximization of the output, which is a standard to measure the effectiveness of the allocation of resources (Zhou 2003). One of the main supply factors of urban economic growth is land. In 1994, China began to implement tax-distribution financial system reform, to build the basic framework of the financial distribution relationship between the central and the local government. Land transfer income has become a piece of “private-plot” for local government. Through the gap between the land collection and transfer prices, local government achieve fiscal revenue, and use land as policy tools to carry out infrastructure construction, investment, and promote urban economic growth. In the past 30 years, the land finance has made an important contribution to the promotion of urban economic growth (Jia and Liu 2007).

Although China’s land resources are abundant, but the per capita amount of land resources is less. Urban construction land in general occupied arable land, China’s total arable land has been close to the country’s red line which clearly adhere to the 1.8 billion acres of arable land, so the scarcity of construction land has faced a grim situation. Both of the construction of affordable housing projects and urban economic growth need to rely on scarce land resources, resulting in the conflict of interest between them.

119.2.1.1 Land Quantity Analysis for Affordable Housing Construction

Urban construction land total planning is Q, if the ratio $r \in [0, 1]$ land through administrative allocation way for the construction of affordable housing, then $1 - r$ land can used for commercial land transfer, and access to the per unit p Land transfer income. Make the cost of per unit of land c, the local government revenue from the land I can be expressed as formula (119.1):

$$I = p * (1 - r) * Q - c * Q \tag{119.1}$$

Arrange the formula, then have

$$I = (p - c) * Q - p * Q * r \tag{119.2}$$

From formula (119.2) we can be seen, the more land amount the local government invest on affordable housing, the less the financial income. Therefore, the opposition between housing security system and local government fiscal revenue, leading to the local government lack of long-term development plan in the land supply and arbitrary in the implementation of the policy (Li 2007).

119.2.1.2 Land Location Analysis for Affordable Housing Construction

Further consider the price difference of land, assume that there are two construction land a_1 and a_2 with the same size, which prices were p_1 and p_2, and $p_1 > p_2$. Because the land allocation whether for affordable housing or for commercial purpose, government has the same requisition and consolidation cost, so as to simplify the model, where it is assumed that different land has the same cost. Local government releases 2 units of land as housing security land and commercial land respectively, the transfer revenue has the following two possible:

(1) a_1 plots as a commercial land, a_2 plots of land for an affordable housing construction, the local government gains land transfer revenue as formula 119.3:

$$I_1 = p_1 * S - 2 * S * C \tag{119.3}$$

(2) a_2 plots as a commercial land, a_1 plots of land for an affordable housing construction, the local government gains land transfer revenue as formula 119.4:

$$I_2 = p_2 * S - 2 * S * C \quad (119.4)$$

To compare the results of the two methods, formula 119.3 subtracts formula 119.4:

$$\Delta I = (p_1 - p_2) * S \quad (119.5)$$

From the formula 119.5 it can be seen that, allocating the land of high price for commercial land and the land of low price for affordable housing construction, can let the local government get more revenue. The land price decreases along with the increase of the distance from the city center, therefore, in order to control the cost of land on affordable housing, and further to reduce the loss of land revenue, local government tends to arrange affordable housing security construction projects in the outskirts of the city or remote locations.

119.2.1.3 Capital Investment Analysis for Affordable Housing Construction

Overall, China's financial investment in affordable housing construction is increasing, but the growth rate and the level of economic development does not match. The statistics in Table 119.1 show that from 2011 to 2014, local government's housing security spending has maintained a low proportion, and a slight decline. Urban economic growth brought by economic development and the rapid increase of local government financial resources did not effectively support the financial investment in housing security. Ouyang and Huang (2014) using the spatial econometric model empirical test results confirmed this conclusion.

In the process of rapid urbanization, the influx of new urban population in a large number undoubtedly brings a great challenge to the government to solve the problem of affordable housing. The central government's goal of the housing security system has increased exponentially, so that the local financial pressure for the expenditure in the housing security project is also greatly increased. For example, by calculating the data of 13 cities in Jiangsu Province, Jia and Ge (2012) found that there is a large housing security spending gap in almost all of the cities,

Table 119.1 Affordable housing expenditure accounts for the proportion of local fiscal expenditure

	2011	2012	2013	2014
Affordable housing expenditure (billion Yuan)	349.187	406.871	407.582	463.831
Local fiscal expenditure (billion Yuan)	9273.368	10718.834	11974.034	12921.549
Proportion (%)	3.77	3.80	3.40	3.59

Data source China Statistical Yearbook and the gap rate of some cities even more than 80%. In recent years the capital supporting the construction of affordable housing in China, in which the proportion of government fiscal expenditure is very small, and that increases the burden on the sustainable development of housing security (Ouyang and Huang 2014).

119.2.2 Legitimacy Mechanism of Housing Security System

Legality mechanism is a kind of institutional power, which induces or forces the organization to adopt the organizational structure or practice in the external environment, which is the most important mechanism of the new institutional theory (Zhou 2003). It explains the organizational behavior from the external environment, such as the legal system, the cultural system, the concept system and the social expectation, which is very different from the efficiency mechanism. In the field of housing security in China, many factors including the development history of the real estate market and housing security system, a series of affordable housing policies, social concern on the protection of housing and the urgent desire of housing for low-income families condense into the institutional environment and has important influence on the operation of government housing security system.

The organization system of housing security system in China has three main levels (Fig. 119.1): (1) the central government is responsible for the overall coordination and guidance, and making the general goal, then implementation by the State Ministry of Housing and Urban-Rural Development; (2) The provincial government is responsible for the region's housing security work, in accordance with the objectives and tasks, making local affordable housing construction plan, and the Provincial Department of Housing and Urban–Rural Development clarifies the details of construction tasks, investment plans, land use plans, sources of funds etc.; (3) In accordance with the national and provincial government planning, the municipal government must develop the annual implementation plan and the

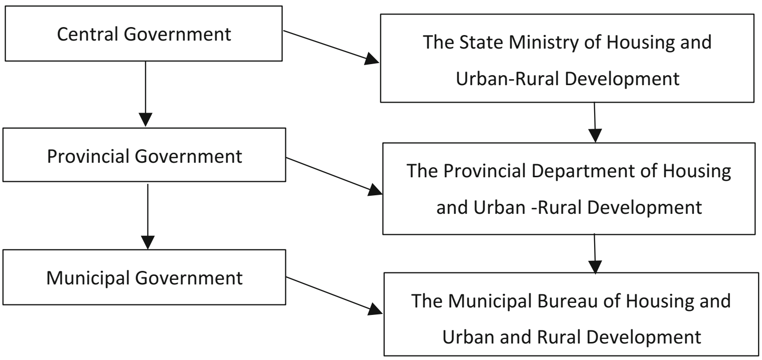


Fig. 119.1 Organization of housing security system

construction projects, the Municipal Bureau of Housing and Urban and Rural Development takes charge of specific implementation of sites selection, construction, sales, management, and other works. In the organization system operation, the target responsibility system and the assessment of accountability are established. The State Council requirements local government to annually report the quantity of the affordable housing projects started or basically completed, and sign the responsibility document with the provinces to ensure the completion of the targets. The completion of the target will be assessed. If the regional government has not completed the annual target task, of which the responsible person will be accountable.

On the institutional arrangements aspect, according to the guidance documents, the central government requires local government to enhance investment and construction efforts, to use land policies to increase the supply of affordable housing. Meanwhile the reserved land and right-recovered land should be priority arranged for the construction of affordable housing. On practical demand aspect, the rapid advance of urbanization keeps to bring a large number of new urban population, which leads to the rapid expansion of housing demand. On the culture and concept aspect, living is the fundamental right of people, the government has the obligation to provide the necessary assistance to the needy families through the second distribution of national income. Legitimacy mechanism forced the local government to accept the central government's construction objectives, the implementation of specific construction tasks. Also in this organization system, guarantee the implementation of housing construction targets plays a positive role in local government officials performance and job promotion, so local officials in order to improve the ability to survive in the organization is bound to cater to the system environment of requirements.

119.2.3 Goal Displacement in the Implementation of Housing Security System

Through the above analysis, we can see that in the housing security system, the efficiency mechanism which in order to pursue urban economic growth and the legitimacy mechanism which in order to meet the requirements for the system environment is contradictory. To obtain legitimacy and efficiency, land resources are also needed, so the distribution of land resources is the internal conflict between the two mechanisms. So what is the strategy of the local government? One of the important measures of the local government is to separate the internal operation of the housing security system and the formal organizational structure (Meyer et al. 1977), then displaces the goal in the implementation of the housing security system.

"Goal displacement" comes from Michels (1962) for the political agent target substitution behavior discussion, He found that in the actual operation due to some reason many organizations deviate from the original target and pursue different and even contradict target. Weber (1958) noted that the hierarchy also has a tendency to evolve into a life that is the object of self-survival as a departure from the original intention of the organization. The phenomenon of "goal displacement" is widely existed in the implementation of various directives of the central government by local governments.

The central government askes local government to solve the housing difficulties of low-income families as an important task, but the preference of the local government is pursuing urban economic growth. Because of the goal conflict, there are many goal displacement phenomenon raised in the running process of housing security system, for example, only pay attention on the number of affordable housing and ignore engineering quality; use the remote and lack of supporting infrastructure plots to substitute the appropriate plots for affordable housing (Zhao 2014); for fast recovery of investment cost, the affordable housing offered for sale are much more than for rent (Xie and Cao 2012), and so on.

119.3 Conclusion

This paper sorts out the operating mechanism of the existing housing security system, and reveals the internal texture of the local government to take the goal displacement because of the conflict between the affordable housing policies and the urban economic growth. Therefore, in order to solve the problems existing in the current housing security system, governments need to start from the root causes of the conflict between the housing security system and urban economic growth, through strengthen supervision, the assessment mechanism improvement and other administrative means to improve the performance of the housing security policies. In the long-term development trend, the housing security system needs to consider the market driven change, from the perspective of the changes in the supply factors of urban economic growth, to explore the direction of the development of housing security system.

Acknowledgements The authors appreciate the financial support by the National Natural Science Foundation of China (Grant No.71373231), and the helpful work from the organizing committee of CRIOCM2016 International Symposium on Advancement of Construction Management and Real Estate.

References

Ba S, Niu B, Yang X (2011) Construction of affordable housing system: international experience and Chinas policy choice. Public Finan Res 12:16–19

Chen J, Liu G, Wang L (2010) Blue Book: economic analysis and forecast China economic situation in 2011. Social Science Literature Press, Beijing

Deng W (2008) Reflections on the construction of affordable housing and countermeasures. Architectural J 8:39–41
Jia C, Ge Y (2012) Measurement of affordable housing expenditures gap of local government. Econ Rev 1:67–75
Jia K, Liu J (2007) To solve the problem of the reform of the housing system in China: the economic and social transformation in the "home ownership". Economic Science Press, Beijing
Li H (2007) The housing security system in China see from the implementation of the housing policy. China Adm 5:11–13
Long F, Dong L (2005) Performance evaluation of urban economical housing policy. Urban Probl 4:48–52
Lv P, Chen H (2014) On the policy orientation based on the relationship between commercial housing and affordable housing. Soc Sci Beijing 11:61–67
Meyer J, Brian R, Chirikov IS, Yudin GB (1977) Institutionalized organizations: formal structure as myth and ceremony. Am J Sociol 83:340–363
Michels R (1962) Polhical parts: a sociological study of the oligarchical tendencies of modern democracy. Free Press, New York
Ong SE, Sing TF (2002) Price discovery between private and public housing markets. Urban Stud 39(1):57–67
Ouyang H, Huang Z (2014) An empirical study of China's inter-regional economic development, urbanization and fiscal supply for housing security: based on a framework of spatial econometric model. Finan Trade Econ 6:5–13
Weber M (1958) From max weber: essays in sociology. Oxford University Press, New York
Wei J, Zhang X (2008) Institutional partition of housing market: the game theory analysis of institution of economic and functional houses. J Shandong Univ (Philos Soc Sci) 1:83–90
Wu H (2009) A research on the housing support problems of the migrants during the movement of urbanization: also on the problem of striving the public rental housing system. Soc Sci Beijing 16(12):82–85
Xie Z, Cao J (2012) Real estate regulation: from administrative control to interest coordination—the informal rules of target substitution and the transformation of real estate control model. J Public Adm 3:86–112
Zhao J (2014) "Interventional disturbance" in the process of the social stability risk assessment for major projects. Chin Public Adm 7:18–22
Zhao L, Pu Z (2003) "Sandwich layer" housing security system innovation. Urban Dev 2003 (12):55–57
Zheng S, Zhang Y (2010) Location patterns of social indemnificatory housing: theories, international practices and the reality in China. Mod City Study 9:18–22
Zhou X (2003) Ten lectures on organizational sociology. Social Science Literature Press, Beijing

Chapter 120
Suggestion for Improving Project Management Competency of Project General Contractors in China

Weiping Jiang

120.1 Introduction

Project general contract has been in China for about 20 years, and has attained a lot of achievements and experience (Lei 2004). According to incomplete statistics, there had completed general contracts with 255 billion RMB, that is to say, it was 32 billion RMB one year on average (Wang 2003a). In 2006, domestic project general contractors completed total value of out-put of more than 360.3 billions (National Bureau of Statistics of China 2007). That was a great leap. What's more, some of these enterprises having developing oversea, and achieve remarkable results. In 2007, Chinese construction companies' oversea contracting business had reached more than 180 countries and areas, and 51 enterprises had been ranked in the 225 largest international contractors (Xinhuanet 2008).

But we should see that general contract is applied to a small extent. General contracts only involve about 10% of all the construction contracts. But this ratio is about 50% internationally (Wang et al. 2008). There are many reasons. First, the client contracts the project to several contractors. Secondly, the structure of construction industry is not reasonable. Thirdly, the legal system is not perfect. Last but not least the core competence of general contractors is not excellent.

General contracting accords with the development of construction market, it should be promoted (Wang 2003a; Shaoting 2003). "Guidance on Cultivating and Developing Project General Contract and Project Management Enterprises" was printed and distributed by Ministry of Construction of China to propel the development of general contracting. Survey companies, design companies and general contractors can take business of general contract according to their qualifications.

W. Jiang (✉)
College of Civil Engineering, Shenzhen University,
Shenzhen 518060, Guangdong, China
e-mail: swingopen@szu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_120

This paper is to give suggestion for improving project management competency of general contractors by analyzing the characteristic of three modes of project general contract.

120.2 The Characteristics of Project General Contract

Ministry of Construction of China (2003) defined general contract as that general contractors are entrusted to contract all the phases (surveying, designing, purchasing, constructing and testing run) or several phases of a project. General contracting does not only combine the phases of a project in general; It has its own connotation and is different to specialty contracting; It systematically manages all phases of a project and is different to the modes of managing a project by separated phases. It accords with law of construction and social large-scale production, and aims to offer products comforting the clients (Pan 2007). General contract includes three kinds, engineering procurement construction (EPC)/turnkey, design-build (D + B) and general contract for construction. We can see in "Guidance on Cultivating and Developing Project General Contract and Project Management Enterprises" issued by Ministry of Construction of China that the ministry is prone to propel EPC/turnkey and design-build. The ministry also explains the two modes of general contract in the document. But in practice of general contract in China, general contract for construction is the most popular (Wang 2003a). To realize the change from general contract for construction to EPC/turnkey or D + B, the contractors should study the characteristics of the three modes, find their strong and week points and defects in their capabilities, and improve themselves.

120.2.1 EPC/Turnkey

Ministry of Construction of China (2003) defined EPC/turnkey as that the contractor takes the work of design, procurement, construction and service for test run according to the contract, and takes responsibilities for quality, safety, duration and cost. Turnkey is an extension of EPC. It means to deliver a project already having usable conditions to meet the functions (Ministry of Construction of China 2003).

EPC/Turnkey has been widely used in west countries. In China, it is mainly used in petrochemical projects. The organizational structure is shown in Fig. 120.1.

In the mode of EPC/Turnkey, the client only makes a contract with the general contractor, and the general contractor makes contracts respectively with design institutes, subcontractors and suppliers. In the implementation of the project, the client only communicates with the general contractor and the general contractor communicates with the design institute, subcontractors and suppliers. The general contractor is the core of the management system. It is important to note that the structure may change in practice.

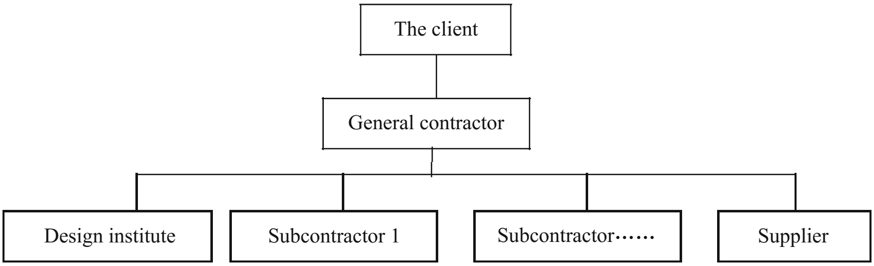


Fig. 120.1 The organizational structure of EPC/turnkey

The characteristics of EPC/Turnkey are as follow:

(1) The client contracts design, procurement, construction and test run to the general contractor. The client only manages the project principally in macro perspectives. The client can set up a management institute or entrust a project management company to manage the project (Yang 2007).
(2) Management channel is single and uniform. The orders follow the sequence from the client to the general contractor and to the subcontractors (or the design unit, the suppliers); feedbacks follow the sequence from the subcontractors to the general contractor and the client finally. This simplifies the work of the client.
(3) The client only makes contract with the general contractor, and does not make contracts with subcontractors. The general contractor takes the work of feasibility study, design, construction, procurement and others. After the general contract is made, the general contractor makes contracts respectively with the design unit, subcontractors and suppliers and entrusts corresponding work.
(4) This mode requires the general contractor to have high ability in communication and management. The client doesn't manage the project in detail. The general contractor is the information and management center. It responds to the goals made by the client, and the goals are achieved by managing subcontractors.
(5) The work of the general contractor include the phases from the earlier stage to the end of the project. So the contents of the general contract are not in detail and the contract price is hard to determine.

EPC/Turnkey mainly applies to:

(1) The client doesn't participate in project management for construction and also doesn't have professionals in project management for construction.
(2) The project is usually industrial building or civil architecture. The frame of the building and technology used in construction are always simple. And the contract price is easy to determine according to similar projects. Or the project has high complexity and only few general contractors can take the work of the project.

(3) The client keeps good relationship with the general contractor and the general contractor has high qualification, professional reputation and social credit.

120.2.2 Design-Build

Ministry of Construction of China (2003) defined design-build as that the general contractor takes the work of design and construction according to the contract, and takes responsibilities for quality, safety, duration and cost of the project. In this mode, the general contractor can subcontract part (or all) of the work of design and also can subcontract part (or all) of the work of construction. But the general contractor must take responsibilities for design and construction.

The organizational structure in the mode of design-build is similar to that in the mode of EPC/Turnkey. It is an alterative name of turnkey in civil architectures (Jiede 2003). The difference between EPC/Turnkey and design-build is that the work of EPC/Turnkey is more extensive. The key to succeed in design-build is that the client carries out functional bid. Functional bid means bid document has description for function and other relevant requirements or conditions before design is completed (Jiede 2003).

The characteristics of design-build are as follow:

(1) Design and building are integrated. The general contractor takes the work of design and building, and makes solutions to the problems caused by separation of design and building such as design hampering construction. The general contractor makes an overall plan and arrangements about the work of design and building.
(2) This mode facilitates the client's management and general control. The client contracts the work of design and building to the general contractor, so the work of contract management is not much. The client can put most of their time in goals management for the project.
(3) This mode can lessen the duration of the project. The general contractor can make plans for construction organization and technology arrangements in the phase of design. If the conditions are met, the general contractor can design and build in the same time. So the duration of the project can be lessened.
(4) This mode saves the cost of the project. On the one hand, the client calls for bids on design and building only in one time, and this saves the cost; on the other hand for the general contractor, during designing it considers the methods to lessen construction cost, keep the quality, and increase its profits (Zhou and Lu 2003).
(5) Project quality control depends on the description for function (Jiede 2003). The description for function influences the work of the general contractor, so the description for function is a key to quality control.

Design-build mainly applies to:

(1) The structure of the building is simple. The work content of design and building and the cost of the project are easily determined.
(2) If the project is complex and medium-scale or large-scale, the client can makes contracts with the general contractor. That is to say, in the first phase they make design contract and determine the work content of the design, the scale of the project, the quality and duration of the design, and both sides' responsibilities and rights in the contract. When the design is completed and has gone through the client's and relevant units' examination and the investment for the project has been determined, the client makes a contract with the general contractor concerning the construction work.

120.2.3 General Contract for Construction

General contract for construction means the general contractor to complete the work of construction according to the contract and take responsibilities for quality, safety, duration and cost of construction. General contract for construction is the first mode of general contract in the world, now it is most widely used in China.

In this mode, after the construction drawings are completed, the client calls for bids on construction and finally makes a contract for construction with the successful tender. The client can nominate subcontractors and suppliers. After the client's approval, the general contractor can subcontract parts of the project or specialty parts of the project to subcontractors. Subcontractors (except nominated subcontractors) make contracts with the general contractor and don't have direct relationship with the client. In the process of construction, the general contractor takes the work of its own, and also coordinates the subcontractors and make efforts to general management and control of the project.

The organizational structure of general contract for construction is shown in Fig. 120.2.

The characteristics of general contract for construction are as follow:

(1) Definite contract price. The prices of the bid are basisd on construction drawings.

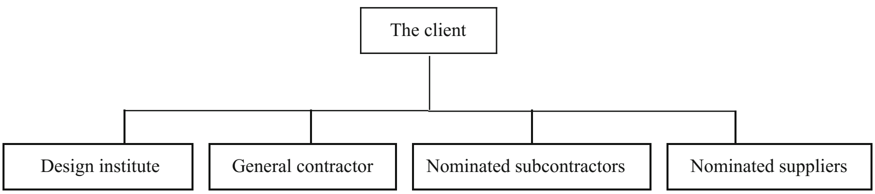


Fig. 120.2 The organizational structure of general contract for construction

(2) The duration of construction is long. The reason is that the general contractor is determined after the construction drawings are completed, and the general contractor need to make preparation for construction.
(3) Design and construction are separated. The design of the project may not consider the feasibility of construction and construction cost. And the general contractor is keen to complete the work of construction and may overlook the faults of the design. There will be many design alternations and design alternation will increase the cost of the project.
(4) The project quality depends on the general contractor. It is important to select the qualified general contractor. The general contractor with strength in technology and high capabilities in management will deliver a excellent project.
(5) The client makes a contract for construction and the work of contract management is not much, and also coordination in construction.

General contract for construction applies to:

(1) The scale of the project is not large such as general industrial buildings or civil architectures. Such projects have complete drawings and the work is easy to determine.
(2) Although the scale of the project is large, the detailed construction drawings are complete and the client doesn't have the ability to manage the project with project management professionals and project management experience.

120.3 Suggestion for Improving Project Management Competency of General Contractors in China

120.3.1 Project Management Competency of General Contractors

Competency of general contractors is a large concept including competency in customer management, financing, human resources management, project management and image management. This part is intended to discuss project management competency of general contractors. Project management competency depends on other resources' support. For example, project management needs human resources with high quality.

Project management competency means a general contractor has the ability to deliver a qualified project satisfying the client's needs under certain cost and time. According to this definition, project management competency includes competency in cost management, time management, quality control and communication with the client. On the other side, according to the three modes of general contract project management competency also contains competency in contract management, design management, construction management and procurement management. The three modes of general contract need these competencies to a different extent.

General contractors make best use of the advantages and bypass the disadvantages on the basis of their current situation and characteristics and at last make a great leap in development.

Project management competency of general contractors needs to be well-rounded and integrated. Nowadays human beings need integration of all specialty technologies from separation of technologies in mechanical times. In the manufacturing industry, integration management systems are being hot topics. There is also project lifecycle integrated management in the field of project construction. The aim of integration of project management competency is to come through the separation of specialty and problems of coordination and conflicts in technology deduced from separation. Project management competency integration lets general contractors consider the whole project lifecycle, design, construction, procurement and project quality, cost and schedule. Please just see Fig. 120.3.

From Fig. 120.3, we can see the effects of integration of project management competency:

(1) supply the client with lifecycle project management. Most of Chinese large general contractors merely supply construction service because they don't have project management competency for project lifecycle. Such service is in low profit rates and with high risk. It constrains project general contractors to compete and grow in international construction market.
(2) specialty separation deduces to all participants' work duplication in the project and work vacuum which no one cares about. And integration of project management competency can decrease work duplication and make the work integrated.
(3) integration of project management competency can make general contractors consider project quality, cost and schedule in a high position and make excellent arrangements, create the best effects of the project at last.

Most of China's general contractors are limited to general contract for construction (Wang 2003a). According to a report of Design Build Institute of America

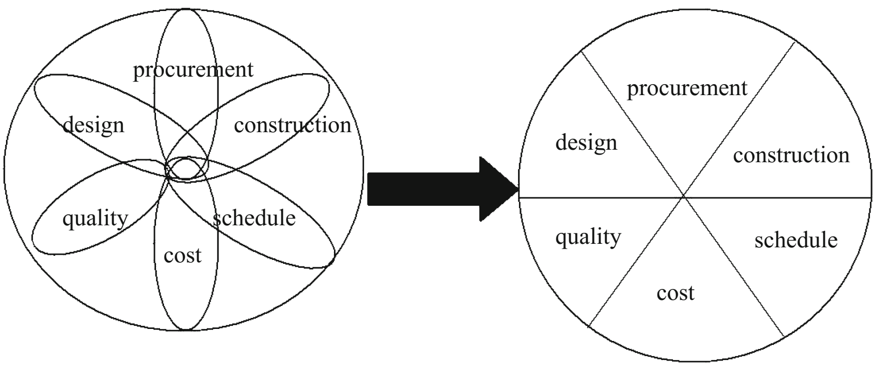


Fig. 120.3 From specialty separation to integration

in 2000, the ratio of design-build contracts in all of engineering contracts climbed from 25% in 1995 to 30%, this ratio was estimated to climb to 45% (Wang 2003b). China's general contractors should follow the current of international project management, satisfy the versatile needs of the market, change the operation modes and improve their own competency. Competency is the basis of operation change.

120.3.2 The Methods of Improving Project Management Competency of General Contractors

Now china's general contractors don't have comprehensive abilities and limit themselves to their familiar field. To change this, the companies can be amalgamated to get overall competency in project management. Design units can amalgamate contractors and contractors also can amalgamate design units. Design units, contractors and suppliers can unit to supply service for the client in the mode of EPC. It is important to note that general contractors are not combination of the three kinds of competencies (design, construction and supply), but integrator of the competencies (Lei 2005).

In the process of enterprises merge, general contractors should pay attention to:

(1) build modern enterprise systems: Sources of investment must be diversified Diversified investment sources is the product of modern economy development, and also the main characteristic of modern enterprise system.

Stake-holding reform of state-owned enterprises not only comfort the requirements of modern enterprise system, but also decrease the problems of low efficiency in state-owned companies. The reform can decrease the ration of state-owned stake-holdings, and improve the operation efficiency of state-owned assets. Stake-holding reform is the way in which the government intervene the company.

"Diversified" is not only meaning diversified subjects but also the effects of the investment subjects. In the process of reform, some companies absorb other investment subjects, but the state-owned stake-holdings are the largest. The result is that the government still intervene the companies operations, and diversified investment subjects are a mere formality.

The organization of limited companies is fit for state-owned companies' reform. on the other hand, in the process of reform we can decrease the ratio of state-owned stake holdings. Now the ratio is generally above 50%, can't make diversified investment subjects realized. According to the reality, we can let unimportant large state-owned companies' state-owned stake-holdings be less than 50% of the total stake-holdings. Large companies can mutually take stake-holdings, and social investment organizations, the managers and the employees can also hold other stake-holdings. Nowadays some large companies in every industry are using the way to reform. Some companies can totally be private-owned.

(2) reform state-owned companies management system

The problems in state-owned companies are complex and need to totally consider the relationships among reform, property rights and management. The key is to make arrangements in property rights. So we need to combine management and property rights.

(3) the key of general contractors reform is large state-owned general contractors
First, large state-owned general contractors are the main force of construction industry and they hold rich experience in construction and management. Second, company reform's prerequisite is property rights reform, and it is a important way to cultivate large construction companies. Thirdly, specialty separations constrain the competition in construction industry, and constrain the companies' long-term development.

Besides the ways of cooperation or amalgamation between companies to use outer resources, general contractors should also pay attention to improve their own competency. General contractors need to put their hands to enterprise organization structure, organization process and human resources management to improve their capabilities in project management.

(1) Set up organization structure and process to meet the requirements of modern project management. Change traditional linear organization structure to matrix organization structure that accords with modern project management. Set up a project team containing excellent members from departments of the company and support the team's work. Change operation process of the company with project information technology, and make operations more efficient.
(2) Strengthen human resources management. Human resources is the basis of existing and developing of a company. Set up systems of human resources training and form a reasonable structure of human talents. What's more, general contractors should supply the employees with good salaries. In general contractors of China, talent drain happens because of defects of cultivation systems of human resources and low salaries. Reasonable structure of human resources is a key to sustainable development of a company. A general contractor needs old employees with rich experience, middle-aged employees with full vigor and aggression, and also needs young employees with flexibility and potentiality.

120.4 Conclusions

General contract develops late in China, and it is not widely promoted. It has not been accepted to a satisfying extent. It is important for China to promote general contract. EPC/turnkey and design-build are popular in the international market. But in China, general contract for construction holds most of the market. General contractors' deficiencies in competency limit their abilities to meet the clients' versatile needs and also limit their development.

Now general contractors in China mainly depend on enterprises merge or cooperation or alliance to improve their competencies (design management, construction management and procurement management) in project management. General contractors need to learn and improve in these processes. The most important to take care is that enterprises cooperation or alliance or merge is not combination of several competencies but integration of them. If so, there will be a great leap in competency of general contractors.

What's more, general contractors should improve their own competencies. They should pay attention to enterprise organization structure, organization process and human resources management. The company should set up organization structure and process that meets the requirements of project management and cultivate human resources for enterprise's sustainable development, and lay a strong foundation for qualitative change of competency.

In conclusion, there are many things for general contractors to do to improve their competencies in China. In order to ensure general contract development in China, general contractors' merge is necessary. In addition, priority should be given to improvement of general contractors' own competency.

Acknowledgements This work was supported by the National Natural Science Foundation of China under Grant 71503171.

References

http://news.xinhuanet.com/newscenter/2008-09/23/content_10097769.htm. Accessed on 4 Oct 2008

Jide S (2003) Design-build contracting in construction projects. China Civil Eng J 9:51–54

Lei Z (2004) Study on the concept of the general contractor. Optim Capital Constr 5:7–9

Lei Z (2005) Basic concepts of engineering general contractor and its capability requirement. Archit Technol 5:390–392

Ministry of Construction of China (2003) Guidance on cultivating and developing project general contract and project management enterprises. Constr Econ 3:8–9

National Bureau of Statistics of China (2007) China statistical year book 2007. China Statistics Press, Beijing

Pan X (2007) Thoughts on design institutes' development in project general contract. Manage Views 12:75–78

Shaoting Lv (2003) China's construction market requests of general contract. Constr Econ 2:7–9

Wang W (2003a) Building general contractors. Archit Constr 7:30–32

Wang Z (2003b) Strive to cultivate and develop project general contract and project management enterprises. China Inv Des 4:8–13

Wang E, Tian B, Ke J (2008) To study on problems and solutions in China's international engineering contracting business operations. Value Eng 6:22–24

Yang B (2007) Analysis of the mode of EPC. Sichuan Constr Mater 6:233–235

Zhou B, Lu Y (2003) Comparison of the international project management mode. Chin Overseas Archit 3:64–65

Chapter 121
The Analysis of Rural Undergraduates' Separation of Registered and Actual Residences and the Separation's Influences on Land Use

Qiong Lin and Yanmei Ye

121.1 Introduction

Chinese rural undergraduates' household registration system came into being not long after the founding of the People's Republic of China. According to the household register system established in 1958 and relevant regulations, with the admission notice from urban schools, rural undergraduates could go through the procedures to accomplish the rural-urban transfer of household registration, they could be included in collective registered residence in school. Given the added values of urban households at that time, the rural-urban transfer of household registration was one important target for rural students then and the transfer rate was 100% at that time. But when Ministry of Public Security put forward seven convenient and beneficial measures concerning the household registration system in 2003, rural undergraduates could decide freely whether to transfer their household registrations to urban ones depending on their own wishes. From then on, development of social economy and changes in policies have caused changes to urban and rural living conditions, the added values of rural household registration have been more obvious, and the rural undergraduates' separation of registered and actual residences has increased. According to regulations of the Chinese household register system, the separation of registered and actual residences means the discordance of Chinese domestic people's permanent residences and their registered residences. And the separation can be expressed directly by the transfer rate when the rural students go to universities. According to previous relevant researches and the preliminary investigation of some rural undergraduates, we found an important association between the separation and the welfare of land attached to rural household registration.

Q. Lin (✉) · Y. Ye
School of Public Administration, Zhejiang University, Hangzhou, China
e-mail: 1393089169@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_121

121.2 Current Situation of the Separation

In order to firstly understand the current situation of the separation, we collected the transference data of Zhejiang University from 2013 to 2015. Table 121.1 shows the specific data of the separation.

In order to learn the regional distribution characteristics of the separation of Zhejiang University, this paper derived the proportion of rural freshmen who transferred their household registration to urban ones for the east area, the middle area and the west area respectively from 2013 to 2015. Figure 121.1 shows the specific data of three areas. Overall, the transference rates of three areas from 2013 to 2015 are all relatively low, among which the highest is merely 20.73%. Meanwhile, the transference rates of three areas all appear a decreasing trend in general. Among three areas, the transference rate of the east area is the lowest, it is probably because the economy of east area is comparatively better, and the compensation for land acquisition and the economic dividends are relatively higher, the rural household registrations here are more beneficial.

To further investigate the essence and reasons for the separation, this paper conducted a questionnaire survey and collected more information for further analysis.

Table 121.1 Enrollment and rural freshmen from 2013 to 2015[a]

Year	Rural freshmen	Transference rate (%)
2013	1374	9.17
2014	1524	9.32
2015	1412	5.38

Data source The household registration data from security department of Zhejiang University
[a]The statistics do not include the data for Hong Kong, Macao and Taiwan

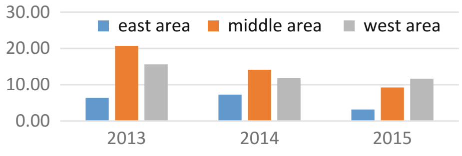


Fig. 121.1 Transference rates (%) of three areas. Here the east area includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan; the middle area includes Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan; the west area includes inner mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang. The northeast China containing Liaoning, Jilin, Heilongjiang is not included because the number of rural undergraduates from these three provinces is too small to be statistically significant. Hong Kong, Macao, Taiwan are also not included

121.3 Questionnaire Survey Analysis of the Separation

121.3.1 Questionnaire Survey of the Separation

121.3.1.1 Data Sources

On the base of past relevant studies and the preliminary interview with some rural undergraduates, we designed a questionnaire about possible influence factors of the separation and rural undergraduates' attitudes towards the land values added to rural households. Then we sent out the questionnaires and 382 of them were retrieved, with 170 from urban undergraduates and 212 from rural undergraduates, the effective return ratio is 55%.

121.3.1.2 Essential Characteristics of the Samples

Table 121.2 shows the essential characteristics of the samples. 85.85% of the 212 respondents did not transfer their household registrations into urban ones, in another word, the separation rate in the survey has reached 85.85%.

Table 121.2 The essential characteristics of the samples

Variable	Options	Number of people	Rate (%)
Gender	Male	98	46.23
	Female	114	53.77
The annual family income level	Less than 30 thousand yuan	53	25.00
	30 thousand to 80 thousand yuan	105	49.53
	80 thousand to 200 thousand yuan	41	19.34
	200 thousand to 300 thousand yuan	5	2.36
	300 thousand to 1000 thousand yuan	6	2.83
	More than 1000 thousand yuan	2	0.94
Whether the family has stable non-agricultural income	Yes	93	43.87
	No	119	56.13
Whether the main family members settle down in the town	Yes	65	30.66
	No	147	69.34
The situation of the contracted land	Fail to get the contracted land	31	14.62
	The land is abandoned	6	2.83
	The land is farmed through land transferring	76	35.85
	The land is farmed by the family	99	46.70

(continued)

Table 121.2 (continued)

Variable	Options	Number of people	Rate (%)
The situation of the homestead land	Fail to get the homestead land	30	14.15
	The house is abandoned	37	17.45
	The land is still in use	145	68.40
The attitude towards the land values	The land is the life guarantee and psychological comfort for them	40	18.87
	The land could bring a decent compensation when chances come	64	30.19
	Both options above are true	108	50.94
The transference of their household registrations	Yes	30	14.15
	No	182	85.85

Data source The questionnaire survey

121.3.2 The Analysis of Influence Factors of the Separation

121.3.2.1 Model Construction

The questionnaire survey aimed at investigating the transference decisions of rural undergraduates with only two choices, transfer or not to transfer. It is a binary choice, so this paper intends to construct a Probit Model to make a quantitative analysis of the influence factors.

The matrix definition of the binary choice model is:

$$y = X\beta + \mu, \tag{121.3.1}$$

where y is a binary discrete variable, representing the transference decision of respondents, the value of y will be 1 when the student responds transference and the value will be 0 when no transference is responded. Given that y is a discrete variable, linear estimation model cannot be adopted directly, so an unobservable latent variable y^* will be introduced which is relevant to X, the relationship between them is given by

$$y^* = X\beta + \mu^*,$$

where the independent variable X is the possible influence factors of the decision, β is a coefficient to be estimated, μ^* is an independent residual term which obeys the normal distribution. The relationship between y and y^* is given by

$$y = \begin{cases} 0, & y^* \leq 0 \\ 1, & y^* > 0 \end{cases}. \tag{121.3.2}$$

Then the probability model of y is:

$$P(y = 1) = P(y^* > 0) = P(\mu^* > -X\beta) = 1 - F(-X\beta) \tag{121.3.3}$$

$$P(y = 0) = P(y^* \leq 0) = P(\mu^* \leq -X\beta) = F(-X\beta) \tag{121.3.4}$$

121.3.2.2 Variable Selecting and the Descriptive Statistical Analysis of Variables

On the base of past relevant studies and the preliminary interview with some rural undergraduates, this paper divides the possible influence factors of the transference decision into four types including personal factors, family-related factors, land-related factors and the attitude towards the land values. Table 121.3 shows the definitions, values and descriptive statistics of variables.

Table 121.3 The definitions and descriptive statistics of variables

Variable	Definition and values	Mean value	Standard deviation
Independent variable (X)			
Personal factor			
Gender (x_1)	Female = 0, male = 1	0.462	0.500
Family-related factors			
Annual family income level (x_2)	Less than 30 thousand yuan = 1	2.113	0.967
	30 thousand to 80 thousand yuan = 2		
	80 thousand to 200 thousand yuan = 3		
	200 thousand to 300 thousand yuan = 4		
	300 thousand to 1000 thousand yuan = 5		
	More than 1000 thousand yuan = 6		
Whether the family has stable non-agricultural income (x_3)	No = 0, yes = 1	0.439	0.497
Whether the main family members settle down in the town (x_4)	No = 0, yes = 1	0.307	0.462
Land-related factors			
The situation of the contracted land (x_5)	Fail to get the contracted land = 0	2.146	1.031
	The land is abandoned = 1		
	The land is farmed through land transferring = 2		
	The land is farmed by the family = 3		
The situation of the homestead land (x_6)	Fail to get the homestead land = 0	1.542	0.731
	The house is abandoned = 1		
	The land is still in use = 2		

(continued)

Table 121.3 (continued)

Variable	Definition and values	Mean value	Standard deviation
The attitude towards the land values (x_7)	The land is the life guarantee and psychological comfort for them = 1	2.208	0.879
	The land could bring a decent compensation when chances come = 2		
	Both options above are true = 3		
Dependent variable (Y)			
The transference of their household registrations (y)	No = 0, yes = 1	0.142	0.349

Data source The questionnaire survey

121.3.2.3 The Influence Factors of the Separation: Results and Analysis

This paper adopted software Eviews 7.2 to make Probit regression with collected data. Table 121.4 shows the regression results. In the regression result, the *P*-value of the LR statistic is less than 0.05, reaching the significance level.

Table 121.4 shows that among the 7 influence factors, only the gender and whether main members settle down in the town have passed the significance test. These two factors have obvious positive influences on the transference decisions. In other words, male students showed more tendencies to transfer among the respondents. It is probably because that male students attach less importance to the values added to rural household registrations, or because that male students hope to settle down in cities as soon as possible to fight for a better future. At the same time, students whose main family members have settled down in town shows higher odds to transfer, which meets the common sense.

Table 121.4 The regression results of the influence factors

Independent variable	Estimated coefficient	Standard deviation	Probability value
1. Personal factor			
Gender (x_1)	0.5138**	0.2374	0.0305
2. Family-related factors			
Annual family income level (x_2)	0.1666	0.1110	0.1336
Whether the family has stable non-agricultural income (x_3)	−0.0521	0.2471	0.8329
Whether the main family members settle down in the town (x_4)	0.5714**	0.2528	0.0238
3. Land-related factors			
The situation of the contracted land (x_5)	0.1443	0.1296	0.2656
The situation of the homestead land (x_6)	0.0997	0.1676	0.5517
4.The attitude towards the land values (x_7)	−0.1469	0.1304	0.2598

Note Variables with ** are statistically significant at 5%

Other possible influence factors have not passed the significance test, indicating that their influences on transference decisions are not obvious. That is to say, students with higher family annual income level and stable non-agricultural income did not show more tendencies to transfer; students from families whose contracted lands and homestead lands are abandoned did not prefer to transfer. Finally, students with different attitudes towards the land values have showed no significant difference on the transference decision. Overall, the survey result indicates that separation is very common for rural undergraduates from different families.

121.3.3 The Attitudes of Rural Undergraduates Towards the Land Values

In the questionnaire survey, respondents were required to make an importance ranking about the land values added to the rural household registration. Table 121.5 shows the specific land values. Students who thought the land is the life guarantee and psychological comfort for them would make an importance ranking on series 1 of land values, those who thought the land could bring a decent compensation when chances come would make the ranking on series 2 of land values; students who thought both were true would make ranking on both series.

We have figured out the scores of land values according to the results of the ranking. Table 121.5 shows the composite scores of all the land values in two series. According to the table, in series 1, rural students value the homestead land most. In series 2, the most treasured land value is the possible compensation for land acquisition.

In the questionnaire survey, 172 respondents who made the ranking about series 2 of land values were also asked to make an overall evaluation about land values in

Table 121.5 Specific land values and their composite scores

	Land value	Composite score
Series 1	Collective economic dividend	1.5541
	Agricultural land income	2.0608
	Homestead land	2.3851
Series 2	Possible compensation for land acquisition	2.9419
	Collective economic dividend	1.9942
	Agricultural land income	2.1744
	Homestead land	2.8895

Data source The questionnaire survey

series 2. The result shows that 58.72% of them think the total value of land values in series 2 is considerable and it is important for improving lives; 41.28% of them think the total value is not high at all but there is no harm to acquire it, which indicates almost half of them do not measure the land values much.

121.4 Influences of the Separation on Land Use

121.4.1 Inefficient Utilization of the Contracted Lands

The survey results show that among students who have not transferred their household registrations, 2.72% of them have abandoned their contracted lands; and for 37.36% of them, their contracted lands are farmed through land transferring. Although land transferring can improve the land utilizing efficiency to a large extent, there are still many problems about later management and negotiation. Besides, disputes on relevant benefits between users of abandoned or transferred lands could appear when land consolidations happen, leading to inefficient utilization of lands.

To better understand the amount of contracted lands allocated to rural undergraduates, this paper tries to do some calculations through the formula below:

$$L_i = \frac{N_i \times K_i \times F_i}{P_i}, \quad (121.4.1)$$

where L_i is the amount of contracted lands allocated to rural undergraduates through out the country in ith year, N_i is the number of rural high school graduates in ith year, K_i is the average proportion of rural students entering colleges and universities through the country in ith year, F_i is the agricultural acreage in ith year, P_i is the national rural population in ith year. This paper collected the number of national rural high school graduates, the average proportion of rural students entering colleges and universities, the agricultural acreage and the national rural population from 2003 to 2013 from *China statistical yearbooks* and C*hina education yearbooks* over the years. Table 121.6 shows the results calculated through the formula.

Table 121.6 shows that the affected contracted land area will be considerable when adopting the separation ratio (85.85%) in the survey for calculation. Table 121.7 shows specific amounts of the affected lands. According to the calculations above, the total amount of affected lands will reach 6,505,900 ha from 2003 to 2013.

Table 121.6 The amount of contracted lands allocated to rural undergraduates[a]

Year	N_i (10^4 person)	K_i (in %)	F_i (10^4 hm^2)	P_i (10^4 person)	L_i (10^4 hm^2)
2003	288.95	83.40	13,003.92	76,851	40.78
2004	349.7	82.50	13,003.92	75,705	49.56
2005	429.41	76.30	13,003.92	74,544	57.16
2006	485.54	75.10	13,003.92	73,160	64.81
2007	504.08	70.30	12,173.52	71,496	60.34
2008	536.47	72.70	12,171.59	70,399	67.43
2009	533.33	77.60	12,171.59	68,938	73.07
2010	517.04	83.30	12,171.59	67,113	78.11
2011	545.57	86.50	12,171.59	65,656	87.49
2012	535.32	87.00	12,171.59	64,222	88.27
2013	536.17	87.60	12,172.59	62,961	90.81

Data source China statistical yearbooks and C*hina education yearbooks* over the years
[a]A comprehensive reform has been carried out about the education statistical reports in 2011, and the "codes for the division of urban-rural area for statistics" first promulgated by the National Bureau of Statistics has been implemented. The new criteria for the division of urban-rural area has adjusted the original three categories including cities, towns and rural areas into three categories and seven subcategories, namely the city (including the main city, urban fringe), township (including the town center, towns and villages binding region, the special area), country (including the central area of the township, village). Thus, in this table, the national rural high school graduates include the graduates from towns and rural areas before 2011; and the national rural high school graduates include the graduates from townships, towns and villages binding regions and countries in 2011 and the years after 2011

Table 121.7 The amount of contracted lands affected by the separation (in 10^4 hm^2)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Area	35.01	42.54	49.07	55.64	51.80	57.89	62.73	67.06	75.11	75.78	77.96

121.4.2 Vacancy and Waste of the Homestead Lands

The survey results above show that among the rural undergraduates who have not transferred their household registrations, the main family members settle down in the towns for 26.92% of them, and the homestead lands are abandoned for 16.48% of them, indicating their homestead lands are partially or totally vacant. To better understand the amount of homestead lands allocated to rural undergraduates, this paper tries to do some calculations through the formula below:

$$T_i = N_i \times K_i \times R, \qquad (121.4.2)$$

where T_i is the amount of homestead lands allocated to national rural undergraduates in *i*th year, N_i is the number of national rural high school graduates in *i*th year, K_i is the average proportion of rural students entering colleges and universities through the country in *i*th year, R is the rural residential area per capita, and the data

Table 121.8 The amount of homestead lands allocated to rural undergraduates and lands affected by the separation (in 10^4 hm^2)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
T_i	4.69	5.61	6.38	7.10	6.90	7.59	8.05	8.38	9.18	9.06	9.14
Lands affected by separation	4.03	4.82	5.47	6.09	5.92	6.52	6.91	7.20	7.88	7.78	7.85

used here is from *China statistical yearbook* in 2007, so $R = 194.6\,m^2$. Table 121.8 shows the calculation results of T_i and the amount of homestead lands affected by the separation when adopting the separation ratio (85.85%) in the survey for calculation. According to the calculations above, the total amount of affected lands will reach 704,700 ha from 2003 to 2013.

121.5 Conclusion

The rural undergraduates' separation of registered and actual residences has been an obvious phenomenon in China, and the separation has caused serious influences on land use both in rural and urban areas. Relevant polices need to be introduced to change the situation in order to improve the land use efficiency.

Acknowledgements The authors appreciate the helpful work from the organizing committee of CRIOCM 2016 International Symposium on Advancement of Construction Management and Real Estate.

Chapter 122
The Decoupling Analysis Between Regional Building Energy Consumption and Economic Growth in China

Ya Wu and Hang Yan

122.1 Introduction

It is appreciated that the world has experienced substantial economic and social development in recent decades, which in turn leads to large amounts of environmental problems, such as global warming, air pollution, traffic congestion and source depletion (Shen et al. 2015; Shuai et al. 2017b; Tan et al. 2017). Globally, energy shortage as one of the most serious problems, has become a focus of practical and academic concern, especially for the building sector, which accounts for the largest proportion of total energy consumption (Ma et al. 2017a). According to the report of Intergovernmental Panel on Climate Change (IPCC), energy consumption of building sector accounts for about 32% of total energy consumption around the world (IPCC 2014). In addition, 1/3 of greenhouse gases emission is closely linked with buildings (Building Energy Conservation Research Center (BECRC) 2015; Ürge-Vorsatz and Novikova 2008). It is therefore considered important to conduct the building energy conservation at the global level.

As the largest carbon emitter around the world, the Chinese government promised at the 2015 COP21 meeting in Paris that the carbon intensity will be reduced by 60–65% by 2030 compared with the 2005 level. Thus, the energy conservation and carbon emission reduction in China is facing immense pressure (Xu et al. 2017). There are three major energy consuming sectors in China, namely industry, building and transportation, and the building sector occupies the largest proportion and enjoies the biggest potential of energy saving (Building Energy Conservation

Y. Wu (✉) · H. Yan
School of Construction Management & Real Estate, Chongqing University, Chongqing, China
e-mail: mswuya@126.com

Y. Wu · H. Yan
International Research Center for Sustainable Built Environment, Chongqing University, Chongqing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_122

Research Center (BECRC) 2015; Ma et al. 2017a). So far, nearly 25% of the total energy in China is consumed by buildings (Fridley 2008; Price et al. 2010). Thus, the building sector which is given its increasing share in national emissions, plays a significant role in achieving the emission mitigation target (Ma et al. 2017b).

