Critical Success Factors (CSFs) of BIM Implementation for Collaboration based on System Analysis

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ABSTRACT

It has been recognized that building information modeling (BIM), as an emerging information communication and technology (ICT), can improve project collaboration to different extents. However, because of the fast progress of BIM adoption both on the scope and in depth, there is a knowledge gap between practice and theory that lack of systematic analysis on critical success factors (CSFs) of implementing BIM for collaboration in construction project. This paper develops a framework of BIM implementation for collaboration from technical, organizational, process and legal scopes, and identifies the CSFs of BIM in each scope based on the latest publications. From system analysis perspective, the pair-relationship matrix is established to reveal the hidden effect between CSFs. The CSFs in the specific BIM application areas are identified based on the matrix.

INTRODUCTION

In order to acquire the full benefits of BIM, construction companies have been continuously working on how to integrate BIM into construction projects under limited resources. The existing weaknesses in CSF research includes: (1) Too many factor are collected as CSFs in current research publications, and the definitions are either too abstract to understand or too specific to induction; (2) As a holistic system, researchers usually neglect the hidden effect between factors, which will result in inaccuracy of the final result; (3) Some publications just concentrate on selecting the CSFs, while ignore how they could contribute to the future research. In this paper the authors develop a project-oriented framework of BIM collaboration which identifies the CSFs of BIM collaboration, builds the relationship pattern of CSFs based on system analysis, then selects the CSFs of BIM collaboration in some application areas.

CSFs OF BIM IMPLEMENTATION FOR COLLABORATION

Researchers acknowledged that both technical and organizational factors should be considered to evaluate BIM for collaboration (Shelbourn et al. 2007; Erdogan et al. 2008). Gu and London (2010) listed a number of barriers of BIM adoption in literature which contains technical, organizational and process scopes. Alfred (2011) pointed out that BIM required a new set of legal instruments to achieve its promise. Based on the existing research, this paper develops a project-oriented framework of BIM implementation for collaboration, which contains four major aspects: technical collaboration, organizational collaboration, Process collaboration and legal issue. Each scope is divided by several CSFs that are shown in Figure 1.

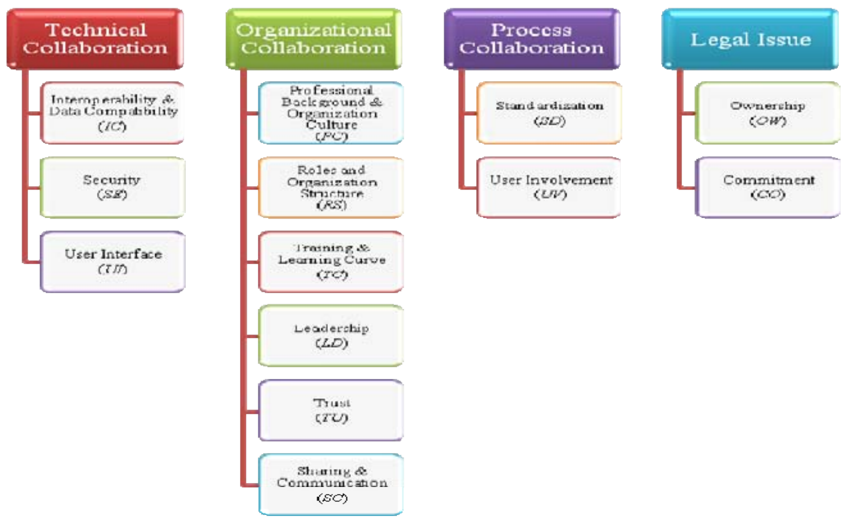

Figure 1 Project-oriented framework of BIM implementation for collaboration

13 CSFs are selected from 16 research papers published in the last 8 years in BIM implementation and collaboration, IT/ICT adoption and collaboration, and traditional collaboration research areas (see Table 1).

