The Impact of Individual Beliefs and Expectations on BIM Adoption in the AEC Industry

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Abstract

The use of Building Information Modelling (BIM) in the construction industry has been growing steadily during the last decade, yet there is a continues resistance to its adoption, due to some users' unawareness of BIM benefits. BIM adoption is associated with an individual's willingness towards using it which is driven by individual beliefs and expectations of BIM use consequences. Technology Acceptance Model (TAM) identified perceived usefulness (PE) and perceived ease of use PEOU as variables to inform us with user's mind-set and intentions towards the use of technology. This research proposes a conceptual framework for exploring and measuring individual willingness level for adopting BIM, based on individual beliefs and expectations of BIM use consequences in construction industry. The research conducted literature review on technology acceptance and use theories from IS mainstream to identify the individual beliefs and expectations variables, then conducted a literature review on case studies researches that directly applied TAM, to contextualize the variables into BIM in construction environment. The research outcome identified the individual willingness constructs to accept and use BIM: performance expectancy, effort expectancy, social conditions, facilitating conditions, and attitude towards using.

Keywords: Building Information Modelling, BIM adoption, individual believes and expectations, Technology Acceptance Model, user satisfaction.

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1. Introduction

Building Information Modelling (BIM) has been promoted as the ultimate solution for the coordination problems, mainly because it is considered as the central repository for information, and covers the entire cycle of the project from its conception up through demolition (Howard et al. 2017). Though it is agreed between researchers and practitioners that BIM has many potential benefits it is still unclear why BIM is not adopted, accepted and used significantly in the construction industry (Lee et al. 2013).

Studies in digital construction showed that resistance (Davis & Songer 2008; Brewer & Gajendran 2012) and other socio-techno behaviours may raise during early stages of adoption: e.g. stubbornness of employees about keeping the old CAD ways of working alive (Morlhon et al. 2014; Tulenheimo 2015). The resistance happens because of even user's unawareness or un-satisfaction of BIM benefits and advantages (Arayici et al. 2011Brewer & Gajendran 2012;Lee et al. 2013)

The acceptance to adopt BIM technology is not a simple case of approval or rejection, various researchers have proposed diverse factors that can influence technology adoption and acceptance. For instance, Davies & Harty (2013) identified that the individual beliefs and expectations regarding the technology consequence use have important role in successful adoption. Deutsch et al. (2011) discussed three change drivers due to technology adoption as people, business, and the technology itself. Furthermore, Venkatesh et al. (2003) attested that performance expectancy, effort expectancy, social influence and facilitating conditions determine the rate of technology acceptance which are subject to people's attitudes towards technology use. In addition, the technology acceptance model proposed that the individual's behavioural intention to use new technology is determine by two beliefs which are perceived usefulness and ease of use. Also, Jacobsson & Linderoth (2012) confirmed that occupational skills and nature of work task influence ICT technology adoption. Based on these facts, there is an indication that the acceptance of BIM technology in the Architectural Engineering and Construction (AEC) industry can possibly be influenced by individual prerequisites. Therefore, this study aims to explore the influence and impact of individual beliefs and expectations on individual's willingness to adopt BIM and thereby true implementation in the industry.

2. Literature Review

Literature review was conducted in two broad areas; theories of technology adoption and BIM adoption in construction. The former informed the factors critical to the adoption of any technology whist the latter investigated how these theories apply in the context of BIM adoption in the construction industry. Among the technologies adoption theories reviewed, two heavily applied ones are discussed below, namely: Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT).

2.1. Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) was introduced by Davis (1989). TAM is an adoption of Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB), specifically tailored for user acceptance of Information Systems (IS). The purpose of TAM is to explain individuals' acceptance of new technologies and their related behaviours. In TAM, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are the key constructs of IS acceptance behaviour. As shown in Figure 1, TAM proposes external variables that directly affect PU and PEOU, which consequently affect indirectly the attitude towards the use (ATT) of a technology, and ultimately leads to the actual use of the technology by influencing PU and PEOU.

