BIM COLLABORATION: A CONCEPTUAL MODEL AND ITS CHARACTERISTICS

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Relationship management has become an important issue for both academics and practitioners in construction project management. Few study provide a clear picture of what specifically constitute collaboration in a construction project in the existing literature and the practical approach. Limit research focus on developing a collaboration theory in construction management. The advent of Building Information Modeling (BIM) has been proved to be helpful for improving project coordination and productivity. However, widely adoption of BIM does not change the fragmented nature of construction sector. An understanding of how to promote such collaborative relationships in BIM enabled projects is crucial to achieve the full potential of BIM. By analysing the characteristics of collaboration from a management perspective and investigating current BIM implementation strategy, this research develops a conceptual model of collaboration in BIM enabled projects and identifies main factors of collaboration. The model categorizes collaboration into three dimension, they are collaboration team characteristics, collaborative environment, and collaborative process. Model also presents high level of collaboration can result better project outcomes and participants satisfaction. This model can be generalized to construction sector and standardized to collaborative process for future BIM implementation.

Keywords: BIM, collaboration, project management

INTRODUCTION

Many studies show that inter-organizational collaboration can improve competitive advantage of firms, facilitate innovation, promote coordination and productivity and other tangible and intangible collaborate benefit (Amabile et al. 2001; Dyer and Singh 1998; Gray 1985; Simonin 1997; Tjosvold 1986). Interorganizational relation studies focus on the relationships among organizations. Analysing relationship helps people understand the characteristics, motivations, rationale and outcome of interorganizational relationships. More and more social events and business move toward complexity and multi-disciplinary. Interorganizational relationships exist in terms of strategic partnership, alliancing and networking in many sectors (Cropper et al. 2008). Collaborative relationship is vital to the process of project delivery in construction. Developing collaborative interaction cross professions has become a key issue for both academics and practitioners in recent years. Studies report the poor productivity and fragmentation in construction industry. There are some improvement and applications of collaboration strategy in construction sector including alliancing, partnering and PPP etc. However, project participants have different objectives and

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interests to the project, and they are subsequently fulfilling their responsibility and maximizing their interests and benefits accordingly. Thus, construction project organizations are, in essence, moving away from integration or collaboration toward a fragmented approach. Nevertheless, some key elements of collaboration have been addressed. Although practitioners agree to promote the collaboration and establish a partnership among the project parties by innovative procurement strategies and contract arrangements, the full collaboration challenges appear to be enormous, as evidenced by many researchers. American scholars report significant losses due to less collaboration effectiveness result in either losses of project performance or unsatisfactions of participants (Gallaher and Chapman 2004).

Previous studies have focused on relations between individuals' relationship and project performance in a construction project, such as the link between individual cooperation and project performance (Anvuur and Kumaraswamy 2007), the link between relationship management strategy and project performance (Phua and Rowlinson 2004) and partnering (Bresnen and Marshall 2000). However, little attention has been given to inter-organizational collaboration in BIM enabled construction projects. There is no clear evidence of successful collaboration approaches of BIM adoption, or the reasons BIM collaboration may potentially fail. Furthermore, the existing literatures and practical BIM applications do not provide a clear indication of what specifically promotes the collaboration in BIM enabled project and why collaboration is vital to the success of BIM implementation in a construction project. Some professionals view BIM as a collaborative technology or software, whereas others treat BIM more expansively and are aggressive in developing collaborative relationships with all the project stakeholders. BIM is accepted for its efficient and effective utilities in project delivery. However, high levels of integration do not represent high levels of collaboration. Furthermore, characteristics of high levels of collaboration are critical to project success such as willingness to cooperate and willingness to share knowledge (Jassawalla and Sashittal 1998). In addition, some companies have implemented BIM to a greater degree than others. Therefore, it is important to identify the characteristics of BIM collaboration that companies can promote and to explore how these relate to their project success.

The key objective of this research is to develop a conceptual framework of interorganizational collaboration in BIM enabled projects and investigate the factors contribute collaborative BIM adoption. Based on the literature review of interorganizational works in other sectors and the importance of collaboration in construction management, this study demonstrates a conceptual model of interorganizational collaboration in BIM enabled projects. In particular, we discuss the characteristics and functions of collaborative strategy that impact to the project performance. Developing such a measurable framework of collaboration will enable us to determine whether higher levels of interorganizational collaboration are associated with better project performance and more satisfaction of BIM implementation.

