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Investigation of Individual Perceptions towards BIM Implementation-a Chongqing Case Study

Abstract

Purpose –This research targeted on individual perceptions of BIM practice in terms of BIM benefits, critical success factors (CSFs), and challenges in Chongqing which represented the less BIM-developed metropolitan cities in China.

Design/Methodology/Approach –Adopting a questionnaire-survey approach followed by statistical analysis, the study further divided the survey population from Chongqing into subgroups according to their employer types and organization sizes. A further subgroup analysis adopting statistical approach was conducted to investigate the effects of employer type and organization size on individual perceptions.

Findings –Subgroup analysis revealed that governmental employees held more conservative and neutral perceptions towards several items in BIM benefit, CSFs, and challenges. It was inferred that smaller organizations with fewer than *100* full-time employees perceived more benefits of BIM in recruiting and retaining employees, and considered more critical of involving companies with BIM knowledge in their projects. **Originality/value –**This study contributed to the body of knowledge in managerial BIM in terms that: 1) it extended the research of individual perceptions towards BIM implementation by focusing on less BIM-mature regions; 2) it contributed to previous studies of influencing factors to BIM practice-based perceptions by introducing factors related to organization type and sizes; and 3) it would lead to future research in establishing BIM climate and culture which address perceptions and behaviors in BIM adoption at both individual and organizational levels.

Author Keywords: Building information modeling (BIM); China; BIM practice; Individual perceptions; Managerial BIM

1. Introduction

BIM (i.e., Building Information Modeling), as the emerging digital technology, is undergoing a rapid growth in the global architecture, engineering, and construction (AEC) industry. China is one of the largest AEC markets worldwide, and it accounted for nearly half of Asia-Pacific industry revenue (MarketLine, 2014). Accompanying the growth of AEC market is the increasing demand for BIM application in China (Jin et al., 2017a). Promoting BIM in AEC projects has become a national policy in China since 2011 (Jin et al., 2015). Although BIM has displayed its impacts on industry practice (Azhar et al. 2012; Francom and Asmar, 2015), a key concern worth investigating was how industry professionals perceived the impact of BIM on their business now and in the future (Jin et al., 2017a), as perceptions have a direct effect in behaviors (Dijksterhuis and Bargh, 2001). So far, most existing managerial studies in BIM have focused on the industry, company, or project levels (e.g., Said and Reginato, 2018), but the individual level perceptions have not been sufficiently studied (Howard et al., 2017). Factors that affect individual perceptions such as AEC professions and BIM experience levels (Jin et al., 2017b) have not been sufficiently investigated. Besides individual BIM competency, the organizational effects on individual perceptions should also be noticed. For instance, to promote BIM as the shared digital tool in the AEC industry, it is critical to accommodate all sizes of organizations that implement BIM such as small and medium sized enterprises (SMEs) (Lam et al., 2017). Succar et al. (2013) identified organizational capability as one of the factors that affected the BIM implementation. Continued from the study of Succar et al. (2013), researchers believe that influence factors to individual perceptions towards BIM adoption include also employer type and organization size.

According to Ministry of Housing and Urban-Rural Development (MHURD) of China (2017a), Chongqing was listed as one of the three provinces/municipalities in the mainland China without any BIM-involved construction projects in the second quarter of 2017. Among the totally *32* provinces/municipalities in China, there were a total of *616* construction projects reported applying BIM, or on average *19* BIM projects per province/municipality. As the largest metropolitan city in the inland of China with booming construction market, Chongqing has its own large potential for BIM implementation. The researchers' earlier investigation of Chongqing's AEC industry indicated that there had been a strong desire from the authority's perspective to promote BIM implementation in Chongqing, and to catch up with the national strategy in BIM movement. Previous studies of BIM movement, practice, and implementation in China, such as Ding et al. (2013), Cao et al. (2016), and Jin et al. (2017a), have focused more on these BIM-leading regions such as Canton and Shanghai. As stressed by Jin et al. (2017b) and Xu et al. (2018), more Chinese regions or municipalities are less developed with BIM practice. China is still in its early stage of BIM movement (Cao et al., 2016). There have not been sufficient studies on investigating BIM implementation in these less-developed regions (e.g., Chongqing).

Compared with other studies related to BIM adoption in other developing AEC markets (e.g., Masood et al., 2013; Juszczyk et al., 2015; and Ahuja et al., 2018), and adopting Chongqing as the case, this research differs from these previously conducted BIM managerial studies both in China and overseas in terms that: 1) it addresses the BIM movement in less BIM-ready regions which contribute to the majority of China's AEC industry revenue (Xu et al. 2018); 2) it incorporates the two main influencing factors, namely employer type and organization size, in their effects in AEC practitioners' perceptions; 3) it leads to further discussion of how AEC practitioners from less BIM-developed regions perceive BIM's benefits, critical success factors (CSFs), and challenges, as compared to their counterparts from more BIM-mature regions. This study contributes to the body of knowledge in managerial BIM targeting on the regional difference of BIM movement, which was defined by Xu et al. (2018) as one indicator of BIM climate describing individual perceptions of BIM implementation and relevant attitudes. This study also extends the previous research of Jin et al. (2017a) which focused on two individual-level factors (i.e., AEC profession and BIM experience level) by incorporating the organization-related factors (i.e., organization type and size) in their influences on individual perceptions. Scholarly, it leads to more future research in building the knowledge framework of various influence factors to effective BIM adoption; practically, the current research provides insights and guides for stakeholders including policy makers in promoting regional and local BIM practice, based on AEC practitioners' perceptions towards BIM.

2. Background

2.1. Motivations in adopting BIM

BIM enables creations of accurate virtual models and supports further activities in the project delivery process, and it is hence one of the most promising developments in the AEC industry (Eastman et al., 2011). It has been applied in assisting multiple AEC activities, such as cost estimate (Ren et al., 2012), schedule management (Tserng et al., 2014), safety risk assessment and management (Skibniewski, 2014), visualized construction management (Lin, 2014), construction quality inspection (Lin et al., 2016), and building performance analysis (Kim and Yu, 2016). Previous studies (Migilinskas et al., 2013; Ahn et al., 2015; Lin et al., 2016; Zhang et al., 2016; Poirier et al., 2017; Ustinovichius et al., 2017; Gholizadeh et al., 2018) have recognized these multiple benefits brought by BIM, including cost savings, 3D visualization, construction planning and site monitoring, reduction of design errors and rework, enhanced project communication, decreased project duration, and improved multi-party collaboration. The enhanced interoperability of BIM software could save up to two thirds of annual costs paid by stakeholders (Furneaux and Kivvits, 2008). Contractors were reported by Khanzode, et al. (2008) having reduced *1%* to *2%* of cost of MEP systems in large healthcare projects through BIM. According to Becerik-Gerber and Rice (2010) and Cheung et al. (2012), other project parties including software vendors have also obtained promising returns on investment in BIM.

2.2. Critical success factors and challenges in BIM implementation

Multiple CSFs matter to achieve these aforementioned benefits. These CSF include but are not limited to: collaborative environment to manage design changes (Eadie et al., 2013; Saoud et al., 2017; Kumar, 2018), policy interventions (Succar and Kassem, 2015; Kassem and Succar, 2017), BIM expertise within project teams (Ku and Taiebat, 2011; Kashiwagi et al., 2012; Eadie et al., 2013; Cao et al., 2016), project location, type and nature (Cao et al., 2016), project budget (Bazjanac, 2006), BIM governance solution (Hadzaman et al., 2018), legal issues and contract involving BIM usage (Oluwole, 2011; Race, 2012; Kumar and Hayne, 2017), adoption of BIM in multiple levels including individual level, company level, and project level (Samuelson and Björk, 2013), as well as client knowledge and motivation in adopting BIM (Vass and Gustavsson, 2017).

