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STRATEGIES FOR THE IMPROVEMENT OF BIM CAPABILITIES IN CHINA: A SURVEY IN SHANGHAI

Tan, Dan[1,4], Wang, Guangbin[2] and Castro-Lacouture, Daniel[3]
[1,2] School of Economics and Management, Tongji University, Shanghai, China
[3] School of Building Construction, Georgia Institute of Technology, Atlanta, GA, USA
[4] dandantan@hotmail.com

Abstract: With the rapid application of Building Information Modeling (BIM) technology in the architecture, engineering and construction (AEC) industry in China during the past decade, it has been recognized that it brings many benefits. However, the benefits derived from the application of BIM do not meet industry expectations, which conflicts with the intent of BIM practitioners. Therefore, practitioners and researchers in this field have begun to realize that the industry needs to improve the BIM capabilities of industry professionals. The main objective of this paper is to understand the status quo of industry firm's BIM capability in China, and find out the critical factors influencing such BIM capabilities, such as strategy capacity, technology capacity and process capacity. The research will establish the theoretical framework of BIM capabilities based on literature review. Then a questionnaire survey to 300 construction project stakeholders in Shanghai, e.g., owner, designer, contractor, IT solution supplier, was used to explore the current status quo of BIM capability. Based on the survey feedback, the strategy capacity, technology capacity and process capacity were analyzed. Results showed that if the level of BIM capability is at the initial stage, then firms are keen on the improvement of BIM capabilities. However, the performance is poorer than expected. To further investigate the causes of lower performance, the major barriers on BIM capability improvement were also analyzed. Finally, several strategies to break the barriers were discussed, which also assist the government to make the policy decision on BIM technology promotion.

1 Introduction

The application of BIM technology has been growing rapidly in China for the past decade, especially since 2013(Cao et al, 2015). Dodge Data and Analytics (2015) forecasted that the percentage of projects that involved in BIM would be greatly increased over the next two years. However, with the government's initial promotion on BIM technology, it is critical for AEC industry to introduce appropriated effort to meet the BIM technology development targets of Shanghai. According to the survey of the Shanghai Municipal Commission of Housing Urban-Rural Development and Management(SHMCHURDM),the number of projects with BIM increased 200% in 2015 compared with 2013(SHMCHURDM, 2016). The higher use of BIM in projects required more and more professionals equipped with BIM skills. But the survey also point out that the lack of qualified BIM users in industry is a key barrier for construction project stakeholders, e.g., designer, general contractor, engineering consultants, etc. when trying to deploy BIM applications. Therefore, practitioners and researchers in this field have begun to realize that the industry needs to improve the BIM capabilities of industry professionals.

Based on a survey of 300 construction professionals involving the use of BIM, the study intended to contribute to the government policy decision on BIM technology promotion and industry firms' BIM strategy and practice, with overview of the status of BIM capabilities and related deployment efforts in the Chinese construction industry. In addition, this research aims at gaining insights into the critical factors influencing BIM capabilities, such as strategy capacity, technology capacity and process capacity, which are three specific BIM capabilities in the domain related to BIM implementation. The rest of the paper is organized as follows. A description of the research method is outlined in Section 3, and the data analysis is included in Section 4. Section 5 discusses the research findings and implications. Section 6 provides conclusions and recommendations for future research.

2 Research Background

Since 2007, several researchers have focused on BIM capabilities and the assessment tools for projects, organizations or individuals. Most of the principles followed the capability maturity model of Carnegie Mellon Software Engineering Institute and the quality management maturity grid by Crosby (Giel & Issa, 2015). However, with the exception of some investigations that addressed emerging BIM roles, and identified capabilities related to a small number of specialties, comprehensive research on overall BIM capabilities is yet to be published(Succar et al., 2013). It is difficult or even impossible to unify the definition about BIM capabilities, due to the multi-dimensional nature of BIM (Smith and Tardif, 2009).Different stakeholders have different views on the BIM capabilities, but most of them focused on the operation or technology domain. For instance, designers regard BIM as modelling the physical and functional characteristics of a building, general contractors regard BIM as a computer software model to improve decision making and the facility delivery process, and owners perceive "BIM as more of a collaborative process" (Chen, et al., 2014). Succar (2009, 2013) established the BIM competence hierarchy from individual perspectives: it is a set of interacting human, information, and technology, administration and operation issues. The BIM competency was defined as a BIM player's ability to satisfy a BIM requirement or generate a BIM deliverable, and also as the basic ability to perform a task, deliver a service or generate a product.

