How to facilitate information exchange process in BIM-related international construction projects in China, with a focus on cultural influences

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CONTENTS

1. INTRODUCTION

Building Information Modeling (BIM) has become more and more popular in the construction industry, which has changed the traditional ways of managing construction projects. Due to the benefits of applying BIM to improve the performance and shorten project duration along with budget in construction projects, BIM adoption rate in US is much higher than the rest of the world [1]. However, the construction industry has experienced a great decline since the worldwide economic recession since 2009. The decreasing internal demand makes construction companies, especially in western developed countries, expand their horizons to the external opportunities. Meanwhile, thanks to the large internal demand and relative stable economic environment, the Chinese construction industry remains growing reposefully with limited influence by the global economic recession. Therefore, it has attracted overseas clients, designers and contractors to the Chinese construction market.

However, as there are more and more international construction projects in China, foreign-invested construction firms have faced great challenges to adapt to the Chinese construction industry. One of the great challenges is the relative lower BIM adoption rate in the Chinese construction industry, which poses problems for the successful information exchange process between Chinese stakeholders and foreign-invested construction companies. Another great challenge is the difficulty to smoothly understand and collaborate with the local contractors and suppliers in a multicultural working environment. The influence of different cultures may cause misunderstanding and inefficient interaction among the members of the project team in the international construction projects in China.

This thesis aims to explore the measures to facilitate BIM implementation in the multicultural working environment in international construction projects in China. It consists of six main parts. First of all, the general background information of the research is introduced. Then the literature review serves as a solid knowledge base. Based on the first two parts, the research problem and goals are defined to illuminate the knowledge gap in this field and the research goals are determined. The research and data analysis methods used in this research are described and the means to ensure the reliability and validity are also provided in the fourth part of this proposal. It is followed by the analysis on research results in terms of both the theoretical and practical impacts. In the end, the findings and limitations of the research are summarized and the future research directions are then illuminated.

2. LITERATURE REVIEW

The smoothness of information exchange process is essential to the overall success of construction projects. Many measures have been taken to improve the efficiency and effectiveness of the information exchange process in the construction industry, one of which is the introduction of information technology (IT). It has enhanced information management systems with great advantages in the consistency of data generation, the accessibility of information exchange and the operation speed. [2] Building Information Modeling (BIM) is defined as a suitable tool to integrate the essential design and process data during the overall construction project life cycle [3]. BIM enables an IT-enabled digital representation of both geometric and non-geometric data throughout all the stages of the project [4]. There have been quite a lot of researches focusing on the benefits of BIM in terms of cost reduction and quality improvement in the construction projects [5-6]. In addition, BIM can provide the seamless information flow throughout the whole process of construction projects [7], which enables the early detection of design errors. BIM can provide an integrated continuous information flow as a support for the smooth communication and accuracy of the information exchange. Due to these benefits, more and more attention is paid on BIM adoption and implementation in the construction industry, including some governmental agencies in western countries. They have shown relatively high willingness to push through BIM adoption and implementation in the public construction projects. UK Government has planned to use BIM in all the future public projects with government contracts by 2016 [8], which would be very effective to accelerate BIM adoption as claimed by the Institute for BIM in Canada [9]. Based on the trend of improving BIM adoption, there are already some researches concentrated on the BIM-based multi-organizational collaboration platform between stakeholders in the construction projects [9,10]. Coates, Paul, et al.[11] conducted case study on a KTP (Knowledge Transfer Partnership) project with BIM adoption and summarized the KPI (Key Performance Indicator) for BIM implementation process, which includes man hours spent per project, speed of development, revenue per head, IT investment per unit for revenue, cash flow, better architect, a better product, reduced cost (travel, printing, document shipping), bids won or win percentage, client satisfaction and retention and employee skills and knowledge development.

However, these researches described above are conducted in a mono- or similar cultural working environment, where the BIM-related knowledge levels of the project team members are sufficient and more or less equal to ensure a smooth information exchange flow in the language of BIM. The situation of BIM implementation becomes much more complicated when it comes to international construction projects, due to the influences of different cultures and different BIM acceptance levels. Take international construction projects in China as example, although the foreign-invested construction firms intend to introduce BIM to facilitate the communication and performance of the

whole project, they will face a much lower acceptance and adoption rates of BIM techniques in Chinese construction industry, with a very different cultural background. There have been few existing researches focusing on this crossed field, which creates a knowledge gap to combine both aspects. There is still a call for more researches on how to implement BIM to facilitate information exchange while mitigating the influences of different cultures and BIM adoption levels in international construction project in China.

Some researches about the cultural influences on information exchange process can illuminate the complexity of collaborating in the multi-cultural environment. Hofstede [12,13] revised his own framework of cross-cultural communication and further defined the six dimensions of culture based on the analysis of people working in the same organization over 40 countries, including power distance, individualism, masculinity, uncertainty avoidance index, long term orientation and indulgence versus self-restraint. It draws an overview of the characteristics and working patterns of international projects. W. Tijhuis [14] conducted a partly-participate research on the international construction projects between Dutch and German stakeholders during 1993 and 1996. As shown in Figure 1, he defined and constructed the "contact-contract-conflict" model (3C model) to explore the different behaviors of individuals in this international collaboration process.

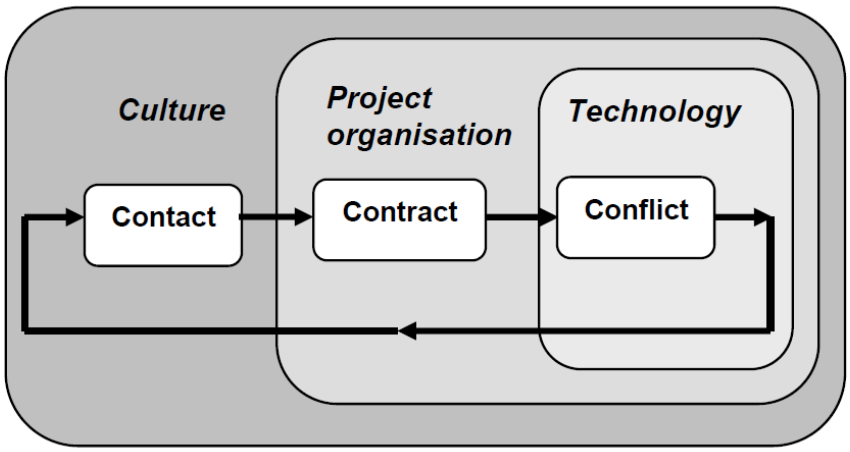


FIGURE 1 REPRESENTATION OF PROMINENT FIELDS OFATTENTION AND CATAGORIES INVOVELED [TIJHUIS, 1996;2001]

The 3C model is formulated under the background of three aspects of culture, project organization and technology. It provides a great framework to analyze the different paths in the international construction projects. With the partly-participative approach, W. Tijhuis [14] was enabled an open access to the on-site information and experiences. His focus on analyzing critical incidents has led to the (cultural) differences existing between the German and Dutch construction industry. Then the corresponding conclusions and recommendations were placed in a so-called NEDU Matrix with key

words, shown in Figure 2. In the NEDU Matrix, the vertical axis distinguishes the three attention fields and the horizontal axis shows the three related categories of background information.

