Research on Cost and Benefit of BIM Application for Construction Enterprises in China

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Abstract Building Information Modelling (BIM) was considered as an effective management tool in improving construction project performance. However, the research into the investment and return on BIM application in the context of the Chinese construction industry is still very limited. Through literature review, the cost factors and benefit indicators of BIM application in construction enterprises were identified, and an evaluation framework of BIM application cost and benefit for the construction enterprises was developed. The questionnaire survey was conducted with 37 BIM professionals to determine the critical cost factors and benefit indicators of BIM application in construction enterprises through the relative importance index (RII) approach. The results indicate that *personnel salary* (0.707), *hardware cost associated with BIM software operation* (0.680) and *consulting service fee* (0.647) are critical cost factors for BIM application, whereas *reduction of change* (0.847), *improvement of design quality* (0.847), and *reduction of project rework* (0.820) are critical benefit indicators for BIM application. The research results provide a theoretical basis for construction enterprises to formulate BIM development strategies.

Keywords Construction enterprise · BIM application · Cost · Benefit · Evaluation indicator system

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1 Introduction

In recent years, the scale of construction projects has increased significantly, the construction technology has become more and more sophisticated, and the requirements of construction projects have enhanced greatly. Therefore, an effective application of BIM by construction enterprises can continuously optimize the efficiency, maximize profits and minimize the construction costs. Since BIM provides the latest, accurate and comprehensive engineering database, construction enterprises can achieve a higher-level of collaboration with other project participants on BIM platform, which can prevent the problems of traditional fragment project delivery method. For example, in Jingdong Group Logistics Park construction project, during the process of joint design review using BIM, 165 problems were found in the drawings in advance and consequently design changes were proposed timely, which also effectively prevented rework and saved the construction cost of RMB 680,000 [35].

To promote the wide application of BIM in Chinese construction industry, the Ministry of Housing and Urban–Rural Development, and other departments continuously issued relevant policies and standards. However, the application of BIM in China is still very low with comparison to other developed countries. One of the primary barriers is that the cost and benefit of BIM application is uncertain and research in this area has been very limited. Additionally, existing research also indicated that majority of benefits of applying BIM in construction project can be achieved in the construction process. However, the investment and return on BIM application from the perspective of construction enterprises is not fully explored, which might restrict the wide application of BIM among these entities. Considering BIM application can save cost, reduce project delivery time and improve quality, promoting the application of BIM by Chinese construction enterprise can further improve their competitive edge in the international construction market. Therefore, this paper aims to identify the critical cost factors and benefit indicators of BIM application from the perspective of construction enterprises.

2 BIM Application Cost and Benefit Evaluation Factors Identification

To identify the BIM application cost and benefit factors for construction enterprises, it is necessary to identify the cost and benefit indicators of BIM application through comprehensive literature review. It was found that some research focus on analyzing the cost and benefit components of BIM application and established an evaluation system. For example, Sun [28] determined the BIM benefit evaluation system based on the combination of literature review and BIM technology application content. Using Delphi method and statistical analysis, five dimensions (finance, product, organization, management and strategy) with 17 factors of BIM application benefit evaluation system was developed which included return on investment, reduction rate

of project time, and qualified rate of product. However, no research was conducted on the evaluation of BIM application cost or benefit from the perspective of Chinese construction enterprises.

In the literature review process, 14 publications related to the cost of application BIM were identified. Ahn et al. [1] pointed out that the cost of applying BIM includes BIM software cost and BIM manager salary, which is 0.75–1.5% of the project cost. Xie et al. [33] used literature review method to identify the cost components of BIM application from the perspective of the whole project life cycle, including software cost, hardware cost, labor cost and other costs, and used the DEMATEL method to identify the key cost influencing factors of BIM application, such as market development condition, knowledge sharing, relationship between software, capability maturity model for software, and policy suitability. A total of 8 cost factors of BIM application were accumulated. The cost of BIM application in construction enterprises can be divided into two categories: direct cost (e.g., Giel and Issa [7], Malkin [23], Tan and Guo [29], Wang et al. [30]) and indirect cost [15, 16, 23, 36]. Direct costs are tangible costs that can be measured in currency. The direct costs of BIM application in construction enterprises mainly include the cost of purchasing BIM hardware and software (e.g., Giel and Issa [7], Malkin [23], Tan and Guo [29], Wang et al. [30], Zhao and Yuan [38]), the cost of consulting (e.g., Malkin [23], Wang et al. [30], Yuan [36], Zhao and Yuan [38]) and training (e.g., Giel and Issa [7], Li [15, 16], Malkin [23], Wang et al. [30], Zhao and Yuan [38]), and the personnel salary (e.g., Gie and Issa [7], Malkin [23]; Wang et al. [30], Xie et al. [33], Zhao and Yuan [38]). And the indirect costs mainly refer to the costs brought by the introduction of BIM technology by construction enterprises, such as opportunity cost (e.g., Li [15, 16], Ma et al. [22], Malkin [23], Yuan [36]), coordination cost (e.g., Chen [5]) and marketing cost (e.g., Chen [5]).