THEORETICAL BACKGROUND OF COLLABORATION

One challenge of collaboration study is that any definition is contingent on the level at which collaboration is situated in an organization or what people believe about the appropriate level of collaboration. Interorganizational relations exist among two or more persons representing different organizations in a relevant way. In this study, we focus on the collaboration at inter-organizational level. This perspective includes the

building of whole picture involving all the project participants and phases in a BIM enabled project. This view addresses the importance of cross-discipline collaboration from early stage of construction project to the end of project. Therefore, this study provides an explicit structure to manage the entire inter-organizational relationship systematically. For this point of view, professionals establish a working relationship based on a mutual objective, but conflictual relationships and problems may rise during the work. Different collaboration attitudes and various personalities of professionals stimulate various relationships. These relationships may create either positive or negative influence to the final project outcomes. Collaboration on organizational level would capture these interactions and, based on the research output, people can assess the influence to project performance from these interactions.

In reviewing the different studies of interorganizational relations in different sectors, theorists explain the relationship from social, political, economic and management perspectives (Cropper et al. 2008; Wood and Gray 1991). A key theoretical foundation for collaboration research is the relationship management literature. Blois (2002) identifies that transaction cost analysis (TCA) is frequently inappropriate adopted for analyzing exchange relationship. TCA proposes transaction as the unit of analysis. However, relational contract theory refers to the parties involved in an exchange. The parties can either be individuals or organizations. Macneil criticizes Williamson's TCA as discrete transactions. He (1981) claims that even a repository transaction involves contractual relations. Dwyer et al. (1987) differentiate discrete exchange from relational exchange in a buyer-seller relationship according Macneil's argument. Macneil (1981) differentiates discrete transactions from relational contracts. Relational exchange exists in an on-going relationship over time. It is based on its collaboration history and future. The potential of future collaboration relies on cognitive perception, trust and planning. Participants in relational exchange can achieve social satisfaction when engaging in a relational exchange (Dwyer et al. 1987). To the broader extent that relational exchange is multi-dimensional and depends on the nature of relational contract. Blois (2002) studies business to business exchanges and he identifies that 'exchange' and 'relationship' represent aggregations of numerous activities undertaken by all involving organizations. Thus, there is 'relationship' between organizations. Few scholar pays attention to processes of inter-organizational relations and how these relations emerge, evolve and terminate over time. Ring and Van de Ven (1994) develop a process framework of cooperative inter-organizational relationships focusing on formal, legal and informal social-psychological processes. They identify that process as the central to managing inter-organizational relationships. Gray (1985) claims that many problems beyond the control by any single organization which is viewed as indivisible problem. Furthermore, Gray (1985) analyses the conditions that facilitate the three phases of collaboration: problem-setting, direction-setting and structuring.

Althogh they developed a collaboration framework from the perspective of education, cross profession collaboration is similar to construction industry. Academic practitioner research collaboration is temporary and project based. Construction project is also project based. It is different from general collabroation studies in other sectors, individuals as the representatives of their mother company work with other professionals in a construction project temporarily form a project organization. In this project organization, each profession work with each other and rely on the output from other professionals. At the same time, they always consider the outcome of their contribution and the interest of their represented company. Furthermore, the

organization is dynamic, some individuals may leave project before completion, but the impacts of their activities beofre may affect to the outcome of final project. We borrow definition of collaboration from Jassawalla and Sashittal, they describe it as "the coming together of diverse interests and people to achieve a common purpose via interactions, information sharing, and coordination of activities" (Jassawalla and Sashittal 1998:239). Amabile et al. (2001) claim that there is little research about corss-profession collaboration. They build up a cross-profession collaboration theory and claim three determinants of successful collaboration: Collaborative Team Characteristics, collaboration environment characteristics, and collaboration processes (See Figure 1). Each determinant contains sub-categorized factors that influence its extent. We borrow their concepts and principles to construction industry. Hence, we discuss the characterists of BIM implementation in construction and explain how these factors influence the success of a BIM enabled project.