TAM proposes that the individual's behavioural intention to use a new technology is determined by two beliefs: perceived usefulness, defined as the extent to which a person believes that using the system will enhance his or her job performance; and perceived ease of use, defined as the extent to which a person believes that using the system will be free of effort. TAM assumes that the effects of external variables on intention to use are mediated by perceived usefulness and perceived ease of use.
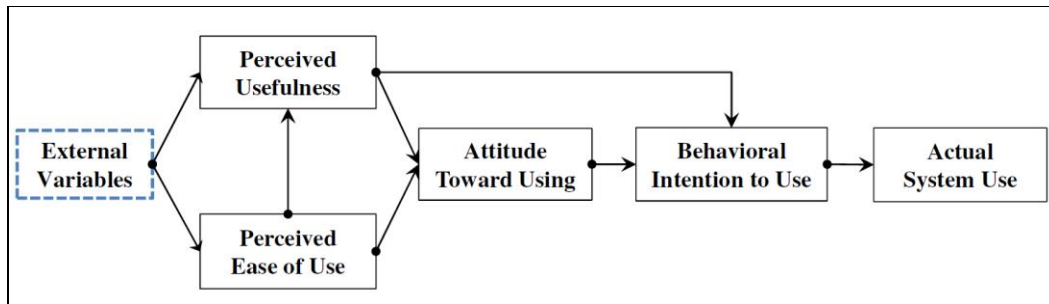

Figure 1: Technology Acceptance Model, (Source: Davis 1989)

Venkatesh and Davis (2000) extended TAM into TAM2 by adding subjective norms as an additional predictor of the behavioural intention, in addition to concluding the definition of external variables (see Figure 2). Further research on TAM led to the development of TAM3 by Venkatesh & Bala (2008)
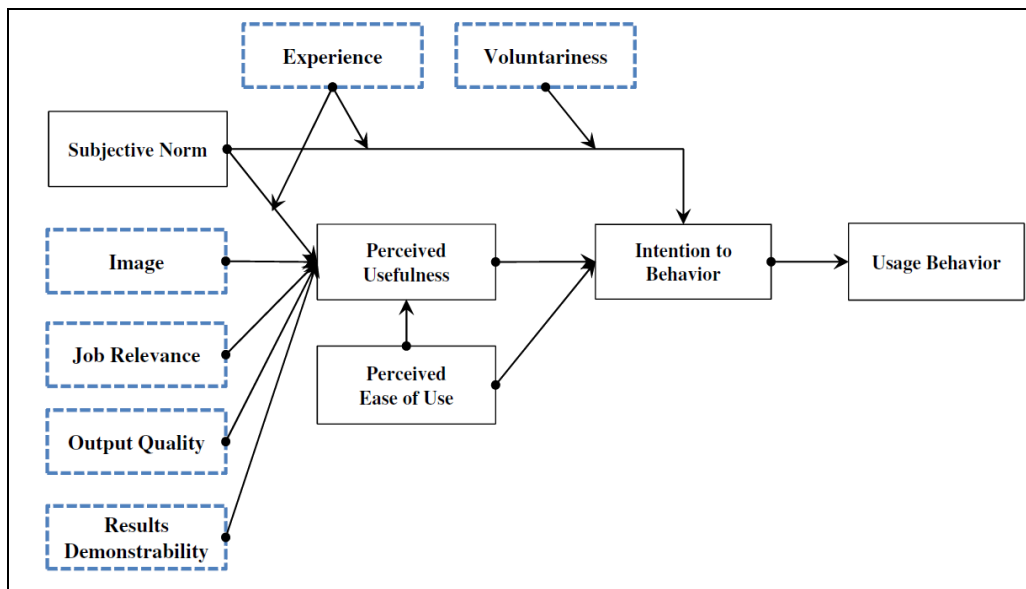

Figure 2: Technology Acceptance Model 2, (Source: Venkatesh & Davis 2000)

2.2.   Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) based on eight technology acceptance and behavior-related theories: Technology Acceptance Model (TAM/TAM2) (Davis 1989), Theory of Reasoned Action (TRA) (Fishbein & Ajzen 1975), Motivation Model (MM) (Davis et al. 1992), Theory of Planned Behaviour (TPB) (Ajzen 1991), Model of Personal Computing Utilization (MPCU) (Thompson et al. 1991), Innovation Diffusion Theory (IDT) (Moore & Benbasat 1991), and Social Cognitive Theory (SCT) (Compeau et al. 1999).

