An Empirical Study of BIM-Implementation-Based Perceptions among Chinese Practitioners

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Abstract

The global movement of Building Information Modeling is spreading the implementation of BIM from developed countries to other developing countries. Practitioners' perceptions on BIM implementation in these developing countries, such as China, a giant building market which is increasing the BIM application in the industry, have not been thoroughly understood. This research adopted the questionnaire survey to investigate the BIM practice and its related perceptions from 94 randomly recruited Chinese BIM professionals. Reductions in design errors and resulted construction rework were considered the top benefit of using BIM. The most important factor in achieving BIM value was the interoperability among various BIM tools. A comprehensive evaluation of BIM in the company level was considered a major difficulty of implementing BIM. The owner was considered the party that received most benefits from BIM. Subgroup differences based on two major categories (i.e., participants' profession and BIM proficiency level) were analyzed in these BIM-implementation-related sections. Statistical analysis revealed that generally neither the profession nor BIM proficiency level would affect participants' perceptions on benefits, factors, challenges, or benefited parties in BIM implementation.

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Introduction

Building Information Modelling (BIM), the digital technology enabling creations of accurate virtual models and supporting further activities in the project delivery process, is one of the most promising developments in the architectural, engineering, and construction (AEC) industries (Eastman et al., 2011). China, the huge AEC market accounted for 47.9% of the Asia-Pacific industry according to MarketLine (2014), was expected to continue the growth of its construction industry from 2013 to 2018 with an average rate at 12.6%. Accompanying China's AEC market growth is the increased BIM application. BIM has been displaying its impacts on the industry practice (Azhar et al. 2012; Francom and Asmar, 2015). One major concern in terms of current and future BIM implementation is the perceptions of industry professionals towards BIM and how they see BIM affecting their business now and in the future. Practitioners' perceptions towards BIM implementation has been studied in developed countries (e.g., Eadie et al., 2013; Ahn et al., 2015). However, it has not been thoroughly investigated in developing countries. Using China, the giant AEC market as the case for BIM empirical studies in developing countries, this research aims to evaluate the major benefits and barriers of implementing BIM, factors impacting BIM to achieve its value, and project parties benefitted from BIM.

Previously conducted BIM-related surveys in China, including China Construction Industry Association (CCIA, 2013) and Shenzhen Exploration & Design Association (SZEDA, 2013), targeted on contractors and design firms respectively to investigate BIM-related activities (e.g., visualization), BIM impacts, and challenges in BIM practice. Collaboration was considered by CCIA (2013), SZEDA (2013), and Eadie et al. (2013) the key for successful BIM practice, as staff from different disciplines and various BIM proficiency levels would be involved in the same project. BIM adoption within the same organization, such as a construction company in the study of Sackey et al. (2014), would also involve multidisciplinary professionals in the sociotechnical collaboration. The mechanism of human behavior in a virtual organization, as identified by Lu et al. (2014), should be further explored when adopting information and communicating technology. The perception would have a direct effect on behavior (Dijksterhuis and Bargh, 2001). Currently, it has not been well studied whether the BIM practitioners' profession (e.g., architects, engineers, consultants, etc.) and their BIM experience would affect the perceptions on BIM implementation. The objectives of this study focus on: 1) gaining the overall picture of how the active BIM practitioners from various fields in China would perceive BIM in terms of its benefits, factors influencing its practice, and challenges to implement it, etc.; 2) recruiting BIM practitioners from multiple disciplines according to their AEC fields and BIM proficiency levels for this empirical study; and 3) adapting statistical methods including Chi-Square test of independence and Analysis of Variance (ANOVA) to explore whether subgroup differences exist in these perceptions. Results from subgroup analysis would provide insights on whether practitioners from different professions and experience levels tend to have consistent perceptions, which could be one of the indicators for the effective collaboration in BIM-involved projects. The findings from this study provide information to international AEC firms involved in or entering the China market as well as relevant building construction authorities in light of the current BIM implementation as well as trend, direction, and movements of future BIM practice.

Literature Review

An Overview of BIM Practice Worldwide

BIM is undergoing the increased application in the global AEC industries. Investigations on the current stage of BIM practice have been conducted in different countries. These studies (Both et al, 2013; Davies and Harty, 2013; Masood et al., 2013; Juszczyk et al., 2015) recruited BIM practitioners from a certain profession (e.g., engineers or contractors) on investigating either the current BIM practices (e.g., to achieve visualization), BIM experience (e.g., years of practicing BIM), and visions of BIM (e.g., benefits and barriers in BIM implementation). Although survey respondents from various professions showed limited BIM experience in countries including China (CCIA, 2013), Poland (Juszczyk et al., 2015) and Pakistan (Masood et al., 2013), the BIM application was expected to grow fast in recent years (McGraw-Hill Construction, 2014). Review of previous BIM studies revealed that the perceptions on specific BIM-related issues may vary depend on respondents' professions. For example, contractors considered themselves benefited most from the BIM technology (CCIA, 2013), while design and staff from other professions tended to perceive the client the party that had the most benefit from BIM (Eadie et al., 2013; SZEDA, 2013). Cost control was perceived by contractors as the major measurement of BIM impact (CCIA, 2013), while the engineers listed the reduction in design changes as the major effect from BIM (SZEDA, 2013).

BIM Practice in China's AEC Industries

China's construction market has the potential to see BIM benefits, but it is restricted to its own structural obstacles (McGraw-Hill Construction, 2014). BIM would be the major breakthrough in China's building industry, but the BIM development faces these challenges including lack of well-developed standards, insufficient interoperability among project members, and difficulties of applying BIM in the whole building lifecycle, etc (He et al., 2012). Despite that the BIM adoption rate was low in 2012 among major large-sized Chinese contractors (CCIA, 2013), the more recently released survey report from Shanghai Construction Trade Association (SCTA) & Luban Consulting (2014) showed that 67% of construction firms nationwide had started BIM practice, and over 10% of clients had used BIM in more than half of their projects by the end of 2014. The governmental policies and industry standards newly announced in recent years could be one driver to the increased BIM usage in China's AEC industries.

