Contextualizing the institutional changes in BIM-based construction: a comparison of BIM-attached and BIM-integrated projects

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ABSTRACT

As BIM diffuses into different aspects of the architecture, engineering, and construction (AEC), the conventional project practices have been disrupted. In particular, projects experience a few obstacles and challenges to integrate BIM into the AEC process. This leads to hybrid AEC practice with BIM and non-BIM information processing. Such a situation can be chaotic with the institutional changes accompanied by the implementation of BIM in AEC projects. Focusing on this issue, the current study aims to identify BIM-invasion modes to AEC projects and contextualize the institutional changes in BIM-based construction. Initially, the possible institutional changes are identified and a theoretical framework to contextualize them is proposed through the review of literature. A following case study compares two projects with different BIM-invasion modes, captures the institutional changes, and verifies the theoretical framework. The case study also validates the major institutional elements related to BIM and demonstrates two BIM-invasion modes to the AEC projects. This research explains how the AEC project changes from an institutional perspective with the systematic implementation of BIM and provides implications to its organizational management. The primary implication is that the extensive use of BIM in AEC projects shall ensure that institutional changes are manageable.

INTRODUCTION

The project provides a mechanism for organizations in the architecture, engineering, and construction (AEC) industry to collaborate and deliver building products (Winch 1989). The project mechanism is further enhanced by institutionalization with constant changes in the industry practice (Lieftink et al. 2019; Winch 2000).

In recent years, the AEC industry keeps promoting the use of Information and Communication Technology (ICT). This leads to the diffusion of BIM into AEC projects. Although a series of favorable effects are found from the use of BIM in projects (Bryde et al. 2013; Lu et al. 2014a), the disruptiveness of BIM spells difficulty to advance the AEC practice (Cao 2016; Ma et al. 2018b; Mancini et al. 2017). However, the disruptiveness of BIM to the AEC project has barely been specified by existing research.

A project has a grounded institutional feature, and institutions exist widely in AEC projects (Scott 2012; Wang et al. 2018). BIM also has a remarkable institutional effect on projects (Cao 2016; Chang et al. 2017). A few studies investigate the institutional changes in AEC projects brought by BIM. An earlier study by Dossick and Neff (2009) finds the division of project organizations with the adoption of BIM technology. Gu and London (2010) indicate the emerging roles and new relationships when introducing BIM in projects result from not only technical innovations but also the work process. Cao et al. (2014) indicate the isomorphism caused by the prevalence of BIM is a major source of institutional changes in the AEC project. According to Chang et al. (2017), the level of BIM use in projects is correlated with the integration of project teams by defining common objectives and promoting cross-disciplinary communication. Furthermore, Akintola et al. (2017) point out the institutional effect of BIM in AEC projects and advocate the BIM capabilities attached to the project teams. However, how the institutional changes are accommodated still needs to be clarified.

Accordingly, this study dedicates to the establishment of a theoretical framework using the institutional theory and strives to contextualize institutional changes brought by the comprehensive implementation of BIM in AEC projects. The research questions include:

1. *What institutional changes emerge in BIM-based AEC projects and how does the institutionalization happen?*
2. *How to identify and manage institutional changes in AEC projects with the systematic implementation of BIM?*

THEORETICAL FRAMEWORK

The adoption of ICT in organizations is correlated with an institutional environment. On the one hand, a few studies confirm the contributing effect of the institutional context to adopt ICT in organizations (e.g., Avgerou 2010; Lapierre and Denier 2005). On the other hand, several studies point out the opposite effect of ICT to reshape the institutional environment (e.g., Bedrina et al. 2012; Redwood et al. 2017). However, Barrett et al. (2006) indicate this interaction is embedded in organizational behavior, which fits the institutionalization of BIM in AEC projects.

The establishment of a theoretical framework on the interaction of BIM and the institutional environment in AEC projects refers to the conceptualization of project with Product Breakdown Structure (PBS), Work Breakdown Structure (WBS), and Organization Breakdown Structure (OBS) (Turner and Cochrane 1993). With the introduction of BIM into the AEC project, the change of PBS disrupts WBS and OBS (Ma et al. 2018a). Such disruptiveness leads to institutional changes in projects. Based

on this interpretation, the theoretical framework refers to the process and elements of institutional changes as introduced by Suddaby and Greenwood (2009).