Smith and Tardif (2009) described BIM as a systematic approach to the lifecycle information related to a building, the adoption of BIM is more than the equipment of staff and technology infrastructure. Efforts for implementing BIM capabilities change over time. As McGraw-Hill (2009) reported, beginners rated BIM software and training as their highest priority investment, while experienced users ranked collaborative BIM procedures and marketing as their top priority investment. Technology is the core measure for information technology (IT) implementation, but the performance will not reach its full potential by focusing only on technology (Chen et al., 2014). Giel and Issa (2015) used the expert Delphi Panel to identify 66 critical factors that influence BIM competencies from the owner perspective, categorized into strategy competencies, administrative competencies, and operational competencies. Succar (2013) developed the BIM competences set into managerial, administration, functional, operation, technical, implementation, supportive and R&D, which can be categorized into technology, process and policy. Table 1 summarizes the impact of factors on BIM capabilities, according to previous research.

Table 1: Factors that Impact BIM Capabilities

Capability factors	Giel & Issa (2015)	Succar (2013)	Chen et al.,(2014)	Ding et al., (2015)	Capability Types
Organizational mission statement	√				Strategy
BIM vision and objectives	√	√	√	√	Strategy
R&D efforts	√	√	√		Process
BIM job duties	√	√	√	√	Process
Training Program	√	√	√	√	Process
BIM hiring practices for new staff	√		√		Process
Evaluation practices for BIM staff	√	√	√		Process
Teaching and coaching	√	√	√	√	Process
Upper management buy-in	√	√	√	√	Strategy
Staff BIM experience	√	√	√	√	Strategy
Model progression specification	√	√	√		Strategy
Team and workflow management	√	√	√	√	Process

Process and tech innovation	√	√	Technology

Accordingly, this paper proposed the framework of BIM capability including strategy capacity, technology capacity and process capacity, which is shown in Figure 1.

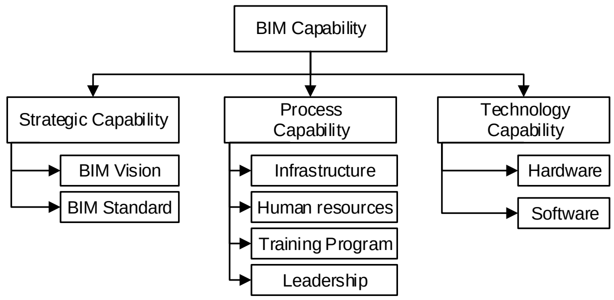

Figure 1: BIM Capability Framework

The effort to improve the BIM capability is based on the content of BIM capability. Therefore, this research proposed the following BIM capabilities: strategy capability, technology capability and process capability, the construction firms will focus on the related efforts to establish their basic abilities and improve them, which is divided into strategy effort, process effort and technology effort accordingly, shown as the left part of Figure 2. Although there have been some attempts to propose key factors affecting BIM capabilities from multiple dimensions, most studies focus mainly on the assessment for projects and individuals. Moreover, because many of the research conclusions are drawn for specific contexts, the situation and findings will be different in China. This research was conducted to fill these gaps by integrating previous research results through an empirical investigation of key factors and efforts that affect BIM capabilities of firms. This was necessary because the results may help complement theoretical and empirical assumptions, and help firms to assess their current situation and strategies for to improving their BIM capabilities. In addition, the suggestions also assist the government's policy decision on BIM technology promotion. The framework of conceptual research model is also shown in Figure 2.

