Streamlining Information Transfer between Construction and Structural Engineering
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# BUILDING INFORMATION MODELING (BIM) ADOPTION AND IMPLEMENTATION: INTERACTION BETWEEN BIM USERS AND NON-BIM USERS

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The research introduces the combination of Diffusion of Innovation Theory and Activity Theory to investigate the process of adoption and implementation of BIM in the construction industry in Vietnam. Data was collected from three large main contractors as they are considered as innovation leading organizations. Qualitative research was employed using semi-structured interviews to analyze respondents' perspectives of their daily BIM activities. Main informants include senior managers, BIM team members and site staff. Key findings were the factors affecting the decision of BIM adoption of senior managers (i.e., non-BIM users), the factors affecting BIM implementation of site staff (i.e., BIM users), and the contradictions emerging when senior managers mandate to use BIM, and employ a BIM team as the change agent for instruction and collaboration on the construction site.

*Keywords*: Diffusion of innovation theory, Activity theory, Senior managers, Site staff, BIM team.

## 1 INTRODUCTION

The construction industry has a historically low increase of productivity when compared with manufacturing industries (Sveikauskas *et al.* 2016). BIM has been introduced as a way of addressing this problem; but even while the percentages of BIM adopters are reportedly increasing around the world (McGraw-Hill 2014), and particularly in Vietnam (Le *et al.* 2017), the level of BIM implementation is quite low. A key reason is not the failure of introducing innovation but the failure of adopting its implementation, which means that the failure to gain targeted employees' implementing the innovation by advancing their skills, using a consistent approach, and commitment to adopt the innovation (Klein and Knight 2005).

BIM research, in general, has used the term "adoption" and "implementation" interchangeably. Klein and Knight (2005) however argued that "Innovation adoption is the decision to use an innovation. Innovation implementation, in contrast, is the transition period during which [individuals] ideally become increasingly skillful, consistent, and committed in their use of an innovation." Further, while the factors affecting BIM adoption and implementation have been well addressed at individual level, such as BIM professionals; investigation of the factors emerging from the interplay between BIM users (e.g., site staff, sub-contractors, and designers) and non-BIM users (e.g., senior managers, clients, and the government agents) within projects using BIM is lacking.

This paper aims to address that gap by proposing a theoretical framework combining Diffusion of Innovation Theory (DOIT) and Activity Theory (AT) to investigate the process of adoption and implementation in a holistic manner. By doing this, the contradictions that emerge from the interactions between BIM users and non-BIM users in the Vietnamese construction industry can also be explored.

## 2 THEORETICAL FRAMEWORK

### 2.1 Diffusion of Innovation Theory (DOIT)

DOIT (Rogers 2003) seeks to explain how innovations are accepted and adopted by social groups. DOIT identified key variables that significantly affect the rate of adoption of an innovation, namely: innovation characteristics, characteristics of decision making unit (i.e., target of innovation adoption), prior knowledge, and environmental characteristics.

Innovation characteristics include five elements which are relative advantage (i.e., the degree to which the innovation is perceived to be superior to current practice), compatibility (i.e., the degree to which the innovation is consistent with the existing values, past experiences and needs of potential adopters), complexity (i.e., the degree to which an innovation is perceived as difficult to understand and use), trialability (i.e., the degree to which an innovation can be tested before permanent adoption), and observability (i.e., the degree to which the results of an innovation are visible to others).

For characteristics of decision making unit, the socio-economic status has a great influence on the possibility of adoption. For example, people having high position in an organization (e.g. senior managers) would likely influence the adoption of followers such as the employees (Wejnert 2002). Further, the behavior of using mass media and internet, and being members of social groups could speed up the adoption rate. Other personal variables, such as formal education and innovativeness are indicators for early adopters.

Another factor affecting the probability of adoption are prior conditions existing in the organization before the innovation is introduced. Rogers (2003) noted that the previous practice provides a basis of familiar by which an innovation can be interpreted, thus decreasing its uncertainty. In addition, an innovation can be perceived as compatible if it meets a felt need and as incompatible if it does not address a need or a problem of a potential adopter. According to Kee (2017), an innovation should be in alignment with the cultural norms of an organization in order to successfully diffuse.

