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BIM based Design Management of a Building Project Collaboratively Designed with a Foreign Design Firm in China:
A Case Study

Algan Tezel, University of Salford, Salford, UK
Zeeshan Aziz, University of Salford, Salford, UK
Chuxiong Jiang, China Academy of Building Research, Beijing, China

ABSTRACT

In parallel with China's growing construction market, there has been an influx of foreign architectural and engineering design firms into the Chinese construction market. Those firms generally form partnerships with local Chinese firms or institutions to overcome various complications in the country. Adding to the complexity, relatively recent technologies such as Building Information Modelling (BIM) also started to play a role in those collaborative project design management efforts in China. This paper presents an in-depth case study of a complex building design project collaboratively executed using BIM by a foreign design firm from the USA and local Chinese firm in China. The project was analysed from different design management and stakeholder perspectives. Some of the findings confirm the pervious accounts from the literature. New insights and the key lessons learned for BIM based design management in this context are also presented.

KEYWORDS

Building Information Modelling (BIM), China, Foreign Design Firms, Partnership, Project Design Management

INTRODUCTION

China has experienced a rapid economic growth since the early 1980s, averaging an annual economic growth of over 9% in Gross Domestic Product (GDP) since 1978 (NBSPRC, 2015). The construction industry is playing a leading role in this rapid economic growth. The average annual growth rate of the Chinese construction industry is 10.4%, which is higher than that of its GDP, and the industry is presently one of the world's largest with a total output of 17.67 trillion Yuan (RMB) (2.88 trillion US$) in 2014 (NBSPRC, 2015). In line with this growth, there has also been a rapid influx of the number of Foreign Architectural & Engineering Design Firms (FDFs) penetrating in the Chinese market in the past decade, especially after the country's entry into World Trade Organization (WTO) in the late 2001. Due to the current complexities of the construction regulations and legal restrictions, many top FDFs entered the Chinese market by means of either project-based collaborations with domestic design institutes/firms or establishing liaison offices (Ling et al., 2005; Xu et al., 2005b; Ling & Low, 2007; Zhao et al., 2012).

In China, the design process is divided into the conceptual design, preliminary design and construction documents phases. On the other hand, in Western countries, the design process consists of three main phases: the schematic design phase, design development phase, and construction

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documents phase (Wang, 2000). In practice, schematic design corresponds to conceptual design and the design development phase is similar to the preliminary design phase in China. However, the contents of design documents in those phases are different, particularly in construction drawings. In China, construction drawings submitted by local design firms are so detailed that contractors can even use them directly for work without having to create their own shop drawings. If there are some drawings similar to the existing "shop drawings", they are produced only to direct site workers and are not submitted to architects for approval. In contrast to the Chinese practice, construction drawings by foreign designers are often not that detailed and consequently, shop drawings by contractors must obtain architects' approval. Due to the difference in understanding of the design process and design documentation, in a project that is cooperatively designed with FDFs in China, FDFs normally play a main role in the conceptual design phase or preliminary design phase; whereas the necessary construction documents are completed by local design firms (Xu et al., 2004). In the collaborative execution of projects' design, if the communication between FDFs and local design firms is not complete and fluent, the inefficient cooperation could lead to negative effects on projects' time, cost, and even quality targets (Pheng & Leong, 2000; Gale & Luo, 2004).

On a global scale, construction projects are becoming much more complex and difficult to manage with increasing reciprocal interdependencies between different stakeholders (Alshawi & Ingirige, 2003; Chan et al., 2004b; Clough et al., 2008). In the Chinese case specifically, the rapid growth within the industry and fast-paced design and development processes can also cause communication challenges in the design phase (Zou et al., 2007). For instance, in some projects, especially in large-scale and complex projects, fast paced design processes often lead to an insufficient understanding of or consensus on the design requirements (Assaf & Al-Hejji, 2006). Also, in general, the investment in construction design has been traditionally low, representing only a minor portion of the total project cost, despite the fact that the design phase has significant impacts on both the construction and maintenance phase. In the construction industry, a reasonable and high quality design can accelerate construction delivery and reduce construction costs; on the other hand, low quality design outcomes suffering from communication and coordination issues could extend the construction durations, increase total construction costs and generated construction wastes (Sambasivan & Soon, 2007; Sun & Meng, 2009; Lu & Yuan, 2010; Xie et al., 2010). Under the light of the current situation, where schedules are tight and many design changes are common, design management becomes even more important to ensure value creation through high quality and timely design solutions. With the increasing complexity and scale of projects, the traditional approach of using 2D Computer-Aided Design (CAD) technologies is constrained by its capabilities to effectively answer to those design management requirements. Frequent design changes and corresponding needs to update relevant plans, sections and elevations can quickly become unmanageable with the extensive coordination need among different design trades and stakeholders as project sizes grow. In order to solve such design update and coordination issues, to better cope with design management complexities and to improve the design quality, more and more researchers and design practitioners are discussing the use of Building Information Modelling (BIM) in an effective way (Azhar, 2011; Eastman et al., 2011; Bryde et al., 2013; Wong and Fan, 2013). Despite some clear developments in the past decade, the overall adoption rate of BIM in China still remain considerably lower than that of pioneering countries (Cao et al., 2015). To better understand the current situation in China, this paper presents a case study to illustrate the key challenges faced in the design management of a complex construction project cooperatively designed using BIM by a local Chinese firm and a FDF. Some of the communication and coordination challenges are analysed and the key lessons learned are documented, as it is argued that the BIM adoption condition in China can be better understood under the light of the country's specific construction conditions, general design management practices and engagement modes with FDFs.

LITERATURE REVIEW

Foreign Design Firms in China

With China's joining into World Trade Organisation, its construction market had to gradually open to the world. The government issued "Regulations on Foreign Investments in Construction Design in China" in December 2002 to set a legal framework for the cooperation between FDFs and local organisations (Zeng et al., 2005). Studies focusing on FDFs operating in China are limited in the literature. Ling et al. (2005a) investigated 13 possible entry methods for foreign architectural, engineering and construction (AEC) firms undertaking work in China. According to the study, foreign AEC firms that are planning to enter the Chinese market should begin by setting up an international division within their organizational structures. When more projects are secured, they can proceed to constitute subsidiary firms in China. One of the more effective market entry modes for foreign AEC firm is to form project joint ventures with a local Chinese firm (Pheng & Leong, 2000; Shen et al., 2001). Foreign AEC firms usually provide superior technology; whereas local organisations provide local knowledge from the industry and connections/networks. This combination can help foreign AEC firms reduce business risks and gain competitive advantage. In longer term, establishing subsidiary firms or offices in China is eventually essential for the smooth completion of projects due to the essential requirement of good communication among all the project stakeholders (Cheah et al., 2006). In addition, research suggests FDFs to set up alliances with private Chinese design firms rather than state-owned large design institutes for the latter are usually more challenging to engage (Cheah et al., 2006). The most popular form of market entry to China for foreign AEC firms are wholly foreign-owned enterprises followed by joint ventures (Utterback & Li, 2007; Zou & Wong, 2008). Joint ventures provide both local knowledge and connections; yet they may suffer from a limited operational control and divergent goals and interests of the partners. Even though wholly foreign-owned enterprises provide complete operational control, protection of technology and know-how, they are susceptible to a slow entry and potentially higher political risks (Zou & Wong, 2008).