In addition, the benefit generated through BIM application for construction enterprises can also be divided into direct benefit and indirect benefit. Direct benefit includes economic benefit (e.g., Bai et al. [2], Barlish and Sullivan [3], Giel and Issa [7], Jin et al. [12], Nepal et al. [24], Song et al. [27], Wang et al. [30]) and product benefit (e.g., Bai et al. [2], Giel and Issa [7], Jin et al. [12], Li [14, 17], Song et al. [27], Tan and Guo [29], Xu [34]), and indirect benefit includes management benefit (e.g., Bryde et al. [4], Li et al. [20], Luo et al. [21], Han et al. [8], Rao [25], Sun [28]), organizational benefit (e.g., Barlish and Sullivan [3], Han et al. [8], Luo et al. [21], Nepal et al. [24], Shen et al. [26], Wu [31]) and strategic benefit (e.g., Bryde et al. [4], Jin et al. [12], Li et al. [19], Han et al. [8], Rao [25], Wu [31], Xu [34]). Huang et al. [11] investigated 204 projects in Singapore and found that the rework rate in projects with BIM application was lower than those projects where BIM is not applied. Furthermore, 64% of the construction projects without applying BIM had rework, while only 46% of the construction projects applying BIM had rework. Huang [9] established the model of engineering cost management based on large amount of BIM application data, aiming to analyze the competition in bidding stage, optimize the bidding scheme, improve the competitive edge of enterprises, simulate construction in construction stage, reduce change and control construction cost, and realize the benefit of BIM applications. Based on the above literature review

Table 1 Overall sample analysis of the importance of BIM application cost factors

Cost factors		Mean	Std	RII	Ranking
Direct cost	Hardware cost associated with BIM software operation $\mathbf{C_1}$	3.460	0.931	0.686	2
	Hardware cost related to assisting BIM application $\mathbf{C_2}$	3.027	0.957	0.584	8
	Software cost $\mathbf{C_3}$	3.324	0.747	0.632	4
	Personnel salary $\mathbf{C_4}$	3.514	0.961	0.708	1
	Training cost $\mathbf{C_5}$	2.973	0.866	0.600	6
	Consulting service fee $\mathbf{C_6}$	3.081	0.954	0.638	3
Indirect cost	Opportunity cost $\mathbf{C_7}$	3.081	0.924	0.622	5
	Coordination cost $\mathbf{C_8}$	3.054	0.848	0.589	7
	Marketing cost $\mathbf{C_9}$	2.865	0.855	0.551	9

results, this paper constructed the benefit index framework of BIM application in construction enterprises (see Tables 1 and 2).

3 Data Collection and Analysis

3.1 Data Collection

Based on critical literature review, a draft of questionnaire was designed and presented to experienced BIM construction professionals for pilot survey. The finalized questionnaire includes three sections. The first section solicits the respondent demographic information, including gender, age, and education background. The second and third sections asked the respondents to assess the importance of each factor (using five-point Likert scale, in which "1" means "totally disagree" and "5" means "totally agree") relating to BIM application cost and benefit, which is derived from literature review results.

Due to the impact of the outbreak of Coronavirus epidemic in 2020, the questionnaire was primarily distributed and collected through online approach. Fifty-seven questionnaires were administrated to BIM professionals in construction enterprises and 43 were returned, which produced 37 valid questionnaires (with a valid rate of 86.05%). Among the respondents, 86.49% were male, close 90% had undergraduate or above education experience, close 65% of them had more than one years' working experience in the construction industry and over 50% of them had been working on more than three projects using BIM.