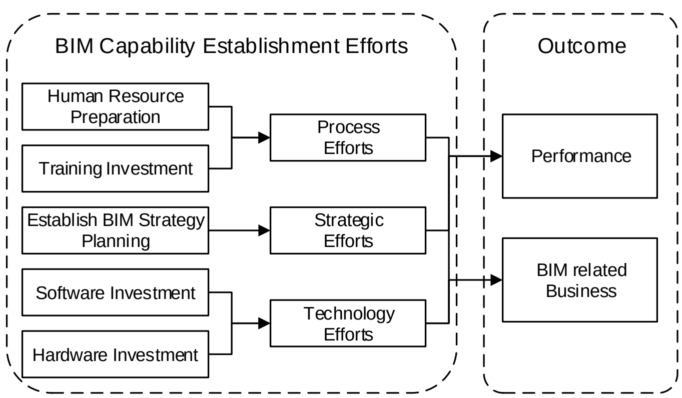

Figure 2: Conceptual Research Model Framework

3 Research Method

3.1 Survey Instrument

This research is part of an industry-wide investigation to understand the status quo of BIM capability and efforts to implement it in the Chinese construction industry. A questionnaire survey was used as the main method for collecting related data. The questionnaire included seven areas, including BIM organization and standard preparation, BIM related business, BIM related human resources, training system, BIM software and hardware investment, the performance status quo of firms' BIM implementation and difficulties encountered in the BIM capabilities establishment. The BIM organization and standard preparation, BIM related business, BIM related human resources, training system, BIM software and hardware investment, are objective, so these questions were asked to industry firms. The awareness of the performance status of firms' BIM implementation from a personal level, as well as the difficulties encountered in the BIM capabilities establishment were asked to the different levels of employees from the related firms.

As the starting point, an exploratory investigation was carried out to gain a preliminary understanding of current BIM implementation in Chinese construction firms. This included semi-structured interviews with related industry professionals from designer, contractor, consultant and software companies that were using BIM. Based on the information obtained from these interviews and related literature, a draft of the survey questionnaire was developed to collect the construction firms' data on BIM capabilities and related implementation efforts. A pilot survey was conducted, sending the questionnaire to one designer institute, one general contractor firm, with the aim of assessing the appropriateness of the questionnaire scope, identifying ambiguous expressions and testing the validity of related items. Based on the feedback of respondents, the questionnaire was further revised and subsequently distributed to targeted professionals of construction firms.

3.2 Sampling and Data Collection

This study includes BIM professionals in Shanghai from owner firms, design institutes, general construction firms, consultant companies, and software companies. A survey was sent to a total of 300bBIM-related professionals from 71 firms in Shanghai. 190 responses were obtained, which represented a response rate of 63%.158qualified responses from 69 firms were filtered out for further data analysis. The detailed information of the responses is shown in Table 2. The profiles of industry responses are listed in Table 3. The characteristics of the responses show that most professionals have a working experience on BIM of less than 3 years, which is adequate for the situation of BIM implementation in China. The profiles of the 69 industry firms are listed in Table4.

Table 2: Information about Responses

Respondent type	Number of questionnaires Sent	Responses received (%)	Valid responses (%)	Qualified responses (%)
Owner	35	20(6.67%)	19(6.33%)	18(6.00%)
Designer	60	39(13.00%)	35(11.67%)	31(10.33%)
Contractor	60	47(15.67%)	45(15.00%)	34(11.33%)
Consultant	84	59(19.67%)	58(19.33%)	51(17.00%)
Software	40	18(6.00%)	18(6.00%)	17(5.67%)
Others	21	7(2.33%)	7(2.33%)	7(2.33%)
Total	**300**	**190(63.33%)**	**182(60.67%)**	**158(52.67%)**

Table 3: Profile of Industry Responses (by roles and years of working experience with BIM)