Xu et al. (2005a) identified that a foreign AEC firm is unlikely to sustain its growth without a firm support from their local partners. Based on this study, strategic alliances with a local design institute/firm or construction company is the most appropriate collaboration form for the local partner will offer the opportunity to utilize their resources for a lower price and help the foreign firm overcome the legal licensing problem. The establishment and communication of a conflict resolution strategy, a genuine willingness to share resources among project participants, a clear definition of responsibilities, a commitment to a win-win attitude, and a regular monitoring of the partnering process were identified as the significant underlying factors for partnering success in China (Chan et al., 2004a). In that sense, using the Design-Build project delivery method as an entry strategy to the Chinese construction market seems feasible, but it was found that the Chinese institutional environment is still a barrier for a wholesale adoption (Xu & Greenwood, 2006).

Ling et al. (2005b) undertook a survey to reveal the factors that help AEC firms secure projects in China. One of the identified key factors is the firm's ability to understand the client's requirements. This means that it is difficult for foreign AEC firms to achieve success if they cannot communicate with the client effectively to address their requirements. Effective communication and engagement with the client and local institutes in China are of the determining factors for the competitiveness of local Chinese AEC firms as well (Lu et al., 2008). For foreign AEC firms to effectively capture and understand the client's requirements as one of the key factors affecting their success in China, they need to be sensitive to the cultural differences, which in most cases is not realized (Ling et al., 2006). According to this study, being able to understand the language, Chinese work environment, the characteristics of the construction industry and predominant organisational culture are essential. Long-term partnerships with local Chinese firms will assist FDFs to overcome those mainly cultural challenges through better mutual understanding (Zhao et al., 2012). In line with appreciating the cultural differences, developing trust should also be given priority by foreign AEC firms, as trust is considered as an important feature and a central mechanism to create business advantages such as lowering costs, shortening durations, and improving performances, especially among Chinese (Jin & Ling, 2005). Effective communication and gained trust also pave the way for a partnering mechanism with either local Chinese institutes or Chinese firms. The other main types of risks that foreign AEC firms may be exposed to in China include clients' irregular behaviour, frequently changing policies, language and contract related issues, technology transfer risks, financial risks and the government's interference in the construction market (Fang et al., 2004; Hsueh et al., 2007; Ling et al., 2009).

Design Management

The importance of an effective construction design management in project success has been widely discussed (Knotten et al., 2015). Poor communication, lack of adequate documentation, deficient or missing input information, unbalanced resource allocation, lack of coordination between disciplines, and erratic decision making have been pointed out as the main problems in design management (Tzortzopoulos & Formoso, 1999). Poor management of design can cause document deficiencies and reworks (Tilley, 2005; Reifi & Emmitt, 2013), project cost overruns and reduced productivity (Baldwin et al., 1999). The design phase is also a major source of problem for the subsequent phases, undermining the systematic management of construction projects (Koskela et al., 2002) and preventing many projects from fully realizing their value potentials (Hamzeh et al., 2009; Hansen & Olsson, 2011). A better management of design can improve constructability, and eventually bring about tangible benefits in terms of time, cost, quality and safety when designers are directly involved in implementing the constructability measures (Pocock et al. 2006; Wong et al. 2007).

Building design is an iterative process in which designers identify problems, exchange information and ideas, implement the ideas and solve the problems. In order to improve design management, it is important to optimize the design process, particularly in the earlier conceptual and preliminary design phases (Tilley, 2005; Reifi & Emmitt, 2013). It is frequently emphasized that there is no infallibly correct design process, and the design process can be seen as a continuous negotiation between problems and solutions. Due to the fact that design problems defy comprehensive description and offer an inexhaustible number of solutions, the design process cannot have a finite and identifiable end (Lawson, 1997). In practice however, design durations and budgets are limited, so it is necessary to control the design process.

Construction design has an iterative form with a multitude of interdependencies and therefore, it needs mutual adjustments between all participants, and coordination among the project stakeholders is a key factor that influences its outcome (Kalsaas & Sacks, 2011). Essentially, it is a process based on information exchange and sharing ideas and solutions with others, so the level of communication and coordination in this phase is of paramount importance (Perry & Sanderson, 1998; Assaf & Al-Hejji, 2006; Otter & Emmit, 2008). Flager et al. (2009) demonstrated that designers can spend as much as 58% of their time in managing the information and coordination in the design phase, including manually integrating discipline-specific design and analytical representations. If more effective information and coordination management fashion were adopted in practice, designers could spend more time on performing the design act and analytic work, where the most value for projects are generated.

There are various process-focused approaches to improve and standardize construction design management, considering the importance of communication and collaboration in the planning and execution of a design act. For instance, Senescu et al. (2013) introduced a Design Process Communication Methodology to improve the effectiveness and efficiency of collaboration, sharing, and understanding. Choo et al. (2004) proposed DePlan as a method for integrated design management during the detail design phase. DePlan integrates two techniques; Analytical Design Planning Technique (ADePT) to overcome rework in the design stage (Austin et al. 1999) and planning according to the Last Planner System (Ballard, 2000) as a collaborative planning approach frequently used in Lean Construction efforts. Rosas (2013) tried to integrate the Design Structure Matrix and the Last Planner System into building design in order to reduce uncertainties in design management. Hamzeh et al. (2009) presented a case study that employs the Last Planner System in the design phase. The authors reported that despite the various challenges emanating from the novelty of the Last Planner System to the designers, the project team managed in transitioning to the new planning process and extensively benefited from it. Process-Parameter-Interface (PPI) model is applied to address the design management issues of improved design process scheduling and efficient collaboration (Chua et al., 2003). Design Interface Management System (diMs) is proposed to manage the iterative design process in large construction projects (Senthilkumar et al., 2010). Dependency Structure Matrix (DSM) is used as a tool not only to build design schedules, but also to represent the information exchange in the design phase (Srour et al., 2013). The Collaborative Design Management (CDM) approach is used in order to achieve a better communication and cooperation within the design team and a better understating of and commitment to the project (Fundli & Drevland, 2014).

