DETERMINANTS OF BUILDING INFORMATION MODELLING (BIM) ACCEPTANCE FOR SUPPLIER INTEGRATION: A CONCEPTUAL MODEL

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Building Information Modelling (BIM) is expected to promote efficiency in project delivery through collaboration and integration within a highly diverse and fragmented construction industry. Yet, uncertainty concerns relating to the technical, human and inter-organisational contexts of the usage of technology for Supply Chain (SC) integration remain. This affects willingness and preparedness of SC to participate in such electronic data exchanges due to perceptions of greater risk compared to traditional paper-centric communications across the SC. It remains unclear, what model best explains acceptability of BIM within the SC. A conceptual model to aid investigation of influencing factors affecting acceptance and use of BIM in the SC context is presented. The model is proposed to aid examination of the inter-relationship between the determinants of acceptance and the readiness of the SC as well as its impact on achieving the highest maturity of BIM adoption i.e. a fully integrated SC. The key constructs from the Unified Theory of Acceptance and Use of Technology (UTAUT) model are extended through consideration of the relational and transactional context of integration in the development of a SC specific BIM acceptance model. Through this proposed model, it is argued that the SC firms' disposition towards BIM is a key determinant of technology usage and implementation success hence the need for the study of determinants of acceptance. Directions for empirical validation of the model are presented with a review of potential benefits of understanding the determinants of acceptance on the readiness of the SC.

Keywords: BIM, supply chain, integration, implementation, technology acceptance.

INTRODUCTION

Fragmentation within a loosely coupled construction industry has contributed to poor communication and resultant process inefficiencies which often leads to poor performance (Mohamed, 2003). A more vertically integrated Supply Chain (SC) working in network-like structures has been advocated to improve information availability and flow efficiency (Dainty *et al*., 2001). This step is regarded as paramount in delivering real time decision making for better collaboration and coordination of processes. Building Information Modelling (BIM) is regarded as an opportunity for achieving such integration through centralised digital inter-organisational communications in virtual 3-D environments (Eastman *et al*., 2008; BIS, 2011). Despite reported benefits of BIM, the extent of its use remains low with

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some lack of clarity pertaining to its role in achieving SC integration (Robson *et al*., 2014). Generally, it is unclear what factors account for BIM acceptance. However, according to Jacobsson and Linderoth (2012, p.339) ‘for the industry to take advantage of ICT’s transformative capacity, more fine-grained knowledge would be needed regarding perceptions of ICT impacts’. Such an understanding includes knowledge of the determinants of users’ acceptance which has become a key measure of implementation success for technological innovation (Venkatesh *et al*., 2003). A typical factor contributing to the acceptance or rejection of a technology includes end-user perceptions about likely consequence of use (Davies and Harty, 2013). In the SC context, this includes whether or not BIM fits the social relational and transactional context of operations (Adriaanse *et al*., 2010). Despite this acknowledgement, these issues have not be adequately incorporated and explored within BIM acceptance studies (Lee *et al*., 2012; Davies and Harty, 2013). A conceptual model is proposed to guide future research on understanding the implementation of BIM in the SC integration context thereof. We argue that research from a user acceptance perspective can broaden the theoretical understanding of the role of user disposition in the success of using BIM to achieve digitally mediated interaction of the SC firms. The practical contribution of this paper is to showcase how user acceptance modelling can be used to assess critical areas affecting readiness. It is envisaged that operationalization of this model will aid prediction of acceptability rates across various disciplines and BIM maturities in the SC. This will further aid prioritisation of key drivers and challenges for managerial focus during implementation.