However, it is worth noting that with the process of rapid urbanization and economic development, the percentage of building sector accounts for total energy consumption in China will gradually increase (Hu et al. 2017). In fact, economic development has great influence on building energy consumption. On one hand, urbanization is a significant engine for economic development, and population living in urban areas grows faster with economic develops, which means more people moving from rural to urban areas (Shen et al. 2016, 2017). According to data of China Statistics Yearbooks, the urbanization rate in China increased from 37.7% in 2001 to 55.0% in 2014, and the urban population grew from 155 million to 264 million households (National Bureau of Statistics of China (NBSC) 2015). In the nearly future, a large number of people will migrate from rural to urban areas, which in turn expand large demand of construction and buildings in urban areas, and consume more energy (Hu et al. 2017). On the other hand, the Chinese economy has been growing at a rate of 10% per year for more than two decades (Hu et al. 2017). This increment of economy reflect not only the growth of production capacity but also the life quality. Higher life quality inevitably leads to greater demand for living condition, for example, the ownership and operation time of household appliance (e.g., air conditioning and refrigerator) will increase, which result in the increase of building energy consumption (Feng et al. 2016). Hence, building energy consumption has close relationship with the regional economy. To sustain the economic growth in the future and control building energy consumption, building energy savings programs have emerged as an important strategic approach at the national level.

To study the relationship between economic development and environmental quality, decoupling theory was widely adopted. The environment quality index in current researches can be classified as, carbon emission (Grand 2016; Wang et al. 2016; Zhao et al. 2016; Zhou et al. 2016), energy consumption (Csereklyei and Stern 2015; Dong et al. 2016; Zhang et al. 2016), environment pollution (Shuai et al. 2017a; Yu et al. 2017). There seems to no existing studies to examine the decoupling relationship between economic development and building energy consumption.

The aim of this study is to quantity analyze the status quo decoupling relationship between economic development and building energy consumption from regional perspective in China, and proposed the applicable policy implications for the Chinese government to effectively conduct the building energy conservation.

122.2 Methodology

122.2.1 The Calculation Method of Building Energy Consumption

Building energy consumption is commonly defined as the energy consumed in building operation stage, including air condition, electrical appliance, lighting, cooking, heating, and other terminal equipment (Ma et al. 2017b). The calculation methods adopted in this study are listed as follows:

E_1 = Heating Energy = Heating Coal + Cogeneration Coal
E_2 = Residential Building Energy Consumption (without Heating) = Life Energy Consumption (coal, kerosene, liquefied petroleum gas, natural gas, and electricity)—Gasoline—95% Diesel Oil—35% Diesel Oil
E_3 = Public Building Energy Consumption (without Heating) = Retail and Catering Energy Consumption + Other Energy Consumption—95% Gasoline—35% Diesel Oil
E_4 = Total Building Energy Consumption = $E_1 + E_2 + E_3$.

122.2.2 The Establishment of Decoupling Model

The growth of environmental pressures may be slower than that of economic development; that is, there is a decoupling relationship. Tapio (2005) introduced the elasticity theory into the decoupling indicator, and subdivided decoupling into eight possibilities: strong decoupling, weak decoupling, recessive decoupling, strong negative decoupling, expansive negative decoupling, recessive coupling, and expansive coupling.

Based on decoupling theory proposed by Tapio (2005), decoupling model constructed in this paper is listed as follows:

$$E_{(BE,GDP)} = (\%\Delta BE)/(\%\Delta GDP) \tag{122.1}$$

$$E_{(BE,TIO)} = (\%\Delta BE)/(\%\Delta TIO) \tag{122.2}$$

where $E_{(BE,GDP)}$ denotes decoupling elasticity of building energy consumption and GDP; $E_{(BE,TIO)}$ denotes decoupling elasticity of building energy consumption and TIO; $\%\Delta BE$ denotes rate of energy consumption increase; $\%\Delta GDP$ denotes the growth rate of GDP; $\%\Delta TIO$ denotes the growth rate of tertiary industry output (TIO).

Take $E_{(BE,GDP)}$ as an example, the decoupling states are listed in Fig. 122.1 (Tapio 2005).

According to Fig. 122.1, the economic growth and building energy consumption can be decoupled, negatively decoupled or coupled.

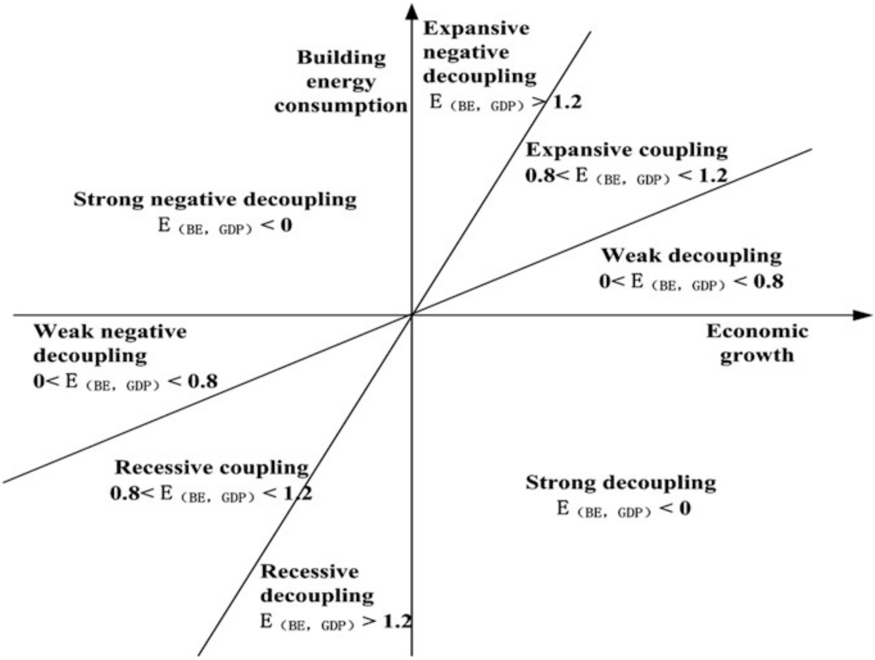


Fig. 122.1 The degrees of coupling and decoupling of building energy consumption (BE)from economic growth (GDP)

The decoupling can be further divided to three subcategories: in weak decoupling, GDP and building energy consumption both increase (and $0 < E_{(BE,GDP)} < 0.8$), strong decoupling occurs when GDP grows and building energy consumption decreases(and $E_{(BE,GDP)} < 0$) and recessive decoupling when GDP and building energy consumption both decrease (and $E_{(BE,GDP)} > 1.2$).

Similarly, negative decoupling includes three subcategories: in expansive negative decoupling, GDP and building energy consumption both increase ($E_{(BE,GDP)} > 1.2$), in strong negative decoupling GDP decreases and building energy consumption increases ($E_{(BE,GDP)} < 0$) and weak negative decoupling occurs when both variables are decreasing ($0 < E_{(BE,GDP)} < 0.8$).

Coupling including two subcategories: in recessive decoupling, GDP and building energy consumption both increase almost the same pace (and $0.8 < E_{(BE,GDP)} < 1.2$), and in expansive coupling, GDP and building energy consumption both decrease almost the same pace (and $0.8 < E_{(BE,GDP)} < 1.2$).

122.2.3 Data Collection

This paper chooses GDP and Tertiary Industry Output (TIO) as the economic index, which are commonly adopted by researchers to describe the situation of regional economic development. GDP reflects the market value of all final goods and services produced in a period. TIO is mainly derived from economic activities, such as wholesale, retail, and trade. The energy consumption of these activities belongs to energy consumption of public building because these activities almost happen in buildings.

The data in this study are from 30 provinces in China (Hong Kong, Macao, Tibet, and Taiwan are excluded because of the lack of data). The data of building energy consumption are collected from the China Energy Statistical Yearbook in the period between 2002 and 2013. Economic indicators come from China Statistical Yearbook in the same period.

122.3 Data Analysis and Discussion

This study analyzed the decoupling state between building energy consumption and TIO, GDP from temporal and spatial variation trends in decoupling development by evaluating the decoupling degree.

- Temporal variation of decoupling elasticity over different time

In order to grasp the situation and development trend of decoupling relationship between building energy consumption and economic development, this study calculated the decoupling elasticity coefficient of building energy consumption and TIO, GDP in 2001–2006 and 2007–2012 periods, as shown in Fig. 122.2.

In Fig. 122.2a, b, $E_{(BE,\ GDP)}$ and $E_{(BE,\ TIO)}$ changed a lot in two periods, and the decoupling elasticity have generally smaller tendency, indicating that decouple state in the later period (2007–2012) are better than early (2001–2006). Thus, at the provincial level the decoupling state between building energy consumption and GDP, TIO are tend to be good.

In addition, Fig. 122.2a, b show that the values of $E_{(BE,TIO)}$ and $E_{(BE,GDP)}$ performance in the same region are nearly unchanging in two period, but values of $E_{(BE,\ TIO)}$ in different areas are slightly higher than values of $E_{(BE,\ GDP)}$. This means that the decoupling degree between building energy consumption and TIO is not obvious as the decoupling degree of building energy consumption and GDP. What's more, the tertiary industry output is salient component of GDP. Therefore, the results illustrate that the decoupling of building energy consumption and TIO has greatly influence on the decoupling of building energy consumption and GDP. In order to achieve decoupling of building energy consumption and GDP, some combined efforts should be made, such as technical progress of energy saving in tertiary industry, optimization of production process in tertiary industry, improvement of energy efficiency.

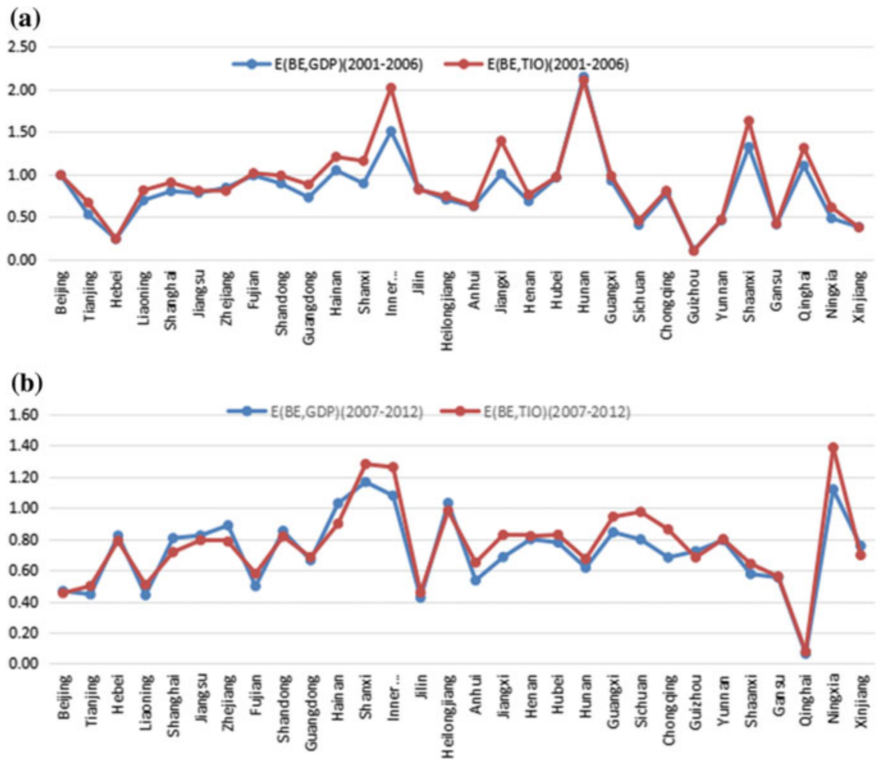
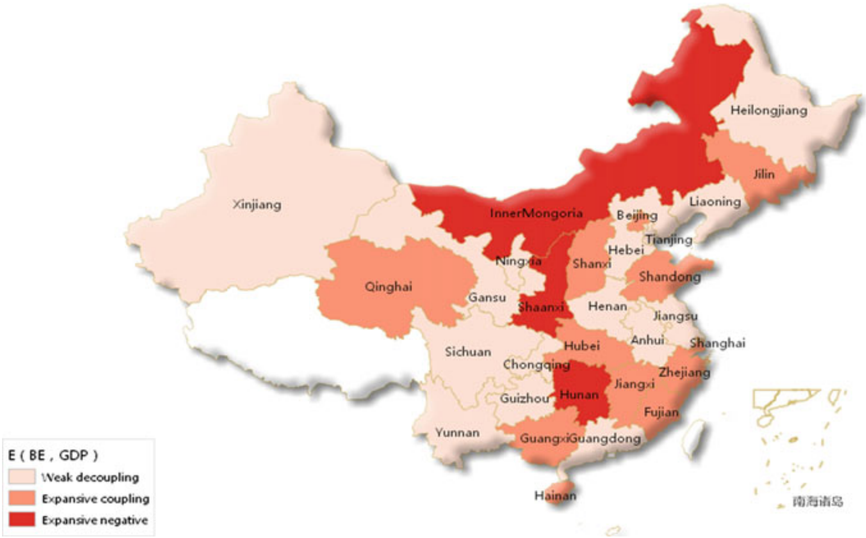


Fig. 122.2 **a** The decoupling coefficient of regional building energy consumption and TIO, GDP in 2001–2006. **b** The decoupling coefficient of regional building energy consumption and TIO, GDP in 2007–2012

- Spatial variation of decoupling elasticity over different region

In order to clearly depict the space evolution of decoupling states of building energy consumption and GDP or TIO between 2001 to 2006 and 2007 to 2012, the results of these decoupling state are graphical represented in Figs. 122.3 and 122.4.

Through the comparison of decoupling situations in two periods, it can be found that the decoupling situations between green building energy and GDP (or TIO) have been improved. The number of regions with weak decoupling increased rapidly, and the number of regions with expansive coupling and expansive negative decoupling are improved obviously. In Fig. 122.3a, the decoupling states of 15 areas performed weak between 2001 and 2007. On the other hand, the decoupling state of three regions, namely, Inner Mongolia, Hunan, Shaanxi, showed expansive negative in the same period. The remaining regions are within the expansive coupling area. During 2007–2012, the decoupling state of all regions showed weak and had expansive coupling, 63.3% of all sample regions had weak decoupling, and the remaining 11 regions showed expansive couplings (Fig. 122.3b). Figure 122.4a

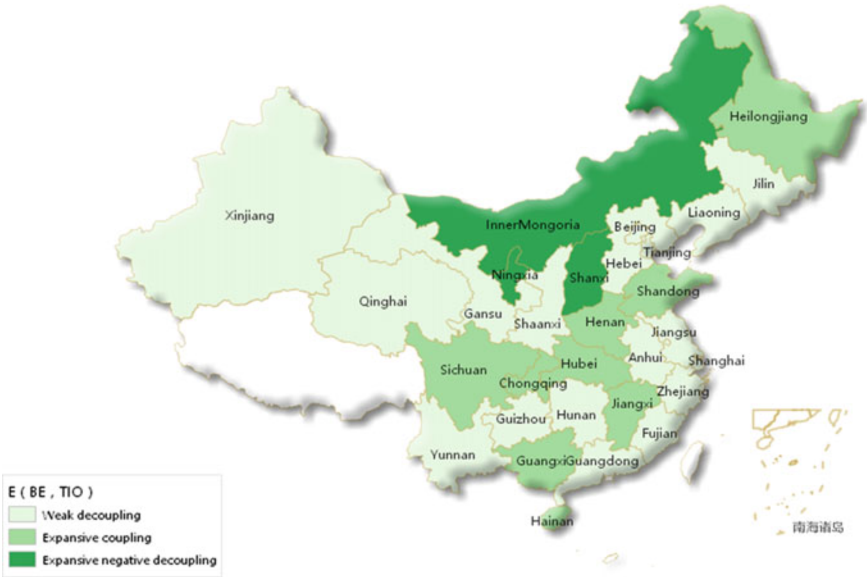


(a) 2001-2006

(b) 2007-2012

Fig. 122.3 The decoupling regional difference between China's building energy consumption and GDP

(a) 2001-2006



(b) 2007-2012

Fig. 122.4 The decoupling regional difference between China's building energy consumption and TIO shows that the decoupling state of 46.7% regions performed weak, and six regions had expansive negative decoupling. The decoupling state of the remaining 13 areas were expansive coupling. During 2007–2012, the regions with weak decoupling performance accounted for 60% of the total samples, only three regions performed the expansive negative decoupling, and the remaining 9 regions showed expansive coupling.

These results show that China pertains to weak decoupling at a provincial level, most provinces belonged to weak decoupling either from 2001 to 2006 or 2007 to 2012. What's more, the decoupling state of building energy consumption and GDP, TIO had improved as time passed. The number of regions with weak decoupling has risen during 2001–2012, while the number of regions with expansive coupling and expansive negative decoupling has reduced. There is room for achieving stronger decoupling, and the development trend of weak decoupling will continue for some time in the future. In addition, the continued presence of expansive negative decoupling and expansive coupling suggests that building energy consumption had a strong dependence on regional economic development, if not take measures, it is difficult to realize the true meaning of decoupling. During the period 2001–2006 to 2007–2012, the decoupling spatial pattern of economy from building energy consumption exhibited a state of dispersion, eastern and central regions of decoupling has improved, while the western region tended to deteriorate.

122.4 Conclusion

1. The decoupling degree of building energy consumption and TIO has a greatly impact on the decoupling degree of building energy consumption and GDP. In order to achieve the decoupling between building energy consumption and GDP, some combined efforts should be made, such as technical progress of energy saving in tertiary industry, optimization of production process in tertiary industry, improvement of energy efficiency.
2. China pertains to weak decoupling at a provincial level between economic and building energy consumption, most provinces belonged to weak decoupling either from 2001 to 2006 or 2007 to 2012. There is room for achieving stronger decoupling, and the development trend of weak decoupling will continue for some time in the future. If not take measures, it is difficult to realize the true meaning of decoupling.
3. During the period 2001–2006 to 2007–2012, the decoupling spatial pattern of economy from building energy consumption exhibited a state of dispersion, eastern and central regions of decoupling has improved, while the western region tended to deteriorate.

Acknowledgements The research team would like to acknowledge with gratitude the funding received from the National Planning Office of Philosophy and Social Science of China (Project No. 15A-ZD025).

References

Building Energy Conservation Research Center (BECRC), T.U. (2015) 2015 annual report on china building energy efficiency. China Architecture & Building Press, Beijing
Csereklyei Z, Stern DI (2015) Global energy use: decoupling or convergence? Energy Econ 51:633–641
Dong B, Zhang M, Mu H, Su X (2016) Study on decoupling analysis between energy consumption and economic growth in Liaoning Province. Energ Policy 97:414–420
Feng F, Li Z, Ruan Y, Xu P (2016) An empirical study of influencing factors on residential building energy consumption in Qingdao City, China ☆. Energy Procedia 104:245–250
Fridley D (2008) Estimating total energy consumption and emissions of China's commercial and office buildings. Office of scientific & technical information technical reports
Grand MC (2016) Carbon emission targets and decoupling indicators. Ecol Ind 67:649–656
Hu S, Yan D, Guo S, Cui Y, Dong B (2017) A survey on energy consumption and energy usage behavior of households and residential building in urban China. Energy Build
IPCC (2014) Climate change 2013: the physical science basis: working group I contribution to the fifth assessment report of the intergovernmental panel on climate change
Ma H, Du N, Yu S, Lu W, Zhang Z, Deng N, Li C (2017a) Analysis of typical public building energy consumption in northern China. Energy Build 136:139–150
Ma JJ, Du G, Zhang ZK, Wang PX, Xie BC (2017b) Life cycle analysis of energy consumption and CO_2 emissions from a typical large office building in Tianjin, China. Build Environ 117:36–48
National Bureau of Statistics of China (NBSC) (2015) China energy statistical yearbook. China Statistic Press, Beijing
Price L, Levine MD, Zhou N, Fridley D, Aden N, Lu H, Mcneil M, Zheng N, Qin Y, Ping Y (2010) Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th Five Year Plan. Energ Policy 39:2165–2178
Shen L, Zhou J, Skitmore M, Xia B (2015) Application of a hybrid entropy–McKinsey matrix method in evaluating sustainable urbanization: a China case study. Cities 42:186–194
Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8:783
Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33
Shuai C, Jiao L, Song X, Shen L (2017a) Decoupling analysis on the relationship between economic development and environment degradation in China. Springer, Singapore
Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017b) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325
Tan Y, Shuai C, Jiao L, Shen L (2017) An adaptive neuro-fuzzy inference system (ANFIS) approach for measuring country sustainability performance. Environ Impact Assess Rev 65:29–40
Tapio P (2005) Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. Transp Policy 12:137–151
Ürge-Vorsatz D, Novikova A (2008) Potentials and costs of carbon dioxide mitigation in the world's buildings. Energ Policy 36:642–661

Wang Y, Xie T, Yang S (2016) Carbon emission and its decoupling research of transportation in Jiangsu Province. J Clean Prod

Xu SC, Han HM, Zhang WW, Zhang QQ, Long RY, Chen H, He ZX (2017) Analysis of regional contributions to the national carbon intensity in China in different Five-Year Plan periods. J Clean Prod 145:209–220

Yu Y, Zhou L, Zhou W, Ren H, Kharrazi A, Ma T, Zhu B (2017) Decoupling environmental pressure from economic growth on city level: the case study of Chongqing in China. Ecol Ind 75:27–35

Zhang M, Bai C, Zhou M (2016) Decomposition analysis for assessing the progress in decoupling relationship between coal consumption and economic growth in China. Resour Conserv Recycl

Zhao X, Zhang X, Li N, Shao S, Geng Y (2016) Decoupling economic growth from carbon dioxide emissions in China: a sectoral factor decomposition analysis. J Clean Prod

Zhou X, Zhang M, Zhou M, Zhou M (2016) A comparative study on decoupling relationship and influence factors between China's regional economic development and industrial energy–related carbon emissions. J Clean Prod

Chapter 123
The Demand for Senior Housing Grows. The Answer Is to Be Found in Various Models of Social "Enterprise"

A.S. Pavesi, A. Ciaramella, M.Y. Leung and M. Gechelin

123.1 Projections on the Ageing Society: The Trend in EU

The Economic and Financial Affairs (ECOFIN) Council gave a mandate to the Economic Policy Committee (EPC) to produce a new set of long-term budgetary projections by 2015, on the basis of a new population projection by Eurostat (EUROPOP2013) (European Commission 2015). This brief introductory paragraph is excerpted on "The 2015 ageing report. Economic and budgetary projections for the 28 EU Member States (2013–2060)".

The demographic projections foresee dramatic changes in the age structure in the EU projected. Due to the dynamics in fertility, life expectancy and migration, the age structure of the EU population will change strongly in the coming decades. The overall size of the population is projected to be slightly larger by 2060 but much older than it is now. The EU population is projected to increase (from 507 million in 2013) up to 2050 by almost 5%, when it will peak (at 526 million) and will thereafter decline slowly (to 523 million in 2060). In terms of drivers of the population changes, total fertility rates are projected to rise for the EU as a whole, though remaining below the natural replacement rate. At the same time, the projections show large and sustained increases in life expectancy at birth. In the EU, life expectancy at birth for males is expected to increase by 7.1 years over the projection period, reaching 84.8 in 2060. For females, it is projected to increase by 6.0 years, reaching 89.1 in 2060 (European Commission 2015) (Fig. 123.1).

A.S. Pavesi · A. Ciaramella · M. Gechelin (✉)
Department of Architecture, Built Environment and Construction Engineering, ABC, Politecnico di Milano, Milan, Italy
e-mail: marta.gechelin@polimi.it

M.Y. Leung
Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_123

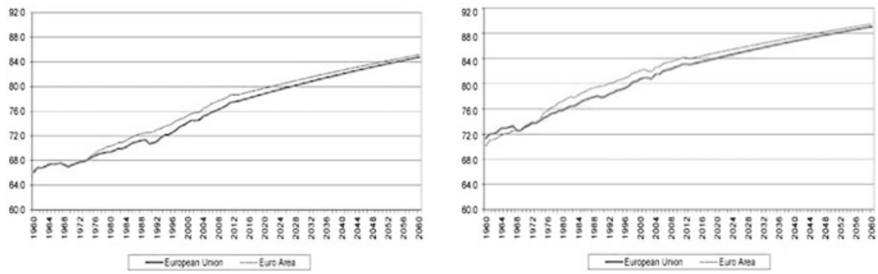


Fig. 123.1 Life expectancy at birth, men (in years), on the left and women (in years), on the right. *Source* Commission services, Eurostat, EUROPOP 2013

As a result of these different trends among age-groups, the demographic old-age dependency ratio (people aged 65 or above relative to those aged 15–64) is projected to double, thus to increase from 27.8 to 50.1%, in the EU as a whole over the projection period. This implies that the EU would move from having four working-age people for every person aged over 65 years to about two working-age persons (European Commission 2015) (Fig. 123.2).

Based on a cohort simulation model, labour force projections show a rise in overall participation rates, particularly visible for ages 50+, reflecting the combined effect of the rising attachment of younger generations of women to the labour market, together with the expected impact of pension reforms. By large, the biggest increases in participation rates are projected for older workers (around 21 pp. for women and 10 pp. for men) in the EU for the age group 55–64, influenced by enacted pension reforms (European Commission 2015).

The large differences between Member States reflect primarily the diversity in public pension arrangements, their degree of maturity and the effects of pension reforms enacted so far. In fact, a reduction of public pension spending as a share of GDP over the long-term is projected in the majority of Member States (HR, DK, LV, FR, IT, EL, SE, EE, ES, PT, PL, BG, RO, CY and HU), mostly as a result of implemented pension reforms. These reform measures, including changes to the retirement age and the pension benefit, have primarily been adopted to address fiscal sustainability concerns of pension systems (European Commission 2015).

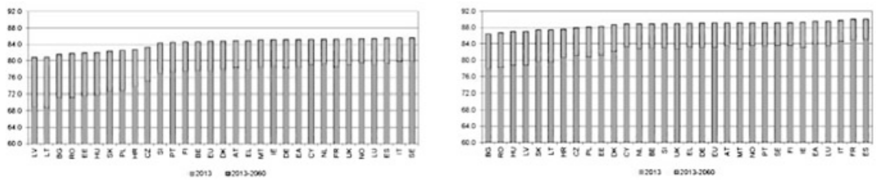


Fig. 123.2 Projection of life expectancy at birth in EUROPOP2013, men (in years), on the left and women (in years), on the right. Source: Commission services, Eurostat, EUROPOP 2013

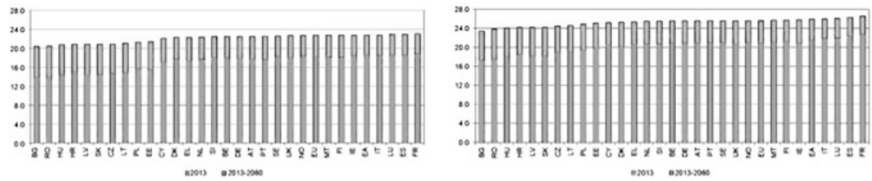


Fig. 123.3 Projection of life expectancy at 65 in EUROPOP2013, men (in years), on the left and women (in years), on the right. *Source* Commission services, Eurostat, EUROPOP 2013

The pension projections rely on unchanged pension legislation, and risks exist. If pensions are being perceived as being "too low" or the retirement age "too high", this could eventually result in changes in pension policies, leading to upward pressure on pension spending, and the projections could thus underestimate future government expenditure. For example, the public pension benefit ratio (i.e. average pensions in relation to average wages) is projected to fall in all Member States (except Luxembourg) in the period to 2060, on average by 9 pp. in the EU and in some countries (CY, PT and ES) by up to 20 pp.. Consequently, the benefit ratio at the end of the forecasting period is generally low. Even including private pensions, the benefit ratio in 2060 settle above 50% in only five countries (DK, EL, IT, LU, NL) while it falls below 30% in some other cases (BG, EE, HR, LV, PL, RO). Another upward risk is related to the projected decrease of the coverage ratio (i.e. the number of pensioners as percent of population aged 65 or more) in some countries, where a large increase of the legal retirement age is legislated. On the other hand, if countries enact additional expenditure-reducing pension reforms (currently being discussed in some countries), the projected expenditures could be overestimated (European Commission 2015) (Fig. 123.3).

123.2 Outline of European Senior Housing Systems

As shown in the previous paragraph, in EU the average lifespan is getting longer and the issue of an active ageing is growing. More elderly—often with a medium-high disposable income—are willing to invest in solutions that give them more independence for longer, thanks to support in carrying out their daily tasks without renouncing a good level of independence and "sociality". Therefore, the role of "senior housing" in real estate is growing—senior housing is the design of residential blocks with apartments designed specifically for this sector of people, with areas available for communal activities and a series of services included in the monthly rent. A trend that basically interests the entire western world, encouraged by demographic data. By 2025, it is predicted that over-65s will represent 20% of the population of the European Union. This slice of the real estate market, however, is still extremely fragmented, with huge differences depending on the country and type of solutions. There is a certain discrepancy between countries in north Europe, for example Scandinavia, which actually have a long tradition in this regards, and the Anglo-Saxon world—i.e., the United States and Great Britain. For the former, public investment is of central importance, while market activities—promoted by private institutions—are more developed in the latter area. Basically, in some areas, senior housing is often a synonym of social housing, created to help disadvantaged sectors, often set up by age but also as disposable income. Elsewhere, on the other hand, there are companies and large foundations which invest millions in the sector.

The type of structure also varies, ranging from simple apartments with communal areas—created for the independent—to the intermediary forms (known as home care in Great Britain, or nursing homes in Denmark) which are characterised by lots of smaller apartments in larger structures, all of which are associated with services such as rehabilitation or actual medical assistance for those needing it. According to the RCA (Real Capital Analytics), in Europe transactions regarding inhabited complexes and healthcare residences for senior citizens reached 644 million euro in the first trimester of this year (the latest data available). The lion's share is found in Great Britain, which alone can generate 1.9 billion exchanges in one year (data regarding March 2014 to March 2015), thanks to the presence of large American operators. For example, a few months ago, the USA Health Care Reit foundation bought a portfolio of 11 residences for senior housing in the south of England for 257 million dollars. In the United States, the sector is soaring. During the third trimester of 2015, a record was reached in building sites for the construction of senior housing since 2008, since the sector has been monitored by the NIC (National Investment Centre for Senior Housing and Care): 44,000 real estate properties in construction in the 99 main metropolitan areas, equal to 5.2% of the entire existing stock. Back to Europe, in Sweden, out of a population of 9 million, there are around 20 thousand units, mainly divided into service flats and rooms more similar to those of a residence—known as service houses. The majority is assigned by Councils through bids for tender. An exception to this is the large Tornhuset complex in Goteborg, where the inhabitants own their own properties as they are partners in the original housing association. The numbers are even higher in Denmark (5.6 million inhabitants) where, since 1988, the law has discouraged the construction of traditional nursing homes to favour residences for the elderly. Today these number is 40,000. The most common model of nursing home consists in structures of around 80 small apartments (none of which are larger than 60 m^2), equipped with services of rehabilitation and recreational activities. Two more pioneers in the sector, with similar models, are Holland and Catalonia in Spain with its vivienda dotacional (Fig. 123.4).

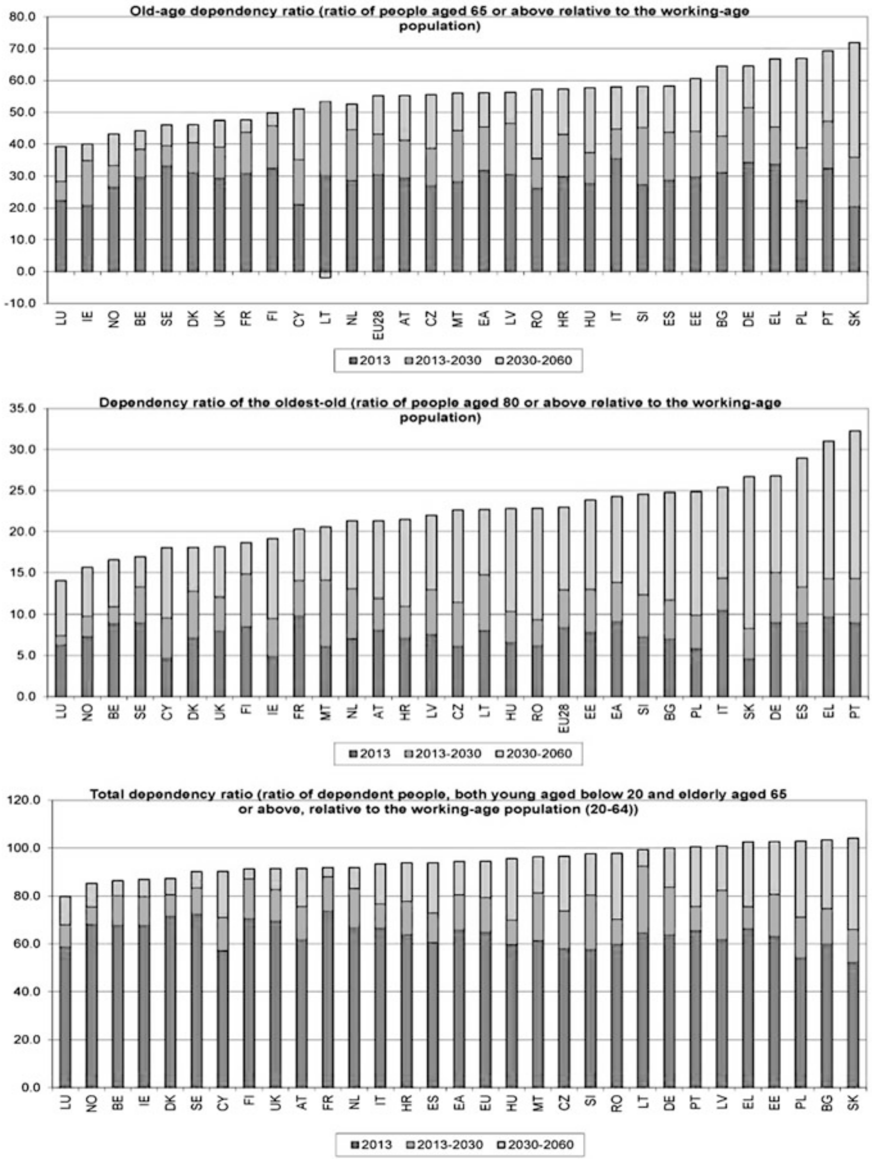


Fig. 123.4 Dependency ratios (in percentage). *Source* Commission services, Eurostat, EUROPOP 2013

123.3 The Italian Case: Social Enterprise Models for Inclusive Senior Housing Systems

And in Italy? Here there are no statistics—at the very best we have examples of "best practices". But ours is a promising model as in 99% of cases senior housing falls below the general umbrella of social housing, which is clearly regulated. And above all, it benefits from a mix of public and private funding, with the CDP in the frontline. A prime example is the Sustainable Village of Figini, at the gates of Milan, which has a number of promoters including the Fondo Immobiliare Lombardia, Cdp Investimenti Sgr, Investire Sgr, Fondazione Housing Sociale and Fondazione Cariplo. It regards the creation of 323 recently-finished apartments which are leased or given in the "rent to buy" project mainly to people with middle-low income. Twenty-three per cent of the dwellings—as stated by the awarding body—is reserved for individuals or couples over 65 years of age, or where there is at least one person of 75 years or older. In Italy, the number of over-65 year olds will jump from 13 million to 16 million by 2030. And many of them like the idea of sharing communal areas and services. According to research undertaken by the Censis per Future concept lab, 89% over over-65s believes their income will increase, one million would like to renovate their homes and 530 thousand do not exclude the possibility of investing in real estate. Therefore, even in Italy cohousing for the elderly is making progress—a business model based on social enterprise.

The totalitarian Welfare State model in which the State takes on the responsibility of the citizens' living conditions is no longer sustainable, both on the economic level as well as it increases the public debt, and also as it does not respect the dignity and needs of people under assistance (Bruni L., Zamagni S., L'economia civile, Pub. Il Mulino, 2015). The last ten years have seen a cultural transaction towards plural welfare in which public organisations, private individuals and the third sector work together in closing the gap of totalitarian welfare caused by the gradual reduction of funding directed a social purposes (healthcare, pensions, welfare, education, etc.). In this new economic setup, corporate welfare has taken shape, the third sector has become more productive and social enterprises, foundations and cooperatives are supplying Italy's economy with vast resources (Fig. 123.5).

One of the most recent projects launched in Milan by Abitare Leggero—a social enterprise of three partners: Cooperativa sociale Eureka, Gadola manutenzione e servizi, Laboratorio di Architettura Rosellini & Partners—comes under this particular scenario. The company has identified 12 apartments in two buildings in different districts of the city (a possible third—for a further 17 residences—is currently being negotiated), which have been renovated and equipped following ergonomic principles. The marketing phase has started and the first residents should

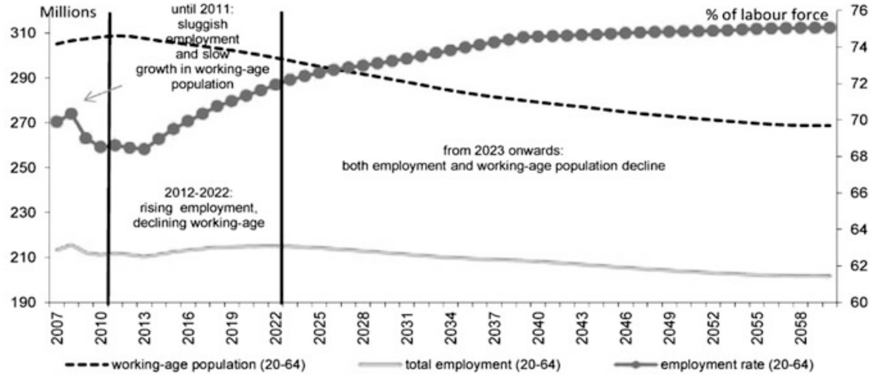


Fig. 123.5 Population and employment developments, EU (million). *Source* Commission services, EUROPOP 2013, EPC

be welcomed between January and February. The social enterprise does not directly buy the homes, but takes on all aspects of maintenance and management. The company signs the rental agreement, basically becoming the lessor and paying all rent in advance. This solution is of great benefit for the owners as well as for the tenants, especially for those who own entire small complexes. For owners, Abitare Leggero becomes a single middle-man and guarantees excellent use and maintenance of the buildings. The residents—mainly individuals or couples of over-65s—will pay a monthly fee which covers rent and a series of shared services, including weekly cleaning, three interventions of maintenance per year, weekly help for shopping, a courtesy visit every two weeks for any particular needs, monthly social visits and administrative management. And many others are available upon request. Regarding the lease, including all services provided, in the Milan-based complex in Via Fauchè, a standard apartment of 75 m^2 costs 1200 euro a month, of which 60–70% is for rent and the rest covers the additional services. Though rent is not cheap, the business model is competitive as the monthly fee gives a saving compared to what tenants would pay for market rent plus expenses for separate services.

The average monthly rent in that semi-central road is around 6–7 euro per m^2, rising however to at least 10–11 euro (therefore 750–800 euro for 75 m^2) for renovated properties in an excellent state. The Abitare Leggero model could also prove to be a flywheel for construction companies. In Milan alone there are dozens of complexes that have already been completed and are inhabited, with ground floor properties that are still empty as obliged for use for so-called compatible functions, such as retail, which are hard to lease. Social enterprise could be a solution for these areas, using them for communal social activities or services (Fig. 123.6).

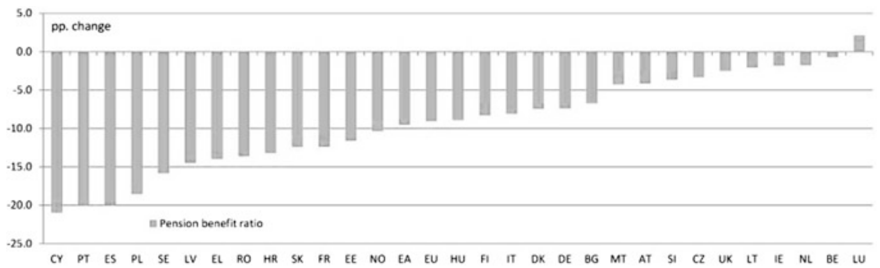


Fig. 123.6 Public pension benefit ratio, change 2013–2060, pp. change. *Source* Commission services, EPC

123.4 Social Responsibility Balance

If this were a possible solution to the market's demand, it is certain that in Italy we need specialist financial tools created especially to sustain the growth and distribution of social enterprise, on the basis of which there must be a holistic push from the world of cooperation. The "social responsibility balance" may be the right tool to evaluate impact. Moreover, we need to strengthen the principle of transparency on which the relationship between social enterprise and the bank is founded and build a network of relationships to give more weight to the enterprise's actions. From the entrepreneurial viewpoint, social enterprise must build an organisation model that favours trust-based relationships so that new financial resources can be found. Furthermore, we also need to keep up with the evolution of the Anglo-Saxon style of social economy and give value to and share innovative banking models based on so-called "ethical" financing as, for example, that of Banca Prossima, a bank from the Gruppo Intesa Sanpaolo dedicated to the third sector and which aims to fund projects of social solidarity for the communities in which they work.

On the other hand, scientific literature in the field of economy increasingly proves how important it is to move beyond the unscientific concept of market as an area "reserved" exclusively for profit-making businesses, in that social sustainability—meaning the ability to guarantee conditions of human wellbeing (security, health, education, democracy, participation, justice) that are equally distributed by class and gender—is in fact spurred by processes of civil welfare and circular support, through opportune economic models and financial tools that are yet to be created and experimented.

References

Bruni L, Zamagni S (2015) L'economia civile. Pub. Il Mulino

European Commission, Directorate-General for Economic and Financial Affairs (2015) The 2015 ageing report. Economic and budgetary projections for the 28 EU Member States (2013-2060)

Ferri G, Pacucci L (2015) Realizzare housing sociale. Promemoria per chi progetta, in the book series “Social housing”, Bruno Mondadori, Pearson Italia, Milano – Torino
Leung MY, Yu J, Yu S (2012) Investigating key components of the facilities management of residential care and attention homes. Facilities 30(13/14):611–629
Leung MY, Chan IYS, Olomolaiye P (2013) Relationships between facility management, risks and health of elderly in care and attention homes. Facilities 31(13/14):659–680
Leung MY, Yu J, Dongyu C, Yuan T (2014) A case study exploring FM components for elderly in care and attention homes using post occupancy evaluation. Facilities 32(11/12):685–708

Chapter 124
The Effect of Contract Control on Contractors' Cooperative Behavior: The Moderating Role of Owner Power

X.K. Jiang and S.J. Zhang

124.1 Introduction

The construction industry suffers a higher level of conflict compared with other industries owning to its higher asset specificity, uncertainty and complexity (Black et al. 2000). The contractors may take advantage of the information asymmetry because of the professional advantage to violate the contract and behave opportunism for their own benefits (Terje 2010). According to the transaction cost economics theory (TCE), contract, as a formal governance mechanism, could significantly restrain opportunism and promote exchange among partners (Williamson 1985). However, it has been argued that research findings about the roles of contracts may not be generalizable to emerging markets (Zhou and Poppo 2010), and due to the culture and the weak legal enforcement in China, the role of the contract is somewhat limited. This paper takes it as a starting point and aims to investigate whether a contract has a crucial impact on improving the exchanges among parties in the Chinese construction industry.

Considering the roles of contracts on the inter-organizational relationships, previous research has drawn different and controversial conclusions. On one hand, scholars believe that contract governance is the guarantee of cooperation. Scholars holding such a view are mostly based on the TCE, which indicates the idea that appropriate governance is needed to deal with the risk of uncertainty and asset specificity, while contract governance is such a kind of governance that can protect investment. Through the control of opportunism behavior and sanctions, contracts

X.K. Jiang
College of Management and Economic, Tianjin University, Tianjin, China
e-mail: jxk0311@126.com

S.J. Zhang (✉)
Department of Real Estate and Construction, Faculty of Architecture,
Hong Kong University, Pok Fu Lam, Hong Kong
e-mail: zhangsj@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_124

could enhance the cost of opportunism behavior (Dyer 1997), reduce the impact of opportunism and conflict on inter-organizational relationships (Mesquita and Brush 2008). Some scholars have pointed out that the contract provides the cooperation incentive in institutional framework (Luo 2002), which ensure that the parties to the transaction have consistent understanding of the roles (Reuer and Ariño 2002). Meanwhile, by encouraging initial cooperation, contracts create a positive attitude in the organization to foster the submissive behavior (Poppo and Zenger 2002).

On the other hand, there are other scholars who emphasized the inhibition of contract governance on inter-organizational cooperation. Contract with strictly controlled terms may reduce the good will of partners, bring about suspicion and inflexibility (Malhotra and Lumineau 2011), restrain positive emotions and behavior. Some scholars have suggested that a contract signals distrust and hostility to the partners, thus encouraging the opportunistic behavior outside of the formal contract (Wuyts and Geyskens 2005). Others believed that the contract does not restrain opportunism, when legal environment is weak (Lui and Ngo 2004). Meanwhile, contracts may restrain the formation of cooperative norms, leading to the confrontation of inter-organizational relationship, which is not conducive to inter-organizational cooperation.

The possible reasons why the above disagreements exist are as follows: (1) Previous studies generally viewed a contract as a one-dimension construct. This one-dimension construct fails to solve the dilemma. (2) Contractual governance has different effects on different aspects of cooperation, such as in-role and extra-role cooperation behavior. (3) The influence of contractual governance on the cooperation is conditioned by the situational factors (Cao and Lumineau 2015). The purpose of this study is to alleviate the disagreements in existing research, and examine the role of contracts on facilitating cooperation in the Chinese construction industry. Hence, based on TCE, this study will propose a two-dimensional cooperation model and try to examine the effect of contract control on contractors' cooperation behavior, including in-role behavior and extra-role behavior.

Furthermore, according to the TCE, a natural choice is to turn to vertical integration which addresses hierarchy to prevent opportunism. However, vertical integration by project owners may not be feasible in the construction projects. Instead, a firm can use a quasi-hierarchical structure which addresses power to influence the behavior and output of other parties (Zhou and Xu 2012). Power produced by such a quasi-hierarchical structure in an owner-contractor relationship refers to the extent to which key decisions are concentrated with one party in the exchange. For instance, owners could influence contractors' behavior by using power. Because centralized control does not equate to pure hierarchy, the contract is still needed. However, extant studies mostly focused on whether contractual governance and relational governance function as substitutes or complements (Ghoshal and Moran 1996). How contract and power jointly produce impacts on cooperation remains unclear. Thus, we further examine the joint effect of contract and owner power on cooperation to address the effectiveness of contract and power governance in the Chinese construction industry.

124.2 Theoretical Background

124.2.1 Contract Control

Contract research has begun to pay more attention to the functional approach which focuses on the specific functionality of contracts. The functional approach divides a contract into three dimension concerning the purpose of the contract: control, coordination, and adaptation (Schepker et al. 2014). In this paper, we mainly focus on the function of control which is the core function of a contract. The dominant theory informing contract control is TCE which viewed a contract as a control instrument that could mitigate ex ante and ex post risks in exchange relationships and safeguard investment from opportunistic behavior (Zhou and Poppo 2010). Yet almost all the risks in the exchange are produced by undesirable behaviors of the trading parties. Thus we argue that a contract exerts its control function mainly by controlling behavior. Through the use of formal and legally-binding agreement, a contract specializes penalties for opportunistic behavior among trading parties. It also gives a description of the roles and responsibilities of each party, and specifies the monitoring procedures to control deviant behavior. Contract control tries to create adherence to a desired outcome with a minimal amount of deviant behavior through authority mechanisms (Lumineau and Quélin 2012). Meanwhile, contract may also provide control over undesirable results. Thus, we define contract control as the degree of control over deviant behavior and undesirable results. Due to the inequality of owner and contractor positions, contract control has different levels of constraints on the contractors and the owner in a construction project. In this paper, we restrict our focus to the control over contractors.

124.2.2 Contractors' Cooperative Behavior

Earlier studies generally considered cooperation as a one-dimensional construct. But as research continues, scholars began to realize that one-dimensional construct of cooperation cannot provide a complete picture of theory and practice (Anvuur and Kumaraswamy 2011). Smith argued that formal and informal partnership exists in inter-organization transactions, formal cooperation is subject to formal structure, while informal cooperation is conditioned by trust, dependence and other social factors (Smith et al. 1995). Kashyap and Sivadas (2012) verified the applicability of in-role behavior and extra-role behavior in the study of inter-organization relationship (Kashyap and Sivadas 2012). Anvuur and Kumaraswamy (2012) tested the validity of multidimensional model of cooperation in the construction industry.

Therefore, in this paper, based on the source of behavior—formal and informal relationship, we divide contractors' cooperative behavior into two dimensions: in-role behavior and extra-role behavior. In-role behavior refers to the following of formal rules and adhering to specifications of contracts, while extra-role behavior is voluntarily oriented toward promoting the goals of the projects which go beyond formal role prescriptions.

124.2.3 Owner Power

In the Chinese context, interdependence has no significantly impact on the perception of power, instead it is power that leads to interdependence (Zhuang and Zhou 2004). The conception of power does not stem from interdependence, instead owners have power because they possesses valuable resources to contractors or even other organizations. Meanwhile, the quasi-hierarchy mechanism in the hybrid organization in a project empowers the project owner. We define owner power as the ability to influence the decisions of contractors in a project. French et al. (1959) classified power into five dimensions: expert, coercive, legitimate, reward and referent power (French et al. 1959). In the Chinese construction industry, legitimate, reward and referent power are less important and can hardly be perceived, while expert and coercive power have been specifically developed to address the power between project partners (Lu and Hao 2013). Therefore, we focus on expert and coercive power in this paper. It should be pointed out that power is a kind of potential or perceived state, which indicates that owners have a high level of power does not mean that they will often use these power to affect the contractors. Instead, the contractors will show obedience through the perception of power.

124.3 Hypothesis Development

The reason why cheating and breach of a contract often occur is because contractual parties find that through sacrificing the interests of other partners, the gain of its own would be maximized. Through specifying responsibilities of each party and sanctions on the commission of violating behaviors, a contract increases the cost of hiding self-interest activities and limit the incentives for opportunism (Parkhe 1993). With a higher level of contract control, the level of supervision and inspection of the contractor also increases, breach of a contract is more detectable and more likely to be monitored by the owner. Hence contracts reduce the contractors' abilities in violation of the provisions of the contracts. Meanwhile, contracts signal cooperative intentions and increase cooperation expectation over the contractors, thus promote cooperation with contractors. Thus we propose the following hypothesis:

H_1: Contract has a positive impact on contractor's in-behavior.

