An Investigation on the Cost and Benefit of BIM Application Among Suzhou Construction Professionals

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Abstract. Existing studies indicated that Building Information Modelling (BIM) has been widely researched and adopted in developed countries, but BIM application in China is still in the preliminary stage, and the study on the cost/benefit of BIM application is vacant. The cost/benefit of BIM application has become a critical factor for construction enterprises to determine whether BIM can be implemented in construction projects. Therefore, this study aims to investigate the perceptions of the cost and benefit of BIM application among construction professionals in Suzhou, China. A mixed method was employed in this study to achieve the research aim. First, a critical literature review was conducted to identify 10 cost factors and 15 benefit factors that affect BIM application. Second, a questionnaire survey was undertaken to collect perceptions of each factor of BIM application from 42 construction professionals in Suzhou. Relevant Importance Index (RII) was performed to determine the ranking of the most influential factors. Statistical analysis results showed that *managerial personnel compensation* (0.84), *BIM design costs* (0.83) and *model development time* (0.82) are the most important cost factors for BIM application; while *reducing project cost* (0.86), *improving communication efficiency* (0.84) *and enhancing project quality* (0.82) are perceived as top 3 significant benefits for BIM application. Interviews were further conducted to verify the findings. This research enriches the study on cost/benefit of BIM application in the field of construction management, and provides potential recommendations based on empirical results for enhancing BIM application in China.

Keywords: Building Information Modelling · BIM application · Construction professionals · Cost and benefit · Mixed method · China

1 Introduction

In recent years, the continuously rapid development of the construction industry has contributed to an increase in larger-scale and more complex construction projects in

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China. This significant transformational trend has made the traditional methods of design and management mode gradually lose their effectiveness and relevance, and thus unable to match new demands brought by the development of modern construction. As a result, the construction industry in China is facing the challenges of revenue losses, resource shortage, and low-level of production (CCIA 2021). To solve these extant problems, Building Information Modelling (BIM) was promoted by the Chinese Government as a solution to adapt the new trends of digitization and informatization. BIM was developed by Charles M. Eastman in 1970s, and it is defined by the National Institute of Building Sciences (NIBS) as "a digital representation of physical and functional characteristics of a facility." (NIBS 2015). Since then, the applications of BIM have been widely researched in developed countries (Succar 2009). In particular, the cost/benefit, as a critical factor of BIM application for organizations to measure value and investment (Barlish and Sullivan 2012), has been studied extensively in the literature. For instance, Sacks et al. (2005) performed a study in the precast concrete industry and they found that potential benefit of BIM implementation is estimated between 2.3%–4.2% of total project costs; Azhar (2011) analysed 4 case projects in Georgia and found that the Return on Investment (ROI) for these projects was 634% on average.

Although the research on BIM cost/benefit has made remarkable achievements in developed countries, there still lack relevant studies in the context of China. In addition, the BIM application in China is still in its preliminary stage. For example, the Chinese BIM Application Value Report jointly issued by Autodesk and Dodge Data & Analytics (2015) indicated that less than 6% of design and contractor enterprises in China have a high application rate (i.e., more than 60% of projects adopted BIM); while 46% and 31% of design and contractor enterprises have a low application rate (i.e., less than 15% of projects adopted BIM). The low-level of BIM application revealed that construction professionals in China lack the cognition of cost/benefit of BIM, and thus hesitate to implement BIM in their projects. The perceived high cost of implementing BIM has become a barrier for many construction professionals to adopt this technology (Giel and Issa 2013). Hence, to comprehensively understand the concepts of cost/benefit and their influences on projects, this paper aims to investigate the perceptions of BIM cost/benefit of Suzhou construction professionals. The main objectives of this study are: (1) to identify the cost factors of BIM application through a literature review; (2) to identify the benefit factors of BIM application through a literature review; (3) to investigate the perceptions of cost/benefit through a questionnaire survey and interviews; and (4) to present possible recommendations for enhancing BIM application in Suzhou.