Although modern design management and its instruction is a relatively recent phenomenon in China, rapid developments are anticipated in the near future alongside the advances in China's innovation-oriented society and its further economic growth (Liu & Zhan, 2008). Local construction design firms in China generally function as independent consultants with many ad-hoc design management practices (Manavazhi & Xunxhi, 2001). Thus, for FDFs operating in China to effectively implement those novel processed based approaches in their design management efforts, they need to closely cooperate with and drive their efforts through their Chinese partners and stakeholders, which may present various challenges (e.g. technological, cultural, institutional, legal) on its own (Zeng et al., 2005).

Building Information Modelling (BIM)

Building Information Modelling (BIM) as a maturing technology holds the potential of effectively and efficiently containing, manipulating and visualising the whole project life-cycle data (physical and functional characteristics) in a single data repository (Hartmann et al., 2008; Guo et al., 2009; Giel & Issa, 2011). The main functions provided by a BIM system in the design phase include: visualization of design, rapid generation of alternative design, building performance prediction, automatically monitoring the integrity of model and reports, providing a communication platform and promoting collaboration between design and construction professions (Sacks et al., 2010). BIM has been increasingly used in the building industry with many well documented benefits such as reduction in project costs, savings in project durations, improvements in project communication, coordination and project quality (Azhar et al., 2008; Khanzode et al., 2008; Azhar, 2011; Bryde et al., 2013; Yalcinkaya & Singh, 2015). Improved multi-disciplinary coordination, communication and shared understating among the design team and stakeholders are some of the most underlined benefits of BIM adoption in the design phase (Korman et al., 2010; Park et al., 2011; Singh et al., 2011; Shen et al., 2012). Similarly, BIM is a comprehensive information management tool capable of simulating the design and construction method alternatives rather than merely a 3D graphic representation of the design intent. Going beyond 3D models, BIM allows designers to choose the best design solution by enabling virtual visits inside a facility, simulating various design alternatives with their possible effects on the project. Thus, BIM facilitates the communication of objectives, problems and changes in design. The use of BIM also provides a means to increase the overall design quality by automatically detecting and solving the conflicts and clashes between different disciplines with fewer coordination related errors (Khanzode et al., 2008). Popov et al. (2006) demonstrated that BIM supports a management environment in which designers can effectively share information, avoid data loss, miscommunication and translation errors for a higher quality design process. Along with better value capturing, the BIM capabilities of generating rapid design alternatives, project drawings, quantity take-offs and presenting a synchronous design platform among different disciplines also facilitate the reduction of non-value adding design activities and design lead-times in the AEC industry (Sacks & Barak, 2008; Flager et al., 2009; Arayici et al., 2011; Eastman et al., 2011).

While government agencies in several countries (e.g., Singapore, South Korea, the UK, and the USA) have already established plans for the mandatory use of BIM for public projects, the Chinese government has not yet issued any nationwide regulations to mandate BIM deployment and, therefore, the evolution of BIM practices in China has primarily been regulated by the marketplace during the past decade (Cao et al., 2015). The BIM adoption gap between various "veteran" BIM user countries' AEC industries and the Chinese AEC industry could also present some technology transfer challenges for FDFs operating and partnering in China. In China's 2011-2015 Development Outline, the need to accelerate the application of BIM and push forward the establishment of IT standards is stressed. Nevertheless, due to the technological maturity and interoperability issues, industrial culture change requirements, lack of BIM standards, and training and education needs, there is a common consensus that BIM is currently still immature for its full adoption over the construction life-cycle in the Chinese AEC industry (Zhiliang et al., 2011; Wong & Fan, 2013; Xu et al., 2014). Liu and Zhang (2014) revealed that although the use of BIM has been gaining momentum in China since 2008, the implementation and practice of BIM is still limited. The authors analysed 10 large-scale projects to identify that BIM was mostly used in the preliminary design and detail design stages. A survey conducted in China in 2011 showed that 73% of the surveyed AEC professionals had never adopted BIM, and only 22% of the professionals considered themselves as being familiar or very familiar with the BIM concept (Zhang et al., 2014). Two main factors contributing to the low adoption rate of BIM were revealed as the lack of management level commitment and BIM knowledge (Zhang et al., 2014).

Yung et al. (2014) reported a BIM based case study in China. It was found that the use of BIM might not save the overall design time as 2D design is still extensively involved mainly because it is required to submit 2D project documentation for regulatory approvals but it is still difficult for BIM software applications to automatically generate 2D shop drawings in accordance with the industry specifications in China (Ding et al, 2012). However, BIM could still save the costs of manual mechanical, electrical and plumbing (MEP) coordination and potentially improve the design quality by reducing the number of change orders (Yung et al., 2014). This also reflects how the current Chinese regulations can affect a wider adoption of BIM in the country. Cao et al. (2015) investigated 106 projects involving the use of BIM in China. The results showed that the in-depth use of BIM to date is still limited principally to the areas of visualization, with the aim of visually conceptualising the form of complex facilities or virtually detecting the conflicts of building systems. The results of the study also underline how more collaborative/integrated project delivery systems, which are currently very limited, can support and be supported by a deeper BIM penetration in China. The main BIM related adoption parameters for architects in China were revealed as architects' motivation (the economic benefits, effectiveness and efficiency of BIM adoption), technological issues (improvement in the compatibility and integration between BIM and other widely available software in the industry) and BIM capabilities of the rest of the project team (Ding et al., 2015).

RESEARCH METHODOLOGY

It was identified from the literature review that in the Chinese construction context, the interaction and effect of all the three points on the design process; FDFs' operation with local Chinese firms, construction design management practices and the use of BIM in China required more research. Therefore, a case study research effort over a BIM based complex building construction project collaboratively designed by a private FDF from Massachusetts, USA and a prominent state-owned local Chinese design firm from Beijing was initiated to identify the current issues and lessons learned for building design management efforts in China. The explorative research question of the study is how those three parameters currently realize and affect the building design process in China.

Case studies are useful to understand a phenomenon through a "how" question in its context when researchers have limited or no control over the phenomenon itself (Yin, 2003). While case studies can be explanatory with an initial research question, they can also exploratory without any prior propositions with the propositions unfolding in due course of the study (Rowley, 2002). They are also valuable research methods for a deeper understanding of a complex reality from different perspectives in practice and can give way to generalizations even over a sing-case (McCutcheon & Meredith, 1993; Flyvbjerg, 2006). In organizational science and management research, case studies represent and important research track as a method of both generating hypotheses for further studies, but for also testing prior findings and theories (Patton & Appelbaum, 2003).

One of the authors of the paper gained extensive access to the local design firm as the project's controller assigned by the Chinese government. He was extensively involved in the execution of the design schedule, attended many technical and coordination meetings with the FDF and the client, and technical and management meetings with different design disciplines at the local design firm (internal meetings). Access to both the local design project team members and design documentation was also granted for data collection purposes. Along with participant observation, conducting semi-structured interviews with some of the key project team members including the local project manager, architect, structural engineer, MEP engineers and investigating the project documents/archives (e.g. the contract, schedules, formal communication, project drawings and models) were adopted as the main data collection methods of the study. The triangulation of the propositions was sought from different data resources whenever possible. Ethical issues were also given utmost importance. The research process was summarized in Figure 1. It should be stated that instead of following a linear sequence, the stages in the research process often overlapped during the execution of the research. The data collection occurred between March 2014 and September 2015 in Beijing, China. The details of the employed data collection methods can be seen in Table 1.