There have also been multiple challenges that had been identified from previous studies, such as lack of competent project participants (Migilinskas et al., 2017), difficult predication of BIM effects (Juan et al., 2017), limited training and technology support (Chien et al., 2014; Juan et al., 2017), insufficient policy and strategy development to cope with BIM technological movement (Lin, 2015). Other challenges or barriers encountered in BIM practice contain insufficient evaluation of BIM value, resistance at higher management levels due to cultural resistance, lack of demand from the client, higher initial investment, organizational change and adjustment in management pattern, and insufficient understanding of BIM technology or practicability (He et al., 2012; Sackey et al., 2014; Tang et al., 2015; Lee and Yu, 2016; Çıdık et al., 2017). Ahmed et al. (2017) further stated that the drivers and factors for BIM adoption, especially in the organizational level, had been disjointedly dispersed. To address these shortcomings, Ahmed et al. (2017) proposed an exhaustive set of drivers and key factors aiming to develop a conceptual model for BIM adoption in organizations.

2.3. BIM adoption in China

Although China's construction market could see BIM benefits, it is restricted to the own structural barriers (McGraw-Hill Construction, 2014). Despite that BIM could be the breakthrough in China's building industry, the movement of BIM faces these challenges due to the lack of sufficiently-developed standards, weak interoperability, and difficulties in applying BIM throughout the project life cycle (He et al., 2012). Despite of these challenges, Chinese governmental authorities have been moving forward the policy, guidelines, and standards to promote BIM usage in its AEC industry in more recent years (Jin et al., 2015). Recently MHURD of China (2017b) approved the *BIM Standard for Construction Application* and it took effect in the beginning of 2018.

Despite the fast BIM movement in China in terms of both standard development and industry practice, there are regional differences in China's BIM practice nationwide (Jin et al., 2017b). Xu et al. (2018) further proposed the concept of BIM climate reflecting the regional BIM practice and AEC practitioners' perceptions towards BIM. A few regions have been the forerunners of BIM practice, including Beijing, Shanghai, and Canton (Jin et al., 2015). For example, Shanghai Housing and Urban-Rural Construction and Management Committee (SHURCMC, 2017) reported that *29%* of new AEC projects in Shanghai had adopted BIM, and *32%* of Shanghai-based AEC firms have achieved a higher maturity level of BIM practice compared to other competitors in the local AEC market in 2016. The Committee further concluded that Shanghai had been in the leading level of BIM implementation in China. In contrast, Chongqing, as another similar-sized municipality, was identified by MHURD (2017a) as one of the few less BIM-active regions. A comprehensive understanding of local BIM practice and culture was imperative for policy making and further promoting local BIM practice (Xu et al., 2018).

3. Research Methodology

This research adopted questionnaire survey followed by statistical analysis in investigating the individual perceptions of BIM practice in Chongqing.

3.1. Data Collection

Questionnaire survey has been a widely adopted research method in the field of construction engineering and management. The questionnaire was initiated by the research team from September to October in 2017. It included two major parts. The first part focused on the background information of survey participants from Chongqing's AEC industry, including their employer type (e.g., contractor, consulting, and engineering design firm, etc.) and organization size measured by number of full-time employees. By adopting the multi-choice question, they were also asked to select the areas that BIM could be applied in, such as cost estimate, site management, and 3D visualization, etc. The second part of the questionnaire was adapted from a similar study conducted by Jin et al. (2017a). It covered three major sections (i.e., benefits of adopting BIM, critical factors for successful BIM practice, and challenges encountered in BIM practice) adopting the Likert-scale format. The initiated questionnaire underwent peer review process by being delivered to five local AEC professionals between November and December of 2017. Their feedback and comments were addressed to finalize the questionnaire and to ensure that these questions were clear without vagueness to AEC professionals in Chongqing.

The data collection process followed the procedures described by Cao et al. (2016) and Jin et al. (2017b), with various ways to reach potential survey participants, including local BIM-related workshops, events, seminars, and on-line survey to those who had been working with BIM or involved in BIM implementation (e.g., policy makers related to BIM). Starting in January 2018, the questionnaire was delivered to potential participants. Guidelines were provided to each participant by explaining the purpose of the study, the anonymous nature of the survey, and what the survey outcomes would be used for. Potential participants were also advised to either decline the survey request or to provide the inputs to the best of their knowledge.

3.2. Statistical analysis

Following the questionnaire survey, multiple statistical methods were adopted to analyze the survey data, including the Relative Importance Index (*RII*) to rank multiple Likert-scale items within each BIM perception-based section, internal consistency adopting Cronbach's alpha value, and one-way Analysis of Variance (ANOVA) accompanied by post-hoc analysis.

3.2.1. RII

For each of the three sections related to individual perceptions towards BIM practice (i.e., benefits, CSFs, and challenges), *RII* was calculated for every individual item within each section following the same equation adopted from previous studies (e.g., Tam, 2009; Eadie et al., 2013). It was used to measure the relative importance of individual items within each BIM-related section.

3.2.2. Internal consistency analysis

Cronbach's alpha (Cronbach, 1951) was adopted to measure the internal consistency of items in each section of perceptions on BIM. Its value ranges from *0* to *1,* and a higher value closer to *1* would indicate that a survey participant who selects one numerical Likert-scale score to one item would be more likely to assign a similar score to other items within the same section. Usually a Cronbach's alpha value from *0.70* to *0.95* indicates acceptable internal inter-relatedness (Nunnally and Bernstein, 1994; Bland and Altman, 1997). Besides the overall Cronbach's alpha value, each individual item is computed with its own value. The individual Cronbach's alpha value lower than the overall one would indicate that this given item contributes positively to the internal consistency. Otherwise, an individual value higher than the overall one would mean that survey participants tend to have different perceptions towards this given item as they would do to others. Each individual Cronbach's alpha value has a corresponding item-total correlation which measures the correlation between this given item and the remaining items within the same section of BIM-based perception.

3.2.3. Subgroup analysis

The whole survey sample was divided into subgroups according to their employer types (e.g., contractor) and organization size measured by number of full-time employees (e.g., between *50* and *100* employees). ANOVA, as the parametric method, was adopted to analyze the subgroup differences in perceiving BIM benefits, CSFs, and challenges. Parametric methods have been adopted in previous studies in the field of construction management (e.g., (e.g., Aksorn and Hadikusumo, 2008; Meliá et al., 2008; Jin et al., 2017b), especially for Likert-scale questions. The superior performance of parametric methods over non-parametric approach was discussed by Sullivan and Artino (2013). Carifio and Perla (2008) and Norman (2010) showed the robustness of parametric methods in survey samples that were either small-sized or not normally distributed. Compared to previous studies such as Tam (2009), the sample size of *100* in this study was considered fair.