2 Literature Review

2.1 Cost Factors of BIM Application

Based on the concept of cost, the connotation of BIM application cost can be extended to the input cost of enterprises for constructing engineering projects by applying BIM technologies. Liu (2018) classified BIM application cost into resource cost, labour cost and time cost, referring to the costs incurred by the investment of resources such as BIM software, relevant BIM personnel salaries, and the time consumption for building and operating models, respectively. By adopting Liu's (2018) classification of cost types and reviewing 9 relevant papers, this study identifies ten factors under three major categories (i.e., resource cost, labour cost and time cost) that affect the cost of BIM application. The identified BIM cost factors under each cost category are demonstrated in Table 1 as the following:

Table 1. Cost factors of BIM application

Cost category	Descriptions	Cost factors	Sources
Resource cost	Resource cost refers to a series of costs incurred by the resources to be invested during the application of BIM technology, calculated by the actual amount of fees	1. Software acquisition costs	Barlish and Sullivan (2012); Bryde et al. (2013); Liu (2018); Yuan (2016)
		2. Hardware facility costs	Wang et al. (2019); Zhang et al. (2013)
		3. Training costs	Liu (2018); Zhang et al. (2013)
		4. BIM design costs	Barlish and Sullivan (2012); Liu (2018)
		5. Consulting costs	Liu (2018); Wang et al. (2019); Yuan (2016)
Labour cost	Labour cost refers to the manpower and its costs required for BIM application, which is calculated according to the actual costs	6. Technician compensation	Bryde et al. (2013); Wang et al. (2019)
		7. Managerial personnel compensation	Bryde et al. (2013); Wang et al. (2019)
Time cost	Time cost refers to the number of days spent during BIM application in a project, which is calculated on the basis of occurred days	8. Model development time	Liu (2018)
		9. Training time	Liu (2018)
		10. Planning and operation time	Liu (2018)

2.2 Benefit Factors of BIM Application

BIM application benefits is defined as the net benefits that can be obtained by the national economy and projects through the implementation of BIM (Shen 2019). In other words, it refers to the difference between inputs (e.g., fees, labour, and resources) and outputs (e.g., financial and managerial aspects) of BIM application. The performance of BIM application benefits can be affected by many factors including construction professionals' level of experience of implementing BIM, and the degree to which BIM technology has evolved in the corresponding applications. After extensively reviewing the literature, BIM benefits were classified into five categories (i.e., technical benefits, financial benefits, managerial benefits, organizational benefits, and top management benefits) with fifteen factors that affect BIM application. Among such, studies on technical benefits, financial benefits, and managerial benefits have achieved remarkable results. For example, Sacks and Barak (2008) conducted a comparative analysis and found that the 3D design provided by BIM enables a 15%–41% reduction of design time than that of traditional 2D projects. Vaughan et al. (2013) highlighted that through the application of information management systems, construction managers can improve their management efficiency by 11.6%. Giel and Issa (2013) undertook 3 case studies in the US and found that with the assistance of virtual design and construction, the ROI of BIM adoption varied greatly from 16% to 1654%. Fanning et al. (2015) conducted a comparative study and found that BIM implementation can reduce up to 89% change orders and achieve 9% cost savings. Rehman et al. (2020) undertook a case study and concluded that BIM based delay risk assessment can significantly reduce delays and shorten 16.88% of project time. After a critical literature review, Table 2 illustrates the factors under each BIM benefit category.

Table 2. Benefit factors of BIM application

Benefit category	Benefit factors	Descriptions	Sources
Technical benefits	1. Reducing project duration	BIM can significantly shorten project time by facilitating prefabrication, early involvement of contractors, and Integrated Project Delivery (IPD) in construction projects	Bryde et al. (2013); Jin et al. (2017); Liu et al. (2017); Mostafa et al. (2020); Rehman et al. (2020)
	2. Improving project quality	Through BIM tools such as common data environment and clash detection, collaboration among multiple stakeholders and coordination among documents can be better facilitated, leading to less-error and high-quality buildings	Ashcraft (2008); Gholizadeh et al. (2018); Liu et al. (2017); Lu et al. (2014); Paik et al., (2020)