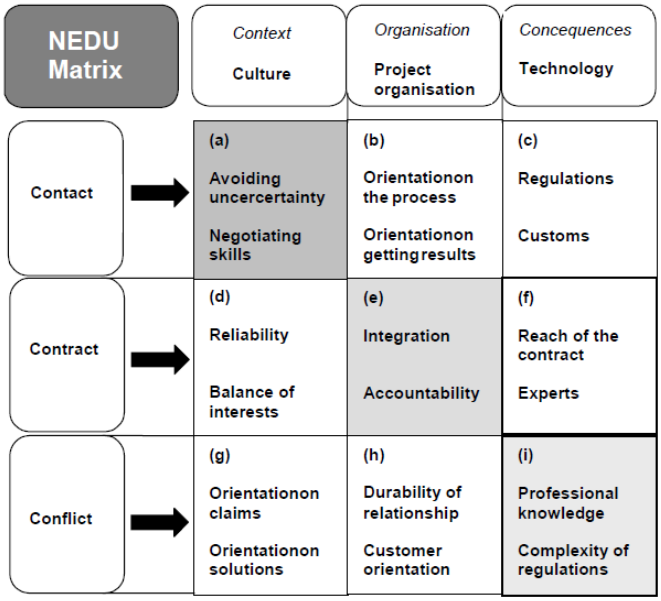


FIGURE 2 NEDU MATRIX WITH CONCLUSIONS AND RECOMMENDATIONS GIVEN AS KEY WORDS [TIJHUIS, 1996].

3. RESEARCH PROBLEM AND GOALS

Based on the literature review above, the research problem of this thesis is

"How to facilitate multi-organizational information exchange process in BIM-related international construction projects in China, with a focus on cultural influences".

For further illumination, it can be further divided into three sub questions:

1) How to describe the multi-organizational information exchange process in BIM-related international construction projects in China? What are the main features of this process?
2) What are the problems encountered by the parties involved, in terms of cultural influence and BIM implementation?
3) What changes are needed to mitigate these problems? What further measures can be taken to facilitate BIM implementation in this multi-cultural working environment?

Therefore, the goals of this research are to 1) observe and explore BIM implementation in the international construction projects in China, with a focus on cultural influence; 2) generate solutions to mitigate the defined information gaps and provide practical suggestions to optimize the efficiency and effectiveness of the information exchange process of international construction projects in China. This research will bridge the studies of both aspects and integrate into an incorporated theory about the information exchange process in the BIM-related international construction projects.

4. RESEARCH METHODS

A qualitative case study was conducted to explore this research gap. This research focused on a single case intended to promote further understanding and gain experience for similar situations [15]. Considering the weakness of lacking certainty to generalize the findings to other situation, the case was carefully selected to improve its external validity. Moreover, the physical environment, economic and social contexts and boundary conditions of the case that have influence on the situation were elaborated to enable readers to determine the applicability of the conclusions [16].

4.1 SELECTION OF THE CASE STUDY

An office renovation project located in Shanghai China was selected as the case, due to its highly integrated collaboration among international stakeholders involved and a consensual scope of BIM implantation. This is a small-scale renovation project with construction area of around 500 square meters and investment of approximate 6 million RMB (0.78 million Euros). This office renovation project initiated with the concept generation in September 2013. After several preparation stages of revising concept, sufficient permitting procedures and lease negotiation, the design phase started in December 2013.

The organization of the core project team is shown in Figure 3 below. The project has four major divisions including architecture design, general contractor, active system and passive system. It is led by the in-house Chinese American project managers. And the other members of the project team from different countries have worked closely for an integrated delivery of a high tech sustainable renovated building. The project team consists of European architects, Chinese American project managers, American consultant and local contractors, which creates a great opportunity to study cultural influences on the information exchange process in the project. In addition, with the consensus of involving BIM, this project becomes the perfect case to combine the influence of cultural impact and BIM implementation on the information exchange process in the international construction project in China.

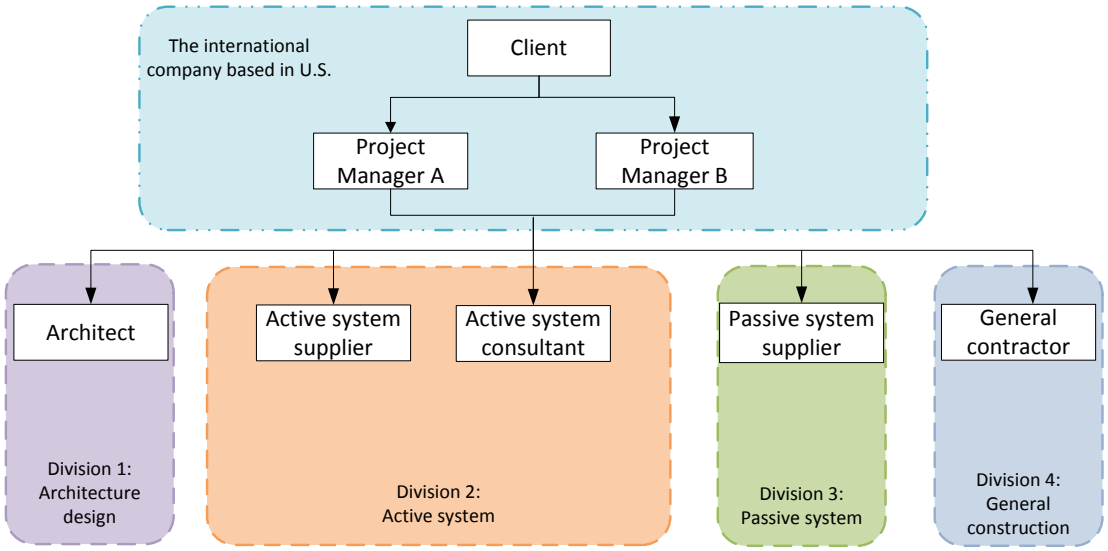


FIGURE 3 THE ORGANIZATION COMPONENTS OF THE CORE PROJECT TEAM

Considering the very limited knowledge and experience of working with BIM of the local contractors, the introduction of BIM implementation in this project brought a new view on how to manage and coordinate the process of projects in a construction project. The project members have reached the consensus to try using BIM to improve the mutual understanding and facilitate the efficiency of the overall process. The international working environment has also posed great challenges for the effectiveness and efficiency of BIM implementation on the information exchange process throughout this project, which indicates a great opportunity for a relative in-depth research.

4.2 FRAMEWORK OF THIS QUALITATIVE RESEARCH

With the help of a thorough literature review, a solid knowledge base was formed to facilitate the field qualitative case study. Multiple research methods were used in this research to collect data, including documents review, observation and interviews. In this way, the researcher was able to identify the existing problems and draw an overview of the current information exchange probes in BIM-related international construction project in China. Based on the analysis of all the data, improvements to mitigate the problems could then be generated. The framework of the qualitative study is shown as Figure 4.