Contractors' extra-role behavior is not subject to the constraints of the contract supervision depending on the contractors' intrinsic motivation. A strong focus on contract control may bring about external pressure which will destroy contractors' intrinsic motivation and reduce contractors' willingness to cooperate (Frey and Jegen 2001). Without contract, control on contractors will bring stress and tension, reduce creativity and cognitive flexibility (Deci and Ryan 1987), making contractors focus more on how to avoid being punished rather than taking the initiative behavior outside the specification of contracts which can promote the goals of project. On other hand, contracts may enable contractors to perceive that they are not trustworthy, restrain behaviors related to trust, increase the implicit aspect of opportunism and then further restrain contractors' extra-role behavior. Thus, we propose the following hypothesis:

H_2: Contract control has a negative impact on contractors' extra-role behavior.

Owners with high levels of expert power have the advantage of making good arrangement of payment to contractors and respond to changes efficiently. Thus with expert power, an owner is able to provide reasonable and effective support to the contractors which nurtures trust and good will of the contractors (Lu and Hao 2013), making the contractors believe that requirements from the owner are worthy to obey. On the other hand, expert power may enable the owner to monitor the work of contractors at a low cost (Lu and Hao 2013), limit the intention of opportunism. Expert power also improves the communication between the owners and contractors and strengthens the positive affective emotions between the two parties. Thus, we propose the following hypothesis:

H_3: When owner expert power is higher, contract control contributes more to contractors' in-role behavior.

Coercive power guarantees the implementation of contracts. The main aim of coercive power is to change the target's attitude or behavior by threatening the contractors with benefit loss (Lu and Hao 2013). If the contractor acts against the contract or contrary to the wishes of the owner, it is likely to be punished by the owner. Such punishment includes slow payment or other additional requirements, unfair distribution of risk threat of termination and so on, which will lower the contractors' benefit.

While contractors' extra-role behaviors are often hard to discover, higher coercive power may restrain the positive intentions of contracts. Coercive power has also been regarded as an obstacle to building affect-based trust, because the use of coercive power may result in conflict or defensive behavior (Gaski 1984). Thus, we propose the following hypotheses:

H_4: When owner coercive power is higher, contract control contributes more to contractors' in-role behavior.

H_5: A higher level of owner coercive power will strengthen the negative impact of contract control on contractors' extra-role behavior.

124.4 Research Methodology

124.4.1 Data Collection and Questionnaire Design

Data for this paper are obtained through a survey from project owners and contractors in the construction industry in China. Totally 400 questionnaires were sent out to respondents by email, and each construction project gets less than 3 questionnaires. We have finally received 190 questionnaires. The response rate is 47%. After removing 9 null responses, we have 181 valid questionnaires. Most of the respondents have been working in the construction industry for more than ten years and in various management positions in a project. The questionnaire was originally developed in English and then translated into Chinese by a construction project management professor in China. Using a Likert scale ranging between "1"-"strongly disagree" and "7"-"strongly agree, the respondents were asked to answer the questionnaire items based on a project they have participated in. To make sure that the questionnaire is coincident with the reality, we interviewed 3 experts to confirm measures of variables and further revised several items which are not suitable. Besides, we included prior experience, intentions to cooperate in the future, contract coordination and contract adaptation as control variables.

124.4.2 Measurement

We selected existing instruments in previous literature to measure each construct in this paper. We have modified some items to make them relevant to the business practices in the Chinese construction field based on the suggestions from the interviews and experts in construction project management. The measure for contract control is based on the items of Parkhe (1993). Owner expert power and coercive power are measured through the scales developed by Lu and Hao (2013). The items developed by Kashyap and Sivadas (2012) are used to measure in-role and extra-role behaviors.

124.4.3 Construct Validity and Reliability

The reliability of the constructs in this paper is reflected by Cronbach's α value. In this study, the Cronbach's α values of contract control, coercive power, expert power, in-role and extra-role behaviors are 0.852, 0.902, 0.856, 0.887 and 0.777, respectively, which are all greater than 0.7. This implies high internal consistency of each construct.

We use a confirmatory factor analysis (CFA) to check overall fit of the model. The model fit indices are $\chi^2/df = 2.520 < 3$, RMSEA = $0.093 < 0.1$, NFI = $0.848 > 0.8$,

Table 124.1 Correlation matrix

Variables	1	2	3	4	5
1. Contract control	**0.77**				
2. Expert power	0.389^{b}	**0.95**			
3. Coercive power	0.035^{a}	−0.04	**0.925**		
4. In-role behavior	0.527^{c}	0.194^{b}	0.050	**0.943**	
5. Extra-role behavior	0.258^{c}	0.135^{b}	0.289^{b}	0.501^{b}	**0.888**

Note $^{a}p < 0.05$ $^{b}p < 0.01$ $^{c}p < 0.001$

GFI = 0.0.844 > 0.8, CFI = 0.901 > 0.8, TLI = 0.879 > 0.8, indicating that the model is acceptable. As for the convergent validity of the constructs, the AVE values are greater than 0.5 and the constructs' CR values are also greater than 0.6, indicating a good convergent validity. Discriminant validity is checked through the comparison of the square root of an AVE with the absolute value of the correlative coefficients of the other latent variables. It can be seen from Table 124.1 that the minimum in the square root of AVE is bigger than the maximum in absolute values of correlative coefficients. Hence, the discriminant validity is acceptable.

124.5 Results

As shown in Table 124.2, contract control has a significant and positive impact on contractors' in-role behavior ($\beta = 0.327$, sig = 0.000), however, Model 5 shows that contract control doesn't have a significant impact on contractors' extra-role behavior ($\beta = 0.102$, sig = 0.273). Hence, hypothesis H_1 is supported while hypothesis H_2 is not supported. The moderating results are shown in Model 2 and Model 3. The interaction between contract control and owner expert power and the interaction between contract control and owner coercive power are significantly and positively associated with contractors' in-role behavior ($\beta = 1.524$, sig = 0.001; $\beta = 0.789$, sig = 0.029), Then high value and low value of owner expert and owner coercive power are selected respectively, the results show that the impact of contract control on contractors' in-role behavior is stronger when the value is high. It demonstrates that higher levels of owner expert and owner coercive power will strengthen the positive effect of contract control on contractors' in-role behavior. Thus, H_3 and H_4 are supported. Meanwhile, the interaction between contract control and owner coercive power has no significant impact on contractors' extra-role behavior. Thus, H_5 is not supported.

Table 124.2 Results of empirical model

	In-role behavior			Extra-role behavior	
	1	2	3	4	5
Control variables					
Prior experience	0.071	0.081	0.078	−0.019	−0.031 0.048
Intentions to cooperate	−0.011 0.139[b]	−0.057	−0.022	−0.018	−0.013
Contract coordination	0.177 −0.100[a]	0.196	0.196	0.142	−0.035
Contract adaptation	0.150	0.133	0.133	0.184	0.292
Independent variable					
Contract control (CC)	0.327[b]	−0.435[a]	−0.006		0.102
Moderating variables					
Expert power (EP)		−1.104[b]			
Coercive power (CP)			−0.648[a]		
Interactions					
CC*EP		1.524[b]			
CC*CP			0.789[a]		

Note [a]$p < 0.05$ [b]$p < 0.01$

124.6 Discussion

Although contract is regarded as a critical factor in promoting cooperation among project partners, how contract affect cooperation remains controversy. In this paper, we attempt to provide insights into the mechanisms of contract and power in the Chinese construction industry by investigating the relationships between contract control and contractors' cooperation (in-role and extra-role behavior), and how these effects are moderated by owners' expert and coercive power. Previous researchers proposed two competing views for the relationship between contract and cooperation. Earlier in this paper, we argued that the reason why controversy exists is because the control dimension of contract has different impacts on different aspects of cooperation and is closely related to the context. Our results show that a contract has a significant impact on contractors' in-role behavior while little impact on contractors' extra-role behavior, which indicates that contract control could obviously improve cooperation. Meanwhile, increasingly reliance on contractual control may not destroy contractors' willingness to cooperate. The reason why no negative impact is found may be that the complexity of construction projects and pursuit of economic interest make the contractors take owners' control over themselves for granted.

Some studies argued that the effect of contract is limited in China because of the culture and the weak legal institutions. While contrary to this idea, our results confirm the effectiveness of contract in governing construction projects in China. In practice, if owners seek to improve cooperation with the contractors, contract control can be emphatically used to achieve this goal. Our results also support TCE theory, proving its relevance in the field of construction project management in China.

Furthermore, the present paper attempts to address the role of owner power in moderating the relationship between contract and contractors' cooperative behavior. Empirical results show that owner expert and coercive power strengthen the positive relationship between contract control and contractors' in-role behavior. This illustrates that owner power plays a complementary role for contract in the management of inter-organizational relationships in the construction industry. Thus owners could use power to promote cooperation with contractors. Some studies argued that a high level of power may led to confronting behaviors, our results are not in line with these arguments.

124.7 Conclusion

Using data from construction projects in China, this paper examines the effect of contract control on contractors' in-role and extra-role behavior, and the moderating role of owner power in fostering contractor cooperation based on the transaction cost economics theory. The research findings indicate that contract control has a significantly positive impact on contractors' in-role behavior, while little impact on contractors' extra-role behavior. When project owners' expert and coercive power are higher, contract control contributes more to the contractors' in-role behavior. In short, this paper verifies the effectiveness of contract control and owner power in promoting contractors' cooperation in the Chinese construction industry. If an owner seeks to improve contractors' cooperation and project performance, contract and power governance can be used to achieve this goal.

Under a Chinese culture, it is interesting to notice that contract control on contractors will not lead to contractors' hostility or feeling of distrusted. Because of the complexity and unique of construction projects, contractors may still behave cooperatively in consideration of economic benefits. While contract control may not enhance cooperative behavior outside the contract, owners should take other measures to promote positive cooperation. At last, this paper helps clarify the confusion in existing research to some extent, enrich extant research on contract and provide several insights for construction project management. The findings may lead managers, specially in the project owner organzations, to make better choices when drafting contracts and exercising power.

The limitations of this paper are as follows: (1) The questionnaires were distributed to only one party in a project, which doesn't cover the view of other parties in the project. Using sources from both parties may enhance the robustness and reliability of the results. (2) This paper does not take mediating factors into account or investigate the impact of cooperative behavior on project performance. Further study could examine whether trust and other factors play mediating roles in predicting the effect of contracts on cooperative behavior and the impact of cooperative behavior on project performance.

References

Anvuur AM, Kumaraswamy MM (2011) Measurement and antecedents of cooperation in construction. J Constr Eng Manag

Anvuur AM, Kumaraswamy MM (2012) Measurement and antecedents of cooperation in construction. J Constr Eng Manag 138(7):797–810

Black C, Akintoye A, Fitzgerald E (2000) An analysis of success factors and benefits of partnering in construction. Int J Project Manage 18(6):423–434

Cao Z, Lumineau F (2015) Revisiting the interplay between contractual and relational governance: a qualitative and meta-analytic investigation. J Oper Manag 33:15–42

Deci EL, Ryan RM (1987) The support of autonomy and the control of behavior. J Pers Soc Psychol 53(6):1024

Dyer JH (1997) Effective interfirm collaboration: how firms minimize transaction costs and maximize transaction value. Strateg Manag J 18(7):535–556

French JRP, Raven B, Cartwright D (1959) The bases of social power. Classics Organ Theor 311–320

Frey BS, Jegen R (2001) Motivational interactions: Effects on behaviour. Ann d'Economie et de Stat 131–153

Gaski JF (1984) The theory of power and conflict in channels of distribution. J Mark 9–29

Ghoshal S, Moran P (1996) Bad for practice: a critique of the transaction cost theory. Acad Manag Rev 21(1):13–47

Kashyap V, Sivadas E (2012) An exploratory examination of shared values in channel relationships. J Bus Res 65(5):586–593

Lu S, Hao G (2013) The influence of owner power in fostering contractor cooperation: Evidence from China. Int J Project Manage 31(4):522–531

Lui SS, Ngo H-Y (2004) The role of trust and contractual safeguards on cooperation in non-equity alliances. J Manag 30(4):471–485

Lumineau F, Quélin BV (2012) An empirical investigation of interorganizational opportunism and contracting mechanisms. Strateg Organ 10(1):55–84

Luo Y (2002) Contract, cooperation, and performance in international joint ventures. Strateg Manag J 23(10):903–919

Malhotra D, Lumineau F (2011) Trust and collaboration in the aftermath of conflict: The effects of contract structure. Acad Manag J 54(5):981–998

Mesquita LF, Brush T (2008) Untangling safeguard and production coordination effects in long-term buyer supplier relationships. Acad Manag J 51:785–807

Parkhe A (1993) Strategic alliance structuring: a game theoretic and transaction cost examination of interfirm cooperation. Acad Manag J 36(4):794–829

Poppo L, Zenger T (2002) Do formal contracts and relational governance function as substitutes or complements? Strateg Manag J 23(8):707–725

Reuer JJ, Ariño A (2002) Contractual renegotiations in strategic alliances. J Manag 28(1):47–68

Schepker DJ, Oh W-Y, Martynov A et al (2014) The many futures of contracts moving beyond structure and safeguarding to coordination and adaptation. J Manag 40(1):193–225

Smith KG, Carroll SJ, Ashford SJ (1995) Intra-and interorganizational cooperation: toward a research agenda. Acad Manag J 38(1):7–23

Terje Karlsen J (2010) Project owner involvement for information and knowledge sharing in uncertainty management. Int J Managing Projects Bus 3(4):642–660

Williamson OE (1985) The economic institutions of capitalism: firms, markets, relational contracting. Free Press

Wuyts S, Geyskens I (2005) The formation of buyer—supplier relationships: detailed contract drafting and close partner selection. J Mark 69(4):103–117

Zhou KZ, Poppo L (2010) Exchange hazards, relational reliability, and contracts in China: The contingent role of legal enforceability. J Int Bus Stud 41(5):861–881
Zhou KZ, Xu D (2012) How foreign firms curtail local supplier opportunism in China: detailed contracts, centralized control, and relational governance. J Int Bus Stud 43(7):677–692
Zhuang G, Zhou N (2004) The relationship between power and dependence in marketing channels: a Chinese perspective. Eur J Mark 38(5/6):675–693

Chapter 125
The Evaluation of Urban Renewal Policies in Shenzhen, China (2009–2016): An Analysis Based on Policy Instruments

Z.Y. Yi, A. Shrestha, L.Z. Wei and G.W. Liu

125.1 Introduction

Urban renewal plays a significant role in the sustainable development of urban areas in China. This is mainly because of the increasing growth in population along with the limited construction land in core areas (Zhang et al. 2014), Shenzhen was the first city that promulgated urban renewal legislations. These legislations were promulgated in 2009 to deal with the urban socioeconomic development problems caused by the lack of construction land. Compared to the data from 2009, the investment in urban renewal have increased six folds to 400 billion CNY, accounting for 15.6% of the total investment in fixed assets.[1] Although, urban renewal is still at its early stages of development in China, the policy instruments in the case of Shenzhen are believed to be quite robust. These policies can be valuable because they can be replicated and employed for other major cities in China. Lessons can also be learned from Shenzhen's experience in implementing these policies by identifying the best practices as well as areas that can be further improved.

In recent years, many studies have focused on the different aspects of urban renewal policy in Shenzhen (Shan 2013; Policy Research Office of Shenzhen Government 2008). Additionally, there are some studies that have focused on examining ways to improve the policy regulations (Deng 2014; Qin and Miao 2015; Song 2015; Mariana et al. 2014). Besides, the aforementioned studies also have some limitations even though they have provided some valuable insights in the area of urban renewal policy research. One of such limitation is that these studies focus

[1]Urban renewal planning innovation in Shenzhen, http://www.upnews.cn/archives/17895.

Z.Y. Yi (✉) · A. Shrestha · L.Z. Wei · G.W. Liu
Faculty of Construction Management and Real Estate, Chongqing University, Chongqing, China
e-mail: yizhiyong@cqu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_125

only on specific urban renewal instruments, such as regulations, planning, and governance while other instruments like incentives, pricing systems and post evaluation have not been included in their analysis. Secondly, these studies rely mainly on qualitative analysis and are rather subjective. Quantitative analysis can provide a distinctive approach in analyzing the policies because it can present the findings in a more robust manner through scientifically verifiable numbers.

Accordingly, the primary objective or this paper was to provide a comprehensive analysis to the Shenzhen's urban renewal policies inclusive of all its policy instruments and activities and processes. To attain the research objective, a framework was developed and applied in the analysis. The framework focused on the roles played by the government and various bodies along with the processes within the city's urban renewal system. A quantitative content analysis was employed as the analysis tool. This study contributes to the existing literature in two ways. Firstly, it provides insight into changing pattern of urban renewal policies, revealing not only the inherent rule behind the policy-making but also the existing problems with urban renewal policy in Shenzhen. Secondly, this paper build a valid and reliable framework for urban renewal policies is established to analysis that comprises of a three dimensions. Urban renewal will play an important role in the urban development of the near future. Shenzhen's urban renewal policy process can be used as a reference for other cities in developing similar policies, and avoid costly mistakes and problems. Therefore, this study also provides strong practical implications.

125.2 Analytical Framework of Urban Renewal Policies

This study investigated the urban renewal policies in Shenzhen by developing and applying a three dimensional theoretical framework (see Fig. 125.1). The framework includes: (i) basic policy instruments; (ii) urban renewal process; and (iii) urban renewal domain. The framework was developed existing studies that have applied it successfully in other contexts. For example, the framework for Basic Policy Instruments (X) was developed based on Rothwell and Zegveld (1985) who defined the classification of policy instruments and Liao who successfully analyzed the policies regarding the development of wind energy in China (Hayes and Krippendorff 2007). Urban renewal activity domain (Y) and process (Z) were developed based on the detailed rules for Implementing the Urban Renewal Measures of Shenzhen Municipality.

125.2.1 X-Dimension: Basic Policy Instruments

There are three main categories policy identified to be X-dimension of the analytical framework in this study including Environment-type, Supply-type and Demand-type policies. The interaction among three types polices is presented in Fig. 125.2.

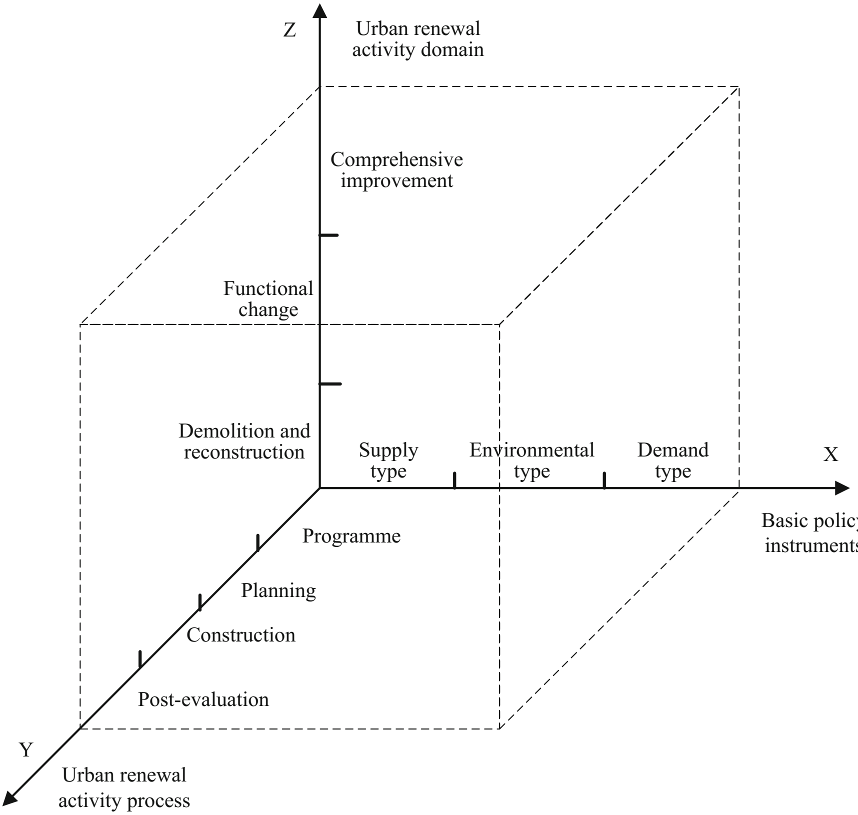


Fig. 125.1 The analytical framework of urban renewal polices

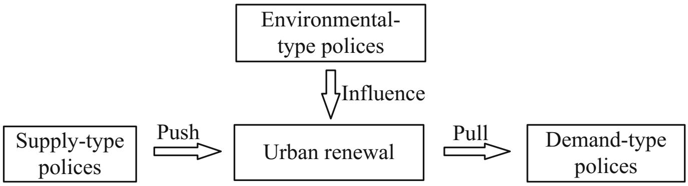


Fig. 125.2 The interaction among three types polices

The Environmental-types policies emphasize on government regulations; for example, financial support and regulation are used as control instruments to help provide a beneficial environment and space, subsequently contributing in the launch of multi-type activities such as planning, design and construction. Furthermore, environmental-type policy could be subdivided into goal planning, financial support, regulation control, strategic measures and so on.

The Supply-types policies deal with promoting and improving urban renewal system via strong incentives provided by the government through policies related to the provision of skilled labor, information management systems, financial support, and public services infrastructure construction.

The Demand-types policies deal with removing barriers to market entry and reduce market risks through procurement and trade control. It provides some essential measures to reduce market uncertainty through the implementation of several instruments like government procurement, trade control and market cultivation.

125.2.2 Y-Dimension: Urban Renewal Activity Process

Urban renewal has its own specific characteristics and implicit trends, which makes the processes and the related activities distinctive to other types of projects. Thus, the process is an important aspect that needs to be analyzed and should be considered during policymaking process. The process of urban renewal consists of four main stages in its life cycle perspective including programming, planning, construction and post evaluation. These stages and activities associated with them are important to examine independently, therefore they have been included in the analytical framework of urban renewal policies in this study.

125.2.3 Z-Dimension: Urban Renewal Activity Domain

Urban renewal polices aim to regulate and guide multi-type activities. So the main activities that are undertaken during urban renewal process is included in the Z dimension of the framework. The Z-dimension thus focuses on the three main aspects, i.e., demolition and reconstruction, functional change and comprehensive improvement. By examining these aspects, it can be illustrated what the main focus of the policies are in regards to the urban renewal activities. Moreover, the activity dimension can be explored to determine the implementation mechanism of urban renewal policy instruments and their strength of impacts.

125.3 Data Collection and Analysis

Data was collected on four urban renewal policies from Shenzhen. While there have been around 52 polices that has been published by Shenzhen Municipal Government in the time period between 2009 and 2016, it is not possible to analyze all the existing documents for practical reasons. Moreover, the total number of documents also includes the ones that have already been updated. So we focused on the key policy documents that are used by practitioners. A pilot study was done prior to data collection in order to identify the policy documents that are important. Three government officials in Shenzhen were interviewed and it was identified that there are four published polices that that provides comprehensive list of policies for the urban renewal systems. The four selected urban renewal policies were: (i) Urban Renewal Measures of Shenzhen Municipality (Decree No. 211, 2009); (ii) Detailed rules for Implementing the Urban Renewal Measures of Shenzhen Municipality (No. 1, 2012); (iii) Suggestion of Shenzhen Municipality on further advancing of Urban renewal work (No. 193, 2010); and (iv) Provisional measures for strengthening and improving Urban Renewal implementation (No. 8, 2014).

125.4 Results and Discussion

125.4.1 X Dimension Analysis of Urban Renewal Policies

As Fig. 125.3 shows, The findings from the analysis illustrates that, the highest number of Urban renewal policy belonged to Environment type policy with 79.4%, of the total number falling under this category. It was followed by supply-type policy with 13.7%, while the Demand-type policy had the smallest proportion accounting to 6.9%. In regards to the subdivision instruments of environment-type policy, regulation control had the highest proportion with 57.7% while Goal planning, Financial support and Strategic measure accounted to 12.6, 6.2 and 2.9% respectively. The percentage of the four subdivision instruments under supply-type policy showed infrastructure construction, technology information support, capital investment and personnel training to be 6.9, 4.0, 1.7, and 1.1% respectively. Finally, the percentage of three instruments under demand-type policy including market-oriented mechanism, trade control and government procurement were 4.0, 2.3 and 0.6% respectively.

125.4.1.1 Over-Use of the Environment-Type Policy Instruments

Looking at to the analysis in Sect. 125.4.2, the factor shown to have a highest proportion within policy instruments was regulation control. While the percentage of goal planning was significantly lower than regulation control, it had the second highest percentage and was higher than the other sub-instruments. What this means is government put too much focus on regulations and planning to promote urban renewal projects. While it has been highlighted that the government is pushing hard to promote urban renewal programs, they are generally implemented as a short-term strategy and undertaken amidst limited timeframes, these programs are difficult to implement due to the lack of foresight as well as operational ability of the government, particularly during the policy design stage (Luo et al. 2013). The over-use

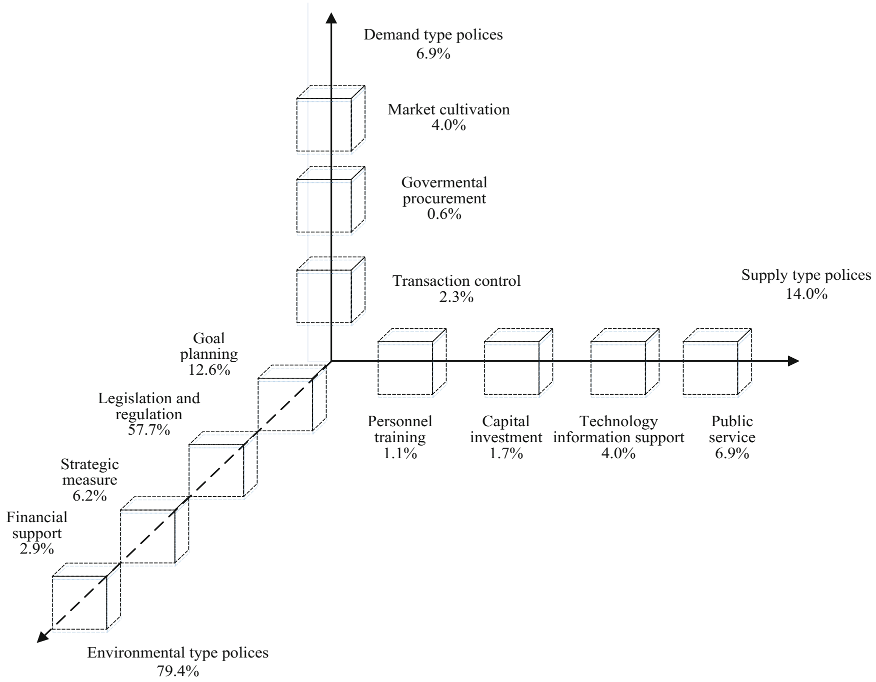


Fig. 125.3 Percentage of basic policy instruments application

of policy instruments could be a result of continued amendment of follow-up polices. Similarly, the over-use of goal planning instrument might result from the government's "optimism bias" at the early stages of urban renewal activity, where governments misjudge the complexities and risks. Partly many urban renewal goals fail because of high requirements for renewal project and complex land price system stated in polices.

125.4.1.2 Deficiency of Supply-Type and Demand-Type Policy Instruments

Compared with environment-type policy instruments, supply-type and demand-type policy instruments seem to be more flexible and direct, which might eliminate unreasonable market-oriented mechanism problems to a certain extent. In addition, these two policy types could effectively promote urban renewal development and balance the profit between different stakeholders. Nevertheless, the percentages of these two types instruments were rather low accumulating to only 20% of the total, which indicates that there is a lack of balance in the overall policy instruments. This may be because urban renewal development has not been the top priority for government spending. Moreover, governments want to attract private financing from real estate companies through land leverage.

125.4.1.3 Use of Inefficient Policy Instruments

An overview of urban renewal policy shows that over-use of Regulation control and Goal planning policy instruments while there is a lack of financial support. Although Shenzhen Municipality has adopted market-oriented land transfer agreement as a financial support instrument to improve urban renewal development, there was a lack of specific policy texts such as tax preference and innovative financing measures. Furthermore, in regards to supply type policies, Public service and Financial support policy instruments seem to be implemented far more often than personnel training and technology information support. It was seen that professional labors significantly impacts the success of projects under market specialization tendency, which further suggests that there is an urgent need for more relevant professional organizations. Since plenty of problems such as complex property rights and divergence of opinions between residents may arise, particularly in reconstruction old residential areas, it is imperative to focus on technology information support systems for project implementation level rather than municipal level.

125.4.2 Y Dimension Analysis of Urban Renewal Policies

125.4.2.1 Y Dimension Analysis

Construction stage had the highest percentage of the total policy counts with 54.2%, which was much higher than the other three stages including Programing (21.8%), Planning (23.2%) and Post-evaluation (0.7%). The findings indicate that the policy focuses mainly on construction and some focus is placed on the earlier stages of the project lifecycle. However the post evaluation phase is rather neglected.

125.4.2.2 Cross Analysis of XY Dimensions

When we cross analyzed the X and Y dimensions (see Fig. 125.4), it was seen that the highest total frequency under was for Construction policy with 45 counts, while the frequency for Programing and Planning were 19 and 22 counts respectively. This suggests that the policies mostly focus on the programming, planning and construction, while there is no policy instrument in regards to post evaluation. The implication is that government needs to pay more attention to the lifecycle of urban renewal projects, particularly in developing policies for post evaluation.

Y	Supply-Type				Environmental-Type				Demand-Type		
	Public service	Technology information support	Capital investment	Personnel training	Financial support	Regulation control	Strategic measure	Goal planning	Government procurement	Trade control	Market cultivation
Programming (21.1%)	1	0	0	0	1	19	1	8	0	0	0
Planning (23.2%)	3	1	0	1	2	22	1	1	0	2	0
Construction (55.0%)	5	3	3	0	7	45	2	3	1	2	7
Post evaluation (0.7%)	0	0	0	0	0	1	0	0	0	0	0

X

Fig. 125.4 Cross analysis of XY dimensions of urban renewal activity

125.4.3 Z Dimension Analysis of Urban Renewal Policies

125.4.3.1 Z Dimension Analysis

The three major activity domains of the basic policy tools, i.e., demolition and reconstruction, function change, comprehensive improvement, accounted to 46.7, 24.8 and 28.4% respectively. Considering the high demand for land, government uses demolition and reconstruction as the primary approach while the other two policy instruments are secondary approaches. Although the policy tools related to the demolition and reconstruction activities are relatively complete, taking into account the future of urban renewal in Shenzhen, there are high possibilities that the ratio the three activities may change in regards to their role and importance.

125.4.3.2 Cross Analysis of XZ Dimensions

As shown in Fig. 125.5, Regulation control accounted to the maximum frequency among demolition and reconstruction, functional change and comprehensive improvement, which are 48, 51 and 85 respectively. Second important policy instrument was goal planning with numbers in different domains are 14, 12 and 18. However, less usage of government procurement, trade control and market

Z	Supply-Type				Environmental-Type				Demand-Type		
	Public service	Technology information support	Capital investment	Personnel training	Financial support	Regulation control	Strategic measure	Goal planning	Government procurement	Trade control	Market cultivation
Comprehensive improvement (27.3%)	4	6	2	2	6	48	2	14	0	2	1
Function changing (27.7%)	4	7	1	2	5	51	2	12	0	4	0
Demolition and reconstruction (45.0%)	10	8	1	2	5	85	5	18	1	0	6

X

Fig. 125.5 Cross analysis of XZ dimensions of urban renewal activity cultivation might result in limited support and low performance from policy instruments, which might demand more impetus in function changing and comprehensive improvement types of urban renewal projects.

125.5 Conclusion and Recommendations

Based on the findings, we put forth some recommendations to optimize urban renewal polices for the development of urban renewal in Shenzhen:

(i) An important measures is to reduce the frequency and stringency of environmental types of polices, the government should enhance to unified management for urban renewal polices and planning have been announced, and the specific useful policy instruments should be choose carefully to improve the effectiveness of urban renewal polices, thus it can avoid the over-use of environmental types instruments. Meanwhile, Admittance threshold, land pricing system, approval process are always changing again and again during the urban renewal process, so the government should investigate the micro situation of urban renewal and evaluate the feasibility of implementation.

(ii) Another measure is to increase the number (as well as the stringency) of demand and supply types of policies. Compared to environmental types polices, supply types and demand types policies are more flexible to improvement, and also, the market-oriented mechanism could be revised substantially. As for supply-type policies, the government may provide sufficient incentives through technological information support by building dynamic database and information platforms for public participation in urban renewal projects. In addition, a three-level integrated decision support system consisting of macro-corporatism programs, meso-corporatism planning and micro-corporatism project can be developed. The government should also focus on personnel training the will strengthen the capabilities of urban renewal professionals to develop skills specific to the urban renewal projects. In relation to supply types urban renewal polices, the general urban renewal not only includes the real estate and industrial park, but also covers renewal of municipal infrastructure and transportation facilities. Thus the government should cultivate more market participation in general urban renewal projects. Furthermore, the government should emphasize on the procurement systems that allows the goals of urban renewal projects to be in line with the goals for Shenzhen's urban development. These procurement systems can guarantee the land-use for industrial innovation and public housing, in order to maintain the competitiveness of Shenzhen.

References

Deng ZW (2014) Urban renewal policy research compared between Taiwan and Shenzhen. J Bus Times (03):139–141

Hayes AF, Krippendorff K (2007) Answering the call for a standard reliability measure for coding data. Commun Methods Measures 1(1):77–89

Luo Y, Du F, Xu LX (2013) The transformation and innovation of urban planning based on the planning of urban development unit in Shenzhen. J Urban Dev Stud 08:101–107

Mariana MM, Elaine M, Joao da RLJ (2014) Analysis of project management process groups in urban renewal in the city of São Paulo. J Urban Regeneration Renewal 4(8):401–412

Policy Research Office of Shenzhen Government (2008) Important problems of urban renewal in Shenzhen. J Pract Theor SEZS (10):38–42

Qin and Miao (2015) Evolutional development of public participation in urban renewal: a review of yantian case in shenzhen. J Urban Dev Stud 22(3):58–62

Rothwell R, Zegveld W (1985) Reindustrialization and technology. Logman Group Limited, New York, pp 83–104

Shan H (2013) Urban renewal and planning reform: concept of development control in the administrative measures on urban renewal of Shenzhen. J City Plan Rev 1(37):79–84

Song (2015) The problems investigation of urban renewal in Shenzhen. J Spec Econ (8):24–27

Zhang X et al (2014) Inner-city urban redevelopment in China metropolises and the emergence of gentrification: case of Yuexiu, Guangzhou. J Urban Plan Dev (4):1–8

Chapter 126
The Improvement of Safety Climate of Migrant Workers Based on Social Mining Technologies

Sheng Xu

126.1 Introduction

Existing construction safety researches have recognised peer influence and worker interactions as factors and moderators in construction safety research. Empirically, questionnaires and surveys confirmed peer influence as one of the factors on safety climate both qualitatively (Choudhry and Fang 2008) and quantitatively (Zhou et al. 2008). Theoretically in the framework of indicators of safety performance (Choi et al. 2017; Brondino et al. 2012) as well as in reviews (Frick 2011), communications, group safety climate, worker interactions were identified as key factors to effectively reduce risks at work. Cohen (1977) argued 6 factors of successful safety programs, one of which was interactions between construction personnel including managers, supervisors and co-workers. His work has been confirmed by a series of researches and questionnaires (Glendon and Litherland 2001) about safety climate stressed on safety communication and peer influence as well.

Yet other research discovered that peer influence played an important role in construction safety management. Williams et al. (2010) examined the impact of a peer-led safety training for Latino construction labourers and found increase in safety and risk concerns and statistically significant improvement in PPE usage and self-protection, which proved the significant positive peer influence on safety attitude and safety behaviour. M. Osama Jannadi (Conner and Armitage 2008) examined the influence of social relationship on pipeline construction and maintenance crews and found that workers who had a good relationship with their co-workers and supervisors had better safety record, and proved the importance of social relationship empirically. The research by Kines et al. (2010) focused on the informal oral safety communication on construction sites which is the exchange of information and learning happening in the social network of construction crews and

S. Xu (✉)
Construction Management, Chang'an University, Xi'an 710061, China
e-mail: sheng.xu@chd.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_126

they found that this verbal communication significantly improved construction safety climate by the comparison of pre-post intervention-control experiment. Fung et al. (2005) investigated the influence of 8 testable factors on safety culture and one of the factors was workmate influence; according to the results of their questionnaire, it ranked the first in the group of managers, second in the group of workers and fifth in the group of supervisors.

The most important question to examine peer influence is to get the social relationships in the group. Traditionally, data about relationships are obtained by self-reporting questionnaires and surveys, for example, by asking questions like "please name 5 most familiar people" or "please tick your friend in the following list". However, their answers can be unsatisfying for various reasons: (a) unnecessary worries about privacy may lead to incomplete answers; (b) social desirability bias may lead to fake answers; (c) incorrect memories may leads to incorrect answers and (d) dynamics among social groups and changes in relationships are not easy to obtain. As pointed out by Pentland, "Surveys are plagued with issues such as bias, sparsity of data, and lack of continuity between discrete questionnaires. This absence of dense, continuous data also hinders the machine learning and agent-based modelling communities from constructing more comprehensive predictive models of human dynamics." In another research, they proved the existence of recence effect and salience effect mathematically (Eagle et al. 2009). The solution is to gather objective data from real world with information technology and devices and build an honest social network for further analysis. The applicable technique and devices are prosperous research fields and can mainly be categorized as special-designed mobile phones, radio frequency identification and cameras.

In this paper, we try to bring up a system framework for detecting real social network in construction crews with information technology that adapts to the constraints and environment of construction sites. After reviewing existing techniques to obtain real social network in Sect. 126.2, the system applicable to construction sites will be designed in Sect. 126.3. The next section will present the analysis results of interpersonal relationships in the applied construction site, followed by discussion and conclusion.

126.2 Literature Review

126.2.1 Safety Culture and Social Influence

It is well recognised that positive safety climate or culture is essential to satisfying safety performance and lower injury rate. For several decades of safety climate research, a lot of efforts have been poured into how to measure it (Lipkus et al. 2005), and various instruments have been developed (Priester and Petty 1996; Vinodkumar and Bhasi 2010). However, not many research discussed the mechanisms of the formation of a positive or negative safety climate.

From the point of organisational research in general, Zohar and Tenne-Gazit (2008) argued group interaction, together with transformational leadership, were predicting factors of organizational climate emergence, safety climate in particular, from the social network perspective, and their results revealed that friendship networks and group communication had greater impacts on climate strength than transformational leadership. Yagil and Luria (2010) found that high quality friendships compensated for low safety climate and was able to help improve workers' safety attitude and behaviour, and this effect did not apply to the relationship with supervisors. Mullen (2004) found that workers' initial socialisation in the organisation is another reason for safety attitude and behaviour besides safety climate, and their perceptions of co-workers and motivation to comply with norms could be used to predict safety behaviours. These works shed light on theoretically examining social influence in crews for safety climate.

In social psychology theories, there are two categories of social influence: informational influence and normative influence. The former refers to the form of conformity which occurs when an individual turns to another in order to obtain information; while the latter involves conforming in order to gain acceptance or like by the group (Augoustinos et al. 2006). They play different roles in social influence.

From the perspective of the relationship between attitude and behaviour, the Theory of Planned Behaviour (Huang et al. 2010) pointed out that the perceived social norms, or judgements and behaviours of others, have a great effect on behaviour; it also pointed out that there were two types of perceived norms, injunctive norms influence individuals through the motivation to avoid social sanction, and descriptive norms influence through an information seeking process of observing others' behaviour (Delgado 2002).

For example, a research on transportation organisations Fugas et al. (2012) argued that patterns of combinations of individual and situational factors explained proactive and compliance safety behaviour in organisations; while co-worker's descriptive norms and attitudes mediated proactive safety behaviour and supervisor's injunctive norms and perceived behaviour control mediated compliance safety behaviour.

126.2.2 Information Technologies in Obtaining Real Social Network Data

In general, there are two types of technology used to dig real social data: mobile phones and relevant apps and radio-frequency identification (RFID). MIT Media Lab used mobile phones to collect position information from cell towers, as well as call or messages logs, and Bluetooth on the phone to collect information on proximity. They did experiments on about 100 students and staffs with their permission for almost a year and gathered a large amount of data. They inferred friendship network structure from the data set (Eagle et al. 2009), and found that co-location and friendship were fundamentally different. To infer the friendship or social ties, the context was taken into consideration and data from working hours and non-working hours was distinguished (Eagle et al. 2009). Although it is still discussable the reliability of inference (Adams, 2010; Eagle et al. 2010), their work was reasonable and feasible.

Furthermore, inferring closeness of relationships is essentially different from detecting proximity (Eagle et al. 2009). For one, co-location at a high frequency and long duration definitely suggest a close relationship and high volume of information transfer, especially face-to-face which indicates dialogues. However, people can be friends even if they are separate in location or without observable communication for a long time. The ultimate factor of social influence is their intimacy, especially when they are in the same circle. The power of persuasion on their attitudes towards certain objectives is to be observed between trusted friends. As a result, not only the length and frequency of proximity is to be collected, but also the context of the statistics. People spending time together during their breaks clearly are more closely related than merely co-located during working hours but separated during breaks. From the empirical work conducted by MIT Media Lab, the probability of proximity for friends was significantly higher than non-friends or asymmetric friends during off hours or outside campus (Eagle et al. 2009).

Radio-frequency identification (RFID) is a technology that uses radio waves to transfer data from an electronic tag, called RFID tag or label, attached to an object, through a reader for the purpose of identifying and tracking the object. The MIT Media Lab used not only mobile phones but also other devices such as accelerometer, infrared sensor, microphone and so on. More importantly, all the devices are combined with each other to provide multi-dimensional data about social interaction and the badge actually went through several upgrades and the current device is light weighted, small badge like, comfortable to wear, with a long battery life (Pentland and Heibeck 2008).

The European "Live Social Semantic" research group used active RFID system called OpenBeacon and operate them in a bi-directional fashion (Barrat et al. 2010). The introduction and source code of this mature RFID tagging system can be retrieved from its website (Giebel and Groeben 2008). The tags transmitted out and detected signals from a 1–1.5 m area in 20s periodically to confirm the co-location of others, and the tags were so worn that they only confirmed proximity when individuals are in a face-to-face position (Barrat et al. 2010). Information about contacts was then sent to central computers and the visualization of network could be shown on several terminals real-time (Cattuto et al. 2010). According to the total times of confirmed contacts two individuals had, the weighted network could be built and multiple nodes cliques could be analysed to show the clusters in the group (Barrat et al. 2010). This work was useful in forming a network and bringing up the idea of contact detection instead of contact inference, which was said to be more precise. It was not only used in indoor environments like for conferences (Cattuto et al. 2010) and hospitals (Isella et al. 2011) but also in outdoor environments like for primary school students (Stehle et al. 2011).

In construction research, Teizer and his group used Ultra Wideband (UWB) RFID for real-time location sensing and tracking of workforce, machines and materials (Walia et al. 2008; Yang et al. 2011). Every person in the construction site wore the helmet with a commercial UWB RFID tag and the system implements triangulation calculation with not only receivers but also reference tags to track the time-stamped position and routes of construction workers (Yang et al. 2011). Data collected included time-stamped position of each individual with a high frequency, and it was able to track multiple workers on site. The system was operated in open area, in fact, on construction sites; but it was not used to detect workers' proximity or connections although it should not be difficult to be analysed with cross-referencing time and position of each record. The nominal error for UWB sensors was under 0.5 m, which was satisfying for identifying the co-locating of less than 1 m (Yang et al. 2011).

Other devices have been used to dig social network, such as the integration of accelerometer, infrared sensors, microphones and so on to provide multi-dimensional data about social interaction and the badge actually went through several upgrades and the current device is light weighted, small badge like, comfortable to wear, with a long battery life (Pentland and Heibeck 2008). In detail, the wearable communicator badge is consisted of the following components: (a) infrared transceiver, which is capable to capture face-to-face interactions including their frequency and duration and the key point is the spreading signal should be low enough to make sure that only people within a certain distance (50 cm) can be captured as proximity; (b) microphone, which is capable to capture the speech signals, and in order to avoid privacy issues, the original recording is garbled by swapping 100 ms of consecutive audio so that when it is still possible to analyse the energy and speech features, the content of conversations remains confidential; (c) accelerometers, which are placed in the badge to detect body movement and recognize daily activities; (d) transceiver, which is capable of tracking indoor locations, also including physical proximity; (e) Bluetooth, which is to connect the badge with mobile phones and computers so that information can be collected through various resources; and (f) speaker, which is to broadcast audio messages to the person who wear it.

The two techniques have different advantages and disadvantages. Mobiles phones are necessity in modern life so that it can be sure to be brought around and gather data continuously, it can also be used to detect large scale networks; however, they are expensive and sometimes privacy can be a big concern. On the other hand, badges can be left over but they are more accurate, and they detect face-to-face situations.

Furthermore, multiple measures are widely employed and integrated in these researches instead of using just one measurement. In a research of epidemiological behaviour change (Madan et al. 2010), four categories of information were collected, including proximity with Bluetooth detection every 6 min, approximate location with wireless WLAN 802.11 Access Point identifiers every 6 min, communication with calls and SMS logs and details every 20 min and daily survey of fever symptoms and stress evaluations delivered by mobiles phones. In another research of music propagation (Madan and Pentland 2009), researchers used Bluetooth devices to collect proximity data, WLAN transceivers to collect location data, mobile phones to collect communication data, a custom music player to collect the behaviour features of music propagation, and surveys to investigate other data such as relationships, political opinions, confidence, smoking, dieting and so on.

Thirdly, it is worth noting that the researchers integrated an output function in one of their researches by installing the speaker into the badge so that it can play audio messages (Olguin et al. 2006). In construction safety, the system can be augmented by providing alarming functions to help equipment promotion and integrate the automatic safety warning system.

The other branch of research is the discussion of precise location sensing using RFID, among which there are (Ni and Liu 2004; Huang et al. 2006; Willis and Helal 2005).

126.3 System Design

126.3.1 Designing a Detecting System

It is a two-stage implementation. The first stage includes data collection with RFID devices and the second stage includes data analysis and modelling. Since the final goal is to build a network, the question that what kind of data to obtain in order to parameterize the network, or more specifically, the weighted edges.

Constructing the network structure requires (a) the existence of a relationship and (b) the closeness of the relationship. The former is dichotomy and can be established by detecting the co-location, especially face-to-face co-existence, which can be revealed by RFID signals. The latter one is more difficult to extract from signals collected.

Differences between the research in construction crews and other existing research on university staffs and students and attendees of conferences are that in construction crews, workers know each other at least—the variance is their familiarity; they spend most of the time in the boundaries of construction site—there are usually temporary dorms on site for them to sleep during nights, which is perfect for the use of RFID.

Another problem worth noticing is the proximity of more than two nodes. It is highly possible because people gather together to share information and exchange their feelings and this phenomenon in fact forms “circle”. The circle is the essence of social influence instead of individual persuasion, to a large extent. Thus the multi-person interactions are important as well.

Discussions over the usage of RFID include the choices of (1) active or negative RFID tags and (2) measurement of face-to-face interaction or proximity in general. Negative RFID tags are cheaper, which are also smaller, lighter, and function by reflecting signals sent out from readers and can only be useful for very close proximity, usually only a few centimetres. On the other hand, active RFID tags contain a battery in them, thus can transmit signals to be captured by readers from relatively further distance. In fact, most locating sensors use active tags even though they are a little bit more expensive.

The second discussion leads to a fundamental question: on what ground are two nodes seen as interacting with each other? Settings in "Live Social Semantic" group which confirms a contact only at the circumstances when the two individuals face each other; in fact, they redesigned their RFID badges so that they can transmit signals and receive them periodically and by wearing them on the chest, those badges can assure to record all face to face interactions with little noise. However, this method requires reprogramming on RFID transponders and it does not cover the circumstances when people sit or stand side by side and communicate with each other.

On the other hand, the absolute positions of each individual are recorded separately and the location information is cross-referenced to explore nodes within a 1-1.5 m area and confirm contacts. By inferring contacts from co-location, communication can be recorded by determining whether people are facing each other or standing side by side.

126.3.2 Constructing a Social Network

This research hereby proposes an approach to construct the social network within a group of workers in a certain trade.

A crew of construction workers of a certain trade with a population of about 10 people is appropriate for the research, because workers within the same trade are working together and have a greater opportunity to form a strong relationship. The first steps of the experiment includes to explain the experiment to the respondents, ask for their permission to obtain data about their location all day long, and ask for their commitment to wear the badge all the time during the experiment.

The experiment will probably last for 2 weeks. According to MIT observation, data of two weeks in their experiment is enough to illustrate all the patterns and infer relationships (Eagle et al. 2009). However, it could also be extended to 4 weeks to make sure the scale of records. A type of commercial RFID system will be picked up for experiments, including tags, central processing computers, data processing software and so on.

A typical item of record should include the following information:

a. The co-location of two nodes by an effective signal received between two devices;
b. The duration of co-location;
c. The frequency of co-location of two specific nodes;
d. The co-existences of multiple nodes identification and their duration and frequency;
e. The context of every proximity.

Processing of data includes the following steps:

a. Distinguishing break time and non-working time from work time by the time stamp in general and absolute position. Firstly, lunch time and after-work hours are easily recognisable from the time stamp; secondly, during working hours, find the records that are away from the operation area.
b. Calculate the following statistics in working and non-working time respectively: the occurrence of contacts for every possible pair of nodes, the frequency and accumulated time collapse for every contacted pair of nodes; the accumulated contacting time for every node.
c. Cross-referencing all records for 3- or 4- cliques by identify records with very close time stamp and absolute location and share one of contacting nodes.
d. Constructing network with statistics for working and non-working time respectively. Weights of edges represent the accumulated time collapse of every contacted pair of nodes (Fig. 126.1).

