**DEVELOPING BIM-FM INNOVATION TECHNOLOGY ACCEPTANCE FRAMEWORK**

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# Abstract

# The adoption of emerging technologies involving open Building Information Modeling (BIM) standards such as Construction Operation Building information exchange (COBie) and Industry Foundation Class (IFC) has been a challenge, especially in the facilities management (FM) domain. The objective of this study is to identify the key factors that influence the adoption of open BIM by investigating the reasons behind its low adoption in facilities management using an integrated framework adapted from the Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT). The BIM-FM Innovation Technology Acceptance Model concentrates on six main constructs; Awareness of BIM, Compatibility of Computer Aided Facilities Management (CAFM) system, Observability, Trialability, Perceived usefulness, and Perceived ease of use. The framework was developed based on extensive literature review of BIM and FM, and informal discussions with industrial experts. This paper discusses these constructs. The major contribution to theory is the conceptualization of key factors that influence the adoption of open BIM standards. Results of this research may better facilitate the adoption of open BIM standards in facilities management. Findings may provide guidance for facilities managers to support the implementation and wider adoption of open BIM standards in the future.

# Keywords:

# Building Information Modeling, Facilities Management, COBie, IFC, Technology Acceptance Model, Innovation Diffusion Theory

***Article history:***

Submitted: 4/8/2017; Revised: 28/11/2017; Accepted: 26/01/2018; Online: 1/06/2018

# BACKGROUND OF STUDY

# Building Information Modelling (BIM) has gradually become a standard in construction practices in the UK (NBS, 2016). In 2016, BIM Level 2 was mandated for all public-funded projects (NBS, 2016) even though the adoption of BIM for facilities management had unresolved challenges (NBS, 2016, Patacas, et al., 2015, Becerick-Gerber, 2012). An NBS (National Building Specification) 2016 survey indicated that a majority of UK construction practitioners failed to adopt emerging open BIM standards of Construction Operation Building information exchange (COBie) as a construction practice (NBS, 2016). This was despite COBie and Industry Foundation Class (IFC) being hailed as a universal standard for information exchange from project stage to handover stage in facilities management. An earlier BIM4FM (2013) report noted the awareness of most facilities managers about BIM and their failure of adopting it. The NBS report (NBS, 2016) suggests that this failure continued to undermine the benefits of BIM’s use. It was thought that BIM’s low adoption can be explained using theories of Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT). Identifying the key factors influencing BIM adoption through the application of this unique combination is therefore the aim of this study.

# LITERATURE REVIEW

# Overview of open BIM standards

# Traditional facilities management systems such as Computer Aided Facilities Management System (CAFM) and Computer Maintenance Management System (CMMS) are the tools that support the functions of facilities management activities (Teicholz, 2013a). However, such systems are often considered inadequate for handling digital information during the handover stage (Bosch et al., 2015; Jylhä and Suvanto, 2014). It was found that building-related information had to be re-created, resulting in often fragmented information which was difficult to retrieve and accessed during the maintenance and operation phase of building (Teicholz, 2013b). Emerging open BIM standards of COBie and IFC sought to mitigate such problems by providing an integrated approach for project teams to transfer design and construction information to facilities managers during the handover period. However, the adoption of COBie and IFC remains uncommon (NBS, 2016, Patacas et al., 2015). Issues that hinder its proliferation in construction practices were lack of methodologies in using BIM in FM, lack of knowledge and experience in open BIM standards (Kassem et al., 2015; Becerik-Gerber et al., 2012; Williams et al., 2014), and lack of support from software vendors (Becerik-Gerber et al., 2012; Williams, et al., 2014). These issues suggest a need for targeted solutions. Therefore, this study adopts theories of TAM and IDT to identify and explain the key factors for adoption of open BIM standards in facilities management.

# Technology Acceptance Model (TAM)

# Davis developed TAM in 1989 to describe and predict technology acceptance of an information system by its end users (Davis, 1989). TAM’s conceptualisation adapted Ajzen and Fishbein’s (1980) Theory of Reasoned Action which provided explanations for Information Technology (IT) user’s intent behaviour (Ajzen and Fishbein, 1980). TAM proposed that an individual’s acceptance of technology was constructed by two beliefs; perceived usefulness (PU) and perceived ease of use (PEOU) (See figure 10) (Davis et al., 1989). PU was defined as the degree to which using IT could improve an individual jobs performance, while PEOU was defined as the level that IT could be use without using any effort (Davis et al., 1989). These beliefs, based on an individual’s attitude and perceptions, led to use intention (Davis et al., 1989).