Social environment is also a critical factor affecting the awareness of the need of innovation adoption. The main feature of social environment is that it is not under the direct control of the organization but has a positive effect on human attitude towards innovation adoption (Buć and Divjak 2016). For example, a government's mandate to adopt innovation can be perceived as a social influence. Furthermore, the innovation has to be accepted by the society (e.g., meeting cultural values) before the actual innovation diffusion can take place. As for instance, innovation diffusion does spread more rapidly in "individualistic cultures" because of the social status rewards associated with innovation in that culture (Tolba and Mourad 2011).

Rogers's DOIT is one of the most used theories for studying adoption of information technologies (IT), and understanding how IT innovations spread within and between communities (Lyytinen and Damsgaard 2001). However, this theory has been criticized to be simplified to focus solely on a new product or innovation, disregarding the complex societal, cultural, economic and other factors that determine how the product is adopted into society (Al-Mamary *et* *al.* 2016). Particularly, DOIT's scholars are found to often collaborate with manufacturers, the government agents, or senior managers to enable the innovation diffusion within a community (e.g., construction industry) by business strategies or policies (Chile 2017). These approaches are focusing on "top-down" diffusion of innovations, and do not guarantee long-term success due to neglecting the actual innovation practices of lower positions such as site engineers (Ayodele 2012). The limitation of DOIT could be compensated by supplementing the investigation of innovation using another theory such as AT. According to Engeström (1987), AT presents a holistic and ecological perspective on human activity, providing the means of studying human actions and interactions with tools (e.g., technologies) within a historical, cultural and environmental context.

## 2.2 Activity Theory (AT)

This study employed Engeström's AT (1987) as a lens to interpret the activity systems of adopting and implementing BIM in main contractors. Three key elements of AT are Subjects (actors engaged in the activity), Tools (instruments used in the activity) and Objects (the targets of the activity). The theory proposes that the work activity is mediated by previous perceptions and behaviors (a historical cultural background of actors) and motivated by objects that take the form of tools as a medium of action in order to obtain expected Outcomes.

However, outcomes of an activity system are not always expected results, but possibly unexpected results that were transformed from the contradictions emerging when the AT system's elements interact with each other (Plakitsi 2013). For example, a contradiction such as a breakdown in the activity, where a tool is used inappropriately or in an unanticipated manner by the subjects. Such contradictions, however, should be seen as a source of change and development rather than problems or conflicts (Engeström 2001). The identification of contradictions in an activity system could help actors to focus their efforts on the root causes of tensions, to make proper decisions and take actions to adopt change.

Other three elements of AT are related to social factors – namely rules (cultural norms and regulation governing the performance of an activity), community (environment or social context in which the activity is being carried out), and division of labor (hierarchical structure of activity – roles and responsibilities of actors in the activity system).

## 2.3 A Theoretical Framework Combining DOIT and AT

Figure 1 shows how DOIT and AT can be organized in a combined theoretical framework. The framework distinguishes the activity of making adoption decision of non-BIM users, and the activity of implementing an innovation of BIM users. These two activities are integrated but not assimilated. Also, it is argued that BIM adoption and implementation are occurring in mandatory settings (Kumar *et al.* 2017), and Vietnam is not an exception (Le *et al.* 2017).

This framework adopts the basic elements of AT which are: Subject – Tools – Object – Outcomes, and adds main features of DOIT on the elements of "Subject" and "Tools". For example, technological characteristics, personal characteristics, and prior knowledge. Some key elements of AT are reorganized to match the condition of the mandate. Non-BIM users (usually senior managers) are affected by environmental factors whereas BIM users (usually employees such as site engineers) are under the influence of organizational factors. Although the employees have no opportunities to make adoption decisions at the initial stage, they could re-evaluate "what an innovation means to them" during the implementation stage, and after that determining their behaviors/responses at post-adoption stage.