Roles	<1Y	1-3Y	3-5Y	>5Y	Total (%)
Management	13(20.31%)	21(32.81%)	15(23.44%)	15(23.44%)	**64(40.51%)**
Engineer	25(34.25%)	35(34.25%)	11(15.07%)	12(16.44%)	**73(46.20%)**
BIM Operator	8(61.54%)	3(23.08%)	2(15.38%)	0(0.00%)	**13(8.23%)**
others	5(62.50%)	1(12.50%)	1(12.50%)	1(12.50%)	**8(5.06%)**
Total	**51(32.28%)**	**50(31.65%)**	**29(18.35%)**	**28(17.72%)**	**158(100.00%)**

Table 4: Profile of Industry Firms (by Firm Type and Ownership)

Firm Type	State-owned	Private	Joint Venture	**Total (%)**
Owner	10(90.01%)	0(0.00%)	1(9.09%)	**11(15.94%)**
Design Institute	10(66.67%)	4(26.67%)	1(6.67%)	**15(21.74%)**

General Contractor	8(61.54%)	5(38.46%)	0(0.00%)	**13(18.84%)**
Consulting	5(26.32%)	11(57.89%)	3(15.79%)	**19(27.54%)**
Software	0(0.00%)	7(100.00%)	0(0.00%)	**7(10.14%)**
Others	4(100.00%)	0(0.00%)	0(0.00%)	**4(5.80%)**
Total	**37(53.62%)**	**27(39.13%)**	**5(7.25%)**	**69(100%)**

4 Analysis and Results

In this section, the analysis was based on the feedback of company level from 69 firms and 158 respondents, including strategy efforts, process efforts and technology efforts.

4.1 Strategy Efforts

The data on strategy efforts by the firms were analyzed, including the BIM organization, strategy planning and standards for BIM implementation in firms. According to feedback from 69 firms, the results in Table 5 showed that 60% of the firms not only establish BIM organization, but also the strategy planning and standards for BIM implementation. This is mostly reflected in software companies (85.71%), design institutes (73.33%), and consulting companies (63%).

Table 5: Status of Implementing BIM Organization and Strategy Planning

Firm type	BIM organization (%)	Strategy Planning and Standards (%)	Both (%)
Owner(N=11)	10(90.91%)	5(45.45%)	4(36.36%)
Design Institute(N=15)	15(100.00%)	11(73.33%)	11(73.33%)
General Contractor(N=13)	12(92.31%)	7(53.85%)	7(53.85%)
Consulting(N=19)	18(94.74%)	12(63.16%)	12(63.16%)
Software(N=7)	7(100.00%)	6(85.71%)	6(85.71%)
Others(No.=4)	3(75.00%)	2(50.00%)	2(50.00%)
Total (N=69)	**65(94.20%)**	**43(62.32%)**	**42(60.87%)**

4.2 Process Efforts

To further explore about the firms' implementation process, the firms were asked to indicate the percentage of BIM related business, BIM related human resources, training systems, etc.

4.2.1 BIM Related Business

Although more than 60% of surveyed firms have established BIM organization and strategy planning, 65% of them responded that BIM related business was less than 10% compared with the firm's core business. Only 8.7% of them had the BIM related business over 20%, being consulting companies the main contributor. Table 6 shows this information.

Table 6: BIM-related Business of Industry Firms

Firm type	<=10%(%)	10%-20%(%)	>20%(%)
Owner	9 (20.00%)	2(11.11%)	0(0.00%)
Design Institute	12(26.67%)	3(16.67%)	0(0.00%)
General Contractor	9(20.00%)	4(22.22%)	0(0.00%)
Consulting	9(20.00%)	5(27.78%)	5(83.33%)
Software	5(11.11%)	1(5.56%)	1(16.67%)
Others	1(2.22%)	3(16.67%)	0(0.00%)
Total	**45(65.22%)**	**18(26.09%)**	**6(8.70%)**

4.2.2 BIM Related Human Resources

BIM skilled professionals are regarded as important factors for BIM implementation. From industry responses, about 64% have less than 10% of staff directly related to BIM for Human Resources,14% has more than 40%, where general contracting firms are the highest, next to consulting firms.