As indicated by Cao et al. (2016), government requirements are one motive to implement BIM. Since 2011, BIM-related policies and standards have been undergoing fast movement. According to Jin et al. (2015), the recent movements of BIM-related governmental policies in China have been undergoing major steps from announcing the digitalization visions in 2011, publishing the first version of BIM standard in 2012, listing strategic objectives in 2013 with detailed timeline of BIM adoption, to further proposing the BIM application crossing the whole project life cycle in 2014.

Benefits of Adopting BIM

Two-thirds of BIM users in the report of McGraw-Hill Construction (2014) had a positive view of the return on their investments in BIM. The increase of interoperability of BIM software was estimated to save up to two thirds of the annual overall cost paid by clients, building users and operators (Furneaux and Kivvits, 2008). Contractors had reduced 1%-2% cost of MEP systems in large healthcare projects by using BIM (Khanzode, et al., 2008). Other parties such as software vendors also acquired large returns on the investment of BIM (Becerik-Gerber and Rice, 2010; Cheung et al., 2012).

Besides the financial benefits gained from multiple parties, other benefits that BIM could bring to the project include 3D visualization, reduction of design errors and rework, clash detection, full understanding of the project, and reduction of construction period (Yan and Damian, 2008; Both et al., 2012; Crotty, 2012; Migilinskas et al., 2013; Ahn et al., 2015).

However, achieving these benefits would depend on various factors including but not limited to collaboration among different teams (He et al., 2012; Eadie et al., 2013; SZEDA, 2013), BIM expertise within team members (Ku and Taiebat, 2011; Kashiwagi et al., 2012; Eadie et al., 2013; SZEDA, 2013; Cao et al., 2016), legal issues within the contract that involves BIM usage (Oluwole, 2011; Race, 2012), project location, type and nature (Cao et al., 2016), and budget (Bazjanac, 2006). These factors, if not properly handled in a BIM-involved project, would possibly barricade the BIM implementation.

Barriers and Challenges of Implementing BIM

The potential challenges of implementing BIM include:

- Insufficient evaluation of BIM value from the company level indicated by Sebastian (2010) when BIM users fail to see the immediate benefits from projects delivered to date
- Resistance at higher management or operation level (Bender, 2010), which could be partly due to the cultural resistance (Denzer and Hedges, 2008; Dawood and Iqbal, 2010)
- Lack of requirements from the client (Birkeland, 2009; Breetzke and Hawkins, 2009)
- High initial cost of BIM (Yan and Damian, 2008; Giel et al., 2010; Azhar, 2011)
- Availability of governmental policies and industry standards (Smith and Tardif, 2009; He et al., 2012)
- BIM education and training (Trine, 2008; Jäväjä and Salin, 2014; Tang et al., 2015)
- The practicability of BIM implementation not well understood (Sackey et al., 2014) and requiring further studies on BIM practice within the AEC organizational context (Lu et al., 2014)

Methodology

The research team from the University of Nottingham Ningbo China (UNNC), in collaboration with Shanghai BIM Engineering Centre (SBEC), has been working on the investigation of China AEC industries' BIM practice and perceptions on BIM-related issues, including benefits generated from BIM, impact factors to BIM implementation, challenges in implementing BIM, and financially benefitted parties from BIM. A relevant questionnaire survey was designed by the UNNC research team and peer-reviewed by professionals from SBEC between August 2014 and May 2015, and approved by the Research Ethics Office in June 2015 at the University of Nottingham Ningbo China to ensure that human-subject related research activities met the research ethics requirements.

Questionnaires were delivered to totally 200 random attendants including consultants, architects, engineers, owners, and other AEC industry practitioners from China's national network of Digital Design and Construction during the First Forum of BIM Technology and Lean Construction organized by SBEC in July 2015. In total 81 responses were received out of 200 hardcopies sent. Electronic questionnaire was sent via SOJUMP, a Chinese online survey system (www.sojump.com) to collect more responses from the survey pool of Chinese AEC professionals who have been adopting BIM or planning to start BIM usage in their work. In total 13 responded surveys were received from 97 questionnaires sent during July 2015. Statistical analysis (e.g., two-sample *t*-test) of responses collected between site survey and on-line questionnaire revealed high consistency. Combining the questionnaires responded from both hardcopies and on-line, finally questionnaires from 94 participants were recruited for the follow-up data analysis.

Two major types of questions were designed in the questionnaire: multi-choice and Likert scale. The survey sample was divided into subgroups based on two categorizations: profession (e.g., architects, engineer, contractor, software developer, etc.), and BIM proficiency level (e.g., expert, advanced level, intermediate level, entry-level, and no BIM experience). For multi-choice questions related to BIM adoption rate and benefited parties, the Chi-Square test of independence from Johnson (2005) at the 5% level of significance was performed to evaluate whether subgroups had consistent percentages of selecting the same option in the given question. A corresponding *p* value lower than 0.05 would reject the null hypothesis that the percentages of subgroups selecting each option is independent on either the profession or BIM proficiency level.

For the rest sections adopting Likert scale format, three main statistical methods were used: Relative Importance Index (*RII*) was the value ($0 \leq RII \leq 1$) used to rank multiple items within each section. An item achieving higher *RII* score would rank higher than those with lower RII values.

It was calculated for each item based on the equation used by previous studies (Kometa et al., 1994; Tam et al., 2000; Eadie et al., 2013; Tam et al., 2009):

$$RII = \frac{\sum w}{A \times N} \qquad (1)$$

where:

w is the Likert score (1 to 5) selected by each survey participant.