(*continued*)

Table 2. (*continued*)

Benefit category	Benefit factors	Descriptions	Sources
	3. Reducing change orders	BIM-based clash detection allows time and spatial checks of designs, which improve the accuracy and clarity of design models	Barlish and Sullivan (2012); Lu (2014)
	4. Reducing reworks	BIM model allows more accurate prefabrication to be involved in construction projects, which reduces errors and construction reworks. 4D simulations enable contractors to visualize site logistics and construction works before construction	Jin et al. 2017; Mostafa et al. (2020)
Financial benefits	5. Reducing project cost	BIM enables more specified and accurate construction materials and equipment to be calculated and prepared, which can reduce procurement cost. The reduced change orders, reworks, and project durations can also save project cost	Azhar (2011); Bryde et al. (2013); Chan et al. (2019); Jin et al. (2017); Lu et al. (2014); Mostafa et al. (2020); Sacks et al. (2005)
	6. Reducing construction materials	BIM can facilitate offsite manufacturing and prefabrications, which reduces waste by avoiding over-ordering and miscalculations on the materials	Giel et al. (2013); Mostafa et al. (2020)

(*continued*)

Table 2. (*continued*)

Benefit category	Benefit factors	Descriptions	Sources
Managerial benefits	7. Improving communication efficiency	BIM common data environment provides parties and project members timely and efficient communication networks. Through BIM tools, 3D models and visualized schedules can be reviewed or modified, which makes communication flows faster	Ashcraft (2008); Bryde et al. (2013); Chan et al. (2019); Giel et al. (2013) Jin et al. (2017); Lu et al. (2014)
	8. Increasing productivity	BIM 4D scheduling enables better allocation of resources, more reasonable and visualized sequencing, and reduced uncertainties, which increase project productivity	Giel et al. (2013) Lu et al. (2014)
	9. Positive impacts on sustainability	BIM tools can facilitate environmental evaluation including the assessment of energy consumptions and carbon emissions	Jin et al. (2017); Liu (2018)
	10. Improving design efficiency	The coordination of design documents makes the design process more efficient. In addition, BIM enables the comparison between alternative designs and thus facilitates design optimization	Bryde et al. (2013); Chan et al. (2019); Jin et al. (2017); Lu et al. (2014)

(*continued*)

Table 2. (*continued*)

Benefit category	Benefit factors	Descriptions	Sources
	11. Enhancing quantity take-offs	BIM 5D tools allow for faster and more accurate quantity take-offs during design phases, which improves the accuracy of project budget	Gholizadeh et al. (2018)
	12. Reducing management cost	BIM implementation reduces the manpower of site management and enhances efficiency of construction management	Lu (2014); Song (2019)
Organizational benefits	13. Improving educational level of employees	Organizational benefits refer the extent to which the operation of organizations benefits from BIM implementation. Proper BIM training can improve the educational level of the employees and thus improve return on BIM cost	Jin et al. (2017)
Top management benefits	14. Improving reputations	The ability of enhancing competitiveness and reputations is considered as one of the key factors for BIM implementation for organizations	Chan et al. (2019)
	15. Improving clients' satisfactions	BIM implementation can improve clients' and other parties' satisfaction which can realise numerous benefits	Liu (2018)

3 Research Methodology

This study employs a mixed approach with the following four steps:

(1) A critical literature review on the identification of cost/benefit factors of BIM application was conducted to identify 10 cost factors and 15 benefit factors affecting the application of BIM in construction projects.
(2) A questionnaire survey was distributed to construction professionals in Suzhou to investigate their perceptions on the cost/benefit of applying BIM in construction projects.
(3) Structured interviews with BIM professionals in Suzhou were further conducted to test the statistical findings derived from the questionnaire survey and to gain deeper insights on the impacts of cost/benefit of BIM application in construction projects.
(4) Both quantitative and qualitative (critical review and interview findings) results were compared and triangulated to discuss the results and to present recommendations to improve BIM application in Suzhou.

The following section describes the questionnaire survey and interview processes in detail.