Table 7: BIM Related Human Resources in Industry

Firm type	<=10%(%)	10%-40%(%)	>40%(%)
Owner	10(22.73%)	1(6.67%)	0(0.00%)
Design Institute	9(20.45%)	5(33.33%)	1(10.00%)
General Contractor	8(18.18%)	1(6.67%)	4(40.00%)
Consulting	12(27.27%)	4(26.67%)	3(30.00%)
Software	2(4.55%)	4(26.67%)	1(10.00%)
Others	3(6.82%)	0(0.00%)	1(10.00%)
Total	**44(63.77%)**	**15(21.74%)**	**10(14.49%)**

To further understand the firms' preparation for the BIM talents, the respondents were asked the firms' efforts on the acquirement of BIM talents. Three ways were measured, including providing BIM training for existing professionals, Recruitment BIM talents, and learning from the projects with BIM consultants. The results in Table 8 showed different way and involvement to prepare the BIM talents, 13 industry firms have high involvements in the above there ways, 62% of them are nation-owned enterprise. Next is private enterprise(23%) and joint venture enterprise(15%).But the most popular way to prepare BIM talent is providing BIM training for existing professionals, which is occupied 44% in the high involvement.

Table 8: High Involvement in the Way to Prepare BIM Talents

Way to Prepare BIM talents	High Involvement (%)	High Involvement in All	Nation-owned (%)	Private (%)	Joint Venture (%)
(1) Providing BIM training for existing professionals	41(43.62%)				
(2) Recruitment BIM talents	28(29.79%)	13	8(61.53%)	3(23.07%)	2(15.38%)
(3) Learning from the projects with BIM consultants	25(26.60%)				

4.2.3 Training System

The training is the highest involvement to BIM talents preparation for the firms, naturally, the training system was also asked, means what kind of training the firm provided for the staffs. The results in Table 9 showed that internal training and the software training are the most popular method that industry firms prefer to provide, respectively, 40% and 37%. Some also involved in the executive training program for high-level management by external training organization and the continue education for certified professional qualification, respectively, 11% and 6%. And joining in the BIM award and related conference or forum were also chosen by the industry firms.

Table 9: Training Method Provided by Firms

(n=158)

Training Method	Number of Correspondents (%)
Continue education for certified professional qualification	9(5.70%)
Internal training	62(39.24%)
Software training	58(36.71%)
Executive training program	17(10.76%)

Others (joining in BIM award, conference and forum etc.)	6(3.80%)
No training	6(3.80%)
Total	**158(100%)**

4.3 Technology Efforts

Richness of the hardware and software investment is also the critical factor for BIM capability establishment (Succar,2009). The results in Table 10 showed that all the industry firms invested in BIM related hardware and software, the focus ranking was RMB0.5-2 million (USD 73,000-290,000) with 36%. And 20% of industry firms' investment was less thanRMB0.5 million (USD 73,000), and about 27% was higher than RMB5 million (USD 727,000).

Table 10: Firm's Investment on Technology

	<0.5 million	0.5-2million	2-5 million	>5million
Number of Firms (%)	14(20.29%)	25(36.23%)	11(15.94%)	19(27.54%)

5 Discussion

The findings from the data analysis will be presented and discussed around three themes, namely: (1) performance of firms' BIM capability efforts; (2) barriers affecting the implementation of BIM capabilities; and, (3) strategies for BIM capability improvement. Based on the following analysis, the causes will be discussed from the industry firm profiles and the responses.

5.1 Performance of Firms' BIM Capability Efforts

In the survey, it was asked about the performance of firms' BIM capability efforts. The feedback from 158 respondents is listed in Table 11, including staff's knowledge on BIM, problem solving and matching expectations. The results showed that the staff's knowledge on BIM is the highest perceived performance, the perception of problem solving is considered as medium, and matching expectations is the lowest perceived performance. The responses from 23 industry firms, 50% of which are nation-owned enterprises, perceived high performance on the three aspects. The results also showed that the responses from about 50% firms willing to invest on technology, perceived a high performance .However, the survey results did not show a strong relationship between the firm's BIM related human resources and performance.