Table1. Reference of CSFs selected from literature review

Reference	CSF for BIM Collaboration												
	IC	SE	UI	PC	RS	TC	LD	TU	SC	SD	UV	OW	CO
Allen et al(2005)				★								★	★
Nitithamyong and Skibniewski(2006)		★	★			★						★	
Erdogan et al(2008)	★	★	★	★	★	★		★	★		★		
Salem and Mohanty(2008)	★			★									
Dossick and Neff(2010)				★			★	★					
Adriaanse et al(2010)		★		★						★			
Gu and London(2010)	★	★				★		★		★			
Jung and Joo(2010)	★									★			
Lam et al(2010)	★	★		★		★							★
Singh et al(2010)		★	★	★	★	★			★	★			
Xue et al(2010)				★				★	★	★	★		
Alfred(2011)		★		★							★	★	★
Azhar(2011)					★	★				★	★	★	★
Arnold and Javernick-Will(2013)	★								★		★		
Hwang and Lim(2013)											★		★
Won et al(2013)	★					★	★		★	★		★	

Technical Collaboration

Interoperability & Data Compatibility. Rigorous efforts have been made to standardize data exchange, such as IFC, IDM and etc. Poor interoperability lead to information barriers and rework. A common issue of this problem is data re-entry. However, data re-entry is not only a technical problem, but also an organizational one. For example, stakeholders with different backgrounds would select different software based on their own benefits.

Security. Although the advancement in encryption technology has made transfer of project data much safer, users of IT systems still worried about unauthorized access, and e-documents are still vulnerable to viruses, hacking and etc. (Alfred. 2011, Lam et al. 2010). Low security always reduces the efficiency of remote communication, information sharing, and harms trust between stakeholders.

User Interface. User interface of BIM software should be friendly and customized based on user's background and role, which will improves user involvement and compatibility (Singh et al. 2011). Sometimes, users from different disciplinary backgrounds only want to adopt their current software, it is essential to integrate and standardize the output of data type among all BIM players.

Organizational Collaboration.

Professional Background & Organization Culture. Different backgrounds and culture among practitioners sometimes impede collaborating work. There is a resistance to change from deeply rooted industry traditions that hinders the BIM implementation and collaboration. An evident case is that although BIM and other VDC technologies have been applied in construction industry for years, practitioners still rely on hard copies against soft copies, which adds additional workloads and information mismatch.

Training & Learning Curve. As an emerging technology, actors with different background may have large different experience with BIM, which will generate outcomes with variable accuracy. To optimize BIM performance, either companies or vendors or both must find ways to lessen the training and learning curve of BIM trainees (Azhar. 2011). In addition, training program must be built based on different requirements, from global and standard to specified and advanced (Singh et al. 2011).

Sharing & Communication. Won et al. (2013) claimed that willingness to share information among project participants was considered as one of the most critical factors to adopt BIM. BIM expands the work scope and blurs the boundary of stakeholders, which requires effective information and knowledge exchange, and efficient inter-organizational communication. In fact, BIM only technically achieves information and resource, synchrony communications still relay on organizational features, such as leadership, trust and etc.

Trust. To date, the lack of trust on completeness and accuracy of 3D model has remained a major concern for the practitioners involved (Gu and London. 2010). At the inter-firm level, researchers believe that trust is a key element for cooperative relationships. The full benefits of BIM as a collaboration platform cannot be achieved without trust between different stakeholders (Singh et al. 2011).

Leadership. Dossick and Neff (2010) argued that BIM-enabled projects are often tightly coupled technologically, but divided organizationally. To avoid this risk, construction projects still need individual leadership to hold the people together and inspire communication. For project leaders, managing team members' expectations under the limited impact of BIM could reduce some of the frustration caused by organizational loose coupling.

Roles & Organization Structure. BIM is a cross-boundary system**,** new roles, such as BIM manager, and organization structure of project teams arise in BIM-enable projects (Singh et al. 2011). Within organization, Roles can be redefined based on individual's backgrounds. However, among organizations, project teams need to reestablish new communication channel and redefine the working pattern based on the new organization structure and role of their partners, which has direct impact on the BIM collaboration.

