SOCIAL CAPITAL, SOCIAL NETWORK AND DIFFUSION OF BIM PRACTICES

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Building Information Modelling (BIM) practice is increasingly accepted in the construction industry, it can now be fairly interpreted as industry best practice. However, the acceptance process of the practice can be affected by greater social forces, social ties, social structure, and systems of the organization/project team, and these effects have yet to be explored. Based on a critical review of social capital and social network perspective, this study proposes a conceptual framework for analysing the social intelligence and the social network embedded in project teams that may impact BIM practices. The conceptual framework consists of five key determinants: structure of interactions, intensity of interactions, exposure of interactions, quality of interactions, and resources. This study proposes a direction for future research, a case study design, and a structural equation modelling (SEM) technique that will be used for evaluating the conceptual framework. Through this research, industry practitioners can use the framework to diagnose social issues and to leverage the social intelligence inherent in a social network for successful diffusion of BIM practice.

Keywords: BIM, social capital, social network

INTRODUCTION

Building Information Modelling (BIM) in the Malaysian construction industry can be considered to be an emerging practice, despite it having received fairly extensive attention from both academics and practitioners. BIM practice is often presented as an attractive business proposition to improve productivity, reduce costs, and increase competitiveness; however, despite the huge potential for many areas, commitment to BIM practice remains uncertain across practitioners in the Malaysian construction industry, with the current reported level of usage largely limited to drawings and 3D visualisation, with separate data modelling and information management. It can thus be said to be at an early stage of maturity: at Level 1 (Zakaria *et al*., 2013) and entering a transition to Level 2 in the very near future. Many construction practitioners are believed to be eager to practice BIM and its applications; however, a lack of well-trained personnel, lack of guidance on the process and legal practice, and lack of support from individuals or government bodies (Rogers *et al*., 2015) are inhibiting factors.

Existing research has broadly concentrated on the internal adoption, success factors, readiness, and measurement of benefits of BIM (Enegbuma and Ali, 2013; Farzad *et al*.,

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Mohd Ishak, S S, Esa, M and Ismail, M H (2017) Social Capital, Social Network and Diffusion of BIM Practices *In:* Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference,* 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 73-82.

2014; Rogers *et al*., 2015; Zakaria *et al*., 2013); however, there is a lack of consideration of its strategic value in an inter-organisational environment. Diffusion of BIM practice in a project team environment remains the least explored area in the research. In addition, many of the perspectives or theoretical background on BIM implementation, processes, and practices previously adopted in the research have been based on the diffusion of innovation theories, acceptance models, and actor network theory. These provide general and background information, but will not provide much insight about the diffusion of the practice, commitment, interaction, and participation of project teams exercising BIM.

This study provides an extended explanation from the social viewpoint of innovation and practice, as based on the assumption that the social benefits, values, and interactions maximise the effective diffusion of BIM practice. This study suggests that the social benefits, values, and interactions of practising and implementing BIM could be thoroughly measured and derived from social capital and social networks that are created by the goodwill, mutual support, trust, shared language, and network exposure of many of the project team members.

The addition of a social network perspective is significant because it more explicitly recognises the influence that others exert on individuals' interactions toward innovation. An innovation can be described as an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 1962: 11). A viable framework would also translate more directly into strategic initiatives to provide practical help in addressing the social barriers and issues that challenge BIM practice in the construction industry. A change of perspective is also necessary to create a simplified structure for the plethora of factors associated with new or emerging practice/innovation in the construction industry, to improve the effectiveness of BIM practice.

Social network is a subject of interest in many disciplines. A significant review by Poleacovschi *et al*., (2017) highlighted the broad variety of social network perspectives being applied to understand knowledge transfer in construction research, and suggested that for a better understanding there is a need to integrate the social network (e.g. strength of weak ties theory) and social capital (e.g. network resources). They found that strong connections between individuals, based on knowledge, saved most time at doing work; however, not all strong connections delivered the same relationship pattern/implication. There are some other social network factors that can be associated with time savings, such as the frequency of communication, types of connections, motivation of interactions, and job role/position (e.g. individuals who are responsible for directing critical tasks).