126.4 Conclusion

This research tried to link the cutting-edge technology with safety climate and presented how these technologies can benefit soft management strategies and discussed the possible use of RFID and BIM to foster positive and stable safety climate, and further benefit the safety performance of high-risk construction industry. The information technology can improve the safety climate from three perspectives. Firstly,

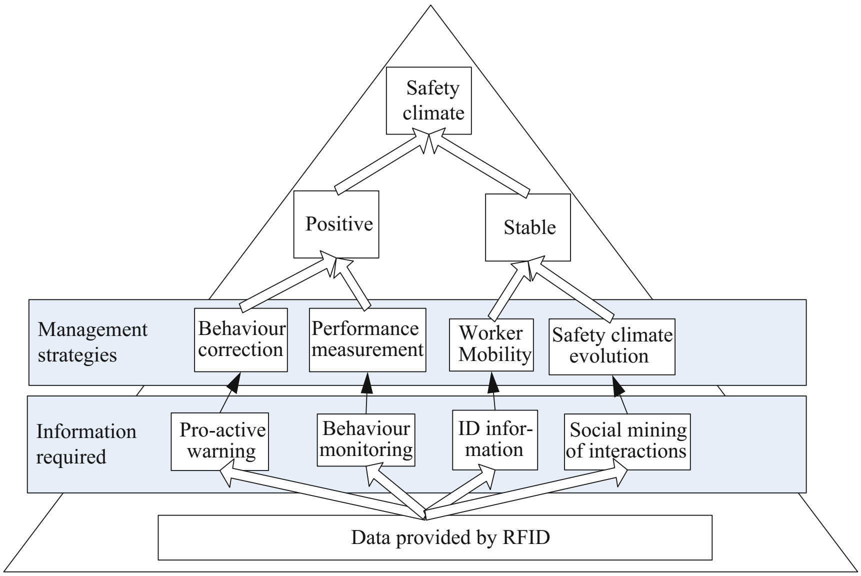


Fig. 126.1 The system framework of social mining technology boosted safety management

safety climate is influenced by interactions in the crews and social mining with RFID technology is able to detect and infer their relationship to analyse the emergence of safety climate. Secondly, the stability of safety climate relies on the stability of crew members. ID information recorded by RFID is able to assist the analysis of construction workers' mobility and its influence on safety climate stability. On the other hand safety training schemes on behavioural instructions can be generated and managed by BIM to intervene and improve safety performance on a regular base. Finally, RFID technology can track and locate workers and warn them from dangers proactively, and combined with BIM, information technology can record real-time risk evolution for better decision making and safety performance measurement.

Acknowledgement This work was supported by the National Natural Science Foundation of China (Program No. 51708039), and Natural Science Basic Research Plan in Shaanxi Province of China (Program No. 2017JQ7005).

References

Adams J (2010) Distant friends, close strangers? Inferring friendships from behavior. In: Proceedings of the National Academy Science USA, vol 107, E29-30; author reply E31

Augoustinos M, Walker I, Donaghue N (2006) Social cognition: an integrated introduction. Sage, London

Barrat A, Cattuto C, Colizza V, Pinton J-F, Broeck WVD, Vespignani A (2010) High resolution dynamical mapping of social interactions with active RFID. PLoS ONE 5 [Online]

Brondino M, Silva SA, Pasini M (2012) Multilevel approach to organizational and group safety climate and safety performance: co-workers as the missing link. Saf Sci 50(9):1847–1856

Cattuto C, Van Den Broeck W, Barrat A, Colizza V, Pinton JF, Vespignani A (2010) Dynamics of person-to-person interactions from distributed RFID sensor networks. PLoS ONE 5:e11596

Choi B, Ahn S, Lee SH (2017) Construction workers' group norms and personal standards regarding safety behavior: social identity theory perspective. J Manage Eng 33(4):04017001

Choudhry RM, Fang D (2008) Why operatives engage in unsafe work behavior: investigating factors on construction sites. Saf Sci 46:566–584

Cohen A (1977) Factors in successful occupational safety programs. J Saf Res 9:168–178

Conner MT, Armitage CJ (2008) Attitudinal ambivalence. In: Crano W, Prislin R (eds) Attitudes and persuasion. Psychology Press, New York

Delgado J (2002) Emergence of social conventions in complex networks. Artif Intell 141:171–185

Eagle N, Clauset A, Pentland A, Lazer D (2010) Reply to adams: Multi-dimensional edge inference. Proc Natl Acad Sci 107:E31–E31

Eagle N, Pentland AS, Lazer D (2009) Inferring friendship network structure by using mobile phone data. Proc Natl Acad Sci USA 106:15274–15278

Frick K (2011) Worker influence on voluntary OHS management systems—a review of its ends and means. Saf Sci 49:974–987

Fugas CS, Silva SA, Melia JL (2012) Another look at safety climate and safety behavior: deepening the cognitive and social mediator mechanisms. Accid Anal Prev 45:468–477

Fung IWH, Tam CM, Tung KCF, Man ASK (2005) Safety cultural divergences among management, supervisory and worker groups in Hong Kong construction industry. Int J Proj Manage 23(7):504–512

Giebel GD, Groeben N (2008) Social desirability in the measuring of patient satisfaction after treatment of coloproctologic disorders: on shortcomings of general bipolar satisfaction scales for quality management. Langenbecks Arch Surg 393:513–520

Glendon AI Litherland DK (2001) Safety climate factors, group differences and safety behaviour in road construction. Saf Sci 39(3):157–188
Huang CY, Tzou PJ, Sun CT (2010) Collective opinion and attitude dynamics dependency on informational and normative social influences. Simulation 87:875–892
Huang X, Janaswamy R, Ganz A (2006) Scout: outdoor localization using active RFID technology. In: 3rd international conference on broadband communications, networks and systems, IEEE, San Jose, CA, pp 1–10
Isella L, Romano M, Barrat A, Cattuto C, Colizza V, Van Den Broeck W, Gesualdo F, Pandolfi E, Rava L, Rizzo C, Tozzi AE (2011) Close encounters in a pediatric ward: measuring face-to-face proximity and mixing patterns with wearable sensors. PLoS ONE 6:e17144
Kines P, Andersen L, Spangenber S, Mikkelsen K, Dyreborg J, Zohar D (2010) Improving construction site safety through leader-based verbal safety communication. J Saf Res 41:399–406
Lipkus IM, Pollak KI, Mcbride CM, Schwartz-Bloom R, Lyna P, Bloom PN (2005) Assessing attitudinal ambivalence towards smoking and its association with desire to quit among teen smokers. Psychol Health 20:373–387
Madan A, Cebrian M, Lazer D, Pentland A (2010) Social sensing for epidemiological behavior change. In: 12th ACM international conference on ubiquitous computing, IEEE, New York, NY, USA
Madan A, Pentland AS (2009) Modeling social diffusion phenomena using reality mining. In: The AAAI spring symposium—human behavior modeling, Palo Alto, CA
Ni L, Liu Y (2004) LANDMARC: indoor location sensing using active RFID. Wirel Netw 10:701–710
Olguin DO, Joseph AP, Pentland AS (2006) Wearable communicator badge: designing a new platform for revealing organizational dynamics. In: 10th international symposium on wearable computers, IEEE Montreaux, Switzerland
Pentland AS, Heibeck T (2008) Honest signals: how they shape our world. MIT Press, Cambridge
Priester JR, Petty RE (1996) The gradual threshold model of ambivalence: relating the positive and negative bases of attitudes to subjective ambivalence. J Pers Soc Psychol 71:431–449
Stehle J, Voirin N, Barrat A, Cattuto C, Isella L, Pinton JF, Quaggiotto M, Van Den Broeck W, Regis C, Lina B, Vanhems P (2011) High-resolution measurements of face-to-face contact patterns in a primary school. PLoS ONE 6:e23176
Vinodkumar MN, Bhasi M (2010) Safety management practices and safety behaviour: assessing the mediating role of safety knowledge and motivation. Accid Anal Prev 42:2082–2093
Walia A, Venugopal M, Teizer J (2008) Ultrawideband for automated real-time three-dimensional location sensing for workforce, equipment, and material positioning and tracking. Transp Res Rec J Transp Res Board 2081:56–64
Willis S, Helal S (2005) A passive RFID information grid for location and proximity sensing for the blind user. In: Proceedings of the ninth IEEE international symposium on wearable computers, pp 34–37
Williams Q, Ochsner M, Marshall E, Kimmel L, Martino C (2010) The impact of a peer-led participatory health and safety training program for Latino day laborers in construction. J Saf Res 41(3):253–261
Yagil D, Luria G (2010) Friends in need: the protective effect of social relationships under low-safety climate. Group Org Manage 35:727–750
Yang J, Cheng T, Teizer J, Vela PA, Shi ZK (2011) A performance evaluation of vision and radio frequency tracking methods for interacting workforce. Adv Eng Inform 25:736–747
Zhou Q, Fang D, Wang X (2008) A method to identify strategies for the improvement of human safety behavior by considering safety climate and personal experience. Saf Sci 46:1406–1419
Zohar D, Tenne-Gazit O (2008) Transformational leadership and group interaction as climate antecedents: a social network analysis. J Appl Psychol 93(4):744–757

Chapter 127
The Potential Cost Implications and Benefits from Building Information Modeling (BIM) in Malaysian Construction Industry

LiWei Chin, ChangSaar Chai, HeapYih Chong, Aminah Md Yusof and NurFakhira bt Azmi

127.1 Introduction

Ineluctably, construction industry serves as one of the decisive industries with its unique characteristic in fragmented organizations, production period, working conditions and labor intensive activities (Forbes 2015; Sageworks 2015). The architecture, engineering, and construction (AEC) industry is experiencing massive technological and institutional transformations and challenges such as the massive entry of information technology and the incorporation of sustainable practices (Becerik-Gerber and Kensek 2009; Becerik-Gerber et al. 2011). The comparatively low productivity rate portraying by the Malaysian construction industry is a reflection of the limited modernisation of construction practices and poor adoption of information technologies (Zahrizan et al. 2013; Mohd Harris 2015).

L. Chin · N. bt Azmi
Department of Structure and Materials, Faculty of Civil Engineering,
Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
e-mail: liwei5494@gmail.com

N. bt Azmi
e-mail: faira_90@yahoo.com

C. Chai (✉)
School of Built Environment, University of Reading Malaysia,
79200 Iskandar Puteri, Johor, Malaysia
e-mail: c.s.chai@reading.edu.my

H. Chong
School of Built Environment, Curtin University, Bentley, Perth, Australia
e-mail: heap-yih.chong@curtin.edu.au

A. Md Yusof
School of Graduate Studies, Universiti Teknologi Malaysia,
81310 Skudai, Johor, Malaysia
e-mail: aminahyusof@utm.my

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_127

Thus, the mutual collaboration and appreciation within AEC industry are of salient and decisive.

Continuous, accurate, and real-time information transferring and sharing among project participants is crucial in conflicts resolution, speedy solutions generation, project completion time guarantee, while contemporaneously, budget compliance. Contrary, poor interoperability and improper project management in building industry are the decisive factor lead to project failure. Kymmell (2008) claimed that the main cumbersome in the planning and construction of building project is the inaccurate visualization of the project information as the details are the evil roots of the confusion. Whereas Eastman et al. (2008) discovered the fragmentation occurred in actual facility delivery process and the heavy reliance upon paper-based mode of communication where lapses and exclusions easily existed within these documents undoubtedly incurred unexpected field costs, delays, lawsuits, conflicts, and even economic losses and setbacks.

Building information modeling (BIM), a modeling technology and associated set of procedures to produce, communicate, and analyze building models (Eastman et al. 2008), is an enabler that may contribute to the building industry in productivity enhancements and integration guarantee.

Although BIM has been existed in the market for years, its adoption in the industry is not to the fullest capacity. Inevitably, the associated technology, process and organizational investments required to initiate BIM are of pretty penny, and contemporaneously, its implementation requires substantial changes to the traditional way in designing and building projects (Becerik and Pollalis 2006). An enhancement in the availability of financial information will be decisive, as the decision of those professionals to adopt new technologies is proportional to the associated opportunity they capable to gain in the operations (Bjork 2003). As the building industry implements BIM, decision makers and end users are capable to benchmark and appreciate the value of BIM to their organizations and projects.

Undeniably, there are abundant available resources and publications regarding the BIM status in Malaysian AEC industry. However, the insufficiency that arose is the lack of actual tabulations or outcomes that can generally sum up the perceive value of BIM in Malaysia, due to the discrepancies and lack of available samples that can be utilized to draw the baseline that is commonly acceptable. This study is intended to boost comprehension and concentration on realistic-concern to generate the outcomes that parallel with real practices. From the research questions exemplified, this study aims to evaluate the workability and applicability of BIM in the Malaysian construction industry; in terms of its potential cost implications and benefits.

127.2 Literature Review

To survive in contemporaneous with globalization and economic integration, the building industry is being exposed to competitive pressures and encumbrance when comparisons are being executed with other industries (Bernstein and Pittman 2005).

Moreover, AEC industry often being acknowledged as a low-technology and an inefficient industry. The delivery process in the AEC industry still remains fragmented, and inevitably which relies heavily upon 2D paper-based drawing as communication medium (Pena 2011). Thus, new approaches and alternatives should be encouraged to enhance the potential improvements.

Undoubtedly, BIM is not merely a software but also a 3D building design which enables the planning, organisation and visualisation of relevant data regarding the building before the real construction is initiated (AGC Committee 2005; Goedert and Meadati 2008; Smith and Tardif 2009; Pena 2011; Aftab et al. 2014; Arup 2015; Autodesk 2015). It is an intelligent model-based design process that enhances its value across the entire lifecycle of the project (Lee et al. 2006; Gu and London 2010; Autodesk 2011, 2015; Hergunsel 2011). Thus, from the featured tailing benefits, its introduction initiated a new platform for construction industry to mark a new milestone in its improvements.

Its flexibility and associating usefulness are gaining popularity among designers, consultants, owners, contractors and facility management companies, with the portrayal that they are embracing and showing appreciation towards BIM technology (Azhar 2011; Hergunsel 2011; Pena 2011; CIC Research Program 2012; Lu et al. 2013). However, BIM is relatively classified as new approach in Malaysian construction industry and rarely being applied in local projects (Aftab et al. 2014). Despite all the exemplifying advantages, sarcastically, the adoption of BIM in Malaysian construction is still below satisfaction level (Aftab et al. 2014; Roger et al. 2015; Nursal et al. 2015).

To ease comprehension, the summary of the driving factors of BIM adoption is exemplified in Table 127.1; the summary of the barriers hindering BIM adoption is revealed in Table 127.2; while Table 127.3 exemplified the summary of the potential cost implications and benefits of BIM in construction project.

127.3 Research Methodology

Interview and literature review are the ways opted for current data collection purpose. Such methods are perfect suited to distinguish objectives that have to be complied, to accomplish the required outcomes and avoidance of any entanglement or inaccuracy of data, which will then distract the genuine intentions at the very initial phase.

In this study, the literature review is established ahead. This inevitably would link to the obtainment of much precious background knowledge regarding the arisen issues, in contemporaneous with the gaining of more detailed review to equip with the relevance outcomes to be stroke. Undoubtedly, the data is been fully utilized to outline the conceptual phase, explicate and elaborate the study's criteria.

The personal interview are executed to generate findings for the desired objectives. This approach is best suited as the upcoming results required have to be specific and personal-oriented. The interviews are directed to respective personnel

Table 127.1 Driving factor of BIM adoption

Driving Factor of BIM Adoption	
Parametric Building Modeling Structure	AGC Committee (2005), Azhar *et al*.(2012), CRC Construction Innovation (2007), Ding *et al.* (2014), Eastman *et al.* (2011), Graphisoft (2015), Howell and Batcheler (2005), Lee *et al.* (2006), Pena (2011)
Design assistance and constructability	AGC Committee (2005), Autodesk (2011), Azhar *et al.* (2008), Azhar *et al.* (2012),CIC Research Program (2012), Eastman *et al.* (2011), Goedert and Meadati (2008), Graphisoft (2015), Hergunsel (2011), John *et al.* (2015), Marcus and Ivica (2012), Mattsson and Rodny (2013), Porwal and Hewage (2013), Sacks *et al.* (2009), Syed Shujaa *et al.* (2013), Usman *et al.* (2015)
Scheduling and sequencing	AGC Committee (2005), Azhar *et al.* (2008), Azhar (2011), Graphisoft (2015), Hergunsel (2011), Irizarry *et al.* (2012), Koo and Fischer (2000), Mattsson and Rodny (2013), Public Buildings Service (2009), Usman et al. (2015)
Estimating	AGC Committee (2005), Azhar *et al.* (2008), Azhar (2011), CRC Construction Innovation (2007), Graphisoft (2015), Irizarry *et al.* (2012), Nassar (2010) Rosenburg (2007)
Clash Detection	AGC Committee (2005), Azhar *et al.* (2008), Azhar (2011), CIC Research Program (2012), Hergunsel (2011), Howell and Batcheler (2005), John *et al.* (2015), Porwal and Hewage (2013)
Visualisation	Azhar *et al.* (2008), Azhar (2011), Graphisoft (2015), Hergunsel (2011), Irizarry *et al.* (2012), Sacks *et al.* (2009)
Greater Speed	Autodesk (2002), Carmona and Irwin (2007), CRC Construction Innovation (2007)
Lower Cost	Autodesk (2002), Carmona and Irwin (2007)
Interoperability	Bernstein and Pittman (2005), Carmona and Irwin (2007), CRC Construction Innovation (2007), Goedert and Meadati (2008), Hardin and McCool (2015), Howell and Batcheler (2005), Lee *et al.* (2006)
Facilities Management	Azhar *et al.* (2008) Azhar *et al.* (2012), Azhar (2011), Bernstein and Pittman (2005), CIC Research Program (2012), CRC Construction Innovation (2007), GSA (2015)

Table 127.2 Barriers hindering BIM adoption

Barriers Hindering BIM Adoption	
High Level of Training	AGC Committee (2005), Becerik-Gerber *et al.* (2011), CIC Research Program (2012), John *et al.* (2015), John *et al.* (2015), McGraw-Hill Construction (2008), Pena (2011)
Cost	Autodesk (2011) Chien *et al.* (2014), Eastman et al. (2011), Gu *et al.* (2007), John *et al.* (2015), McGraw-Hill Construction (2008), Takim *et al.* (2013), von Both and Kindsvater (2012)
Organisation and Data Management	Azhar *et al.* (2012), Chien *et al.* (2014), Gu *et al.* (2007), von Both and Kindsvater (2012)
Process Barrier	Bernstein and Pittman (2005), Chien *et al.* (2014), CRC Construction Innovation (2007), Graphisoft (2015), Gu *et al.* (2007), Hergunsel 2011 John *et al.* (2015), Migilinskas *et al.* (2013), Singh *et al.* (2011)
Inadequate Advice/Experience	Chien *et al.* (2014) Farr *et al.* (2014), John *et al.* (2015), McGraw-Hill Construction (008), Migilinskas *et al.* (2013), Woo (2006)
BIM Risks	Azhar *et al.* (2012), Azhar (2011), Bernstein and Pittman (2005), Chien *et al.* (2014), Gu and London (2010), Gu *et al.* (2007), Hergunsel (2011), McGraw-Hill Construction (2008), Porwal and Hewage (2013), Rosenberg (2007), Thompson and Miner (2007)

of BIM-related projects; as inevitably, actual and professional perspectives and facts are highly demanded to boost the results' reliability. It is important to opt for the personal interview as abundant private and confidential data and information were necessitate for current research and thus, privacy and approval are decisive.

Table 127.3 BIM's potential cost implication and benefits of construction project

Cost benefits elements	Description
Consultancy fee	The adoption of BIM triggered a very high initial cost and loss in productivity (AGC Committee 2005). As the familiarity and skills gaining with time, the professionalism associated rising in parallel too. Integration of BIM model and required professionalism for the sake of the Client ineluctably will incur higher consultancy fee to be paid. Although BIM adoption benefits the Consultants in distinguish aspects such as higher productivity, less coordination predicaments and precipitation in creditability and as like, the query is how the consultant firms will allocate the consultancy fee. Consultancy fees are classified as the 'cost' when calculating CBA; as the Client now has to consume different pay rates to the Consultants due to distinguished services provided
Variation orders	It should be greatly appreciated that in Osman et al. (2009), the authors recommended that the mitigation of variations can be guaranteed by: involvement of the contractor at the design phase; accurate and meticulous designs during the design stages; constant coordination and direct communication; proper management of variation orders; thorough design or design details and teamwork among all project team members to monitor and reduce variation orders. Coincidently, these stated desires can be executed with BIM implementation, and its applicability and reliability in Variation Order reduction is portrayed in further analysis part
Re-measurement	The main idea to incorporate re-measurement as one of the CBA elements is because comparisons can be made upon the precision of estimation and the accuracy of BIM in giving clear visualization and information accuracy. Re-measurements are based upon the concept that the actual works constructed is measured and valued at previously agreed rates or tendered by the Contractor (RICS 2015); which will normally result in additional or reduction of quantities among planned and actual incurred. Concurrently, the associated costs will either be heighten or lowered down. As BIM is termed with accuracy assurance, thus there should be no huge difference in initially planned measurement and re-measurement value. Thus, current study is required to justify such hypothesis
Mark-up	The main intention to involve mark-up as an element to calculate CBA because there are queries of how the Client or even the consultants or contractor will allocate the mark-up percentage for BIM-adopted project. It is always the most worrisome concern that there is no standard to be used as a reference guideline or baseline to ensure the fairness is established and achieved. It will be of salient and decisive to place a 'right' and 'fair' mark-up. As widely known, the percentage is varied and will be modified and adopted based on different scenarios such as complexity, risks or uncertainty, or even professionalism (Tey 2009). With BIM application, how the mark-up will be altered is yet, to be determined

(continued)

Table 127.3 (continued)

Cost benefits elements	Description
Liquidated ascertained damages (LAD)	The LAD set for each agreed contract is reliable and of acceptable accuracy and standard precision (Malaysian Construction and Contract Law 2012; Designing Buildings Wiki 2015). Since it emerged to represent the actual loss that the Client will suffer; vice versa, it can be utilized as a measurement to how much the Client managed to save if the project completed ahead, based on the set baseline. As pinpointed previously, BIM implementation will result in time saving as lapses, queries and ambiguities are significantly mitigated, thus to a certain point, it should be observed with visible reduction in completion time. Since costs are the easiest to comprehend element, converting the related elements in Ringgit Malaysia will be much persuasive and convenience, as the outcomes from the analysis can be significantly appreciated and understandable for every stakeholder

The interview sessions are carried out on May 2016 and consumed one month for the full execution of data collection. The data obtained from the interviews is transcribed and analysed. The Framework Analysis is used to analyse the interview data. Srivastava and Thomson (2009) defined framework analysis as a qualitative method that is well-appropriated for applied policy research. Framework analysis is portraying satisfying performance when adapted to research that has specific questions, a limited time frame, a pre-designed sample and a priori issues. During the analysis process, data is sifted, charted and sorted in parallel with key issues and themes using five steps, which are:

- Familiarization: Transcribing and reading the data;
- Identifying a thematic framework: Initial coding framework which is developed both from a priori issues and from emergent issues;
- Indexing/Coding: Using numerical or textual codes to identify specific piece of data which correspond to different themes;
- Charting: Charts created using headings from thematic framework;
- Mapping and interpretation: Searching for patterns, associations, concepts and explanations in the data.

The outcomes are then being utilised to form a proposed framework of the Potential Cost Implications and Benefits from BIM in Malaysian Construction Industry.

127.4 Findings and Discussions

There are three (3) quantity surveyors, one (1) government representative and one (1) contractor participated in the interview session. The interviewees' profile are gathered and recorded, as per exemplified in Table 127.4. From the background of the interviewees, it is found that 80% of the interviewees are middle executive level and above, 60% of them are new to BIM adoption in AEC. The managerial position of the interviewees indicated his/her working experience, commitment and job completion integrity in their organisation. Their experience in construction cost planning is salient to justify BIM contribution in this matter.

BIM implementation in Malaysian AEC is still at minimal level can be seen from the limited BIM experience among the interviewees. However, some initiatives are taken by the Malaysian government to improve the situation through tax relief scheme, financial bridging opportunities and others. Moreover, Construction Industry Development Board Malaysia had invested RM1.5mil lately for BIM awareness programme to enhance BIM adoption in the country. These initiatives portray that Malaysian government is moving forward automation in construction which indicated a revolution from analogue decision to digital decision age.

127.4.1 Review of BIM Implementation Status in Malaysia Construction Industry

The first question is shed light upon the necessity of BIM investment in current Malaysian construction industry. This is decisive as it indicates how the professionals defined the extent and salience of BIM investment towards local industry. This inevitably reflects the intended purposes for initial investments and early participation of BIM. Thorough appreciation upon the necessity of BIM investment represents how the industry allocated the desirable achievements. From the analysed data, the necessities obtained from the interviewees are to: heighten local construction image; nurture healthier construction culture; emerge as a developed nation/precipitate national growth; export construction services; maximize investment value; execute transformation to technology, people and processes or policy.

Table 127.4 Interviewees' profile

Interviewee	Profession	Executive level	BIM experience
Ng	Quantity surveyor	Senior	More than 8 years
Chin	Quantity surveyor	Middle	3–5 years
Razif	Government representative	Junior	1–3 years
Sie	Quantity surveyor	Senior	1–3 years
Tan	Contractor	Middle	1–3 years

The second question shed light upon the sufficiency of Government's efforts in BIM adoption encouragement. This is decisive as it indicated the sufficiency and efforts poured by Government in encouraging the adoption of BIM. Government's commitment in encouraging advancements is salient in helping nurture better construction practice, utilization of ICT, explore more opportunities and even precipitating national growth. Thus, this question is intended to test the genuineness and sufficiency of the portrayed efforts. Thorough appreciation upon the necessity of BIM adoption will formulate distinguished perspectives regarding the allocated efforts. From the portrayed answers with 'Yes' (Chin and Razif), it is supported with the high awareness revealed, high implementation rate, effective BIM road-map, abundant workshops and seminars provided; and vice versa.

The third question is highlighted upon the significance of BIM implementation in terms of cost benefits. This is paramount as it exemplified how the professionals define the significance and salience of BIM investment in terms of cost benefits. This inevitably reflects the intended purposes for initial investments and how they expect BIM investments will be returned and benefited. High appreciation upon the cost benefits associated with BIM investment will represent how the industry defines the affiliating desired outputs. There are two outcomes, which are 'pros' and 'cons' and their associating justifications. The former contributing in cost benefits through the ease of control, less error-prone, less labour-intensive and consumption of short cycle times; the latter are associating with the high level of training, high and miscellaneous costs, inadequate expert, legal and technical issue.

127.4.2 Cost Implications and Benefits from BIM Implementation

127.4.2.1 Will BIM Implementation Affect the Consultancy Fee?

Inevitably, BIM adoption will trigger a very high initial costs and an early phase of productivity loss, but as time passed by, the adopters are improving vis-à-vis the learning curve. However, it is also proportional with the necessary software updates, trainings and re-trainings and associated indirect costs. As the familiarity and skills gaining with time, the professionalism indirectly also rising in parallel too. Thus, integration of BIM model and the additional skills to be performed for the sake of the Client ineluctably will incur higher consultancy fees to be paid. Additionally, the higher consultancy fee can be served as the rewards and appreciations of Clients towards the efforts paid by consultants in committing upon for the sake of projects.

It is widely accepted that the charging fees by consultants will be varied according to project size, project type and complexity, scope of services required by the Client, engagement conditions and as like. For current situation, from the perspectives of Chin, Razif and Ng, the requirements of BIM implementation indicating additional works as those engaging tasks are beyond the conventional scopes of works that need to be carried out, such as the necessity for coordination within the BIM environment, formation of 3D modelling and as like. All of the efforts required standard professionalism and competency, and the consultants are executing these additional tasks for the sake of Client, so they are entitled for higher consultancy fee.

However, Tan commented that for long term planning, consultancy fee will not be affected as its embrace is gaining popularity and soon, it will be a common acceptable practice rather than something with additional competitive advantage. In contemporaneously, consultants can utilize BIM to precipitate the workloads to achieve higher Clients' satisfaction, where it does not purely benefits sole party. While Sie defined consultancy fee as professional fees credit to services provided, and BIM is just merely a procurement method that assists the consultants in fulfilling their professionalism.

127.4.2.2 Will BIM Implementation Affect the Variation Orders?

The major causes of variations always tagging with insufficient coordination between the client and the design team, ambiguous and imprecise specification, late amendments or ineffective communication between all parties. The lessons learnt should be cherished and rectified to achieve better outcomes. It is worthwhile to pinpoint that one of the main intentions for BIM implementation is to reduce the possibility of existence of variation works. It is therefore positive that with benefits associating within BIM model, such variations can be mitigated or decimated, and early planning can be executed accordingly.

These consequences due to variations are correlated and interlinked. To mitigate the occurrence, it can be executed along with BIM implementation, and its applicability and reliability in Variation Order reduction are agreed by the interviewees. With BIM being adopted, the ambiguities will be cleared and the Client-involved personnel can visualize the final facility and kick off early planning, where amendments and modifications can be initiated at early phase; if changes only triggered at post stage, the involved costs, time and risks are heightening as project going. Thus, it is positive that its application will reduce the variations that will spark off during the project delivery process.

127.4.2.3 Will BIM Implementation Affect the Re-measurement?

Re-measurement method is one of the types of Forms of Contract, but not applicable to all projects. It is salient to be informed that in a measurement contract, the contract sum is only established with sureness on project completion, where re-measurement of the quantities of work actually carried out will be executed at later stage. The re-measurement amount will be measured and calculated on a mutually-agreed basis. Generally, the re-measurement will normally result in additional or reduction of quantities; which in concurrently, the associated costs will either heighten or lowered down.

BIM is always termed with accuracy assurance, thus it is believe there should be no huge difference in the initially planned measurement and the re-measurement value. Such statement are supported by the respondents (Tan, Chin, Sie and Ng) that, the models, if correctly modelled, the created construction drawings can technically and theoretically be used as as-built drawings, where extreme differences or changes are decimated and actual expectations can be revealed. The real time synchronization and auto update will actually decimate re-measurement requirement. In fact, re-measurement will not be triggered if there is no major changes upon the drawings or design changes. Thus, it will mitigate the necessity of re-measurement, as there should be no huge difference in the initially planned measurement and the re-measurement value. It is best believe that with effective BIM implementation, the necessity upon re-measurement needs will be mitigated and pre budget planning and allocation can be properly executed.

127.4.2.4 Will BIM Implementation Affect the Mark-up?

Once the estimation of hard costs related to the Works is done, the costs will be marked-up to obtain the bid price. The mark-up is necessary to include the necessary overhead, profit and contingency, which are greatly affected by influential elements in mark-up size decisions. The main intention to involve markup as an element to calculate CBA because there are queries of how the Client or even the consultants or contractor will allocate the markup percentage for BIM-adopted project as it will be is salient and decisive to place a 'right' and 'fair' markup. From the outcomes obtained (Tan and Chin), it is positive that mark-up can be reduced as the sophistication and accuracy offered by BIM rectified the weakness existed in conventional way of estimation. The traditional way is lack of coordination and integration, and in concurrent with short time frame allowed for planning and procurement stage, there is always a huge contradiction or gap between the first estimated quantity and last submitted quantity. Thus, ineluctably, the standard errors obtained for BIM-assisted group will substantially lower than the manual group, where it indirectly mitigates the contingency allowances.

It is well accepted that in construction industry, the estimations costs and prices of a project need to be justified before the real execution of project; and inevitably, it is associating with worrisome due to the uncertainties such as construction market, fluctuations of the economies, unpredictable or inclement weather, unknown risks or as like. Even though BIM tool will ensure in estimation or information precision, however, it does not included all external risks. Thus, reasonable considerations are given to the inclusion of contingency allowance in the mark-up amount. Such statement iss supported by the respondents (Sie, Razif, Ng) which commented that BIM only serves as an intelligent tool that heighten the chances to be outstanding in tender bidding, but proper inclusion of unpredictable risks still cannot be neglected, thus the mark-up will not be affected with BIM adoption.

127.4.2.5 Will BIM Implementation Affect the Liquidated Ascertained Damages (LAD)?

It is important to appreciate that LAD are not penalties, but they are pre-determined damages set at the time that contract is agreed upon, where its calculation is based on the actual loss the client is likely to suffer if the contractor failed to execute the agreed Works. Since it emerges to represent the actual loss that the Client will suffer; with proper utilisation, it can be utilized as a measurement to how much the Client managed to save if the project completed ahead, based on the set baseline. As pinpointed previously, BIM implementation will result in time saving as lapses, queries and ambiguities are significantly mitigated, thus to a certain point, it should be observed with visible reduction in completion time. Such statement is then confirmed by the interviewees (Tan and Ng), where BIM adoption might decrease the amount set for LAD as project quality can be greatly heighten and secured from dissatisfying Works.

LAD are damages set to compensate the actual loss the client is likely to suffer if the contractor failed to execute the agreed Works. Further elaborated, LAD provisions that normally constituted in construction contracts are expressed as a certain sum payable per day, or week by which practical completion is delayed; or its amount is being deduct periodically as parts of the project are available for occupation and use. Thus, in contemporaneously with above statement, one of the respondents (Chin) stated that LAD is the actual loss of Client due to the construction delay, which its value will not be affected with or without BIM implementation. Such statement also supported by Sie, who commented BIM will not affect the LAD set, but it assists in project precipitation and management, which will avoid the actuation of LAD.

Another perspective to the disagreement is due to the ease and convenience offered from BIM implementation are actually benefit all stakeholders within a project team. The cost, time and wastage mitigation and reduction are in fact favour all stakeholders; as all project information can be obtained in precise before project initiated, 3D model reference enhances the visualization and comprehension and as like. Thus, with the equally-gained benefits by all stakeholders, the LAD should not be solely reduced.

127.4.2.6 The Most Beneficial Party Resulted from BIM Implementation

It is undoubtedly that all of the relevant stakeholders will benefit from BIM implementation throughout the project delivery process. From all of the data obtained, some interviewees (Razif and Chin) agreed that Client is most beneficial stakeholder in this aspect. With the promising vantages associating within the intelligent model, the overall project constructability will be significantly heighten before the official take-off. Necessary modifications and planning can be triggered and optimised at earlier phase. Project completed within planned timeframe in simultaneously with efficient consultation service assisted will contribute in effective short term and long term cash flows, post construction or facility management. However, Sie preferred the Contractor, as early coordination with consultants and effective waste and site management can be sparked of ahead.

From the analysed outcomes, interrelationships are identified and they are being exemplified as framework as illustrated in Fig. 127.1.

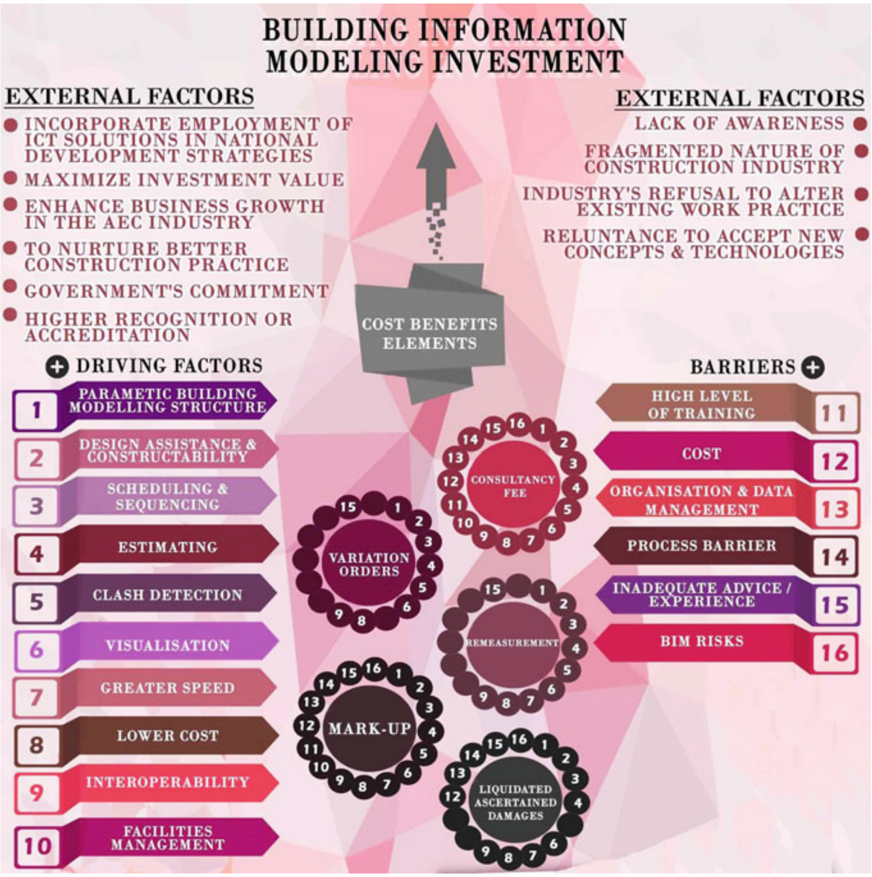


Fig. 127.1 Proposed framework of the potential cost implications and benefits from BIM in Malaysian construction industry

127.5 Conclusion

BIM, as one of the new emerging technologies, can be deployed in the various project phases to facilitate and ease the exchange and interoperability of information in a digital format. Despite the advantages exemplified from the paradigm, reluctance of implementation of such technology within project delivery process by local construction industry is still strong. An enhancement in the availability of financial information will be decisive, as the decision of those professionals to adopt new technologies is proportional to the associated opportunity they capable to gain in the operations. As the construction industry embraces BIM, decision makers and end users are capable to benchmark and appreciate the value of BIM to their organizations and projects. Thus, the necessities of BIM investment in current Malaysian construction are to: improve local construction image; nurture healthier construction culture; emerge as a developed nation; precipitate national growth; export construction services; maximize investment value; execute transformation to technology, people and processes or policy. Contemporaneously, Government's commitment in encouraging advancements is salient in helping nurture better construction practice, promote utilization of ICT, explore more opportunities and encourage national growth. Significance of BIM implementation in terms of cost benefits are contributing through the ease of control, less error-prone, less labour-intensive and consumption of short cycle times; but concurrently, associating with high level of training, high and miscellaneous costs, inadequate expert, legal and technical issue. Consultancy fees, variation orders, re-measurement, mark-up and LAD are opted to represent cost benefits relevancy roofed under BIM implementation.

This paper aims to evaluate the workability and applicability of BIM in the Malaysian construction industry, in terms of its potential cost implication and benefits is greatly achieved. Although the findings are encouraging and capable to serve as baseline of reference, the present study has certain limitations that necessitate future research. First, whether the findings can be generalized for public and private sector and upon all stakeholders, as the initial decision to invest in BIM will be varied, thus shed light will be shifted in proportional too. Further research is necessary to verify the generalizability and suitability. Second, the opted cost elements can be further added based upon limelight focus to enhance the reliability of outcomes; to branch out the necessary details based on suitability. Third, the interviewees are of distinguished professions, thus, further research can be extended to study the impacts upon one profession to comprehend how BIM investment will vary based on different professions.

Acknowledgements This study was supported by Universiti Teknologi Malaysia, PAS grant, vote no: Q.J130000.2722.02K11.

References

AGC Committee (2005) The contractor's guide to BIM, 1st edn. Associated General Contractors of America, AGC Research Foundation, Las Vegas, NV

Arup (2015) Building information modelling (BIM). Accessed on 27 Nov 2015. Available at: http://www.arup.com/Services/Building_Modelling.aspx

Autodesk (2002) Building information modeling. Accessed on 30 Nov 2015. Available at: http://www.laiserin.com/features/bim/autodesk_bim.pdf

Autodesk (2011) Realizing the benefits of BIM. Accessed on 27 Nov 2015. Available at: http://extreme.rs/wp-content/uploads/2013/10/2011_realizing_bim_final.pdf

Autodesk (2015) Building information modeling. Accessed on 26 Nov 2015. Retrieved from: http://www.autodesk.com/solutions/building-information-modeling/overview

Azhar S (2011) Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry. Leadersh Manage Eng 241–252. 10.1061/(ASCE)LM.1943-5630.0000127

Azhar S, Nadeem A, Mok JYN, Leung B HY (2008) Building information modeling (BIM): a new paradigm for visual interactive modeling and simulation for construction projects. In: Proceedings of the first international conference on construction in developing countries, Karachi, Pakistan, pp 435–446

Azhar S, Khalfan M, Maqsood T (2012) Building information modelling (BIM): now and beyond. Australas J Constr Econ Build 12(4):15–28

Becerik B, Pollalis SN (2006) Computer aided collaboration in managing construction. Meridian System

Becerik-Gerber B, Kensek K (2009) Building information modeling in architecture, engineering, and construction: emerging research directions and trends. J Prof Issues Eng Educ Pract

Becerik-Gerber B, Gerber DJ, Ku K (2011) The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. J Inf Technol Constr 16:411–432

Bernstein PG, Pittman JH (2005) Barriers to the adoption of building information modeling in the building industry. Autodesk Building Solutions Whitepaper, Autodesk Inc., San Rafael, CA

Bjork B (2003) Electronic document management in construction research issues and results. J Inf Technol Constr (ITcon) 8:105–117

Carmona J, Irwin K (2007) BIM: who, what, how and why. Building Operating Management. Accessed on 5 Dec 2015. Available at: http://www.facilitiesnet.com/software/article/BIM-Who-What-How-and-Why–7546

Chien KF, Wu ZH, Huang SC (2014) Identifying and assessing critical risk factors for BIM projects: empirical study. Autom Constr 45:1–15

Computer Integrated Construction (CIC) Research Program (2012) BIM planning guide for facility owners. Version 1.0, April. The Pennsylvania State University, University Park, PA, USA

CRC Construction Innovation (2007) Adopting BIM for facilities management: solutions for managing the Sydney Opera House. Cooperative Research Center for Construction Innovation, Brisbane, Australia

Designing Buildings Wiki (2015) Liquidated damages in construction contracts. Accessed on 21 Dec 2015. Available at: http://www.designingbuildings.co.uk/wiki/Liquidated_damages_in_construction_contracts

Ding L, Zhou Y, Akinci B (2014) Building information modeling (BIM) application framework: the process of expanding from 3D to computable nD. Autom Constr 46:82–93

Eastman C, Teicholz P, Sacks R, Liston K (2008) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors. Wiley, New York

Eastman CM, Teicholz P, Sacks R, Liston K (2011) BIM handbook: a guide to building information modeling for owners, managers, designers, engineers, and contractors. Wiley, New York

Forbes.com (2015) Accessed on 9 Nov 2015. Available at http://www.forbes.com/

Goedert J, Meadati P (2008) Integrating construction process documentation into building information modeling. J Constr Eng Manage 134(7):509–516. doi:10.1061/(ASCE)0733-9364
Graphisoft (2015) Open BIM. Accessed on 27 Nov 2015. Available at: http://www.graphisoft.com/archicad/open_bim/about_bim/
GSA (2015) Facility management. Accessed on 1 Dec 2015. Available at: http://www.gsa.gov/portal/content/122555
Gu, N, Singh V, Taylor C, London K, Brankovic L (2007) Building information modelling: an issue of adoption and change management. In: ICAN conference 2007, 28 August, 2007, Sydney, Australia
Gu N, London K (2010) Understanding and facilitating BIM adoption in the AEC industry. Autom Constr 19(8):988–999
Hardin B, McCool D (2015) BIM and construction management: proven tools, methods, and workflows. Wiley, New York
Hergunsel MF (2011) Benefit of building information modeling for construction manager and BIM base scheduling. Worchester Polytechnic Institute
Howell I, Batcheler B (2005) Building information modeling two years later—huge potential, some success and several limitations. Accessed on 27 Nov 2015. Available at: http://www.laiserin.com/features/bim/newforma_bim.pdf
Irizarry J, Meadati P, Barham WS, Akhnoukh A (2012) Exploring applications of building information modeling for enhancing visualization and information access in engineering and construction education environments. Int J Constr Educ Res 8(2):119–145
Kymmell Willem (2008) Building information modeling: planning and managing construction projects with 4D CAD and simulations. McGraw Hill Professional, New York
Lee G, Sacks R, Eastman CM (2006) Specifying parametric building object behavior (BOB) for a building information modeling system. Autom Constr 15(6):758–776
Lu W, Peng Y, Shen Q, Li H (2013) Generic model for measuring benefits of BIM as a learning tool in construction tasks. J Constr Eng Manage 195–203. 10.1061/(ASCE)CO.1943-7862.0000585
Malaysian Construction and Contract Law (2012) Liquidated damages explained—how to calculate them. Accessed on 21 Dec 2015. Available at: https://simplymalaysia.wordpress.com/articles/liquidated-damages/liquidated-damages-explained-how-to-calculate-them/
McGraw-Hill Construction (2008) Building information modeling: transforming design and construction to achieve greater industry productivity, New York
Memon AH, Rahman IA, Memon I, Azman NIA (2014) BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level. Res J Appl Sci Eng Technol 8(5):606–614
Migilinskas D, Popov V, Juocevicius V, Ustinovichius L (2013) The benefits, obstacles and problems of practical BIM implementation. Procedia Eng 57:767–774
Mohd Harris I (2015) Strategic implementation of BIM in the Malaysian construction industry. Accessed on 13 October, 2015. Available at http://www.bimcenter.com.my/wp-content/uploads/2015/09/bimstrategic.pdf
Nursal AT, Omar MF, Nawi M N. M (2015) The design of TOPSIS4BIM decision support for building information modeling software selection. Jurnal Teknologi 77(5)
Osman Z, Omran A, Foo C (2009) The potential effects of variations orders in construction projects. Ann Fac Eng Hunedoara J Eng 7(2):141–152
Pena G (2011) Evaluation of training needs for building information modeling (BIM). M.A. Thesis, Civil Engineering, University of Texas at Arlington, United States
Porwal A, Hewage KN (2013) Building information modeling (BIM) partnering framework for public construction projects. Autom Constr 31:204–214
RICS (2015) 2.3 Measurement (‘remeasurement’ or ‘measure and value’). RICS draft guidance note—developing a building procurement strategy and selecting an appropriate procurement route. Accessed on 21 Dec 2015. Available at: https://consultations.rics.org/consult.ti/procurement/viewCompoundDoc?docid=2704532&partid=2704948&sessionid=&voteid=

Rogers J, Chong HY, Preece C (2015) Adoption of building information modelling technology (BIM). Eng Constr Architectural Manage 22(4):424–445

Rosenberg TL (2007) Building information modeling. Accessed on 8 Dec 2015. Available at https://www.academia.edu/1283324/Building_Information_Modeling

Sacks R, Treckmann M, Rozenfeld O (2009) Visualization of work flow to support lean construction. J Constr Eng Manage 135:1307–1315

Sageworks (2015) Industry report: inside the U.S. construction boom. Accessed on 9 Nov 2015. Available at http://www.inc.com/graham-winfrey/inside-the-us-construction-boom.html

Singh V, Gu N, Wang X (2011) A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Autom Constr 20(2):134–144

Smith DK, Tardif M (2009) Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers. Wiley

Srivastava A, Thomson SB (2009) Framework analysis: a qualitative methodology for applied policy research. JOAAG 4(2):9–72

Takim R, Harris M, Nawawi AH (2013) Building information modeling (BIM): a new paradigm for quality of life within architectural, engineering and construction (AEC) industry. Procedia Soc Behav Sci 101:23–32

Tey KH (2009) Factors affecting the contractor's mark-up size decision in Malaysia. Doctoral dissertation. Universiti Teknologi Malaysia, Faculty of Civil Engineering

Thompson DB, Miner RG (2007) Building information modeling—BIM: contractual risks are changing with technology. Accessed on 9 Dec 2015. Available at: http://www.aepronet.org/wp-content/uploads/2014/03/GE-2006_09-Building-Information-Modeling.pdf

von Both P, Kindsvater A (2012) Potentials and barriers for implementing BIM in the German AEC market: results of a current market analysis. In: 14th international conference on computing in civil and building engineering

Woo JH (2006) BIM (building information modeling) and pedagogical challenges. In: Proceedings of the 43rd ASC national annual conference, pp 12–14

Zahrizan Z, Mohamed Ali N, Tarmizi Haron A, Marshall-Ponting A, Abd Hamid Z (2013) Exploring the adoption of building information modelling (BIM) in the Malaysian construction industry: a qualitative approach. Int J Res Eng Technol 2(8)

Chapter 128
The Researches on Construction Project Manager Competency and Its Application

Jingru Li, Junpeng Li and Ruirui Xia

128.1 Introduction

Along with the industrial economy structure adjustment of our country, construction industry is currently facing with a more intense and severe challenge. According to statistics, the growth of national real estate development investment fell to 1% in 2015, which was a decline of 10% year on year. Facing with severe economic and industrial environment, the project has become the main carrier of completing the organization's activities in the field of construction projects (Zhang 2015a). As the leader of the project, the project manager has an important influence on the operation, control and performance of the project.

But as a leadership of the temporary organization–Project Manager Department, what the characteristics of competency a project manager should possess has been at the centre of the academic and industry for many years (Kang and Zhang 2013). Based on this situation, this paper analyzes current researches on construction project manager competency by literatures reviewing, and then discusses the direction of future research.

128.2 The Concept of Competency

The concept of competency comes from the Latin word—competency, which means adaptation, appropriate, and then it slowly developed into a discipline of psychology. As a foreign word, there are many translation of competency, such as competency, quality, qualification and so on. David McClelland, the teacher of Harvard University,formally put forward the concept of competency for the first

J. Li · J. Li (✉) · R. Xia
Department of Civil Engineering, Shenzhen University, Shenzhen, China
e-mail: 1749414579@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_128

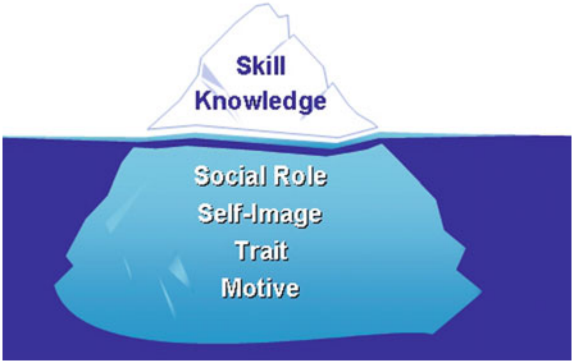


Fig. 128.1 The classical model of competency

time, which was defined as an individual in-depth feature that can distinguish persons from the outstanding achievements and ordinary work (McClelland 1973). Competency can be made of knowledge and skills, role orientation, self cognition, quality and motivation, which are the individual characteristics that can be reliably measured or counted, and distinguish excellent and general performance. David McClelland put forward the classical model of competency which is shown in Fig. 128.1.

The model shown in Fig. 128.1 embodies two parts, one is beyond the water and the other is in water. The part beyond the water includes the skill and knowledge which are acquired through learning and training, and can be easily measured. While the other is abstract, not easy to measure, acquire and change.

Nowadays, the competency research has come to the stage that the competency is largely impacted by the situation of the industry characteristics, organizational culture, and social interactions from the early stage that the competency is independent of the situation. According to the relevant researches, competency has different meanings to different people, and no universally accepted definition currently exists. Boyatzis (1982) considered that the competency was the potential individual ability and characteristic which can lead to the effective or excellent work performance (Boyatzis 1982). Spencer and Spencer (1993) regarded the competency as an individual potential characteristic associated with effective or outstanding performance (Spencer and Spencer 1993). But competency mainly includes the following three characteristics (Zhang 2015a; Chen 2008; Cui and Wang 2012): competency is dynamic and associates the background of the task; competency and job performance are closely related, which means competency can be used to predict the performance of employees; competency can distinguish person who has outstanding performance.