Table 2 Overall sample analysis of the importance of BIM application benefit indicators

Benefit indicators		Mean	Std	RII	Ranking
Economic benefit	Reducing construction costs $\mathbf{B_1}$	3.892	0.809	0.784	7
Product benefit	Improving quality of design $\mathbf{B_2}$	4.081	0.759	0.838	2
	Reducing the number of changes $\mathbf{B_3}$	4.243	0.683	0.859	1
	Reducing rework on projects $\mathbf{B_4}$	4.135	0.713	0.838	2
	Saving project delivery time $\mathbf{B_5}$	3.649	0.824	0.741	11
	Improving the quality of projects $\mathbf{B_6}$	3.703	0.777	0.735	12
	Improving the safety level of projects $\mathbf{B_7}$	3.541	0.900	0.697	13
Management benefit	Reducing project risk $\mathbf{B_8}$	3.757	0.723	0.762	10
	Enhancing the integration between different disciplines in the company $\mathbf{B_9}$	3.946	0.743	0.795	5
	Enhancing the cooperation between different stakeholders $\mathbf{B_{10}}$	3.784	0.886	0.762	10
	Improving communication efficiency $\mathbf{B_{11}}$	3.946	0.780	0.800	4
	Improving the efficiency of work $\mathbf{B_{12}}$	3.892	0.567	0.784	7
	Improving the accuracy of quantity takeoff $\mathbf{B_{13}}$	3.838	0.800	0.773	8
	Reducing the number of claims $\mathbf{B_{14}}$	3.378	0.893	0.697	13
	Reducing the number of disputes $\mathbf{B_{15}}$	3.784	0.750	0.762	10
	Reducing operation and maintenance cost $\mathbf{B_{16}}$	3.676	0.852	0.746	15
	Improving operation and maintenance efficiency $\mathbf{B_{17}}$	3.811	0.660	0.768	9
Organizational benefit	Improving the efficiency of manpower use $\mathbf{B_{18}}$	3.378	0.953	0.670	14
	Improving the ability and quality of employees $\mathbf{B_{19}}$	3.730	0.962	0.768	9
Strategic benefit	Improving the company's competitive advantage $\mathbf{B_{20}}$	4.162	0.800	0.832	3
	Improving customer satisfaction $\mathbf{B_{21}}$	3.892	0.774	0.789	6

3.2 Reliability Test

The *Cronbach's alpha* is generally employed to assess the consistency of different indexes in the same dimension. According to the above standards, this paper used SPSS22.0 software to analyze the reliability of the cost factors and benefit indicators of the application BIM of the construction enterprises in the questionnaire data, respectively. The *Cronbach's alpha* values of cost factors and benefit indicators are 0.703 and 0.913, respectively, which indicates that the stability and reliability of questionnaire data over the threshold for further analysis [32].

3.3 Analysis on the Relative Importance of BIM Application Cost Factors and Benefit Indicators

According to Jin et al. [12], relative importance index (*RII*) was adopted in this paper to measure the magnitude of the cost factors and benefit indicators of BIM application. Ranging from 0 to 1, the *RII* value is calculated with Eq. (1).

$$\mathrm{RII} = \frac{\sum w}{A \times N} \tag{1}$$

where, *W* represents the Likert score (numerical values from 1 to 5) selected by each respondent in the questionnaire. *A* represents the highest score for each item (*A* is 5 in this survey), and *N* represents the number of valid questionnaires. The higher the *RII* value of a factor or indicator, the higher its importance for particular factor or indicator.

3.3.1 Analysis on the Relative Importance of BIM Application Cost Factors

RII was used to collate the importance of each direct cost factor and indirect cost factor based on the perspective from respondents. The results were shown in Table 1.

In order to understand whether the respondents with different demographic features (gender, age and educational background) have different perceptions on the importance of cost factors, two sample t-test or analysis of variance (ANOVA) was conducted to different groups of respondents. And the results found that all *p* values are higher than 0.05, indicating that survey participants have similar views on the importance of BIM application cost factors, regardless of their gender, age and educational background.

From Table 2, it can be seen that the critical cost factors of BIM application for construction enterprises are personnel salary, hardware cost associated with BIM software operation, and consulting service fee.