The division-integration process

The introduction of BIM leads to hybrid project practice with the coexistence of both conventional and BIM-enabled approaches (Davies et al. 2017; Gledson 2016). This accompanies with the division of organizations and the emergence of new roles (Dossick and Neff 2009; Akintola et al. 2017). Furthermore, new institutional environment is required to accommodate such a change (Cao 2016; Chang et al. 2017). The following process is the integration of the work process and merging of capabilities of BIM and AEC teams (Cao 2016; Davies et al. 2017). The division-integration process is illustrated in Figure 1.

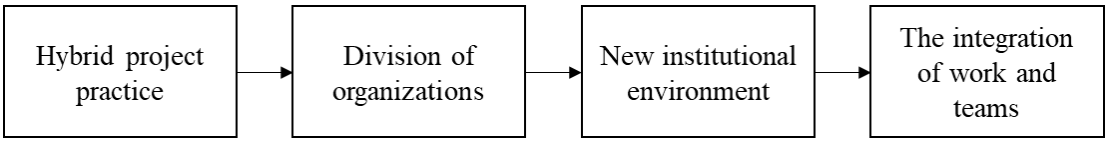

Figure 1. The division-integration process of institutional changes brought by BIM

Identifying the institutional changes

Based on the previous interpretation, the elements of BIM-related institutional environment can be categorized into two groups. One group of institutional elements related to project work/WBS entails technical specification, industry standard, work responsibility, and delivery strategies (Davies et al. 2017; Gledson 2016; Ma et al. 2018b). The other group of institutional elements related to project OBS includes organizational structure and hierarchy, code of practice, work culture, cooperative interface, networks and relationships (Akintola et al. 2017; Ma et al. 2018b). Both groups of elements reshape the institutional environment.

METHODOLOGY

Research design

The preliminary stage has established a theoretical framework to map the BIM-related institutional environment and categorize elements. The following case study is employed to validate the theoretical framework. The steps of the case study include differentiating the BIM-based AEC projects, selecting appropriate cases, and comparing the different institutional changes in them. The appropriate research design helps realize the objectives. The justification of method and case selection is discoursed in the subsequent section.

Case study is a widely used strategy that probes into a particular case in the real-life situation to develop an in-depth understanding of a research issue (Yin 2017). This case study involves the collection and analysis of the qualitative data through a content-analysis approach. As content analysis favors multiple sources of data (Mayring 2015), the collection of data relies on three means including interviews, questionnaire surveys, and document studies. Focusing on the key source of the case information, we approached the BIM execution managers as the interviewees of the

interview and also the respondents of questionnaire surveys. Also, a document study applies to supplement the data collection. Thus, both subjective and objective perspectives are covered.

From the organizational perspective, the division of the BIM team keeps occurring in BIM-based AEC projects (Akintola et al. 2017; Dossick and Neff 2009). As BIM shall work for the benefit of the AEC project (Ahn et al. 2015; Ma et al. 2018b), outsourcing BIM consultancy for its implementation can lead to dual leadership in BIM affairs by the BIM consultant team and the project management team due to their clear organizational boundary. Accordingly, this study selects organizational division as a factor to differentiate the cases, and the BIM-based AEC project organizations are categorized as the BIM-integrated and the BIM-attached. These two modes represent different levels of BIM invasion to AEC projects, thereby are compared by this case study.

Data collection and analysis

The nature of this research influenced the strategy for data collection and analysis as a comparative study. The primary function of a comparative case study is to identify patterns, establish categories, and testify results through the analysis of discrepancies in cases (Bennett 2004; Kaarbo and Beasley 1999). Accordingly, the objective of the data collection and analysis is to categorize the content of BIM institutionalization and benchmark the categories with comparative analysis.

The first step of this study was to identify the pattern and category of the theoretical framework. The open-ended interview method is adopted, as it helps avoid the limitation of interviewers and extend the analysis of interviewees (Rapley 2001). Open-ended interviews with BIM managers investigated elements for the model. Secondly, the questionnaire survey was executed to compare cases. After the interviews, the BIM managers were invited to complete a simple questionnaire, which allows the evaluation with five scales including, 5=totally agree; 4=quite agree; 3=neutral; 2= not quite agree; 1=totally not agree. Both the interview and the questionnaire survey involve the BIM manager of each case project. In the third place, document study is employed to supplement and confirm the collected information. All the sources shape the case content for further analysis.