The overall aim of this research is to establish a viable conceptual framework that incorporates the social network and social capital of the key factors that influence effective diffusion of BIM practice in project teams. Limited by the progress of the research, this paper is not able to provide specific research findings, which are suggested as future tasks. The next sections of this paper provide the theoretical background, propose a conceptual framework, future work, and conclusions.

THEORETICAL BACKGROUND

Social Capital

The topic of social capital has interested academics and practitioners for decades and continues to be of relevance today, as evidenced by its application to various disciplines and numerous subject areas. It should be noted that this is not a new area of inquiry. It also has not adopted a clear and substantive definition (Dolfsma and Dannreuther, 2003), and a study will be developed based on the discipline and level of investigation (Robison

et. al, 2002). In social research, for example, the "capital" dimension of the social is conceptualised as "bonding" and "bridging" (Putnam, 1995), which are considered to be important aspects by which to measure the social capital. Putnam (1995: 67) defined social capital as "features of social organization such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefit". Adler and Kwon (2002:13) defined social capital as goodwill that others have toward individuals or groups. Coleman (1990: 302) viewed social capital as function and structure, by which the structure contains different entities having two characteristics in common and they facilitate certain actions of individuals who are within the structure. Burt (2009) regarded social capital as a network of brokerage opportunities that can be obtained from relationships with friends, colleagues, and more general contacts. Similarly, Nahapiet and Ghoshal (1998) viewed social capital as networks and resources that can be delivered through relationships held by individuals or the social unit. Based on these definitions, it can be suggested that social capital is fundamentally about the value of interaction. Social capital lies in the structure, resources, and content of the social relations of individuals, and it affects the information, influence, and cohesion that makes individuals/actors available within the network. This study concentrates on these definitions and the four dimensions of social capital: structure of social interactions, intensity, content, and resources.

Structure of social interactions

Based on the concept by Coleman (1990), it can be stated that social capital is a form of social structure that has function, in which certain actions facilitated by individual members of the group/organization are defined by the social structure embedded within them. The social structure may exist in formal forms, such as organization, or in more loose social system, such as families and communities. Burt (2009) introduced the concept structural holes. The concept suggests that the diffusion of new ideas, information, and behaviour will be more efficient if an individual can maximize the number of redundant contacts, and concentrating on the primary contact, it saves time and effort in keeping a large network. It will also be effective if the primary contact is connected to a variety of secondary contacts (clusters of people) who have broad resources.

Intensity

The intensity of the social interactions of one organisation can be used as an indicator of the social capital (Nahapiet and Ghoshal, 1998). Social interaction involves the dissemination of information and resources between individuals or groups who modify their actions and reactions due to the actions by their interaction partner. These interactions involve engaging in intensive activity with people at various levels of an organisation or project environment. Through discourse in a social interaction, knowledge is diffused throughout the whole network. A number of current studies have demonstrated the importance of social interaction on knowledge creation, which provides additional insights into this subject.

For example, Koh *et al*., (2015) highlighted the intensive social interactions as one of the crucial factors that promote team members' engagement, learning, and independence at the team level, as well as the organisational level. Similarly, in a study by Molina-Morales and Teresa (2010), the authors investigated the effect of social variables on the firm's innovation. Their findings suggested a need to incorporate the social interaction on the use of innovation towards knowledge creation. Against this backdrop, the research evidence suggested further evaluation of the influence of social interaction in various innovation environments, especially with BIM technology, for successful knowledge transfer is needed.