Through the participant observation, the authors managed to observe and record the key interactions between the parties during the design process. Important points from the meetings like the main meeting themes, pressing design issues, time schedule related discussions, and the parties' concerns/comments were recorded. In the semi structural interviews, the issues emerging in due course of the design process in connection with the findings from the participant observation were asked directly to the local design team members. It was a dynamic process shaped by the condition of the design process. The responses were recorded by taking notes and voice recording. The main analysis method of the interviews was classifying the key arguments and emerging patterns. The researchers' notes taken during the interviews were also studied. The document analysis method was used mainly to support the findings from the first two data collection methods as a means of triangulation.

Project Description

The case project is a complex, four-storey building construction project conceived to serve as a social activity and leisure centre in the Qinghai province in Western Mainland China. As a part of a series of high-end public urban development projects to cater for the growing urban population, the Design-Build delivery based project started in March 2014 with the actual completion of the design phase in September 2015. The client is a large property development group from the same province. The construction duration is estimated at one year after the design completion. The estimated total project cost is 72 million US$. The design was based on the provincial government's green building action plan with a distinctive emphasis on building energy efficiency, environment-friendly material selection, responsible water and electricity use, low carbon emission and utilization of rain water. On steel-structure frames, the building covers a total floor area of 16700 square meters and changes from 2-storey to 4-storiey above ground from the southwest to the northeast due to the inclination of the roof. The building height gradually changes from 10 meters to 25.6 meters correspondingly. The project's overall view is presented in Figure 2.

The first storey height is 6.5 meters and its function is mainly to present a space for the theatre area for 500 people, classroom, leisure lounge and equipment rooms. The second storey height is 5.5 meters and the storey function is mainly to provide space for the theatre stand, music classroom and education house. The third storey height ranges from 5 meters to 13 meters and the storey contains the activity room and sports ground. The fourth storey height ranges from 5 meters to 6.7 meters and presents space mainly for the offices (see Figure 3 and Figure 4).

Figure 1. The research process

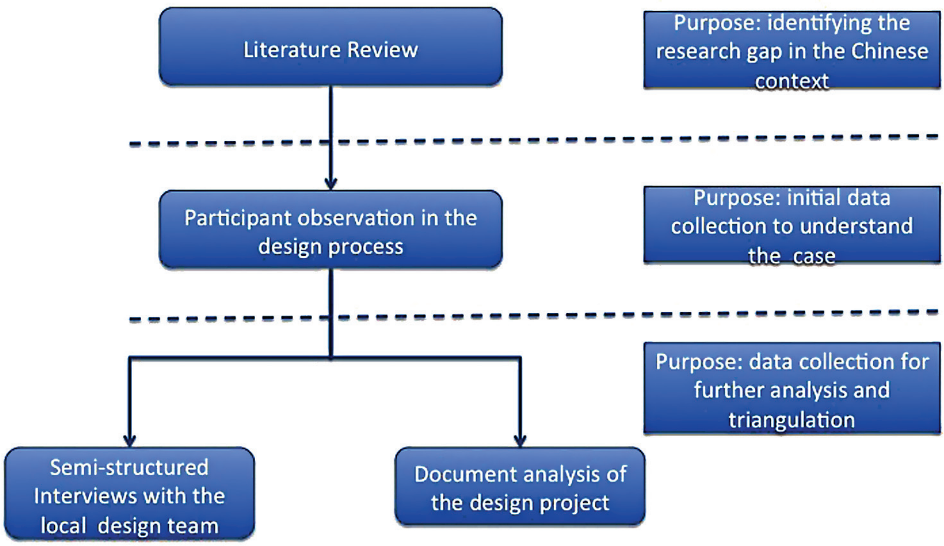


Table 1. Details of the data collection

Main Project Stakeholders	Data Collection Method	Data Sources	Time Frame
Local design firm (Beijing, China), FDF (Massachusetts, USA) and client (Qinghai province, China)	Participant observation	Project kick-off meeting with the FDF and client, videoconferences with the FDF during the conceptual design phase, client coordination meetings and internal design coordination meetings at the local firm.	March, 2014 – May, 2015
	Semi-structured interviews and open-ended discussions with the project team	Project manager, lead architect, structural engineer and MEP engineers at the local design firm	October, 2014 – May, 2015
	Project documents	Project drawing and BIM model log, estimated and actual project schedules, minutes of meetings, formal communications with the client and FDF, project contract between the local firm and client	December, 2014 - September, 2015

Figure 2. The general project view

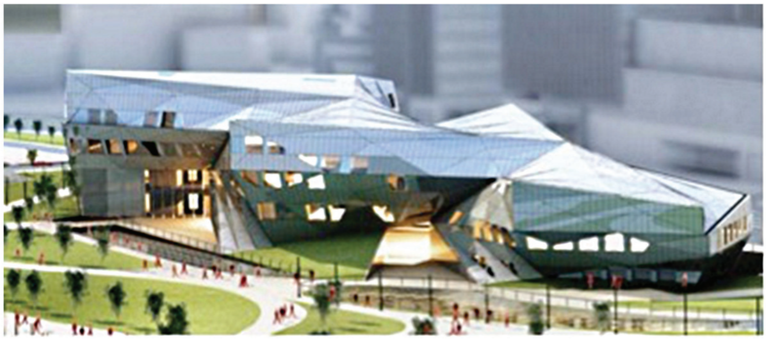


Figure 3. The 3D architectural model

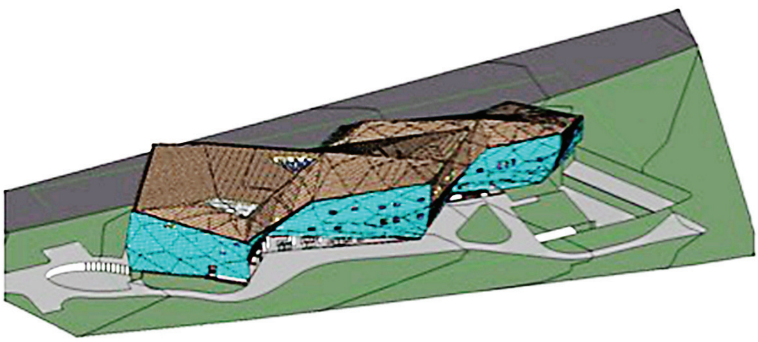
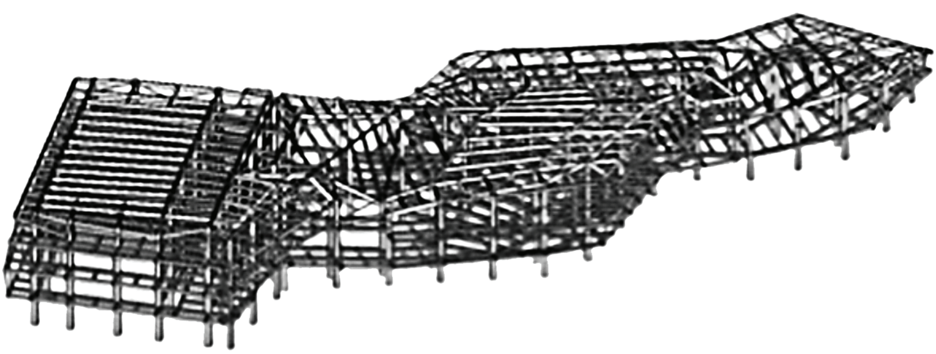