As the institutional effect is brought by the implementation of BIM and BIM-based platform (platform also known as Project Management Information System), the survey questions focus on critical success factors (CSFs) regarding these two subjects. The CSFs help assess the success of the implementations of both BIM and BIM-based platform. Considering the research topic, only CSFs related to institutional changes are identified. The retained CSFs are listed in Table 1 with their sources.

FINDINGS OF THE CASE STUDY

General information

The two projects, namely Project C and Project X, are located respectively in Chengdu and Xi'an, two of the major cities of China. Project C is a building complex, while Project X is an airport terminal. Both of them involve a large volume of complex building works, which is a key motivation for BIM use. The investments for Project C

and Project X are approximately 3 billion USD and 10 billion USD with areas of around 800,000 sqm and 950,000 sqm, respectively, as listed in Table 2. Moreover, as the owners of both projects advocate the application of innovations, the use of BIM in the projects is comprehensive. However, different strategies of BIM implementation vary the institutional effect of BIM on the two projects. Project C outsources a BIM team to work with the project team while Project X establishes a BIM team within the project team. Thus, they are regarded as the BIM-attached and the BIM-integrated respectively.

Table 1. CSFs Related to the Institutionalization of BIM in AEC Projects

Factor	Sources
The project teams adapt well to the information management with BIM	Gu and London (2010); Nitithamyong and Skibniewski (2011); Gledson (2016)
The work culture of the project is flexible, which facilitates the implementation of BIM.	Linderoth (2010); Davies et al. (2017)
The project management impel BIM implementation	Linderoth (2010); Gledson (2016)
The exchange of data promotes the sharing of project information.	Nitithamyong and Skibniewski (2011); Eadie et al. (2015)
The BIM-based platform supports the interface of different teams and serves for project management affairs.	Lee and Yu (2012); Gledson (2016)
Some organizational, contractual, and delivery measures are taken to safeguard the implementation of BIM in the project.	Chong et al. (2017); Davies et al. (2017)
The implementation of BIM is well planned with the project.	Wu and Issa (2014); Ahn et al. (2015)
The objective of BIM and platform use follows the project goal.	Nitithamyong and Skibniewski (2011); Gledson (2016)

Table 2. The Demographic Information of the Case Projects

	Project C	Project X
Type	Building complex	Airport terminal
Investment	Around 3 billion USD	Around 10 billion USD
Area	Around 800,000 sqm	Around 950,000 sqm

Findings of interviews and document analysis

The examination of institutional changes refers to the category of the institutional elements identified in the theoretical framework. They are verified in the results of interviews and document analysis. As presented in Table 3, changes are confirmed in most of the elements except *industry standard*, *work culture*, and *organizational structure and hierarchy*. The interviews only confirmed these three elements. The contents of the changes are also investigated. Most of the changes have different levels of involvement in the two compared projects, while three of them, including the elements of *project technical specification*, *industry standard*, and *organizational structure and hierarchy* have a similar extent of changes. The diffusion of institutional

effect is quite balanced for the two categories, with no clear tendency of changes toward work-related or organization-related elements.

Table 3. Institutional Changes in the Case Projects by Interviews and Document Analysis

	Project C	Change of Project C	Project X	Change of Project X
BIM-work related				
Project technical specification	I/D*	Added	I/D	Added
Industry standard	I	Only use as a reference for project-based standardization	I	Only use as a reference for project-based standardization
Work responsibility	I/D	Outsourced	I/D	Emerged and rearranged
Delivery strategies	I/D	Some basic arrangements with the standardization of managerial and technical affairs	I/D	Some arrangements such as EPC, software alignment.
Organization related				
Work culture	I	Some change but limited	I	Resistance from the construction contractors
Code of practice	I/D	Some limited change	I/D	Some, but project manager tried to compromise BIM use to avoid the change.
Organizational structure and hierarchy	I	Limited	I	Limited, BIM manager is lack of authority
Networks and contractual relationship	I/D	Outsourced BIM team connected to project team	I/D	Emerging BIM team
Cooperative interface	I/D	Outsourced BIM platform	I/D	BIM-integrated information system