From the above analysis, the conclusion can be drawn: (1) the competency structure is hierarchical, and each level has difference in plasticity, culture, and acquired; (2) the elements and the level of competency requirements are not the same for different industries, organizations and positions (Zhang 2015a).

128.3 The Researches on Construction Project Manager Competency

128.3.1 The Responsibility of Construction Project Manager

Project manager is the sole agent of the enterprise in the engineering project who is responsible for the operation and management of the project (Chen 2008). It means the project manager plays a very important role in the full life cycle of the project (Zhang 2015a). Firstly, due to the complexity of project management, project manager need often contact, communicate and coordinate with various stakeholders to ensure that the project is carried out smoothly. Secondly, in order to ensure the successful outcomes are to be achieved, the project manager should control the cost, quality, schedule and information of the whole project. Notably, it places demands upon manager to respond flexibly to rapidly changing circumstances in order that he/she can replan and refocus their strategies for meeting competing project objectives.

128.3.2 Researches on the Competency of Construction Project Manager

At present, the project manager's competency has been defined by several the project management research systems in the field of international project management: (1) The Project Manager Competency Development Framework (PMCDP) from the Project Management Institute (PMI) describes three parts: knowledge, performance and personal competencies; (2) The International Project Management Association's (IPMA) competency Baseline—ICB3.0 describes the technical ability, behavior capability and environment factors of project management; (3) UK Association For Project Management (APM) divides the project manager ability into seven knowledge module and five stages (Cui and Wang 2012). Combined with the characteristics of the construction industry and the special position of the construction project manager, the construction project manager's competency researches mainly focus on the following aspects.

128.3.2.1 The Features of Construction Project Manager Competency

Because of the particularity and the complexity of project manager's responsibilities, the composition of the project manager's competency has been one of the hot research topics. Fisher (2011) drew the conclusion by the method of focus groups and individual interviews that the project manager should possess six competency traits including behavioral trait understanding force, influence, leadership, truly important behavior, conflict management skill and cultural awareness

Table 128.1 The elements of construction project manager competency (Zhang 2015a; Chen 2008; Cui and Wang 2012; Fisher 2011; Takey and Carvalho 2015; Yu et al. 2006; Lu 2008)

Elements	Subelements
Knowledge quality	Professional knowledge
	Work experience
	Supplementary knowledge
	Learning capacity
Project management skills	Risk management
	Conflict management
	Information acquisition
	Decision-making
	Human resources management
Communicate skills	Team spirit
	Interpersonal skills
	Coordination ability
	Developing relationship
Attitude and values	Achievement desire
	Customer awareness
	Master attitude
	Holistic view
	Initiative
Personal traits	Sense of responsibility
	Adaptability
	Innovation
	Self-confidence
	Justice integrity

(Fisher 2011). Takey found that a good project manager should occupy four competency characters which are project management abilities, skills, personal qualities, organization and coordination ability using the method of behavior research and expert panel (Takey and Carvalho 2015). Yu et al. (2006) conducted a research to build a project competency force feature library which contains core competency, professional background, project management competency, personal tacit quality (Yu et al. 2006). This paper sorts out the main elements of the construction project manager competency by reviewing related literatures (Table 128.1).

The competency elements of construction project manager are not only consistent with the classic competency model but also incorporate the characteristics based on the field of the engineering construction. Especially, the supplementary knowledge means that the project manager should have some knowledge of economic and foreign languages in addition to professional knowledge.

128.3.2.2 The Application of Construction Project Manager Competency

Along with the deepening of research, the competency research has come to the stage that the competency is largely impacted by the situation of the industry characteristics, organizational culture, and social interactions which is different from the early stage that the competency is independent of the situation. The research on project manager competency is more than just staying the level of characteristics competency, while the applying research on project manager competency becomes the hotspots. The applications of project manager competency mainly focused on the following aspects.

(1) **Prediction of management performance**

Intelligence has been regarded as one key predictor variable on individual job performance for a long time. However, several scholars have doubted about its prediction power. McClelland (1973) pointed out that the accuracy that intelligence predicts the level of performance was relatively poor; meanwhile there was a serious deviation (McClelland 1973). A few of scholars found that competency rather than the intelligence is better in predicting job performance. Peng researched the interaction between competency and performance from the perspective of input-output (Peng and Jing 2003). Dainty established the model of project manager's competency and predicted the performance of the project manager by the regression analysis (Dainty et al. 2004). Xu (2013) studied the correlation between project manager' competency and performance and then establish a performance evaluation system based on competency of the project manager (Xu 2013). Kang (2014) studied the impact mechanism of project manager competency on project performance combined with the team effectiveness theory, social exchange theory and multi-dimensional construction theory (Kang 2014). Zhang (2015b) performed a paths analysis and found the performance was affected by management skills and personal qualities while the cognitive trust was the intermediate variables (Zhang 2015b).

(2) **The selection of project manager**

The traditional selection of the project manager is based on job analysis to judge whether they occupy the project manager's knowledge, experience and personal qualities or not. The recruitment procedure is not very scientific, reasonable, fair, and lack of the evaluation and predictions for future job performance. The selection of project manager based on competency can make up these deficiencies of the traditional selection methods. It not only improves the selection process on the science, rationality and fairness, but also provides a complete picture of the post demand diagram for the selection of project manager. Yu et al. (2006) exploited the basic operation process and operation method of the project manager selection based on the library of project manager competency characteristics (Yu et al. 2006). Lu (2008) studied the selection model of project manager based on project manager competency dictionary which is established by behavior event interview and questionnaire (Lu 2008). Takey discussed the application of competency in personnel selection (Takey and Carvalho 2015).

(3) **Education and training**

Education and training are the important ways to enhance the project managers. Through education and training, the project manager can not only improve job performance, but develop potential ability. The research results of project manager competency will make education and training more focused on improving specially needed abilities of project managers. Tao discussed the problem needed to be thought when the competency model applied to training and development (Tao and Feng 2002). He discussed the theoretical and practical significance on the application of competency theory in training (He and Sun 2004). Dainty et al. (2005) had explored the application of project manager competency model in human resource management, vocational training and education (Dainty et al. 2005). Wang (2009) focused on the training based on project manager competency characteristics that include the construction of motivation, personality, quality, self-image, social roles, attitudes, knowledge and skills (Wang 2009).

128.4 Conclusions and Outlook

According to literature reviewing, this paper finds that the application researches on project manager competency mainly focuses on the performance prediction, the selection and the training of project managers, which has a wealth of theoretical and practical significance in the research of competency.

However, we believe that there are still at least two areas that need for further exploration. The first area needed for more attention is the application of project manager competency in career planning. A systematic career planning of is very important for the students. Therefore, unraveling "black box" between the project manager competency and the career planning for students has important theoretical significance in complementing the current research. Otherwise, these kind of studies also possess important practical significance in vocational education practice of the project managers.

Secondly, the relationship between personality and competency deserves further investigation. Personality is a stable indicator that may be used in selection of candidate of project manager who deserve extra training. Personality has a great impact on behavior pattern of one person and thus affects performance of the project manager. However, limited researches have been conducted on this topic. At the same time, the interaction among project manager competency, personality and performance is extremely rare and need for further research in the field of project management.

Acknowledgements This study is supported by the National Nature Science Foundation of China (No. 71503171).

References

Boyatzis RE (1982) The competent manager: a model for effective performance. Wiley, New York

Chen GZ (2008) Project manager competency model research. Civil Engineering Planning and Management of Central South University

Cui CY, Wang JP (2012) Construction project manager competency model research. Constr Econ 11:28–30

Dainty ARJ, Cheng MI, Moore DR (2004) A competency based performance model for construction project managers. Constr Manage Econ 22(8):877–886

Dainty ARJ, Cheng M, Moore DR (2005) Competency-based model for predicting construction project managers' performance. J Manage Eng 21(1):2–9

Fisher E (2011) What practitioners consider to be the skills and behaviours of an effective people project manager. Int J Project Manage 29(8):994–1002

He B, Sun XF (2004) The needs analysis based on the competency of training and its application. Bus Econ (1):66–67

Kang F (2014) A research on influence mechanism from project manager's competency to project performance. Tianjin University

Kang F, Zhang SB (2013) The project manager competency research: current situation and prospects. J Tianjin Univ (Social Science Edition) (1):35–40

Lu ZS (2008) Construction of competency model and its application to the selection and decision-making of project manager. Hefei University of Technology

McClelland DC (1973) Testing for competence rather than for intelligence. Am Psyehologist 28:1–14

Peng JF, Jing XJ (2003) Staff quality model design. China Renmin University Press, pp 18–174

Spencer LM, Spencer SM (1993) Competence at work: model for superior performance. Wiley, New York

Takey SM, Carvalho MMD (2015) Competency mapping in project management: an action research study in an engineering company. Int J Project Manage 33(4):784–796

Tao K, Feng M (2002) Research on training design based on competency. Foreign Econ Manage 24(4):18–21

Wang Z (2009) Study on training of the construction project manager. Tsinghua University

Xu SQ (2013) A Research on competency evaluation and performance appraisal system of the real estate project manager. Huaqiao University

Yu YH, Zhou P, Wei RJ (2006) The mechanism research based on the competency of project manager selection. Constr Econ (10):21–24

Zhang XL (2015a) Research on the relationship between the project manager's personality traits and project performance. Shandong University, Shandong

Zhang SD (2015b) Real estate enterprise project manager competency research effects on performance. J Eng Manage (1):154–158

Chapter 129
The Rise of the Smart Circular City: Intelligent Modelling of Cities for Improved Waste Reuse and Environmental Effects

R. Vrijhoef

129.1 Introduction

In the Netherlands alone the potential of the circular economy for the economy is estimated at an annual cost saving effect of 7.3 billion Euros and job creation of 54,000 jobs (Bastein et al. 2013). However this potential needs to be used in applied solutions in often local settings such as cities. Cities are reliant on local development for their employment, business activity, and reduction of energy consumption, waste and air pollution in the city. In these areas cities feel more and more pressure and they set high ambitions.

Last few years particularly cities have restrained the entering of polluting vehicles and improving the inner-city climate and air quality in general. Particularly construction transport is relevant to this aim while typically 30–40% of all transport is related to construction traditionally. This represents some 40% of vehicle emissions and road congestions. Governments and road users are keen to reduce this. While load factors of construction transport tend to remain structurally under 50%, in few cases down to 15% of their loading capacity a need to act is felt urgently (Vrijhoef 2015).

Another aim of the circular economy city is that waste is re-used from demolished buildings into new design solutions for the built environment. To establish this circular city, there is a need of information on various levels in an open source structure. Examples of such data need can be, where and when is what kind of building material needed, and where can building materials be gained by demolishing buildings? For these kinds of questions, a smart 3D city model is proposed.

R. Vrijhoef (✉)
Delft University of Technology, Delft, Netherlands
e-mail: r.vrijhoef@tudelft.nl

R. Vrijhoef
Utrecht University of Applied Sciences, Utrecht, Netherlands

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_129

This model should contain various types of intelligences, like GIS-BIM integration and real time and modelled environmental data. The combination of data creates new, innovative possibilities for the built environment (Heere et al. 2016).

129.2 The Idea and the Potential of the Smart Circular City

In this paper we conceptualise the smart circular city by a 3D city model aimed at improved reuse of construction and demolition waste (CDW) and reduced impact on the environment. The Ellen MacArthur Foundation, a "global thought leader" in the field of circular economy, defines the circular economy on their website (www.ellenmacarthurfoundation.org) as follows: "A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur Foundation 2012).

For the built environment, focus is on eliminating waste through re-use of materials and re-designing building components, systems and logistics. Most materials in the construction industry are part of the technical cycle as defined by the Ellen MacArthur Foundation (2012). This means we should design for remanufacturing and refurbishing to keep components and materials circulating in, and contributing to the economy. Circular systems use tighter, inner loops (e.g. maintenance, rather than recycling) whenever possible, thereby preserving more embedded energy and value. The technical cycle involves the management of stocks of finite materials. Use replaces consumption.

In general 40% of all raw material flows are related to building and construction. Reusing CDW is no new phenomenon in the construction industry. Already some three decades ago the urgency for reuse increased by the great demands for building materials. However compared to that time, currently technical possibilities to separate and reprocess CDW to be reused in new projects have increased dramatically. The demolishment in itself will cost extra labour (estimated 10%) and costs for control and compliance, but this is compensated by higher revenues of raw materials and preventing dumping costs. Preferably supply and demand would meet 'just in time' (Cramer 2015). However in practice, it is to be expected that meeting supply and demand will need digital support such as smart city data models.

129.3 Modelling the Smart 3D City by Integrating BIM and GIS

In the context of this paper and the digital 3D city model, a circular city could be described as an industrial and economic system where re-use of products and materials add value to every link in the system. By linking the information a tool can predict which route and which traffic system is the best to transport materials in the city (Vrijhoef et al. 2016).

For a circular city is important to know how much materials and resources you have available within the boundaries of a city, or, as Zhu states, "(…) location-based information or location intelligence about waste and recyclables and their potential stocks and values can help identify actions to build capacity, ensure an appropriate suite of services is available to communities and assist in site selection of waste collection facilities and the recycling industry in order to maximise economic benefits and minimise environmental impacts" (Zhu 2014). The city can turn into an urban mine, where resources can have a new meaning within the city.

Within the city there are various data resources that can help us to make the city more sustainable. Resources such as cycloramas (very detailed 3D panoramic photo imaging), point clouds, City Engine, traffic information, etcetera can provide us with very detailed and real time data. All these different types of intelligence can be combined into the 3D spatial city model, hereby we have the ability to show real time traffic information and real time and modelled environmental data. This combination of data establishes valuable information for the built environment (Heere et al. 2016).

The visualization of the urban mine makes it very easy to use materials from within the city. Most of these materials have been used in other buildings, infrastructure, industries or products and can be re-used (Cossu and Williams 2015). Within our research group an investigation has been done to develop a renovation with used materials from another building (in this case from the same owner). This investigation has been done to find out which information needs to be known about a resource and to see if this can be done by comparing different (BIM)models. This comparison can be done using a Building Information Model (BIM), but it can be more valuable if we integrate different types of information such as BIM and GIS and distribute this information (Heere et al. 2016; Fig. 129.1).

To make the developments and processes described above efficient, good data management is important. There is a need of data about the buildings, which are to be built or demolished and the surroundings of these buildings, including the infrastructure. A 3D city model is an effective way to manage these data. These models can handle an increasing number of tasks concerning environmental issues, like noise mapping, training simulators, disaster management, architecture, and city planning (Stadler and Kolbe 2007).

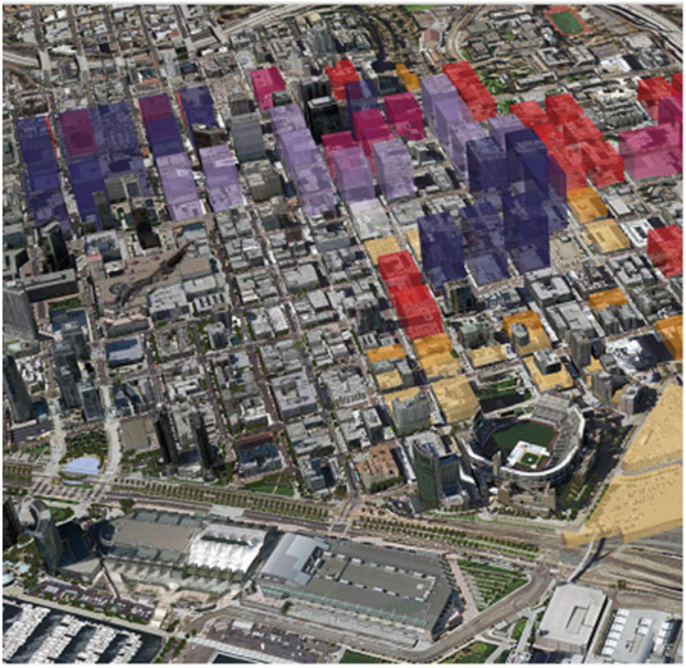


Fig. 129.1 Visualisation of integrated information from BIM and GIS. *Source* https://blogs.esri.com/esri/arcgis/files/2016/04/BIM-GeoDesign.png

129.4 Examples of Cities and Applications of 3D City Models

In various cities 3D city models have been developed (Fig. 129.2). In London thematic information has been displayed on a 3D city model and tools for city planning have been added (Source: http://www.geoinformatics.com/cybercity-3d-creates-3d-interactive-maps-to-help-cities-visualise-their-future. Seen: December 2015). The Planning Support System (PSS) for the City of London contains a 3D city model, data and the calculation rules, necessary for thematic analysis. In Berlin an open 3D city model has been developed that can be used by inhabitants and firms in the city (Source: http://www.3dcontentlogistics.com/en/solutions/demos/berlin-3d-city-model-smartmap-web/, seen December 2015). Shanghai applies a virtual reality theatre for city planners, architects, city officials and inhabitants and firms to collaborate. In Rotterdam and other Dutch cities digital city models have been developed e.g. to check building activities to building regulations (Stadler and Kolbe 2007).

Various types of analyses have recently been developed in 3D modelling such as establishing optimal solar panel orientation on roofs (Fig. 129.3).

Fig. 129.2 Examples of 3D city models of London, Berlin, Shanghai and Rotterdam (clockwise from upper left corner)

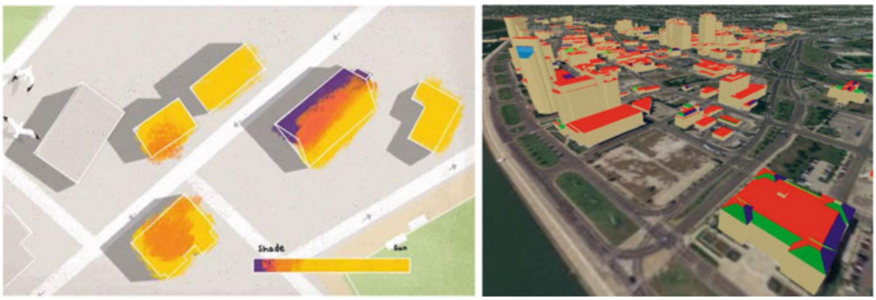


Fig. 129.3 Roof orientation analyses in 3D for optimised installation of solar panels

129.5 Case Study of a City Area in the City of Utrecht, Netherlands

The ongoing research this paper is based on originates from the idea to develop an integrated and open 3D data modelling platform for cities and city areas to do multi-thematic analyses for various aims such urban mining for increased reuse of construction and demolition waste and increase the insight in environmental impact.

In this case we looked into the area of the City of Utrecht called 'Werkspoorkwartier'.

A literature study has been conducted to find similar studies that have also done research on this topic. The conclusions en findings of a number of these studies were used in the rest of this study. A theoretical study has also been performed in which all of the key concepts and techniques that are involved when making 3D city models are explained. To determine the functions and purposes of a 3D city model, interviews were held with stakeholders like the city of Utrecht.

129.5.1 3D Smart Modelling of a City Area Based of Existing Data

Most data sources needed had appeared to deliver free and open data, making them very suitable to serve as a base for the rest of the 3D city model. Apart from these two data sources, there are many other data sources in the Netherlands which are available as open data. Many of the data sources which have been examined are not yet suitable for 3D, or are not free of charge.

To investigate what the possibilities were related to sharing the 3D city models, previously used software was looked at. Since all of the used software is made by Esri, it soon became clear that ArcGIS Online at the moment is the most suitable platform to easily and quickly develop open 3D city models. Adding rules to existing and readily available data appeared to be another suitable technique to develop smart and open 3D models, i.e. useful for multiple analytical purposes (Heere et al. 2016; Fig. 129.4).

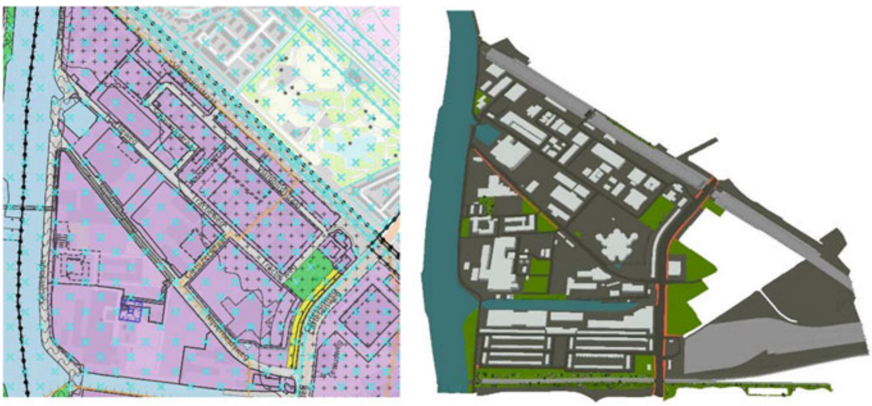


Fig. 129.4 Abstracting available maps and adding data rules to existing data and maps to develop a 3D city model

129.5.2 Applying the 3D Model for Improved CDW Reuse

In the time of the 3D model development in the City of Utrecht the business case was studied for reuse of construction and demolition waste (CDW). For ten housing projects with a prospected number of around 10,000 houses to be built in Utrecht the potential demand for CDW and interests of stakeholders were analysed.

Particular interest was for buildings about the same age and their possibility to use large quantities of the same raw materials from the demand and supply side. To determine which raw materials, materials and products are of interest, information and data from various sources have been collected, added to calculations models and studied, including governmental databases freely available and historic building and project data. Further analyses showed potential materials transfers from buildings being (partly) demolished (so called 'donor buildings') to buildings that would need materials to be built or renovated (so called 'receptor buildings') (Fig. 129.5).

129.5.3 Applying the 3D Model for Noise and Emission Analysis

The second application of the model was adding environmental data to the model. More specifically this included available traffic data from local traffic control and registration services and databases, and data of noise and greenhouse gas production by types of traffic passing. Noise models and emission calculations applied by governments and specialists concluded on 3D noise and emission profiles of infrastructure and their impact on buildings around (Fig. 129.6).

Fig. 129.5 Collecting and comparing data of buildings being (partly) demolished thus supplying materials ('donor buildings') and buildings in need for materials ('receptor buildings') (Jochemsen 2016)

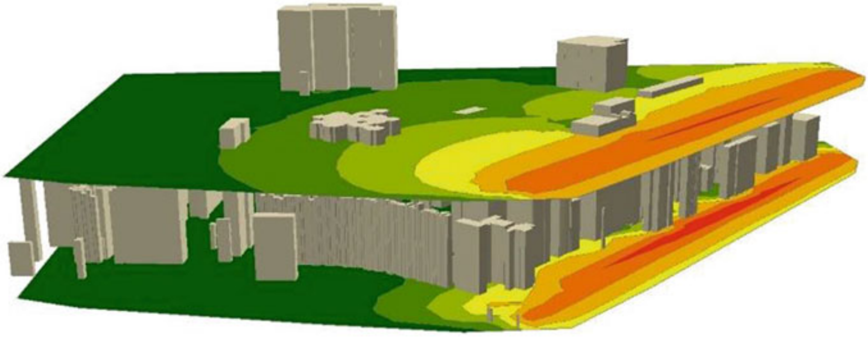


Fig. 129.6 Noise profiles visualised in the 3D city model of Werkspoorkwartier on 3 and 15 m height (Jochemsen 2016)

129.6 Conclusion

In this paper we explored the concept of the smart circular city and particularly the intelligent modelling of cities in order to do thematic analyses and gain insights to improve the circular aspects of cities such urban mining for increased reuse of construction and demolition waste. The applications of smart 3D city models would be capable of facilitating improved urban distribution and traffic control too and thus the decrease of greenhouse gas emissions.

Notwithstanding the potential benefits and applicability of 3D city modelling for circular and environmental aims in this seminal paper, further research needs to be done in these directions. Particularly this applies to the further development of the 3D city model as an open and multi-thematic platform for various calculations and analyses

More specifically the proposed smart 3D city model distinguishes itself from traditional models by adding open data and analytical functions to the model, like environmental data and tools, so that the model is used for communication, analysis and decision making purposes.

The potentials advantages of such a smart and open 3D city model in urban planning are various. It could include multiple views on data analyses with higher and lower abstraction levels, and therefore useful for anyone. It can contain or be connected a lot of data and databases, which improves the quality of the analyses done through the model. The calculation modules linked to the model could be available to anyone involved with urban planning, not only professionals but also inhabitants of the city.

This would make the smart ad open 3D city model a very powerful tool. None of the 3D city models currently available do this, and none of them contain so much data and functions so to be useful to professionals as to the wider public. This will need further research with potential partners including local government, firms and universities. This paper is aimed to be another step in that process achieving the smart circular city.

References

Bastein T, Roelofs E, Rietveld E, Hoogendoorn A (2013) Kansen voor de circulaire economie in Nederland. TNO Report 2013 R10864. Delft: TNO (In Dutch)

Cramer J (2015) Green Deal Cirkelstad: Voorwaarden voor een marktconforme aanpak. Utrecht Sustainability Institute (In Dutch)

Cossu R, Williams ID (2015) Urban mining: concepts, terminology, challenges. Elsevier, pp 1–3

Ellen MacArthur Foundation (2012) Towards the circular economy vol 1: economic and business rationale for an accelerated transition. Available at: http://www.ellenmacarthurfoundation.org. Downloaded: 2 Dec 2015

Heere E, Mens J, Trip C, Vreeswijk K (2016) The digital 3D city model as a base data infrastructure for innovative solutions for the built environment. In: SBE2016 conference Utrecht

Jochemsen J (2016) 3D Stadsmaquettes. B.Sc thesis. Hogeschool Utrecht, Utrecht, Netherlands (In Dutch)

Stadler A, Kolbe TH (2007) Spatio-semantic coherence in the integration of 3D city models. In: Proceedings of the 5th international symposium on spatial data quality, Enschede, Netherlands, pp 1–8

Vrijhoef R (2015) Reducing the environmental impact and improving the efficiency of construction transport. In: Egbu C, Farshchi MA (eds) Proceedings CIB joint international symposium going north for sustainability: leveraging knowledge and innovation for sustainable construction and development. IBEA, pp 363–375

Vrijhoef R, Vreeswijk K, De Boer M (2016) Circular hub: towards zero transport emission and zero construction and demolition waste on a local scale. In: SBE2016 conference Utrecht

Zhu X (2014) GIS and urban mining. Resources 3:234–247. http://www.mdpi.com/2079-9276/3/1/235

Chapter 130
The Simulation and Evaluation Method and Technology of Passenger Flow in Urban Rail Terminal

W.K. Huang, M.W. Hu and S.Y. Zhai

130.1 Introduction

Urban rail terminal combines private transportation, bus and the rail into a comprehensive passenger hub. Reasonable planning, design and the scientific operation of the rail terminal, can improve the performance of urban public transport system, such as shortening the travel time and improving the Level of Service (LOS) (Kuby et al. 2004; Yin 2012). Therefore, it is significant to evaluate and improve the operational efficiency and safety of the urban rail terminal. And it also provides the reference for the planning of other urban rail terminals.

Although some researches have been conducted about the pedestrian simulation and evacuation in urban rail station, there are still lack of the details of the pedestrian activities. Furthermore, there are few discussions about the inbound/outbound time, walking distance and LOS of multi-scale evaluations. In this study, we have fully considered the passenger passing the gates, ticketing, taking the escalator, as well as waiting in a queue, realistically modeling the behavior of pedestrians in the rail terminal. A pedestrian simulation model is established by the complex system modeling software AnyLogic (The AnyLogic Company 2016). A series of studies including simulations under different situation, evaluation, and layout-optimization could be executed based on the model as well.

W.K. Huang · M.W. Hu (✉) · S.Y. Zhai
College of Civil Engineering, Shenzhen University,
518060 Shenzhen, Guangdong Province, China
e-mail: humw@szu.edu.cn

W.K. Huang
e-mail: hwk727@163.com

S.Y. Zhai
e-mail: s_un0128@qq.com

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_130

130.2 Methodology

In this paper, the social force model (SFM) was chosen to simulate the behavior and movement of pedestrians. The microscopic simulation is capable of evaluating the organization of passenger flow visually and quantitatively. At the microscopic level, each passenger's movement is modeled, including his or her walking speed, step size and frequency, and walking trajectory. The SFM was introduced two decades ago by Helbing and Molnár (1995), and has since then been frequently investigated in the literatures and is also implemented in commercial software (Johansson et al. 2015; Kretz et al. 2011). The SFM can make pedestrians move in the simulation environment just like in the real world, who can also react to other pedestrians and the surrounding environment.

Based on a wide range of considerations (such as the application fields, the technology maturity and the cost), the pedestrian simulation software AnyLogic Professional 7.3 was selected as the pedestrian simulation platform. Pedestrian Library, an advanced library of AnyLogic, and secondary development was used to simulate and evaluate the behavior and movement of passenger flow in the urban rail terminal.

130.2.1 Model Architecture

The simulation of pedestrian generally includes three stages: acquisition of basic data, modeling, and simulation analysis and optimization (The AnyLogic Company 2016). The first step is to collect the basic data of the model by the field investigations and the traffic operation characteristics of the simulation area. Secondly, according to layout of facilities, the data of passenger flow and other related parameters, we can establish a pedestrian simulation model comprising environment and behavior. Finally, we can run the simulation to evaluate the performance of the urban rail terminal by performance index, animation and pedestrian density map, and optimization can be further carried out.

The pedestrian model is built by the AnyLogic to realize the function of simulation and evaluation. Our research route is shown in Fig. 130.1.

130.2.1.1 Environment Modeling

In environment modeling, the simulation environment is established for pedestrian movements after the detailed layout was obtained by the field survey. In other words, this process stores the space information into AnyLogic's database to provide necessary environmental details for the pedestrian behaviors and movements. It involves many elements, such as walls and pillars which represent the boundaries of a building, staircases and escalators connecting different floors, ticket vending

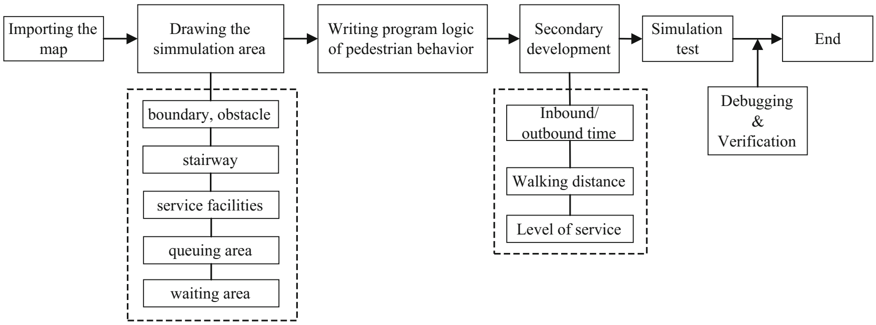


Fig. 130.1 The flow chart of pedestrian model by AnyLogic

machines (TVM), ticket gates, the shielding doors, the queue before the service facilities, and passenger waiting area. The main blocks of Pedestrian Library used in environment modeling are shown in Table 130.1.

130.2.1.2 Pedestrian Behavior Modeling

After the environment modeling, the pedestrian behavior modeling should be carried out. Pedestrian behaviors are a series of traffic-related activities in the process of traveling by urban rail, and these behaviors would be affected by environment, physiological and psychological factors. The method of behavior modeling is DEM. Based on this method, the pedestrian activities can be divided into a series of different and orderly activities, which mainly includes generating, walking paths, walking destination, waiting, services and so on. The orderly activities of a typical urban rail terminal are shown in Fig. 130.2.

The most common blocks in AnyLogic to model pedestrian behavior include: *Ped Source* (generates pedestrians), *Ped Sink* (disposes incoming pedestrians), *Ped Go To* (guides pedestrians to go to the specified location), *Ped Change Ground*

Table 130.1 The main environmental blocks of pedestrian library

Type	Environmental facilities	Blocks	Instruction
Fixtures	Walls, pillars, and other obstacles	Rectangle wall, circular wall, wall	Setting the forbidden area in the simulation area
	Stairs and escalators	Ped escalators, area	Setting the parameters of escalators or stairs such as shape, speed and so on
Services	Service facilities and queues	Service with lines, service with area	Setting the location of services and the queue, serving time and other parameters
Others	Waiting area	Rectangular area, polygonal area	Defining the waiting areas

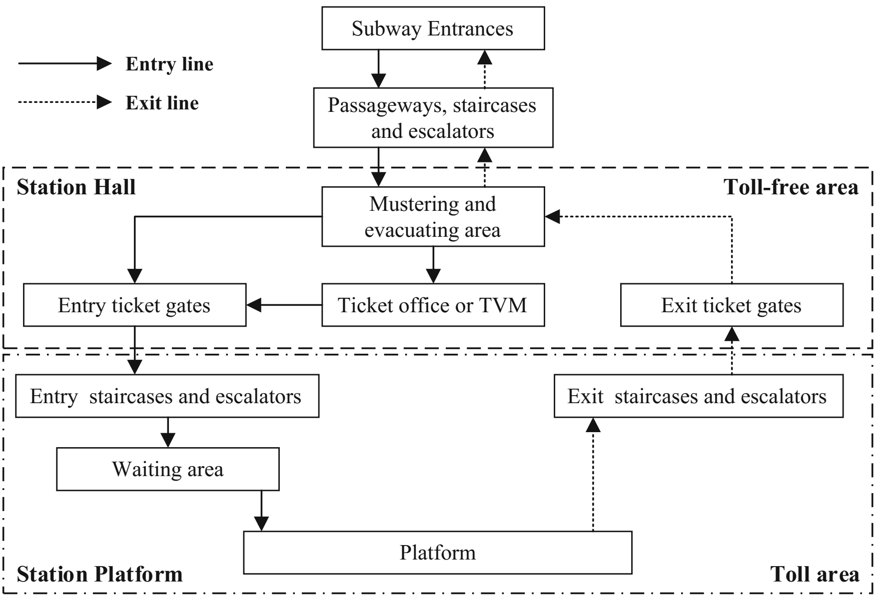


Fig. 130.2 Passenger flow in the urban rail terminal

(guides pedestrians to change floor), *Ped Wait* (guides pedestrians to go to the specified location and wait there for a specified period of time), *Ped Service* (directs pedestrian flow through group of services). The commonly used pedestrian group blocks are *Ped Group Assemble* (pedestrian group concentration), *Ped Group Change Formation* (guides group to change its formation to a specified one) and *Ped Group Disassemble* (pedestrian group dissolution) (The AnyLogic Company 2016).

130.2.1.3 Secondary Development

Compared to other pedestrian simulation software, AnyLogic has an open system structure and supports secondary development (Borshchev 2013). Furthermore, AnyLogic can work with other softwares or applets written in Java or other languages, providing greater flexibility for pedestrian simulation modeling (Hu 2011). Even some performance index can not be directly obtained, users can use secondary development through application program interface to calculate them.

130.2.2 Performance Index

We present an evaluation method mainly based on the efficiency of passenger's boarding and alighting process and comfort of passengers. By analyzing passengers boarding and alighting time, walking distance and comfort within the area of a station, we select three performance indices: inbound/outbound time, walking distance and LOS. These indices can not only reflect the actual operation of the urban rail terminal well, but also help to identify the bottleneck and compare the different alternatives easily (Chen et al. 2013).

(1) Inbound/Outbound time

The inbound time is for passengers boarding the train, and its value is the sum of time of all related activities. For each passenger, it is calculated from the time entering the subway hall to the time boarding the train. The activities in this process mainly include: purchasing ticket, security check, passing the ticket gate, taking the escalator, waiting, walking, etc. The outbound time is for passengers alighting the train. It is calculated from the time alighting to the time leaving the station. The main activities of outbound passenger flow include: walking, queuing, taking the escalator, and passing the ticket gate, etc. (Dai and Zhao 2010). The formulations for calculating the inbound/outbound time of each passenger are as follows:

$$t_{inbound} = \sum t_i = t_{Leave,In} - t_{Enter,In} \tag{130.1}$$

$$t_{outbound} = \sum t_j = t_{Leave,Out} - t_{Enter,Out} \tag{130.2}$$

Where $t_{inbound}$ represents the average time of inbound passengers staying in the station (*second*); t_i represents the time of the specific activity i of inbound passenger flow (*second*); $t_{Leave,In}$ represents the time stamp of passenger boarding the train (*second*); $t_{Enter,In}$ represents the time stamp of passenger entering the station through the entrance (*second*); $t_{outbound}$ represents the average time of outbound passengers staying in the station (*second*); t_j represents the time of the specific activity j of outbound passenger flow (*second*); $t_{Leave,Out}$ represents the time stamp of passenger leaving the station through the entrance (*second*); $t_{Enter,Out}$ represents the time stamp of passenger getting off the train (*second*).

(2) Walking distance

The walking distance is the length of passenger's movement in the simulation area, which reflects the comfort of the rail terminal to some extent. For the longer passengers walked, the more uncomfortable ones felt and the more inefficient the rail terminal operated (Chen et al. 2013). The method to obtain walking distance can be collecting the coordinate of each passenger in each time stamp during his staying in the area and then calculated the walking distance based on formulation (130.3).

$$s = \sum_{i=t_{Enter}}^{t_{Leave}} \sqrt[2]{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2 + (z_{i+1} - z_i)^2} \tag{130.3}$$

where s represents the distance of passenger traveled (m); (x_i, y_i, z_i) represents the coordinate of passenger in this time stamp; $(x_{i+1}, y_{i+1}, z_{i+1})$ represents the coordinate of passenger in next time stamp.

(3) LOS

LOS is a comprehensive index to measure the operation condition and the quality of the service (Transportation Research Board 2010). It mainly aims at the safety level of the facilities and the comfort of pedestrians. It can be evaluated according to the number of pedestrian flow crossing, the evacuation time, capacity of specific facilities, or according to the pedestrian space, speed and so on. This paper takes pedestrian space as a primary index to evaluate the LOS according to the Highway Capacity Manual (HCM 2010).

130.3 Case Study

Shenzhen North Railway Station is one of the largest high-speed railway station in South China. It is the core terminal of the Shenzhen railway network. The overall layout is shown in Fig. 130.3. Compared with the traditional railway station, Shenzhen North transportation hub integrates urban rail, bus, taxi, coach, cars and other traffic modes. Passengers can enjoy the convenience of seamless transfer in the hub. In addition, the Huanzhong Line terminal is an important part of this transportation hub, which plays a key role in passengers' assembling and

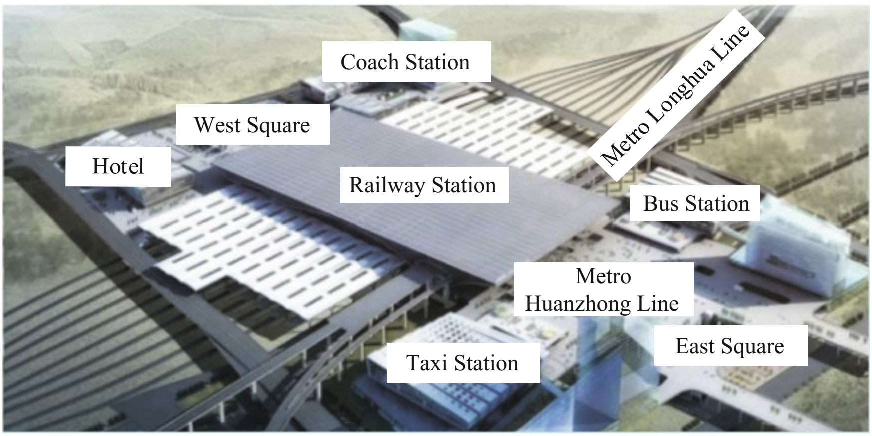


Fig. 130.3 Aerial view of the whole terminal

disassembling. Thus we established a detailed simulation and evaluation of Shenzhen North terminal on Huanzhong Line.

130.3.1 Data

130.3.1.1 Facility Layout

Shenzhen North terminal on the Huanzhong Line is the one with two side platforms. The total area is about 10,000 m^2. It has two floors, the basement level is the platform, and the ground floor is the station hall. The layout of station hall and the platform are shown in Fig. 130.4.

The area shown in Fig. 130.4 is the main scope to be simulated. There are six ticket gates groups within the terminal, namely A, B, C, D, E, F. Among them, the two light blue arrows shown inbound passenger flow, while the other four are for outbound passenger flow. On both sides of the paid area there are TVM groups G and H, which can provide one-way tickets for passengers. Referring to *Code for Design of Metro* (*GB 50157-2013*), the angle between the escalator and the level is 30° and the tangent speed is 0.65 m/s.

130.3.1.2 Pedestrian Characteristics Investigation

Pedestrian walk speed, step size, and frequency are passenger flow characteristics and basic parameters for a pedestrian simulation model. On the hall level, passenger

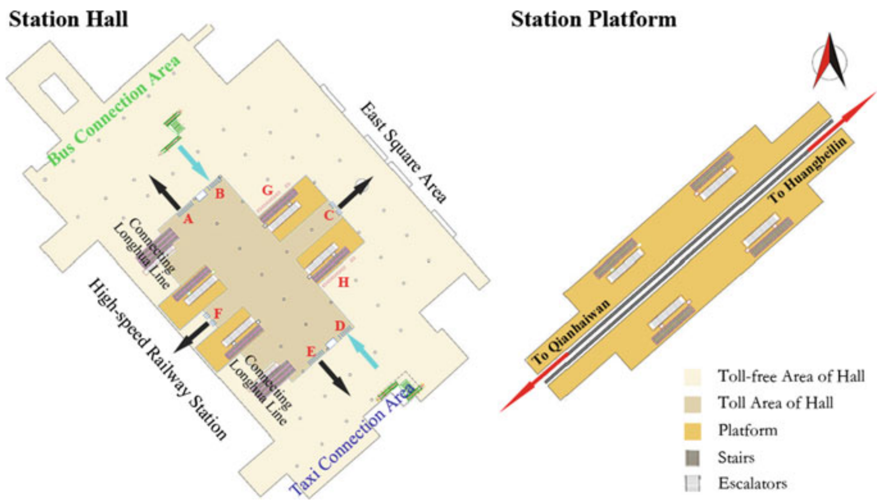


Fig. 130.4 The layout of Shenzhen North terminal on HuanZhong Line

Table 130.2 Passenger walk statistics at Shenzhen North terminal on HuanZhong Line

Passenger walk statistics	Crowd category	Avg. speed (m/s)	Avg. step size (m)	Avg. frequency (step/s)
Free flow area	Male	1.46	0.69	2.10
	Female	1.22	0.59	2.07
	All	1.34	0.64	2.09
Congestion area	Male	1.16	0.60	1.92
	Female	1.05	0.54	1.94
	All	1.11	0.57	1.94

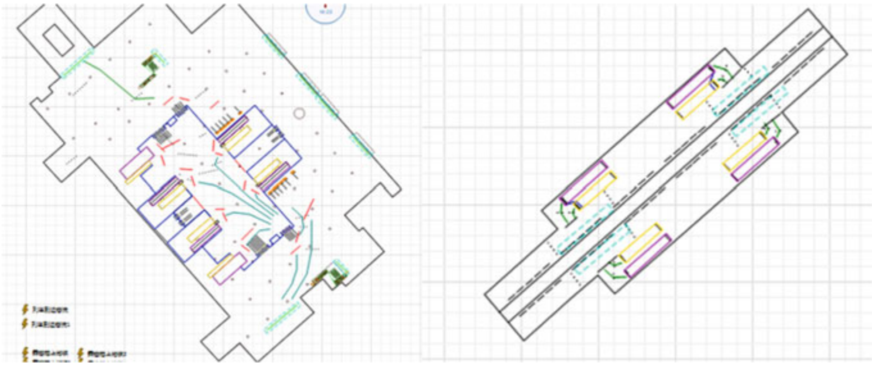


Fig. 130.5 The pedground of the platform and hall

walk areas are classified into free flow areas and congestion areas. Then we investigated passenger walk speed, step size, and frequency walk characteristics influenced by gender under the two walk area conditions. The statistics are summarized in Table 130.2. According to the survey, the current market penetration rate of the transit card in Shenzhen reaches about 70%.

130.3.2 Model Establishment

We use the Pedestrian Library of AnyLogic to establish the pedestrian model, which comprises environment modeling and behavior modeling. The layout and facilities of this terminal were defined graphically as parts of the environment of model base on the background, and their properties also were set up suitable. The environment of Shenzhen North terminal on Huanzhong Line (includes platform and hall) was built, as shown in Fig. 130.5.

We also dragged the blocks of Pedestrian Library to define pedestrian behaviors according to the passenger flow. And then the objects were connected as an

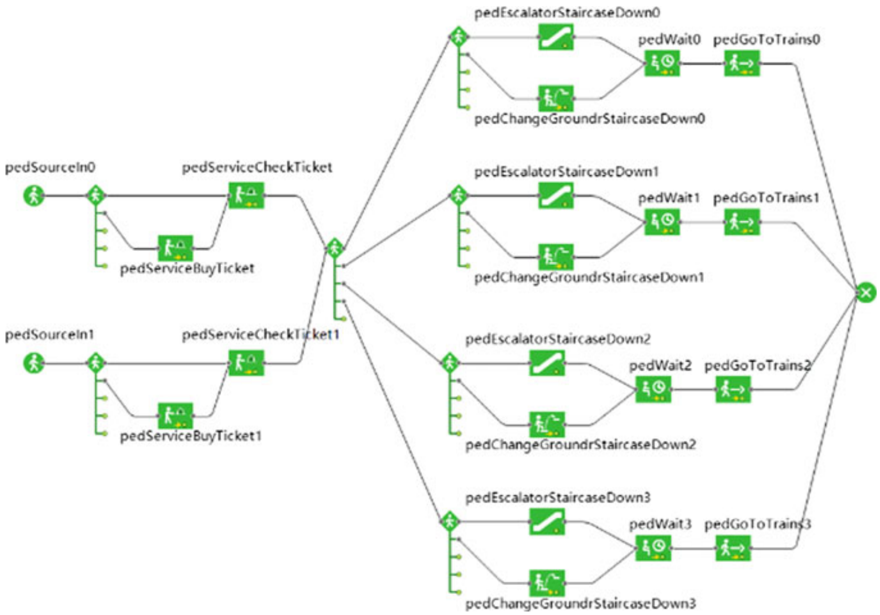


Fig. 130.6 The flowchart of pedestrian behavior of inbound passenger flow

activities flowchart, their properties were set based on the investigation, as shown in Fig. 130.6. Pedestrians move in this model, reacting to other passengers and obstacles.

130.3.3 Simulation Analysis

The current situation of this terminal at peak hour (baseline) were simulated and analyzed in this section. We explore whether the model's output is in accordance with the field test at the same time. Based on the fact that passengers are developing the habit of using transit card to pay the fare, the impact of the transit card penetration rate of the inbound passenger flow is studied further.

130.3.3.1 Simulation and Output

According to field data, the entry and exit flow volume and distribution and walk characteristics in the peak hours were input into the pedestrian model. The 3D animation screenshots are displayed in Fig. 130.7, where red pedestrians represent inbound passengers while blue ones represent outbound passengers.

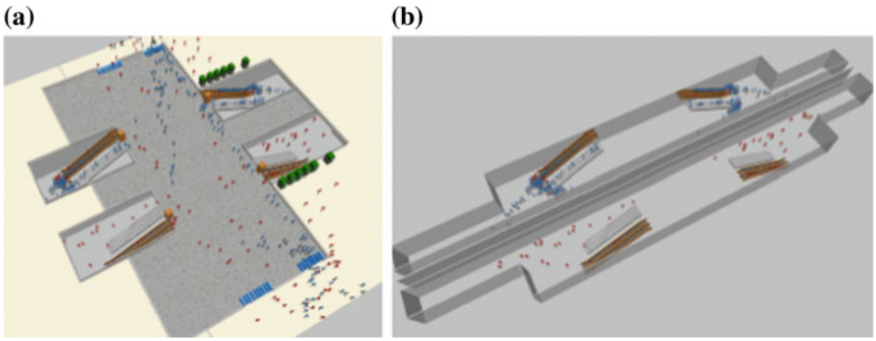


Fig. 130.7 Simulation screenshot of station hall (**a**) and station platform (**b**)

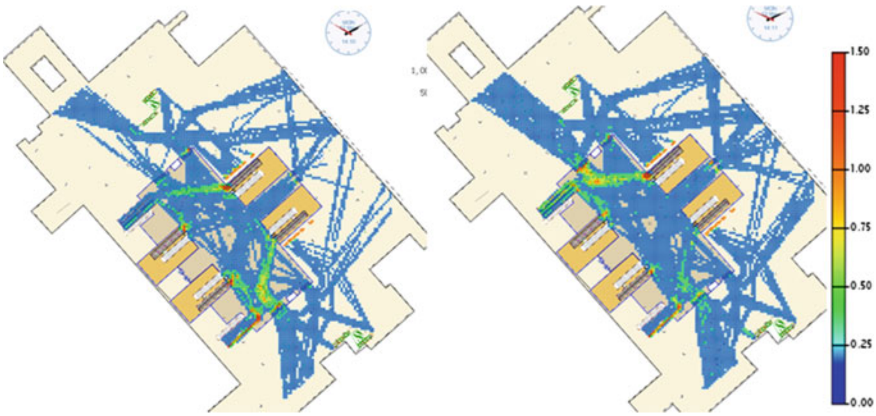


Fig. 130.8 The density map of pedestrian model at different model time

The simulation result of pedestrian model was just as the actual observation in the weaving conflict area. In this kind of area, pedestrian would choose to dodge other pedestrian, and this would cause the density higher than adjacent area, and pedestrian walk speed is relatively slower than other areas. According to the real-time pedestrian density map, we can clearly see the change of the weaving area with time, as shown in Fig. 130.8.

After the pedestrian model running, all data of passengers were collected and stored into the database. The statistical characteristics of inbound and outbound passenger flow are calculated and shown in Table 130.3. The result shows that the average inbound time is higher 44.8% than outbound time, since inbound passengers should wait for the subway arrival and even some of them need to buy one way ticket. As for walking distance, inbound passengers walk more 18.6% distance on average than outbound passengers.

Table 130.3 Statistical indicators of the pedestrian model

Passenger flow	Inbound/outbound time		Walking distance	
	Media	Mean	Media	Mean
Inbound	274 s	281 s	115 m	121 m
Outbound	190 s	194 s	103 m	102 m

130.3.3.2 Transit Card Penetration Rate

As mentioned earlier, the transit card penetration rate in baseline is 70%. The distribution of travel time and walking distance of inbound and outbound passenger flow under current situation are shown in Fig. 130.9.