# TAM has been used in the construction industry (Son et al., 2014; Lee et al., 2012). A parallel study by Lee et al. (2012) on TAM for BIM-based FM investigated the key factors affecting facilities managers’ acceptance of BIM. Results from semi-structured interviews identified seven external variables: self-efficacy, compatibility, beliefs in benefits, collaboration environment, information quality, resource facilitating condition and technology facilitating condition. However, the validity and reliability of this study was not examined. Son et al. (2014) utilised TAM to investigate to examine the factors influencing architects’ behavioural intention to adopt BIM amongst Korean design firms. Their extended TAM consisted of five external variables; top management support, subjective norm, compatibility, technical support, and computer self-efficacy. Results suggested that design firms required improved top management support, subjective norm, compatibility, and computer self-efficacy for conducive BIM adoption. The technical support variable was found to be not significant because respondents were competent in using BIM-related software.

# TAM was criticized for being subjected to self-reported use of data, which many consider unreliable in measuring the actual use of a system (Yousafzai et al., 2007). Bagozzi (2007) argued that TAM may inherently have a poor theoretical relationship between intention-actual constructs because the time-period of intention and adoption has uncertainties and other factors may influence an individual’s decision to adopt a technology. Therefore, these studies suggest that being solely dependent on TAM theory may result in inadequacies when measuring the actual adoption of open BIM in facilities management. The two constructs of TAM; Perceived Usefulness and Perceived Ease of Use may be limited in determining the individual decision of adopting open BIM standards. Since open BIM standards involved a degree of complexity between people, process and technology when changing construction practices, external factors need to be considered and extended when utilising a TAM model. The formulation of an integrated model is needed to better predict the use of open BIM standards.

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# Innovation Diffusion Theory (IDT)

# Innovation Diffusion Theory (IDT) was developed by Rogers in 1962 to understand why, how and at what rate innovative ideas and technologies spread in a social system (Rogers, 2003). This was refined to describe how the use of innovation was diffused or communicated through certain channels over time among a social system’s members (Rogers, 2003).

# Only one prior research applied IDT to explain technology acceptance in the construction industry. Panuwatwanich and Peansupap (2013) investigated the factors affecting the diffusion of BIM using IDT theory. Results from 45 selected posts in LinkedIn revealed that relative advantage, compatibility, observability, and complexity have significant impact on adoption. Trialability had no significant effect on adoption of BIM. Although four of IDT’s factors influenced user adoption, the findings suggested that users were not influenced by experimentation of BIM for its full life-cycle management of building but rather only on the modelling aspect of BIM.

# In conclusion, the use of IDT to explain how technology is adopted within an organisation and the use of TAM to identify individual intention can be useful in identifying adoption enablers. However, both have shortcomings that may misconstrue actual technology adoption. This may be mitigated when TAM and IDT is adapted into an integrated combination as a new theoretical model fulfilling the aim of this study.

# BIM-FM Technology Acceptance Innovation Framework

# A conceptual model was developed through iterative process of extensive literature review and informal discussion with industry experts. This resulted in the development of the BIM-FM Technology Acceptance Innovation Model. The integration of TAM and IDT can be justified because they often share similarities in terms of terminology. Moore and Benbasat (1991) pointed out contextual similarities between “Relative Advantage” in IDT and “Perceived Usefulness” in TAM. “Perceived usefulness” was more appropriate because it had a broader term and was a generalizable concept rather than an intuitive appeal (Moore and Benbasat, 1991). Furthermore, the term “complexity” in IDT and “perceived ease of use” in TAM also shared the same purpose and meaning (Moore and Benbasat, 1991) in predicting behavior intention.

# In this study, the terms “perceived usefulness” and “perceived ease of use” maintained the contextual meaning of Davis’ (1989) definition used in TAM as predictor to behavior intention. Three innovation attributes from Rogers’ (2003) IDT; compatibility, trialability, and observability are used. In adapting IDT, this study proposes that Rogers’ (2003) five innovative characteristics (relative advantage, compatibility, complexity, trialability, and observability) have a direct relationship to the behavioral intention of adopting open BIM standards in FM. This was supported by research evidencing such relationships (Chang & Tung, 2008; Wu & Wang, 2005). Figure 1 is the proposed BIM-FM Innovation Technology Acceptance Framework consisting for six main concepts.