Note. I: Confirmed by interview; D: Confirmed by document

Findings of questionnaire surveys

According to the assessed scores of the two case projects, the analysis of factors probes into the discrepancy and commonality of institutional changes. Based on the ratings that Project C surpasses Project X, the BIM-attached case suffered less from the organizational changes regarding cooperation and work culture (Table 4). However, as we regard two scale points as a significant discrepancy, none of the relative strength

of the BIM-integrated case is found in the comparison. Meanwhile, the sum scores are also examined to evaluate BIM-based construction. It can be concluded that institutional changes have a significant impact on project governance and organizing regarding the high score (over 8, as 6 represents neutral) of the assessed factors.

Table 4. The Assessment Scores by the Questionnaire Surveys

CSF	Project C	Project X	Minus*	Sum*
The project teams adapt well to the information management with BIM	5	2	**3**	7
The work culture of the project is flexible, which facilitates the implementation of BIM.	4	2	**2**	6
The project management impel BIM implementation	5	4	1	**9**
The exchange of data promotes the sharing of project information.	4	3	1	7
The BIM-based platform supports the interface of different teams and serves for project management affairs.	3	3	0	6
Some organizational, contractual, and delivery measures are taken to safeguard the implementation of BIM in the project.	5	5	0	**10**
The implementation of BIM is well planned with the project.	4	5	-1	**9**
The objective of BIM and platform use follows the project goal.	4	5	-1	**9**

Note. Minus: Project C-Project X; Sum: Project C+Project X

DISCUSSION

BIM is the digital representation of building production (Lu et al. 2014b; Miettinen and Paavola 2014). The change of information processing in project products diffuses into work and organization. From the content analysis of the cases, the BIM-attached mode has brought fewer changes to the project organizations. It can also be inferred from the analysis of interviews and documents that the BIM-attached mode is the prelude of the BIM-integrated, as the institutional changes in the BIM-integrated project covers those in the BIM-attached project, but not vice versa.

Institutionalization triggered by information processing and sharing needs a balance between efficient utilization and redundant chaos (Ménard 2008). This applies to the BIM effort in AEC projects. The use of BIM shall match the concurrent practice of AEC projects. This is a primary principle for the appropriate choice of BIM-invasion modes in project practices. Another issue is the maturity of BIM. Due to the current hybrid BIM/none-BIM practice in AEC projects (Davies et al. 2017; Gledson 2016), the BIM-attached mode applies more widely than the BIM-integrated. All this implies BIM institutionalization shall be manageable when implementing AEC projects. Such institutionalization can resort to the identified institutional changes.

CONCLUSION

As BIM diffuses into AEC projects, its institutional effect has become phenomenal. To contextualize the institutional changes in AEC projects brought by BIM, this study establishes a theoretical framework to position the BIM institutionalization and verifies the institutional process and elements in a comparative case study. Through content analysis of the cases, two BIM-invasion modes are identified and compared. The institutional effects of BIM on project work and organizations are also clarified.

This study has a few research contributions. First, it identifies general institutional elements to contextualize institutional changes caused by the comprehensive use of BIM in AEC projects. Second, the study induces the basic institutional process of BIM in AEC projects. Third, the study analyzes the discrepancy of two different BIM-invasion modes in AEC to provide implications for the organizing BIM-based AEC projects.

The key implication is that the institutionalization of BIM shall be limited to a manageable degree, and ad hoc institutional changes shall not be excessive to ensure the effectiveness of BIM and smooth implementation of the projects. The study also has some limitations. The questionnaire surveys have one respondent for each case. There could be a source of errors due to the fuzziness of humans' evaluation. In accordance, only significant discrepancy and commonality are accepted in the analysis to alleviate the deviation. Also, although the BIM manager is the person mainly responsible for BIM related affairs, the perspectives from project managers or other team leaders of discipline works can enhance the findings. To reduce possible errors, content analysis with multiple means of data collection is employed to validate the investigation. Future research can further the exploration with more robust data.

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