Quality of content

The content of the interaction is concerned with effective connections and is a key aspect to the relationships. Effective connections or relationships should be grounded broadly on psychological integration or, in very specific terms, it should be based on the quality of the content, such as trust, intimacy, obligations, and expectations. A study by Bolina *et al*., (2002) found that effective networks within organisations are dependent on the level of trust between the parties involved. In another study, Molina and Martínez (2010) found that trust is fundamentally a social process, and without trust there will be limited information and knowledge sharing. The creation of a feeling of trust in a team makes people internally submissive and pleasing while giving an impetus to the emergence of much more powerful groups. These findings provide a firm support for the importance of understanding the underlying psychological perceptions that influence one's environment about desired outcomes.

Shared resources

Shared resources include the collective goals and aspirations of the members of the network, and they refer to any resources that could provide representations, interpretations, and systems of meaning among parties (Molina and Martínez, 2010). Knowledge, information, and ideas flow even more easily due to a shared language, codes, and narratives, which are the key factors in this aspect (Nahapiet and Ghoshal, 1998). They also may consist of elements of commitment and cooperation that encourage the sharing of information, mutual morale building, and coaching others to achieve demanding objectives. The shared resources of an organisation or team encourage interactive communication, which leads to a shifting of values by the parties involved toward common ground. For example, a study by Nahapiet and Ghoshal (1998) revealed that social capital is necessary for the development and dissemination of knowledge within organisations. Similarly, Huysman and De Wit (2004), who studied the practices of knowledge sharing in 10 large companies with more than 1000 employees, discovered that the notion of social capital should be seen as an important attribute for continuous transformation, shaping processes and a culture that together forms the intellectual capital of an organisation. The absence of a willingness by employees to share knowledge can cause significant damage to the relationship and consequently affect the efficiency and effectiveness of teams and organisations, particularly during the assimilation of any new knowledge.

Social Network Perspectives

Social network has been developed out of social theory and application, with formal mathematical, statistical, and software applications (Marsden, 1990). In the literature, a social network is often said to be a 'perspective', rather than a theory. The social network perspective contains theories, models, and applications that address the processes of interaction between individuals (Borgatti and Halgin, 2011). Borgatti and Halgin (2011) stated that network theory refers to the mechanism processes that interact with network structure to yield certain outcomes for individuals or groups. One example of network theory is the strength of weak ties theory (SWTT) by Granovetter (1973). When one person in a project team posits an idea, support from the other members of that project team should be readily apparent. Propositions, such as this, can be tested by adopting SWTT. SWTT assumes that social relationships are characterised by infrequent contact, an absence of emotional closeness, and no history of reciprocal favours. This theory posits that people actually frequently depend on other people with whom they maintain only 'weak ties'.

The social network perspective views social relationships between individuals in terms of nodes and ties. Nodes are the individuals or actors that are connected by the ties between them. The ties, or relationships, such as friendship, kinship, and so on, exist between nodes. An additional property is that, taken together, the characteristics of these linkages may be used to interpret the social behaviour of the persons involved. Wasserman and Faust (1994) described a social network as a finite set or sets of actors and the relation(s) between them. The term 'network' might imply that only those linkages that actually occur should be considered as part of the network. Since a network is defined as consisting of a finite set of actors, the boundary of the network should be established. However, according to Marsden (2011), the boundary for the overall network is often difficult to specify. The aim should be to focus on the entire structure of the social group by collecting one or more types of relations that link the nodes or actors within the group. In contrast, egocentric (small world) and/or dyadic approaches are focussed on only those network relations that immediately surround the actors. In this case, the aim is to make inferences about the features of the personal and their personalised network. For example, in surveying one sample of respondents, each respondent identified a set of people to whom they have ties, and indicated the type of relationship, along with the level of satisfaction they have with that relationship.