A is the highest score (equal to 5 in this survey).

N is the number of responses.

Cronbach's alpha is the tool to measure the internal consistency of items in a test (Cronbach, 1951; Tavakol and Dennick, 2011). Its value ranges from 0 to 1. A higher value indicates a higher degree of consistency among these items. Usually, an Alpha value from 0.70 to 0.95 is considered acceptable or with high internal inter-relatedness (Nunnally and Bernstein, 1994; Bland and Altman, 1997; DeVellis, 2003). A higher Alpha value within one section also means that a survey participant who selects a score for one item is likely to assign a similar score for other items in this section. A low alpha value indicates poor correlation among items (Tavakol and Dennick, 2011).

Parametric methods including ANOVA have been applied in the data analysis of Likert scale questions in the field of construction engineering and management (Aksorn and

Hadikusumo, 2008; Meliá et al., 2008; Tam, 2009). Parametric methods have been proved in multiple studies adopting parametric methods (e.g., Carifio and Perla, 2008; Norman, 2010) in its robustness when applied in samples that were small in size or not normally distributed. Examples of small sample sizes in parametric methods include subgroup size at 4 in Tam (2009)'s study and highly skewed non-normal distributions with subsample sizes as small as 4 in Pearson (1931)' case. The overall sample size and subsample sizes in this research are considered fair compared to all these previous studies. ANOVA tests whether the subgroups had consistent mean values in the given section. Based on a 5% level of significance, a *p* value lower than 0.05 would suggest that subgroup differences exist when perceiving the given item.

Findings on the Status of BIM Practice in China's AEC Industries

The major findings from this questionnaire are divided into six sections, namely survey participants' background and BIM experience, BIM adoption rates in their past projects, BIM benefits, factors that affect BIM implementation, challenges encountered in BIM, and parties that benefit financially from BIM.

Survey Participants' Background

The working locations of survey participants are summarized in Fig.1.

Participants in this questionnaire survey came from five major regions as shown in Fig.2. Bejing, Shanghai, and Canton are the major BIM-leading regions in the mainland of China according to the earlier released BIM report (Jin et al., 2015). Participants from Shanghai and its nearby regions contributed to the majority of this survey sample. A small portion of the survey pool came from the inland of China and the remaining were Chinese BIM practitioners working overseas.

The background of survey participants were also categorized in Fig.2 and Fig. 3 according to their professions and self-perceived BIM proficiency levels.

Other professions in this survey included material supplier, company administration directors, etc.

The self-perceived BIM proficiency level was measured by the years of BIM experience. Box plots are provided in Fig. 4 displaying numbers of years of using BIM for the whole sample and three subsamples.

The box plot for each sample in Fig.4 has maximum (i.e., max), 75th percentile, median, 25th percentile, and minimum (i.e., min) values. It is indicated from Fig.4 that the participants in the overall sample has skewed distribution of years of BIM experience, with the majority from 1 to 5 years. When divided into subsamples, it is indicated that the proficiency levels of BIM usage are in a correlation with the number of years that participants have been adopting BIM, with median values released from the three subsamples at 5 years, 2 years, and 0.5 year respectively. The years-of-experience-based BIM proficiency level will be adopted as one categorization criteria to divide the whole survey sample into subgroups in the following sections.

BIM Adoption Rate

Survey participants were asked the BIM adoption rate in their past projects in the multi-choice question. The adoption rate was categorized as: 1) very frequent adoptions defined as having been using BIM in over 60% of their recent five years' projects, 2) frequent adoptions (i.e., using BIM between 30% to 60% of their projects), 3) moderate adoption (i.e., 15% to 30% of their projects with BIM involved), and 4) few adoptions with BIM adopted in less than 15% of their projects. In order to capture the information of whether BIM practice is independent of professions or BIM proficiency levels, the adoption rates among subgroups are compared and displayed in Table 1.

The calculated Chi-Square value of 18.167 and the corresponding p value of 0.445 indicate that professions of survey participants listed in Table 1 do not affect the BIM adoption rate among AEC professionals. In contrast, the *p* value of 0.001 would suggest that there are significant differences in BIM adoption rates among subgroups at different BIM proficiency levels. Generally experts or participants in the advanced level tended to have more frequent BIM adoptions.

Benefits of Adopting BIM

Survey participants were asked to provide their options in the Likert-scale question (with "1" being strongly disagree, "3" denoting neutral, and "5" representing strongly agree) regarding the benefits from BIM. The option of "N/A" was also given for each item when the participant did not have the knowledge to answer it. The overall answers from the survey pool is presented in Table 2 following the *RII* score ranking of 13 BIM-benefit-related items from B1 to B13.

Reductions in design errors and resulted construction rework were ranked highest in benefits of using BIM as shown in Table 2, followed by better project quality. Table 2 reveals that cost and time related items (i.e., B7, B8, B10, B11) were not ranked as high as reductions in errors or rework. Generally all of the proposed benefits from BIM were perceived positively from survey participants. The item B13 was perceived the lowest-ranked item with an average of 3.29 out of 5, with nearly half (47%) of respondents selecting the neutral score "3". That would reflect participants' views that BIM did not necessarily benefit companies in hiring new employees or keeping the existing staff.