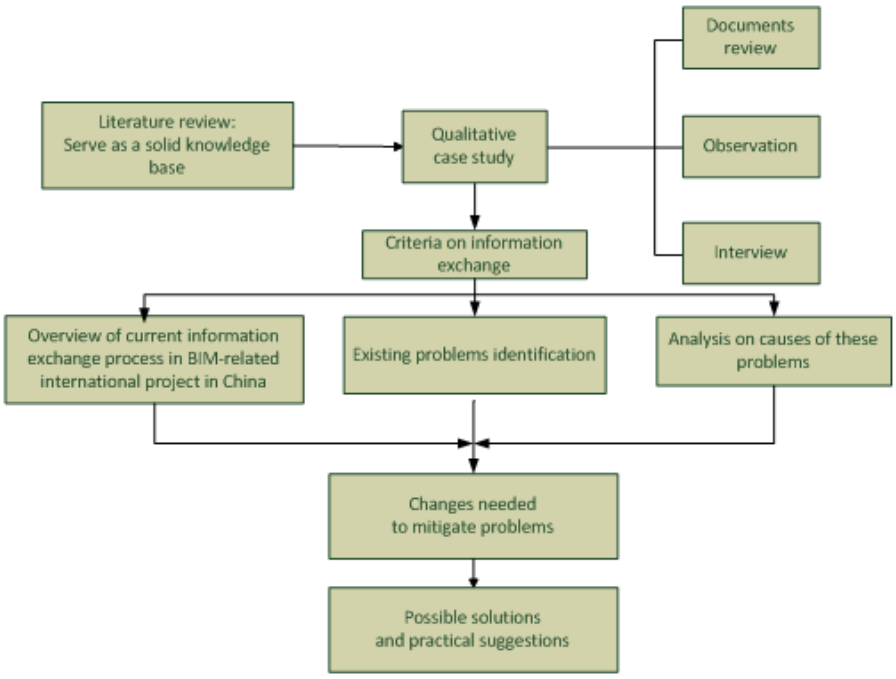


FIGURE 4 SYSTEMATIC FRAMEWORK OF THIS QUALITATIVE RESEARCH

4.3 RESEARCH METHODS

The interpretations of data in the qualitative study are inevitably influenced by the researcher's subjectivity to some extent. To mitigate this influence and increase the validity of the research, three methods were used in this research. The reliability and validity of the data collected through different methods were also considered accordingly.

1) **Documents review:**

   The researcher reviewed the related documents about the previous process of the project to draw an overview on the current information exchange process, including the minutes of the previous regular project meetings and the milestone documents.

   Ensure the reliability and validity of data collected with this method:

   The researcher specially paid attention to the documents selected for review. Documents submit by different parties in the project team were equally considered, to enhance the understanding of the overall picture of the project and mitigating the researcher's subjectivity.

2) **Observation:**

   The researcher attended the weekly project meetings and took minutes, photos and records to gain first-hand experience on the on-going interaction among the

members of the multi-cultural project team. The observation was highly flexible so that the researcher could make use of unforeseen data sources.

Several rules were followed to improve the quality of researcher's observation. Firstly, different data recording strategies of field notes, audiotapes and videotapes were practiced beforehand to test which was the best method for this research. And the final data recording method was decided after discussing with the participants. Secondly, the researcher was introduced to the participants before starting the observation. The researcher briefly described her research to gain the understanding and informed consent of the participants. Thirdly, the researcher remained quiet and inconspicuous in order not to disturb the usual process. During the observation, the research mainly focused on the interaction among the participants and contents related to BIM implementation.

Ensure the reliability and validity of data collected with this method:
The researcher used two columns to make the field notes that distinguished the objective observation and the subjective preliminary interpretations. In this way, the researcher was able to conduct the further analysis on a relatively objective basis. In addition, since the relevant literature review had been conducted, it served as a solid knowledge basis, which also guaranteed the quality of the observation on the regular project meeting.

3) Interview:

The interviews conducted were semi-structured with several key questions to balance the flexibility and preciseness of the contents. The interview questions were designed to lead the interview and gather the expectations and major concerns about the effect of different cultures and BIM implementation on the information exchange process in this project. The key questions are presented in Appendix A.

A proper purposeful sampling is essential to the qualitative interview. In this case, interviewee samples were selected based on the different roles, cultural backgrounds and levels of BIM-related knowledge in the project team to ensure the typicality and variability at the same time. As shown in Figure 3, the core project team is made up of 5 major parts: in-house project managers on client side, external consultant of the active system, external BIM team, architects, general contractor, and strategic contractor for the active system. The representatives were selected accordingly for the interview. The role and responsibility of the selected representatives are introduced as follows:

According to different roles and responsibilities, 6 representatives of the core project team were selected for the in-depth interviews, shown in Table 1:

No.	Interviewee position	Nationality	BIM knowledge level	Description
1	Project manager A	Chinese-American	Expert	She is the in-house project manager for this project on the client side. Although with American nationality and years of living experience in U.S., she lived in China for her childhood and can speak fluent Chinese. Therefore, she plays an important role between non-Chinese speakers and Chinese speakers in the core project team.
2	Project manager B	Chinese-American	Expert	He is the other in-house project manager mainly responsible for the BIM model development in this project. In the initial stage, he already got very involved in the design working as an external BIM expert to this project. Then, he got onboard and became the in-house BIM manager to work closely on site in Shanghai. He is Chinese American and can speak accurate Chinese. Since BIM model well integrates architecture design, active system and passive system, he works closely with different project members.
3	Active system consultant	American	Advanced	He works as external consultant for the active system. He's American and has years of working experiences in China. He's specialized providing specialty project development and sustainable community consulting services in China. He can only speak a little Chinese. He plays a very active and strong role during the project meetings and also the management of the overall project procedures.
4	General contractor	Chinese	Beginner	He is the lead of the general contractor. He is Chinese and can speak accurate English. He can use English for presentation but sometimes answers questions in Chinese and depend on others for translation. He has heard of BIM but never used it. BIM implementation in this project is new to him.
5	Active system supplier	Chinese	Beginner	He is the lead of the strategic contractor responsible for all the active system in this project. He is Chinese and can speak fluent English. Mostly he speaks English during the project meeting. But sometimes, he would speak Chinese to answer questions or talk to other Chinese-speaking members. He has heard of BIM but never used it. BIM implementation in this project is new to him.
6	Architect	German	intermediate	He is the lead of the architecture design team in this project. He is German and has years of working experience in China. He

				communicates with other project team members in English. He has intermediate levels of using BIM but using BIM as the central platform throughout the process is also new to him.

TABLE 1 THE BRIFE INTRODUCTION OF INTWEVIEWEES

Ensure the reliability and validity of data collected with this method:

The key questions were sent to interviewees beforehand to allow the recall of previous experience. During the interview, the researcher also came up with further questions based on the answers of interviewees. After signing an informed consent form, the interviews were recorded. And the preliminary interpretation was confirmed with the interviewees for verification.

4.4 DATA ANALYSIS METHODS

In this qualitative research, data analysis was conducted in parallel with the process of collecting data. Due to the semi structured process and high flexibility, the quality of data collection was enhanced through the preliminary interpretations. Creswell [14] summarized a data analysis spiral to illustrate the systematic framework for analyzing data in this case, shown in figure 5.

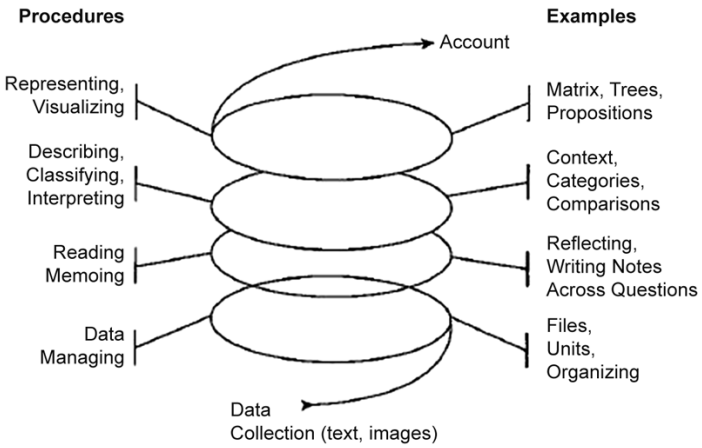


FIGURE 5 QUALITATIVE DATA ANALYSIS SPIRAL (CRESWELL, 2007)

There are four major steps to analyze the data collected:

1) **The organization of raw data**. Large amounts of raw materials were collected in this research, including 22 copies of weekly project meeting documentation and the interview records and transcription of 6 key project team members. These large units of data were broken into small pieces to make it easy for the future calling. For example, the records of the interviews were transcripted and organized as the smooth text file question by question to create an ordered database.