Based on the null hypothesis that subgroups divided according to employer type or organization size had consistent perceptions towards the given item of perception towards BIM, a F value and a corresponding p value were computed for each individual item. Setting the level of significance at *5%*, a p value lower than *0.05* would decline the null hypothesis and suggest the alternative hypothesis that either employer type or organization size affects survey participants' perceptions towards the given BIM item. Following ANOVA, post-hoc tests were conducted to further identify the significant differences between each pair of subgroups. In this study, Fisher Least Significant Difference (LSD) was adopted as the post-hoc analysis tool. Fisher LSD is used only when the null hypothesis in ANOVA is rejected and it enables direct comparisons between two means from a pair of subgroups (Statistics How to, 2018).

2. Results

From *507* questionnaires sent through site visits and on-line survey, a total of *100* valid responses were received in Chongqing by the end of March 2018. The survey participants had an average BIM usage experience of 6 months, with the maximum experience of 84 months. Survey participants from governmental authorities generally had no BIM usage experience. But similar to others with little practical experience of BIM, all of them had been working with other professionals in BIM-involved projects. Survey data were summarized in these following sections, namely background information of survey participants, as well as their perceptions on benefits of BIM, CSFs of BIM practice, and challenges encountered in BIM practice.

2.4. Background information of survey participants

The survey population is summarized according to their employer or organization type, and organization size defined by numbers of full-time employees. Figure 1 displays the percentage of each subgroup.

<Insert Figure 1 here>

It is seen in Figure 1 that survey participants came from A/E (i.e., architecture and engineering) design firm, contractor, consulting firm, quality inspection, governmental authority, and others. Other employer types included design-build firms, BIM software developers, urban planning companies, business developer or entrepreneur, and construction material suppliers, etc. Around *60%* of the participants had their organization more than *100* full-time employees. Respondents were asked of the multi-choice question regarding BIM's application areas (i.e., functions). Figure 2 displays the percentages of respondents that selected each given BIM function.

<Insert Figure 2 here>

According to Figure 2, a significantly higher percentage of respondents (i.e., *73%*) selected 3D visualization as one BIM function. The significantly higher percentage of respondents in selecting 3D visualization was consistent with the finding from Jin et al. (2015) that many Chinese AEC practitioners had been basically using BIM as a 3D visualization tool. Other BIM functions selected by more than half of survey participants included BIM in construction site management (e.g., site monitoring), as well as project management throughout project life cycle from design to facility management. In contrast, clash detection was chosen by only *26%* of respondents. The bottom-ranked BIM functions were enhancing company image, and increasing the chance of winning project bidding.

2.5. BIM benefits

Survey participants were asked to rank multiple five-point Liker-scale items related to the benefits of BIM implementation, with the numerical value *1* meaning "least beneficial", *3* indicating a neutral attitude, and 5 being "most beneficial". An extra option of *6* was given to those who were unsure of the answer. Excluding those who were unsure of the provided items, the overall sample analysis is summarized in Table 1.

<Insert Table 1 here>

Table 1 shows that B4 (i.e., offering new services) was the top-ranked BIM benefit among all the *13* listed items. According to Figure 2, 3D visualization is considered the main BIM service. Other higher ranked BIM benefits with *RII* score over *0.800* include B1 (i.e., reducing omissions and errors), B2 (i.e., reducing rework), and B3 (i.e., better project quality). These four highly-ranked BIM benefits were consistent with the finding from Jin et al. (2017a) who conducted the survey of the same question to AEC practitioners mostly from more BIM-developed regions (e.g., Shanghai). The main difference between Chongqing respondents in this study and their counterparts from BIM-advanced regions in Jin et al. (2017a) lied in that B1 was the top-ranked BIM benefit in the latter study. The overall Cronbach's Alpha value at *0.9352* showed excellent internal consistency of survey participants' views of BIM benefits. The generally high item-total correlation coefficients and lower individual Cronbach's Alpha value in Table 1 indicated that a survey participant who selected a numerical score to one Likert-scale item was likely to assign a similar score to other items. Subgroup analysis by dividing the whole survey sample according to their organization type and size is summarized in Table 2.

<Insert Table 2 here>

According to Table 2, generally there were consistent perceptions of BIM benefits except B13 related to BIM benefits in recruiting and retaining employees. B13 was only item that was perceived differently among subgroups divided according to both employer type and organization size. The post-hoc analysis adopting Fisher LSD revealed that consultants, A/E design firms, and contractors held more positive views on B13 compared to quality inspection firms, governmental authorities, and other employer types. Employees from governmental authorities held the lowest average Likert-scale score at *3.091* indicating a neutral attitude. In comparison, consultant had the average score at *4.333*. In terms of organization size, those organizations with full-time employees fewer than *100* held more confirmatory views on B13 compared to organizations with more than *100* full-time employees. Specifically, those from organization size between *50* and *100* employees had the average score of *4.375*, compared to those from organization sizes of over *200* full-time employees (average score at *3.292*) and those with employee size from *100* to *200* (average score at *3.286*). The Fisher post-hoc analyses for B13 are demonstrated in Figure 3 and Figure 4.

<Insert Figure 3 here>

The horizontal interval lines show the comparison between each pair of subgroups in Figure 3. Based on the *95%* confidence interval, those lines which do not cover the zero neutral point indicate the significant differences between the given pair. Figure 3 shows that consulting firms had a significant difference with governmental authorities, quality inspection organizations, and others. Similarly, Figure 4 indicates the significant differences between the given pair of subgroups from different organization sizes, such as the difference between organizations with *50* to *200* full-time employees and those with *100* to *200* employees, and between organizations over *200* employees and those with *50* to *100* employees.

<Insert Figure 4 here>

2.6. Critical Success Factors

Survey participants were asked to rank the importance of CSFs in effective BIM implementation. Based on the five point Likert-scale with *1* meaning least important, *2* being not important, *3* indicating neutral, *4* inferring important, *5* being most important, and the extra *6* for those who were unsure of the answer. Excluding those who chose *6*, the overall sample analysis is summarized in Table 3.

<Insert Table 3 here>

Similar to the survey in Jin et al. (2017a), the interoperability of BIM software was considered the top critical factor for BIM to achieve its potential values. Besides interoperability which could be considered internal factor of BIM, the external factor in terms of project complexity was considered another critical factor in both this study and Jin et al. (2017a). Project complexity was defined as the interdependencies and interrelationships among trades, uncertainties causing change orders, and overlapping of construction activities according to Jarkas (2017). These bottom-ranked items (i.e., F12, F13, and F14) were also consistent between this study and Jin et al. (2017a). Different from Jin et al. (2017a) where clients' sophistication was considered a key CSF, client's knowledge on BIM was not ranked high in this study. Instead, contract form and project budget were considered more critical in successful BIM implementation.

The Cronbach's alpha value at *0.9343* indicated a strong internal consistency among all the *14* CSFs, inferring that a survey participant who selected one CSF would be likely to choose a similar answer to other CSFs. All individual Cronbach's alpha values in Table 3 lower than the overall value also suggested that each CSF contribute to the overall internal consistency among CSF items. The subgroup analyses based on ANOVA were performed as summarized in Table 4. Linking Table 4 to Table 3, it was found that these three bottom-ranked items, including F7 related to BIM technology consultants, F13 related to project location, and F14 related to staff working locations, received the highest variations among the survey population. However, these variations did not come from the employer type or organization size.