The Cronbach's alpha at 0.922 indicates that a participant that select one Likert scale score in one BIM-benefit-related item is likely to provide a similar score to other items. To analyze the contribution of each given item to the overall consistency of the whole 13 items, the given item can be removed for the rerunning of the internal consistency analysis. The Cronbach's Alpha values listed in Table 2 show the changed value if the given item is removed. All values slightly lower than the original 0.922 indicate that each of the 13 items would positively contribute to the internal consistency. The item-total correlation in Table 2 quantifies the correlation between the given item and the summed score of the rest 12 items. For example, the correlation coefficient at 0.644 for B1 indicates fairly positive and strong relationship between B1 and the remaining items. It is hence reasonable to assume that the score in B1 is internally consistent with composite scores from the rest items. Generally each item within Table 2 displays a strongly positive relationship with the remaining items except that B11 (i.e., Reducing time of workflows) shows a relatively lower correlation, which could infer that respondents are more likely to have an inconsistent view on B11 than the remaining BIM-benefit-related items.

The overall sample was then divided into subgroups according to the profession and BIM proficiency levels. Table 3 displays the ANOVA analysis on perceptions of these 13 BIM-benefit-related items among subgroups.

All the *p* values higher than 0.05 for each item among the subgroups divided according to both categories (i.e., profession and BIM proficiency level) suggested that the profession and BIM experience did not affect their perceptions towards the benefits that BIM could bring to the AEC industries.

Factors Related to BIM Implementation

The survey participants were asked of their perceptions on the effects of various factors that could have for BIM to achieve its full potential. Each factor was given in the format of Likert scale with "1" being the least significant, "3" being neutral, and "5" being the most significant. Participants were also allowed to choose "N/A" if without knowledge to respond to the given item. Table 4 summarizes the findings related to *RII* and internal consistency analysis. Totally 14 items in BIM value factors are listed following the ranking of *RII*.

The interoperability of BIM software tools among different project team members was considered the most important factor in achieving BIM value. This truly reflects the problem in China's BIM practice that various BIM tools from different IT developers used by project members could make it difficult to fully implement BIM when connecting from architecture to structural engineering, and further to cost estimate or other disciplines. The number of BIM-knowledgeable professionals was ranked the second highest factor that has significant effects in BIM implementation, followed by the project complexity in terms of managerial and technological risks as defined by Gidado (1996). It is also shown in Table 4 that project size, budget, and schedule-related factors were not ranked in priority as compared to project complexity. The project location and whether staff work in the same location were ranked lowest in Table 4. As the AEC industries are moving towards the digitalization, the physical location of project members from different disciplines plays a less significant role in the project delivery process as compared to the days when BIM was not available.

Similar to the section of BIM benefits, the BIM-value-related factors in Table 4 also display a high degree of internal consistency with the Cronbach's alpha at 0.919. The item total correlation values in Table 4 generally display a strongly positive relationship between the given factor and the remaining 13 factors except for F1 and F14, both of which had correlation lower than 0.50. The lower correlation values would indicate that the BIM tool interoperability was considered top priority above other factors, while the colocation of project teams was not that significant in influencing BIM values compared to the rest factors.

The subgroup analysis is presented in Table 5 in evaluating the BIM-value-related factors. The p value higher than 0.05 within each factor would convey the information that survey participants from different professions or various BIM usage experience all shared consistent views on factors that would affect BIM implementation.

Challenges and Difficulties

The data analysis were performed regarding the perceptions on challenges and difficulties encountered in implementing BIM. Based on the Likert scale options between 1 and 5, with

"1" denoting very easy to overcome, "3" being neutral, and "5" representing the most difficult, Table 6 illustrates the *RII* score and internal consistency of the nine items describing BIM-implementation-related challenges.

Compared to sections in BIM benefits and BIM-value-related factors, *RII* scores received from this section appear generally lower. C6 to C9, these four items with *RII* scores lower than 0.600 indicate that the training, cost-related factors, and the companies' entry-level staff's acceptance to BIM are not difficult to achieve. In contrast, the acceptance of staff from higher level of management seems more challenging (C2 and C3). The lack of thorough evaluation regarding the benefits, risks, and challenges of BIM to the company business was considered the major challenge in implementing BIM. Client demands and government regulations were middle ranked in Table 6, and this could indicate that the major challenges would generally come from BIM implementers themselves rather than other driving factors (e.g., client demands or government requirements).

The Cronbach's alpha value at 0.796 is considered a high degree of consistent views on all the nine challenge-related items, though not as high as that in the previous two sections. The Cronbach's alpha values listed in Table 6 lower than the overall value indicate that each item within this section is positively contributing to the overall internal consistency. The lower item-total correlation values in Table 6 compared to that in Table 2 and Table 4 indicate that respondents are less likely to choose consistent options for challenges in implementing BIM. The bottom-ranked item, C9, found with the lowest correlation, suggests that participants are more likely to have a different opinion in the difficulty of effective BIM training compared to the rest items.

The ANOVA analysis is performed in Table 7 to evaluate the potential subgroup differences in perceiving challenges encountered in implementing BIM.

It is seen in Table 7 that subgroups from various professions have significantly different views on the difficulty of C8. Basically the academics, BIM consultants, owners, and architects perceived the acceptance from entry-level staff more challenging with mean scores of 4.000, 3.875, 3.500, and 3.376 respectively. In contrast, the engineers, contractors, and software developers considered the same item with much less challenge (mean scores received at 2.600, 2.444, and 1.250 respectively). The other significant difference was found in C9 among subgroups divided by different BIM proficiency levels. It is inferred from the mean score of subgroups that those without any BIM experience tended to think that achieving efficient BIM training would be difficult (mean score at 4.000), while those with certain BIM experience were more likely to perceive less challenge in BIM training, according to mean scores for entry-level, intermediate, advanced, and expert BIM users ranging from 2.333 to 2.947, all below the neutral score at 3 in the Likert-based scoring system.