Figure 1. Collaboration Determinants and Outcomes by (Amabile et al., 2001)

BIM COLLABORATION

BIM is a collaborative approach to construction that involves integrating the various disciplines to build a structure in a virtual and visual environment. The essence of BIM implementation is collaborative working process in construction work. Therefore project participants could generate the maximum benefit of collaborative arrangements increasing efficiency and effectiveness (Succar 2009). The process allows project team to work effectively, particularly when identifying potential problems before they start to build on site. AIA defines BIM as "a digital representation of physical and functional characteristics of a facility"(AIA 2007:53). As such it serves as a collaborative platform for all stakeholders to share their knowledge resource and information. Sufficient information increases communication effectiveness. Effective communication allows stakeholders to exchange accurate, update and clarified information for decision makers to form a reliable decision. AIA also identifies that "BIM is a shared digital representation founded on open standards for interoperability" (AIA 2007:53). Therefore, BIM demands collaboration in order to unleash the utility of BIM implementation and maximize stakeholders' return on investment. Succar (2009) demonstrates three stage of BIM: object-based modelling, model-based collaboration and network-based integration. It is important to know that

BIM project requires a specific process of activities. The process involves high level of transactions on data, information and knowledge. A successful BIM project highly relies on effective collaboration among project participants including owners.

BIM becomes one way to cope with the cooperation, integration and coordination challenges faced in construction. However, very little study investigates BIM from the perspective of project management. Many study recommend construction industry to move toward Integrated Project Delivery (IPD), but few identify that IPD as the ultimate objective of construction project delivery method strongly demands closer collaboration and more effective communication (Eastman et al. 2011). BIM has been proved that enhance collaboration and information sharing comparing those traditional construction processes. BIM is linked to higher level of efficiency in terms of communication and collaboration (Bryde et al. 2013; Grilo and Jardim-Goncalves 2010; Lee 2008; Olatunji 2011). Sebastian (2011) confirms that multi-disciplinary collaboration can be achieved through optimal use of BIM, but changing roles of key parties, new contractual relationships and re-engineered processes challenges need to be overcome. Further, Bryde, Broquetas, and Volm (2013) identify that coordination defects are the second largest negative impact to project performance after software issue in 35 construction projects BIM enabled projects. Collaboration issue cannot be demonstrated by any single contract theory or economic theory. Few study expose the complexities of collaboration in BIM implementation. All the project participants need to be aligned with self-interest, mother company's requirement and project objective. So this is not an issue of individual collaboration in a team or an organizational collaboration issue in a joint venture. Collaborative process is one of the key factors for BIM success. The full potential of BIM can be realize by considering knowledge, technology and relationship. Many researches focus on the discussion of BIM technology. Few research address the importance of collaborative process of BIM implementation.

MODEL DEVELOPMENT OF BIM COLLABORATION

Based on Amabile's collaboration framework, our model suggests that each of the determinants of BIM collaboration has sub-categorized factors (See Figure 2). First, four preconditions of collaborative team characteristics are identified, they are professional knowledge, collaboration skill, attitudes and motivation and BIM acceptance. The most important features of professional knowledge in BIM project apear to be their profesional experience and the understanding knwoledge of BIM (BIM acceptance). Simonin (1997) argues that organizations change their approach to collaboration according their experiences with past partners. Complementarity of professional knowledge contribution across diciplinaries assure the proceeding of construction project and inter-organizational collaboration. Their BIM acceptance is the perception how they contribute to the utilization of BIM and motivate to collaborate with other professionals within BIM context. Collaboration skill referes to experience of collaboration with others and individual social skills with other team members in a project organization. When project adopts new technolgy such as BIM and use this technology, adoption triggers new challenges of organizaton inculding structures and power relations (Jacobsson and Linderoth 2010). BIM acceptance is important that participants have mutual perception of BIM implementation in a project. To what extend participant's BIM acceptance can influence the effectiveness of BIM collaboration. Attitudes and motivation appear to be individual intestest in learning BIM and incentive of using BIM. Regarding attitudes, trust is found to be the most important determinants paired with mutual respect and common understanding

that determine the appropriate team members (Jones and George 1998). Few attention given to cultural issues, We beieve cultural differences do exist but it doesn't impact the formation of collaborative project organizaiton. Because Hong Kong as an international city has a well delveloped history and achieves certain norm among profesionals no matter they are foreigners or new commers in construction industry in Hong Kong. They all can find their role and interact with other team members in a short period. In other words, the vacancy can automatically be filled by the appropriate person due to highly competitive and open maket. So, professsionals in construction industry work together as a temprorary organization to deliver construction projects, they have enough experience to break the cultural barriers and build up a common aggreement with each other. However, cultural issue may become important when dealing with other collaboration parties and industries.