BIM AND CONSTRUCTION SUPPLY CHAIN INTEGRATION

Building Information Modelling (BIM) is expected to bridge communications gaps which have contributed to lack of collaboration and process inefficiencies associated with current fragmented structures (Vrijhoef, 2011). BIM has been described as an embodiment of policies, processes and technologies towards generation and management of project data in digital format throughout a building's life-cycle (Eastman *et al*., 2008). The benefits of such a system include real time information availability and access for early decision taking, reduction in lead-time and accountability (Vrijhoef, 2011). UK Government’s construction strategy expects some level of implementation of BIM on all government projects by 2016 in a road map towards universal adoption of BIM across the industry (BIS, 2011). It is expected that the highest maturity of BIM will be a fully integrated SC where a single parametric environment will be the basis of communication between each project participant during the entire lifecycle (BIS, 2011). However, the establishment of a system to facilitate such inter-organisational communication presents a challenging task due to its sheer scale and the need for congruence in the interest of participants within such a commercially driven environment (Adriaanse *et al*., 2010). Implementation is therefore still challenged by technological complexities of BIM as well as human, organisational and commercial context of its usage (Gu and London, 2010). For instance, it has been reported that higher perceptions of risks exist as a result of the openness of a centralised system, which may expose valuable intellectual property (Singh *et al*., 2011). These affect the willingness of users to adopt BIM (Mahamadu *et al*., 2013). Information scientists have described this phenomenon as the psychological representation of a complex interaction of individual perceptions about consequences and attitudes towards use (Venkatesh *et al*., 2003; Lee *et al*., 2012). This eventually determines level or extent of use, general described as user acceptance (Davis, 1989). Related theories and models have proliferated and have been successfully used in explaining or predicting implementation success through assessment of factors that contribute to user disposition towards these technologies (Venkatesh *et al*., 2003; Davies and Harty, 2013).

THE ACCEPTANCE OF BIM FOR SUPPLY CHAIN INTEGRATION

Most of the initiatives associated with implementing integration have failed as a result of non-acceptance due to a lack of fit between these initiatives and existing work practices or industry cultures (Briscoe and Dainty, 2005). Lack of trust and risk adversity particularly between clients and main contractors (focal suppliers) have reportedly derailed prescribed mechanisms for integration including procurement methods, lean techniques and even information technology use (Dainty *et al*., 2001). According to Briscoe and Dainty (2005 p.323), the relative failures of such 'formulaic prescriptions' for integration is because they are more effectively achieved at the social-relational level. Mohamed (2003) however posited that ICT usage would actually improve such relationship building through the provision of opportunities for collaboration as well as its potency in improving inter-organisational trust. Such assertions need to be validated in the BIM context particularly in view of contrasting evidence, that, lack of trust and risk adversity may rather hamper implementation of such centralised forms of communications (Adriaanse *et al*., 2010). Linderoth (2010) describes BIM as an artefact that shapes the roles and relationships across organisational networks based on actor-network theory. In assessing the potential impact of BIM, it was concluded that the consequences of deployment is determined by a combination of actors' (SC firms) interpretations of the patterns of action induced or inscribed by the artefact (BIM). Such patterns include risk, or perceptions of significant changes to the status-quo (Lowry, 2002; Linderoth, 2010). These naturally create resistance and aggravates unwillingness to use BIM (Lee *et al*., 2012). They further highlight the importance of identifying the interplay between drivers and inhibitors including perceptions of risk associated with adoption of BIM for integration.

U.K Government's primary expectation of BIM use by firms in the SC includes the attainment of a fully integrated SC (BIS, 2011). The extent and effect of BIM usage has been described as a reflection of its acceptance (Lee *et al*., 2012). BIM usage within the SC is, however, still low with evidence pointing to incomplete acceptance and making the envisaged full integration illusory (Khosrowshahi, 2012; Robson *et al*., 2014). With this growing recognition, it is imperative to assess the real impact of user disposition towards BIM use in the SC context and to further understand the determinants of its acceptance.

MODELLING SUPPLY CHAIN ACCEPTANCE OF BIM

Technology Acceptance Models (see Davis, 1989; Venkatesh *et al*., 2003) have provided a basis for investigating the role and impact of perception and behavioural disposition towards technology usage based on psychological theories. They provide theoretical linkages among beliefs, motivation, attitude, intention, and action (Venkatesh *et al*., 2003). A generic feature of these models is the hypothesis that actual system use is determined by users' behavioural intention to use, which is in turn influenced by users' attitudes towards use (Davis, 1989; Venkatesh *et al*., 2003). It helps in predicting the likelihood and rate of adoption of an innovation and has been applied and validated in various contexts of IT usage (Lee *et al*., 2012). According to Davies and Harty (2013), beliefs and expectations of the consequences of ICT use predict subsequent and extent of usage within BIM environment. Professionals are therefore increasingly interested in understanding the determinants of acceptance and ensuring new technological solutions designed are implemented so as to minimize resistance (Lee *et al*., 2013).