2) **Perusal of the memos**. In this step, field notes and the preliminary interpretations were reviewed to get an overall impression of the data. Reflections were also made on the relationships between different data sets and the possible indication for formulating the interview questions in the later stage of research. The field study in this research lasted for three months and the documents review and observations in the early period helped the researcher to gain information of different stakeholders and define the emphasis points when selecting interviewees and formulating the interview questions in a later stage.
3) **Classification**. In this step, data was interpreted and identified into different categories according to their themes. The software of Atlas.ti was used to support the qualitative data analysis. The software offered a systematic platform which helped the researcher organize large amounts of documents and keep in track with the memo, interpretation and codes etc. during the process of data analysis.
4) **Synthesis**. The researcher integrated and summarized the data to illuminate the relationships among different categories. Diagram and tables were constructed to visualize the final educated interpretations. Firstly, a general overall analysis was conducted to address the major features and differences in terms of multi-cultural collaboration and BIM implementation. It was followed by the detailed analysis on critical incidents using W. Tijhuis' [12] Contact-Contract-Conflict (3C) Model and the so-called NEDU Matrix. As described in the literature review above, the 3C model summarizes the three main fields of attention (contact, contract and conflict) and three related background categories (culture, project organization and technology). And the so-called NEDU Matrix applies this framework to the critical incidents analysis and allows summarization. The situation of BIM implementation within the critical incidents was paid special attention to bridge the aspects of cultural influences and BIM implementation.

5. RESULTS AND ANALYSIS

5.1 OVERALL ANALYSIS

Based on the documents review, observation and interviews of the researcher, some overall analysis can be conducted based on the commonness shared by project team members of similar cultural backgrounds and BIM experiences. This can show some major perceptional differences towards the project process and BIM implementation in an international project in the Chinese construction industry.

1) UNCERATINTY AVOIDANCE ORITENTION AND TIMELY DELIVERY ORITENTATION
The different characteristics and working habits of project members from different construction industries of different cultural backgrounds have posed some

challenges for the smooth process of this international collaboration. Stakeholders from the U.S. led the information exchange process through this project, including organizing frequent project meetings, integrating discussions into BIM model, reviewing the quality of delivery and so on, mainly with their used working habits. They highly emphasized the importance of the preparation and design stage with strict review of the deliveries and sometimes changed the design details afterwards according to new inputs, which took quite much time in the early stage.

This process of improving design quality and avoiding uncertainty in early stage was essential to them and they believed that it would help achieve higher quality of the final delivery. However, during the interviews, the local contractor and supplier expressed some negative comments on this working pattern. As one of the local stakeholder mentioned, "Compared to the other on-going projects in my hand, I have spent too much time on this small project and I am very worried about missing the deadlines. I feel not so good to have the design of my part changed all the time and my colleagues have to spend much time on these changes each time. I do hope they have made a good decision first and then assign it to us for realization, which will be more timely-efficient." In the Chinese construction industry, it is very common to complete the design phase and then pass the design drawings to the contractors and suppliers for construction. They will detect and deal with the design problems during the construction phase. The overall project duration needs to be strictly managed and the timely delivery is crucial.

Therefore, the different working orientation of the stakeholders from U.S. and China were observed. Table 2 below shows different orientations of process and outcome of these two groups of stakeholders.

	Working patterns	Characteristics
American stakeholders	Uncertainty avoidance orientation	-long-term learning focus -emphasis on early stages of preparation and design -highly-integrated collaboration -high-quality orientation
Chinese stakeholders	Timely delivery orientation	-project-based completion -emphasis on correcting while construction -clear responsibility allocation - good-enough quality orientation

TABLE 2 MAJOR DIFFERENT WORKING PATTERNS OF STAKEHOLDERS IN US AND CHINA

Although with all the differences, because of the common interests of building a long-term relationship, both the stakeholders from U.S. and China are willing to understand and comprise for a good collaboration. One of the local Chinese stakeholders mentioned "this is very new experience for me. Although taking much, I want to learn from it and see what it will go to". On the other hand, one American stakeholder with much experience working in China said, "I try to avoid the words of *Western high-quality* or *Chinese low-quality*. As for me, it is not good or bad, but commonly acceptable in the specific industry."

2) THE DIFFERENT DEFINITION AND ROLE OF BIM

As described in the literature review above, BIM, as a great platform for information exchange and integration throughout the whole project process, has been highly adopted in the U.S. While, in China, it still remains a relatively quiet area waiting for wider-range of acceptance. Therefore, members of this project team are equipped with different levels of BIM understanding and relevant knowledge. It results in non-coincidence on the definition and role identification of BIM in the project by stakeholders from U.S. and China.

The BIM-related process is led by the American stakeholder and special BIM expert is responsible for integrating and then exporting 2D-formatted information of different aspects. The local Chinese stakeholders mainly just react to the request and delivery of the BIM manager, still working with their used 2D drawings. One Chinese stakeholder defined BIM as a "useful tool to detect pipeline crashing". He also admitted that BIM may have more advanced functions but he thought it was too much for this project. This reflects the initial opinions of many local stakeholders towards BIM implementation in Chinese construction industry. The only benefit of BIM within their vision right now is the detection of pipeline crashing, especially for this small-scale project.

However, this opinion of some local Chinese stakeholders seems to change a bit after the 3D visual projection organized by the American project managers. As one Chinese stakeholder said in the interview, "the straight-forward 3D visualization was so impressive that I finally realized how BIM actually worked to integrate information. It is really an eye-opener. I am looking forward to what BIM can help in the coming construction stage."

Without the wide adoption rates of BIM in the construction industry, most of Chinese stakeholders have very limited knowledge of BIM and what BIM can help. This lack of understanding highly restricts the effectiveness and efficiency of BIM-related collaboration between the American and Chinese stakeholders. However, if fed in with impressive demonstration and sufficient knowledge of BIM,

the interests and working passions of Chinese stakeholders can be triggered. It will encourage them to act more proactively, which is beneficial to the smoothness of information exchange through the project process.