Table 11: Perception on Performance of Firms' BIM Capability Efforts

(n=158)

perception of performance	Low (%)	Medium (%)	High (%)
Staff's knowledge on BIM	13(22.81%)	64(26.23%)	**81(46.82%)**
Problem solving	18(31.58%)	85(34.84%)	55(31.79%)
Matching expectations	**26(45.61%)**	**95(38.93%)**	37(21.39%)

5.2 Barriers Affecting the Implementation of BIM Capacities

The impact of implementing BIM capacities was further investigated by asking respondents to rank seven potential barriers that may be encountered. Other potential barriers they were also requested to add to the list. The result showed that "*lack of the unified BIM standard and specification"* was the most important barrier followed by "*owner's low knowledge on BIM"* and *"the lack of BIM skills". The high-level management not paying attention to implementing BIM capabilities"* and "*BIM courses not satisfying the industry requirement"* were the lowest, as shown in Figure 3.

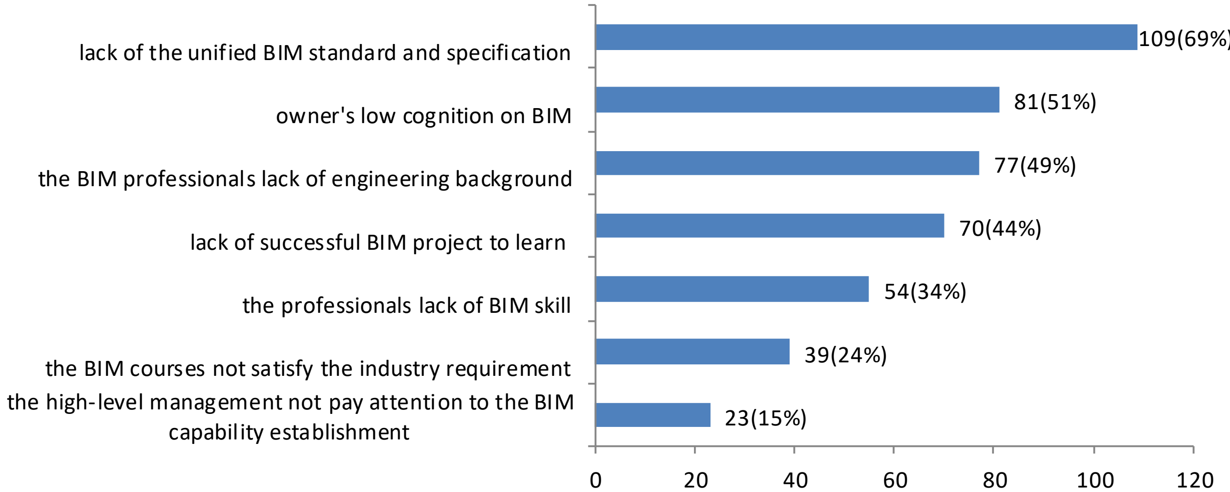

Figure 3: Barriers Affecting the Implementation of BIM Capabilities

This research further analyzed the 158 respondents' feedback on barriers by the different firm types shown in Table 12. The results showed that owner's barriers focused on *"owner's low knowledge on BIM", "lack of unified BIM standard and specification", "BIM professionals' lack of engineering background"* and *"lack of successful BIM project to learn"*. It was common for the designer, contractor, consultant and software provider to focus on "*lack of the unified BIM standard and specification", "owner's low cognition on BIM ","lack of BIM skills"* and *"lack of successful BIM project to learn".*