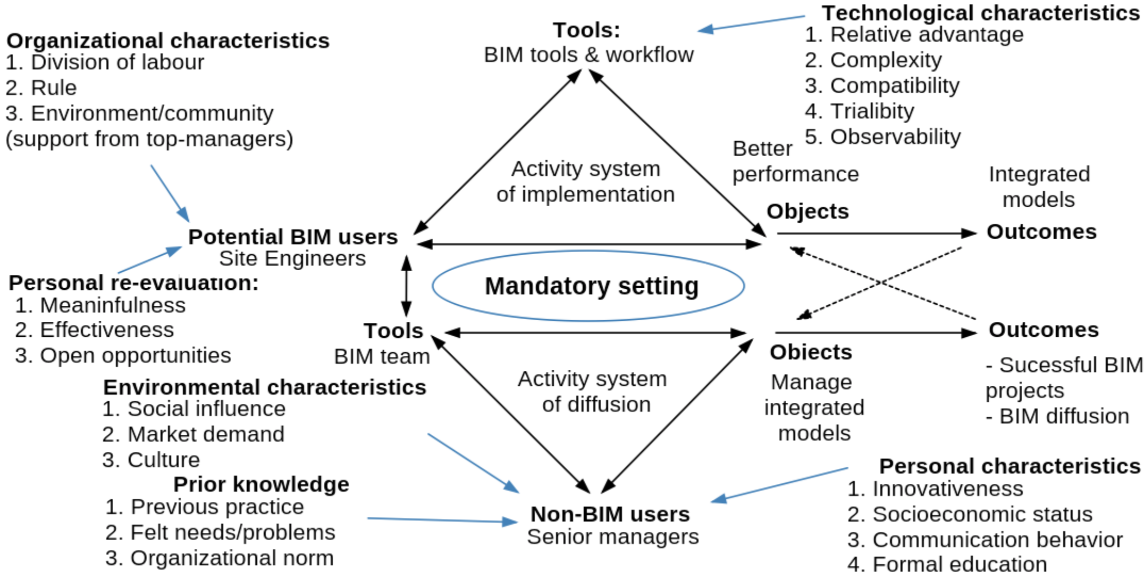


Figure 1. The combined framework of DOIT and AT.

The outcome of each activity system can impact the object of the other system and vice versa. For example, if the number of BIM adopters is accelerating, the site engineers would likely increase their awareness and intention to adopt BIM because they see the new job opportunities as well as competitive pressures on the labor market. On the other hand, if the site engineers create useful integrated models that can reduce issues such as costly re-works, and increase quality of building, then potentially senior managers might enhance the support and commitment.

## 3 APPLYING THE COMBINED FRAMEWORK FOR THE CONSTRUCTION STAGE

Due to the limited space, this paper only investigates the application of the combined framework of DOIT and AT during the construction stage, focusing on the factors affecting senior managers' decisions of BIM adoption, and information transfer among BIM team and site engineers.

### 3.1 Data Collection Method

The data used in this study was collected through semi- structured interviews of three main contractors in Vietnam with key informants are senior managers, BIM team, and site engineers. To maintain confidentiality, names of companies and respondents were put into codes (Table 1).

Table 1. Respondents' profile.

| Contractors | Senior managers | BIM members | Site Engineers |
|---|---|---|---|
| C1 | R1C1 (10+/0) | R3C1 (5+/3+) | R5C1 (15+/0) |
| | R2C1 (10+/0) | R4C1 (7+/3+) | R6C1 (7+/0) |
| C2 | R1C2 (30+/0) | R3C2 (7+/5+) | R5C2 (20+/0) |
| | R2C2 (8+/5+) | R4C2 (3+/3+) | R6C2 (5+/0) |
| C3 | R1C3 (20+/0) | R3C3 (20+/5+) | R5C3 (5+/0) |
| | R2C3 (10+/5+) | R4C3 (3+/2+) | R6C3 (10+/0) |
| Total | 6 respondents | 6 respondents | 6 respondents |