Venkatesh et al. (2003) proposed and defined four constructs of UTAUT (see Figure 3): (1) Performance Expectancy (also referred as Perceived Usefulness); the degree to which an individual believes that using the technology will help him or her to achieve improvements in job performance, (2) Effort Expectancy (also referred as Perceived Ease of Use); the degree of ease linked with the use of the technology, (3) Social Influence (also referred as subjective Norms); the degree to which an individual perceives that others believe he or she should use the new technology, and (4) Facilitating Conditions, the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the technology.
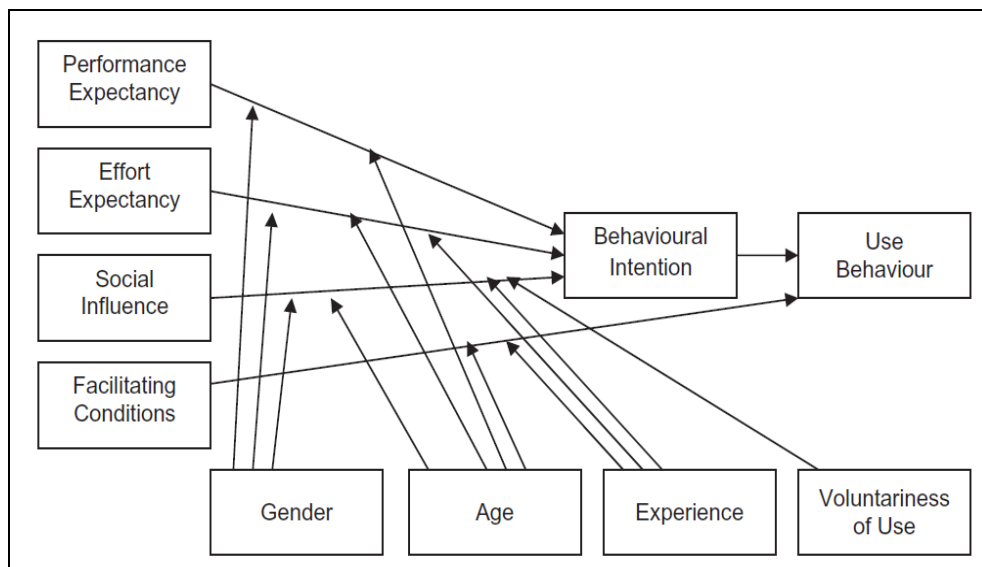

Figure 3: Unified Theory of Acceptance and Use of Technology, (Source: Venkatesh et al. 2003)

2.3.   BIM Acceptance in the Construction Industry

The above theories have been applied by few researchers to investigate BIM adoption in the construction industry, which are discussed below.

In the South Korean construction industry context, a BIM Acceptance Model (BAM) was proposed by Lee et al. (2013b). BAM identified 28 key factors and used them as TAMs external variables. The factors were classified into; compatibility, output quality, collective efficiency,

organizational innovativeness, self-efficacy, personal innovativeness, top management support, internal pressure, and external pressure. The research concluded that perceived usefulness has a significant impact on individual intent to accept BIM, also concluded that organizational competency has the most significant impact on perceived ease of use.

Davies and Harty (2013a) explored the individual beliefs about BIM consequence use in large construction contracting organizations in the United Kingdom. The examined the relationship between the salient individual-level variables; performance, effort, social influence, facilitating conditions, compatibility, and attitude towards using the technology. The outcome showed that there is a strong relationship between the expectations that BIM would enhance job performance (user's perception) and the expectation that BIM use was compatible with preferred and existing ways of working (facilitating conditions).

Wang and Song (2017)examined the influence of five variables on BIM user satisfaction in the AEC industry. Three of these variables were from TAM, which are perceived benefits, perceived ease of use, and attitude, in addition to two management variables: top management support, and management by objective. The results showed that perceived usefulness, top management support and management by objective are significantly associated with BIM user satisfaction, and the influence of management by objective on BIM user satisfaction is stronger than top management support and perceived usefulness. Also, perceived ease of use and attitude have a significant influence on perceived usefulness.

Howard et al. (2017) directly used UTAUT to explore the individual perceptions towards working with BIM in the UK AEC industry. The study extended UTAUT with extra variables: gender, age, and experience. The results revealed that performance expectancy does not directly affect the behavioural intention, suggesting that BIM is perceived as an unrewarded addition to existing work processes. The research finding highlights the need to redefine the strategies, policies, and incentive schemes to advance the acceptance of BIM in the UK.