<Insert Table 4 here>

According to Table 4, significant differences were found among subgroups divided by employer types in light of F8 related to the project nature and F10 (i.e., number of BIM-knowledgeable companies in the project). Adopting the Fisher post-hoc analysis, Figure 5 shows the differences between each pair of subgroups according to employer types. It is seen in Figure 5 that the main difference came from the governmental authorities. With the average score of *3.182* indicating a somewhat neutral attitude, respondents from governmental authorities held significantly less confirmatory views of the significance of project nature, compared to those working for consulting firms (*4.333*), contractor (*4.286*), and others (*3.857*). Similarly, participants from governmental authorities also perceived less significantly of F10 as seen in Figure 6. The average scores on F10 for governmental employees, contractors, consulting firms, A/E firms, and others were *3.091, 4.364, 4.167, 4.000*, and *3.781* respectively.

<Insert Figure5 here>

<Insert Figure 6 here>

The subgroup analysis based on organizations' number of full-time employees revealed that those with *100* to *200* employees held less confirmatory views on F10. They had the average score of *3.381*, compared to those with *50* to *100* employees (*4.222*), *20* to *50* (*4.071*), and below *20* (*3.833*).

2.7. Challenges

In the section of challenges encountered during BIM practice, survey participants were asked to rank the difficulties of the nine items listed in Table 5. A similar five-scale point Likert scale was provided for each challenge item, with *1* meaning least challenging, *2* being not challenging, *3* suggesting a neutral attitude, *4* indicating challenging, and *5* inferring most challenging. Excluding those who chose *6* indicating unsure of the given item, the overall sample analysis and subgroup analysis are summarized in Table 5 and Table 6 respectively.

<Insert Table 5 here>

The *RII* data in Table 5 show the significance of each challenge. Compared to the study in Jin et al. (2017a), some consistent rankings were found in this study, specifically: 1) lack of sufficient evaluation of BIM and acceptance of BIM from the senior management level were considered top two major barriers in BIM implementation; 2) acceptance of BIM from the entry-level staff was ranked as one of the least challenging item. However, differing from the study targeting on more BIM-developed regions in Jin et al. (2017a), Chongqing participants considered BIM training a key challenge. Also, they did not perceive the lack of client requirement a key challenge. The overall Cronbach's alpha value at *0.8915* indicated a fairly high internal consistency of survey participants' perceptions towards these nine challenge related items. The only exception came from C7 (i.e., cost of purchasing BIM software) with its individual Cronbach's alpha value higher than the overall one. It was inferred that compared to other items in Table 5, survey participants tended to have differed view on C7.

<Insert Table 6 here>

The largest variation measured by standard deviation came from C2 (i.e., acceptance of BIM from the senior management level).The subgroup analysis indicated that variations of perceptions towards challenges in BIM practice mainly came from employer types. Specifically, governmental employees held less confirmatory views of C6 and C7 related to the costs of upgrading hardware and purchasing software. They had the average score of *3.000* and *2.700* respectively for C6 and C7, indicating a neutral attitude or even perceiving cost-related issues not a challenge. In comparison, contractors (*3.800* and *3*.810 respectively), consulting firms (*3.800* and *3.800*), A/E (*3.833* and *3.583*) perceived cost-related issues more challenging in BIM investments.

3. Discussion and summary

3.1. Summary of findings in the China context

As indicated by Jin et al. (2017b) and Xu et al. (2018), there was a need to address the regional difference of BIM movement in a large AEC market (e.g., China). The 3D visualization was selected by the significantly higher percentage of survey participants (i.e., *73%*) as one major BIM function. The overall survey sample's reaction to BIM function could be linked to the Liker-scale question regarding the perceived benefits by adopting BIM, in which offering new services was ranked top. It was indicated that survey participants from Chongqing mainly considered BIM a 3D visualization tool. Consistent to Jin et al. (2015) and the research team's earlier investigation, BIM had been basically used for visualization purpose, especially when the inexperienced or unsophisticated clients preferred to see well-visualized pre-construction work. For BIM to demonstrate its further potential in the project life cycle management, it is critical to take into account of various levels of stakeholders' maturity, capacity, and readiness (Rezgui et al., 2013).

Compared to AEC practitioners' perceptions from China's more BIM-mature regions (Jin et al., 2017a), both similarities and differences in Chongqing survey participants' perceptions were found. In light of similarities, reducing errors and rework were considered main benefits of adopting BIM. Interoperability of BIM software tools was identified as the top critical factor for effective BIM implementation. Interoperability issues encountered in BIM have been highlighted in multiple studies (e.g., Shadram et al., 2016; Akinade et al., 2017; Oduyemi et al., 2017) and remain an ongoing research theme in both technical and managerial BIM. Project complexity was also considered by both studies as a key important CSF in BIM practice. Lack of sufficient evaluation of BIM (e.g., ratio of investment to output) as well as acceptance of BIM from the top management level in an organization were perceived as main challenges. However, differing from Jin et al. (2017a)'s finding, Chongqing survey participants in this study did not perceive clients' knowledge of BIM a key important CSF. Instead, they believed that the project budget and contract-form supporting BIM were more important. This conveyed the information that in less BIM-ready region such as Chongqing, certain external factors were considered more important, such as project contract and budget. In comparison, those AEC practitioners from more BIM-mature regions would consider internal factors more critical such as BIM-knowledgeable professionals and clients' knowledge of BIM. Compared to these more BIM-mature regions, Chongqing participants considered more challenges from lack of effective BIM training. This was consistent from the study of Xu et al. (2018) that less BIM-ready regions would need more BIM training compared to more BIM-developed regions.

3.2. Generalisation of the findings in the international context

Different from previous BIM adoption-based studies conducted in China, such as Ding et al. (2015) and by Zhao et al. (2018) in which the survey populations were limited to designers, this study recruited a variety of different employer types. Although adopting Chongqing as the regional case study, this research could be implied in the international context in terms of the organizational features emphasized by Ahmed et al. (2017) and Wan Mohammad et al. (2017). Subgroup analyses were performed according to survey participants' employer type and organization size. Several subgroup differences were found in participants' perceptions towards BIM benefits, CSFs, and challenges. The same BIM benefit item related to BIM in recruiting and retaining employees received different views among subgroups divided by both employer type and organization size. It appeared that AEC industry practitioners including consultants and A/E design firms, perceived more positive views of BIM in retaining and hiring employees compared to those from governmental authorities, quality inspection organization, and others. Those from smaller-sized organizations with fewer than *100* full-time employees perceived more positively on BIM compared to those organizations with over *100* employees. It was further indicated that BIM as an advantage to hire or keep employees was considered an even more important benefit from the perspective of smaller-sized organizations. Similarly, organizations with fewer than *100* full-time employees also held more confirmatory view of the importance of number of BIM-knowledgeable companies in the project, compared to those with *100* to *200* employees.

Overall, employees from governmental authorities seemed more conservative in BIM benefits and CSFs. For example, besides BIM benefits in human resources, they also held neutral attitudes towards CSFs in BIM including the project nature and number of BIM-knowledgeable companies. In contrast, employees from contractors, A/E firms, and consulting firms generally had significantly more confirmatory perceptions towards these items. It was also found that industry practitioners (i.e., A/E firms, contractors, and consulting firms) considered the cost in BIM-related hardware and software more challenging compared to governmental employees. This gap between government and industry should be addressed for promoting BIM in less BIM-mature regions. The less confirmatory views from governmental employees inferred that they might need to gain more insights from industry practitioners before adopting relevant guidelines and local policies, as BIM movement asked the joint-effort and collaboration not only among building trades or AEC disciplines (Eadie et al., 2013), but also between the industry and governmental authorities.