One consistent finding from the literature review is that a network is more likely to be used to provide information pointing to individuals and others within an organisation because of the adoption of innovations (new technologies, process, and practice). For instance, Valente (1996) noted in a study of personal network thresholds, that the social system in the adoption of innovation includes opinion leaders, peers, and followers who are connected to (or may work with) innovation. Opinion leaders, peers, and followers do not necessarily direct the adoption, but their own adoption behaviour (if combined) can influence the behaviour of others. Further, individuals vary in their willingness to take risks in adopting a new idea or product. Certain individuals accept the risk of adopting a new technology, idea, or product before anyone else. Some people are reluctant to adopt a new idea or technology and prefer to wait until other people have tried it first.

In the context of this research, the Social Network Threshold (SNT) model proposed by Valente (1996) is promising. It introduces a 'frame of reference' with respect to the social system and network that can be used to identify those individuals that will most likely play an important role in promoting adoption. The threshold is the exposure at time of adoption. Exposure is a measure of the proportion of previous adopters in an individual's personal network. Exposure can be estimated by counting the number of adopters in each individual's network that provide information and influence with regard to adoption behaviour. This number can vary. For instance, the individual who is earliest to adopt (or an innovator themselves) will have a low threshold of adoption. The early adopter will accept a new idea almost without intervention, and interpersonal network influences are rarely needed for adoption. Conversely, a late majority individual has a much higher threshold. The later majority individual's peer network must exert a heavy influence to overcome their resistance. In either event, however, an individual is more likely to adopt an innovation if more of the others in his or her personal network have already adopted that innovation.

Not all members of a network are equal. There are typically particular individuals who are more interconnected than others. These individuals are linked to others by patterned communication flows. Valente (2005) suggested a mathematical model as follows:

$$E_i = \frac{\sum w_{ij} y_j}{\sum w_i}$$

where E_i represents network exposure, w represents the social network weight matrix, and y is the vector of adoption. Using this mathematical equation in an example, if an individual i reports that two out of their three network contacts have already adopted a particular technology before they themselves adopted it, then the network exposure E_i is estimated at 66 percent (see Figure 1). If only one contact out of three network contacts has already adopted, then the network exposure value is 33 percent.

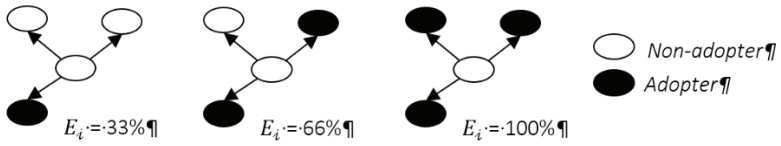

Figure 1: Example of different network exposures (adapted from Valente, 2005).

The SNT model also estimates the number of times that direct communication may have happened between the adopter and their network partners. Network partners are those who act in terms of friendship, direction, and advice, as well as discussion partners. These people may have a position as opinion leaders, peers, or affiliates. Opinion leaders have been theorised by Rogers (1962) as those individuals that have the greatest influence on the rate of adoption of an innovation. Peers are people who have the same position as the adopter, as based on the theory of structural equivalence. Affiliates, as derived from the SWTT by Granovetter (1973), are those who may know many facts about an innovation (e.g., technical staff, customer support service, and technology providers), but who are only loosely connected to the adopter in the network.

PROPOSED CONCEPTUAL FRAMEWORK

The rationale behind the social capital and social network used in this study is two-fold. First, in the organisation, individuals interact with and influence each other to produce homogeneity of "bonding" and "bridging". Bonding is channelled through bridging. The concepts of bonding and of social capital in this study refer to a capacity and quality for accessing resources in relationships (e.g. association, mutual benefits, and trust), while bridging refers to a social network or interaction between individuals across levels of structure, hierarchy, power, exposure, or proximity that promotes action. For example, a study by Orlikowski (2000) found that the use of technology in organisations is strongly shaped by users' understandings of the conditions and functionalities of a technology, actions (e.g. to achieve collaboration or process-support), and consequences of actions. Based on this view, the understanding of how and why people engage with BIM technology and practice can be associated with human actions and choices, and the conditions of technology that have evolved from social interaction. Orlikowski (2000) believed that social interactions can be viewed as support mechanisms when using technology. If supports are embedded and valued within social groups, technology use is alleviated. Consequently, people may choose to enact and adjust their behaviour towards the technology, based on a desire to share files with co-workers, or due to having become more knowledgeable about using that technology through attending training and/or watching co-workers' demonstrations.