Merschbrock & Nordahl-Rolfsen (2016) directly used TAM to examine ironworkers' acceptance of using BIM for facilitating on-site placement of reinforcement bars with a sophisticated virtual model, replacing the traditional way of using shop-drawings for fabrication and placement of the reinforcement bars, for the Oslo new airport terminal project in Norway. The findings showed that the workers perceived the virtual model as more beneficial over the paper-based shop drawings.

The above mentioned researches explored the influence of users' perception on BIM acceptance, and the effect of external variables, such as; top management role, gender, age, experience, beliefs and expectations, efficiency compatibility, output quality, collective efficiency, organizational innovativeness, self-efficacy, and personal innovativeness. Moreover, both user satisfaction and perceived usefulness emphasise on the individuals' perception of the new technology; their beliefs and expectations on how the new technology will affect their work in addition to an embedded assumption that their positive expectations about using BIM will result in benefits (positive impact) for the organization. Aligning users' perception with their expectations and believes for the technology adoption will reveal the satisfaction level. These factors are significant for understanding BIM acceptance and use (Davies & Harty 2013).

Information System stream identified the three phases for innovation adoption in business: pre-adoption phase, actual adoption phase, and post-adoption phase. The above mentioned researches mainly discuss the user's acceptance for BIM in actual adoption phase. The proposed willingness framework will be checking the user's mindsets in pre-adoption phase to predict users' reactions and behaviors before adoption, which is considered the research knowledge gap.

Performing "willingness health-check" for employee's readiness for BIM adoption, will be valuable for organizational management in decision making and planning proper strategies for enhancing BIM adoption.

3. Framework of BIM Adoption Willingness and Behaviour

Figure 4 illustrates a new framework that is developed to address the knowledge gap identified above. The framework draws on technology acceptance and use theories mentioned in the literature review to measure the individual willingness level of using BIM, and consequently the reflected actual usage behaviour. Measuring the willingness level will reveal the behavioural intention whether it was resistance (negative level) or motivation (positive level). Understanding the variables that affect the level of willingness e will assist in controlling BIM adoption behaviours.
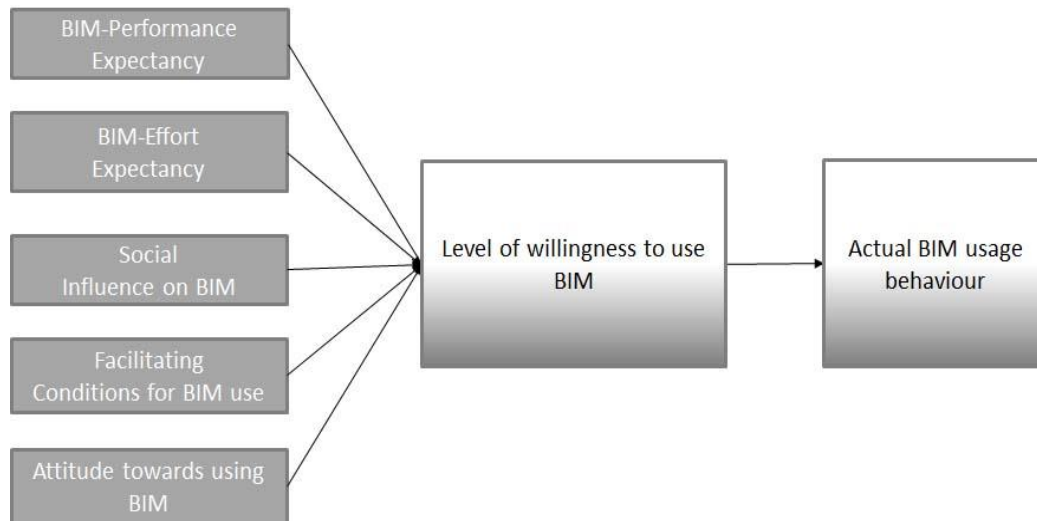

Figure 4: Research conceptual framework

The IS literature clarified how perceived usefulness PU and perceived ease of us PEOU form the individual perception of technology use, and consequently the individual expectations for performance expectation PE and effort expectation EE. UTAUT identified social influence SI and facilitating condition FC as influential variables for individual beliefs for the technology consequence use. See Table 1 for UTAUT constructs referenced to their original technology acceptance and theories.