Taking an overview of all the documents review, observation and interviews, three critical incidents are selected and further discussed below

5.2 CRITICAL INCIDENTS ANALYSIS

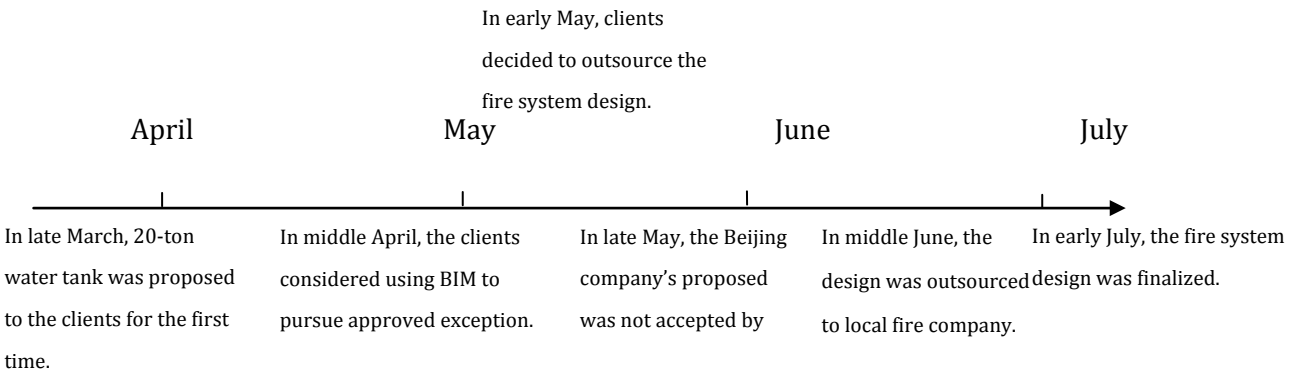
5.2.1 FIRE SYSTEM DESIGN SELECTION

The divisions of this office renovation projects are architecture design, active system, passive system, and general contractor and BIM consultant. The active system supplier was responsible for the fire system design of the office renovation project. However, they had little experience working on fire system design in their previous projects. The first design proposed to the clients contained a 20-ton water tank on the roof, which was dramatically large for a building of this scale. It also posed great challenges for the roof layout arrangements in BIM model.

The clients challenged the design and asked for detailed explanations. The active system supplier stated that they made the design strictly following the local fire regulations and showed clients the corresponding clause. The clients accepted the explanation but still doubted the design of 20-ton water tank. They asked BIM team to simulate this design to test the practicability and consulted the local general contractor for their previous working experience. Based on the feedback and the simulation results of the roof layouts in BIM model, the clients decided the 20-ton water tank design was unacceptable and had to be changed.

Although there is relevant clause in the general municipal fire regulation, there are different detailed requirements in different districts in Shanghai. There is also space left for interpretation that different design plans could also fulfill the basic fire resisting requirements. Therefore, to get the approved exception, the clients planned to use BIM model for fire system simulation and present the results to the officials of the local fire bureau to indicate that it would also be safe enough for this building not to include the 20-ton water tank on the roof. At the same time, the active system supplier proposed that it may help to hire a local professional fire system design company to deal with this since they were inexperienced. The in-house project managers thought through the situation and weighed two plans. Finally they took the proposal for outsourcing. They outsourced the fire system design to a professional company located in Beijing, which proposed a very expensive and complicated plan to replace the 20-ton water tank because of unfamiliarity to the local requirements in Shanghai. During several rounds of unproductive discussion and correction of this plan, the clients decided not to accept

this plan and turned to assign the general contractor to deal with the fire system design. They outsourced the fire system design to a known professional company based in Shanghai with good reputation. With rich experience dealing with local buildings and precise interpretation on the fire clauses, the new company presented a practical and doable fire system design which would meet the basic requirements. The clients were satisfied and accepted it. It took more than 3 months to finally get the fire system design decided which was unusually long for a building of this size.



As mentioned in the interview by the representatives of the local general contractor, it was very unusual for a small-sized building with no more than 500 square meters to take such a long time to decide its fire system design based on their previous experiences on local projects. The detailed analysis shows in the table 3, representing the NEDU-Matrix model from Tijhuis' model [based on Tijhuis, 1996, 2001]:

NEDU Matrix	Context: Culture	Organization: Project Organization	Consequences: Technology
Contact	The local contractors were passive for contacting clients outside the project meeting.	The foreign clients, project managers and consultants were quite process oriented, while the local contractors and suppliers were used to the outcome-oriented working patterns.	BIM performed as a central media in this project to collect information and transfer it to project members in the corresponding formats. It was constructed and managed by the project managers and other stakeholders simply followed the inquiries of information about their parts.
Contract	The fire system design was	External company was hired to specially	It is beyond the access of the researcher.

	outsourced to the local professional company. It is beyond the access of the researcher.	coordinate the contracting issues. It is beyond the access of the researcher.	
Conflict	The local contractors were submissive to clients' requirements, even for unexpected changes. It resulted in very few conflicts during the whole process.	The local contractors and suppliers were willing to make some concession for a potential long-term relationship with the client. Conflicts are few.	BIM helped error detection and practicality check, which saved some potential naming and blaming.

TABLE 3 THE NEDU-MATRIX ANALYSIS ON FIRE SYSTEM DESIGN INCIDENT FROM TIJHUIS' MODEL [BASED ON TIJHUIS, 1996, 2001]

BIM implementation within the incident:

In the fire system design incident, BIM helped integrate information of different aspects and conduct the practicality check to evaluate the quality of proposed design. However, due to the very low BIM adoption rate in China, all the fire system plans were submit in 2D format. It had to rely on project manager B to translate these 2D drawings into BIM language and integrate it into the current BIM model for the practicality check. This was a time-consuming process. In other words, the built-in strength of BIM to quickly conduct the design practicality check was highly diminished because of the unequivalent levels of BIM-related knowledge and adoption among project stakeholders. The extended time made the project process less flexible about reacting at changing plans. One of the reasons why the fire system design has taken such a long time is the inefficient BIM implementation (2D-BIM-2D) loop in this case.

However, it's not easy to improve the BIM-related knowledge level of the local Chinese stakeholders in the context of the Chinese construction industry with very low BIM acceptance. Although the local stakeholders showed quite a high interest in BIM in the beginning of the project, they were actually very conservative on BIM implementation in actions. As both the general contractor and active system supplier mentioned in the interview, "it can be imagined that quite a capital and human resource investment is necessary if we want to initiate BIM implementation within our own company. Given such a small project, I have to hesitate a lot because of its low investment-return rate." This is also in line with the single project outcome-oriented working patterns of Chinese stakeholders analyzed above. At the same time, the American project managers A said in

her interview that "…they (the general contractor) did show interest in learning BIM and actually using BIM in this project in the beginning. But it was truly difficult for them to actually implement BIM. We cannot push them to do that, right? So we just leave this alone."

To conclude, despite the interest in BIM of the local Chinese stakeholders, they actually did not take any actions on real BIM implementation in this project. They did not ask for BIM-related training or support and the American project managers did not offer either. The BIM-related knowledge gap remained and kept influencing on the efficiency of information exchange and the whole project process without any measures taken for mitigation.

5.2.2 FAILED DELIVERY OF CFD SIMULATION ASSIGNMENT

The cooperation between project managers and the local active system supplier, had been quite well since they have had a consensus that high technical standard is required in this project from the beginning. The active system supplier has been very collaborative and tried to coordinate their working pace with the constant changing ventilation plan discussion. In early May, the project managers asked them to produce CFD (Computational Fluid Dynamics) simulation results of both ceiling and displace ventilation plans to assist their decision making. However, in the next regular weekly meeting, the active system supplier only provided the CFD simulation result for the ceiling ventilation plan of the building. Moreover, the boundary conditions of the CFD simulation model were not accurate enough, which led to an unreliable result. Therefore, the project managers and consultants were very unsatisfactory with this CFD simulation presentation. Based on the observation of researcher, the American consultant raised his voice and expressed his strong discontent for the active system supplier's poor performance directly. He said there was no more time to wait for them to work on the CFD simulation for the displacement plan due to the tight schedule. He also emphasized that they were "forced" to adopt the ceiling ventilation plan any way since this was the only option provided and this was not what they were expecting. In face of this direct and sharp criticism, the representatives of the active system supplier apologized without many explanations and remained pretty silent during the rest of the project meeting. In the end, the project managers and consultant decided that they would adopt the ceiling ventilation plan any way considering the tight schedule. In another week, the active system supplier improved the boundary conditions of their CFD simulation model of the ceiling ventilation plan and presented the new results to the project managers and consultant, which was well received.