(1) Personnel Salary
For a single BIM application construction project, the salary of personnel shall be based on the time to hire BIM engineers in the whole project cycle. According to *51job.com*, BIM engineer's salary range is 6000–15,000 Yuan per month. If the construction enterprise subcontracts the BIM application package of the construction project to a BIM consulting firm, the contract amount should be considered as the salary of personnel. Currently, in order to fully apply BIM in their construction projects, some Chinese construction enterprises have recruited a large number of BIM professionals, and established an independent BIM application department, including managers, software developers and so on [14]. In this case, the personnel salary will be much higher with comparison to single application.

(2) Hardware Cost Associated with BIM Software Operation
Hardware cost associated with BIM software operation includes the cost of purchasing hardware/equipment such as computers, storage servers or workstations used by BIM engineers. BIM technology has a high requirement for computer hardware standard, and sometimes the existing computers at the construction enterprises cannot meet the requirements of efficient use of BIM software. Procurement of necessary computers and virtual equipment is a large initial investment for construction enterprises in this type of hardware cost [6].

(3) Consulting Service Fee
As mentioned above, sometimes the BIM application work is outsourced by construction enterprises to a BIM consulting company through bidding, if they do not have in-house BIM talents. For some construction enterprises, they prefer to develop their own BIM team and consider BIM as their long-term development goal. In this case, they may also need the professional service from BIM consulting company for training. In the long run, construction enterprise should follow this later strategy for BIM application, since outsourcing BIM services to other consultants will increase their costs significantly when their business is booming [14].

According to the survey report of Dodge Data & Analytics (2015), construction enterprises invest most of the BIM cost through promotion incentive mechanism (20% of the budget for BIM application) to encourage employees to use BIM, and this part of cost can be considered as personnel salary. This investigation result is also similar to current research which highlights the importance of personnel cost in applying BIM in Chinese construction enterprises.

3.3.2 Analysis on the Relative Importance of BIM Application Benefit Indicators

Similar to the cost analysis, the results *RII* about BIM application benefit are shown in Table 2.

Similarly, two sample t-test or ANOVA was conducted to different groups of respondents. And the results indicated that survey participants have a similar view on the importance of BIM application benefit indicators, regardless of their gender, age and educational background.

From Table 2, it can be found that the critical benefit indicators of BIM application in construction enterprises are *reduction of change* (0.847), *improvement of design quality* (0.847), and *reduction of project rework* (0.820).

(1) Reduction of change
Before construction, BIM can be used to carry out the clash detection among various disciplines and to optimize the drawings. Since majority of changes are design oriented, and as a result the changes can be reduced because design error or omission is prevented through applying BIM in the design process [31]. In addition, BIM can be used to simulate the construction of project, and in this process, the construction methods can be verified and communication between different stakeholders can be improved. These will also lead to less changes to the site construction.

(2) Improvement of design quality
As mentioned above, the integration of design from different disciplines can be achieved through using BIM technology in the design process. This enables the design team to detect design errors and omissions which cannot be effectively implemented in the traditional design process [7]. In addition, the design team member can get timely information about the change of design from other designers or other participants (e.g., subcontractors) and make revision accordingly. BIM can also facilitate designers carrying out design performance analysis to optimize the design, such as saving energy during the life cycle of project construction and operation. All these can improve the design quality with the assistance of BIM application.

(3) Reduction of project rework
Huang et al. [10] claimed that the rework of the construction project is due to the owner's changes to the contract content, design and procurement errors, suppliers' errors, changes and omissions in materials, machinery, manufacturing and transportation, construction enterprises' conflicts or inappropriate cooperation with the subcontractors and other factors. Construction enterprises can use BIM to verify the drawings from the client and detect quality problems before construction, which will significantly reduce rework in construction projects.

Kaner et al. [13] found that through applying BIM in the projects the design quality of construction projects was significantly improved for error-free drawings, and the labor productivity was steadily improved. These research results are similar to the

findings of current paper. However, Bryde et al. [4] concluded that the most influential benefit of BIM application was cost control (60%), followed by communication and project time (27%). This is contradictory to current research which indicated that the most critical benefits through BIM application were strategic benefit, product benefit and economic benefit.