UTAUT constructs	Corresponding theory title	Corresponding technology acceptance theory
Performance Expectancy	Perceived Usefulness	Technology Acceptance Model (Davis 1989)
Effort Expectancy	Perceived Ease of Use	Technology Acceptance Model (Davis 1989)
Social Influence	Social Factors	Model of Personal Computing Utilization (Thompson et al. 1991)
Facilitating Condition	Facilitating Conditions	Model of Personal Computing Utilization (Thompson et al. 1991)
Facilitating Condition	Compatibility	Innovation Diffusion Theory (Moore & Benbasat 1991)
Attitude Toward using Technology	Attitude Toward Behaviour	Technology Acceptance Model (Davis 1989)

Table 1: UTAUT Constructs

The conceptual framework contextualises the UTAUT constructs and their item wording to BIM. The conceptual framework postulates that the degree of actual BIM use in one's job role is dictated by his/her level of willingness to adopt BIM, which in turn is influenced by five factors, such as: (1) BIM performance expectance (BPE), (2) BIM effort expectance (BEE), (3) social influence on BIM (SIB), (4) facilitating condition for BIM use (FCB), and (5) attitude towards using BIM (ATTB). Table 2 below shows the contextualised variables definitions and the item wording originated from the original theories. The last column of the table lists questions that can help to measure each of the construct with construction professionals.

Variable	Scale Description	Scale item wording
BIM-Performance Expectancy	The degree to which a person believes that using a particular system would enhance his or her job performance (Davis 1989).	1. Using BIM in my job would enable me to accomplish tasks more quickly. 2. Using BIM would improve my job performance. 3. Using BIM in my job would increase my productivity. 4. Using BIM would enhance my effectiveness on the job. 5. Using BIM would make it easier to do my job. 6. I would find the system useful in my job.
BIM-Effort Expectancy	The degree to which a person believes that using a system would be free of effort (Davis 1989).	1. Learning to operate BIM would be easy for me. 2. I would find it easy to get BIM to do what I want it to do. 3. My interaction with BIM would be clear and understandable. 4. I would find BIM to be flexible to interact with. 5. It would be easy for me to become skilful at using BIM. 6. I would find BIM easy to use.
Social Influence on BIM	The individual's internalization of the reference group's subjective culture. and specific interpersonal agreements that the individual has made with others, in specific social situations (Thompson et al. 1991).	1. I use BIM because of the proportion of co-workers who use the system. 2. The senior management of this business has been helpful in the use of BIM. 3. My supervisor is very supportive of the use of BIM for my job. 4. In general, the organization has supported the use of BIM.
Facilitating Condition for BIM use	Objective factors in the environment that observers agree make an act easy to do. including the provision of computer support (Thompson et al. 1991). The degree to which an innovation is perceived as being consistent with existing values, needs. and experiences of potential adopters (Moore & Benbasat 1991).	1. Guidance was available to me in the selection of BIM. 2. Specialized instruction concerning BIM was available to me. 3. A specific person (or group) is available for assistance with BIM difficulties. 4. Using BIM is compatible with all aspects of my work. 5. I think that using BIM fits well with the way I like to work. 6. Using BIM fits into my work style.

| Attitude Toward using BIM | An individual's positive or negative feelings about performing the target behaviour (Davis 1989). | 1. I have control over using BIM. 2. I have the resources necessary to use BIM. 3. I have the knowledge necessary to use BIM. 4. Given the resources, opportunities and knowledge it takes to use BIM, it would be easy for me to use BIM. 5. BIM is not compatible with other systems I use. |

Table 2: Constructs description and item wording

4. CONCLUSION

This research proposed a conceptual framework for measuring the level of willingness for using BIM, based on individual beliefs and expectations variables: performance expectance, effort expectance, social influence, facilitating condition, and attitude toward using BIM. Accordingly, willingness level will be reflected on the actual BIM usage behaviour whether it is motivated or resistance behaviour.

To verify the conceptual framework, a questionnaire will be created based on the item desertion shown in Table 2 above, and will be sent to BIM users in Australian construction organizations.

Understanding employees' behaviours based on willingness level will be valuable and beneficial for organizational management for different purposes: assist management in putting implementation strategies, reduce the implementation cost and financial risk, will guide in setting BIM benefit realisation context for users, and finally it will help management to work on their motivation schemes or incentives.

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