Parties Financially Benefited from BIM

Survey participants were further asked which parties received the most and least financial benefits from BIM. Consistent to the results gained from BIM questionnaire surveys conducted by SZEDA (2013) and Eadie et al (2013), the owner was considered the party that received the most benefits from BIM, with a dominating rate at 87% in this study as shown in Table 8. The engineering firms, contractors, and consultants were the major parties perceived with the least benefits from BIM, accounted for totally 95% of the whole survey pool.

The perceptions of BIM-benefited parties were analysed of their potential subgroup differences. The Chi-Square test summarized in Table 9 with all p values higher than 0.05 indicated that survey participants' views on parties that gain the most and least benefits were independent of their profession and BIM proficiency level.

As suggested from the Chi-Square test of independence performed in Table 9, the owner is consistently perceived the party benefited most from BIM among all subgroups. It would be hence worthwhile for the owner to consider more BIM applications in their invested projects.

Summary of the Results

The findings from this questionnaire-based survey to AEC professionals can be summarized as follows:

- Participants' BIM experience level was highly correlated to their years of using BIM, and BIM adoption rate in their previous projects.
- Reducing design errors and construction rework were deemed the major contributions of adopting BIM. In order to achieve the value that BIM could bring to the industry, the interoperability among different BIM tools was considered the key impact factor.
- The *RII* scores received in the challenge-related items were generally lower compared to two other Likert-scale-based sections. It was also shown from the *RII* scores lower than 0.60 that costs spent in BIM-related hardware and software were not major difficulties. Instead, participants considered the major challenge coming from the thorough evaluation of BIM value within the AEC companies, and the acceptance of BIM from the higher management level.
- The subgroup analysis within the survey sample indicated that the profession and experience level did not affect respondents' generally positive perceptions on BIM benefits.
- Merely two items within the section of BIM challenge were found with significant subgroup differences: one being that academics, BIM consultants, owners, and architects considered more the acceptance of BIM from entry-level staff a challenge than engineers, contractors, and software developers; the other being that effective BIM training was not perceived a challenge by most participants except those without any BIM experience.

Conclusion

This empirical study collected the data on BIM practitioners' experience, their perceptions on BIM benefits, factors relevant to achieve BIM values, challenges in BIM implementation, and opinions on BIM-benefited parties. The background information of survey participants was provided including their working locations, professions, and BIM usage experience. The high Cronbach's alpha value over 0.750 obtained from Likert-scale-based questions indicated that survey participants had generally consistent views over the items within each perception-related section and every item within each section positively contributed to the overall consistency. It was a positive signal that perceptions towards BIM-introduced benefits would not be significantly changed as the practitioner gains more BIM experience. Similarly consistent perceptions were found on BIM-value-related factors, challenges encountered in practicing BIM, and parties benefitted from BIM. Some further information generated from this study can be highlighted as below:

- Encountering the compatibility issues was not uncommon when multiple BIM tools are being used in a single project. Usually no specific BIM software would be required in the project contract. How BIM tools used by different project teams could be interoperable would remain a technical issue to be further discussed.
- Generally the acceptance of BIM was deemed more difficult to achieve from the senior management level than the lower levels. Consistent to other previous studies conducting BIM-related questionnaire survey, the owner was identified as the party that received the most benefits by adopting BIM.
- Gaining more BIM experience would change practitioners' perceptions on training-related difficulties from "it is a challenge" to "it is not really a challenge."

The generally positive and consistent views of participants on BIM benefits could provide the clue that BIM would be increasingly applied in China's AEC industries following government strategies in the coming years. The consistent perceptions towards BIM implementation among respondents from different professions and BIM experience levels would also serve as a positive signal that joint-effort among multiple project teams using BIM as the platform is highly achievable. According to the perception of AEC practitioners, this empirical study provides the picture of BIM implementation in developing countries where BIM is gaining a growing practice. Based on the data analysis generated from this questionnaire survey, future research would target on recruiting case studies of BIM-involved projects to provide quantitative analysis of how BIM could achieve these benefits listed in this questionnaire, with a comprehensive evaluation of BIM values.

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Table 1. Comparison of BIM adoption rates among different subgroups of survey participants.

Subcategory		**Very frequent adoptions (%)**	**Frequent adoptions (%)**	**Moderate adoptions (%)**	**Few adoptions (%)**	**Total (%)**
	Overall	28	16	18	37	100
Profession: Chi-Square value = 18.167, degrees of freedom at 18, *p* value = 0.445	Academics	0	40	20	40	100
	Architects	10	10	30	50	100
	Engineers	40	8	16	36	100
	BIM consultants	55	9	27	9	100
	Owners	33	33	0	33	100
	Contractors	23	31	8	38	100
	Others	18	18	18	47	100
BIM proficiency level: Chi-Square value = 43.364, degrees of freedom at 12, *p* value = **0.001***	Expert	50	25	13	13	100
	Advanced level	59	18	18	5	100
	Intermediate level	25	32	18	25	100
	Entry level	9	0	27	64	100
	No BIM experience	0	0	13	88	100

*: statistically *p* value less than 0.05 indicates that the BIM adoption rate is dependent on the BIM proficiency level.

Table 2. The RII analysis results of BIM benefits within the whole survey sample (Cronbach's alpha = 0.922).

Item	Percentage of selecting each option (%)					N*	*RII*	Item-total correl-ation	Cron-bach's Alpha
	1	2	3	4	5				
B1: Reducing omissions and errors	3	0	0	21	76	86	0.930	0.644	0.917
B2: Reducing rework	5	1	6	25	63	87	0.883	0.678	0.918
B3: Better project quality	1	1	13	28	57	87	0.878	0.660	0.917
B4: Offering new services	2	5	8	32	53	87	0.857	0.727	0.914
B5: Marketing new business	4	6	14	33	44	85	0.814	0.639	0.917
B6: Easier for newly-hired staff to understand the ongoing project	1	8	20	34	37	87	0.795	0.639	0.917
B7: Reducing construction cost	2	6	16	45	30	86	0.791	0.674	0.916
B8: Increasing profits	1	6	23	40	31	88	0.786	0.633	0.917
B9: Maintaining business relationships	2	3	26	41	26	87	0.772	0.663	0.916
B10: Reducing overall project duration	3	8	20	36	32	88	0.770	0.709	0.915
B11: Reducing time of workflows	5	11	16	33	34	87	0.763	0.589	0.917
B12: Fewer claims/litigations	1	8	28	39	24	85	0.751	0.723	0.914
B13: Recruiting and retaining employees	3	16	47	18	16	79	0.658	0.631	0.918

*:The total number of responses for each given item.