4 Conclusion

Building Information Modelling (BIM) was considered as an effective management tool in improving construction project performance. However, the research into the investment and return on BIM application from the perspective of Chinese construction enterprises is scant. Understanding the actual cost and benefit of BIM application is a precondition of adopting BIM in their business. This paper aims to identify critical factors influencing the cost and benefit of BIM application in the Chinese construction industry. Questionnaire survey to BIM professionals was conducted to gather their insights and statistical analysis was followed to obtain research results. It was found that *personnel salary* (0.707), *hardware cost associated with BIM software operation* (0.680) and *consulting service fee* (0.647) are critical cost factors for BIM application, whereas *reduction of change* (0.847), *improvement of design quality* (0.847), and *reduction of project rework* (0.820) are critical benefit indicators for BIM application. In addition, construction professionals with different demographic features share similar perceptions about the importance of cost and benefit factors. Cost and benefit frameworks were also developed according to the data analysis results.

The BIM application cost and benefit evaluation system constructed in this paper can enable construction enterprises to comprehensively calculate the investments and returns of BIM application in actual construction projects, which will be helpful for them to formulate effective policies for their business operation. In addition, the researchers in this field can embark on future study about the cost and benefit of BIM application from the perspectives of other stakeholders. Due to the outbreak of Coronavirus epidemic and less availability of BIM professionals with comparison to other research topic in construction management field (e.g., risk management), only 37 valid responses were gathered for data analysis. Similarly, Zhang's [37] research in PPP also used 46 valid survey response for statistical analysis. Considering this, the research findings of this paper are valuable for researchers and practitioners understanding more comprehensively about the cost and benefit of BIM application in Chinese construction enterprises.

References

1. Ahn, Y. H., Kwak, Y. H., & Suk, S. J. (2016). Contractors' transformation strategies for adopting building information modelling. *Journal of Management in Engineering*, *32*(1), 05015005.
2. Bai, S., Zhang, Y. K., Han, F., Zhang, D. H., & Li, W. (2015). Analysis on the application value of BIM technology in prefabricated building. *Construction Economy, 36*(11), 106–109. (in Chinese).
3. Barlish, K., & Sullivan, S. (2012). How to measure the benefits of BIM–A case study approach. *Automation in Construction, 2012*(24), 149–159.
4. Bryde, D., Broquetas, M., & Volm, J. M. (2012). The project benefits of building information modelling (BIM). *International Journal of Project Management, 31*, 971–980.
5. Chen, X. R., Yu, H. Y., & Li, G. Y. (2014). The ROI of Tekla BIM in the practical application. *Value Engineering, 33*(32), 135–137. (in Chinese).
6. Fan, X. X. (2016). *Study of BIM application in construction enterprises*, Xi'an University of Architectural Science and Technology. (in Chinese).
7. Giel, B. K., & Issa, R. R. A. (2013). Return on investment analysis of using building information modeling in construction. *Journal of Computing in Civil Engineering, 27*(5), 511–521.
8. Han, Y. Q., Guo, J. X., & Wu, P. Q. (2016). Study on benefit valuation of BIM application. *Chongqing Architecture, 15*(8), 16–18 (in Chinese).
9. Huang, H. Z. (2016). Research on project cost management based on big data and BIM. *Construction Economy, 37*(9), 56–59. (in Chinese).
10. Huang, M. G., & Wang, P. Y. (2013). The impacts of BIM on construction general contracting project management. *Journal of Information Technology in Civil Engineering and Architecture, 5*(5), 88–91. (in Chinese).
11. Huang, B. G., Zhao, X. J., & Yang, K. W. (2019). Effect of BIM on rework in construction projects in Singapore: Status quo, magnitude, impact, and strategies. *Journal of Construction Engineering and Management, 145*(2), 04018125.
12. Jin, R. Y., Hancock, C. M., Tang, L., et al. (2017). BIM Investment, returns, and risks in China's AEC industries. *Journal of Construction Engineering and Management, 143*(12), 04017089.
13. Kaner, I., Sacks, R., & Kasslan, W. (2008). Case studies of BIM adoption for precast concrete design by mid-sized structural engineering firms. *Electronic Journal of Information Technology in Construction, 13*, 303–323.
14. Li, J. (2017). *The evaluation of BIM application benefit in construction industrialization.* Chongqing University. (in Chinese).
15. Li, A. L. (2018). *The research of the benefits and factors of BIM application.* Overseas Chinese University. (in Chinese).
16. Li, J. M. (2018). *Research and demonstration on benefit evaluation system of BIM application.* South China University of Technology. (in Chinese).
17. Li, X. K. (2018). Research on the impact of BIM commercial economic benefits application on the project life cycle. *Project Management Technology, 16*(3), 63–66. (in Chinese).
18. Li, J., Wang, Y., Wang, X., et al. (2014). Benefits of building information modelling in the project lifecycle: Construction projects in Asia. *International Journal of Advanced Robotic Systems, 11*(1), 1–11.
19. Li, P. W., Xu, J., & Duan, Y. Z. (2019). Evaluation method of property right of building information modeling in construction enterprises. *Science and Technology Management Research, 39*(1), 183–189. (in Chinese).
20. Li, J., Hou, L., Wang, X., et al. (2014). A project-based quantification of BIM benefits. *International Journal of Advanced Robotic Systems,* 11–15.
21. Luo, L., Ou, Y. M., Qiu, K. N., & Li, Y. G. (2019). On the enterprises' BIM demonstration project management practice. *Journal of Information Technology in Civil Engineering and Architecture, 11*(3), 1–10. (in Chinese).
22. Ma, X., Zhang, D. D., & Zhang, S. (2019). Study on the cost and benefit of BIM application: Curtain wall engineering works as the case. *Engineering Economy, 29*(10), 11–14. (in Chinese).