3.1 Questionnaire Survey

Based on the identification of cost and benefit factors of BIM application through a critical literature review, a draft questionnaire was designed and presented to experienced construction professionals for pilot study, which resulted in a more simplified and explicit content of the questionnaire. In addition, following the respondents' suggestions, the "*organizational benefits*" and "*top management benefits*" were combined into "*other benefits*" for clarity. The finalized questionnaire comprised two sections. The first section was intended to collect demographic information of the respondents, including their genders, ages, current roles, and years of working experience in the construction industry. The second section sought to ask the construction professionals to assess the impact of each of the 25 cost/benefit factor on BIM application according to their experience, on the basis of a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = medium; 4 = agree; 5 = strongly agree). A total of 48 questionnaires were distributed through the online approach to the construction professionals in Suzhou, China, and 42 valid questionnaires were received, with a valid rate of 87.5%. Since the application rate of BIM in construction industry significantly varies among stakeholders (Giel and Issa 2013), the data obtained of this research were collected from multifarious stakeholder groups, including professionals working as clients, contractors and designers. Table 3 illustrates the sample characteristics.

Table 3. Characteristics of the respondents

Category	Characteristics	Number of respondents	Percentage (%)
Gender	Male	36	85.71
	Female	6	14.29
Age	Less than 20 years old	3	7.14
	21–30 years old	18	42.86
	31–40 years old	12	28.57
	41–50 years old	5	11.91
	More than 51 years old	4	9.52
Years of experience	Less than 1 years	3	7.14
	1–5 years	6	14.29
	6–10 years	14	33.33
	11–20 years	12	28.57
	More than 21 years	7	16.67
Role	Contractor	3	7.14
	Supervision (*Jianli*)	1	2.38
	Designer	5	11.90
	Quantity surveyor	10	23.81
	Engineer	7	16.67
	Project manager	16	38.10

3.2 Interview

Following statistical analysis of the questionnaire survey dada, three semi-structured interviews were further conducted to verify the statistical findings and to capture qualitative insights about the importance of the cost/benefit factors of BIM application in the construction industry. For a successful interview process, the interviewees were contacted with a brief background information about the procedures of the interview through

Table 4. Brief information of the interviewees

Interviewee	Brief description
Participant 1	A quantity surveyor with 6 years' working experience in the construction industry, who has been involved in 2 projects implementing BIM technologies
Participant 2	A project manager who has 14 years' working experience in the construction industry, and has managed 4 building projects with BIM implementation
Participant 3	A new generation quantity surveyor who has experience on BIM model construction and takes BIM trainings frequently

social networking platform before making appointments with them, which ensured that they are ready and have formed general understandings of the interview. The following Table 4 presents brief information of the interviewees.

4 Data Analysis

4.1 Reliability Test

This study employs SPSS23.0 to calculate and test the reliability of the cost/benefit scales. The reliability of each category factor was assessed by Cronbach's alpha coefficient, which showed to be excess of 0.7 for both cost and benefit samples (0.719 and 0.770, respectively). This indicates that the internal consistency of items is reasonable since it is over the threshold of 0.7 (Morgan et al. 2007).

4.2 Relative Importance Index (RII)

The Relative Importance Index (RII) for each cost/benefit factor was calculated using Eq. (1) to determine the ranking of the most influential factors on the cost and benefit categories of BIM application in the scales. The RII is in the range of 0–1, and the higher value of the RII represents the higher importance of a factor. This technique is widely used in construction management fields (Sambasivan and Soon 2007; Shahsavand et al. 2018).

Relative importance index,

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

where

W weight assigned to each factor by the respondent (ranging from 1–5).
A the highest weight (5 in this case).
N total number of valid respondents (42 in this case).