In the interview, different from the shape criticism in the project meeting, the American consultant expressed his much understanding to the active system supplier's failure to deliver CFD simulation results of two ventilation plans in time without blame. He said

that he understood this project was not their priority compared to the other proceeding large-scale projects. He was satisfied with the result presented in the second meeting. Although there are some conflicting arguments between project members about the CFD simulation incidents, in the end, they chose to understand and accept the current optimal result.

In the mean time, during the interview, the representative of the active system supplier mainly expressed their willingness to coordinate their work with the requirements of project managers but also complained a little about how much time they had spent in this project disproportionately. They would prefer the project managers to make decisions more precisely to minimize their wasted human capital for constantly changing plans. Another reason why it required more time in this project was that sometimes they had to wait for the integrated information from the BIM model. Among the project members, only a few have sufficient knowledge to work directly on BIM model. The rest had to wait for the BIM experts to collect all updated information, integrate it in the model and export the documents that different parties need. After several rounds of error detection and discussion, project members could receive the latest integrated information from BIM experts in their corresponding formats. The repetitive of the active system supplier pointed this process was interesting but much slower than their usual working habits to exchanging 2D drawings for this small size of building. It actually raised the time cost of this project.

In the same incident, the American consultant and the local supplier have different reactions to the conflicting arguments. The detailed analysis shows in the table 4, representing the NEDU-Matrix model from Tijhuis' model [based on Tijhuis, 1996, 2001]:

NEDU Matrix	Context: Culture	Organization: Project Organization	Consequences: Technology
Contact	The local supplier is more introverted and reactive, while, the American project managers and consultant are quite extroverted and proactive. It results in a one-way communication only led by the American members and the local	The American members are used to frequent collaborative discussion. The local members are submissive to these arrangements of the project managers. However, they are actually not so used to this working habit and have some negative comments about this in private.	The professional project managers and consultant can efficiently and accurately translate clients' requirements into technical expression and deliver to the supplier directly. With the help of BIM, the information can be checked on an integrated level and delivered accurately after

	ones are just responding.		several rounds of error detection.
Contract	It is beyond the access of the researcher.	Performance contracting is introduced. It is beyond the access of the researcher.	With more high-tech devices involved, performance contracting is introduced.
Conflict	When there is conflict, local members usually hold back their emotions, although they actually have some disagreement and discontent. Then they will work to fix it soon. At the same time, the American members are very direct and express their dissatisfaction on the spot. However, this strong emotion seems not to last long. After the outburst of anger, they understood the difficulties of local members and adjusted their requirements and maintain a good cooperation relationship with the local members.	One of the important drives for UTC and Disney chose to understand each other and reach agreements is that they both value the possibility to build a long-term collaborative relationship between two organizations.	The project managers and consultant have much experience and professional knowledge. Therefore they can detect the errors of the only CFD simulated results quickly. It shortens the process of naming and blaming.

TABLE 4 THE NEDU-MATRIX ANALYSIS ON CFD SIMULATION INCIDENT FROM TIJHUIS' MODEL [BASED ON TIJHUIS, 1996, 2001]

BIM implementation within the incident:

Similar with the analysis of the fire system design, due to the unequivalent BIM adoption levels in the project team, the majority of BIM-related integration work was only relied on by the project manager B. He worked as the central media in this project to collect

information corporated into BIM model and transfer it to project members in the corresponding formats. The other stakeholders just responded to his information request and had to wait for the exported 2D drawings. Considering the highly integrated design process, constant iterative changes were inevitable, which made this 2D-BIM-2D working method even more time-consuming. The active system supplier complained during his interview that "my colleagues have spent disproportionately much time on this small project. The design keeps on changing. We have to first wait for information from BIM and then redo the design constantly. This really takes too much time." Therefore, one of the deep reasons of this failed delivery of CFD simulation is the remaining incompatible BIM-related knowledge levels of project team members.

The active system supplier mentioned several times during the interview about the time-consuming BIM-related information exchange process in this project. He only took BIM implementation in this project as one of the requirements of the client. This low acceptance and lack of understanding of the local Chinese stakeholders made the smooth BIM implementation even more difficult in this project.

5.2.3 DELAY OF WINDOWS DELIVERY:

Different from the active system supplier, there is not a major representative from the passive system supplier for this particular project to connect the project team and their various small subsidiary companies. Therefore, the contact among the project team and passive system suppliers is almost limited within the communication on the project meeting. In middle May, the project team met the subsidiary windows supplier for two times. After reviewing several samples, the project team discussed and decided the modes of windows. The architect drew the detailed modes that he wanted freehand and explained to the windows supplier. In the end of the project meeting, the windows supplier said they understood and kept the conventional hand drawing. After the meeting, the BIM experts also integrate the modes of windows selected in the model and produce 2D drawings to send to the supplier. Busy with other issues in the project, the project managers did not contact the windows supplier very often. The windows supplier did not contact the project team for confirmation either. When it came to early June, the other parts were ready to install windows. The project team saw the products of the windows, which was not even close to what they had discussed. Since the exterior wall insulation has to be installed after the windows, the wrong products of windows made it very critical to keep pace with the planned schedule. The re-ordering of new windows would cause great danger of missing the deadline for preparing the exterior wall. The project managers were very unsatisfactory with the performance of the window supplier. To deal with this problem as quickly as possible, the project manager spoke to the regional superintendent of the overall passive system supplier to put on

pressure on the windows supplier for accelerating their work. The effect was very good that the supplier responded quickly and tried their best to compensate this delivery mistakes. Because of the hard work, the correct window delivery was just a little delayed and did not influence the insulation installation too much.

The detailed analysis shows in the table 5, representing the NEDU-Matrix model from Tijhuis' model [based on Tijhuis, 1996, 2001]:

NEDU Matrix	Context: Culture	Organization: Project Organization	Consequences: Technology
Contact	The local supplier is introverted and reactive, while, the American project managers and consultant are quite extroverted and proactive. It results in a one-way communication led by the American members and the local ones are just responding. If the project managers fail to keep tracing the process and confirm the accuracy, it may go out of control without notice and effect the lead time when the problem is discovered.	Although the entire passive system is supplied by Saint-Gobain, detailed contracts were signed with several subsidiaries loosely coupled. These subsidiaries are not regularly participating into the project team. They usually do not hold a clear picture of this project, which may lead a misunderstanding on the interpretation of clients' requirements.	With the help of BIM, the information can be checked on an integrated level and delivered accurately after several rounds of error detection, which may take some time. When problem is not detected in time, correction with BIM may take some extra time.
Contract	It is beyond the access of the researcher.	The loosely coupled structure of the passive system supplier makes the separate contracting procedures more time-consuming and complex.	It is beyond the access of the researcher.
Conflict	The local suppliers are very reactive and	The reason why the problem was quickly solved by the	The introduction of BIM helps keep tracing the

	usually do not approach the project managers spontaneously. If the project managers do not trace the procedures in time, problems may rise without notice. In this case, when conflicts happened, it might actually influence the overall on-time delivery.	windows supplier is that they were informed that the durability of relationship with Disney is crucial to Saint-Gobain. Therefore, they tried to compensate and minimize the negative effect of the delivery delay.	overall project process and integrate different aspects of information of the design plan. Therefore, when conflicts arise, BIM model can also perform as consensual criteria for the naming and blaming. In this case, the function of BIM in this aspect was not fully used.