The Unified Theory of Acceptance and Use of Technology (UTAUT) is adopted in this study as a result of its prior usage in inter-organisational context due to additional constructs that consider the socio-organisational context of ICT usage (Venkatesh *et al*., 2003; Adriaanse *et al*., 2010). The primary constructs of the UTAUT model are theorised as the key determinants of user acceptance, namely: *Performance Expectancy*: perception of the degree to which using a technology will help attain performance in work tasks; *Effort Expectancy*: the degree of ease associated with the use of the technology; *Social Influence*: perception of importance associated with usage within social context of organisations or influence of peers; and *Facilitating Conditions:* perceptions about the prevalent environmental and organisational conditions that facilitate ease of use and support (Venkatesh *et al*., 2003). In view of transactional risk concerns often associated with SC relationships, *Security Expectancy* as an extended construct of UTAUT represents the degree to which an individual believes that security, relational or transactional risk impedes or support use of BIM. This construct is on the basis of successful extension of UTAUT in previous studies where information security is often regarded as very important such as research in online banking acceptance (Luo *et al*., 2010).

The core UTAUT constructs have been found to be affected by antecedent factors which provide stimulus for users' cognitive responses to new technology (Venkatesh *et al*., 2003).These factors can be categorised based on the characteristics and capability of the technology (BIM), the organisational context (SC) of usage as well as wider environmental influences such as industry and conditions provided by Government (Sargent *et al*., 2012; Davies and Harty, 2013).

Similar assertions led to development of Technology-Organisational-Environmental (TOE) framework which has previously been used in information studies to categorise implementation factors (Tornatzky and Fleischer, 1990). This framework has however been used extensively without recourse to technology acceptance (Oliveira and Martins, 2011). Building on the UTAUT model, the TOE framework is incorporated to assess antecedent factors that influence the core constructs. TOE framework has been advocated to allow appropriate consideration of all organisational level factors (Tornatzky and Fleischer, 1990). This is proposed to further alleviate the individual-user bias in previous application of UTAUT model in research (Oliveira and Martins, 2011). The consideration of external variables on the core constructs does not only contribute to theory development, but also improves understanding of technology acceptance (Sargent *et al*., 2012). As such, external variables provide a better context and understanding of what influences the core UTAUT constructs (Venkatesh *et al*., 2003). Therefore as opposed to previous studies which have often focussed on the impact of core constructs on acceptance, this model proposes direct incorporation and measurement of the influence of these antecedent factors on acceptance. Identified antecedent factors (determinants) to UTAUT constructs relating to BIM are presented in Table 1 and elaborated in the subsequent sections. Further exploration based on this framework is however required to aid completeness and comprehensiveness in the list of antecedent factors which can be later prioritised through empirical measurement within BIM enabled construction projects.

Table 1: Relationship between Determinants and Core UTAUT Model Constructs

Technological Determinants	Organisational Determinants	Environmental Determinants
Integration Capability (PE); Interoperability (EE); Cost (EE); Security and Privacy (SE, EE); Scalability and Information Risk (SE, EE); Standards (EE, FC)	Executive Support (FC); Inter-Organisational Trust (SE, SI); Legality and Data Ownership (SE, SI); Competence and Capacity (EE, FC)	Industry Support and Guidance (FC); Legislation (FC); Competitive Pressure (SI, PE); Image (SI); Vendor Support and Training (FC); Procurement (FC; EE)
UTAUT constructs: Performance Expectancy(PE); Effort Expectancy (EE); Social Influence (SI); Security Expectancy (SE); Facilitating Conditions (FC)		

Technological Determinants of Acceptance

Rogers (1995) describes five attributes related to a technology which influences implementation: relative advantage it provides: compatibility with existing task and systems; complexity, observability of its benefits and the ability to try it before deployment. This is similarly conceptualised within the proposed model to include variables with direct effect on Effort, Performance and Security Expectancy. BIM characteristics that are likely to affect or influence these perceptions generally relate to current state of development, technological challenges and its ability to deliver specific SC related performance expectations (Sargent *et al*., 2012).