Note: The data analysis of RII excludes those who selected "N/A". The same rule applies to other *RII* analysis tables.

Table 3. ANOVA analysis of subgroup differences towards BIM-benefit-related items.

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to professions**		**ANOVA analysis for subgroups according to BIM proficiency level**	
			F value	*p* value	F value	*p* value
B1	4.651	0.804	0.64	0.719	1.09	0.366
B2	4.414	1.000	0.61	0.742	0.80	0.530
B3	4.391	0.848	0.90	0.513	0.39	0.813
B4	4.287	0.961	0.90	0.510	1.29	0.279
B5	4.071	1.060	0.77	0.618	0.45	0.771
B6	3.977	1.000	1.16	0.333	1.29	0.281
B7	3.953	1.038	0.83	0.568	0.41	0.803
B8	3.932	0.932	0.99	0.443	0.40	0.812
B9	3.862	1.068	1.00	0.441	1.01	0.408
B10	3.852	1.006	1.23	0.299	1.71	0.156
B11	3.816	1.160	1.21	0.309	1.80	0.137
B12	3.753	0.986	0.87	0.536	1.36	0.255
B13	3.291	0.980	2.05	0.061	0.22	0.929

Table 4. The RII analysis results of BIM-value-related factors within the whole survey sample (Cronbach's alpha = 0.919).

Item	Percentage of selecting each option (%)					N	RII	Item-total correl-ation	Cronb-ach's Alpha
	1	2	3	4	5				
F1: Interoperability of BIM software	1	1	12	36	49	73	0.860	0.471	0.918
F2: Number of BIM-knowledgeable professionals	1	0	22	47	32	73	0.822	0.618	0.914
F3: Project complexity	3	1	18	44	34	74	0.811	0.607	0.914
F4: Clients' knowledge on BIM	1	3	21	42	32	71	0.803	0.636	0.913
F5: Companies' collaboration experience with project partners	1	4	16	48	30	73	0.803	0.618	0.914
F6: Contract-form that is BIM-collaboration supportive	3	4	26	34	34	74	0.784	0.666	0.912
F7: BIM technology consultants in the project team	1	4	25	40	29	72	0.783	0.789	0.909
F8: The project nature (e.g., frequency of design changes)	6	8	15	39	32	72	0.767	0.695	0.911
F9: Project schedule	4	7	28	31	30	71	0.749	0.692	0.911
F10:Number of BIM-knowledgeable companies in the project	4	4	28	43	20	74	0.743	0.752	0.909
F11: Project budget	6	8	20	42	24	71	0.741	0.642	0.913
F12: Project size	8	11	25	32	25	73	0.707	0.703	0.911
F13:Project geographic location	7	15	42	21	15	72	0.644	0.625	0.914
F14: Staff from different companies working in the same location	6	21	38	21	15	72	0.639	0.481	0.919

Table 5. ANOVA analysis of subgroup difference towards BIM-value-related items.

Item	Overall Mean	Standard deviation	ANOVA analysis for subgroups according to professions		ANOVA analysis for subgroups according to BIM proficiency level	
			F value	*p* value	F value	*p* value
F1	4.301	0.828	0.43	0.879	0.21	0.934
F2	4.110	0.842	0.35	0.928	1.04	0.395
F3	4.055	0.938	1.29	0.268	0.25	0.908
F4	4.014	0.904	1.49	0.186	0.63	0.642
F5	4.014	0.959	1.02	0.427	0.47	0.756
F6	3.919	1.805	0.48	0.842	0.94	0.448
F7	3.917	0.905	0.12	0.997	0.14	0.965
F8	3.833	1.128	1.27	0.277	1.08	0.375
F9	3.746	1.107	0.35	0.927	1.05	0.386
F10	3.716	1.010	0.38	0.912	0.58	0.681
F11	3.704	1.170	1.21	0.310	0.71	0.591
F12	3.534	1.230	0.55	0.793	0.29	0.885
F13	3.222	1.248	1.28	0.277	0.83	0.512
F14	3.194	1.149	1.56	0.165	0.54	0.705

Table 6. The *RII* analysis results of BIM challenges within the whole survey sample (Cronbach's alpha = 0.796).

Item	**Percentage of selecting each option (%)**					**N**	***RII***	**Item-total correl-ation**	**Cronb-ach's Alpha**
	1	2	3	4	5				
C1: Lack of sufficient evaluation of BIM	1	6	27	21	8	63	0.692	0.577	0.763
C2: Acceptance of BIM from senior management	1	12	19	23	10	65	0.689	0.414	0.785
C3: Acceptance of BIM from middle management	1	12	24	18	10	65	0.674	0.431	0.783
C4: Lack of client requirements	5	10	22	15	13	65	0.665	0.533	0.770
C5: Lack of government regulation	6	15	20	13	11	65	0.625	0.504	0.774
C6: Cost of hardware upgrading	5	19	22	13	6	65	0.588	0.591	0.760
C7: Cost of purchasing BIM software	5	19	22	16	4	66	0.585	0.429	0.784
C8: Acceptance of BIM from the entry-level staff	11	21	11	12	11	66	0.573	0.541	0.768
C9: Effective training	11	21	15	11	8	66	0.552	0.363	0.793

Table 7. ANOVA analysis of subgroup difference towards BIM-challenge-related items.