Table 12: Barriers by Firm Type

Barriers	Owner (%)	Design Institute (%)	General Contractor (%)	Consultant (%)	Software(%)
(1) owner's low knowledge on BIM	12(66.67%)	13(41.94%)	16(47.06%)	28(54.90%)	10(58.82%)
(2) lack of unified BIM standard and specification	10(55.56%)	25(80.65%)	23(67.65%)	31(60.78%)	13(76.47%)
(3) BIM professionals' lack of engineering background	8(44.44%)	7(22.58%)	11(32.35%)	19(37.25%)	8(47.06%)
(4) lack of BIM skills	7(38.89%)	12(38.71%)	18(52.94%)	28(54.90%)	11(64.71%)
(5) BIM courses not satisfying industry requirements	5(27.78%)	10(32.26%)	6(17.65%)	13(25.49%)	3(17.65%)
(6) lack of successful BIM project to learn	8(44.44%)	13(41.94%)	15(44.12%)	23(45.10%)	8(47.06%)
(7) high-level management not paying attention to implementing BIM capabilities	2(11.11%)	4(12.90%)	8(23.53%)	8(15.69%)	1(5.88%)

The respondents' roles were also analyzed, as shown in Table 13. Regardless of roles, the biggest barrier was "*lack of unified BIM standard and specification".* For other barriers, management roles focused more on "*lack of BIM skills*" and "*owner's low knowledge on BIM*", Engineer and BIM operator roles focused more on "*owner's low knowledge on BIM*" and "*lack of successful BIM project to learn*".

Table 13: Barriers by Roles

Barriers	Management (%)	Engineer (%)	BIM Operator (%)
(1) owner's low knowledge on BIM	35(54.69%)	35(47.95%)	8(61.54%)
(2) lack of unified BIM standard and specification	41(64.06%)	54(73.97%)	10(76.92%)
(3) BIM professionals lack of engineering background	18(28.13%)	29(39.73%)	7(53.85%)
(4) lack of BIM skills	40(62.50%)	29(39.73%)	6(46.15%)
(5) BIM courses not satisfying industry requirements	21(32.81%)	13(17.81%)	4(30.77%)
(6) lack of successful BIM project to learn	26(40.63%)	32(43.84%)	9(69.23%)
(7) high-level management not paying attention to implementing BIM capabilities	11(17.19%)	8(10.96%)	1(7.69%)

For the firms with high performance on implementing BIM capabilities, the biggest barrier was "*lack of unified BIM standard and specification",* followed by "*owner's low knowledge on BIM*".

In general, the barriers for implementing BIM capabilities mainly focus on "*lack of unified BIM standard and specification",* "*owner's low knowledge on BIM*", "*lack of BIM skills*" and "*lack of successful BIM project to learn*".

5.3 Strategies for BIM Capability Improvement

Based on the analysis of barriers, the direction on strategy making for BIM capability improvement was made evident. 50% of the respondents provided feedback that both owner and government play an important role on BIM capability improvement. Respondents were asked to rank seven potential measures to improve BIM capabilities. A 3-point Likert scale was used where *3 is very important* and *1 is not important*, and the results are shown in Figure 4. "Implementing BIM standards", "leading and demonstrating a public project with BIM", "BIM project demonstration and experience sharing" were rated as the top three important measures.