4.3 Analysis of Cost Factors of BIM Application

As shown in Table 5, the statistical results of three primary cost categories revealed that *labour cost* (RII = 0.82) is the most influential cost factor for BIM application in the construction industry of Suzhou, followed by *time cost* (RII = 0.72) and *resource cost* (RII = 0.63). This result contradicts the findings obtained through the critical literature review, in which majority of the studies mainly focused on the *resource cost* (e.g., Barlish and Sullivan 2012 and Bryde et al. 2013) of applying BIM, instead of *labour cost* and *time cost*. This inconsistency reflects the differences in the perception of the cost for BIM application among different regions and groups (e.g., construction professionals in Suzhou and Beijing), which sheds light on a new perspective for the corresponding measures to improve the efficiency of BIM application cost in Suzhou.

Table 5. Statistical results of cost category

Cost category	Mean value	RII	Rank
Resource cost	3.16	0.63	3
Labour cost	4.12	0.82	1
Time cost	3.60	0.72	2

Table 6 presents the statistical results of the effects of each cost factor on BIM application. Based on the ranking, the top five cost factors affecting BIM application perceived by construction professionals in Suzhou are: *managerial personnel compensation* (RII = 0.84), *BIM design costs* (RII = 0.83), *model development time* (RII = 0.82), *technician compensation* (RII = 0.81), and *training time* (RII = 0.68). The results revealed that construction enterprises in Suzhou are facing tremendous workload and economic pressure in the design phase as they need to design and develop BIM models on their own, the cost of which cannot be intuitively reflected in the budget planning (Zhang et al. 2013). Liu (2018) conducted a case study in Zhengzhou, Henan Province, and found that inexperienced BIM modelers would spend a total of 40 days to construct BIM models before the commencement of construction. Hence, the success of BIM implementation relies heavily on the knowledge and expertise of BIM personnel (i.e., managerial and technical staffs), which greatly increases the training cost and time of BIM use. Zhang et al. (2013) also claimed that the approximate compensation of BIM personnel in a 3-year building project is close to RMB 780,000, which far more exceeds the acquisition fees for software and hardware devices.

Table 6. Statistical results of each cost factor

Cost factors affecting BIM application	Mean value	Standard deviation	Median	RII	Rank
Resource cost					
BIM design costs	4.17	0.62	4	0.83	2
Consulting costs	3.21	0.68	3	0.64	7
Training costs	2.86	0.57	3	0.57	8
Software acquisition costs	2.79	0.72	3	0.56	9
Hardware facility costs	2.76	0.66	3	0.55	10
Labour cost					
Managerial personnel compensation	4.19	0.74	4	0.84	1

(*continued*)

Table 6. (*continued*)

Cost factors affecting BIM application	Mean value	Standard deviation	Median	RII	Rank
Technician compensation	4.05	0.88	4	0.81	4
Time cost					
Model development time	4.10	0.66	4	0.82	3
Training time	3.40	0.77	3	0.68	5
Planning and operation time	3.31	0.64	3	0.66	6

4.4 Analysis of Benefit Factors of BIM Application

As presented in Table 7, the statistical results of four primary benefit categories showed that *financial benefits* (RII = 0.78) and *technical benefits* (RII = 0.73) are the most influential benefit factors for BIM application perceived by the construction professionals in Suzhou; while *managerial benefits* and *other benefits* are less influential, with the RII of 0.69 and 0.72, respectively. The result is also slightly inconsistent with the literature review findings (e.g., Ashcraft 2008 and Bryde et al. 2013), in which both Chinese and international studies mainly addressed the *technical benefits* and *managerial benefits* of BIM application.

Table 7. Statistical results of benefit category

Benefit category	Mean value	RII	Rank
Technical benefits	3.63	0.73	2
Financial benefits	3.90	0.78	1
Managerial benefits	3.44	0.69	4
Other benefits	3.61	0.72	3