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to professions**		**ANOVA analysis for subgroups according to BIM proficiency level**	
			F value	*p* value	F value	*p* value
C1	3.460	1.024	0.50	0.833	1.64	0.177
C2	3.446	1.056	1.71	0.126	1.74	0.153
C3	3.369	1.009	0.93	0.490	2.04	0.100
C4	3.323	1.223	0.61	0.748	0.75	0.559
C5	3.123	1.260	1.16	0.340	0.79	0.538
C6	2.938	1.193	0.65	0.715	0.35	0.841
C7	2.924	1.101	0.70	0.670	0.21	0.933
C8	2.864	1.365	2.27	**0.041**[*]	1.35	0.261
C9	2.758	1.307	0.23	0.976	3.35	**0.015**[*]

*: *p* value lower than 0.05 indicates the significant differences among subgroups

Table 8. Perceptions on BIM-benefited parties among different subgroups of survey participants.

Subcategory		Owner (%)		Engineering firms (%)		Contra-ctors (%)		Consultants (%)		Others (%)	
		M*	L*	M*	L*	M*	L*	M*	L*	M*	L*
	Overall	87	0	0	38	12	26	1	33	0	3
Profession	Academics	100	0	0	100	0	0	0	0	0	0
	Architects	75	0	0	63	25	0	0	38	0	0
	Engineers	75	0	0	25	25	25	0	50	0	0
	BIM consultants	84	0	0	56	11	28	5	11	0	6
	Owners	90	0	0	11	10	33	0	56	0	0
	Contractors	67	0	0	100	33	0	0	0	0	0
	Software developers	100	0	0	0	0	33	0	67	0	0
	Others	100	0	0	17	0	42	0	33	0	8
BIM proficiency level	Expert	83	0	0	83	17	0	0	17	0	0
	Advanced level	94	0	0	40	6	40	0	13	0	7
	Intermediate level	85	0	0	16	10	37	5	47	0	0
	Entry level	84	0	0	29	16	18	0	47	0	6
	No BIM experience	80	0	0	80	20	0	0	20	0	0

Note: M and L in Table 8 represent parties considered with the most and least benefits from BIM respectively. The same definition applies to Table 9.

Table 9. The Chi-Square test of independence of parties benefitted from BIM

		Chi-Square value	Degree of freedom	*p* value
Profession	M	9.377	28	1.000
	L	23.762	28	0.694
BIM proficiency level	M	3.894	16	0.999
	L	20.375	16	0.204

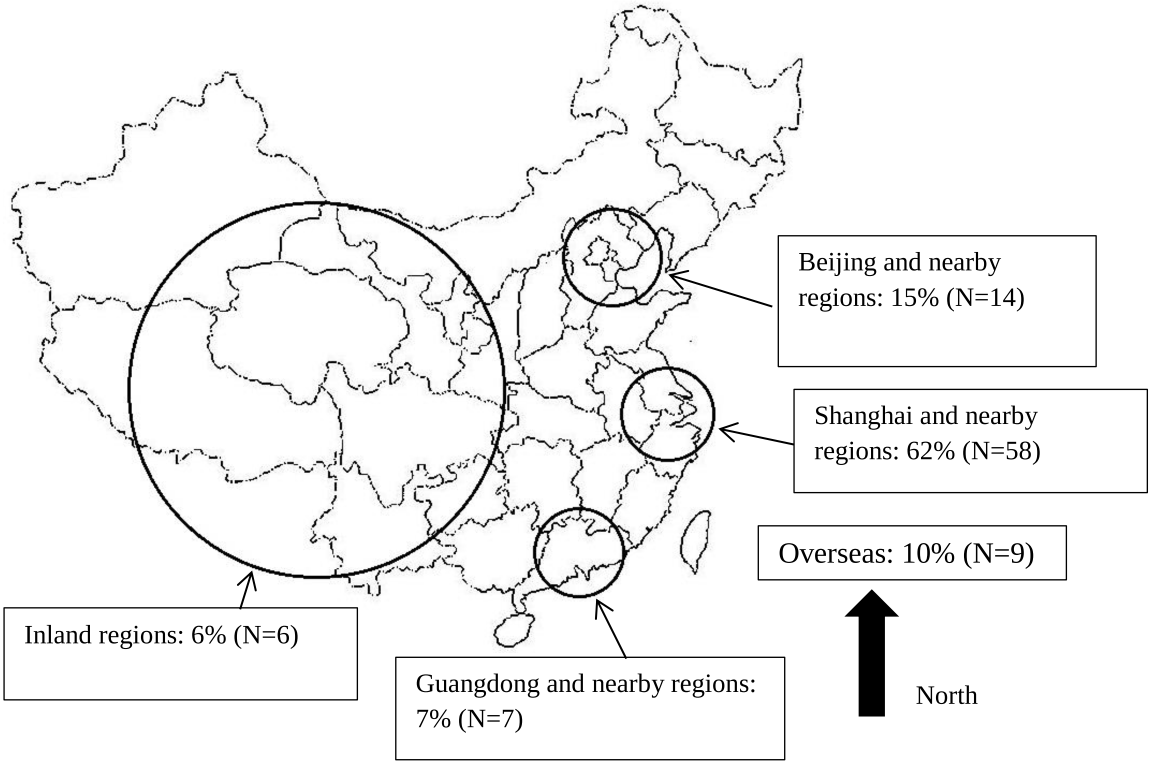
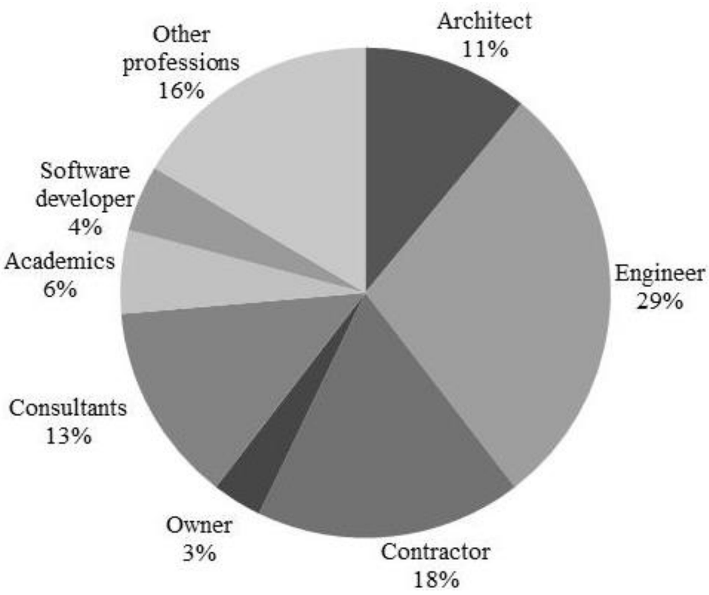