From the review of literature, these have been identified to include *interoperability* which refers to the compatibility and data exchange related challenges associated with the high levels of heterogeneity in software and IT systems used across the SC (Aranda-Mena and Wakefield, 2006). Several case studies of BIM have highlighted high levels of cost and technical effort in remedying interoperability making it a key determinant of implementation success (Sargent *et al*., 2012). *Cost* of implementation or acquisition has also been a major factor affecting BIM implementation decisions (Lee *et al*., 2012). With the high numbers of small firms within the SC and a perception of high cost of implementation, it is unclear whether the anticipated benefits will outweigh perceptions of associated high cost (Robson *et al*., 2014). *Integration capability* refers to the ability of BIM to deliver key objectives of integration within the SC. Related benefits of BIM with regards SC integration include delivering information, flow efficiency and effectiveness, transparency, visibility and collaboration (Dainty *et al*., 2001; Hu, 2008; Mohamed, 2003). Other critical issues in relation to this element is early involvement, coordination and control of supply (Vrijhoef, 2011). *Security and privacy* concerns are critical in the SC because issues such as intellectual property theft and accidental data losses remain a critical concern in digital collaborative environments (Smith *et al*., 2007). There however remains a lack of understanding of the role of the characteristics of technology on these risks or perceived risk as this is critical for designing measures to foretell them in the deployment of BIM (Mahamadu *et al*, 2013). *Scalability and information risks* refer to the ability and capacity of individual SC systems to handle ever increasing volume and complexity of BIM based data. This is primarily caused by high levels of attached data including product or operational data from SC (Eastman *et al*., 2008). The scale and transitional requirements of data across the lifecycle of facilities therefore poses significant risk which may require additional effort by SC to become BIM compliant or to manage related data quality issues that may emanate from this (Singh *et al*., 2011). *Standards* are developed to ensure streamlined and consistent approach to managing BIM systems and data exchange

(Eastman, *et al*., 2008). The Industry Foundation Classes (IFC) (by the International Alliance of Interoperability) and International Organization for Standardization's (ISO) specification (ISO/PAS 16739) have proliferated recently largely for the purpose of achieving a unified approach to describing data structures and rules for encoding project information (Howard and Björk, 2008; Singh, *et al*., 2011). Widely fragmented state of development across the various disciplines also makes adoptability and universality challenging (Howard and Björk, 2008). The importance of current approaches and the extent to which this affects implementation of BIM is however not clearly known.

Organisational Determinants of Acceptance

This aspect of technology acceptance is most critical in dealing with the inter-organisational context of the SC. According to the TOE framework, related factors in this dimension often border on the transactional and social relational aspects of technology usage (Tornatzky and Fleischer, 1990). IT usage is underpinned by a web of social actions motivated by business objectives (Venkatesh *et al*., 2003). Thus, the structure, power and control dynamics, socio-cultural and transaction cost context of relationships and their relative influence on collaborative information exchange needs further investigation (Davies and Harty, 2013). This therefore considers factors related to prevailing organisational conditions that affect BIM usage for inter-organisational communications within a commercially driven environment.