Second, people do not belong to just one relationship or network in an organisation. They can be members of a number of different social networks, with each based on different types of interaction or relationship. For example, Pryke (2005) explored construction

project governance and identified the patterns of interactions between key actors, including clients, consultants, main contractors, and sub-contractors. Three main types of network were identified: contract, performance incentive, and information exchange networks. Pryke (2005) showed that the consultants were involved in all three kinds of networks, often concurrently. However, the degree of involvement varied. The consultants' roles were relatively weak in the contractual network and performance incentives network, but they played a very important role in the information exchange network. A recent study by Poleacovschi *et al*., (2017) tested the significance of social networks that facilitate the sharing of knowledge as related to time savings on work tasks, and based on these, it was confirmed that the knowledge network and strong knowledge connections are crucial to individual work productivity.

Arguments for using social capital and social network in observing the impact of a social system on the diffusion of BIM practice are clear: the structure, intensity, quality of content, and shared resources, as well as exposure of others, are important to how each individual responds to an innovation or adoption of new practice. To get a complete description of exposure, the research must look at employee-to-employee relationships, such as relations with and the support of, managers, acquaintances with other employees, and other relational variables. Co-workers may form a network based on the exchange of information relating to getting their job done. At the same time, they may also form a different network based on friendship. A network perspective is critical to better understand the decision to adopt, and to shed some light on the role and variety of networks that affect the extent of diffusion.

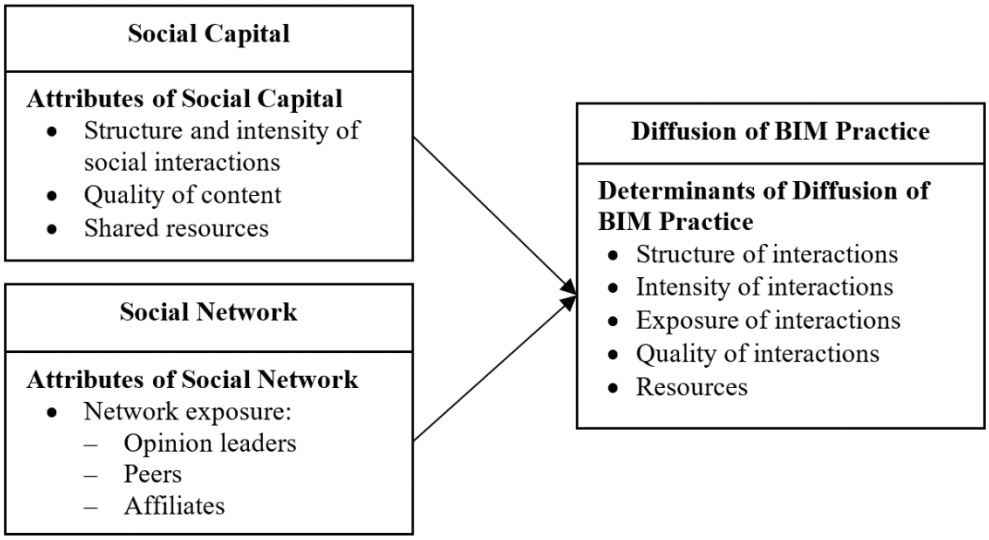

Figure 2: Proposed conceptual framework

Combining social capital and social network perspectives, as shown in Figure 2, a conceptual framework is proposed. The conceptual framework suggests five key determinants for the diffusion of BIM practice: (1) structure of interactions, (2) intensity of interactions, (3) exposure of interactions, (4) quality of interactions, and (5) resources. The structure of interactions refers to the relations between individuals across levels of the organisation, hierarchy, or project environment. The intensity of interactions refers to the weight or frequency of the communication that occurs between individuals and indicates network influence. The exposure of the interaction refers to the number of people in each individual's network that facilitate mutual actions. The quality of interactions is about the effective connections that are based on trustworthiness, norms,

intimacy, obligations, and expectations. Resources or shared resources include knowledge, information, and morale building embedded within the individual's network to achieve common ground. All these broader conceptualisations of the attributes explain in detail the characteristics of the networks and progression that should be considered in evaluating the successful diffusion of BIM practice.