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# Figure 1 The BIM-FM Innovation Technology Acceptance Framework

# Awareness of BIM: This theme indicates the existence of knowledge and understanding of BIM based on respondent’s information and experience. BIM4FM report indicated that 65% of facility managers were aware of BIM, yet with some not using it nor have plans to use it in the future (BIM4FM, 2013). This could be attributed to misconceptions about what constitute BIM which in turn causes a lot of confusion and difficulty in visualising its use (Kassem et al., 2015; William et al., 2014). This study predicts that it is crucial to expand BIM literacy to increase awareness of BIM and to influence its adoption.

# Compatibility: is the degree to which innovation is perceived as consistent with values, past experience and needs of potential adopters (Rogers, 2003). In this study, systems should be consistent with facility managers’ normal routine of handling and updating facility information. If BIM export files are typically easy to be used, then BIM adoption is more likely. Panuwatwanich and Peansupap (2013) have shown that a compatibility variable has a significant impact on technology adoption. This suggests that compatibility is perceived to have a strong impact of facility managers’ behavior intention to adopt open BIM standards.

# Trialability: is the degree to which innovation may be experimented with on a limited basis (Rogers, 2003). Experimenting and exploring features in COBie and IFC are useful experience to understand the structure and process of generating COBie worksheets and IFC data exchange formats. Relevant skill sets can be learned and utilised in small scale projects to gauge the capabilities and challenges that may occur during trial. This can positively affect intent to use BIM. Therefore, trialability is perceived to be a significant factor for behaviour intention of adopting open BIM standards.

# Perceived Usefulness: is the degree to which using open BIM standards (i.e. COBie and IFC) could improve an individual’s job performance. The key factors that influence the usefulness of open BIM standards are; i) Classification of BIM data, ii) Employer Information Requirement, iii) Key information requirement for FM, iv) Level of Details (LOD), v) Communication with design team and vi) Standards Guidelines and vii) Up-skilling. These factors were derived from the extensive literature, informal discussion and pilot interviews with industry experts.

# Perceived Ease of Use: is the degree of effortlessly using open BIM standards. PEOU belief is influenced by external factor of Up skilling and Standard Guidelines. If facilities managers have the skill of using BIM (IFC data format and COBie data), it will be easier and more intuitive when incorporating those information into the facilities management systems.

# CONCLUSIONS

# This study proposed a BIM-FM Innovation Technology Acceptance Framework that represents the key factors influencing the adoption of open BIM standards in facilities management. This included six main themes (i) Awareness of BIM, (ii) Compatibility, (iii) Observability, (iv) Trialability, (v) Perceived Usefulness, (vi) Perceived Ease of Use. The framework was developed based on the extensive literature review, informal discussions and pilot interviews with industry experts.

# The framework will be tested through the pragmatism paradigm. A mixed-methods approach was employed to address the research aim. A qualitative in-depth interview was used as a strategy to gain knowledge and insight from industry experts, which helped to identify and substantiate the key factors of adopting open BIM standards. A quantitative structured survey was formulated from the conceptual framework to test the generalization of the key factors. It is anticipated that the framework will help to better facilitate the adoption of BIM in facilities management. Several issues that may be faced in this study that include (i) concerns regarding bias, the sample is small and limited to several industry experts, chosen non-randomly; ii) low participation from industry in completing the survey where respondents may not have the time or sufficient knowledge to answer some of the questions; (iii) difficulty in conducting validity and reliability of the framework in facilities management practice.

# This paper is motivated by the emergence of BIM in FM despite integration difficulties during facility management handover. The expected theoretical contribution is the conceptualization of key factors that influence the adoption of open BIM standards. The resulting BIM-FM Technology Acceptance Framework is anticipated to facilitate this adoption. Identifying key factors could support future research surrounding the issues of BIM adoption and standard guidelines. Results could also provide a guideline for actual implementation in facilities management and enhance the handing over and operation of facility information. Findings may better enable facilities managers to work in a BIM-driven environment.

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