Table 8 illustrates the statistical results of the effects of each benefit factor on BIM application. According to the ranking, the top five benefit factors affecting BIM application perceived by construction professionals in Suzhou are: *reducing project cost* (RII = 0.86), *improving communication efficiency* (RII = 0.84), *improving project quality* (RII = 0.82), *reducing reworks* (RII = 0.79), and *improving educational level of employees* (RII = 0.77). The findings are consistent with many researchers, who suggested that BIM can facilitate to improve cost control, communication and collaboration among stakeholders, and reduce design errors and reworks throughout the project lifecycle (Chan et al. 2019; Jin et al. 2017; Liu et al. 2017). For instance, Bryde et al. (2013) analysed secondary data from 35 BIM projects and highlighted that the most frequently reported benefits of BIM implementation are associated with cost reduction and control through the project lifecycle. Lu et al. (2014) pioneered the use of time-effort distribution curves to assess the cost/benefit of BIM application and found that the cost per square meter of GFA of the sample BIM project reduced 8.61% than that of the non-BIM project. Du et al. (2020) undertook a social network analysis by collecting 50,000 mails from both BIM and non-BIM projects and concluded that communication efficiency is enhanced and interpersonal information exchange is more direct and faster in BIM projects.

Table 8. Statistical results of each benefit factor

Benefit factors affecting BIM application	Mean value	Standard deviation	Median	RII	Rank
Technical benefits					
Improving project quality	4.10	0.69	4	0.82	3
Reducing reworks	3.93	0.68	4	0.79	4
Reducing change orders	3.31	0.81	3	0.66	12
Reducing project duration	3.17	0.79	3	0.63	15
Financial benefits					
Reducing project cost	4.29	0.60	4	0.86	1
Reducing construction materials	3.52	0.99	4	0.70	7
Managerial benefits					
Improving communication efficiency	4.19	0.80	4	0.84	2
Improving design efficiency	3.33	0.93	3	0.67	9
Enhancing quantity take-offs	3.33	0.72	3	0.67	9
Increasing productivity	3.33	1.03	3.5	0.67	9
Positive impacts on sustainability	3.29	0.83	3	0.66	12
Reducing management cost	3.19	0.89	3	0.64	14
Other benefits					
Improving educational level of employees	3.83	0.96	4	0.77	5
Improving reputations	3.57	0.77	3.5	0.71	6
Improving clients' satisfactions	3.43	0.74	3	0.69	8

4.5 Analysis of Interviews

After statistical analysis of quantitative data, qualitative data were further collected through interviews to make comparison and verify the findings. In terms of the cost factor of BIM application, all of the interviewees agreed that *labour cost*, including BIM personnel compensation and training fees, is the most influential factor. As Participant 1 and 3 suggested:

> *"On the basis of current market situations in Suzhou, the cost for employing 2 BIM engineers per project is around RMB 250,000/year, which is very expensive, even higher than the fees for BIM software and tools." (Participant 1).*
>
> *"Qualified BIM modeler and coordinator are highly demanding for project teams, and the high training cost for BIM personnel in our organization is a big concern when adopting BIM." (Participant 3).*

In addition, the interviewees agreed that financial benefits are the most crucial factors that affecting BIM application in their organizations. As Participant 2 pointed out:

> *"The key point of adopting BIM in our project lies in the dynamic cost control of the construction stage, the core of which is the cost analysis during the process of project implementation, leading to enhanced construction progress tracking and cost management."*

5 Conclusion and Recommendations

As a revolutionary tool to overcome the challenges faced by traditional construction projects, BIM has been widely researched and adopted in developed countries. However, relevant studies, in particular the perceptions of cost/benefit of BIM application among construction professionals, have obtained less attention in the context of Chinese construction industry. In order to fill this knowledge gap, this research first identified 10 cost factors and 15 benefit factors that affecting BIM application, and then explored the perceptions of each factor on BIM application among construction professionals in Suzhou, China. After conducting a mixed method involving a questionnaire survey and interviews with multidisciplinary construction professionals, the results indicated that *labour cost* and *financial benefits* are the most influential cost and benefit factors for BIM application among construction professionals in Suzhou. By calculating the RII of each cost and benefit factors, this research further revealed that *managerial personnel compensation* (0.84), *BIM design costs* (0.83), *model development time* (0.82), *technician compensation* (0.81), and *training time* (0.68) are the most important cost factors for BIM application; while *reducing project cost* (0.86), *improving communication efficiency* (0.84), *improving project quality* (0.82), *reducing reworks* (0.79), and *improving educational level of employees* (0.77) are perceived as top five significant benefit factors for BIM application in Suzhou. Several existing studies (e.g., Liu 2018 and Zhang et al. 2013) and the interview results also confirmed that the high BIM personnel compensation and training costs are one of the key concerns for construction entities in Suzhou. In addition, the reduction of project cost and reworks as well as the enhancement of communication are the key point for projects implementing BIM, which is similar to Bryde et al. (2013).