The widely reported determinants include *executive (focal supplier) support* which refers to the decision by leadership within an organisation to commit resources for BIM implementation. This is often based on top management willingness which might be influenced by perceptions of risk (Sargent, *et al*., 2012). This, in the SC context may be focal firms such as main contractors or first tier suppliers (Vrijhoef, 2011). Sargent *et al*., (2012) found such executive commitment as having direct impact on BIM acceptance. *Trust* has more recently been recognised as a key influencer of SC performance (Briscoe and Dainty, 2005). According to social exchange theory, inter-organisational trust influences the ability of partners to adjust for uncertainties within exchange relationships including the use of integrative technologies (Wei, *et al*., 2012) such as BIM. Extensions of UTAUT have generally incorporated measurement of the impact of trust particularly where transactional or inter-organisational related risk exist (Luo *et al*., 2010). This is particularly important in view of ambiguity and legal constraints concerning ownership of data in these open BIM environments (Gu and London, 2010). *Competence and capacity* is regarded as a vital influencer of BIM implementation and acceptance by SC (Robson *et al*., 2014). Such capacity and competence include the human, financial and technical resource needed to deliver BIM (Eastman *et al*., 2008). It however remains unclear which level of competence or capacity will be required for each participant. *Legal risks* perceptions often moderate the actions of project actors, particularly where multi-party interactions are mediated by IT (Hassan *et al*., 2004).However, the conceptual ambiguity in the definitions of the BIM process and the relative misperceptions in practice however create significant legal uncertainties (Eastman *et al*., 2008; Gu and London, 2010). It is reported that current contracts have not adequately catered for the uncertainties and risks associated with digitally mediated integration (McAdam, 2010). Further, it is unclear how these influence BIM acceptance and usage.

Environmental Determinants of Acceptance

This represents the arena in which a firm conducts its business (industry, competitors, and governmental). Such industry level factors or prevailing conditions influence actions of technology adopters (Tornatzky and Fleischer, 1990). These external factors include technology vendor related issues which significantly affect the usability of technology (Oliveira and Martins, 2011).

Competitive pressure is a key determinant in the use of BIM within the SC context because of the general commercial nature of relationships within that environment (Khosrowshahi, 2012). Apart from coercive powers that influence strategy (e.g., rewards and threats), it has been found that the desire to remain in business could affect BIM acceptance (Adriaanse, *et al*., 2010). *Image:* If organisations believe they can receive industry rewards by using BIM, they will develop more positive attitudes and intentions towards the use of BIM (Lee *et al*., 2012). Such rewards include recognition as being innovators or having technological ability which may serve as extrinsic motivation to alleviate some of the challenges and risks (Adriaanse *et al*., 2010). *Vendor support and training* including up-skilling affects the ability to adapt (Lee, *et al*., 2013). Similarly, the provision of after-sales support by vendors of BIM systems, may serve as an appropriate facilitating condition for its continued usage (Xu, *et al*., 2014). *Industry leadership and support* including governmental intervention is believed to be a key driver of enabling environment. If U.K government targets of universal adoption will be met, SC firms will require adequate industry support, capacity building or even promotion (Robson, *et al*., 2014). Available guidance and protocols or other incentives that may reduce effort required to implement BIM is therefore needed (BIS, 2011). The real impact of such support on SC integration through BIM is yet to be ascertained. *Procurement* is used in establishing the basic governance framework for SC relations including their integration (Vrijhoef, 2011; Dainty, *et al*., 2001). While some particular forms have been advocated for integration, it is unclear what their contribution will be in facilitating BIM based integration and implementation (McAdam, 2010). In view of the challenges in achieving integration through procurement in the past, it is imperative to ascertain its role in successful BIM based integration.