TABLE 5 THE NEDU-MATRIX ANALYSIS ON DELAIED WINDOW DELIVERY INCIDENT FROM TIJHUIS' MODEL [BASED ON TIJHUIS, 1996, 2001]

BIM implementation within the incident:

In this delay of window delivery incident, the project managers failed to keep tracking the information exchange process between the BIM expert and the window components supplier. The local supplier was reactive and did not contact the project manager in time for confirmation. In total, the two aspects resulted in very late error detection and almost influence the overall on-time delivery. BIM implementation with this 2D-BIM-2D working method requires stronger supervision and tracing levels on the process to ensure the accuracy of information exchange and understanding of client's requirements.

In addition, BIM implementation enables tracing the overall information exchange process. In the incident of the delayed window components delivery, the discussion about the types and sizes of the window components is well recorded and stored in the BIM model. If any conflicts rose, the BIM model could provide convincing criteria for the naming and blaming.

5.2.4 INTEGRATED ANALYSIS ON CRITICAL INCIDENTS

Taking an overview of the critical incidents above, there are some similarities and differences among the behaviors in terms of BIM implementation of the American and local Chinese stakeholders of this international construction project in China.

Under the matrix of 3C model, the four critical incidents can be well summarized and analyzed, representing the NEDU-Matrix model from Tijhuis' model [based on Tijhuis, 1996, 2001]

NEDU Matrix	Context: Culture	Organization: Project Organization	Consequences: Technology (BIM in this case)
Contact	**Fire system design:** reactive and proactive; one-way communication. **CFD simulation:** reactive and proactive; one-way communication. **Windows delivery delay:** reactive and proactive; one-way communication; danger of going out of control without notice.	**Fire system design:** frequent collaborative discussion and infrequent periodical reports. **CFD simulation:** frequent collaborative discussion and infrequent periodical reports. **Windows delivery delay:** without a clear picture of the project vision, the misunderstanding on the interpretation of clients' requirements is likely to arise.	**Fire system design**: clear translation and delivery of client's requirements; time-consuming. **CFD simulation**: clear translation and delivery of client's requirements; time-consuming. **Windows delivery delay:** clear translation and delivery of client's requirements; time-consuming.
Contract	**Fire system design, CFD simulation and windows delivery delay:** Based on the limited access to the contracting issues of the researcher, there is no evidence that the contracting procedure is obviously influenced by different cultures.	**Fire system:** shared project vision, performance contracting, long-term relationship oriented. **CFD simulation:** shared project vision, performance contracting, long-term relationship oriented. **Windows delivery delay:** separate contracts with subsidiaries of the loosely-coupled supplier make the contracting procedures more	**Fire system:** BIM helps clarify the requirements of the client. **CFD simulation:** BIM helps clarify the requirements of the client. **Windows delivery delay:** BIM helps the possible naming and blaming.

		time-consuming and complex.	
Conflict	**Fire system:** indirect and direct, hold back emotions and burst out on the spot. **CFD simulation:** indirect and direct, hold back emotions and burst out on the spot; proactive remedy and understanding adjustment; both long-term relationship oriented. **Windows delivery delay:** reactive and proactive; If the project managers do not trace the procedures in time, problems may arise without notice.	**Fire system:** both long-term relationships oriented; **CFD simulation:** both long-term relationships oriented; both result-oriented and positive at solving the conflicts without the official claiming procedure. **Windows delivery delay:** both long-term relationships oriented; the local supplier is willing to compensate and minimize the negative effect of the conflicts to maintain the good collaboration relationship.	**Fire system:** It shortens the process of naming and blaming. **CFD simulation:** It shortens the process of naming and blaming. **Windows delivery delay:** When conflicts rise, BIM model can also perform as consensual criteria for the naming and blaming. In this case, the function of BIM in this aspect was not fully used.

1) From the perspective of contact:

a) Cultures:

The local supplier is more introverted and reactive, especially in their unfamiliar aspect. The American project managers and consultant are quite extroverted and proactive. It results in a one-way communication only led by the American stakeholders and the local ones are just responding. If the project managers fail to keep tracing the process and confirm the accuracy, it may go out of control without notice and effect the lead time when the problem is discovered. On the other hand, methods can be generated to encourage the participation of the local project members, for instance, the visual projection of the 3D BIM model. In addition, the American born Chinese project managers in this project well balance the communication between the English-speaking stakeholders and the

local Chinese-speaking ones. They also mitigate the sense of distance among the project team members from different cultural backgrounds in terms of language usage during project meetings, which helps facilitate mutual understandings.

b) Project organization:
The American stakeholders arrange very frequent collaborative discussion meetings, which the Chinese local ones are actually not used to. It is due to that the American project managers are quite process-oriented, while the Chinese local project team members are result-oriented. However, with a clear picture of the vision and a consensus of the working contents of the project from the beginning, although not fully used to the working patterns, the local project members tend to remain submissive to the arrangements of the American project managers. If the different working habits can be taken into consideration by the project managers with a balanced information exchange frequency and routes coming up, a smoother and more efficient information exchange process between the Chinese local stakeholders and the American project managers can be expected.

c) Technology:
The professional project managers and consultant can efficiently and accurately translate clients' requirements into technical expression and deliver to the supplier directly. With the help of BIM, the information can be checked on an integrated level and delivered accurately after several rounds of error detection. In the project where only a few stakeholders are equipped with sufficient knowledge of BIM, this detection and feedback procedures may be time-consuming. When problems are not detected in time, correction with BIM may take some extra time. A visualized presentation of BIM model can effectively deepen the understanding and acceptance of BIM implementation of the Chinese local stakeholders in the project.

2) From the perspective of contract:

a) Cultures:
Based on the limited access to the contracting issues of the researcher, there is no evidence that the contracting procedure is obviously influenced by different cultures.

b) Project organization:
The American project managers and consultant introduced performance contracting into the project for the active system design delivery. Project members reached a consensus of working for high-technical sustainable building from the beginning, which formulates the basis for performance contracting. The

local strategic partners are selected based on their high reputation and possibility for future collaboration. In the mean time, Disney, as the client, is also a potential great cooperative partner to form a long-term collaboration for the local contractors and suppliers. That's one of the reasons why they are willing to concede and spend so much human capital on this small project. However, it needs to be noticed that separate contracts with subsidiaries of the loosely-coupled supplier make the contracting procedures more time-consuming and complex. Therefore, given the different organizations of the local companies, different contacting and information tracing strategies are necessary.

c) Technology:
Since the performance contracting is introduced and the core members in the project team are experts with quite many experiences, it makes the contracting process very detailed and many technology-related contents involved, led by the project managers. The local suppliers are mostly responding. In this case, BIM implementation helps clarify and detail the requirements of the client, which enables a quality delivery and forms the basis for possible naming and claiming.