This research enriches the study on cost/benefit of BIM application in the field of construction management. In addition, based on the empirical results, potential recommendations for enhancing BIM application in Suzhou are provided as the following.

(1) Due to the fact that *labour cost* ranks first in the cost category, it is recommended that the facilitation of BIM knowledge sharing among construction professionals in Suzhou is crucial to mitigate the impact of high BIM personnel training cost encountered by construction enterprises.
(2) Since BIM has been proved to bring huge benefits to the construction industry (Lu et al. 2014), the local government in Suzhou is recommended to issue relevant policies (e.g., tax cuts and preferential land approval) to provide support and incentives for projects implementing BIM, which can mitigate cost risk incurred by construction enterprises.
(3) In order to increase the effects of BIM benefits, major project stakeholders (e.g., the client) are recommended to establish a clear goal for the project and to develop BIM implementation strategies to ensure a precise BIM workflow with project-tailored software and tools.

There are two main limitations in this research. First, the survey was conducted in Suzhou, and the results cannot represent the overall situation of China. Second, the research samples for the questionnaire survey is relatively small, which may affect the universality of the findings. Future studies are advocated to undertake a more comprehensive literature review (e.g., a systematic review) and to survey larger groups of construction professionals in the region of Jiangsu Province or China to achieve more universal results.

References

Ashcraft, H.W.: Building information modeling: A framework for collaboration. Constr. Lawyer **28**(3), 1–14 (2008)

Azhar, S.: Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadersh. Manag. Eng. **11**(3), 241–252 (2011)

Barlish, K., Sullivan, K.: How to measure the benefits of BIM — A case study approach. Autom. Constr. **24**, 149–159 (2012)

Bryde, D., Broquetas, M., Volm, J.M.: The project benefits of building information modelling (BIM). Int. J. Project Manage. **31**, 971–980 (2013). https://doi.org/10.1016/j.ijproman.2012.12.001

Chan, D.W.M., Olawumi, T.O., Ho, A.M.L.: Perceived benefits of and barriers to building information modelling (BIM) implementation in construction: The case of Hong Kong. J. Build. Eng. **25**, 100764 (2019)

CCIA (China Construction Industry Association): Heavy! Statistical analysis of the development of the construction industry in 2020. China Construction Industry Association (2021). https://baijiahao.baidu.com/s?id=1693994683461602883&wfr=spider&for=pc. (in Chinese)

Chinese BIM Application Value Report: Auto Desk & Dodg Data & Analytics (2015). (in Chinese)

Du, J., Zhao, D., Issa, R.R., Singh, N.: BIM for improved project communication networks: Empirical evidence from email logs. J. Comput. Civ. Eng. **34**(5), 04020027 (2020). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000912

Fanning, B., Clevenger, C.M., Ozbek, M.E., Mahmoud, H.: Implementing BIM on infrastructure: Comparison of two bridge construction projects. Pract. Period. Struct. Des. Constr. (2015). https://doi.org/10.1061/(ASCE)SC.1943-5576.0000239

Gholizadeh, P., Esmaeili, B., Goodrum, P.: Diffusion of building information modeling functions in the construction industry. J. Manag. Eng. **34**(2), 04017060 (2018)

Giel, B.K., Issa, R.R.A.: Return on investment analysis of using building information modeling in construction. J. Comput. Civ. Eng. **27**(5), 511–521 (2013). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000164

Jin, R., Hancock, C., Tang, L., Chen, C., Wanatowski, D., Yang, L.: Empirical study of BIM implementation–based perceptions among Chinese practitioners. J. Manag. Eng. **33**(5), 04017025 (2017). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000538