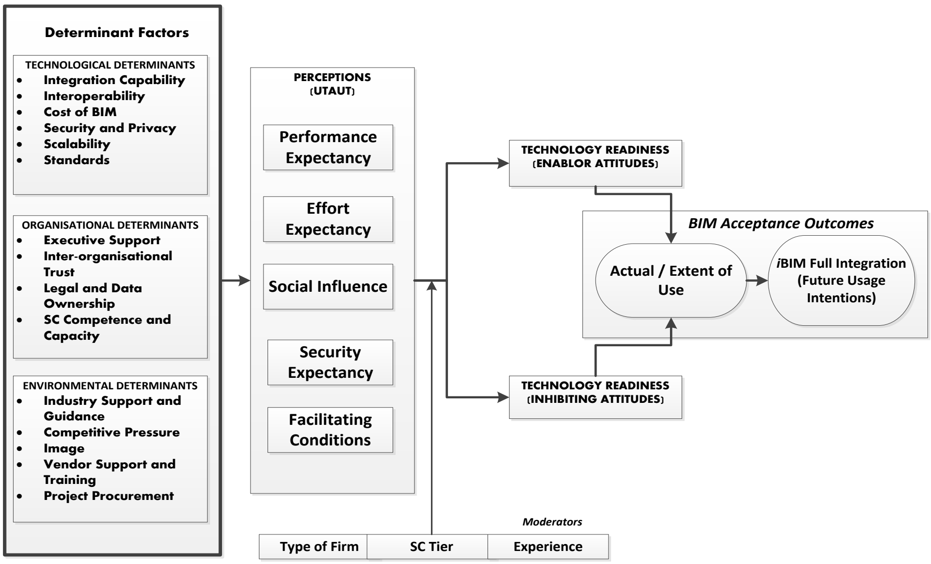
Incorporating Technology Readiness (TR) in Assessing BIM Usage Intentions

Building on the proposed concept of UTAUT-TOE modelling of acceptance, TR measures proposed by Parasuraman (2000) is regarded as appropriate for assessing the synergistic effects of acceptance determinants on the extent and intentions to use BIM for SC integration. Devolder *et al*. (2008) advocated that acceptance research must integrate user traits that reflect their preparedness to use a new technology. This is referred to by Parasuraman (2000) as technology readiness (TR) representing the complex interactions between conflicting positive (enablers) and negative (inhibitors) feelings about such technology usage. TR enablers include attitudes associated with optimism while inhibitors relate to constructs that measure feeling of insecurity (Parasuraman, 2000). TR is regarded as a suitable measure of user intentions which represent a user's affective response to new technology (Devolder *et al*., 2008). Its incorporation therefore provides a platform for more holistic readiness assessment where the cognitive dimensions (perceptions of consequence) play a key role in assessing readiness (affective response). This is in contrast to the current limitation of readiness assessment which have focussed on resource-centred capability and maturity modelling of readiness (see Haron, 2013).

Contextual participant attributes is also acknowledged as a determinant of variation in acceptance studies (Venkatesh *et al*., 2003). SC firm's professions, size, experience and role within the SC (ie Tier of the supplier they participate in) is therefore regarded as important in assessing peculiarity of acceptance from the varied perspectives of the SC. Such attributes therefore need to be incorporated as moderators in the modelling of BIM acceptance.

Drawing from the foregoing discussion, Figure 1 is represented to show the relationships between the key themes of BIM acceptance for SC integration. The integrated model adapted from UTAUT model (Luo *et al*., 2010; Venkatesh *et al*., 2003) and TOE frameworks (Tornatzky and Fleischer, 1990) for identifying and categorising determinants of acceptance. TR is incorporated to assess aggregated contribution of determinants on user disposition towards use.

Figure 1: An integrated Acceptance model for BIM in Construction SC



CONCLUSION

BIM has become a prerequisite in delivering integrated construction SC practice. Adoption is, however, still slow due to a plethora of implementation challenges. A theoretical model to aid further investigation of such challenges is proposed with a focus on the role and influence of user perceptions about the consequence of implementation. The relationships between the key determinants of acceptance is established from the literature and are forwarded as critical criteria for assessing implementation success, in view of its likely impact on willingness and preparedness of the SC to use BIM. TOE framework is incorporated into UTAUT to provide a wide arm for exploring stimulus for SC acceptance of BIM based on a categorisation that reflects growing recognition of the socio-technical complexities of the SC. From this model it is demonstrated that user acceptance plays a major role in understanding BIM implementation within the SC context. A conceptual model of influencing factors affecting acceptance and associated usage behaviours of BIM in the SC context is thus demonstrated to guide future research. It is recommended that future research adopts this model as a framework for the exploration of determinants particularly to assess their suitability in the construction SC context as well as for empirical validation.

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