Social capital is distinct from, but seems convergent with, social network perspective. Both are mature and established theories that contribute to the understanding of the importance of several important sociological concepts, such as social structure, intensity, integration, exposure, and shared resources. However, it is necessary to note a few of the weaknesses of the social capital and social network. For example, the parameters or estimations of a social network's exposure are typically based on two variables: exposure level and time of adoption; however, the time of adoption between them is typically not taken into account (Valente, 1996). Thus, the assumption that personal thresholds determine the speed of adoption has not yet been subjected to a robust test. Despite these weaknesses, the concepts and elements introduced through both the social capital and social network literature can usefully contribute to the broader consideration of the diffusion of BIM practice, particularly in terms of the variety of networks, network partners, and the roles of partners within networks at play and relative to diffusion. It also provides a basis upon which to measure the strength and intensity of a network, using the number of times that direct communication occurs between the individuals and their network partners to indicate network influence.

FUTURE WORK

A number of social attributes, based on social network and social capital, have been mentioned in this paper. However, while clearly interrelated, social network, and social capital are rarely studied or applied in concert, integrating these together is a means to enhance the social perspective and social intelligence of BIM. The social intelligence of BIM practice may improve the bureaucratic efficiency and stability of the practice. The social system, structure, resources, and associate networks can all affect the social intelligence, the decision of individuals and the acceptance of a new practice. A new practice may be entirely pleasing when it is adopted by an organization, but concerns about the flexibility, trust, obligations, and expectations may discourage its adoption in a project team. The more a person engages with others, the less potential there is for such disparities to arise. Seeking and receiving help with a new practice from others (e.g. supervisors, peers, and technical staff) can increase exposure to and promote the adoption of a BIM practice. Thus, this study addressed the following overarching questions that merit future research: (1) How can social intelligence of BIM practice be defined? (2) What are the social attributes that influence the diffusion of BIM practice? (3) What are the most promising networks of diffusion for BIM practice? To answer these research questions, a case study design and mixed methods research will be used. Data will be collected using two approaches: interviews and survey. The interviews are necessary at the early stage of this study, as they could help to establish the framework and initial network model, and also deepen the understanding of the proposed determinants. The survey is to test the initial model with a series of explicit research hypotheses. Data collected from the survey will be analysed using a structural equation modelling (SEM) technique.

CONCLUSION

Having considered the motivation for the research and theoretical foundation, it can now be stated that social theory/dimension provides key determinants of the diffusion of BIM

practice. Previous studies on BIM have focussed on a range of implementation factors of BIM application, thereby promoting bias and a limitation of our understanding of the specific social aspect. In this study, an extension to the social network and social capital concepts is proposed as a means to break this impasse. There is an important correlation in how the two theoretical perspectives might be considered in concert and extended with the BIM literature.

In summary, the core ideas in the literature and conceptual framework that have been reviewed/proposed here can be stated as follows: diffusion of BIM practice is directly influenced by social interactions and that social interactions are directly influenced by network structure, intensity, network exposure, quality of interactions, and shared resources. The social interactions fit together with the diffusion of BIM practice to sustain the diffusion process for the BIM practice.

ACKNOWLEDGEMENT

This research was supported by the Fundamental Research Grant Scheme (FRGS), Ministry of Higher Education [Grant No: FRGS/1/2015/TK06/USM/02/9].

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