With the development of technology, the form of transit card is becoming increasingly diverse, such as traditional card, smart phone with NFC and so on. As a result, the penetration rate of transit card would reach a higher value even 100% in the near future. So we conducted another simulation with 100% transit card penetration rate to find the maximum traffic benefits of inbound flow through promoting transit cards.

The result shows that the inbound time and walking distance can be reduced to a large extent and the efficiency of the terminal would also be improved when the transit card penetration rate reach 100%. The probability density distribution of inbound time is shown in Fig. 130.10, and more detailed statistical indicators are shown in Table 130.4. In summary, the average inbound time with 100% penetration rate is 253 s, while average time of baseline is 281 s, reduced by 10%. As for walking distance, passengers walk less 14.0% distance on average than baseline.

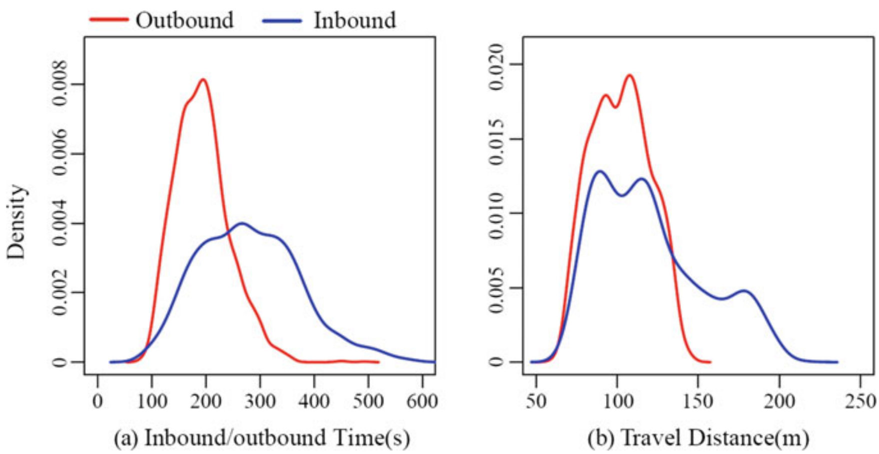


Fig. 130.9 The distribution of inbound/outbound time and walking distance

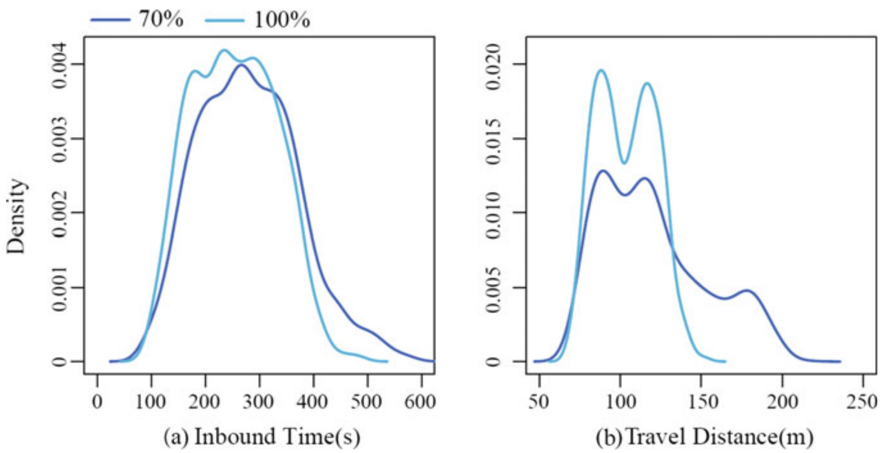


Fig. 130.10 The distribution of time and walking distance of inbound passenger flow under different transit card penetration rate

Table 130.4 Statistical indicators under different transit card penetration rate

Transit card penetration rate	Inbound/ outbound time		Walking distance	
	Median	Mean	Median	Mean
70%	274 s	281 s	115 m	121 m
100%	252 s	253 s	101 m	104 m
Benefits	8.0%	10%	12.2%	14.0%

130.4 Conclusion

In this paper, we discussed the passenger flow organization of Shenzhen North terminal on Huanzhong Line. We proposed a simulation-based evaluation method. Based on this method, we used the complex system simulation software AnyLogic to build a microscopic model, then analyzed and evaluated qualitatively and quantitatively facilities layout, and performance of passenger flow organization. This paper provided a general method for the evaluation of the layout of the urban rail terminal facilities.

The simulation results not only show that the model's output is in accordance with the field test, but also can provide technical support for the operation and management of urban rail terminal. In addition, the sensitivity analysis of the transit card penetration rate shows that the 10% inbound time and 14.0% walking distance could be cut down and the efficiency of terminal would be improved.

In the next study, we can further improve and refine the evaluation indicators according to the needs of the urban rail terminal planning and layout. For example, we can optimize the layout of urban rail terminal facilities to reduce the transfer time and distance.

Acknowledgements The authors thank Shenzhen Key Laboratory Research Grant of Urban Rail Transit (Grant Number: SZCSGD201402), Shenzhen Science and Technology Plan (Grant Number: JCYJ20140418181958475) and National Natural Science Foundation of China (Grant Number: 50878132) for funding and support.

References

Borshchev A (2013) The big book of simulation modeling: multimethod modeling with AnyLogic 6. AnyLogic North America

Chen L, Song R, Li Z, Li T (2013) Simulation study on the layout of metro station hall facilities based on AnyLogic. J Transport Inf Saf 31

Dai J, Zhao J (2010) Evaluation methods for high-speed rail station facility. Urban Transport Chin 08:16–22

Helbing D, Molnár P (1995) Social force model for pedestrian dynamics. Phys Rev E 51: 4282–4286

Hu M (2011) A survey and simulation of passenger flow organization of the Shenzhen urban rail transit station, international conference of Chinese Transportation Professionals, Nanjing pp 2991–2997

Johansson F, Peterson A, Tapani A (2015) Waiting pedestrians in the social force model. Physica A 419:95–107

Kretz T, Große A, Hengst S, Kautzsch L, Pohlmann A, Vortisch P (2011) Quickest paths in simulations of pedestrians. Adv Complex Syst 14:733–759

Kuby M, Barranda A, Upchurch C (2004) Factors influencing light-rail station boardings in The United States. Transp Res Part A Policy & Pract 38:223–247

The AnyLogic Company (2016a) AnyLogic 7 pedestrian library reference guide, St. Petersburg, Russian Federation

The AnyLogic Company (2016b). AnyLogic 7 pedestrian library tutorial, St. Petersburg, Russian Federation

Transportation Research Board (2010) Highway Capacity Manual 2010

Yin J (2012) Passenger transfer between urban rail transit and national railway terminal. J Railway Eng Soc

Chapter 131
The Supply and Demand for Green Housing in China: A Micro-Perspective

L. Zhang, H. Liu, X. Wang and X. Tang

131.1 Introduction

As construction activities are a major contributor to environmental pollution, lots of researches from both industry and academia have investigated mechanisms to boost green building development as a crucial part of environmental conservation. Green building development is especially important in emerging economies such as China. About half of the annual floor area of new construction in the world is currently being built in China.[1] Especially, the residential sector accounts for around 78% of Chinese building energy consumption.[2]

Although regulations and incentives from the government may be necessary in the face of market failures, it is most desirable for the market mechanism to automatically boost sustainable development in the private sector (Zhu and Lin 2004). However, the conventional wisdom of business sectors on environmental protection is that the additional costs and risks involved may erode financial performance. Companies will not voluntarily embrace standards that internalize significant environmental and social costs that remain externalities to their competitors. This is particularly the case in the real estate sector, where there is a widespread perception that building green is significantly more expensive than

[1]Source: Ministry of Science and Technology of the PRC, *Special Plan for Green Building Technology Development in the 12th Five Year Plan Period*. May, 24th, 2012. (www.most.gov.cn/fggw/zfwj/zfwj2012/201206/t20120608_94918.htm).
[2]Source: U.S. Energy Information Administration.

L. Zhang · H. Liu (✉)
Department of Construction Management, Hang Lung Center for Real Estate, Tsinghua University, Beijing, China
e-mail: liuhy@tsinghua.edu.cn

X. Wang · X. Tang
Department of Construction Management, Tsinghua University, Beijing, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_131

traditional methods of development, resulting from the costs of green equipment, materials, management and consultancy (Kahn and Kok 2014). Although green buildings can provide a wide variety of benefits, including cost savings from reduced energy, water and waste, and enhanced occupant productivity and health (Kats 2003), all these are enjoyed by the occupants. Therefore, developers are especially vulnerable to build green properties, unless there are sufficient demand and enough economic returns. Therefore, the green price premium has been extensively tested in the last decade to estimate the green building demand (Deng and Wu 2014; Eichholtz et al. 2010; Kahn and Kok 2014). However, there is still no concrete evidence on whether the buyers/renters do know the greenness of these buildings and pay the premiums for it.

To advance this long-standing and contentious debate empirically, this paper investigates the determinants of green housing supply and demand based on the data of listed real estate enterprise and a survey of residents in Beijing. The remainder of the paper is organized as follows. Section 131.2 provides background information about the Chinese Green Building Label. Sections 131.3 and 131.4 analyze the drivers for green housing supply and demand respectively. Section 131.5 concludes.

131.2 Chinese Green Building Label

It is widely recognized in developed economies that certifications for the sustainability of buildings have influenced the consumption choices by providing trustworthy information, which would in turn influence suppliers' decision (Heinzle et al. 2013). Although some developers in China also pursue the LEED certification, which is the most internationally prestigious program, the vast majority of LEED-certified buildings in China are high-end offices and commercial complexes hosting foreign and upper-class clienteles (Zhou 2015). Due to the absence of green building certification system, Chinese real estate developers also distinguish their developments from other buildings by advertising the green technologies employed in their buildings. Words like "green (*lv-se*)", "energy-saving (*jie-neng*)" or "environmentally-friendly (*huan-bao*)" are often adopted to attract homebuyers who believe these buildings do have a superior performance in energy consumption or living comfort (Zheng et al. 2012). Considering the presale arrangement, which allows the developers to list the units when they are still under construction, the information asymmetry problem is more severe. Residents can only learn about the actual greenness of buildings by living in it for months and receiving energy bills. Risks result from lack of trustworthy information may reduce the green building demand.

To facilitate the green building development, the Chinese government began implementing the "Chinese Green Building Label" (CGBL) program in 2008. The evaluation standards cover six categories: land, energy, water, materials, indoor environment and operation. In each category, the detailed requirements are summarized as a list including mandatory, general and preferred items. A building seeking to be green-certified has to meet all of the mandatory items first, and its rating level is then determined based on how well it meets the general and preferred items. However, the promotion of the CGBL rating was sluggish in the early years, as depicted in Fig. 131.1. The 1587 green-certified housing projects by 2015 only accounted for a tiny fraction of new residential buildings, and the gross floor space only reached about 7% of the newly-built gross floor space that year.

131.3 Drivers for Green Housing Supply

131.3.1 Data

We start with the determinants of developers' green practice based on the data of real estate enterprises listed on Shanghai, Shenzhen and Hong Kong exchanges through the Wind and CSMAR databases. Based on the public notification by MOHURD, we calculated the green housing projects developed by each enterprise in each year. In this way, we established a panel dataset of 171 enterprises during 2008–2016, as listed in Table 131.1.

131.3.2 Empirical Analysis

We first directly relate the number of green housing projects to the main indicators of enterprises and control for the year- and enterprise-fixed effects. The model is specified in Eq. (131.1):

$$GREEN_{it} = \alpha_i + \gamma_t + \beta_1 \ln(ASSET)_{it} + \beta_2 LEVERAGE_{it} + \beta_3 ROA_{it} + \varepsilon_{it} \quad (131.1)$$

Where: α_i is the enterprise-fixed effect to capture the omitted enterprise characteristics; γ_t is the year-fixed effect to capture the omitted time-related factors; the logarithm of *ASSET* indicates the size of enterprises; *LEVERAGE* is a measure of enterprises' financial risk; *ROA* indicates the profitability of enterprises; ε_{it} is the error term clustered at the enterprise level. The result is reported in Column (1) of Table 131.2.

However, considering that the number of green-certified housing projects is censored at zero, we adopt the Tobit model in the empirical analysis; that is:

$$\begin{gathered} GREEN^*_{it} = \alpha + \gamma_t + \beta_1 \ln(ASSET)_{it} + \beta_2 LEVERAGE_{it} + \beta_3 ROA_{it} + \mu_i + \varepsilon_{it} \\ GREEN_{it} = GREEN^*_{it},\ \text{if}\ GREEN^*_{it} > 0;\ GREEN_{it} = 0,\ \text{if}\ GREEN^*_{it} \le 0 \end{gathered} \quad (131.2)$$

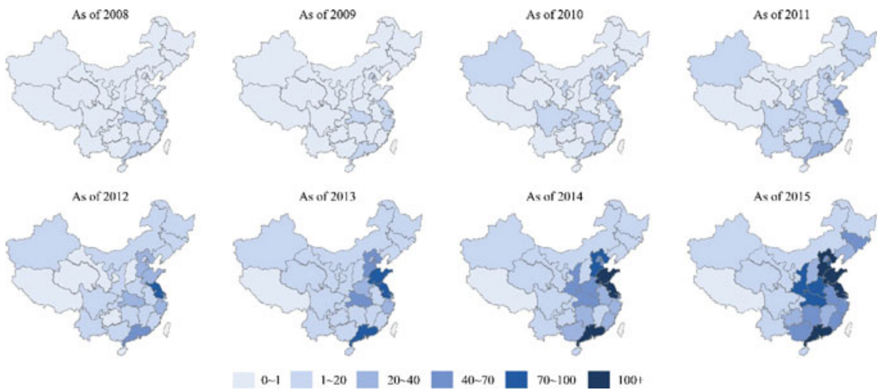


Fig. 131.1 Accumulative number of green-certified residential buildings. *Source* Authors' calculations based on data from MHURD

Where: $GREEN^*$ is the latent dependent variable, while *GREEN* is the number of housing projects receiving green building certifications by enterprise-year, which we can directly observe; the random effect at the enterprise level (μ_i) and the error term (ε_{it}) are assumed to be mutually independent. As reported in Column (2), only the coefficient of enterprise size is significant in this model. In Column (3), we further include time-invariant variables, *SOE* and *LISTED_HK*. It is interesting to find that the enterprises listed on the exchanges in Mainland China are more likely to adopt green practice. However, the state-owned enterprises have not acted as first movers in the green housing development. In Column (4), we investigate the role of chairman's educational attainment. It is widely believed that higher-educated people evaluate environmental sustainability as a more important issue (Dippold et al. 2014; Kahn 2002), and thus the education level of the top executives may have an impact on the enterprise's environmental strategy. However, we have not found any significant influence of such factors. One possible explanation may be that the environmental responsibility of enterprises are undervalued in current China, the top executives mainly focus on the enterprise's financial performance. In addition, we acknowledge that this result should be interpreted with cautious as only 39 enterprises in this sample are available in terms of the chairman's education information. In Columns (5) and (6), we replace the dependent variable with star-weighed number of green-certified housing projects (*GREEN_STAR*), and the results remain robust.

Table 131.1 Definition and summary statistics of key variables

Variables	Definition	Obs.	Mean	SD	Min	Max
GREEN	Number of green-certified housing projects the enterprise developed in the year	1368	0.372	1.746	0	28
GREEN_STAR	Star-weighed number of green-certified housing projects the enterprise developed in the year	1368	0.699	3.591	0	72
ASSET	Total asset of the enterprise (10^{10} yuan)	1490	5.84	26.2	0.000134	680
LEVERAGE	Debt-to-asset ratio of the enterprise	1331	0.665	0.493	0.0145	13.63
ROA	Return-on-asset of the enterprise	1331	−0.00130	1.418	−51.30	6.109
SOE	Whether the enterprise is state-owned (1 = yes, 0 = o/w)	171	0.392	0.490	0	1
LISTED_HK	Whether the enterprise is listed on the Hong Kong Exchange (1 = yes, 0 = o/w)	171	0.380	0.487	0	1
CHAIRMAN_BA	Whether chairman of the board holds a bachelor's degree (1 = yes, 0 = o/w)	39	0.256	0.442	0	1
CHAIRMAN_MA	Whether chairman of the board holds a master's degree (1 = yes, 0 = o/w)	39	0.590	0.498	0	1
CHAIRMAN_PHD	Whether chairman of the board holds a doctor's degree (1 = yes, 0 = o/w)	39	0.0769	0.270	0	1

Table 131.2 Drivers for green housing supply

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	*GREEN*	*GREEN*	*GREEN*	*GREEN*	*GREEN_STAR*	*GREEN_STAR*
ln (*ASSET*)	0.087	0.951	1.238	4.035	2.496	8.865
	(1.96)*	(3.69)***	(4.41)***	(3.93)***	(4.31)***	(3.85)***
LEVERAGE	0.163	0.192	−0.886	−5.567	−2.460	−12.004
	(1.98)**	(0.11)	(−0.46)	(−0.81)	(−0.61)	(−0.78)
ROA	0.023	−0.273	−0.591	6.077	−1.387	−2.539
	(1.39)	(−0.43)	(−0.90)	(0.17)	(−1.01)	(−0.03)
SOE			0.379	2.030	0.569	3.816
			(0.43)	(1.00)	(0.31)	(0.84)
LISTED_HK			−2.514		−5.163	
			(−2.49)**		(−2.49)**	
CHAIRMAN_BA				−0.025		1.603
				(−0.01)		(0.21)
CHAIRMAN_MA				−1.201		−1.382
				(−0.34)		(−0.18)
CHAIRMAN_PHD				3.095		8.235
				(0.64)		(0.76)
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Enterprise-fixed effect	Yes	No	No	No	No	No
Enterprise-random effect	No	Yes	Yes	Yes	Yes	Yes
Constant	−2.064	−41.945	−47.034	−108.636	−96.519	−239.975
	(−1.92)*	(−6.40)***	(−6.90)***	(−4.59)***	(−6.71)***	(−4.52)***
Observations	1331	1331	1331	308	1331	308
Number of enterprise	171	171	171	39	171	39
R^2	0.058					
Log-likelihood	−2008	−688.9	−685.1	−197.9	−810	−238

Notes (1) Robust t-statistics in parentheses; (2) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

131.4 Drivers for Green Housing Demand

131.4.1 Data

We conducted a survey in three green housing projects in Beijing and three comparable conventional housing projects in the corresponding submarkets. These three pairs of projects locate in Dongcheng, Fengtai and Haidian Districts respectively and were all apartment buildings. Such approximately even distribution in the space increases the representativeness of the sample. Questionnaire consists of three parts: questions about their apartments, green buildings, and personal characteristics. Besides the greenness of their current apartments (*LIVING_GREEN*), we also ask them about the price premium they are willing to pay (*WTP*) for green apartments compared with all-else-equal non-green counterparts. Characteristics of residents are listed in Table 131.3. In addition, we ask the respondents whether they are familiar with the CGBL, and investigate their understanding of green buildings with a multi-choice question.

We further compare green and non-green residents' knowledge about green buildings in Table 131.4. It is clear that residents in green housing projects know more about the CGBL. Non-green residents' understanding about green buildings focuses on reducing carbon emission and waste disposal, which are environmental externalities. Green residents are more aware of the superior performance of green buildings in built environment and living comfort. However, around thirty percent of both green and non-green residents have the misconception that green buildings must be collections of state-of-art technology.

131.4.2 Empirical Analysis

We start with the analysis of respondents' current green or non-green housing choices by Logit models. The model is specified in Eq. (131.3):

$$\begin{aligned} LIVING\_GREEN_i^* &= \boldsymbol{X}_i\beta + \mu_i^* = \beta_1 AGE_i + \beta_2 EDUCATION_i + \beta_3 INCOME_i + \mu_i^* \\ P(LIVING\_GREEN_i) &= P\left(LIVING\_GREEN_i^* > 0\right) = P\left(\mu_i^* > -\boldsymbol{X}_i\beta\right) \end{aligned} \tag{131.3}$$

We only keep those respondents who are accurately aware of their apartments' green status. For instance, some respondents had no idea about whether the apartments they lived in were green or not, and some respondents in non-green housing projects even thought their apartments were green. These respondents actually did not consider the greenness of buildings when they made their home choices. The results are listed in Table 131.5. *AGE* is significant in the purchase choice of green housing, as older people may care more about living comfort and health benefits, which are exactly the selling points of green housing. The green

Table 131.3 Definition and summary statistics of key variables

Variables	Definition	Obs.	Mean	SD	Min	Max
LIVING_GREEN	Whether the respondent is living in a green housing project (1 = yes, 0 = o/w)	401	0.429	0.496	0	1
WTP	Willingness-to-pay for green housing compared with all-else-equal non-green housing (yuan/m^2)	401	259.6	220.4	0	800
AGE	Age of the respondent	401	41.21	10.50	30	60
EDUCATION	Year of education the respondent received	401	15.61	2.890	9	22
INCOME	Annual income of the household (10^4 yuan)	401	27.59	18.84	10	100
FEMALE	Whether the respondent is female (1 = yes, 0 = o/w)	401	0.546	0.498	0	1
OWNER	Whether the respondent is the owner of the apartment (1 = yes, 0 = o/w)	401	0.731	0.444	0	1
GREEN_CERT	Respondent's knowledge of CGBL (1 = "Do not know it"; 2 = "Only heard of it"; 3 = "Familiar. Know its logo"; 4 = "Very familiar")	401	1.404	0.676	1	4
GREEN_ENERGY	Whether the respondent considers green buildings to save energy and reduce carbon emission (1 = yes, 0 = o/w)	401	0.758	0.429	0	1
GREEN_WASTE	Whether the respondent considers green buildings to reduce "three wastes" during the building's life cycle (1 = yes, 0 = o/w)	401	0.579	0.494	0	1
GREEN_COMFORT	Whether the respondent considers green buildings to provide higher living comfort (1 = yes, 0 = o/w)	401	0.706	0.456	0	1
GREEN_TECH	Whether the respondent considers green buildings to be high-tech (1 = yes, 0 = o/w)	401	0.319	0.467	0	1

Table 131.4 Comparison of green and non-green residents' knowledge of green buildings

Variables	Non-green (μ_1)	Green (μ_2)	t-test (H_0: $\mu_1 = \mu_2$)
Respondents	229	172	
GREEN_CERT	1.323	1.512	−0.188***
GREEN_ENERGY	0.825	0.669	0.157***
GREEN_WASTE	0.607	0.541	0.0660
GREEN_COMFORT	0.646	0.785	−0.139***
GREEN_TECH	0.332	0.302	0.0300

Notes *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 131.5 Drivers for green housing demand

Dependent variable	*LIVING_GREEN*			*WTP*
Sample	(1) All	(2) Owners	(3) Renters	(4) All
AGE	0.043	0.057	0.003	2.103
	(3.45)***	(3.87)***	(0.11)	(1.67)*
EDUCATION	−0.030	0.015	−0.149	18.309
	(−0.61)	(0.26)	(−1.40)	(3.89)***
INCOME	0.024	0.018	0.056	−0.063
	(3.55)***	(2.37)**	(2.93)***	(−0.10)
FEMALE				9.435
				(0.40)
OWNER				32.420
				(1.20)
GREEN_CERT				67.393
				(3.75)***
GREEN_ENERGY				−47.323
				(−1.67)*
GREEN_WASTE				133.738
				(5.55)***
GREEN_COMFORT				46.216
				(1.78)*
GREEN_TECH				−139.884
				(−5.35)***
Constant	−2.176	−3.401	0.685	−283.760
	(−2.01)**	(−2.56)**	(0.32)	(−2.66)***
Observations	317	242	75	401
Pseudo R^2	0.0678	0.0720	0.129	0.0185
Log-likelihood	−203.6	−154.2	−45.27	−2392

Notes (1) Robust t-statistics in parentheses; (2) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

housing owners and renters seems to be richer than their non-green counterparts. We acknowledge that there are some limitations in these Logit models, as it is inevitably that some other factors may influence residents' choices of the housing projects, even though we have already controlled the location characteristics to some extent by pairing. The residents actually choose a bundle of characteristics besides greenness when they bought green apartments.

To eliminate the effects of other factors, we ask directly about the monetary premium that respondents are willing to pay for green apartments compared with all-else-equal non-green ones. We employ the Tobit model to estimate the determinants of residents' preference. The result is reported in Column (4) of Table 131.5. It suggests that older and higher-educated residents are willing to pay more for green housing, while the income is not significant. One explanation for his inconsistency with the result in Column (1) may be that while higher-educated residents evaluate environmental sustainability as a more important issue, the actual payment is still influenced by their economic capabilities. The second explanation is that the lack of public information about green housing hindered their purchase choices, as most of them stated their worry about the fake- or over-advertising. In addition, we try to estimate the influence of residents' knowledge about green buildings. The result suggests that the residents more knowledgeable of green building certification have higher WTP. We also find that knowledge about the waste reduction and living comfort improvement of green buildings increase residents' WTP, but the misunderstanding that green buildings are collections of state-of-art technology will reduce residents' WTP for green housing. It is interesting that knowledge about energy-saving of green buildings actually lower residents' WTP, which is supported by other research which suggests that in developing countries residents prefer improving living comfort through consuming more energy (Lin and Liu 2015).

131.5 Conclusion

The government has been trying to facilitate the green building development by the market mechanism. Based on the data of Chinese listed real estate enterprises and a survey, we provide a preliminary evidence about the determinants of green housing supply and demand. The results suggest that in current China, only large enterprises and those listed on exchanges in Mainland China are prone to invest in green housing. The profitability of the enterprise and top executives' educational attainment have no significant impact on the enterprise's green practice, and the state-owned enterprises have not taken the lead. From the demand side, we find that the richer and older residents self-selected into green housing projects. We also find that residents who know more about the certification system or the features of green buildings (e.g. waste reduction during the building's life cycle and improvement in living comfort) are willing to pay more for green buildings. Therefore, the economic development and more public information of green buildings for residents could stimulate the green housing demand, which may in turn increase the developers' attention to the adoption of green housing design and technology.

While this research is a first step for the thorough understanding of the green housing development from the economy perspective, there are several important issues on the agenda for the future research. First, it is important to open the black box of real estate enterprises' green housing development decision, such as how the enterprises are stimulated by the stakeholders' pressures and the role of different departments in the decision. Second, more evidence about how the green housing demand encourages the enterprises' supply is called for.

Acknowledgements This research is funded by the National Natural Science Foundation of China (Project No: 71673156).

References

Deng Y, Wu J (2014) Economic returns to residential green building investment: the developers' perspective. Reg Sci Urban Econ 47:35–44

Dippold T, Mutl J, Zietz J (2014) Opting for a green certificate: the impact of local attitudes and economic conditions. J Real Estate Res 36(4):435–473

Eichholtz P, Kok N, Quigley JM (2010) Doing well by doing good? Green office buildings. Am Econ Rev 100(5):2492–2509

Heinzle SL, Yip ABY, Xing MLY (2013) The influence of green building certification schemes on real estate investor behaviour: evidence from Singapore. Urban Stud 50(10):1970–1987

Kahn ME (2002) Demographic change and the demand for environmental regulation. J Policy Anal Manag 21(1):45–62

Kahn ME, Kok N (2014) The capitalization of green labels in the California housing market. Reg Sci Urban Econ 47:25–34

Kats G (2003) The costs and financial benefits of green buildings. Capital E, Washington, DC

Lin B, Liu H (2015) A study on the energy rebound effect of China's residential building energy efficiency. Energy Build 86:608–618

Zheng S, Wu J, Kahn ME, Deng Y (2012) The nascent market for "green" real estate in Beijing. Eur Econ Rev 56(5):974–984

Zhou Y (2015) State power and environmental initiatives in china: analyzing china's green building program through an ecological modernization perspective. Geoforum 61:1–12

Zhu Y, Lin B (2004) Sustainable housing and urban construction in China. Energy Build 36(12):1287–1297

Chapter 132
Trend Analysis of the Labor Supply and Demand in China's Construction Industry: 2016–2025

H. Ye and Y. Zhang

132.1 Introduction

With the continuous expansion of industrial scale, known as a labor-intensive industry, the construction industry requires more labor force. Because of its features—large market demand, low technological threshold, relatively higher income, a large number of rural surplus labor are absorbed into the construction industry. But in recent years, China's demographic dividend definitely disappears and the rural surplus labor force continues to decrease, which causes a "partial" labor shortage, leads the construction industry to lose the comparative advantage of low labor costs, and creates the market environment of carrying out construction industrialization.

The theory of labor supply and demand started early and is relatively well-developed. Freeman (1987) argued that the number of labor supply depends on the size and composition of the population, the proportion of workers who are willing to work, as well as the factors of education, skill level and so on. After analyzing the above factors, Hoffman (1989) and other scholars reached a conclusion that labor participation rate and the actual working hours are main factors that influence the number of labor supply. Malthus (1959) proposed that labor supply will be in the infinite elastic situation in a certain time period. Lewis (1954) argued that there were a large number of zero marginal productivity of labor in the developing countries, and people in the agriculture industry were confronted with "insufficient employment" and unlimited supply of "surplus labor". Thus, the supply of labor was unlimited in some years.

At present, the academic research for the number of labor in the construction industry mainly focused on descriptive analysis, which is that, in a stable macroeconomic background, though the demand for the construction industry labor

H. Ye · Y. Zhang (✉)
School of Economics & Management, Beijing Forestry University, Beijing, China
e-mail: zyj2015@bjfu.edu.cn

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_132

will continue to expand in the future, with the decline of rural labor force and the intensification of the aging phenomenon, future labor supply to the construction industry will reduce, so that labor shortage appears. Wen et al. (2005) put forward that, construction safety and work environment problems in some degree hindered the transfer of rural surplus labor force to the construction industry, leading to migrant workers who want to engage in the construction industry gradually reduce. Xiaolin and Ningyu (2014) believed that China's urbanization would slowly increase the labor demand of the construction industry. Zhongfu and Shiqing (2015) thought that the main reasons of the shortage of labor in the construction industry of migrant workers were gradually decreasing growth of migrant workers engaged in the construction industry, the prominent aging problem of construction workers, and the deviation of migrant workers' occupation tendency from the traditional construction industry. With the "partial" labor shortage increasing, and Chinese construction labor market becoming unsteady, scholars started to do quantitative research about labor force in the construction industry. Dai (2013) proposed that 2012–2016 labor demand in Construction was at an average annual growth rate of 0.97%, and Liu (2015) found that the balance time of construction labor supply and demand by considering the low effective labor supply of the elderly is 2014.

To effectively solve the problem of shortage of labor in the construction industry, Tharmaratnam and Shaw (1985) argued that construction industrialization had more advantages in scale economy, construction cycle and low impact on the environment. Ye and Guo (2004) believed that China's construction industry must take the road of construction industrialization to achieve intensive production. Wu et al. (2013) analyzed the correlation between the construction industrialization and the labor cost, and it was considered that compared with the traditional construction methods, the labor productivity of construction industrialization had been greatly improved.

As an emerging research point, the prediction model of the labor supply and demand in the construction industry and its impact on the construction industry are still in the exploratory stage. Therefore, this paper focuses on two issues: firstly, how the demand and supply number of construction labor will change in the future; secondly, how the future demand and supply situation will effect on construction industrialization.

132.2 Analysis of the Labor Supply in China's Construction Industry

China's Construction labor force consists of about 95% of the rural labor force and 5% of the urban labor force, and the main cause of the shortage of migrant workers taken into account is that the rural labor cannot continue unlimited supply (Dai 2013). Therefore, this paper studies the supply of migrant workers in the construction industry to replace the supply of labor force in the construction industry.

Based on the existing research, this paper puts forward the prediction model of the future supply of migrant workers in the construction industry, as follows:

Set i as the year, S_i as the number of migrant workers in the construction industry of i year, T_i as retirement rate of i year, M_i as the rural surplus labor force of i year, N_i as the ratio of rural surplus labor force engaged in the construction of i year, then:

$$S_{i+1} = S_i * 1 - T_i + M_i * N_i \qquad (132.1.1)$$

The Eq. (132.1.1) shows, there are four influencing factors in the future supply of the construction industry (Fig. 132.1).

This paper calculates the number of actual demand for labor in agriculture and the number of rural surplus labor in 2000–2014 by adopting the method of the estimation of the rural surplus labor force (Li 2012; Xinghua 2013).

This paper predicts the number of migrant workers engaged in the construction industry in 2009–2015 with the use of the Eq. (132.1.1).

From the analysis of Fig. 132.2, it is found that the actual number of migrant workers in the construction industry is almost in the same trend with the predicted number. The correlation coefficient is 0.92, which shows that the model has certain rationality and feasibility.

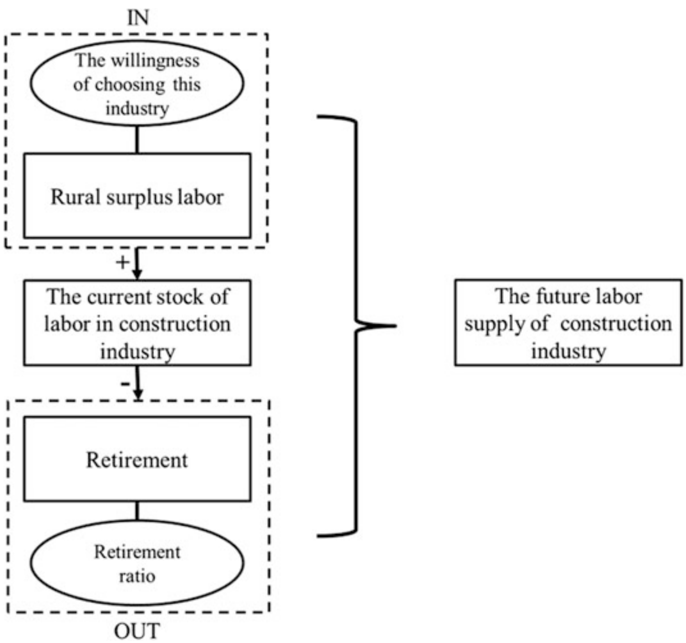


Fig. 132.1 Impact factors for the future labor supply in construction industry. *Note* Due to data availability, the model used in this paper does not consider cross-industry labor mobility

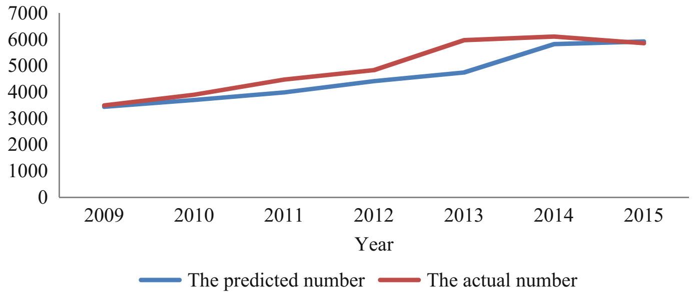


Fig. 132.2 Comparison of the actual and predicted number of migrant workers: 2009–2015 (10 thousand)

Table 132.1 Predicted number of surplus rural labor: 2015–2025 (10 thousand)

Year	Rural surplus labor force	Year	Rural surplus labor force
2015	422	2021	111
2016	337	2022	88
2017	270	2023	71
2018	216	2024	57
2019	173	2025	45
2020	138	–	–

The rural surplus labor force in 2015–2025 is predicted by using the grey model (Table 132.1).

This paper makes two hypotheses based on the current situation and possible future changes, and calculates them with Eq. (132.1.1) (Table 132.2):

Hypothesis I: According to *the Chinese Human Resources* and *Social Security Almanac* of 1990–2012 and *the Chinese Statistical Almanac of 1990–2015*, the average annual retirement rate in 1990–2012 is 4.7%, and the rural labor's age structure in 2011–2015 is relatively stable, and the Chinese labor population ratio in 2001–2014 stabilizes at 62%. Therefore, the average annual retirement rate of 2016–2025 is assumed as 4.7%.

Table 132.2 Predicted labor supply of China's construction industry: 2016–2025 (10 thousand)

Year	The future labor supply of the construction industry		Year	The future labor supply of the construction industry	
	Hypothesis I	Hypothesis II		Hypothesis I	Hypothesis II
2016	5718	5909	2021	4646	5588
2017	5507	5874	2022	4438	5496
2018	5291	5820	2023	4235	5400
2019	5074	5752	2024	4039	5301
2020	4858	5674	2025	3849	5200

Based on *the 2015 Migrant Workers Monitoring Report*, the proportion of migrant workers engaged in the construction industry stabilizes at 22% in 2013–2015, so let's assume that the average annual rate of migrant workers engaged in the construction industry in 2016–2025 is 22%.

Hypothesis II: Taking into account the new retirement scheme proposed in 2016, the average retirement age will be prolonged from 55 years old to 60 years old, so it is assumed that the annual average retirement rate of 2016–2025 is 2.2%.

According to the new requirements of the construction industry of China, the future work environment of the construction industry will be greatly improved. Because the working environment of the construction industry is the primary factor for migrant workers to choose jobs, it is assumed that the ratio of migrant workers engaged in the construction industry in 2016–2025 is 28%.

132.3 Analysis of the Labor Demand in China's Construction Industry

This paper adopts the future labor demand prediction model of the construction industry (Dai 2013), verifies it and modifies the parameters as following:

Set i as the year, D_i as the average number of construction workers of i year, O_i as the total output value in construction industry of i year, P_i as the labor productivity in construction industry of i year, $R_{O(i+1)}$ as the increasing rate over the previous year of the total output value in construction industry of $i+1$ year, $R_{L(i+1)}$ as the increasing rate over the previous year of the labor productivity in construction industry of $i+1$ year, then:

$$D_{i+1} = D_i\left(1 + R_{O(i+1)}\right)/\left(1 + R_{Li+1}\right) \quad (132.2.1)$$

From the analysis of Fig. 132.3, the trend of GDP is similar to the trend of the total output value of construction industry, and the correlation coefficient is 0.997, showing the development trend of GDP is highly correlated to the development trend of total output value of construction industry. Therefore, this paper estimates the average annual growth rate of total output value of construction industry by the average annual growth rate of GDP, then:

$$B_{i+1} = \frac{D_{i+1}}{G_i} * C_i \quad (132.2.2)$$

Set i as the current five-year plan, G_i as the average annual actual growth rate of GDP in current five-year plan, D_{i+1} as the average annual planning growth rate of GDP in the next five-year plan, C_i as the average annual actual growth rate of total

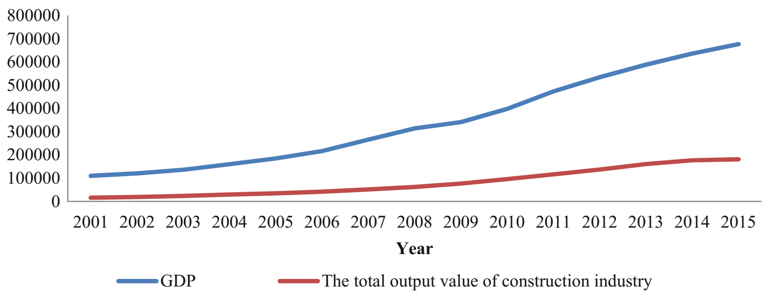


Fig. 132.3 GDP and the total output value of construction industry in 2001–2015 (100 million yuan)

output value of construction industry in current five-year plan, B_{i+1} as the average annual actual growth rate of total output value of construction industry in the next five-year plan.

According to the outline of *the 13th Five-Year Plan,* the rate of urbanization will reach 60% in 2020, 5% higher than that of the 12th Five-Year period. The research of Li and Wei (2005) showed that the construction industry had a strong industrial correlation effect to other industries, but little dependence on other industries. Therefore, the future development trend of China's construction industry can be roughly judged: large development space with growth rate slowed down.

From the calculation with the Eq. (132.2.2), the average annual predicted growth rate of the total output value of the construction industry of *11th Five-Year Plan*, *12th Five-Year Plan* and *13th Five-Year Plan* are obtained, then, then the predicted value and the actual value are compared, leading to the result that the model is reasonable (Table 132.3).

Dai (2013) argued that the growth rate of labor productivity in construction industry would not be changed significantly in the future because the growth rate of technical equipage and the level of construction technology were limited. Thus, this paper uses the average annual growth rate of labor productivity in construction industry of 2011–2015 is 10.1% as prediction parameter of 2016–2025.

Liu (2015) found that the growth tendency of the number of migrant workers in the construction industry were in line with that of the construction workers. Therefore, it can be argued that the annual growth rate of migrant workers in the construction industry was approximately equivalent to the annual growth rate of the construction industry. Meanwhile, this paper believes that the number of migrant workers in the past is on behalf of the demand.

Lin (2013) argued that the future growth rate of China's GDP would remain between 6.6–7.8% during 2012–2020, and kept the trend in the long run. Other scholars believed that the future growth rate of China's GDP would be below 6%. Therefore, this paper assumes that the growth rate of GDP in 2016–2025 has three kinds of situations, which are calculated by Eqs. (132.2.1) and (132.2.2) (Table 132.4):

Table 132.3 The comparison of the actual and planned growth rate of GDP and the total output value of construction industry (%)

Five-year plan	Tenth (2001–2005)	Eleventh (2006–2010)	Twelfth (2011–2015)	Thirteenth (2016–2020)	Average
Average annual actual growth rate of GDP	9.6	11.0	7.8	–	9.5
Average annual planned growth rate of GDP	–	7.5	7	6.5	–
Average annual actual growth rate of total output value of construction industry	22.58	22.70	13.69	–	19.65
Average annual predicted growth rate of total output value of construction industry	–	17.6	14.4	11.4	–

Date Source the 10th Five-Year plan, the 11th Five-year plan, the 12th Five-year plan, the 12th Five-year plan, China Statistical Yearbook from 2002 to 2015, the 2015 Construction Development Statistical Analysis Report, the 2015 Statistics Bulletin of the National Economy and Social Development

Table 132.4 Predicted number of demand for migrant workers: 2016–2025 (10 thousand)

Year	Predicted number of demand for migrant workers in the construction industry			Year	Predicted number of demand for migrant workers in the construction industry		
	Hypothesis I	Hypothesis II	Hypothesis III		Hypothesis I	Hypothesis II	Hypothesis III
2016	5861.4	5989.7	5855	2021	5893.7	6710.9	5855
2017	5867.9	6127.4	5855	2022	5900.2	6865.2	5855
2018	5874.3	6268.4	5855	2023	5906.7	7023.2	5855
2019	5880.8	6412.5	5855	2024	5913.2	7184.7	5855
2020	5887.3	6560.0	5855	2025	5919.7	7349.9	5855

Note Average annual growth rate of the labor demand in construction industry is 0.12% in Hypothesis I, 2.3% in Hypothesis II, 0 in Hypothesis III

Hypothesis I: According to the national planning target for the 13th Five-Year growth rate of GDP, it's assumed that average annual growth rate of GDP in 2016–2025 is 6.5%.

Hypothesis II: According to Zhang Lin's research, take the average value of 6.6 and 7.8%, it's assumed that the average annual growth rate of GDP in 2016–2025 is 7.2%.

Hypothesis III: According to other scholars' research, it's assumed that average annual growth rate of GDP in 2016–2025 is 5.8%.

Under the conditions of policy stability and development momentum, it's reasonable to adopt statistical linear prediction method (Dai 2013) and get the corresponding construction labor growth rates of 0, 0.12, and 2.3%.

According to the analysis of the predicted data of labor supply and demand in the construction industry, the labor supply of the construction industry began a downward trend from 2015, while the labor demand keeps a slowly increasing trend, and discussions have been made of six situations, the following two conclusions are obtained:

Scenario I: In the case of the first hypothesis of the supply, which means the stable development in accordance with the status quo of the construction industry, with the future growth rate of China's GDP at more than 5.8%, there will be in short supply in China.

Scenario II: In the case of the second hypothesis of the supply, which means there will be stronger industry attractiveness of the construction industry in the future, when the growth rate of China's GDP are 5.8%, 6.5%, 7.2%, the years when there will be in short supply would be 2018, 2018 and 2016 respectively.

In conclusion, the short supply in the labor force of China's construction industry will occur during 2016–2018.

132.4 Conclusion and Implication

As the labor supply from rural area is continuing to decrease, the supply of labor for the construction industry is also negatively impacted by this tendency. While under the situation, in which the government is promoting the urbanization, it is safe to project that the future of construction industry is promising, that conduces to huge demand for labor in this industry. Based on multi-scenario analysis, the labor demand will be less than its supply in 2016–2018. What is more, the discrepancy between labor demand and supply would enlarge in the upcoming ten years, and the situation of "partial shortage of labor" would downgrade to the "total shortage of labor".

The "total shortage of labor" could deeply impact the whole construction industry. Based on the analysis above, the shortage of labor will give rise to the increasing costs in terms of labor construction, the complete rate of the project, the negative effect on firms' credit, and these will further lead to the harm to the development of the construction industry and the nation's GDP growth. If this vicious cycle continues, there would be none sustainable development in the construction industry. As a new mean of production for the construction industry, the high efficiency of industrialization has already been sufficiently proven by the practice in both China and abroad. To conclude, it is of much necessity for the construction industry to transform and upgrade.

However, if we focus on the other side of the coin, one of the positive aspects of these trend analysis is that this would help to mitigate the cost pressures for while promoting the construction industrialization. Even given substitution effect of industrialization to labor, the shortage of labor supply relative to demand will improve the unit labor cost, which are a good news to some extent for the benefit-cost-analysis of construction industrialization.

References

Dai G (2013) The tendency and influence factors of future labor force supplies for construction industry. Zhejiang University, Hangzhou

Freeman (1987) Labor economics. Commercial Press, Beijing

Hoffman (1989) The labor market economics. Sanlian Bookstore, Beijing

Lewis WA (1954) Economic development with unlimited supplies of labor. Manchester Sch Econ Soc Stud 22:139–191

Li Z (2012) The estimation and structure analysis of surplus labor in Chinese agriculture among 2000–2010. South China University of Technology, Guangzhou

Li Z, Liu S (2015) Analysis of labor shortage situation and its impact in Chinese the construction industry. Constr Econ 02:18–21

Li C, Wei Y (2005) The ten years for the prop position of the construction industry. Constr Econ (4):5–8

Liu S (2015) The effect of housing industrialization to solve the problem of labor shortages in the construction industry. Dalian University of Technology, Dalian

Malthus (1959) Principle of population. Commercial Press, Beijing

Tharmaratnam K, Shaw Choo B (1985) Industrialized housing in Singapore. Int J Hous Sci Appl 9 (Compendex):291–302

Wen F, BaiLiping, Ma Z (2005) The research of current situation and solution of labor costs of medium and small construction enterprises. Constr Econ (3):67–69

Wu S, Guo R, Liu J (2013) Association analysis of building industrialization and labor cost. Build Constr 02:172–175

Ye L, Guo S (2004) The necessity and practical approaches of housing industrialization. Constr Econ 11:74–76

Zhang L (2013a) The estimation of potential GDP growth rate in China. South China University of Technology, Guangzhou

Zhang X (2013b) The revaluation of China's surplus labor. Chin Rural Econ 08:49–54

Zhu X, Yin N (2014) The developing trend of Chinese construction labor market and its impact. Reformation Strategy 06:108–110

Author Biography

Zhang Yingjie Ph.D., Lecturer, research focus on urban economics and housing market. Ye Huaiyuan, master student major in housing market and property management.

Chapter 133
Understanding Construction Technology Transfer from a 'SCOT' Perspective

K. Oti-Sarpong and R. Leiringer

133.1 Introduction

For decades, it has been a well-known fact that developing countries are heavily reliant on the developed ones in many areas, including construction. This dependence still exists mainly because the former group of countries is less advanced in technology, compared to the latter (Devapriya and Ganesan 2002). Developing countries predominantly rely on foreign construction firms to undertake important projects (e.g. dams, bridges, airports, harbours, hospitals, oil and gas processing plants, etc.) that are of large scales, with high complexities and technological requirements. For most of these projects, local construction firms in developing countries do not have the technology to successfully execute them. As a result, foreign construction firms who usually have the necessary technology are brought into execute such projects. This situation begins a cycle that sustains the gap in technology between developed and developing countries, and leaves the local construction industries of the latter still lacking in technology (United Nations Conference on Trade and Development 2014).

To help narrow technology gaps between developed and developing countries, the United Nations Commission on Trade and Development (UNCTAD) proposed technology transfer (TT) as an alternative to foreign direct investment in 1985. TT, according to the international code of conduct for technology transfer, should be arranged based on the levels of economic development, infrastructure gaps and technological deficits between countries (United Nations Conference on Trade and Development 2014). Through this arrangement, the UNCTAD anticipates that

K. Oti-Sarpong (✉) · R. Leiringer
Department of Real Estate and Construction, The University of Hong Kong, HKSAR, China
e-mail: kotisarp@hku.hk

R. Leiringer
e-mail: roine.leiringer@hku.hk

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_133

alliances would be formed to help improve the levels of technology in crucial economic sectors of developing countries. Prior to this suggestion by the UNCTAD, TT was mainly a means of trade expansion, from an economic perspective (*ibid*). It was a means through which 'technology-rich' countries could increase their income by expanding trade with countries that were 'poor' in technology (Mansfield 1975). With the direction provided by the UNCTAD in 1985, TT caught on with several developing countries, making attempts through diverse channels, including collaborative inter-firm arrangements (e.g. IJVs), subcontracting, licensing, mergers and acquisitions/take-overs (Ofori 1994).

TT has gained an appreciable level of research interest in construction. Studies have been conducted from perspectives borrowed from strategic management, international trade, organisational competiveness and, in recent times, organisational learning (Manimala and Thomas 2013; Wahab et al. 2012a). In construction, the variety of technology adopted to undertake a project ranges from tangible to intangible components. These include plant and equipment, computer software, construction methods, systems and processes, prior experiential knowledge, and management skills. This assortment makes it difficult for construction technology to be conceptualised broadly as merely artefacts only, or a system of processes alone (Manimala and Thomas 2013; Harty 2005). Relatedly, the process of construction project delivery is intricate. It involves series of interactions between human actors, technology, and their context of operation within a wider social setting. This makes its process of transfer more than a transactional arrangement of handing over, or selling equipment, or passing on documented information between a transferor and a transferee. The process of TT in construction is therefore a complex process of interactions between actors, technology and a specific context. Despite the foregoing, some studies in construction TT (e.g. Ofori 1994; Abbott et al. 2007; Simkoko 1992) distinctively present technology as merely a physical artefact, or a system of processes standing alone, devoid of any form of social/contextual identity. Concomitantly, the transfer of such technology in construction is described as a linear process of transferor-transferee transactions (e.g. Ofori 1994). Such views actively ignore the essential micro-processes, leaving the intricacies of construction TT poorly understood.