3.3. Research directions

The current study extends the research of Succar et al. (2013) by linking organizational features into individual perceptions, with two organizational factors studied, namely employer type and organization size. It leads to future studies on more organization factors' effects on individual perceptions towards BIM adoption, as guided by Ahmed et al. (2017). It follows the recommendation from Xu et al. (2018) by exploring the BIM adoption in less BIM-developed regions. It advances the knowledge from Ding et al. (2015) in which the BIM empirical studies were basically limited to those BIM-leading or more developed regions in China. Findings generated from this study could be extended to other developing countries or regions during the process of BIM promotion, such as Vietnam and Pakistan. The findings generated from this study could be further applied in other less BIM-developed countries or regions (e.g., Vietnam) which are also in the early stages of initiating BIM. This study could also lead to further research in the BIM adoption of Chinese SMEs by dividing the size of organizations according to their revenues. So far, investigating the BIM adoption and practice of SME in China has not yet been sufficiently performed. China has significant regional variations in BIM implementation level (Jin et al., 2017b) or BIM climate (Xu et al., 2018). This study serves as a reference to investigate the barriers and critical factors in implementing BIM in less developed regions. The empirical data collected from this study could be further compared with previous BIM studies adopted in more BIM-active region such as Shenzhen (Ding et al., 2015).

4. Conclusions

Although this study was based on data collected from a single region (i.e., Chongqing) in China, the study approach and findings generated from the research in terms of organizations features' effects on BIM adoption could be extended to the rest of the world, especially those less BIM-developed AEC markets. Two main influence factors, namely employer type and organization size, were studied of their impacts on individual perceptions towards BIM. The research also allowed the comparison in BIM climate between less BIM-ready regions and their more BIM-mature counterparts. It contributed to the managerial BIM research and practice from both theoretical and practical perspectives. Scholarly, it extended previous studies of BIM climate in terms of individual level perceptions by focusing on less BIM-ready regions or countries and its influence factors (e.g., organization size); practically, it provided insights and suggestions for stakeholders on local BIM practice and culture, which should be incorporated in promoting the regional BIM practice.

Although BIM, as the emerging digital technology in the AEC industry with multiple promising functions such as sustainable and integrated design and construction, the current stage of BIM practice might still be limited to visualization especially in less BIM-ready regions. The gap between academic research and industry, as well as between the potential outreach of BIM and its currently limited applications should be addressed, especially in those less BIM-ready regions such as Chongqing in this study. These regions should vision reaching higher potentials of BIM from barely being as a tool to achieve visualization to a more integrated information sharing platform that truly improves project delivery efficiency. Public policies could be considered in setting a regional BIM climate among stakeholders.

Through comparison with previous studies conducted in more BIM-developed regions, it was indicated that AEC practitioners from Chongqing considered several external factors more important in effective BIM implementation, including project contract supporting BIM and project budget, rather than other internal factors such as BIM knowledgeable professionals and clients' BIM knowledge. They also perceived the lack of effective BIM training more challenging. On the other hand, consistent with peers from more BIM-mature regions, this study revealed several consistent findings, including: 1) main benefits of BIM included reductions in errors and rework; 2) interoperability was the main critical factor in BIM implementation together with the project complexity; 3) lack of sufficient evaluation of BIM as well as acceptance of BIM from the organizations' senior management level were major barriers in BIM implementation.

Subgroup analyses revealed that governmental employees held more conservative perceptions towards certain benefits, critical factors, and challenges in BIM practice, such as BIM benefits in human resources, project feature, and number of BIM knowledgeable companies. Compared to governmental employees, these AEC practitioners from design firms, contractors, and consulting held more confirmatory views. It was suggested that these who were practicing BIM tended to have more positive or confirmatory perceptions of BIM than governmental authorities. On the other hand, practitioners also perceived more challenges in terms of BIM investment or costs. Therefore, there was a gap between the government and the industry practitioners. The subgroup analysis by dividing the survey sample according to organization size revealed that smaller-sized organizations (i.e., with fewer than *100* full-time employees) held more positive views on BIM benefits in recruiting or maintaining employees, as well as the importance of having certain number of BIM knowledgeable employees in the project.

Suggestions for promoting BIM practice in less BIM-ready regions or countries worldwide are proposed: 1) developing the local BIM standard and guideline to enhance BIM adoption in the local AEC market, such as the contract language to support BIM practice; 2) bridging the gap between industry practitioners and governmental authorities through different approaches such as government-funded projects promoting BIM usage; 3) providing more BIM training for local AEC practitioners, not only technical training for entry-level employees, but even more importantly, managerial training for senior management staff and employees from governmental authorities. The BIM training could be provided from public and private institutions joint with industry representatives experienced in BIM; A variety of BIM education or training sessions can be offered, including but not limited to seminars, physical or on-line workshops, and series of modules towards achieving different levels of BIM skills; and 4) certain policies to be enacted accommodating the smaller-sized AEC organizations to nurture the growth of BIM within them. International examples of effective BIM policies in promoting BIM practice could be considered in initiating local BIM policies, such as BIM policies implemented in United Kingdom and Singapore. To increase the public awareness of the true nature of BIM, multiple drivers need to be considered, including public demonstration projects, institutional training and education of BIM by linking it to emerging practices such as augmented reality and artificial intelligence, as well as policy intervention. The promotion of digital applications to enhance AEC project efficiency requires multi-stakeholder joint effort because BIM, by its nature, stresses information sharing through interdisciplinary coordination and collaboration.

The organization size defined in this study was limited to the number of full-time employees. More future research could extend the current funding by introducing more influence factors to BIM-based individual perceptions, such as annual revenue which could be another indicator of organization size. Only two organization features (i.e., employer type and number of full-time employees) were studied in this research, more organizational indicators could be studied in BIM adoption. Also, a more comprehensive framework of BIM climate reflecting individual perceptions towards BIM practice could be established in the future, such as how top executives, mid-level management personnel, and entry-level A/E employees perceive and behave in adopting BIM within their own organizations.

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Table 1. *RII* analysis results of perceptions towards BIM benefits within the whole survey sample (Cronbach's alpha = *0.9352*).

Item	***RII***	**Ranking**	**Item-total correlation**	**Cronbach's Alpha**
B1: Reducing omissions and errors	0.806	4	0.728	0.9296
B2: Reducing rework	0.815	2	0.700	0.9303
B3: Better project quality	0.815	2	0.749	0.9288
B4: Offering new services	0.827	1	0.678	0.9309
B5: Marketing new business	0.779	7	0.616	0.9329
B6: Easier for newly-hired staff to understand the ongoing project	0.785	6	0.669	0.9312
B7: Reducing construction cost	0.770	9	0.734	0.9291
B8: Increasing profits	0.776	8	0.807	0.9266
B9: Maintaining business relationships	0.767	10	0.663	0.9315
B10: Reducing overall project duration	0.764	11	0.715	0.9297
B11: Reducing time of workflows	0.794	5	0.770	0.9280
B12: Fewer claims/litigations	0.755	12	0.678	0.9312
B13: Recruiting and retaining employees	0.725	13	0.646	0.9326

Table 2. ANOVA analysis of subgroup differences towards BIM-benefit-related items.