Figure 4. The 3D structural model

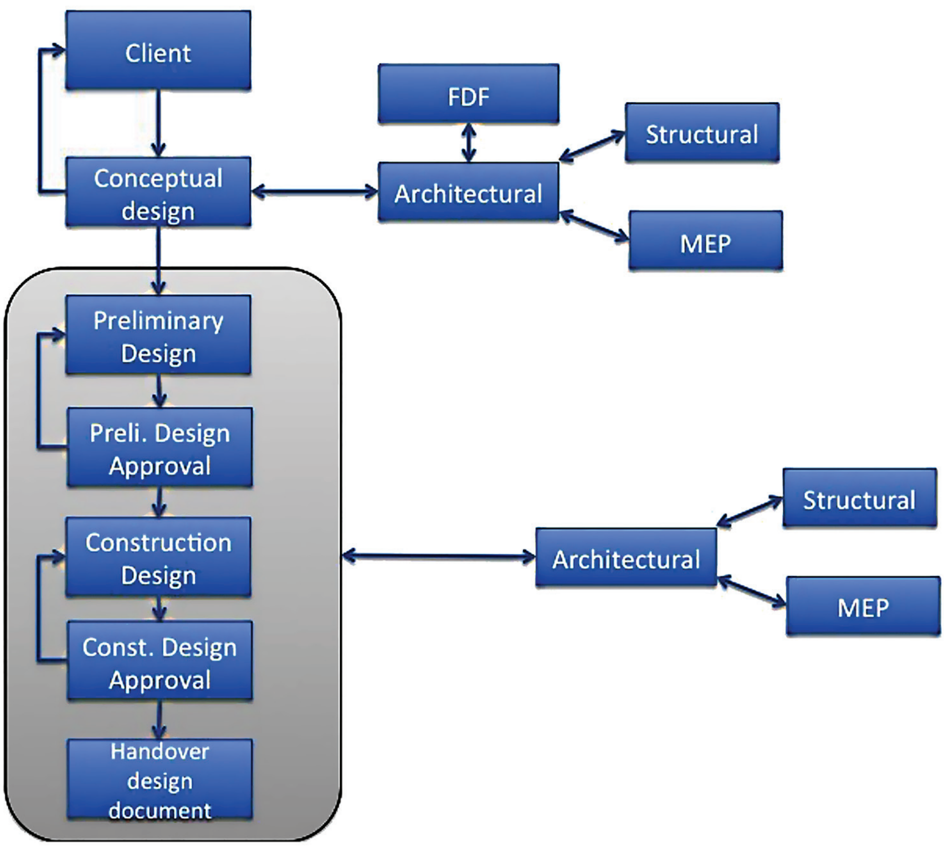


Design Process and Design Schedule

The conceptual design of the project was originally completed by the FDF with a design inspiration from fabric weaves. When the research started, the FDF and local firm had recently formed a project-based partnership for the design service for the project series from the same client in the province. Before the start of the preliminary design, the communication with the FDF was executed by the local firm to optimize the design and to ensure that the conceptual design fulfils various Chinese building standards and codes. The engagement with the FDF started in March 2014 and completed in November 2014, after which the preliminary design could start. The design process is presented in Figure 5.

In the conceptual design stage, the work was undertaken together with the FDF. The FDF took charge of the architectural concepts, such as the general appearance, the storey height, the functional divisions, the placement of the vertical elements etc. The architectural department of the local firm mainly carried out the communication with the FDF at this stage. As identified in the literature, in this project-based partnership, while the FDF was providing the design know-how, the local firm was executing the necessary local engagements with the client and local authorities, and proving the required design licensing. After the US firm submitted the 2D CAD layout plan drawings and the exterior 3D AutoCAD Revit model, all the design disciplines from the local firm would become involved to check and further develop the design (check for errors and mistakes, compatibility issues against the Chinese standards etc.). The main communication media between the local firm and the FDF were email and videoconference.

Figure 5. The design process



The US firm was no longer involved in the preliminary design and construction design stages. The local firm completed all the reaming work. A weekly internal design meeting was undertaken with all the disciplines involved to resolve the design matters. The project manager and discipline leaders attended those meetings to discuss the technical issues, the requirements from the client, the time schedule and so on. The local architectural and structural departments mainly generated the detailed 3D BIM model in the preliminary design phase, and the information exchange and technical issues could be coordinated with the help of the model. There was a strict demand for the composite façade to realize the complex building appearance. Its construction details had important effects on the other disciplines. Hence, in the preliminary design stage, some façade suppliers were consulted. A design schedule was prepared when the preliminary design began in November 2014 and all the design work was expected to finish in seven months with two weeks allocated for the design approval and document handover at the end. The planned design schedule is presented in Figure 6.

PROJECT ANALYSIS

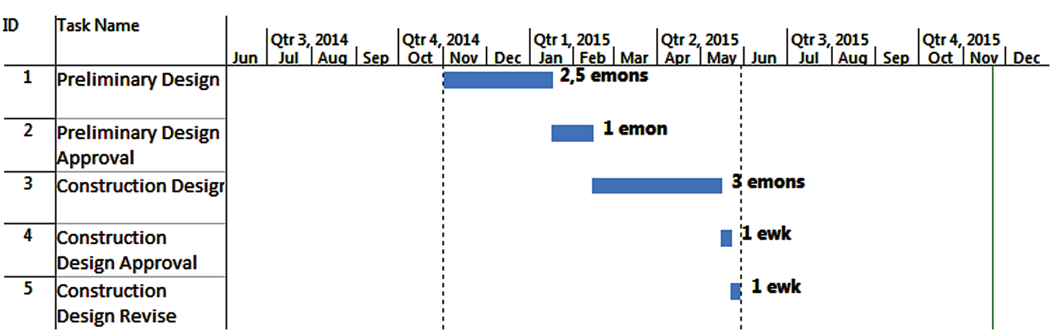
In the following sections some specific issues identified after the data analysis regarding the design process are discussed and several recommendations are given. The discussed issues include the following; communication with the client, the client's role in projects collaboratively designed with FDFs, communication and coordination with the FDF, implementing BIM, collaboration within different disciplines and subcontractor involvement.