In this paper, we argue that to better understand construction TT, it should be examined from a socio-technical perspective. We begin by positioning technology as being socially constructed, departing from popularly held views about technology as being distinctively a product, process or system, without any social identity. This is followed by presenting TT as a series of socio-technical interactions within a defined context, with actors engaged in series of negotiations with each other, as well as with technology. Theoretical constructs of the social construction of technology (SCOT) (i.e., relevant social groups, interpretative flexibility, closure and stabilization, and the wider context) are used in explaining the process of TT as a series of socio-technical interactions that involves the social shaping of technology. We conclude by arguing that exploring into TT through this lens will help provide a better understanding of the micro-processes it entails.

133.2 Technology and Technology Transfer

133.2.1 Technology

There is a plethora of definitions for 'technology' owing to its usage in different areas of industry and research (Manimala and Thomas 2013; Wahab et al. 2012b). The root word '*techne*' implies, bringing out the essence of a thing in its true form. It transcends physical artefacts, and entails the initial conception, the processes involved in converting that thought into a process, or tangible or intangible reality (Heidegger 1977). From this meaning, the development of technology starts with a human actor, and its nature is shaped by series of processes within a social context (Williams and Edge 1996; Orlikowski 2000). Here, we consider 'Technology' as comprising: tangible and intangible components, as well as systems or processes that interact with human actors towards an intended, specific output. This composition varies across contexts, and undergoes series of modifications as it is moved from one place to another, to be re-developed and re-shaped socially through a series of interactions.

Early definitions can be broadly grouped under process, product, or management technology, or, as a set of rules, hardware, or a system (Wahab et al. 2012b; Li-Hua 2009). In recent studies, it is generally categorised into two basic forms; 'hard'/'explicit', or 'soft'/'tacit', with definitions usually featuring terms such as skills, knowledge, managerial expertise, products/artefacts and procedures/processes. Broadly, technology is considered to comprise four intertwined components: knowledge; technique; products and the organization involved. 'Knowledge' refers to the explicit facts and embedded experiences associated with technology, and is as such an intrinsic component. 'Technique' refers to the practical methods, skills and processes deployed in conjunction with knowledge and physical 'products' towards realising a desired outcome. The 'organisation' is the immediate context which hosts the interactions between the other three components (Li-Hua 2009). According to the UNCTAD, technology is: "bought and sold as capital goods including machinery and productive systems, human labour usually skilled manpower, management and specialised scientists. Information of both technical and commercial character, including that which is readily available, and that subject to proprietary rights and restrictions" (Li-Hua 2009, p. 19). This definition sets out technology as being socially neutral, and distinctively as merely production input, made up of machinery or systems and human expertise. Linked to this, widely held perspectives of technology consider it distinctively as a physical artefact/gadget, or a system in place (e.g. Ofori 1994; Abbott et al. 2007; Simkoko 1992; Lin 2003). It further suggests that technology is fully developed, completed and standardized in one context, and simply picked and used in another context. Conceptualising technology in such a compartmentalised manner, as we will argue below, effectively disregards its social construction (Williams and Edge 1996), and the socio-technical interactions involved in its development, and subsequently its transfer between parties. Consequently, this limits the extent to which the intricacies of TT can be explored.

133.2.2 Technology Transfer

There are several definitions for TT brought about by the different meanings ascribed to technology (Wahab et al. 2012b). Generally, earlier definitions, mainly from economic perspectives considered TT as a production input, or as a means through which transaction and production costs could be reduced (e.g. Mansfield 1975). Others, mainly from strategic management and learning perspectives emphasise that TT is neither merely handing over documented information, nor a simplistic sale of machinery to a transferee. Rather, it is a collaborative process that requires a close, sustained relationship between the parties involved over a period (Manimala and Thomas 2013; Wahab et al. 2012b; Lin 2003). Here we consider 'Technology Transfer' as a deliberate process through which technology is moved from one party to another through series of interactions, within a specific channel towards an intended outcome.

TT is, as such, a process that unfolds over a period, comprising a series of interactions between: the transferor, the technology, the transferee, the channel/vehicle of transfer, and the context of transfer. The process can be either intra- or inter organisational, based on the direction of the transfer. Also, the process may be categorised as local or international, based on the home countries of the parties involved. The transferor is the primary entity in possession of a relatively stabilized technology desired by others, and the transferee is the entity which receives from the former. The process can however be bi-directional as the transferor and transferee positions are not fixed throughout the period of interactions. The channels are the intermediary conduits, modes and agents which facilitate the process, generally referred to as 'vehicles of transfer'. Popular channels in the construction industry include subcontracting and joint ventures (JV) (Wahab et al. 2012b).

Largely, studies in construction TT have usually been conducted through the lenses of strategic management, economic transactions costs, international and local policies, international trade and more recently, organisational learning. Majority of these studies mainly make cases for how best construction firms can use TT as a means to improve their organisational competitiveness (drawing heavily on the ideas of rational choice). Therefore, if a construction firm (e.g. consultant or contractor) is interested in maximising their profits and expanding their business, then as part of a strategic decision, they should be able to identify and engage with suitable partners who can help boost their competitiveness. Other views also present that, as part of efforts to improve an organisation, making attempts to be ahead in technology is crucial. Based on this, construction firms endeavour to form strategic TT alliances with advanced counterparts, so that they can learn from them (Manimala and Thomas 2013; Wahab et al. 2012a, b). Despite the contributions of such perspectives in construction TT research these studies largely overlook the complexity of construction technology, and eventually its transfer (Manimala and Thomas 2013). This is mainly due to, among other reasons, holding deterministic views of technology, and 'technology optimism-bias' (Williams and Edge 1996; Schweber and Harty 2010). As a result, there is a lack of understanding of exactly how the interactions between the multiple actors and technology take place during TT. This presents the need for the process to be reconceptualised and explored from a perspective that promises a more comprehensive explanation.

133.2.3 A Socio-Technical Perspective of Construction Technology and Its Transfer

The socio-technical studies (STS) view of technology offers a lens through which interactions between humans and technology can be examined. From this perspective, the development of any kind of technology is not devoid of social influence; its identity is embedded in the characteristics of the society in which it is found (Harty 2005; Williams and Edge 1996; Schweber and Harty 2010). Here, society refers to the human actors, the institutions and setting within which the development, adoption, and use of the technology occurs (Williams and Edge 1996; Bijker 2001). Hence, technology is not considered as 'complete' unless it has been socialized into the context of application (Leonardi and Barley 2010). Technology in this sense is a composition of explicit (e.g. machinery, plant and equipment, tools and devices) and tacit components (e.g., knowledge, intuitive ideas, experience and skills) that are developed through series of interactions with human actors in a social context, and shaped towards a desired outcome (Pinch and Bijker 1984). From the STS view, the components of technology are inseparable; they are all in a constant relationship. Thus, technology is inadequately conceptualised if presented distinctively as an artefact, or a system of processes only, detached from the intuition and social interactions related to its development (Williams and Edge 1996; Orlikowski 2000; Elle et al. 2010).

Generally, construction technology refers to any form of technology used by construction firms towards the delivery of a construction product. Broadly, it consists of tacit and explicit technology, with the tacit form being most difficult to transfer. The tacit aspect refers to the embedded, intangible assets of an organisation, which includes operational and experiential knowledge, management ideas, skills, systems and processes. Owing to its embedded nature, its transfer is considered largely impossible without person-to-person interactions between transferor and transferee (Harty 2005). Explicit technology, on the other hand, refers to tangible machinery, tools or equipment that are guided by knowledge to produce desired results (Li-Hua 2009). In executing projects, construction firms employ a blend of tacit and explicit technology (e.g., construction plant and equipment, project techniques, construction and management processes, as well as intuitive ideas that are incorporated in a project design, and managing construction processes) (Harty 2005). The human actors form a core part of the process of blending these elements of construction technology during project delivery. From the foregoing, we argue that the process of construction project delivery involves a series of socio-technical interactions between human actors and technology. As part of the interactions, technology is socially ‘constructed’ or ‘shaped’ (i.e., modified by actors to suit their respective organisational and contextual requirements for effective utilisation). The interactions lead to the creation of a technological system, which is used in delivering projects such as buildings, bridges, dams or harbours (Schweber and Harty 2010). The complexity of the interactions increases in the face of inter-firm project delivery arrangements.

Notwithstanding the foregoing, TT in construction has been generally conceptualised as a linear process (Ofori 1994; Abbott et al. 2007; Simkoko 1992). Accordingly, the transferee identifies the desired technology and its owner, after which arrangements are made for its transfer. Over a trial and re-trial period, the transferee is able to make adjustments to the technology to suit their operations. This approach fails to put into perspective the inter-organisational and socio-technical interactions that occur during the transfer process (Manimala and Thomas 2013), as well as the development, and social shaping of the technology involved. Hence, the relationship between the nature of the technology being transferred, the context of the transfer and, the interactions of the actors involved (with each other, as well the machinery, systems or processes of technology) are subsequently neglected. This further reveals the need for a re-think in approaching construction TT, to explore into areas that will help provide a comprehensive explanation of the interactions involved in it.

Reflecting on the nature of construction technology, TT is neither the mere act of passing on, or selling proprietary documented information from one firm to another, nor transferring a piece of hardware from one location to another. It involves a series of socio-technical interactions between actors and technology (Manimala and Thomas 2013), which provoke varying levels of adjustments, modifications and alterations in the firms involved. These changes contribute to the abilities of the TT parties to receive and incorporate new technology into their organisational practices and routines. Few studies in construction research have adopted a socio-technical perspective on technology, focusing mainly on intra-organisational analysis of technology adoption (Schweber and Harty 2010; Boyd et al. 2015), adoption of smart electricity meters in domestic buildings (Skjølsvold and Ryghaug 2015) and systems building in the use of 3D CAD technology in construction (Harty 2005). The socio-technical view in technology studies presents a coherent and inclusive approach to examine the complex realities of interactions between people, technology and organizations. It puts into perspective the co-development of the parties involved, and the modification of technology in the process of its transfer within a defined social context (Schweber and Harty 2010). This view helps to explain the series of interactions between actors in a defined context, and in turn the multiple interactions that influence technology development and uptake, or transfer (Harty 2005; Skjølsvold and Ryghaug 2015). This will help provide a comprehensive explanation of the intricacies involved in construction TT, through the theoretical lens of the social construction of technology (SCOT).

133.3 The Social Construction of Technology (SCOT)

The social construction of technology (SCOT) was first put forward by Pinch and Bijker (1984). This perspective is embedded in the socio-technical studies (STS) view of technology, which emerged in the 1970s to oppose hitherto long-held views of technological determinism (i.e., technology being an autonomous entity that evolves on its own, and with an identity devoid of any human and/or social influence) (Bijker 2001). SCOT presents “a coherent and inclusive approach for interrogating the complex realities of interactions between people, technology and institutions in empirical settings” (Schweber and Harty 2010, p. 673). The theoretical framework describes the development, uptake and adoption of technology within a context as a continuous process of evolution, and a continuous cycle of alternation of variations and selection (Orlikowski 2000).

SCOT is based on a set of assumptions. First, technology is socially constructed, and does not comprise of only artefacts, products or machinery. It is developed through a system of interactions between human and non-human elements within a social context to achieve an intended outcome. The development of technology is not devoid of society; all technological developments are influenced by a context. Hence, the shaping of technology is commensurate with the shaping of its social context. Second, a technological system is developed through interactions between the components of a social context being: the technology, the environment, the organisation(s) and the human actors. Finally, technology, its transfer, social context, and the actors are not considered as different components of a technological system governed by different rules. Altogether, they form a single unit, operating and influencing each other through series of interactions and negotiations towards a desired outcome (Pinch and Bijker 1984).

133.3.1 Core Constructs

SCOT is made up of four major constructs: (i) relevant social groups (RSGs), (ii) interpretative flexibility, (iii) closure and stabilization, and, (iv) the wider context. RSGs refer to the parties who influence the nature of a technology, i.e. an individual, organisation or, group(s) of individuals; whether organised or not. The relevance of a group is primarily linked to the extent to which the technology involved is important to them. Direct and indirect RSGs vary per the technology and the context (Pinch and Bijker 1984; Bijker 2001). They are grouped according to the closeness of their views on the technology, not based on institutionalized affiliations. For every technology, the RSGs may have a set of shared and/or conflicting meanings, forming different 'technological frames'. A technological frame is "the understanding and interpretation of the technology in question, shared by all the members of an RSG" (Elle et al. 2010, p. 137). It comprises goals, problems, guiding principles, operation procedures, and artefacts. The technological frame of RSGs inform their understanding of what a technology is, or what it can be used for. It shapes how RSGs perceive a technology, which eventually informs how the meaning of that technology will be constructed. The technological frame of RSGs are informed by their backgrounds and experiences (Orlikowski 2000; Leonardi and Barley 2010). Differences in technological frames lead to conflicting views among RSGs. This creates strata between groups with different technological frames on the explicit and/or tacit aspects of a technology. The differences in technological frames between RSGs reflect the complexity of technology, hence depicting its 'interpretative flexibility'. Different technological frames exist because technology can be designed in several ways, and as such likely to be understood from different perspectives. Additionally, the development of technology encounters conflicting opinions among RSGs, because they do not share the same, or similar expectations of the functions of technology owing to their different backgrounds (Pinch and Bijker 1984). In achieving closure and stabilisation, steps are taken by the RSGs to merge the different perspectives by way of exchange of explicit information and tacit experiences. This allows the RSGs to relate to the technology from a common understanding. When this has been achieved, there will not be any need for further modifications of the technology among the actors in a given context. However, attaining this level is not absolute. Technology is considered to have reached a level of closure and stabilisation for the RSGs involved. All the socio-technical interactions in the development and transfer of technology do not take place in a vacuum; the wider context is the environment within which technological development and transfer takes place (ibid). This may be an organisational or inter-organisational, industrial or sectorial, national or international setting within which all the interactions take place.

133.4 Technology Transfer Through a 'SCOT' Lens

In exploring TT via the theoretical framework of SCOT, the individual actors from local and foreign construction firms (consultant and/or contractor) constitute different relevant social groups (RSGs). At the onset of the process, the interpretative flexibility of technology is revealed in conflicting understandings among the actors involved. The understanding of the actors about what the technology stands for, how it can be used on a construction project, and its potential effect on their internal and external operations vary. These disparities are linked to differences in the actors' experiences and past knowledge, which subsequently influence how they interpret a new technology. Leonardi and Barley argue that: "People draw on the familiar to make sense of the new. Yet, some of their understanding of a technology must inevitably emerge as they encounter its constraints and affordances in the here and now" (Leonardi and Barley 2010, p. 15). Conflicting views about technology are therefore inevitable at the onset of the TT process since all actors have different sets of past frames. They even become pronounced in the face of contextual differences between developed and developing countries.

During the process of TT on a construction project, the series of socio-technical interactions between RSGs and the technology, instigate some alterations and modifications in the technological frames of the former and nature/make-up of the latter. The process of alterations in technological frames is inseparable from the socio-technical interactions actors undergo. They contribute to the reconstruction of frames, leading to the gradual elimination of conflicting understandings among the RSGs. Relatedly, the technology undergoes phases of alteration and variation as part of being received, in order for the actors to obtain a 'stabilized' version of it (Pinch and Bijker 1984). All these modifications contribute to achieving some level of 'closure and stabilisation', which could be partial or absolute, for the technology (Skjølsvold and Ryghaug 2015). Through this, the actors would have eliminated their conflicting understandings to an extent, and TT would have been achieved. The inter-firm project delivery arrangement forms the wider context.

To explain the process of TT as series of socio-technical interactions between local and foreign construction firms working on a construction project through SCOT, we argue that, it is imperative to identify: Who make up the RSGs involved in the development and transfer of technology? How do the RSGs ascribe different meanings to the technology in question? Which aspects of the technology are considered important by the parties? What purpose is the technology in question addressing from the perspectives of the RSGs? What processes do the RSGs go through to adjust to the alterations and modifications because of transferring and/or receiving technology? How are the RSGs able to negotiate series of meanings throughout TT, as part of achieving some closure and stabilisation for the technology, to achieve satisfactory transfer of technology? Exploring these questions will help explain how the parties involved in TT negotiate meanings, and adjust to modifications amidst series of interactions. The answers will also shed light on how technology is altered to suit the interests of the actors during TT. Contrasting with traditional views where technology is usually fixed, and TT is a linear arrangement, the answers will contribute to providing a more comprehensive explanation for TT on a construction project.

133.5 Concluding Remarks

Technology transfer in construction has traditionally been studied from compartmentalised perspectives, neglecting the socio-technical interactions that take place. This we argue has led to the failure to capture the co-development of technology and the actors involved, alongside the multiple interactions within the process. In this paper, we have, therefore, argued that technology and its transfer should be viewed as a process of socio-technical interactions between actors, the technology and a context. This allows for the complexities in the process of TT to be explored, putting the socio-technical interactions into perspective. We have also demonstrated that the theoretical framework of SCOT can be used to explain the interactions between actors, technology and organisations working towards the delivery of a construction project within a context. This will help provide additional explanation of TT between construction firms in developing and developed countries. Relatedly, this may offer useful insight to developing countries who are attempting to improve their local construction industries through TT. The next step is to test these ideas empirically.

References

Abbott C, Jones VL, Sexton MG, Lu SL (2007) Action learning as an enabler for successful technology transfer with construction SMEs. RICS Res Paper Ser 7(16):1–41

Bijker WE (2001) Understanding technological culture through a constructivist view of science, technology, and society. Visions of STS: counterpoints in science, technology and society studies, pp 19–34

Boyd P, Larsen GD, Schweber L (2015) The co-development of technology and new buildings: incorporating building integrated photovoltaics. Constr Manag Econ 33(5–6):349–360

Devapriya K, Ganesan S (2002) Technology transfer through subcontracting in developing countries. Build Res Inf 30(3):171–182

Elle M, Dammann S, Lentsch J, Hansen K (2010) Learning from the social construction of environmental indicators: From the retrospective to the pro-active use of SCOT in technology development. Build Environ 45(1):135–142

Harty C (2005) Innovation in construction: a sociology of technology approach. Build Res Inf 33 (6):512–522

Heidegger M (1977) The question concerning technology, and other essays. Harper & Row, New York

Leonardi PM, Barley SR (2010) What's under construction here? Social action, materiality, and power in constructivist studies of technology and organizing. Acad Manag Ann 4(1):1–51

Li-Hua R (2009) Definitions of technology. In: Olsen JKB, Pendersen SA, Hendricks VF (eds) A companion to the philosophy of technology. Blackwell Publishing Ltd., UK

Lin BW (2003) Technology transfer as technological learning: a source of competitive advantage for firms with limited R&D resources. R&D Manag 33:327–341

Manimala MJ, Thomas KR (2013) Learning needs of technology transfer: coping with discontinuities and disruptions. J Knowl Econ 4(4):511–539

Mansfield E (1975) International technology transfer: forms, resource requirements, and policies. Am Econ Rev 65(2):372–376

Ofori G (1994) Construction industry development: role of technology transfer. Constr Manag Econ 12(5):379–392
Orlikowski WJ (2000) Using technology and constituting structures: A practice lens for studying technology in organizations. Organ Sci 11(4):404–428
Pinch TJ, Bijker WE (1984) The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. Soc Stud Sci 14(3):399–441
Schweber L, Harty C (2010) Actors and objects: a socio-technical networks approach to technology uptake in the construction sector. Constr Manag Econ 28(6):657–674
Simkoko EE (1992) Managing international construction projects for competence development within local firms. Int J Project Manag 10(1):12–22
Skjølsvold TM, Ryghaug M (2015) Embedding smart energy technology in built environments: a comparative study of four smart grid demonstration projects. Indoor Built Environ 24(7): 878–890
United Nations Conference on Trade and Development (2014) Transfer of technology and knowledge sharing for development. No. 8. United Nations, Geneva
Wahab SA, Rose RC, Osman SIW (2012a) The theoretical perspectives underlying technology transfer: a literature review. Int J Bus Manag 7(2):277–288
Wahab SA, Rose RC, Osman SIW (2012b) Defining the concepts of technology and technology transfer: a literature analysis. Int Bus Res 5(1):61–71
Williams R, Edge D (1996) The social shaping of technology. Res Policy 25(6):865–899

Chapter 134
Urban Green Land Carbon-Sink in Different Functional Cities: The China Case

Z.H. Huang, N. Xiong, X.L. Zhang, S.P. Li and L.Y. Shen

134.1 Introduction

Due to the burning of a large amount of fossil fuels, deforestation and land use change as a result of industrialization and urbanization, the carbon emission is increasing, which leads to greenhouse effect and global warming. The climate change and global warming will contribute to a serious of significant economical and ecological consequences. In fact, 76% of the global consumption of coal and 71% of global carbon emissions occur in cities, even though they cover less than 1% of the earth's surface (Sullivan 2011). The C40 Large Cities Climate Leadership Group reported that 80% of the world's anthropogenic greenhouse gases (GHGs), which are mainly composed of CO_2, are emitted from cities and that the world's total urban emissions are increasing at a rate of 1.8% per year. Furthermore, GHGs emitted from cities in developing countries are expected to increase at a higher than average rate. It is clear that cities are now the main contributors to the greenhouse effect and global warming, and scholars around the world have paid increasing attention to CO_2 emissions (Hildemann et al. 1994; Koerner and Klopatek 2002; Mulholland and Seinfeld 2011; Shen et al. 2016, 2017).

Along with its increasing economic development and population growth, China has become one of the world's leading CO_2 emitters (Yang et al. 2012; Shuai et al. 2017). It contributed 13.5% of global CO_2 emissions in 2000, which made it the

Z.H. Huang (✉) · N. Xiong · S.P. Li · L.Y. Shen
School of Construction Management & Real Estate, Chongqing University, Chongqing, China
e-mail: 20150302017t@cqu.edu.cn

Z.H. Huang · N. Xiong · S.P. Li · L.Y. Shen
International Research Centre for Sustainable Built Environment, Chongqing University, Chongqing, China

X.L. Zhang
Department of Public Policy, City University of Hong Kong, Kowloon Tong, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_134

world's second largest emitter after the United States of America (Zhang 2000). China's contribution is expected to exceed that of the United States of America by 2020 if the country continues to develop at its current rate (Zhang 2000). Therefore, the study of CO_2 emissions in China is significant for the reduction of CO_2 emissions on a global scale. The problem of excessive CO_2 emissions is particularly severe in China's cities. For example, 40% of the nationwide consumption of energy and 40% of nationwide carbon emissions occurs in the 35 provincial capitals, which only have less than 40% of the population of China (Dhakal 2009). At the same time, with China undergoing rapid urbanization, Chinese cities have a decisive impact on the CO_2 emissions and low-carbon development in the country, and they are the most promising areas of carbon reduction. The pressure on China due to international negotiations related to reducing emissions is greater than ever. To mitigate this pressure, China officially submitted Intended Nationally Determined Contributions (INDCs) before the United Nations Conference on Climate Change held in Paris in 2016, which clearly states that carbon dioxide emissions per unit of GDP in China will peak around 2030 and China will try best to evidence this peak target as soon as possible. China also made some specific targets that carbon dioxide emissions per unit of GDP would decline by 60–65% in the 2030 in the comparing with that in 2005, the proportion of non-fossil energy in the primary energy consumption would increase by around 20%, and forest stock would increase by 4.5 billion cubic metres. To achieve the reduction targets mentioned above, the national emission reduction targets are allocated to various provinces and municipalities by the central Chinese government.

There are various ways which can be used to reduce carbon dioxide intensities, such as an integrated CO_2 capture and storage (CCS) operation system. However this technology is not attractive in China in the current stage because it is an expensive technology for limiting CO_2 emissions (Liang and Wu 2009). On the contrary, the method of increasing UGLC is widely considered a better way among these methods, since it can not only remove carbon dioxide from the air but also improve ecological environment.

China has an vast area with 272 prefecture-level cities and more than 600 county-level cities in 2014. These cities are different in several aspects such as population size, GDP, resources endowment, urbanization, development stage and energy consumption structure. These aspects are also carbon emissions, driving factors, so there are differences in the structure of UGLC of different cities. The aim of this paper is to provide important references to the Chinese government for allocating the national emission reduction targets to various provinces and municipalities by analyzing Urban Green Land Carbon Sinks in different functional cities of China.

Carbon reduction can be made possible by both reducing carbon sources and increasing carbon sinks at the same time. A considerable amount of research on carbon source and carbon sink in the context of China has been done. However, these studies were carried out at the provincial scale not at the urban scale and they do not provide much attention to the relation of carbon-sink and the function of cities in China. For example, Lu et al. (2013) made an overall estimation of carbon emissions from energy consumption, and carbon sinks from forest, grassland and arable land at the provincial scale. Current researches related to urban carbon sinks are mostly for a single city or a group of cities which adjoin each other. Taking the highly urbanized city of Shenzhen as an example, Ye et al. (2012) adopted the IPCC (Intergovernmental Panel on Climate Change) default factor method and carbon sink model to analyze the basic characteristics of the urban carbon sinks. Yang (2010) made an analysis to show the present situation of carbon source and carbon sink, and the distribution of carbon emission in different industries in Shanghai. The study of Yang (2012) demonstrated the emissions from energy activities, industry processes, waste disposal, cropping and breeding industry and carbon sink of wetland and forest to monitor the performance of greenhouse gas in Chongqing. Yi et al. (2015) evaluated the inventory of carbon sources and sinks in Yangtze River Delta Region during 1995–2010 and analyzed their spatiotemporal patterns. Yang and Zou (2013) investigated the status of low carbon economy in the East of China between the year of 2005—2011 in the view of carbon source, carbon sink and carbon productivity. Obviously, the results of those research mentioned above are often only available in a certain regions or in a particular city, and can not be promoted widely. Therefore, this paper aims to fill the gap by analyzing the urban green land carbon-sinks in different functional cities in China and explore the relation of the both.

The remainder of this paper is organized as follows. In the second section, we present our method of classifying the 269 prefecture-level cities of China based on their function, the classification results and chosen method of UGLC calculation. In the third section, we predicted outcomes of these quantitative measurements of 289 cities' UGLC. Finally, we analyze the urban green land carbon-sink in different functional cities of China.

134.2 Data and Method

134.2.1 Data

Our data about those indexes listed in Table 134.1, which was used for classifying the 269 prefecture-level cities in China, are obtained from the *China City Statistical Yearbook 2006–2015*. The data on area of green land used for UGLC calculation are from *China Urban Construction Statistical Yearbook 2006–2015*.

Table 134.1 Indexes for evaluating the function of cities

NO.	Indexes
1	Economic factor
1.1	Per Capita GRP
1.2	Number of Industrial Enterprises
1.3	Investment in Fixed Assets (Excluding Rural Households)
1.4	Total Retail Sales of Consumer Goods
1.5	Total Sales of Commodities of Enterprises above Designated Size in Wholesale and Retail Trades
1.6	Primary Industry as a Percentage of GDP
1.7	Secondary Industry as a Percentage of GDP
1.8	Tertiary Industry as a Percentage of GDP
2	Social factor
2.1	Total population at Year-end
2.2	Number of Beds of Hospitals and Health Centers
2.3	Collections of Public Libraries per 100 persons
3	Labor Force and Employment
3.1	Persons Employed in Primary Industry
3.2	Persons Employed in Mining Industry
3.3	Persons Employed in Manufacturing Industry
3.4	Persons Employed in Construction Industry
3.5	Persons Employed in Real Estate
3.6	Persons Employed in Traffic, Transport, Storage and Post
3.7	Persons Employed in Catering and Business Services
4	Traffic factor
4.1	Total volume of transport
4.2	Total volume of freight
4.3	Per Capita Area of Paved Roads in City
5	Resources and environment
5.1	Per Capita Area of Green Land
5.2	Area of Built-up Area Covered by Green
5.3	Volume of Industrial Waste Water Discharged

134.2.2 The Functional Classification of 268 Prefecture-Level Cities in China

Urban Function refers to the tasks and the roles which cities should undertake in the political, economic and cultural fields of the country or region. Cities differ in function, which has long been recognized (Harris 1943) and functional types such as industrial, commercial, mining, university, and resort towns have been differentiated by numerous researchers (Tian and Yang 2010; Belsky and Karaska 1990). However, due to the complexity of factors influencing city function and the situation where most cities have a variety of functions, literature on the functions of cities is deficient in studies on criteria for distinguishing types and in classifications. This paper attempts to remedy these deficiencies by a quantitative method of functional analysis. First, this paper establishes a set of indexes for evaluating the function of cities, which was showed in Table 134.1. Second, by the technical support of software SPSS 20.0, the method of principal components analysis and clustering analysis are adopted to analyze these indexes and classify these 268 prefecture-level cities.

134.2.3 Estimation of UGLC

According to the United Nations Framework Convention on Climate Change (UNFCCC) which entered into force on February 16, 2005, carbon sinks are processes, activities or mechanisms that remove CO_2 from the atmosphere (Yang et al. 2012).

Urban green land carbon-sink (UGLC) is measured by estimating area of urban green land and the carbon-sink factor of green land (Eq. 134.1).

$$\text{Carbon-sink}_{\text{green land}} = \text{C}_{\text{green land}} \times \text{S}_{\text{green land}} \tag{134.1}$$

Carbon-sinkgreen land is the urban green land carbon-sink (tons), Cgreen land is the carbon-sink factor of urban green land (tons C/km^2), and Sgreen land is the area of the urban green (km^2). According to existing studies on carbon sinks (Fang et al. 2007; Jiang 2010), together with regional green land characteristics, the carbon-sink factor of urban green land is commonly adopted as 3380 tons C/km^2.

134.3 Result

134.3.1 The Results of the Functional Classifications Between 289 Prefecture-Level Cities

By using the software SPSS 20.0, six main factors are formulated, as shown in Table 134.2, as the results from applying the method of principal components analysis. The applications of the six factors are further explained as follows: (1) The first factor was labeled “ integrated cities”, as the load values of the items on this factor did not have much different from each other. (2) The second factor was labeled “industrial cities”, as the load values of the industrial-related items (1.2, 1.7, 3.3, 3.4) on this factor is larger. (3) The third factor was labeled “transportation cities”, as the load values of the transportation-related items (3.6, 4.1) on this factor is larger. (4) The fourth factor was labeled “cultural and tourist cities”, as the load values of the cultural and tourist related items (2.3, 5.1) on this factor is larger.

Table 134.2 Exploratory factor analysis

Items	Factor 1: integrated cities	Factor 2: industrial cities	Factor 3: transportation cities	Factor 4: Cultural and tourist cities	Factor 5: larger-scale cities	Factor 6: resource-dependent cities
1.1 Per Capita GRP	−0.046	0.012	0.137	0.040	0.096	0.015
1.2 Number of Industrial Enterprises	−0.038	0.302	0.048	−0.076	–	–
1.3 Investment in Fixed Assets (Excluding Rural Households)	−0.024	0.138	−0.014	0.034	0.063	0.000
1.4 Total Retail Sales of Consumer Goods	0.040	0.047	0.001	0.030	–0.094	0.003
1.5 Total Sales of Commodities of Enterprises above Designated Size in Wholesale and Retail Trades	0.101	−0.116	0.024	0.035	−0.145	−0.043
1.6 Primary Industry as a Percentage to GDP	−0.015	0.025	−0.041	–0.297	–0.008	0.132
1.7 Secondary Industry as a Percentage to GDP	0.037	0.320	−0.057	0.135	–0.007	–0.530
1.8 Tertiary Industry as a Percentage to GDP	−0.013	−0.040	0.064	0.109	–0.010	0.445
2.1 Total population at Year-end	−0.018	0.162	−0.197	–0.014	0.089	–0.031
2.2 Number of Beds of Hospitals and Health Centers	0.037	0.100	−0.138	0.067	0.305	–0.024
2.3 Collections of Public Libraries per 100 persons	0.074	−0.042	0.126	0.318	–0.129	0.010
3.1 Persons Employed in Primary Industry	0.007	−0.146	0.024	0.098	0.194	–0.066
3.2 Persons Employed in Mining Industry	−0.024	0.195	0.134	–0.133	−0.117	0.224
3.3 Persons Employed in Manufacturing Industry	−0.028	0.457	0.019	–0.104	0.080	–0.025
3.4 Persons Employed in Construction Industry	0.195	0.524	0.040	–0.038	0.003	–0.042
3.5 Persons Employed in Real Estate	0.177	−0.117	0.020	–0.004	0.328	–0.010

(continued)

Table 134.2 (continued)

Items	Factor 1: integrated cities	Factor 2: industrial cities	Factor 3: transportation cities	Factor 4: Cultural and tourist cities	Factor 5: larger-scale cities	Factor 6: resource-dependent cities
3.6 Persons Employed in Traffic, Transport, Storage and Post	0.128	−0.037	0.356	–0.031	0.102	–0.048
3.7 Persons Employed in Catering and Business Services	0.125	−0.163	−0.001	0.012	–0.025	–0.058
4.1 total volume of transport	0.142	−0.050	0.210	0.080	0.002	–0.019
4.2 total volume of freight	0.083	0.043	−0.065	–0.036	–0.035	–0.027
4.3 Per Capita Area of Paved Roads in City	−0.101	0.108	−0.018	0.100	0.256	0.119
5.1 Per Capita Area of Green Land	−0.182	0.021	0.277	0.343	0.264	0.181
5.2 Area of Built-up Area Covered by Green	0.064	−0.031	0.300	–0.308	–0.009	–0.284
5.3 Volume of Industrial Waste Water Discharged	0.032	0.436	−0.092	–0.409	0.048	0.078

(5) The fifth factor was labeled “larger-scale cities”, as the load values of scale-related items (2.2, 3.5) on this factor is larger. (6) The sixth factor was labeled “resource-dependent cities”, as the load values of the resource-related item 3.2 on this factor is larger.

With the support of software SPSS 20.0, we categorized the 289 prefecture-level cities of China into six types by the method of clustering analysis (Table 134.3).

134.3.2 The Result of UGLC Estimation

The results of the UGLC estimation using the Eq. (134.1) are listed as follows in Table 134.4, which shows the per capita UGLC of the six types of cities from 2005 to 2014. In Fig. 134.1, we use a line chart to provide a visual interpretation of the per capita UGLC of the six types of cities from 2005 to 2014.

Table 134.4 and Fig. 134.1 show that the level of per capita UGLC in industrial cities, transportation Cities, larger-scale cities, and resource-dependent cities increased between 2005 and 2014, with the average annual growth rate of 7.16, 10.48, 3.62 and 7.22% respectively. Integrated cities is the most significant contributor to the increasing of UGLC among these six types of cities, which increased by 5.90 tons per capita in this period: from 8.34077×10^{-3} tons per capita in 2005 to 14.24290×10^{-3} tons per capita in 2014. The level of per capita UGLC in integrated cites is much larger than other five types of cities. Meanwhile, UGLC in cultural and tourist cities increased from 2.22569×10^{-3} tons per capita to 7.39556×10^{-3} tons per capita between 2005 and 2008, declined to 2.77142×10^{-3} tons per capita in 2009, and increased slowly in the following years. Furthermore, it can be seen that only the level of per capita UGLC in integrated cities is more than the national average.

134.4 Discussion

According to Table 134.4 and Fig. 134.1, it can be found there is significant difference in UGLC between the six types of cities. This difference can be explained by the different function of cities.

Integrated cities have a larger city-size, and its function is more comprehensive and special. Most of the integrated cities are metropolises such as Shanghai, Beijing and Guangzhou. Their special function includes providing International airport and subway service, high-tech development zones, research and education base, a large variety of public services, a variety of domestic and international offices, etc. It seems that achieving these functions necessarily use up a lot of land and the land used for greening is relative smaller. Actually, some of the integrated cities which are economic and political center put high value on green land which is important in beautifying the surroundings. For example, as an external window of China, Beijing

Table 134.3 The result of urban function classification

Integrated cities	Beijing, Guangzhou, Tianjin, Chongqing, Wuhan, Shenyang, Hangzhou, Xian, Chengdu, Nanjing, Kunming, Changchun, Xiamen, Taiyuan, Dalian, Changsha, Fuzhou, Lanzhou, Hefei, Qingdao, Foshan, Nanchang, Guiyang, Nanning, Ningbo, Tangshan, Huizhou, Yantai, Daqing, Zibo, Wuxi, Xuzhou, Anshan, Urumchi, Harbin, Shijiazhuang, Shanghai, Jinan, Zhengzhou, Shenzhen
Industrial cities	Suzhou, Laiwu, Anyang, Weihai, Yibin, Quanzhou, Leshan, Shaoxing, Wuhu, Loudi, Jiangmen, Xiangtan, Liaoyang, Heyuan, Jiaxing, Liuzhou, Deyang, Ezhou, Baoji, Taizhou, Weifang, Xuchang, Wenzhou, Yichang, Xinyu, Shanmenxia, Huzhou, Changzhou, Dezhou, Yueyang, Shanwei, Luzhou, Qingyuan, Yuxi, Zigong, Tonghua, Yangzhou, Xianyang, Rizhao, Qujing, Shiyan, Sanming, Neijiang, Linyi, Nanping, Baishan, Zhenjiang, Taizhou, Ziyang, Luoyang, Mianyang, Xiaogan, Zunyi, Jiayuguan, Songyuan, Baotou, Dongguan, Zhangjiakou, Tianshui, Shizuishan
Transportation cities	Xinyang, Dazhou, Nanyang, Cangzhou, Shaoyang, Chenzhou, Baoding, Hengyang, Yancheng, Zhoushan, Liuan, Jincheng, Xiangfan, Suzhou, Yongzhou, Fuyang, Yiyang, Dingxi
Cultural and tourist cities	Xining, Taian, Yinchuan, Liaocheng, Huangshan, Beihai, Guilin, Heze, Wuzhou, Linfen, Jiujiang, Huanggang, Langfang, Changzhi, Zhangzhou, Dandong, Chaozhou, Lijiang, Ganzhou, Jinzhong, Yingtan, Jinmen, Huaihua, Yanan, Hohhot, Hulunbeir, Tsitsihar, Lianyungang, Kiamusze, Zhangjiajie, Mudanjiang, Qinhaungdao, Haikou, Zhaoqing
larger-scale cities	Zhuhai, Sanya, Yulin, Qingyang, Fangchenggang, Heihe, Jiuquan, Shangluo, Hezhou, Hengshui, Guyuan, Bayannur, Lishui, Zhangye, Jian, Meizhou, Linchang, Yingkou, Guigang, Chengde, Tieling, Siping, Tongliao, Lvliang, Yaan, Anshun, Zhaotong, Yulin, Wuzhou, Bengbu, Baicheng, Wuwei, Laibin, Kaifeng, Zhongwei, Shangqiu, Bozhou, Suqian, Baise, Pingliang, Meishan, Hechi, Shangrao, Maoming, Chizhou, Zhumadian, Guangan, Hanzhong, Chaoyang, Congzuo, Chaohu, Jinzhou, Guangyuan, Huaian, Jilin, Chifeng, Xianning, Zhoukou, Puzhou, Ningde, Anqing, Suizhou, Weinan, Suining, Yichun, Xinxiang, Bazhong, Chuzhou, Jinzhou, Fuxin, Jinhua, Nanchong, Changde, Suozhou, Quzhou, Zhuzhou, Nantong, Chantou, Bijie, Tongren, Baoshan, Lasa, Lanzhou, Longnan, Wuzhong, Luohe, Binzhou, Dezhou, Jining, Puer, Jieyang, Yunfu, Yangjiang, Yuncheng
Resource-dependent cities	Handan, Xingtai, Yangquan, Wuhai, Fushun, Benxi, Panjin, Hulushan, Liaoyuan, Baishan, Jixi, Hegang, Shuangyashan, Qitaihe, Huinan, Maanshan, Huibei, Datong, Yuncheng, Xinzhou, Huangshi, Tongling, Zaozhuang, Dongying, Pingdingshan, Hebi, Jiaozuo, Puyang, Baiyin, Karamay, Tongchuan, Jjinchang, Panzhihua, Erdos, Wulamchabu, Liupanshui, Ankang

has took a lot of measures to increase the green of city which is a visualization of the city. So, the area of green land of integrated is larger, which lead Integrated cities is the most significant contributor to the increasing of UGLC among these six types of cities.

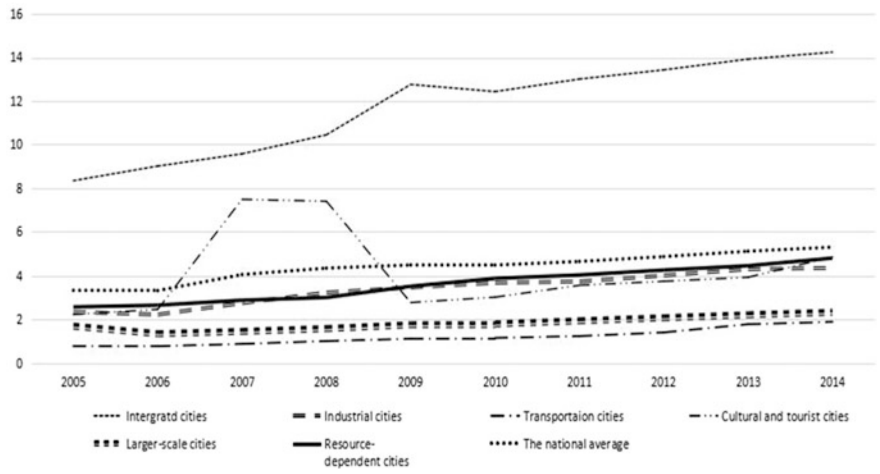


Fig. 134.1 The per capita UGLC of the six types of cities from 2005 to 2014

The function of industrial cities is producing various industrial products, so the most land of industrial cities is used for building large-scale factories, stacking industrial material, and internal transport. As a result, the land for green is relatively smaller, which lead to the level of per capita UGLC in industrial cities is lower. However, some industrial cities is adjusting industrial structure to promote the intensive utilization of land and pay higher attention on improving ecological environment by increasing green area, which lead to the level of per capita UGLC in industrial cities keep increasing year by year.

Transportation Cities have the functions of collecting and decentralizing of products, which is achieved by transportation system. These transportation systems consist of great transport facilities such as railroad, airport, port and dock, which cover a large area. As there is a trend that international trading will further develop, more land of transportation cities will be transform into storage land and be used for expanding the existing transportation system. So, the land of transportation cities used for green is more and more small, which lead to the level of per capita UGLC in transportation cities is lower for a long time.

Compered to integrated cities, the function of larger-scale cities is also comprehensive, but larger-scale cities are economic and political centers of smaller regions and integrated cities are economic and political centers of bigger regions. Another difference is that the economic strength of larger-scale cities is weaker and their influence is smaller. As shown in Table 134.4 and Fig. 134.1, the level of UGLC in larger-scale cities is much lower than that of integrated cities. Most of larger-scale cities developed from small country towns, so the local government pay more attention on city economic development than the urban planting, which contribute to the obvious difference in the level of UGLC in these two types cities.

Table 134.4 The per capita UGLC of the six types of cities

Year	Integrated cities ($\times 10^{-3}$ tons per capita)	Industrial cities ($\times 10^{-3}$ tons per capita)	Transportation cities ($\times 10^{-3}$ tons per capita)	Cultural and tourist cities ($\times 10^{-3}$ tons per capita)	Larger-scale cities ($\times 10^{-3}$ tons per capita)	Resource-dependent cities ($\times 10^{-3}$ tons per capita)	The national average ($\times 10^{-3}$ tons per capita)
2005	8.34077	2.34002	0.77028	2.22569	1.68967	2.56845	3.33109
2006	9.01033	2.22034	0.76843	2.45792	1.34376	2.64963	3.32024
2007	9.57357	2.74498	0.87015	7.48101	1.44906	2.87853	4.05826
2008	10.44734	3.23181	1.00492	7.39556	1.57774	3.00265	4.35268
2009	12.76053	3.46514	1.10864	2.77142	1.75466	3.52000	4.49766
2010	12.43161	3.67854	1.14643	3.01929	1.79170	3.880058	4.49394
2011	13.00665	3.73899	1.23191	3.56445	1.93473	4.03842	4.65903
2012	13.43050	4.01477	1.39878	3.74595	2.07457	4.26441	4.88300
2013	13.92357	4.30413	1.77580	3.93357	2.21120	4.461897	5.13009
2014	14.24290	4.36147	1.88442	4.86753	2.32677	4.81244	5.31619
The annual average rate of growth (%)	6.13	7.16	10.45	9.08	3.62	7.22	5.33

The foundation of the development of cultural and tourist cities is abundant tourism resources, so beauty spots of which the greening degree is higher occupied a lot of land. This may contribute to the higher level of UGLC in cultural and tourist cities. As shown in Table 134.4 and Fig. 134.1, the level of UGLC in cultural and tourist cities increased significantly in 2007 and 2008, because the area of green land of Tsitsihar which is one of cultural and tourist cities increased significantly in 2007 and 2008.

134.5 Conclusion

This study provides a functional classification of the 269 prefecture-level cities in China into six categories, including integrated cities, industrial cities, transportation cities, cultural and tourist cities, larger-scale cities, and resource-dependent cities. According to the analysis results, it can be found that there is significant difference in UGLC between the six types of cities. This difference can be explained by the different function of cities. It also demonstrates that integrated-type cities contribute far more to the national average value of UGLC. In addition, the increasing of the national average of UGLC year by year is also due to China's Eleventh Five-Year Plan (2005–2010) and Twelfth Five-Year Plan (2011–2015), which was designed to control and limit CO_2 emissions, increase green area and reform urban environment.

The findings of this study provide important references to the Chinese government for allocating the national emission reduction targets to various cities, of which the function determines the level of carbon sink. This study may lead the further research to explore how the ways of increasing urban carbon sink through improving the functions of different types of cities.

Acknowledgements This study is part of the research project sponsored by the Chinese National Social Science Program Fund, entitled "Assessment indicators for low-carbon city (15AZD025)".

References

Yi B, Han J, Zhou X, Yang F, Meng X, Cao WX et al (2015) Spatiotemporal pattern of carbon sources and sinks in Yangtze River Delta Region, China. J Appl Ecol (Ying yong sheng tai xue bao) 26(4):973–80 (Zhongguo sheng tai xue xue hui, Zhongguo ke xue yuan Shenyang ying yong sheng tai yan jiu suo zhu ban)

Belsky ES, Karaska GJ (1990) Approaches to locating urban functions in developing rural areas. Int Reg Sci Rev 13(13):225–240

Dhakal S (2009) Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy 37(11):4208–4219

Fang JY, Guo ZD, Amp SL, Chen AP (2007) Terrestrial vegetation carbon sinks in china 1981–2000. Sci China 50(9):1341–1350

Lu Y, Zhang Y, Qin Y, Chen Z, Wang G (2013) Spatial patterns of provincial carbon source and sink in china. Prog Geogr 32(12):1751–1759

Hildemann LM, Klinedinst DB, Klouda GA, Currie LA, Cass GR (1994) Sources of urban contemporary carbon aerosol. Environ Sci Technol 28(9):1565–1576

Harris CD (1943) A functional classification of cities in the United States. Geogr Rev 33(1):86–99

Jiang Y (2010) Impacts of land use change on ecosystem carbon sinks and sources. J Anhui Agric Sci

Koerner B, Klopatek J (2002) Anthropogenic and natural CO_2, emission sources in an arid urban environment. Environ Pollut 116(3):S45–S51

Liang D, Wu W (2009) Barriers and incentives of CCS deployment in China: results from semi-structured interviews. Energy Policy 37(6):2421–2432

Mulholland M, Seinfeld JH (2011) Inverse air pollution modelling of urban-scale carbon monoxide emissions. In: Residential interior design: a guide to planning spaces. Wiley, NY

Shen L, Shuai C, Jiao L, Tan Y, Song X (2017) Dynamic sustainability performance during urbanization process between BRICS countries. Habitat Int 60:19–33

Shen L, Shuai C, Jiao L, Tan Y, Song X (2016) A global perspective on the sustainable performance of urbanization. Sustainability 8(8):783

Shuai C, Shen L, Jiao L, Wu Y, Tan Y (2017) Identifying key impact factors on carbon emission: evidences from panel and time-series data of 125 countries from 1990 to 2011. Appl Energy 187:310–325

Sullivan P (2011) Energetic cities: energy, environment and strategic thinking. World Policy J 27 (27):11–13

Tian G, Wu J, Yang Z (2010) Spatial pattern of urban functions in the beijing metropolitan region. Habitat Int 34(2):249–255

Yang L, Hao JM, Lv ZY, Chen HY, Wang Y (2012) Analysis and prediction of carbon sources and sinks in Quzhou County of Huang huaihai Plain, China. J Food Agric Environ 10(1):656–661

Yang P, Tao X, Cui F (2010) Carbon emission and carbon source distribution in Shanghai. J Tongji Univ 38(9):1397–1402

Yang J (2012) Greenhouse gas inventory and emission accounting of Chongqing. China Popul Resour Environ

Yang YU, Zou YM (2013) Investigation on carbon source, carbon sink and carbon productivity in the East of China. Resour Dev Mark

Ye YE, Zou JF, Wu F, Li J, Liang YX, Wu J (2012) Characteristics of carbon sinks in highly urbanized areas and related improvement strategies. Res Environ Sci 25(2):240–244

Zhang Z (2000) Decoupling China's carbon emissions increase from economic growth: An economic analysis and policy implications. World Dev 28(4):739–752

Chapter 135
Use of a Mobile BIM Application Integrated with Asset Tracking Technology Over a Cloud

J. Park and Y.K. Cho

135.1 Introduction

With the advancement of mobile communication technology, construction management has become busier, complex and dynamic. These trends demand that construction professionals be more effective and organized to handle the demands of modern operations. Over the last decade, Building Information Modeling (BIM) has become an essential tool that provides an intelligent platform to efficiently plan, design, construct, simulate, and manage buildings and relevant information in a digital form (Eastman et al. 2011). This digital form of data allows sharing and managing of project plans and information among stakeholders much more effectively than the conventional paper-based methods. A rapid adoption of BIM followed this technological advancement by the industry. The evolution of BIM in the AEC industry brought a paradigm shift from the traditional project delivery process.