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to organization types**		**ANOVA analysis for subgroups according to organization size**	
			F value	*p* value	F value	*p* value
B1	4.030	0.738	1.39	0.237	0.22	0.926
B2	4.075	0.858	0.79	0.562	0.76	0.556
B3	4.075	0.765	0.53	0.753	0.81	0.521
B4	4.134	0.815	0.29	0.919	0.42	0.796
B5	3.896	0.837	0.76	0.580	0.54	0.707
B6	3.925	0.841	0.33	0.891	1.37	0.253
B7	3.851	0.821	1.01	0.418	0.91	0.464
B8	3.881	0.844	0.99	0.426	0.21	0.932
B9	3.836	0.881	1.24	0.298	1.32	0.270
B10	3.821	0.869	1.96	0.094	0.40	0.809
B11	3.970	0.797	0.87	0.503	0.45	0.775
B12	3.776	0.813	0.41	0.843	0.92	0.459
B13	3.627	0.967	**2.40**	**0.045***	**2.70**	**0.037***

*: A *p value lower than 0.05 indicates significant subgroup differences in their perceptions towards the given BIM benefit item.*

Table 3. The overall sample analysis results of BIM CSFs within the whole survey sample (Cronbach's alpha = *0.9343*).

Item	*RII*	Ranking	Item-total correlation	Cronbach's Alpha
F1: Interoperability of BIM software	0.857	1	0.579	0.9326
F2: Number of BIM-knowledgeable professionals	0.800	5	0.726	0.9286
F3: Project complexity	0.836	2	0.644	0.9310
F4: Clients' knowledge on BIM	0.764	11	0.716	0.9287
F5: Companies' collaboration experience with project partners	0.795	7	0.635	0.9311
F6: Contract-form that is BIM-collaboration supportive	0.813	3	0.695	0.9293
F7: BIM technology consultants in the project team	0.758	13	0.713	0.9290
F8: The project nature (e.g., frequency of design changes)	0.792	9	0.730	0.9283
F9: Project schedule	0.797	6	0.661	0.9303
F10: Number of BIM-knowledgeable companies in the project	0.795	7	0.766	0.9274
F11: Project budget	0.810	4	0.677	0.9299
F12: Project size	0.766	10	0.693	0.9294
F13:Project geographic location	0.761	12	0.752	0.9276
F14: Staff from different companies working in the same location	0.709	14	0.671	0.9312

Table 4. ANOVA analysis of subgroup difference towards BIM CSF items.

Item	**Overall Mean**	**Standard deviation**	**ANOVA analysis for subgroups according to employer type**		**ANOVA analysis for subgroups according to organization size**	
			F value	*p* value	F value	*p* value
F1	4.286	0.723	0.56	0.728	0.55	0.698
F2	4.000	0.811	0.89	0.492	0.78	0.539
F3	4.182	0.739	0.54	0.745	0.58	0.677
F4	3.818	0.996	1.06	0.388	0.37	0.831
F5	3.974	0.794	1.51	0.197	0.94	0.446
F6	4.065	0.879	0.97	0.439	0.26	0.900
F7	3.792	1.068	1.63	0.162	0.43	0.789
F8	3.961	0.880	**2.80**	**0.022***	1.59	0.184
F9	3.987	0.866	1.74	0.135	0.87	0.486
F10	3.974	0.843	**3.47**	**0.007***	**2.56**	**0.044***
F11	4.052	0.826	1.49	0.203	0.11	0.980
F12	3.831	0.951	1.26	0.291	0.54	0.706
F13	3.805	1.052	1.30	0.273	0.81	0.522
F14	3.545	1.165	0.80	0.551	0.76	0.555

*: a *p* value lower than 0.05 indicates the significant differences among subgroups towards BIM CSFs

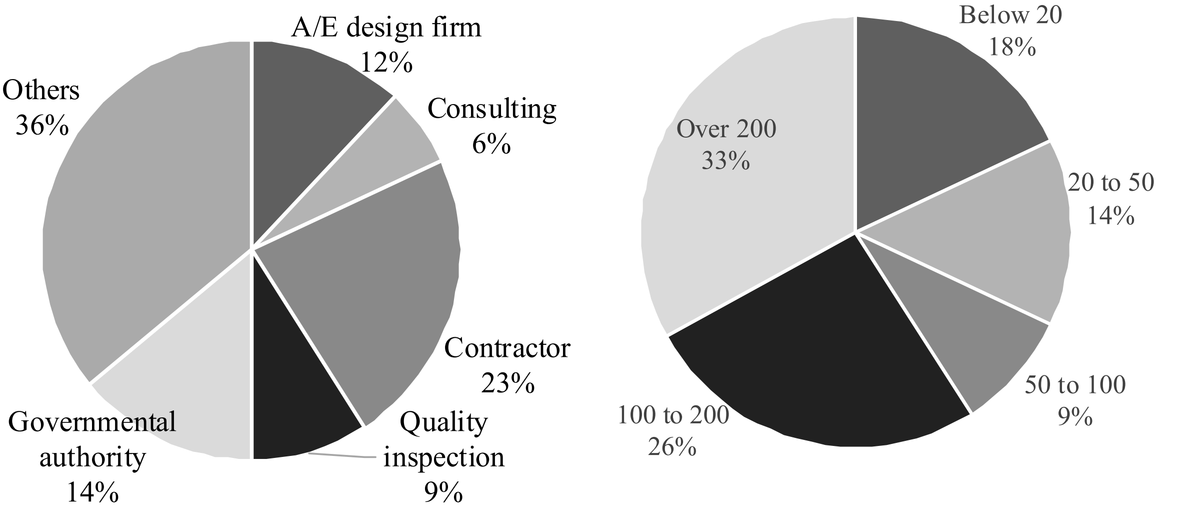
Table 5. *RII* analysis results of BIM challenges within the whole survey sample (Cronbach's alpha = *0.8915*).

Item	***RII***	**Ranking**	**Item-total correlation**	**Cronbach's Alpha**
C1: Lack of sufficient evaluation of BIM	0.736	1	0.6905	0.8762
C2: Acceptance of BIM from senior management	0.707	2	0.5661	0.8878
C3: Acceptance of BIM from middle management	0.696	5	0.7654	0.8715
C4: Lack of client requirements	0.667	8	0.7416	0.8717
C5: Lack of government regulation	0.696	5	0.6842	0.8767
C6: Cost of hardware upgrading	0.699	4	0.6863	0.8768
C7: Cost of purchasing BIM software	0.685	7	**0.4889**	**0.8916**
C8: Acceptance of BIM from the entry-level staff	0.664	9	0.6660	0.8781
C9: Effective training	0.704	3	0.6840	0.8767

Table 6. ANOVA analysis of subgroup difference towards BIM-challenge-related items.