Process Collaboration

Standardization. Up to now, there is a lack of BIM documents which could provide instructions on BIM application and use, and on how BIM can be integrated with the current business practices (Gu and London. 2010). Players adopt BIM just based on their own definition which will result in low-efficiency when they cooperate with partners. Thus, in order to avoid this difficulty, there is a need to standardize the BIM process and define the guidelines for its implementation (Azhar. 2011). However, participants should also understand that BIM can be accessed for only parts of the project's lifecycle, the flexible scope of BIM must be realized in the AEC industry.

User Involvement. Erdogan (2008) found that unsuccessful projects are usually due to the facts that the users were kept away from all decisions at the design and construction phase. With owner's review, suggestion and feedback, consultants can better understand the owner's requirements and help ensure that the project is on track (Hwang and Lim. 2013). While, finding a right time to include the right people will undoubtedly be a challenge, more factors should be considered under this circumstance (Azhar. 2011).

Legal Issue

Ownership. Ownership of BIM needs to be protected through copyright laws and other legal channels to ensure data's security and owner's benefit. American Institute of Architects(AIA) have formalized and documented legal regulation for digital design system, and argued that ownership of the final output should belongs to the client. While the passive impact of this regulation is that designers no longer want to bear the risk of design errors, rather use this as an excuse to transfer commitment to the ultimate owners (Alfred. 2011). Thus, model ownership combine with security system may in turn restrict users' access and hinder communication.

Commitment. Commitment defines who will control the data enter into the model and be responsible for any inaccuracies. In construction projects, the temporary participants with different objective and culture hinder the high performance (Brewer et al. 2006). Hence, such issues must be addressed in the contract document, case law, regulation and status. BIM documents must be carefully formulated to avoid unnecessary legal issues.

SYSTEM ANALYSIS

A system is "a set of interrelated components that must work together to achieve some common purpose" (Martin et al. 2005). As a BIM-based collaboration system, the interaction among CSFs must be identified to improve the accuracy of research's value. For instance, incompatible software may not the only reason of information mismatch, other possible reasons includes: different organization culture and legal problems. Based on the literature review, case study and practical experience, the pair-relationship matrix of CSFs for BIM collaboration is developed (see Figure 2), which shows the relationship pattern between different CSFs.

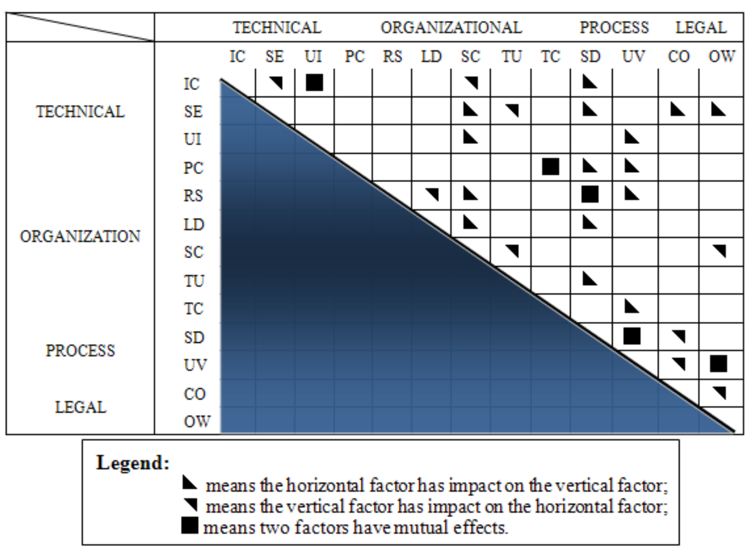

Figure 2 Pair-relationship matrix of CSFs for BIM collaboration

CSFs IN BIM APPLICATION AREAS

In practice, project participants only join parts of BIM, this means that practitioners will more interested in how to get the benefits of BIM in the specific areas they involved. However, there is a limited number of publications that directly identified the CSFs of BIM collaboration in different application areas because BIM promotes the integration of design and construction practice, and dim the bounds of participants' work. Based on the systematic analysis method of CSFs discussed above, the problem can be solved.