Despite the advancement, the construction sector still struggles from the lack of effective construction management methods in various aspects of construction operations: safety management (Carbonari et al. 2011; Park et al. 2015), assess control (Fiatech 2012), quality inspection and control (Wang 2008; Kim et al. 2008), and progress of as-built environment (Wang et al. 2014; Leung et al. 2008). For instance, project inspectors/managers spend a considerable amount of time on-site for (1) looking up information such as plans and specifications, (2) manually taking notes in the field and logging in such information in the office. Existing methods of tracking and managing defect detection and material inspection still rely on a labor-intensive, unreliable manual recording on paper-based documents (Wang 2008). Furthermore, other common on-site problems include time and space dis-

J. Park · Y.K. Cho (✉)
School of Civil and Environmental Engineering, Georgia Institute of Technology,
790 Atlantic Dr. N.W, Atlanta, GA 30332-0355, USA
e-mail: yong.cho@ce.gatech.edu

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_135

crepancies between a construction site and a remote office, insufficient number of on-site managers, and inefficient communication among project stakeholders (Kim et al. 2008; Kimoto et al. 2005). To address this, Cho et al. (2015) proposed a cloud-based energy management system and showed its efficacy as a decision support tool. In construction, use of such cloud-based communication can help to better address the mentioned on-site issues, but such a tool is missing in state of the art construction management tools. In addition, the digital data representing a building model often fail to provide construction-specific information and therefore requires extra effort in analyzing the model and then developing detailed project-specific construction plans (Kim and Cho 2015).

Recent advancements in mobile technology enabled commercial development of mobile BIM. These are, however, still in the beginning stage of development and use in construction. Our recent in-person interviews with construction companies indicate that there are many issues with such technologies to be practically used on-site. The users are required to be familiar with them for operation. This, in turn, necessitates extra costs in training and educating crews on regular basis. In addition, due to the lack of location awareness within a current mobile BIM system, the users need to manually navigate through the virtual BIM environment to find their locations. Also, due to the same reason, the system does not have the interactive ability to visualize near-by context information and provide object data relevant to the users.

As discussed above, although the benefits of BIM are evident for use in office, they are still questionable for construction in field because of existing challenges and issues that limit the effective use of BIM in certain aspects. Thus, this research presents a new approach to provide a more effective tool for on-site use. The approach combines a tracking system with a mobile BIM. The research uses sensing and mobile technologies to explore the integrated system. This system has potential to realize Internet of Things (IoT) through the use of a cloud, which can offer an increased connectivity to the world and a transformative, revolutionary impact on the construction domain. In the remaining sections, this paper will introduce an initiating effort by realizing a Bluetooth Low Energy (BLE) indoor tracking system on a mobile BIM environment that provides a cloud communication tool.

135.2 Literature Review

Positioning technology has gained rapid attention and has in fact been used in our lives for decades. With the introduction of Global Positioning System (GPS) technology, it has already been rooted in many forms of outdoor applications including navigating, tracking and monitoring. Available position information can be extended to location-based applications. Over the last decade, many researchers have investigated various topics of the indoor positioning field with different sensing protocols, including UWB (Park et al. 2016; Cho et al. 2010), RFID (Fang et al. 2016; Li et al. 2015), and Wi-Fi (Woo et al. 2011), with different tracking algorithms including fingerprinting, multilateration, and proximity. Despite these efforts, there still exist many technical and practical challenges that prevent widespread use of indoor tracking applications (Kodeboyina and Varghese 2016). To overcome the challenges, this study uses a relatively new technology, BLE, that offers special features over other sensing technologies, including low cost, small form factor, and low energy researchers (Gomez et al. 2012; Palumbo et al. 2015; Zhuang et al. 2016).

In another aspect of effort to overcome the drawbacks, a few researchers have explored BIM in the development of a tracking/monitoring system. Shen and Marks (2016) introduced a framework to visualize near-miss data, manually collected by construction-site personnel, in a BIM platform. Fang et al. (2016) proposed an integrated BIM-RFID tracking system for construction management applications. This study, however, presents several drawbacks as for real-time application yet: (1) BIM was used only for visualization purposes, (2) the used approach, proximity cell-based localization, was unable to perform continuous tracking of a target, and (3) the system required complex installation of sensors with wired power sources. Li et al. (2014) conducted a study to develop a positioning algorithm that takes into account the signal attenuation from walls. This study made an initiating effort to utilize a BIM model to iteratively recognize nearby walls and consider a certain signal loss from each of detected walls nearby the target. To fully consider the signal attenuation occurring in radio-signal-strength-indication (RSSI)-based technology, one must take into account more factors, such as ceiling, floor, human, and existing radio signals that can negatively impact the signal quality. In addition, although BIM was integrated as part of the system, the role of BIM was limited to iteratively detecting walls, and the walls were assumed to offer a constant factor of signal reduction. A more recent study conducted by Park et al. (2016a, b) presented an effective use of BIM in conjunction with tracking for a safety application. Their developed system extracted and used BIM object data to serve as geometric boundaries to assist tracking and visualize the tracking results with respect to the safety hazard conditions used in their study. Although these efforts are found within the BIM and tracking domain, previous research has inadequately covered research studies that utilize a 3D BIM model to create a virtual environment presenting a construction site and that utilize building digital elements as a base of communication tool for construction applications.

135.3 Objective

The objective of this study was to develop a cloud-based on-site construction management tool that utilizes BIM and tracking technologies. This system should provide (1) location information of the user within a mobile BIM environment; (2) project information from BIM; and (3) a communication platform to store and share information collected at the site with other associated stakeholders.

135.4 Methodology

To meet the requirements defined by the objective, three entities, namely a BIM model, a tracking system and a cloud server, are integrated into a single system platform. Through this integration, information sharing takes place between components. Figure 135.1 shows a flowchart of the integrated system. The following sub-sections will discuss each of the components in detail.

135.4.1 BIM Component

BIM plays three important roles in the integrated system: (1) visualization, (2) geometric constraints for tracking, and (3) object information for on-site communication. Figures 135.2 and 135.3 show examples of object information property and geometric constraint property information, respectively. Information of any object that is modeled within a BIM model can be extracted. Such accurate BIM object information are combined with visualization of the site to form a virtual BIM model for on-site use. Also, the geometric properties of elements including walls and doors are extracted from BIM and imported into the tracking component of the integrated system. These elements construct boundaries and prevent a target from moving across the boundary by serving as geometric constraints. The exchange of the geometric constraint information enhances the quality of tracking and thereby provides more reliable visualization to the end user.

135.4.2 Sensor Component

The tracking component is one of the most critical components of the integrated system as it provides the location information of the target, on which the visualization and data communication are based. Our system uses the BLE-based

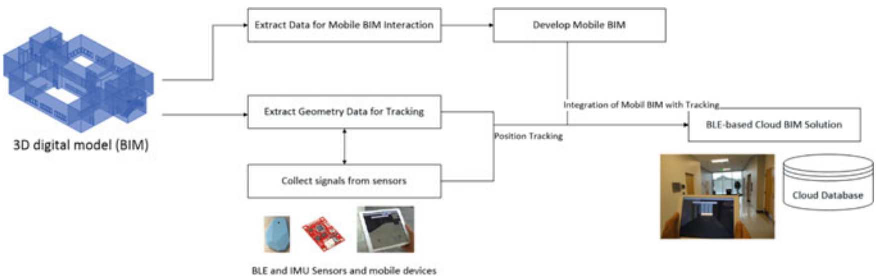


Fig. 135.1 Flowchart of the mobile BIM system

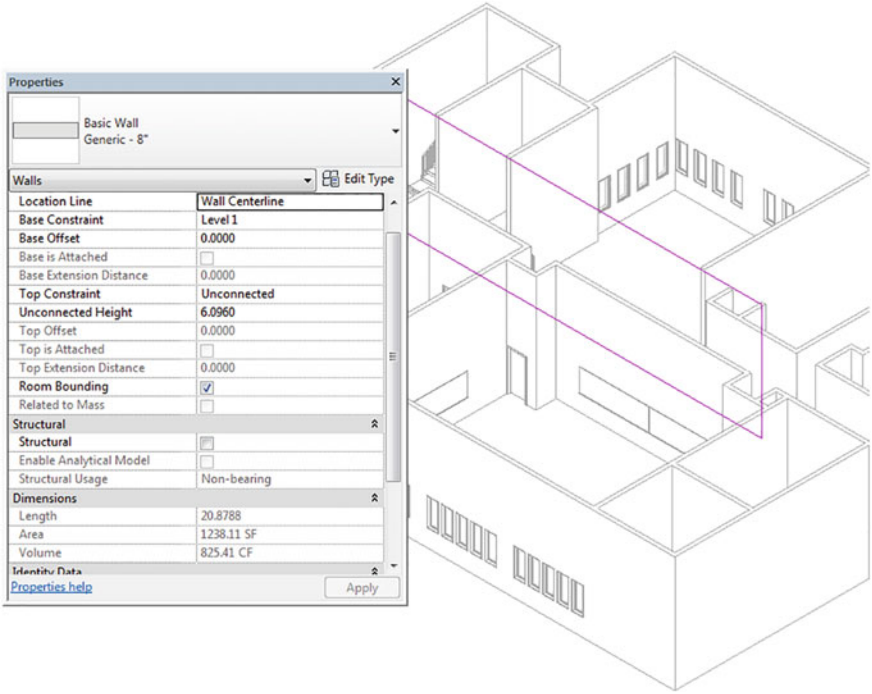


Fig. 135.2 Example of object information from BIM

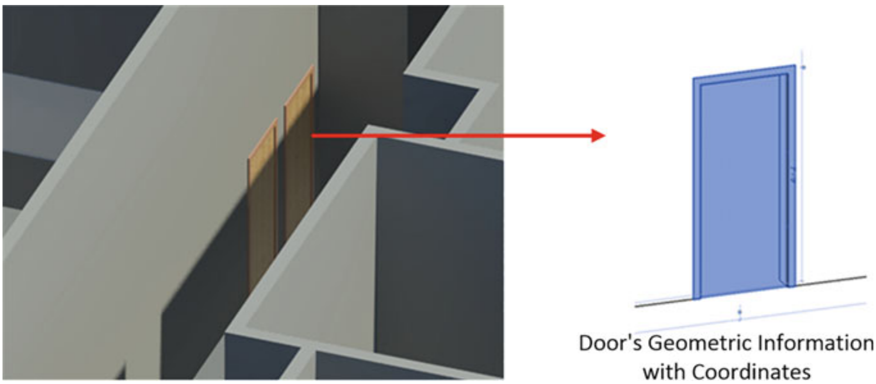


Fig. 135.3 Example of geometric constraint property information from BIM

technology to realize a low-cost and reliable tracking system. Figure 135.4 shows the interaction of the tracking system with the BIM component. The BLE sensors communicate with the mobile device, and this communication provides absolute position reference estimation. At the same time, the inertial measurement unit

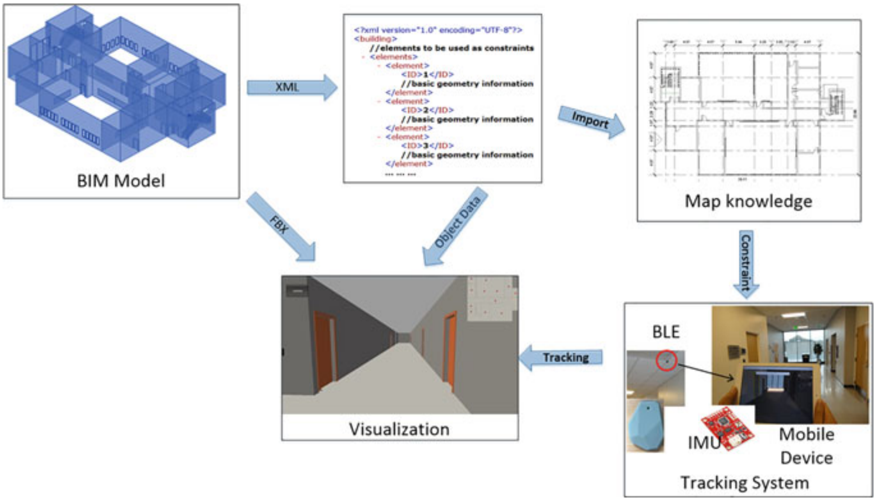


Fig. 135.4 Tracking part of the integrated system

(IMU) component, which broadcasts the data over a BLE package, provides relative position estimation with respect to the previously known location. This estimation of relative movement also minimizes the fluctuation in the position estimation provided by the BLE sensors. Furthermore, the orientation data from the IMU sensor is interpreted as the heading direction of the target and used to visualize the scene of the site.

135.4.3 Cloud Component

The developed system utilizes a cloud server to provide a platform for data storage and exchange. The use of a cloud server offers the capability of storing information at a more global level, where such information can be instantly shared with other relevant stakeholders and modified with on-going processes. For example, any issues found on-site, which require immediate attention of relevant parties, can be directly reported to the cloud and immediately shared with the relevant parties.

Figure 135.5 shows examples of a few on-site issues that need attention from workers: (a) an unsafe scaffold without bottom plates, (b) hazardous materials on the ground, and (c) inappropriate sharp metal piece on a thin rubber mat. The last example with a sharp metal piece on a rubber mat seems trivial, but can have a considerably negative impact on the building. If not properly treated or the end-tip of the metal piece rips the rubber mat, water can flow through below the roof and may cause damage to concrete or cause leakage somewhere inside the building. With the cloud components, these issues can be immediately reported to the associated workers, so preventive actions can take place in a timely manner. Therefore, the cloud component is essential in developing an integrated-mobile BIM construction application.

135.5 Experimentation

A field experiment was designed with consideration of two aspects. First, to prove the capability of the tracking components of the integrated system, the test was designed with different spaces and complex movements. Second, BIM information including the model view as well as property information was verified though the provided mobile BIM user interface, which communicates over a cloud.

The entire third floor of the Mason building at Georgia Institute of Technology was selected as a testbed. This testbed presented complexity with respect to space configuration and existing infrastructure. Such complexity is one of the most critical components that a tracking system should overcome as discussed in the literature review section. Figure 135.6 shows the layout of the system set-up for the experiment. A total of 18 BLE beacons were installed on the ceiling area over the testbed. The test subject was asked to move in and out of different spaces (e.g., Corridor, Room 1 and Room 2) and make multiple turns while walking.

Figure 135.7 shows the tracking results of the test showing the estimated location information at the top-right corner in each of the sub-figures (a, b, c and d) as well as the corresponding virtual BIM views. Figures 135.7a, b, c and d are the representations of the sequential movements in space. These results demonstrate that the mobile BIM application was successfully integrated with the BLE-based tracking system, and provided virtual mobile BIM views together with location estimation in real time.

Figure 135.8 shows interactions that the mobile BIM application can create over the pre-configured cloud; Fig. 135.8a shows the developed application that can be used by a site manager. BIM objects that are extracted shown as an example in Figs. 135.2 and 135.3 can be inspected by the site manager. The pre-configured

(a) Unsafe scaffold (b) hazardous material (c) inappropriate stock

Fig. 135.5 On-site issues requiring preventive actions

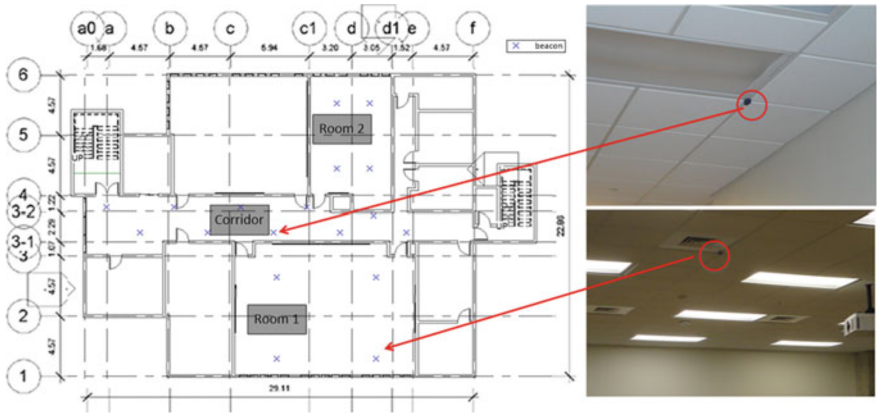


Fig. 135.6 Testbed and system installation

(a) Tracking at initiation

(b) Entering Room 1

(c) Turning in Room 1

(d) Entering in Room 2

Fig. 135.7 Tracking test result and virtual BIM view

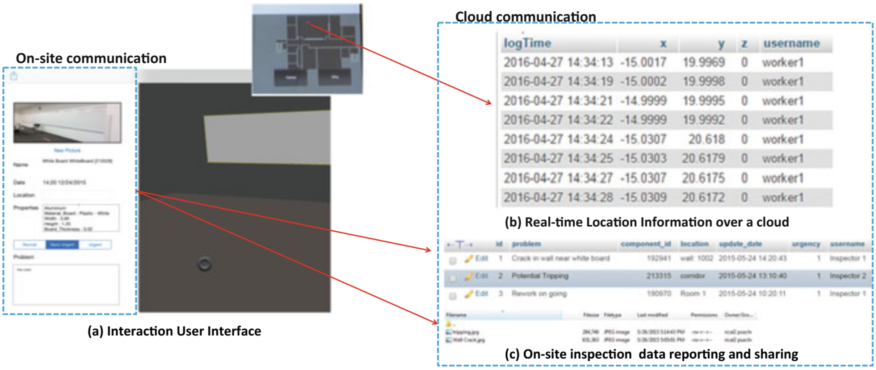


Fig. 135.8 On-site and cloud communication

cloud stores real-time site information collected by individual personnel; Fig. 135.8 presents real-time location information of the personnel (Fig. 135.8b) as well as data collected through the on-site communication (Fig. 135.8c).

135.6 Conclusion

Over the last decade, BIM and tracking have been explored by many researchers. Despite the extensive efforts in these domains, they have been mostly individually studied, and limited efforts were made to fully integrate them into a single system. This study proposed a new development of a virtual mobile BIM platform for an on-site application by integrating the two systems. The proposed system was created by (1) developing a low-cost BLE-based tracking system, (2) developing a mobile BIM platform, and (3) integrating the developed components over a cloud. The tracking system was comprised of BLE-sensors, IMU sensors, and map knowledge. The mobile BIM platform was developed through data extraction from BIM and then integration into the tracking system. A field experiment was conducted to demonstrate the capability of the system with respect to the real-time tracking information, the corresponding virtual BIM view, and communication. The test results showed that the successful integration of the system was made between the tracking system and the mobile BIM system, and that a new on-site communication tool using BIM and tracking was successfully implemented. In conclusion, the study advanced the use of BIM and tracking with system integration that can improve the overall project management and coordination.

Acknowledgements This material is based upon work supported by the National Science Foundation (IIP-1513589). Any opinions, findings, and conclusions or recommendations expressed on this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Carbonari A, Giretti A, Naticchia B (2011) A proactive system for real-time safety management in construction sites. Autom Constr 20:686–698. doi:10.1016/j.autcon.2011.04.019

Cho YK, Youn JH, Martinez D (2010) Error modeling for an untethered ultra-wideband system for construction indoor asset tracking. Autom Constr 19:43–54. doi:10.1016/j.autcon.2009.08.001

Cho YK, Li H, Park J, Zheng K (2015) A framework for cloud-based energy evaluation and management for sustainable decision support in the built environments. Procedia Eng, pp 442–448. doi:10.1016/j.proeng.2015.08.445

Eastman C, Teicholz P, Sacks R, Liston K (2011) BIM handbook: a guide to building information modeling for owners, managers, designers. Eng Contract. doi:10.1002/9780470261309

Fang Y, Cho YK, Zhang S, Perez E (2016) Case study of BIM and cloud-enabled real-time RFID indoor localization for construction management applications. J Constr Eng Manag 142. doi:10.1061/(ASCE)CO.1943-7862.0001125

Fiatech (2012) RFID for access control in construction sites. doi:10.1016/S0022-3913(12)00047-9

Gomez C, Oller J, Paradells J (2012) Overview and evaluation of bluetooth low energy: an emerging low-power wireless technology. Sensors 12:11734–11753. doi:10.3390/s120911734

Kim K, Cho YK (2015) Construction-specific spatial information reasoning in building information models. J Adv Eng Inf. doi:10.1016/j.aei.2015.08.004

Kim YS, Oh SW, Cho YK, Seo JW (2008) A PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects. Autom Constr 17:163–179. doi:10.1016/j.autcon.2007.03.006

Kimoto K, Endo K, Iwashita S, Fujiwara M (2005) The application of PDA as mobile computing system on construction management. Autom Constr 14:500–511. doi:10.1016/j.autcon.2004.09.003

Kodeboyina SM, Varghese K (2016) Low cost augmented reality framework for construction applications. In: 33rd international symposium on automation and robotics in construction (ISARC 2016) Low, 2016

Leung SW, Mak S, Lee BLP (2008) Using a real-time integrated communication system to monitor the progress and quality of construction works. Autom Constr 17:749–757. doi:10.1016/j.autcon.2008.02.003

Li N, Becerik-Gerber B, Soibelman L (2014) Iterative maximum likelihood estimation algorithm: leveraging building information and sensing infrastructure for localization during emergencies. J Comput Civ Eng 3:4014094. doi:10.1061/(ASCE)CP.1943-5487.0000430

Li N, Becerik-Gerber B, Soibelman L, Krishnamachari B (2015) Comparative assessment of an indoor localization framework for building emergency response. Autom Constr 57:42–54. doi:10.1016/j.autcon.2015.04.004

Palumbo F, Barsocchi P, Chessa S, Augusto JC (2015) A stigmergic approach to indoor localization using bluetooth low energy beacons. In: 12th IEEE international conference on advanced video and signal-based advance video signal based surveillance (AVSS), pp 1–6. doi:10.1109/AVSS.2015.7301734

Park J, Marks E, Cho YK, Suryanto W (2015) Performance test of wireless technologies for personnel and equipment proximity sensing in work zones. J Constr Eng Manag 142:4015049. doi:10.1061/(ASCE)CO.1943-7862.0001031

Park J, Cho YK, Martinez D (2016) A BIM and UWB integrated mobile robot navigation system for indoor position tracking applications. J Constr Eng Proj Manag 6:30–39. doi:10.6106/JCEPM.2016.6.2.030

Park J, Kim K, Cho YK (2016b) Framework of automated construction-safety monitoring using cloud-enabled BIM and BLE mobile tracking sensors. J Constr Eng Manag 5016019. doi:10.1061/(ASCE)CO.1943-7862.0001223

Shen X, Marks ED (2016) Near-miss information visualization tool in BIM for construction safety. J Constr Eng Manag 142:1–12. doi:10.1061/(ASCE)CO.1943-7862

Wang LC (2008) Enhancing construction quality inspection and management using RFID technology. Autom Constr 17:467–479. doi:10.1016/j.autcon.2007.08.005

Wang C, Cho YK, Park J (2014) Performance tests for automatic 3D geometric data registration technique for progressive as-built construction site modeling. Comput Civ Build Eng ASCE, pp 1053–1061

Woo S, Jeong S, Mok E, Xia L, Choi C, Pyeon M et al (2011) Application of WiFi-based indoor positioning system for labor tracking at construction sites: a case study in Guangzhou MTR. Autom Constr 20:3–13. doi:10.1016/j.autcon.2010.07.009

Zhuang Y, Yang J, Li Y, Qi L, El-Sheimy N (2016) Smartphone-based indoor localization with bluetooth low energy beacons. Sensors (Switzerland) 16:1–20. doi:10.3390/s16050596

Chapter 136
Using Switching State-Space Model to Identify Work States Based on Movement Data

Xincong Yang, Heng Li, Fenglai Wang, Xiaochun Luo and Dongping Cao

136.1 Introduction

Productivity issues are common in the construction industry of today. To improve productivity, it is considered worthwhile conducting an objective approach to investigating how limited time is spent on various construction activities. Conventional onsite supervision is based on direct or indirect observation, like inspectors and video monitoring (Teicholz 2013; Gong and Caldas 2009; Song and AbouRizk 2008; Lu et al. 2000). Such manual methods categorize the observed labors as either working or non-working and utilize the working proportion as an essential indicator of productivity (Dozzi and AbouRizk 1993). Obviously, the subjective measurements are time-and labor-consuming (Dixon et al. 2014). At the same stage, it is impossible for observers to track workers' behaviors anywhere and anytime across the whole project (Han and Lee 2013; Rodriguez et al. 2010), especially encountering hidden scenarios because of blind spots (Teizer et al. 2010).

To inquire further into the time allocation that has been used within different construction activities, the objective identification of work state onsite in timely manners is crucial. Existing popular research deploy computer vision-based motion capture systems, and wireless wearable motion sensor systems on construction fields to recognize and set a benchmark for worker/activity behaviors (Han and Lee 2013; Starbuck et al. 2014; Khosrowpour et al. 2014; Kim and Caldas 2013; Park and Brilakis 2012; Han et al. 2012, 2013; Cheng et al. 2013a, b; Cheng and Teizer 2013). Although detailed skeletal kinematic dynamics enables managers to assess work performances onsite, cumbersome wearable sensors and receivers

X. Yang · H. Li (✉) · X. Luo · D. Cao
Department of Building and Real Estate, Hong Kong Polytechnic University, Hung Hom, Hong Kong, China
e-mail: heng.li@polyu.edu.hk

X. Yang · F. Wang
School of Civil Engineering, Harbin Institute of Technology, Haerbin Shi, China

K.W. Chau et al. (eds.), *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*,
https://doi.org/10.1007/978-981-10-6190-5_136

frequently interrupt labors' procedures and are prone to generating erroneous recognitions because of the sophisticated exposed environment (Wang and Razavi 2015). Therefore, the primary objective of this study is to objectively identify actual work states of workers on construction sites and facilitate a better understanding of the time allocation of activities without interfering with the normal work process.

At current stage, real-time location system (RTLS) as a portable solution to supervision onsite enables to track workers/activities across the whole project. The generated movement data, considered as a comprehensive and complex consequence of multiple behavioral modes in both mechanism and statistics (Jonsen et al. 2005), provides a wealth information of workers/activities onsite. However, it is a challenge for inspectors to establish an accurate model and estimate the corresponding parameters from locations with noises. Alternatives are being sought to deal with the sophisticated issue, state-space model (SSM), an efficient method for time series analysis has emerged as one such alternative, which is prominent to inquire into movement data in ecology (Patterson et al. 2008). By coupling a hypothetical mechanistic model of individual movement, such as Lévy walk (Ramos-Fernández et al. 2004), random walk (Wu et al. 2000; Morales et al. 2004), etc., SSM enables scholars to infer the behavioral modes, estimate the process characteristics like speed and turning angles, as well as the variance of observation errors (Patterson et al. 2008). Similarly, aiming to gain a deep insight into work state onsite without interruption, this study attempts to apply and improve SSM to model the movement date from RTLS to objectively assess time allocation of workers and activities in practical construction projects. The identification process is mainly composed of four parts:

Eliminate potential erroneous location tracks by iterative forward/backward-averaging filter.
Establish SSM integrated with first-different correlated random walk model and derive the priors from pilot study.
Estimate posterior distribution of parameters, working and non-working states in constant time intervals by Bayesian inference using Gibbs sampling.
Extract the objective time allocation of workers and activities involved in practical project.

136.2 Error Elimination

RTLS adopted in this study is proactive-construction management system (PCMS) (Li et al. 2016), containing 6 anchors deployed on frameworks and more than 20 tags attached to safety helmets. As the basis of subsequent analysis, initial of observed locations from PCMS is critical to the validity of the ultimate conclusion. Thus, iterative forward/backward averaging filter (Austin et al. 2003, 2004; McConnell et al. 1992) accounting for eliminating the potential erroneous locations based on speed is employed to ensure the efficacy of the movement data. For each location point $\boldsymbol{s}_i$ in ascending order by time, the previous two travel speed $V(\boldsymbol{s}_{i-2}, \boldsymbol{s}_i)$ and $V(\boldsymbol{s}_{i-1}, \boldsymbol{s}_i)$, the subsequent two travel speed $V(\boldsymbol{s}_i, \boldsymbol{s}_{i+1})$ and $V(\boldsymbol{s}_i, \boldsymbol{s}_{i+2})$, and the geometric mean speed are calculated:

$$V = \sqrt{\frac{1}{4} \sum_{j=-2, j \neq 0}^{j=2} V\left(\boldsymbol{s}_i, \boldsymbol{s}_{i+j}\right)^2}$$

If any of the computed speed is larger than the maximum feasible velocity, which is based on the 95% percentile measured distribution of true speed, and hence the location point $\boldsymbol{s}_i$ is rejected. For the starting location points, extra border (padding) with the same constant values as the first location points is temporally added and finally removed before modeling.

It is noted that though the iterative filter is effective and simple to apply, the sampling size is dramatically decreasing to be deficient because of the immediate removal of noisy locations. Therefore, iterative forward/backward-averaging filter is only adopted to get rid of tremendously extreme locations, while the component of coordinate errors is estimated and modeled by independent Student's t-distribution, and hence influences from observation errors are minimized on parameter estimation without decreasing the sampling size, but accounting for noisy locations.

136.3 Switching State-Space Model

As the core of location data processing, state-space model (SSM) refers to a mathematical representation that utilizes input, output and state variables to describe the dynamics of system by first-order differential equations, consisting of coupled stochastic processes: state transition and state observation.

State transition process is a Markov process, a stochastic process with Markov property that change of states only depends on the current state. For a simple walk of worker onsite, a transition equation instinctively describes the dynamics of movement process in constant intervals as follows:

$$\boldsymbol{s}_{t+1} = \boldsymbol{s}_t + \boldsymbol{\eta}_t$$

where $\boldsymbol{s}_t$ is a two-dimensional vector of the observed location at time t, including x- and y-coordinates, and $\boldsymbol{\eta}_t$ is the process variability. With the respect of movement, such variability can be generally decomposed into two bivariate distributions, step lengths and turning angles (Morales et al. 2004). For an instance, when a worker is bending steel bars onsite, characterized by small-scale movements, the step lengths are denser relatively to zero, and when a worker is pouring concrete, characterized by large-scale movements, the step lengths tend to be longer and turning angles to be smaller. Both variables from the first difference of location coordinates intuitively indicate the direct working and non-working states of workers. Therefore, a first-difference correlated random walk (DCRW) model for movement process is employed to describe the complex behavioral modes, concerning on movement dynamics but not static location coordinates. The complete DCRW can be represented as:

$$\boldsymbol{d}_t \sim \gamma \boldsymbol{T}(\theta)\boldsymbol{d}_{t-1} + N_2(0, \boldsymbol{\Sigma})$$

where $\boldsymbol{d}_t$ is the first-difference vector revealing the dynamic changes between the location vector $\boldsymbol{s}_t$ and $\boldsymbol{s}_{t-1}$, and $\boldsymbol{T}$ is a transition matrix that indicates the rotation components leading to the shift from $\boldsymbol{d}_{t-1}$ to $\boldsymbol{d}_t$:

$$\boldsymbol{T}(\theta) = \begin{pmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{pmatrix}$$

where θ is the mean turning angle in a constant time interval. N_2 is a bivariate Gaussian distribution with mean 0 and covariance matrix $\boldsymbol{\Sigma}$:

$$\boldsymbol{\Sigma} = \begin{pmatrix} \sigma_x^2 & \rho\sigma_x\sigma_y \\ \rho\sigma_x\sigma_y & \sigma_y^2 \end{pmatrix}$$

where σ_x^2 and σ_y^2 are process variance in x- and y-coordinates respectively, and ρ is the correlation coefficient. Finally, coefficient γ is added to cope with the variability in the autocorrelation of direction and speed, so that the built model is flexible with various workers.

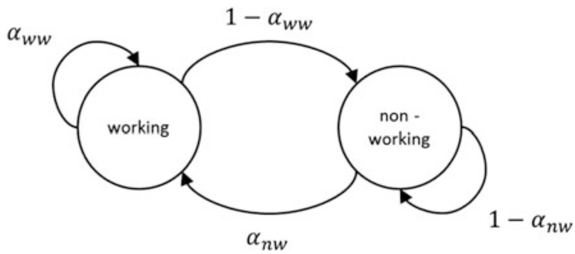
Another main component of SSM is the state observation process, indicating the prediction of unobserved states based on observed data by a measurement equation. Accounting for the irregular location tracks observed in discrepant sampling intervals, not all of unobserved states can be modeled and exemplified relying on corresponding observed locations. A simple assumption is proposed that a worker travels straightly from front to end locations during sampling intervals, thus, an estimation of irregular observations can be interpolated linearly as follows:

$$\boldsymbol{y}_t = (1 - j)\boldsymbol{s}_{t-1} + j\boldsymbol{s}_t + \boldsymbol{\varepsilon}_t$$

where $\boldsymbol{y}_t$ is the direct observation during the regular time interval from $t - 1$ to t and j is the time proportion of this time interval, and $\boldsymbol{\varepsilon}_t$ represents for the random measurement errors, attributed to equipment deployed in real-time location systems. Such error result from PCMS is assumed to follow t-distribution that stays robust to extremes values as mentioned in data processing.

Although the above SSM is apt to simulate a simple random walk, the practical movement data on construction sites are comprehensive and complex consequence of various behavioral modes. A potential method to partition the mixed movements into multiple states is devising a statistic basis for switching model according to first-difference of locations that parameters including step lengths and turning

Fig. 136.1 Working and non-working states transition



angles are estimated for disparate behavioral modes respectively. Here, parameters are added into the unobserved state vector comprised of components relevant to moving speed, turning angles, location coordinates, process, and measurement variability. Thereby, a switching model where γ and θ are mainly indexed by behavioral modes is constructed to describe working and non-working states, providing the basic information for further analysis of productivity. It is noticed that working state refers to direct productive activities onsite, for example, laying bricks, mixing mortar, etc., meanwhile non-working state represents for supporting and semi-productive activities, for example, materials handling, travelling to workplaces, etc. Non-productive activities like personal breaks, waiting and relax are not involved in, as these behaviors are deeply uncertain attributing to personalities. Therefore, the transitions between working and non-working states are shown in Fig. 136.1. α_{ww} represents the probability of being in working state at time t given the same working state at time $t-1$, and α_{nw} refers to the probability of being in working state at time t given non-working state at time $t-1$. Accordingly, the complete transition matrix can be constructed with only couple variables.

136.4 Parameter Estimation

To estimate the parameters and infer work states, a pilot study of a housing project was conducted. The initial dataset-trajectories were collected by PCMS across the construction of 28th standard floor. A variety of workers wearing helmet tags were involved in, including plumbers, concreters, welders, bar benders and carpenters. The location coordinates of these workers were detected and communicated through Bluetooth Low Energy (BLE) by six anchors fixed on scaffoldings around at relatively robust frequency of 2 Hz.

To wipe off the extreme locations with errors, 3 m/s as the maximum travel speed (Thorstensson and Roberthson 1987) was set up in iterative forward/backward and McConnell filters. Hereafter, a series of observed locations did exist during most of the constant intervals of one minute was generated with allowable errors, ensuring at least one locations were kept between each dyad of unobserved locations at adjacent time points.

To devise a methodology sufficient robust to estimate the discrete parameters, WinBUGS was selected to fit the DCRWS model to the observed data, enabling Bayesian analysis of statistic model via Markov Chain Monte Carlo methods. Since the natural mechanisms and experiences of working and non-working states were unknown, vague priors as initial input were set up in DCRWS model:

$$\theta \sim \mathrm{Uniform}(-\pi, \pi)$$
$$\boldsymbol{\Sigma} \sim \mathrm{Wishart}\left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, 2\right)$$
$$\gamma \sim \mathrm{Beta}(1, 1)$$
$$\alpha_{ww}, \alpha_{nw} \sim \mathrm{Uniform}(0, 1)$$

Although the convergence to stationary distributions is independent with the starting point according to Gelman-Rubin convergence statistics, to reach convergence in short time manners, assumptions that the initial states of workers during the record hours across the project were all defined as working. The reason was that workers tend to be always working under supervision during the pilot study. A hundred thousand possible states and behavior parameters were generated, tested and updated for 24 workers, through iterating the proposed model, potential work states in per time interval were estimated. As Fig. 136.2 plots, the blue and red filled circles are predicted locations from DCRWS while the dark rectangles are observed locations. The blue nodes are estimated states associated with working modes, so as red nodes with non-working modes.

Compare with the actual scenarios of the pilot study, the estimated states are reasonable that the working trajectories are more smooth and humanlike. The ultimate posterior medians and credible 95% limits of parameter estimation are listed in Table 136.1, suggesting that DCRWS model is fit to most of plumbers and concreters but not to bar benders, welders, and carpenters for behavior recognition. For example, the turning angle θ from plumber 2 of working and non-working reveals a substantial discrepancy in median and the step variable γ covers almost no intersections, indicating that plumber 2 performs working and non-working activities in obviously different movement behaviors. Apart from plumber 5, the rest members of pip-installation team tend to undertake reciprocal tasks with large turns rather than other travelling or handling tools and materials. Though some γ of plumbers are overlapping partially, such patterns reveal persist movement steps whenever working or non-working. Meanwhile, for workers like Bar Bender 4, both of θ and γ share substantial overlap ranges, suggesting the initial model without switching may be a better fit because of the only behavioral mode shown.

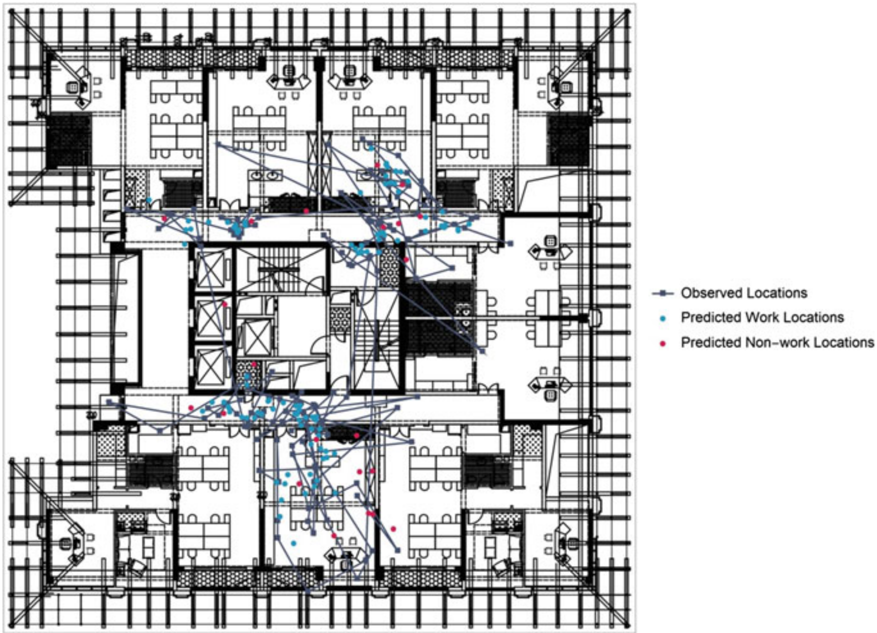


Fig. 136.2 Observed and predicted locations of a plumber

136.5 Time Allocation

According to the parameter estimation from the pilot study, the reasonable posteriors of work states are summarized in Table 136.2. Here, work rate is used to assess the performance of construction activities and the level of time allocation onsite. This indicator is defined as the working time divided by the total time, or the amount of working state divided by the total states when the time interval is constant. As Table 136.2 listed, the direct work rates of the housing project generated by the proposed method are far more than the common field rating 60 and 30–40% work sampling (Dozzi and AbouRizk 1993), and the work rates of plumbers and concreters are obviously less than that of carpenters and bar benders. As mentioned in parameter estimation section, a possible reason is that there exist more than two movement behavioral modes for such workers onsite and the simple switching model improperly combines parts of non-working into working state. Another possible reason is that the movement behavioral modes when working and non-working are almost same, which is impossible to distinguish from each other.

An interesting find is that no leaders performed the highest work rate in professional teams respectively, somehow suggesting they have to spend time on non-working activities, like team cooperation and communication, with sacrificing working time.

Table 136.1 Posterior medians and credible 95% limits of parameter estimation

Parameter	Plumber 1			Plumber 2			Plumber 3		
	2.50%	Median	97.50%	2.50%	Median	97.50%	2.50%	Median	97.50%
θ_W	2.80	3.09	3.14	3.08	3.13	3.14	3.11	3.14	3.14
θ_N	−0.34	0.04	1.03	0.02	1.24	1.94	0.84	1.90	2.31
γ_W	0.77	0.93	0.99	0.93	0.98	1.00	0.90	0.99	1.00
γ_N	0.69	0.93	1.00	0.20	0.56	0.90	0.69	0.94	1.00
Parameter	Plumber 4			Plumber 5			Plumber 6		
θ_W	−3.12	1.27	3.13	−3.07	−0.15	3.11	−3.11	−2.77	2.19
θ_N	−3.12	0.73	3.12	−3.05	−0.84	3.09	−2.96	0.16	3.02
γ_W	0.18	0.82	0.99	0.05	0.74	0.99	0.37	0.85	1.00
γ_N	0.17	0.71	0.99	0.05	0.73	0.99	0.46	0.88	1.00
Parameter	Welder 1			Welder 2			Carpenter 1		
θ_W	2.97	3.10	3.14	−3.14	−3.12	−3.01	−3.13	−2.80	3.13
θ_N	−2.42	−2.18	−0.23	−2.61	−2.01	2.74	−3.12	−2.51	3.13
γ_W	0.82	0.94	1.00	0.87	0.95	1.00	0.26	0.88	0.99
γ_N	0.79	0.97	1.00	0.15	0.88	1.00	0.19	0.87	0.99
Parameter	Carpenter 2			Carpenter 3			Carpenter 4		
θ_W	3.00	3.10	3.14	-3.13	2.50	3.13	1.93	3.05	3.12
θ_N	−1.00	0.88	2.00	−3.12	1.52	3.13	−3.12	1.76	2.99
γ_W	0.85	0.96	1.00	0.05	0.89	1.00	0.44	0.96	1.00
γ_N	0.09	0.56	0.97	0.03	0.67	0.99	0.02	0.51	0.99
Parameter	Concreter 1			Concreter 2			Concreter 3		
θ_W	2.79	3.07	3.14	−3.14	−3.11	−3.05	3.02	3.09	3.14
θ_N	−0.54	0.51	0.72	−0.25	−0.08	0.05	0.10	0.30	0.56
γ_W	0.75	0.95	1.00	0.93	0.98	1.00	0.91	0.96	0.99
γ_N	0.84	0.96	1.00	0.84	0.95	1.00	0.87	0.97	1.00
Parameter	Concreter 4			Concreter 5			Concreter 6		
θ_W	2.76	3.01	3.13	−3.14	−2.96	−2.82	3.05	3.12	3.14
θ_N	−0.91	−0.25	0.31	0.68	1.47	2.08	−2.07	0.66	1.30

(continued)

Table 136.1 (continued)

Parameter	Plumber 1			Plumber 2			Plumber 3		
	2.50%	Median	97.50%	2.50%	Median	97.50%	2.50%	Median	97.50%
γ_W	0.86	0.96	1.00	0.85	0.95	1.00	0.86	0.93	0.99
γ_N	0.46	0.82	0.99	0.16	0.62	0.96	0.32	0.73	0.98
Parameter	Concreter 7			Bar Bender 1			Bar Bender 2		
θ_W	2.96	3.06	3.13	−3.14	−0.96	3.14	−3.14	−3.02	3.10
θ_N	−0.64	0.32	0.79	−3.14	0.22	3.14	−2.69	−2.08	−0.81
γ_W	0.88	0.95	0.99	0.10	0.94	1.00	0.79	0.97	1.00
γ_N	0.38	0.71	0.97	0.06	0.90	1.00	0.18	0.63	0.95
Parameter	Bar Bender 3			Bar Bender 4			Bar Bender 5		
θ_W	−3.10	2.96	3.12	−3.13	2.88	3.13	−3.14	−1.36	3.14
θ_N	−3.12	−2.63	3.12	−3.12	2.71	3.13	−3.14	−0.82	3.14
γ_W	0.57	0.92	1.00	0.04	0.91	1.00	0.07	0.94	1.00
γ_N	0.49	0.90	0.99	0.03	0.54	1.00	0.06	0.91	1.00

Table 136.2 Work state estimation

Worker	Position	Working states	Non-working states	Direct work rate (%)	Mean work rate (%)
Plumber 1	–	100	13	88.50	86.12
Plumber 2	–	111	2	98.23	
Plumber 3	Leader	112	6	94.92	
Plumber 4	–	78	25	75.73	
Plumber 5	–	72	25	74.23	
Plumber 6	–	104	22	82.54	
Welder 1	–	98	21	82.35	87.03
Welder 2	–	63	3	95.45	
Carpenter 1	–	92	1	98.92	95.95
Carpenter 2	Leader	88	8	91.67	
Carpenter 3	–	103	2	98.10	
Carpenter 4	–	96	5	95.05	
Concreter 1	–	97	21	82.20	85.83
Concreter 2	–	144	48	75.00	
Concreter 3	–	151	28	84.36	
Concreter 4	–	108	11	90.76	
Concreter 5	–	117	18	86.67	
Concreter 6	–	171	10	94.48	
Concreter 7	Leader	175	23	88.38	
Bar Bender 1	–	52	0	100.00	93.61
Bar Bender 2	Leader	44	9	83.02	
Bar Bender 3	–	48	6	88.89	
Bar Bender 4	–	52	2	96.30	
Bar Bender 5	–	53	0	100.00	

136.6 Conclusion

To objectively assess and gain insight into the practical productivity and time allocation onsite, this paper proposes a switching state-space model integrated with first-difference random walk process to infer actual work states from historical movement tracks, containing four steps: eliminate erroneous locations, establish the integrated model, estimate the involved parameters, and extract objective time allocation and work rate for management. Such information can enhance productivity, layout planning, safety monitoring, ergonomics analysis, and responsibility assignment (Peddi et al. 2009). Although the housing project seems to validate the accuracy of two-state model for plumbers and concreters, the generated work rate is tremendous higher for carpenters and bar benders. Therefore, in future, more experiments and more workers will be carried out and involved in; advanced equipment will be utilized to improve the accuracy and minimize the effects on normal construction activities; extra variables like environment, climate will be taken into consideration.

References

Austin D, McMillan J, Bowen W (2003) A three-stage algorithm for filtering erroneous argos satellite locations. Mar Mamm Sci 19(2):371–383

Austin D, Bowen W, McMillan J (2004) Intraspecific variation in movement patterns: modeling individual behaviour in a large marine predator. Oikos 105(1):15–30

Cheng T, Teizer J (2013) Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications. Autom Constr 34:3–15

Cheng T, Teizer J, Migliaccio GC, Gatti UC (2013a) Automated task-level activity analysis through fusion of real time location sensors and worker's thoracic posture data. Autom Constr 29:24–39

Cheng T, Migliaccio GC, Teizer J, Gatti UC (2013b) Data fusion of real-time location sensing and physiological status monitoring for ergonomics analysis of construction workers. J Comput Civil Eng 27(3):320–335

Dixon MR, Whiting SW, Rowsey K, Gunnarsson K, Enoch MR (2014) Direct observation of road construction worker behavior. J Org Behav Manag 34(3):179–187

Dozzi SP, AbouRizk SM (1993) Productivity in construction. Institute for Research in Construction

Gong J, Caldas CH (2009) Computer vision-based video interpretation model for automated productivity analysis of construction operations. J Comput Civil Eng

Han S, Lee S (2013) A vision-based motion capture and recognition framework for behavior-based safety management. Autom Constr 35:131–141

Han S, Lee S, Peña-Mora F (2012) Vision-based detection of unsafe actions of a construction worker: case study of ladder climbing. J Comput Civil Eng 27(6):635–644

Han S, Achar M, Lee S, Peña-Mora F (2013) Empirical assessment of a RGB-D sensor on motion capture and action recognition for construction worker monitoring. Vis Eng 1(1):1–13

Jonsen ID, Flemming JM, Myers RA (2005) Robust state-space modeling of animal movement data. Ecology 86(11):2874–2880

Khosrowpour A, Niebles JC, Golparvar-Fard M (2014) Vision-based workface assessment using depth images for activity analysis of interior construction operations. Autom Constr 48:74–87

Kim JY, Caldas CH (2013) Vision-based action recognition in the internal construction site using interactions between worker actions and construction objects. In: International symposium on automation and robotics in construction and mining, pp 661–668
Li H, Yang X, Wang F, Rose T, Chan G, Dong S (2016) Stochastic state sequence model to predict construction site safety states through Real-Time Location Systems. Saf Sci 84:78–87
Lu M, AbouRizk SM, Hermann UH (2000) Estimating labor productivity using probability inference neural network. J Comput Civil Eng 14(4):241–248
McConnell B, Chambers C, Fedak M (1992) Foraging ecology of southern elephant seals in relation to the bathymetry and productivity of the Southern Ocean. Antarct Sci 4(04):393–398
Morales JM, Haydon DT, Frair J, Holsinger KE, Fryxell JM (2004) Extracting more out of relocation data: building movement models as mixtures of random walks. Ecology 85(9): 2436–2445
Park M-W, Brilakis I (2012) Construction worker detection in video frames for initializing vision trackers. Autom Constr 28:15–25
Patterson TA, Thomas L, Wilcox C, Ovaskainen O, Matthiopoulos J (2008) State–space models of individual animal movement. Trends Ecol Evol 23(2):87–94
Peddi A, Huan L, Bai Y, Kim S (2009) Development of human pose analyzing algorithms for the determination of construction productivity in real-time. Construction Research Congress, ASCE, Seattle, WA, Vol 1, pp 1–20
Ramos-Fernández G, Mateos JL, Miramontes O, Cocho G, Larralde H, Ayala-Orozco B (2004) Lévy walk patterns in the foraging movements of spider monkeys (Ateles geoffroyi). Behav Ecol Sociobiol 55(3):223–230
Rodriguez A, Zhang C, Hammad A (2010) Feasibility of location tracking of construction resources using UWB for better productivity and safety. In: The international conference on computing in civil and building engineering. Nottingham, United Kingdom
Song L, AbouRizk SM (2008) Measuring and modeling labor productivity using historical data. J Constr Eng Manag 134(10):786–794
Starbuck R, Seo J, Han S, Lee S (2014) A stereo vision-based approach to marker-less motion capture for on-site kinematic modeling of construction worker tasks. In: Proceedings of the 15th international conference on computing in civil and building engineering (ICCCBE), Orlando, FL
Teicholz P (2013) Labor-productivity declines in the construction industry: causes and remedies (another look), AECbytes Viewp 67
Teizer J, Allread BS, Mantripragada U (2010) Automating the blind spot measurement of construction equipment. Autom Constr 19(4):491–501
Thorstensson A, Roberthson H (1987) Adaptations to changing speed in human locomotion: speed of transition between walking and running. Acta Physiol Scand 131(2):211–214
Wang J, Razavi SN (2015) Low false alarm rate model for unsafe-proximity detection in construction. J Comput Civil Eng 04015005
Wu H-I, Li B-L, Springer TA, Neill WH (2000) Modelling animal movement as a persistent random walk in two dimensions: expected magnitude of net displacement. Ecol Model 132 (1):115–124