Fig.1. Geographic location of survey participants (N=94)



Note: 1. Engineers involved in this survey pool included civil engineers, building services engineers, and structural engineers.
2. Three participants did not provide the answer to this question. Therefore, only 91 valid responses were summarized.

Fig.2. Box plots for number of years of using BIM among survey participants (N=91)

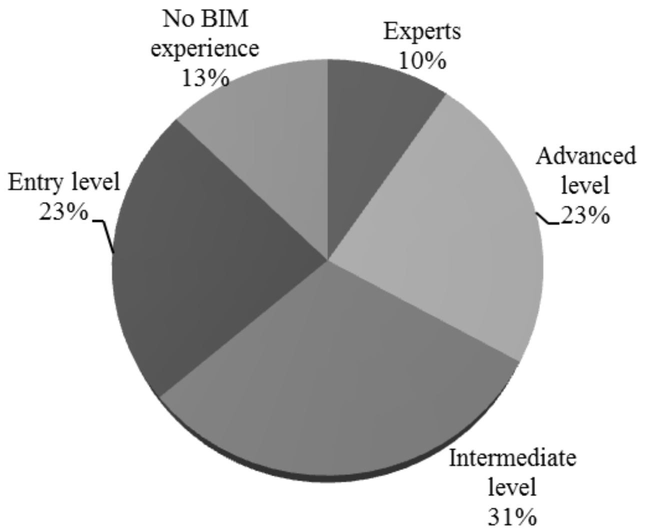
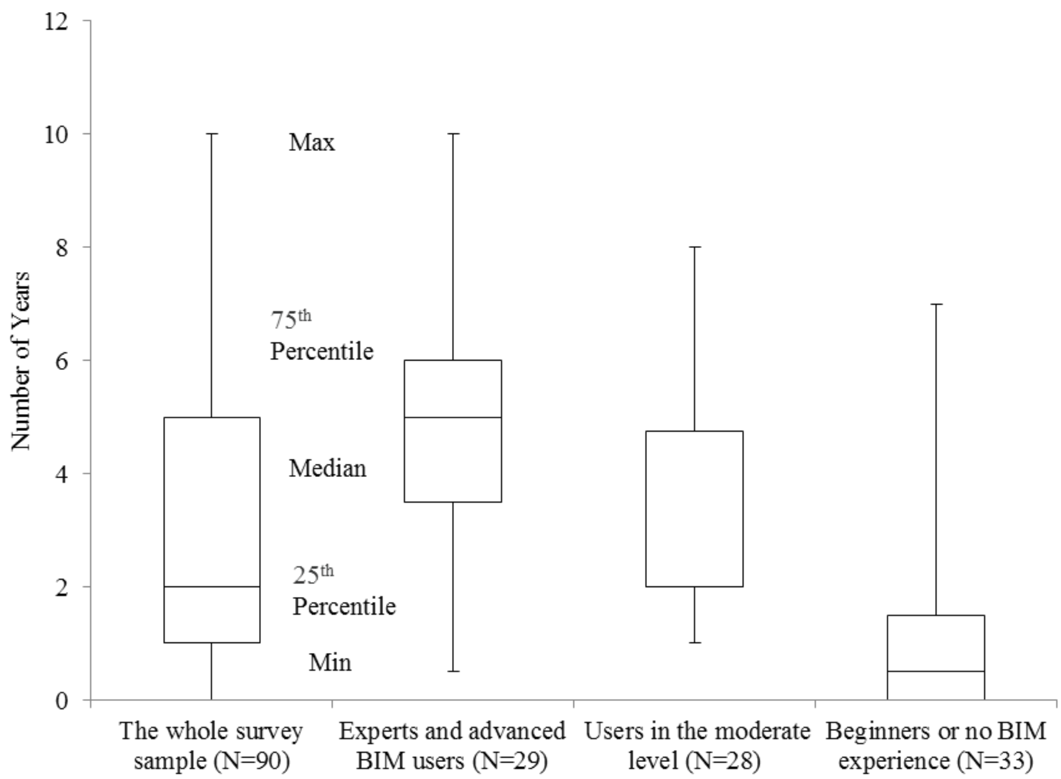


Fig.3. Survey participants' BIM proficiency level (N=94)



Note: 1. The median and 25th percentile value for the subsample of moderate level users were the same (i.e. two years).
2. Four participants did not provide valid answers to this question and 90 responses were adopted as the overall sample.

Fig.4. Box plots for number of years of using BIM among survey participants