Communication with the Client

In order to understand the client's requirements, frequent communication and coordination with the client is necessary for designers. Specifically in this case, two examples were captured to illustrate the importance of this communication. The first example is about the communication of design parameters. In China, critical design parameters, such as building area, building height and plot ratio need to be approved by the government's planning department before the start of a design work. These design parameters have to be strictly followed. When a design work starts, the design firm should ensure that the client has obtained the formal design parameters from the government. In this project, the design team commenced the design work when they had just received the building area parameters informally. However, the officially given formal building area was smaller than that of the design team had received informally. Therefore, the architect had to change the plan layout to satisfy the building area limitation, and the rework resulted in a considerable waste of time for the project design team.

The design team knew how critical the building area was for the final design and its change would cause much rework. When asked, the project manager stated the design team had communicated with the client a couple of times regarding the issue, but the client had insisted to give the instruction to

Figure 6. The planned design schedule



begin the design work without obtaining the formal design parameters. On the other hand, the client highlighted that the design firm had not fully explained the possible consequences. The situation was a major source of conflict between the client and firm. When the written communication between the parties was reviewed, it was found that the firm had warned the client of a possible rework but without giving a comprehensive explanation of the extent of the risks involved. In the communication process, the design team should have better explained the importance of the formal building area parameter and its influence on the design effort to the client. The client, on the other hand, should not have insisted the work to start without having all the prerequisites and inputs of the design task in place, which caused a typical making-do waste in the design tasks (Koskela, 2004; Emmitt et al., 2012). Consequently, it took all the project members (all disciplines) three weeks to correct the building area mismatch.

The second example is about the optimization of the conceptual design. After receiving the drawings and model from the FDF in the conceptual design stage, the design team had to change some rooms' functions and adjusted the column layout plan in order to fulfil various Chinese construction standards and codes. The project team explained those changes to the client using the 3D BIM model. The project manager and architect underlined that the client could better see and had a clear understanding of those changes on the 3D model. Through the participant observation during the client engagement meetings and the interviews, it was identified that the 3D model helped the design team explain the changes to and finally receive acceptance from the client.

In China, clients usually demand to complete a building project as soon as possible. Before the start of a design act, the design team should support the client to finalize the preceding approvals from the government, if needed. Moreover, the design team should ensure that the client has obtained the approvals and instructions correctly. Also, it is important to clearly and fully explain to the client the possible implications and risks of starting a design effort before receiving those government approvals or any other prerequisites to avoid the making-do waste. Through the design stages, the design team should also keep a frequent communication with the client and explain technical issues in an easy to understand manner, if those design issues necessitate the client's decisions. In line with that proposition, as local design firms frequently need to adjust the designs from FDFs to comply with various Chinese standards and codes, the use of BIM can assist local design firms to explain and justify the differences between the initial design intent by the FDF and the modified design solution by the local design firm. When Chinese standards and codes are better integrated in BIM software on a global scale, those adjustment necessities can be automated to a greater extent for both FDFs and local design firms.

The Client's Role in Projects Collaboratively Designed with Foreign Design Firms

In China, FDFs are often separately contracted by clients as consultants. Local design firms and FDFs usually have to work together without having a reciprocal contractual obligation. In this type of configuration, the main coordinating body becomes the client. Thus, in maintaining the coordination between a FDF and a local design firm, if the client does not take necessary and timely initiatives, and enforce an effective control mechanism, extended design durations (particularly in the design coordination interface between the FDF and local design firm) can be seen.

A similar situation was documented in the case project. There are many windows on the project's complex composite façade. The FDF was responsible to finalize the windows' dimensions and positions. Despite many urging emails from the local design project team, the FDF could finalize the work one month after the task deadline. The project manager from the local design firm underlined that he had witnessed many similar examples in projects within the same FDF and local design firm configuration. There were no clear and consistent mechanism enforced by the client for the coordination and control of the interface between the FDF and local design firm. It took the FDF and the local firm eight months to complete the conceptual design as opposed to the planned four months. There would have been more time for the domestic design firm to work on the project in the succeeding design stages, if a reasonable interface management had been in place at the beginning of the design effort.

In similar configurations, it was identified that clients should play an active role in the projects collaboratively designed with FDFs. In this case specifically, it can be stated that the client should have better clarified the responsibilities of the FDF and domestic design firm in their contracts respectively. Also, design coordination matters should be well addressed. For instance, in the contracts, the client could present a collaboration flowchart or matrix for the FDF and the domestic design firm to address the coordination means and methods, points of contact, expected response duration and possible penalties/implications. Effective in due course of the project, there should have been a consistent monitoring and control mechanism in place by the client. Chinese clients should also be careful in choosing FDFs. FDFs' past Chinese experience and willingness for close-engagement with the local construction industry should be taken into account. In one step further, when both mutual trust and a long-term vision are established, more integrated (collaborative) project delivery systems, in which project risks and gains are collectively shared among clients, FDFs and local firms can be introduced (Kent & Becerik-Gerber, 2010).

Communication and Coordination with the Foreign Design Firm

The communication methods between the FDF and local design firm were email exchanges and videoconferences. The FDF would send the 2D plan layout, plan sections, elevation drawings and 3D exterior model to the domestic design team. Then the domestic design team would develop the conceptual design. The comments and changes from the local firm were sent to the FDF through email. After evaluating the comments and changes, the FDF would redevelop the design and urge the domestic design team to check the work and give comments again. This circular communication process would continue until a mutual agreement on various issues was achieved. Only when there were many design issues to discuss with the FDF, videoconferencing was preferred. The main design trade from the local firm executing the communication with the FDF was the architect (point of contact). The FDF's design team located in the US was composed of some building designers of Chinese descent. Also, the FDF had a previous record of building design experience in similar complex projects in China. Therefore, the possible linguistic and cultural barriers underlined in the literature could be mitigated.

In practice, it was observed and identified form the interviews with the project manager and architect that the communication process was not efficient. The design discussion was mainly carried out through email exchanges with the responses being almost always late. The project manager instanced the optimization of column placement as an example of the inefficient communication. The local design team adjusted the column placement according to the comments from the local structural engineer. The adjusted drawings were sent to the FDF by email. Then the FDF provided their comments by email as well. The whole communication process, which would have normally taken a couple of hours face-to-face, took two days. Videoconferencing, as a more interactive communication method, was undertaken only twice during the conceptual design phase. Thus, many technical issues could not be solved quickly. It was observed during the videoconference meetings with the FDF that the FDF team members also expressed their concerns over the delayed communication process.