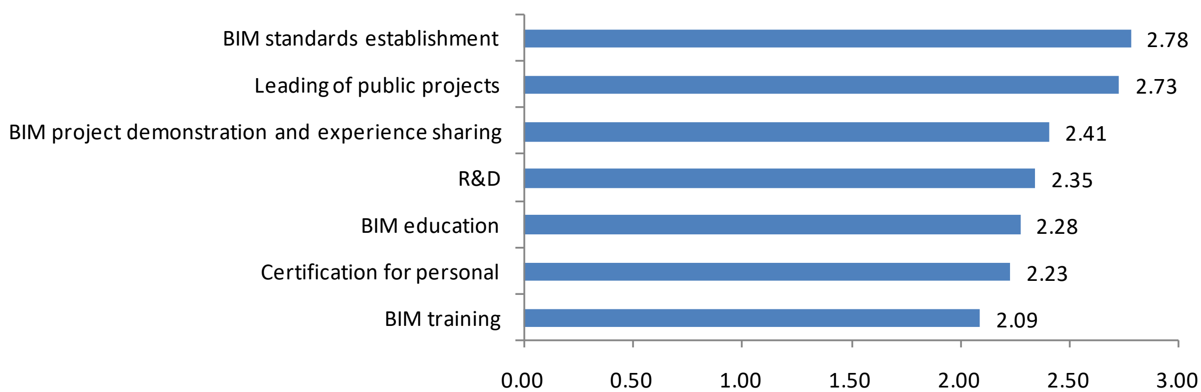

Figure 4: Weighted average rating on measures for BIM capability improvement

Based on the survey, the strategies for BIM capability improvement were developed considering three domains: government, enterprise and society. BIM is an inter-organizational innovation in the AEC industry, whose successful development strongly depended on government policy and implementation environment. The government plays a very important role in BIM capacity improvement. Firstly, government should establish the policy supporting the implementation of BIM capabilities, to create the guidance and promotional environment facilitating firms to make efforts on BIM capability. Secondly, enterprises should make efforts on independent innovation with business process optimization, to make the integration development of BIM and enterprise and realize the potential benefit of BIM. Finally, the society, including academic institutions, should develop basic BIM courses for the students to prepare the BIM knowledge to satisfy industry requirements.

6 Conclusion

Despite the great potential of BIM, the status quo of BIM capability in the AEC industry is still on a relatively initial stage. Based on an investigation of 158 professionals from 69 firms, this paper aims to provide an overview of the status of BIM capabilities and related implementation and deployment efforts in the Chinese construction industry. In addition, this research aims at gaining insights into the critical factors influencing the BIM capabilities, such as strategy capacity, technology capacity and process capacity, which are three specific BIM capabilities in the implementation domain. 60% of the firms have established both BIM organization and BIM standards, but the BIM related business and human resources are less than 10%. Furthermore, internal training and software training are the major instructional methods provided to the staff. The investment on technology focused on the RMB0.5-2million (USD 73,000-290,000).The survey also showed that the performance of implementing BIM capabilities is not balanced with the firm's efforts, the majority of the responses are on the medium range. However, respondents are also aware of the barriers on implementing BIM capabilities, including lack of BIM standards to guide, skills shortage, lack of demand by clients, and lack of awareness of BIM benefits. Finally, this paper proposed a strategy for improving BIM capabilities from the perspectives of government, enterprise and society.

It should be noted that the interpretation of the findings from this research is subject to several limitations. Firstly, the surveyed firms were not selected through a random sampling method. In order to improve the representativeness of the analyzed firms, the samples were diversified with varied firm types, roles and working experiences with BIM. Secondly, this research did not adopt a statistical generalization. It has provided insight into implementing BIM capabilities in Chinese AEC firms.

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8 References

Cao, D., Wang, G., Li, H., Skitmore, M., Huang, T., & Zhang, W. 2015. Practices and effectiveness of building information modelling in construction projects in China. *Automation in Construction*, *49*, 113-122.

Chen, Y., Dib, H., and F. Cox, R. 2014. A measurement model of building information modelling maturity. *Construction Innovation*, 14(2), 186-209.

Ding, Z., Zuo, J., Wu, J., and Wang, J. Y. 2015. Key factors for the BIM adoption by architects: A China study. *Engineering, Construction and Architectural Management*, *22*(6), 732-748.

Giel, B., andIssa, R. R. 2015. Framework for evaluating the BIM competencies of facility owners. *Journal of Management in Engineering*, 32(1), 04015024.

Sackey, E., Tuuli, M., and Dainty, A. 2013. BIM Implementation: From Capability Maturity Models to Implementation Strategy. In Sustainable Building Conference 2013.

Shanghai Municipal Commission of Housing Urban-Rural Development and Management.2016.*Shanghai BIM Technology Application & Development Report (2016)*. Shanghai, China.

Succar, B. 2009. Building information modelling maturity matrix. *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies*, IGI Global, 65-103.

Succar, B., Sher, W., and Williams, A. 2013. An integrated approach to BIM competency assessment, acquisition and application. *Automation in Construction*, *35*, 174-189.