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Understanding effects of BIM on collaborative design and construction: An empirical study in China

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Abstract

In construction projects, Building Information Modeling (BIM) influences on the common way of collaboration, including the roles of different participants. The goal of this research is to explore current practices and identify the critical effects of BIM on collaborative design and construction. Through a focus group discussion and interviews with BIM related participants, we explored project professions' understandings of BIM implementation on collaborative design and construction and adopted the grounded theory to analyze the qualitative data. Eight concepts influencing the development of BIM collaboration are identified and classified: (1) IT capacity, (2) technology management, (3) attitude and behavior, (4) role-taking, (5) trust, (6) communication, (7) leadership, (8) learning and experience. We discussed the taxonomy of BIM effects into three dimensions: technology, people and process. Our findings provide empirical insights into the collaborative nature of BIM construction projects and highlight the importance of collaboration within project teams in BIM project delivery.

Keywords: Collaboration; BIM; Design; Construction; Grounded theory

1. Introduction

In Architecture, Engineering and Construction (AEC) industry, design and construction activity involves numerous organizations working together and depending on each other to provide tailored solutions for owners. Each party working with others in the project-based construction has its own specialization, work patterns, and commitments as well as individual interests, values and culture. For many years, owners, contractors and designers from different disciplines are working together in order to achieve the project goals. However, in recent years there have been some developments that have influence on the common way of working and collaboration, including the organization of construction projects and the roles of different participants, most notably the trend towards more openness between project participants (Hertogh and Westerveld, 2008) and the proliferation of Building Information Modeling (BIM) (Bryde et al., 2013).

What we call "Building Information Modeling" nowadays was already presented by Van Nederveen and Tolman (1992) though the original BIM concept can date back to 1970s (Eastman et al., 2011). The concept still remains relatively new for the industry, but attracts more attention and can achieve great improvement (McGraw-Hill Construction, 2014).

BIM can be described as a socio-technical system (Sackey et al., 2014), because it is made up both of technical dimensions, e.g. 3D modeling, and dimensions with social impact, e.g. process reengineering. The BIM trend has led to changes in the way designers and contractors work and collaborate, such as the way information is shared.

Despite these trends, it seems that the organization and roles of design and construction teams often do not change significantly. There are only few examples in which it was tried to use a

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radically different approach such as Integrated Project Delivery (IPD) (Kent and Becerik-Gerber, 2010). In these projects, key participants form a partnership from the beginning of the project and contractual boundaries are eliminated.

Proper collaborative design and construction activities enable the information transfer, knowledge creation, technological coordination and resource allocation to operate effectively and reduce unnecessary conflicts. Grilo and Jardim-Goncalves (2010) argued that technical interoperability is not the problem for construction projects in implementing BIM, which has been shown to be feasible. Rather, the challenge is to understand and determine the value of the business interoperability, expanding the definition of collaboration.

The purpose of this paper is to explore the implication of BIM through a socio-technical systems perspective, with a particular focus on multidisciplinary inter-organizational collaboration practices. In this paper, the focus group discussion and interviews with the principles of the grounded theory are used as the research methods. It identifies the collaborating characteristics and key concepts that influence the effects of successful collaboration in BIM construction projects.

2. Literature review

2.1. Characteristics of AEC collaboration

The AEC sector is a typical paradigm of a project-based industry. The new non-routine design and construction processes also accompany complex working relationships and interrelations (Bresnen et al., 2004). A set of teams from various disciplines including the owner, designer, general contractor, project manager, civil engineer, MEP (Mechanical, Engineering, Plumbing) engineer, subcontractor, material and equipment supplier and BIM coordinator are employed to deliver a project. They made inter-dependent discipline decisions and naturally form a temporary multi-organization. The individual participants will finally affect the overall progress (Benne, 2005). In addition, different individual and organizational interests, expertise, expectations, resources, and constraints feature different participants (Lau and Rowlinson, 2010). Great attentions are drawn to manage these complicated interactions between different participants. Construction management is confronted with great challenges due to its increasing complexity such as the complicated and varied relations between numerous participants (Hertogh and Westerveld, 2008).

Collaboration has been explored in organizational studies' literature from a dominantly functional perspective, with much of the research emphasizing its potential benefits and purposes (Hardy and Phillips, 1998). Many innovations can be considered unbounded within the construction's inter-organizational context (Harty, 2005). The AEC industry is well known for its interdisciplinary knowledge. The collaboration process involves sharing decision making as well as data and resources (Popp et al., 2004). Project managers receive diverse information that must be checked for the reliability of content and source. With the participants of construction projects being specialized and segmented, suboptimal and inefficient solutions will be found, because each participant usually focuses on its own interests and tries to maximize these. These phenomena make us start rethinking of the collaboration of construction projects, in which legal and informal boundaries need to be overcome over the life cycle of the project-based construction. As the implementation of BIM brings in new and complex activities, an important topic is the identification of collaboration element in BIM projects.

2.2. The impact of emerging BIM on project management for construction

There is no universally accepted definition of BIM. In this study, BIM is defined as a process rather than just as software. The essential concepts for BIM were identified in the context of project communication with BIM in this research.

BIM is used for executing tasks more efficiently and in later stages more effectively, including things that were not possible before. The BIM support for collaboration has become an inevitable need due to the fragmented nature of the design and construction environment and the large quantities of information which need to be exchanged between the various participants (Isikdag and Underwood, 2010). It means that in design and construction, organizations depend on information technology to execute their specific well-defined tasks to make construction projects possible.

Therefore, the process of BIM implementation should focus on balancing these social and technical subsystems within a project in order to ensure joint optimization of both subsystems. In particular, the AEC sector is highly collaborative and requires collaboration among multiple parties.

Discussions on BIM often include arguments for collaboration across organizational boundaries. Some argue that new technologies (and BIM in particular) offer an opportunity to the paradigm shift of construction work practices (CURT, 2005) while others suggest that successful adoption of BIM requires the technologies' changes to adapt to the current work of team members (Hartmann, 2008).

However, Hartmann et al. (2008) found that most of the projects have applied 3D/4D models for only one application area in one project phase through 26 case studies in major construction projects and the majority is in the design phase. Similarly, the findings of a survey conducted by Howard and Björk (2008) indicated that BIM solutions seem so complex that they may need to be initially applied in limited areas. The coordination is limited to visualization and clash detection (Shafiq et al., 2013). Researchers contend that designers and contractors are adopting BIM tools slowly when compared to the earlier adoption of 2D CAD (Whyte et al., 2002). Important reason for this is that BIM projects are often tightly coupled technologically, but divided organizationally. This means that BIM is not fostering closer collaboration across different organizations though it makes connections among project members visible (Dossick and Neff, 2009).

Collaborative design and construction build upon two recent trends in the AEC industry that have seen the widespread adoption of technologies such as BIM and innovative processes such as IPD. However, these innovations are seen to develop in isolation, with little consideration of the overarching interactions

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