The number of projects collaboratively designed with FDFs is increasing in China. The engagement mechanism between the FDF and the domestic design firm directly affects the design schedule. In the interviewed local design teams' experience, there are two efficient ways to communicate with FDFs. The first way is foreign designers' temporary relocation to China for a project, in which local design firms offer office space for the designers so that they can work together with their local peers. The designers then can discuss the technical issues face to face at any time to solve various problems relatively quickly. The second way is that the foreign designers stay in their own countries most of the time, but an efficient platform for communication and information exchange is established (e.g. a combined use of ftp servers, cloud servers, emails, videoconferencing and face-to-face meetings).

In this regard, it should be stated that one of the strengths of BIM is increased coordination among multidisciplinary project teams. In the case project, the use of BIM in collaboration with the FDF was very limited (mainly for the visualisation of the 3D exterior model). The FDF had to produce 2D drawings, as a governmental requirement in China, without resorting to BIM for the local approvals. Moreover, as identified from the interviews with the project manager and architect that using BIM with FDFs poses its own challenges for the local design company; different BIM capabilities of the FDF and local firm, contractual agreement between the FDF and the Chinese client for the BIM use, software interoperability issues and lack of Chinese standards integrated into BIM software. In line with shifting the design conversation to face-to-face communication with FDFs, the BIM "Big Room" concept, in which multidisciplinary designers are collocated with the mandated use of BIM for a better communication flow, can be promoted in the Chinese construction market (Miettinen & Paavola, 2014). The "Big Room" concept can also be taken to the virtual environment. A virtual "Big Room" will enable the companies to create a similar collaborative design platform without having to be in the same place (Dave et al., 2015). A FDF's having previous experience in China and familiarity with the Chinese language and culture were noted as some of the contributing factors for an effective communication process.

Implementing BIM

Autodesk's Revit software was utilized to produce the BIM models in this project. The local design firm produced most of the BIM model content. Nevertheless, not all the design team members were familiar with the BIM concept and the specific software. Therefore, three external BIM modellers were employed for the project to train those designers on BIM capabilities and using the software. Afterwards, the local architect established a central BIM file including the position of the columns, the floor slabs, the floor levels and so on. The structural designer then integrated the structural models on the central file. The two disciplines could work synchronously on the 3D model. For instance, if the architect adjusted the plan layout, the structural designer could see how it affected the structure on the 3D model and evaluate if it was feasible for the structural systems. Likewise, if the structural engineer adjusted a column position, the architect also could check the feasibility and influence from the architectural side on the model. Moreover, along with the visualisation and coordination, soft and hard clash detection and rapid generation of quantity take-offs functions of the software were also utilized. There was a collaboration between the two disciplines over the BIM model. It should also be underlined that this collaboration was strengthened with face-to-face communication.

The MEP design team members were not as familiar with the BIM software. Extending the overall design duration, they were the design trades that struggled with the technology the most. The BIM model also helped the design team engage better with the client in terms of explaining the design intent and capturing the client's requirements. The client's architect approved that they could "better visualise what the design team wants to suggest and express their requirements to the team clearly" on the BIM model. This statement also links to better value capturing using BIM. The project manager was also content with the fewer design change orders due to the level of engagement achieved with the client. The architect and structural engineer both underlined that BIM had helped them in the design coordination between their disciplines and saved time in many tedious design tasks (e.g. rapidly generating the bill of quantities and updating the drawing views/sections). Nevertheless, as some team members had not been familiar with working within a BIM based design process before, the total design duration including the learning of the software and the actual design act took more than that of the traditional 2D design fashion for the case project.

BIM can be an efficient way to exchange the design information between different disciplines. It can also improve design quality and reduce design time with fewer design change orders from the client. Design firms should train their designers to use BIM software effectively. If a design firm is not fully capable of using the technology, as in this case, a 3D modelling consultant firm can be an option to help the design firm carry out BIM based projects. It is also important to synchronise the BIM competencies of different design trades in a design team, as those trades with lesser BIM competencies can become bottlenecks in due course of a BIM based design project. As underlined in the literature, the actual use of BIM features was limited (mainly in visualisation, coordination, and soft and hard clash detection) in the project. Also, the BIM based coordination was not essentially extended to the subcontractors or FDF. The use of BIM was implemented as and perceived more of the local design firm's pursuit. The firm took the initiative of using BIM without much external impetus or any contractual obligation. The case also confirms the proposition from the literature review that the BIM development in China among design professionals is mainly market-driven.

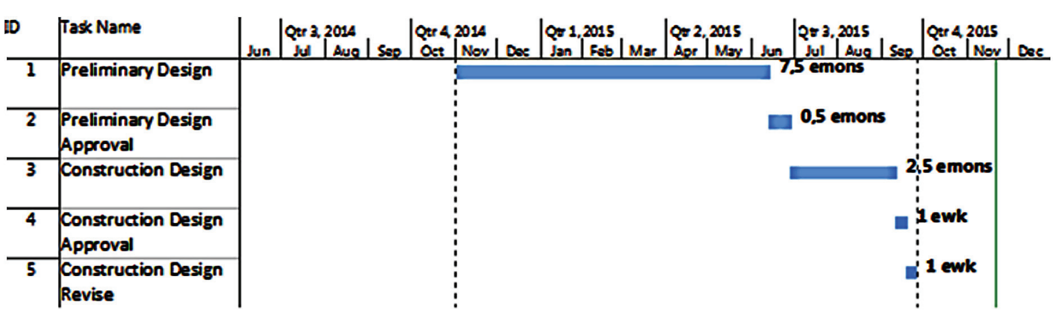
Collaboration within Different Disciplines

In China, all the design services (i.e. architectural, structural and MEP) can be provided by a single design firm. All those design disciplines usually work in the same office space; hence, the communication between the disciplines can be very convenient. In the case project, a weekly meeting, in which the main project designers attended, was held to discuss the design schedule and technical issues. The meeting minutes were regularly recorded and issued to all participants after the meetings. However, it was observed that some designers had not fulfilled their work duties according to the agreed meeting minutes, negatively affecting the overall design schedule. One of the authors took part in those meetings several times, and observed that many technical issues that could be solved relatively quickly were discussed repeatedly over a couple of weeks time in those meetings. The problems related to the inter-disciplinary collaboration, forward planning and systematic design constraint analysis, extended feedback durations from the client when necessary, lack of a systematic design management approach and the learning curve of the BIM software led to a time overrun in the actual design work schedule (see Figure 7).

Although the project delivery method is Design-Build, the involvement of the construction team was limited particularly at the earlier design stages. The construction site team was also formed later in the design stage. Therefore, their input on the final design could not be taken to a greater extent with a possible loss of some valuable constructability insights from the construction team (Baiden et al., 2006; Song et al., 2009).