Second, actions of individuals may impact cooperative inter-organizational relationships. Environmental conditions also influence the success of inter-organizational collaboration (Ring and Van de Ven 1994). Few scholars identify the importance of collaboration environment characteristics, despite a collaborative context is more likely to success (Amabile et al. 2001). Jassawalla and Sashittal (1998) demonstrate a framework of interorganizational collaboration. In this framework, organizations create macro-environmental forces and organizational forces impact the extent of collaboration achieved. The degree of institutional support that individuals receive from their home institutions can determine their willingness to contribute their time and resources to the project. In BIM enabled projects, BIM maturity varies from projects and organizations. Sometimes, BIM maturity is also constrained by technology itself (Porwal and Hewage 2013). Contract strategy is an important moderating variables in BIM collaboration. This will directly lead the success of BIM implementatin as a whole. Practically, we find people adopt BIM under traditional procurment strategy such as design-bid-build which eliminate BIM as a visualization tool at earlier tendering stage. Some other cases we encountered that advisarial contract bind the motivation of individuals to collaborate with other company representatives due to economic consideration and provide minimum contribution according contract responsibility. However, the situation changes significantly in a relational contract environment. Professionals work together as a team and more willing to communicate and solve problem together and creatively. Therefore, we investigated specific contract strategy as a contextual characteristic for our research.

Last, an operational platform with appropriate technology is likely to facilitate professionals to communicate and collaborate. Gray (1985) developed a process model of collaboration: problem setting, direction setting and structuring. In this model, specific goals are set, clear roles and tasks are assigned to participants. Collaboration can be enhanced in this sustainable long-term activity. (Gray, 1985); Ring and Van de Ven (1994) identify the importance of process development in an inter-organizational collaboration. Furthermore, this process is dynamic and evolving over time. BIM collaboration is mainly utilized through its process. This results high demand of software interoperability and clear role and responsibility for each party (Porwal and Hewage 2013). Although it is difficult, interorganizational collaboration depends on specific input and effort contributed by individual members to have a common understanding of roles and responsibilities in different organizations (Patel et al. 2012). Greenwood and Wu (2012) also confirm the link between communication and collaborative working. Based on these two sub-conditions, process could be

fluently developed through a well communication context. Both formal and informal communications are crucial to the success of project delivery (Li et al. 2009). Patel et al. (2012) demonstrate a framework of collaboration model. In their model, several factors are identified positively relate to the collaborative working. They claim that collaborative decision making involve both formal structured judgement and informal alternative exploration. Decision-making strongly relies on collaborative process and experience of participants. Satisfied decision-making can increase the individual satisfaction and commitment. Uncertainty and conflicts emerge in construction process. Different decision may cause negative relationship. For this reason, decision making in collaborative process is important. When project has high levels of collaborative relationship and participants are willing to share information and communicate, conflict decreases.