Item	Overall Mean	Standard deviation	ANOVA analysis for subgroups according to employer type		ANOVA analysis for subgroups according to organization size	
			F value	*p* value	F value	*p* value
C1	3.680	0.918	0.65	0.666	1.41	0.237
C2	3.533	1.070	1.99	0.089	0.68	0.610
C3	3.480	0.828	0.53	0.751	0.36	0.834
C4	3.333	0.963	2.22	0.061	0.76	0.552
C5	3.480	0.921	1.29	0.276	1.18	0.324
C6	3.493	0.876	**2.46**	**0.040***	1.34	0.262
C7	3.427	0.888	**2.89**	**0.019***	1.04	0.390
C8	3.320	0.975	1.32	0.263	0.72	0.578
C9	3.520	0.950	0.77	0.573	1.28	0.283

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



a)Employer type of survey participants in Chongqing

b)Organization size measured by number of full-time employees

Figure 1. Background information of survey participants from Chongqing's AEC professionals (N=*100*)

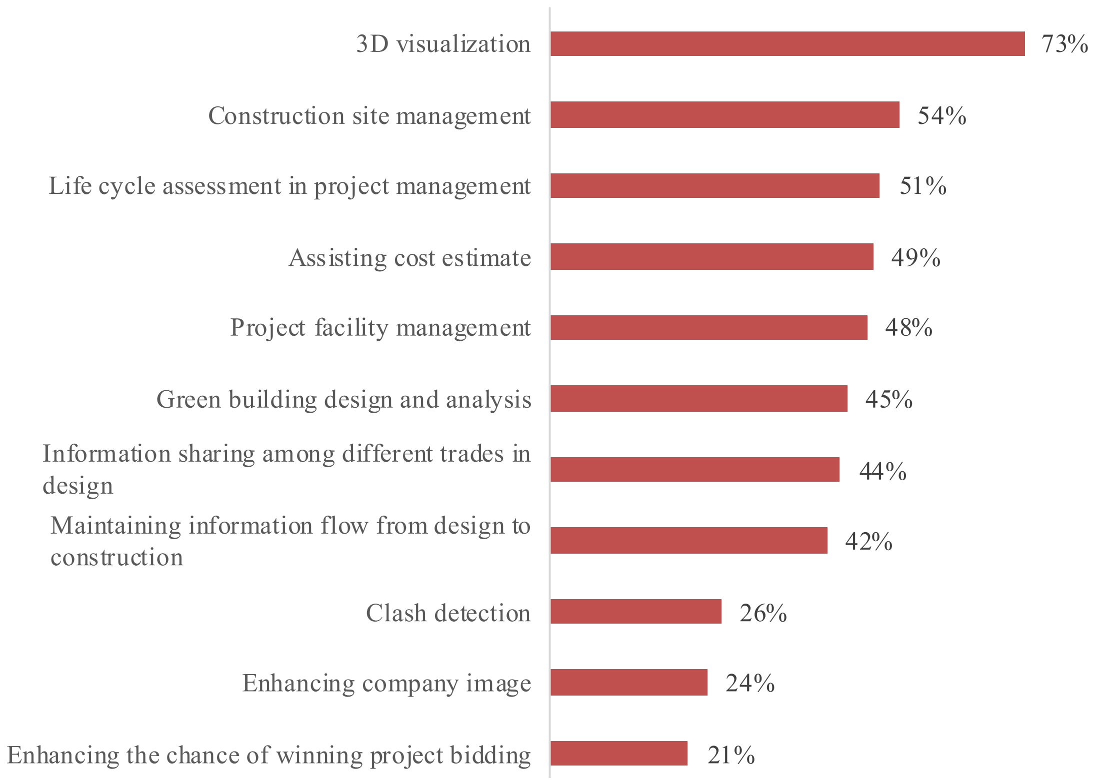


Figure 2. Percentages of the overall survey sample in selecting each BIM function

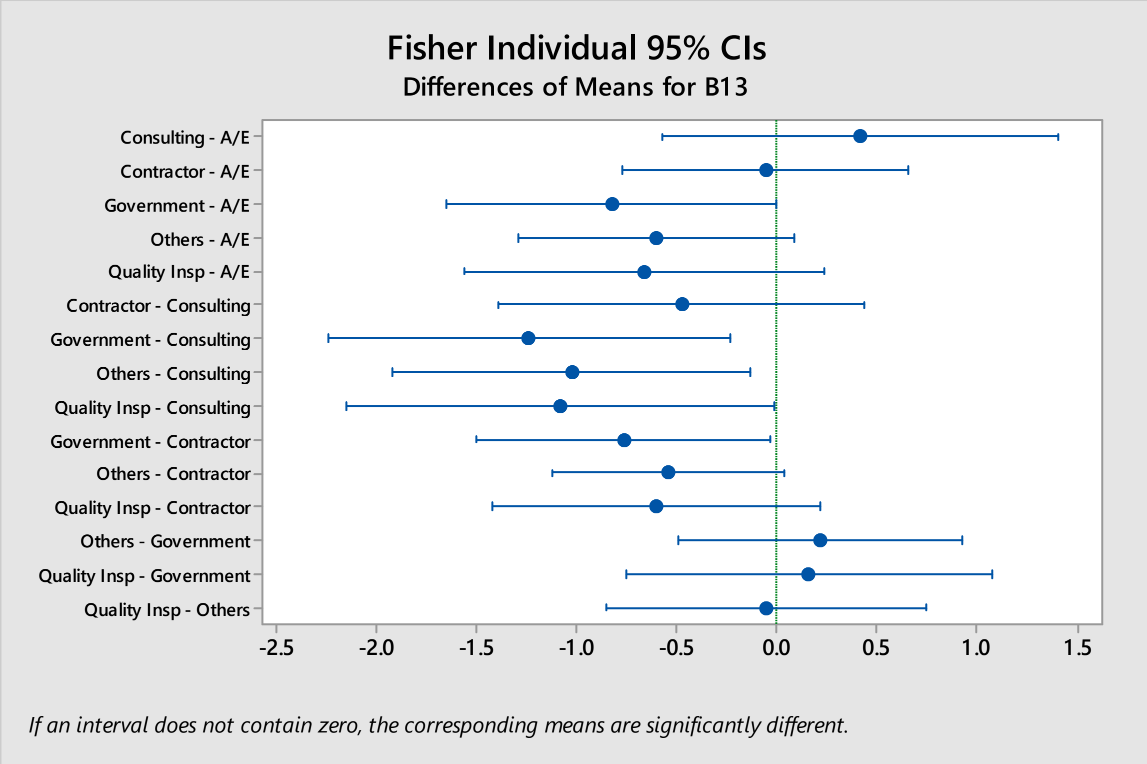


Figure 3. Post-hoc analysis for subgroup analysis of B13 among survey participants from different employer types