**Code:** Respondent (R)- Contractor (C)- (Industrial/BIM professional experience - years)

## 3.2 Findings and Discussions

### 3.2.1 *Factors affecting decision of BIM adoption of senior managers*

Through the interviews, the factor of "felt need" to innovation is more significant than environmental characteristics or personal characteristics. Despite low government, client, and competitive pressures on BIM adoption, main contractors are surpassing design professionals in term of BIM investment and application. This is because Vietnamese construction market has slowly shifted from a fully documented project to Design and Build (DB) based project delivery. As senior managers (R1C1, R2C2, and R3C3) said "The ability to implement technical solutions designed to achieve efficiency and aesthetics as well as reasonable costs were seen as the reason for the clients to contract us to design and build their entire projects." Therefore, large main contractors have been developing their in-house BIM experts and infrastructures for internal document management and quality control of project lifecycle. Their aims are to build trust with clients, and prepare for long-term plan of DB market in future.

### 3.2.2 *Factors affecting BIM implementation of site people*

The factors of "relative advantage", and "complexity" appear to be more influential in the level of BIM implementation within people based on site. Firstly, the majority of site personnel (e.g., R5C1, R6C1, R5C2, R6C2, R6C3) admitted that, "contractors only implement 3D BIM at the pre-construction stage for clash detection, and visualization purposes." This is due to the unavailability of information content developed for use at the actual construction stage such as 4D BIM (time management), and 5D BIM (cost management). While 4D BIM requires the constant collaboration of multiple participants such as sub-contractors, and designers to update the integrated model regarding change orders, specifications, and shop-drawings; 5D BIM obliges all parties to be transparent in the project budget. In the case study BIM was not a mandatory component of the contract which equated inconsistent commitment, and use of BIM through the construction project life-cycle; 4D BIM cannot be fully utilized. Additionally, the phenomenon of "lobbying for project" appears culturally as a part of business activity (e.g., winning tenders) in Vietnamese construction industry, thus, the interest groups such as main contractors and owners may be unwilling to share cost information with 5D BIM due to legal concerns.

Secondly, the use of BIM onsite is not flexible and speedy when addressing the urgent tasks or unexpected issues. Slow loading and editing of Revit files frustrated site staff. Further, the designs were often late in being handed over from the BIM team to the construction site, and in some cases the work at the building site had to start without ready- made designs to meet the programmed deadline. In other words, the developed models were not able to capture the "as-built" conditions, roadblocking extended usage of the 3D model to the construction stage.

### 3.2.3 *Contradictions emerging within the interaction between senior managers and site staff*

To increase the adoption rate of BIM, senior managers sent a qualified BIM team to site for onsite training and collaboration. This BIM team can be seen as a tool, serving as change agents in adoption activity (see Figure 1). However, the interactions between Senior managers – BIM team – Site staff created a contradiction that impeded the adoptability of BIM, particularly, the contradiction regarding "division of labor" issue. The BIM team had a responsibility to help site people with information management and visualization, and simultaneously report site activities related BIM uses to senior managers. The role of BIM team was negatively perceived as "double agent" by site people. Most BIM team members (e.g., R3C1, R4C1, R4C2, R3C3, R4C3) acknowledged that "we feel isolated as site people watch out us and are reluctant to support and share information for model update." As the result, senior managers failed to build "trust" with site staff despite supporting them with BIM experts.

## 4 CONCLUSIONS AND FUTURE WORK

This research proposed a framework combining DOIT and AT with the potential of holistically analyzing the process of BIM adoption and implementation across multiple parties during project life-cycle. Using this framework, not only the factors affecting BIM adoption and implementation of BIM users (e.g., relative advantage, and complexity) and non-BIM users (e.g., felt need) were individually identified; but the factors emerging from the interaction between them (e.g., contradictions in division of labor) were also explored. The future work will extend the range of interviews, with additional participants of BIM users (e.g., sub-contractors, and designers), and non-BIM users (e.g., clients, and the governments agents) to provide a complete view of their interactions in BIM based projects from the design stage to hand-over stage.

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