BIM application areas. Refer to the demarcation of major BIM application areas from Azhar (2011) and Eastman (2011), this paper selects the areas as: Parametric Modeling, Clash Detection, and Fabrication, 4D Scheduling, 5D Cost Estimating and Facility Management.

Parametric Modeling. BIM-based parametric modeling system combines the spatial model with its function, production and other criteria together as a system, each element in this system is linked with the others (Eastman et al. 2011). The use of BIM allows designers create intelligent 3D model with analysis and simulation tools to do the preliminary cost estimation, energy efficiency, operation simulation and etc.

Clash Detection. BIM-based clash detection provides many advantages over traditional 2D methods, for example, not only the building components overlay can be detected, the crew space, equipment space, hazard space, protected and temporary space can also be detected. In order to eliminate most space-time conflict problems from BIM-enable clash detection, effective communication channels must be established among BIM participants.

Fabrication. Today, fabricators produce and assemble many building components offsite in factories and delivered to the site for installation (Eastman et al. 2011). In order to alignment onsite construction with offsite fabrication, owners and designers must allow contractors and fabricators access the parametric model early, and cooperate with them to decide the job content before the construction phase begin.

4D Scheduling. BIM allows schedulers to create, review and edit the schedule with 3D model, which always called 4D schedule modeling. Mature 4D modeling includes: schedule and BIM import, BIM model update, reorganization, temporary components, animation, analysis, output and automatic linking processes(Zhou et al. 2012). Thus, both technical and nontechnical are essential to ensure the sequencing process efficiently.

5D Cost Estimating. 5D model is 4D integrates with cost estimating tools which could automatically extract and update material quantities when any changes are made in the model(Azhar. 2011). The BIM-enabled parametric model provide preliminary cost estimating during the early design phase, track variance between budget and actual cost, and enhance procurement management during construction phase.

Facility Management. Researchers start to pay more attentions to applied BIM during operation and maintenance phases in recent years. A survey investigated by Becerik-Gerber(2012) claimed that the barriers to implement BIM in FM includes: unclear and invalidated benefits of BIM in FM practices; amount of work that needs to be done; lack of interoperability; lack of clarity about responsibility; lack of effective FM tools and process; and FM personnel's limited BIM knowledge. Thus, the ability to support facility management is considered as a valued-added feature for the BIM approach.

CSFs for collaboration in BIM application areas based on system analysis. On the basis of the characteristic of BIM in each application areas, the CSFs which have already been recognized are gathered. Then, according to the system analysis pattern (Figure 2), all specific CSFs can be identified, as showed in Table 2 below.

Table 2 CSFs of BIM for collaboration in specific application areas

BIM Application Areas	Major Participant	CSFs Recognized	CSFs identified Based On System
Parametric	Designer	SC; TC; UV	All CSFs except: IC
Clash Detection	Contractor	SD; SC; LD	All CSFs except: TC
Fabrication	Fabricator	SC; SD; IC;	All CSFs except: TC；
4D Scheduling	Contractor	IC; SD; TC	All CSFs except:
5D Cost	Contractor	IC; SD; TC	All CSFs except:
Facility	Facility	CO; IC; SD;	All CSFs

CONCLUSION

This paper develops a framework of BIM implementation for collaboration, collects the CSFs from the technology, organization, process and legal scope, and determines the relationship of the factors based on the system analysis approach. The CSFs in each specific BIM application areas are identified based on the result. This paper could be a guideline for future works for BIM collaboration in specific application areas. The major limitation of this paper is that CSFs are only collected from literature review, no case study or survey is conducted to validate the accuracy in practice. The future work of this paper includes: (1) Conducts an industry-wide survey to validate the result of this paper; (2) Establishes a quantitative model which could assess and optimize BIM-enabled projects.

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