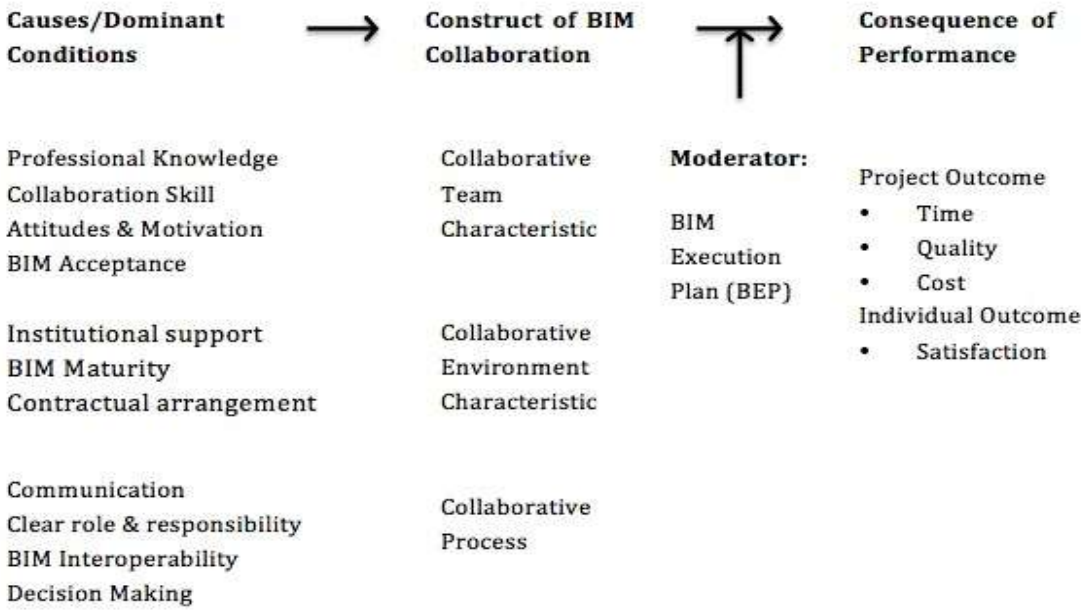

Figure 2. Model of BIM Collaboration and Outcomes

BIM execution plan (BEP) is reported as a priority before BIM implementation. A well defined BEP is able to assure the compliance of project objectives and requests (BSI 2013). Further, McAdam (2010) identifies BEP as the key to the information management. BEP sets out protocols for interoperability, project delivery milestones, dimensional accuracy and other details. He also claims that BEP specifies roles and responsibilities for team members and makes BIM collaboration successful. It is clear that there are correlated relationships between BEP and BIM collaboration success. Because there are more positive effects, we herewith hypothesize a positive moderating effect for BIM collaboration. According to our interviews, a well-prepared BEP can reduce the uncertainty and clarify the role and responsibility in most of BIM enabled projects.

In terms of consequence of collaboration, Chan and Ho (2001) test the relationship among overall project performance, interorganizational teamwork and participants' job satisfaction. Well developed construts of BIM collaboration facilitates better project performance as the consequence of colaboration. Together with individual outcome such as satisfaction to the project and personal achievement through the participation can confirm the positive impacts of BIM collaboration. Many researchers measure time, cost and quality as the measurements of project performance (Blois and Ivens 2006; Bresnen and Marshall 2000; Grilo and Jardim-Goncalves 2010; Phua and

Rowlinson 2004). Greenwood and Wu (2012) test different degrees of collaborative working relative to project performance and identify that higher level of collabroative working is more likely to produce higher levels of project performance. Other researchers also address that working relationships have positive impact on project performance in terms of project time cost and quality. This research conceptualizes the formalization of how to collaboration in BIM enabled projects. If participants are able to collaborate through construction project, they are able to perform more productively and project is more successful. In certain way, company will transmit those benefits to individual benefit such as incentives and more investments in technology and training. This demonstrates us how it can align idividual satisfaction to the project success.

DISCUSSION AND CONCLUSION

The goal of this study is threefold: 1) to develop a concetual model of BIM collaboration, 2) to investigate whether the BIM collaboration is link to project performance and individual satisfaction, and 3) to identify BEP as a moderator of BIM collaboration and project performance. Based on literature review, past researches support for our conceptual model of BIM collaboration for the dominant conditions. We identify key BIM characteristics in terms of three BIM collaboration determinants: collaborative team characteristic, collaborative environment characteristic and collaborative process.. We then structure the dominant conditions as measurements to assess the extent to which those constructs are perceived. This is an important contribution which fill the gap between BIM technology and project mangement theory. First, this represents a theoritical foundation for promoting BIM collaboration. Second, this demonstrates a framework of measuring BIM collaboraton. Third, there are many researches promoting collaboration both in constructon industry and other disciplines. BIM is also discussed intensively from the perspective of technology. This research bridges both by providing a guide for examination. Last, we highlights the importance of collaboration issues in BIM enabled projects and indicates the relation to project performance and individual outcome.

BIM provides people a new working logic in construction. The constructs capture the degree of BIM collaboration. If project team is able to work more collaboratively and understand the value of BIM collaboration, they can perform more effectively on their task delivery and information sharing. Project then can be completed more efficiently. As a result, all the stakeholders can benefit from time saving, cost saving and good quality. The collaborative process within BIM implementation is essential for the exchange of project information and professional knowledge. All the parties can satisfy with project performance according to such efficient and effective interaction. Given the essential role that collaboration plays in construction project, it is important that we understand the collaborative process within BIM enabled projects that leads higher efficiency and better performance. An examination of these collaborations using ideas and theories borrowed from previous researchers with be helpful to identifying strengths and weakness in BIM implementation and will provide the basis for a model of an effective BIM implementation. Beyond collaboration analysis, a better understanding of the BIM process has potential benefits for a number of project participants that adopt BIM technology to problem solving, including coordination, communciation, resource and knowledge sharing and innovation.

Of all the discussions, it is worthwhile that future studies focus on more individual specific and company specific characteritics contribute to BIM collaboration. BIM

collaboration study should be dynamic and cross professions. It is also possible that technology changes and improves over time. It also should be noted that contractual arrangement should be customized according to the BIM adoption in order to maximize the utilization of BIM.

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