23. Malkin, R. (2011). BIM' S return on investment. *Architecture Australia, 100*(6), 116–117.
24. Nepal, M. P., Jupp, J. R., & Aibimu, A. A. (2014). Evaluations of BIM: Frameworks and perspectives. In *2014 International conference on computing in civil and building engineering* (pp. 769–776).
25. Rao, Y. (2016). *Research on measuring benefits of using BIM for owner*. Huazhong University of Science and Technology. (in Chinese).
26. Shen, L., Song, J. R., & Qian, J. (2018). Key factors and countermeasures of BIM application benefit based on DEMATEL model. *Journal of Civil Engineering and Management, 35*(2), 45–51. (in Chinese).
27. Song, J. R., Shen, L., & Li, Y. F. (2017). The game theory analysis between owner and the design company on the benefit distribution of BIM application. *Value Engineering*, *36*(6), 42–44 (in Chinese).
28. Sun, W. (2017). *Evaluation of operating benefit of stadium project based on BIM technology*. Shandong Construction University. (in Chinese).
29. Tan, K. B., & Guo, J. J. (2015). Research on return on investment of BIM application. *Project Management Technology, 13*(3), 122–126. (in Chinese).
30. Wang, X. Q., Chen, H., Qi, L., & Qiu, X. (2019). Study on investment efficiency of BIM hierarchical application. *Construction Economy, 40*(7), 95–99. (in Chinese).
31. Wu, W. (2014). *Research on BIM benefits evaluation method and application.* Huazhong University of Science and Technology. (in Chinese).
32. Wu, M. L. (2019). *Questionnaire statistical analysis practice: SPSS operation and application.* Chongqing University Press. (in Chinese).
33. Xie, T. R., She, J. J., and Song, J. R. (2018). Countermeasure research on promoting BIM based on the analysis of key cost factors. *Journal of Civil Engineering and Management, 35*(1), 152–157, 163. (in Chinese).
34. Xu, J. (2017). Research on EPC project benefit evaluation of construction enterprise based on BIM. Xi'an University of Science and Technology, Xi'an (in Chinese).
35. Yang, W. B., Wang, C. J., Wang, Z. X., Zhu, J., Ren, J., & Yu, Z. Y. (2019). Application of BIM+VR technology in construction of intelligent logistics and warehousing projects. *Journal of Information Technology in Civil Engineering and Architecture, 11*(2), 6–12. (in Chinese).
36. Yuan, S. H. (2016). *The evaluation of BIM application benefit for the owners.* Chongqing University. (in Chinese).
37. Zhang, X. Q. (2006). Public clients' best value perspectives of public private partnerships in infrastructure development. *Journal of Construction Engineering and Management, 132*(2), 107–114.
38. Zhao, B., & Yuan, S. H. (2015). Research on the BIM application modes and benefit evaluation based on the owners drive. *Construction Economy, 36*(4), 15–19. (in Chinese).