Liu, Y., Nederveen, S.V., Hertogh, M.: Understanding effects of BIM on collaborative design and construction: An empirical study in China. Int. J. Project Manage. **35**, 686–698 (2017)

Liu, Z.: Analysis of the application benefit of BIM technology in project management. Wuhan Institute of Technology (2018). (in Chinese)

Lu, W., Fung, A., Peng, Y., Liang, C., Rowlinson, S.: Cost-benefit analysis of building information modeling implementation in building projects through demystification of time-effort distribution curves. Build. Environ. **82**, 317–327 (2014)

Vaughan, J.L., Leming, M.L., Liu, M., Jaselskis, E.: Cost-benefit analysis of construction information management system implementation: Case study. J. Constr. Eng. Manag. **139**(4), 445–455 (2013). https://doi.org/10.1061/(ASCE)CO.1943-7862.0000611

Morgan, G.A., Leech, N.L., Gloeckner, G.W.: Correlation and regression. In: Proceedings of SPSS for Introductory Statistics: Use and Interpretation, pp. 129–131. Lawrence Erlbaum Associates, Mahwah, NJ (2007)

Mostafa, S., Kim, K.P., Tam, V.W.Y., Rahnamayiezekavat, P.: Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice. Int. J. Constr. Manag. **20**(2), 146–156 (2020)

NIBS (National Institute of Building Sciences) (NIBS): National BIM standard-United States: An authoritative source of innovative solutions for the built environment (2015). http://www.nebb.org/assets/1/7/Henry_Green_NIBS.pdf

Paik, S.M., Leviakangas, P., Choi, J.: Making most of BIM in design: analysis of the importance of design coordination. Int. J. Constr. Manag. (2020). https://doi.org/10.1080/15623599.2020.1774837

Rehman, M.S.U., Thaheem, M.J., Nasir, A.R., Khan, K.I.A.: Project schedule risk management through building information modelling. Int. J. Constr. Manag. (2020). https://doi.org/10.1080/15623599.2020.1728606

Sacks, R., Eastman, C.M., Lee, G., Orndorff, D.: A target benchmark of the impact of three-dimensional parametric modeling in precast construction. J. Precast Constr. Ind. **50**(4), 126–139 (2005)

Sacks, R., Barak, R.: Impact of three-dimensional parametric modelling of buildings on productivity in structural engineering practice. Autom. Constr. **17**, 439–449 (2008)

Sambasvian, M., Soon, Y.W.: Causes and effects of delays in Malaysian construction industry. Int. J. Proj. Manage. **25**(5), 522–531 (2007). https://doi.org/10.1016/j.ijproman.2006.11.007

Shahsavand, P., Marefat, A., Parchamijalal, M.: Causes of delays in construction industry and comparative delay analysis techniques with SCL protocol. Eng. Constr. Archit. Manag. **25**(4), 497–533 (2018). https://doi.org/10.1108/ECAM-10-2016-0220

Shen, W.: Research on evaluation of influencing factors of BIM application benefit based on SEM. Beijing University of Civil Engineering and Architecture (2019). (in Chinese)

Song, Y.: The application and benefit analysis of BIM technology in engineering cost management. China Hous. Facil. **2019**(5), 72–73 (2019). CNKI: SUN: ZZSS.0.2019-05-034. (in Chinese)

Succar, B.: Building information modelling framework: A research and delivery foundation for industry stakeholders. Autom. Constr. **18**(3), 357–375 (2009)

Wang, X., Chen, H., Qi, L., Qiu, X.: Study on investment efficiency of BIM hierarchical applications. Constr. Econ. **40**(7), 95–99 (2019). https://doi.org/10.14181/j.cnki.1002-851x.201907095. (in Chinese)

Yuan, S.: The evaluation of BIM application benefit for the owners. Chongqing University (2016). (in Chinese)

Zhang, Z., Jiang, H., Fu, P.: The value of BIM input and output. Construction Enterprise Management **2013**(12), 40–41 (2013). https://doi.org/10.3969/j.issn.1001-9251.2013.12.008. (in Chinese)