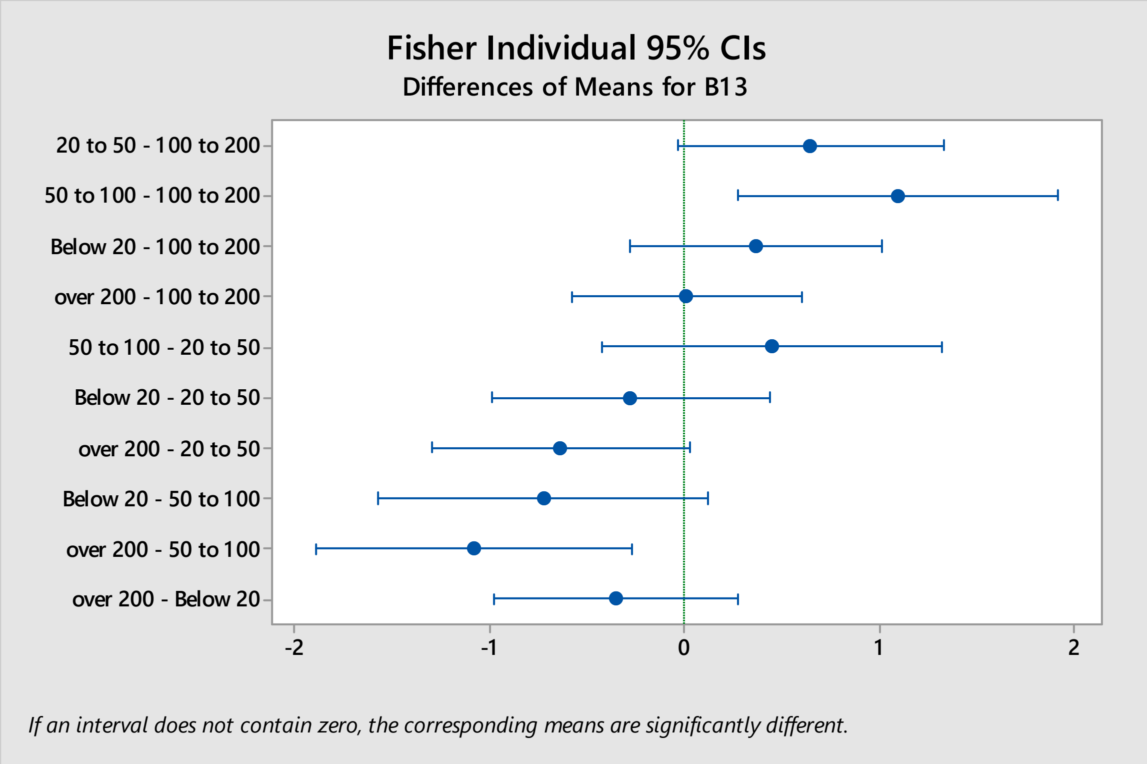


Figure 4. Post-hoc analysis for subgroup analysis of B13 among survey participants from different organization sizes

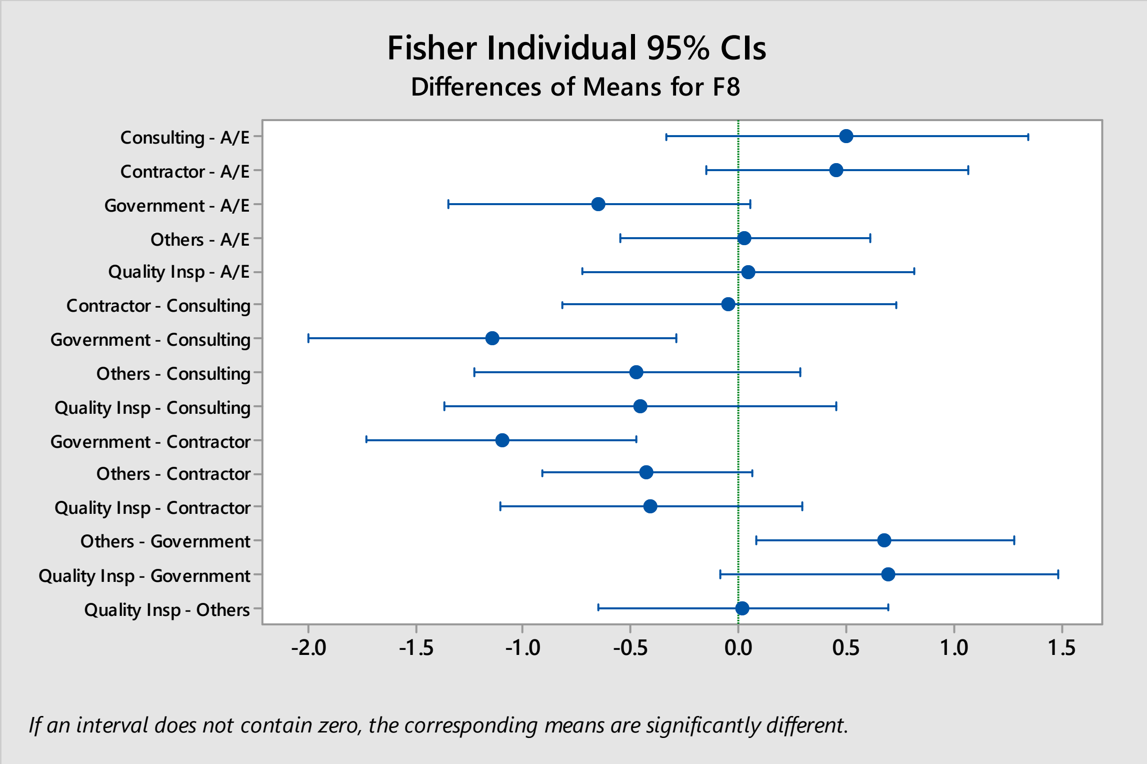


Figure 5. Post-hoc analysis for subgroup analysis of F8 among survey participants from different employer types

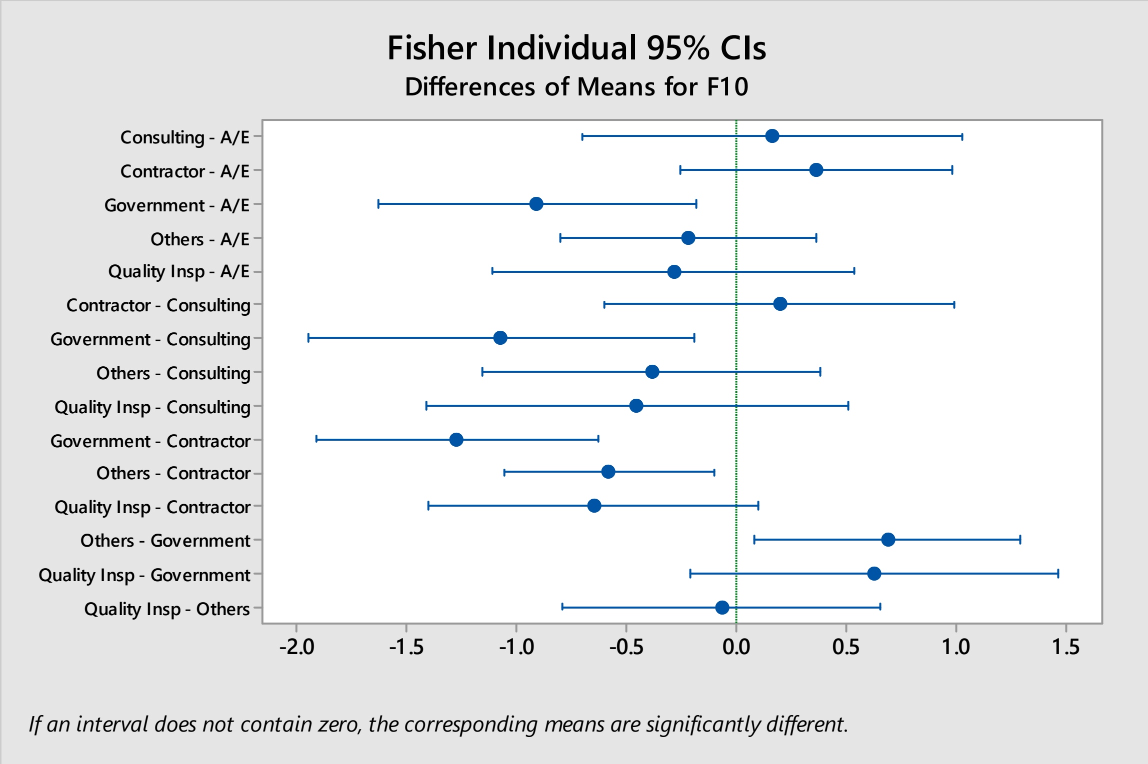


Figure 6. Post-hoc analysis for subgroup analysis of F10 among survey participants from different employer types