Regular meetings seem necessary for the project coordination process to solve technical issues and control design schedules. However, It was found from the case study that it is not sufficient just to regularly organize those meetings and issue their minutes to related disciplines. Following on those minutes, a structured and continuous communication and control mechanism should be undertaken and any design adjustment that may influence other disciplines should be discussed with the corresponding discipline in advance. Moreover, earlier involvement of the construction team is necessary to extract a real value from their input to the final design outcome. More collaborative and structured design control and planning mechanisms as outlined in section 2.2 can be tried in that sense. In line with the inter-disciplinary design coordination issue, the effective use of BIM should be extended to all design trades involved as well.

Figure 7. The actual design schedule



Subcontractor Involvement

There are some important subcontractors in the case project. The complex externals of the building will be realized through the façade and steel subcontractors. However, the designers did not know many necessary details of the façade, such as the thickness, construction details, drainage requirements, connection details with the steel and so on. All those details would affect the design of not only the architectural but also the other disciplines as well. Because the project is a Design-Build contracting project, the main subcontractors would not sign a contract with the client until the design was completed. The local design firm tried to consult some façade subcontractors but no information of use was obtained. Essentially, the subcontractors perceived their speciality information as a commodity that they would not agree to exchange with the design team unless there was a work certainty for them in the construction phase. Therefore, the façade design was completed based on the past experience of the local design firm. It is a project risk that will require major design rework if the façade subcontractor cannot manage to fulfil the design assumptions after entering the project.

Important construction/ material supply subcontractors should be brought in as early as possible in the design process. The subcontractors should present their requirements and assist the designers to incorporate their know-how into the design stage. The expected deeper penetration of BIM in China can also present a technological medium for an extended designer/sub-contractor collaboration in the near future. However, as documented in the case project, the actual realization of this collaboration depends also highly on the project delivery method and mentality. Partnering based, more integrated project delivery methods in China will expectedly push construction stakeholders towards more collaborative practices even in the pre-construction phases (Humphreys et al., 2003).

CONCLUSION

This research presents a detailed study executed between March 2014 and September 2015 on the design process of a complex building project cooperatively designed with a FDF and a local Chinese design firm using BIM. The findings from the study were discussed from the perspectives of different design management parameters. A summary of the main findings can be seen in Table 2.

The case confirms a number of points identified in the literature; (i) in a partnership with a FDF, Chinese design firms' main role is adjusting the design outcome and executing the necessary engagements with other stakeholders in the Chinese context, (ii) the inefficient collaboration and communication between the FDF and the local design firm has negative effects on the schedule and consequently the cost of the project (iii) the FDS's familiarity with the language, culture, institutional environment and work context are contributing factors to the design process, (iv) ad-hoc design management practices are common in China with a lack of systematic design collaboration and control system, (v) BIM can contribute to client engagement and interdisciplinary coordination in the design stage, (vi) the BIM penetration is mainly market-driven in China, (vii) the use of 2D design drawings is still prevalent as a legal requirement, (viii) the use of BIM capabilities is generally limited with a comprehensive BIM training requirement in local design firms (lack of knowledge), and (ix) no client push towards the BIM use as a lack of managerial support.

The other important findings that were highlighted by the research include; (i) clients and design firms should pay extensive attention to their complete and continuous communication to avoid the making-do waste in the design process, (ii) the client should enforce a rigorous communication framework between the FDF and local design firm, if there is no contract between the two parties, (iii) an interactive, collaborative communication medium (e.g. cloud serves or a real/virtual "Big Room") should be in place between the FDF and local design firm to facilitate the much needed continuous communication, (iv) more systematic design management approaches widely available in the literature could be tried in design management efforts in China, (v) in order to fully utilize the coordination features of BIM, it is essential to have similar BIM competencies between different

Table 2. Summary of the main findings

Design parameters	Main Findings
Client	Clients should take more initiative and a leading role in BIM adoptions Clients management of the interfaces between FDFs and local clients is critical Clients should enforce a communication framework between FDFs and local design firms
Design management practices	Ad-hoc design management Having continuous and effective communication channels between FDFs and local firms are important Lack of coordination and inefficient communication between FDFs and local firms have negative impacts on the design process Construction teams' early involvement in design process is important Systematic design practices available in the literature should be tried in the Chinese contexts Partnership based project delivery methods could be tried to further benefit from critical subcontractors' inputs in the design process.
FDFs	FDFs familiarity with the Chinese culture and practices affects the design process positively FDFs mainly provide technical know-how in the design process
Local design firms	Local design firms generally play a coordination role between the Chinese context and FDFs All design trades generally work within a local firm with different BIM capabilities
BIM	BIM can significantly contribute to design practices in China. Market driven penetration. 2D drawing is still prevalent in part due to the Government requirements. Practical BIM capabilities are limited in local design firms. Lack of client push toward BIM. Having similar BIM capabilities across different disciplines are important. Despite initial challenges in BIM adoption, the overall benefits of BIM are conscious. The level of BIM based coordination between FDFs and local firms should be extended

design disciplines, (vi) although training for BIM can add to the total design duration, it will eventually bring about its benefit, (vii) the BIM coordination features can be extended over the FDF, local design firm and client/subcontractors for a better flow in the communication (viii) regardless of the project delivery method, construction teams should be involved earlier in the design stage for a real effect on the constructability, (ix) in order to obtain the necessary design involvement of critical stakeholders (i.e. important subcontractors), more integrated, partnering based project delivery methods can be deployed in China. Those findings can be further investigated in the Chinese design management context. It will be also useful to document the findings from their implementation in a real-life design management case in the country.

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Algan Tezel is a research Fellow at the School of the Built Environment, University of Salford. His research interests include Lean Construction, Building Information Modelling, visualisation and mobile technologies in construction.

Zeeshan Aziz has over 10 year's research experience in construction informatics. He is currently supervising 9 PhD students, 2 Professional Doctorate and 1 MPhil student. He is on reviewing panel of major academic journals in the field and has played a key role in organisation of major academic conferences including Intl Post Grad Research Conference (IPGRC, 2011), Intl. Conf. for Enhanced Building Operations (ICEBO, 2012) and IPGRC, 2013. Dr Aziz's research has received research grants from Royal Academy of Engineering, Higher Education Authority, British Council, Qatar Foundation and Highways Agency. Areas of interest: Intelligent Construction Collaboration, Building Information Modeling, Building Energy planning and modeling, Sustainable building design, Climate mitigation and adaptation, Life Cycle Assessment, Mobile Computing.

Chuxiong Jiang gained master degree from Wuhan University in 2007, then joined China Academy of Building Research as a structural engineer. Chuxiong's work is related to structural design, structural consulting, and design management. Chuxiong has abundant experiences in design management and all kinds of designs of civil architecture buildings, such as urban complex, hospital, school, and residential buildings etc. Chuxiong studied in University of Salford from April 2015 to October 2015 as a visiting scholar in the field of project management.

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