3) From the perspective of conflicts:

a) Cultures:
The local Chinese contractor and suppliers are very reactive and usually do not approach the project managers spontaneously. If the project managers do not trace the procedures and confirm the accuracy in time, problems may arise without notice. In this case, when problems are detected and conflicts happen, it might actually influence the overall on-time delivery. When conflicts arise, e.g. the unsatisfied fires system design and the failure of delivering the CFD simulation results on time, the local Chinese contractors and suppliers usually hold back their emotions, although they actually have some disagreement and discontent. Then they will work to fix it soon. At the same time, the American project managers and consultant are very direct and express their dissatisfaction on the spot. However, this strong emotion seems not to last long. After the outburst of anger, they understand the difficulties of local project members and adjust their requirements to maintain a good cooperation relationship with the local ones. The American born Chinese project managers also help buffer the conflicts and bridge the understanding between stakeholders from different cultural backgrounds.

b) Project organization:
In this case, both American and the local Chinese stakeholders are long-term relationship oriented. When it comes to conflicts, although with different ways of expression as described above, they are positive at solving the conflicts quickly

without the official claiming procedures since the final result matters the most to both of them. To deal with the conflicts, the local Chinese contractors and suppliers are willing to compensate and minimize the negative effect of the conflicts to maintain the good collaboration relationship. On the other hand, the American project managers and consultant also show understanding and willingness to reasonably adjust their requirements for a good-enough result. The unfamiliarity of BIM of the local Chinese contractors and suppliers poses challenges for the smooth project progress. In this case, the visual presentation activity of BIM model shortens the distance between the American and the Chinese project team members and improves the understanding and acceptance for BIM of the local Chinese contractors and suppliers. It helps minimize the possible conflicts related to BIM implementation in the future.

c) Technology:
The project managers and consultant have much experience and professional knowledge. Therefore they can detect the errors of the delivery. In addition, the introduction of BIM helps keep tracing the overall project process and integrate different aspects of information of the design plan. It shortens the process of naming and blaming. If equipped with deeper understanding of BIM model, the local Chinese contractors and suppliers could better interpret the requirements of clients and understand the criteria in the language of BIM.

6. CONCLUSIONS AND RECOMMENDATIONS

Although many studies have showed that BIM implementation can highly improve the performance of construction projects, a deeper second consideration is needed when it comes to international projects with a multi-cultural working environment and different levels of BIM adoption. In China, BIM has not been largely adopted and the majority of the industry is not equipped with sufficient knowledge to be compatible with the American construction companies in terms of BIM implementation. Given the influences of these two aspects, several conclusions and recommendations can be addressed to facilitate BIM implementation in the international construction projects in China, with a focus on cultural influence.

1) The local Chinese project team members are introverted and reactive, especially in the fields which they are unfamiliar with. In terms of BIM implementation, a visual demonstration of the actual benefits and effectiveness of BIM will effectively deepen the understanding of BIM definition and improve the acceptance of BIM implementation among the local Chinese stakeholders. Project managers with

experiences of different cultural backgrounds help smooth the information exchange process and buffer the possible conflicts.

2) Consensual vision and scope is very critical to construction projects, especially for the international ones with BIM involved. The role of BIM in the project has to be made clear from the beginning. The reactive character of many Chinese stakeholders makes them not approach the foreign project managers and consultant spontaneously. A shared scope and clear mapping out of the procedures will help keep the BIM-based trans-cultural collaboration in track.

3) The Chinese local stakeholders are mostly single project outcome-oriented, while members from the western countries are more process-oriented. This results in different working habits, for instance, the frequency of project meetings. Although with frequent project meetings, the local Chinese contractors and suppliers still have to wait and rely on BIM experts to translate and integrate their work to give feedback, since they are not familiar with BIM usage. This information exchange latency makes Chinese stakeholders mistake the input-output ratio of BIM implementation. To mitigate this problem, the project managers need to take the working habits of both parties into consideration and compromise into a plan that can coordinate different stakeholders accordingly and integrate the discussion into BIM model efficiently.

4) When stakeholders all pursue a possible long-term relationship, the conflicts rarely go into the official claiming procedures in the international construction projects in China. Although with different emotional expressions, project members from different cultural backgrounds try to understand each other and make the corresponding adjustment to reach a good-enough result timely.

5) Since BIM model performs as an integrated platform for the information exchange and storage, it helps keep tracing the overall project process. It could provide sufficient criteria for the naming and blaming for the errors during the process. It increases the accuracy of information and mitigates the possible conflicts because of difficult naming.

Based on the case study in this research, the effectiveness and efficiency of BIM implementation is highly influenced by the specific circumstances of the project organization and working patterns, especially in the multi-cultural working environment of the international construction projects. It poses even greater challenges if significant gaps of BIM-related knowledge levels exist among stakeholders in the international construction project. Several measures can be taken to improve this

situation and effectively facilitate BIM implementation with the multi-cultural working environment and incompatible BIM knowledge levels.

1) Stakeholders with limited BIM-related knowledge should be fed in with sufficient initiation of the scope and usage of BIM, such as visual demonstration of 3D BIM models. It will create a convincingly vivid image of BIM implementation, which helps increase the willingness and acceptance of BIM usage among these stakeholders.

2) Training on the basic use of BIM is necessary to get stakeholders with limited BIM-related knowledge more involved in the BIM-based information exchange chain in the project. This involvement is essential to facilitate the seamless information flow with BIM as the unified language and integration platform. It also makes the information exchange process more timely efficient without fully relying on the BIM expert to perform as the only information translating media.

3) The level of supervision and tracing of the information exchange should be stronger in the international construction project with incompatible BIM-related knowledge levels. It can facilitate the accuracy of exchanged information and understanding of the client's requirements.

7. LIMITATIONS OF THE RESEARCH

In this research, there are still aspects that need to be improved. First of all, although many measures have been taken into consideration to mitigate the subjectivity of the researcher, it still has some investable influences on the research. Also, to some extent, the single case study method also affects the generalization levels of the conclusions to other circumstances. Further study on more case is still needed to enable an overview on the situation of BIM implementation in international construction projects in China. In addition, with the limited access to the project, the researcher got very little information about the contracting procedures. It still remains silent about the influences of culture, project organization and technology on the contracting issues in BIM-related international construction projects in China. Secondly, there is just one case studied in the condition of American project managers and Chinese local contractors in the international construction project in China. Although multiple methods have been adopted to mitigate the influence of researcher's subjectivity, the generalization level of the findings is still limited due to the small sample number.

In the future, more case studies on different conditions about the international construction projects in China can be conducted to enrich the contents and broaden the boundaries of this research. Furthermore, more cultural backgrounds can be corporated into the scope of the research on cultural influences on BIM implementation in international construction projects. Then, a comprehensive framework of BIM implementation in different cultural environment can be formulated and even perform as a practical manual for a smooth BIM implementation in the future international construction projects.

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APPENDIX A INTERVIEW QUESTIONS LIST

(1) How do you feel about the levels of BIM implementation in the 624 project?

(2) How do you feel the BIM-related information exchange process and how you communicate and deal with these BIM issues with other project team members?

(3) How BIM is involved in your organization?

(4) How do you feel about the support levels of BIM implementation inside the project team during the project process?

(5) Why do you think BIM is involved in your part during the process?

(6) What is the attitude towards investing in BIM in your organization?

(7) What information exchange systems do you use in your organization? Is it compatible with BIM? How do you deal with existing incompatibleness?

(8) What do you say about the multi business cultural working environment in this project?

(9) What kind of critical moments can you recall in the project so far?

(10) Tell me about your ideas about the BIM implementation in the future similar international projects in China?