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Building Information Modelling: Proposed Adoption Model For Quantity Surveying Firms

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Abstract. Building Information Modelling (BIM) represents the formation, utilisation and sharing of digital models between key stakeholders during the lifecycle of a facility. Academics and practitioners alike have advanced the idea of embracing BIM within the construction industry. Abundant of reports illustrating the benefits of BIM when deployed within design and construction phase such as better enhanced designs, more efficient construction processes, effective collaboration, cost and time savings. However despite receiving massive attention within the AEC industry, it appears that the adoption rate is not portraying such phenomenon. Inconsistency of adoption rate exists not only between countries but between industry key players as well. Surveys conducted showed that Quantity Surveyors (QSs) are among those who are least adopting BIM. Literature reviews reveal limited studies have been undertaken to investigate the key factors influencing BIM adoption in general, and among QSs specifically. As a result, this paper presents a model of BIM adoption factors based on the amalgamation of Technological-Organisation-Environmental framework, Diffusion of Innovation theory and Institutional theory.

Keywords: Building Information Modelling (BIM), Information Technology (IT), Adoption Model, Quantity Surveyor (QS)

INTRODUCTION

Building Information Modelling (BIM) is a digital representation of the physical and functional characteristics of a facility [1]. The multidimensionality in BIM is achieved by creating digital models for different parts and assemblies which incorporate additional information [2]. BIM is acknowledged within the industry to have the potential to improve productivity and quality which ail the industry for long.

A considerable amount of literature has been published on the enormous potentials of BIM to positively affect the construction industry processes. Some authors claimed that BIM permits designers to enhance their design not only by providing the possibility of designing more complex structures [3] but also allowing technical analysis of building performance to be done during design stage [2]. Thus, designers not only create intricate buildings but also sustainable buildings.

Better visualization will also facilitate builders to visualise what they will be constructing. This will assist the construction management team concerned with the entire project in planning their resources [4]. Improved constructability will save time and cost and indirectly the quality of the buildings [5]. In addition, better visualisation also meant improved quality of contract documentations [6]. This is due to the more understanding of the design intent of the designers to be translated into documentation.

Construction industry has been known to be slow in adopting any new technology innovation. Although there are numerous benefits involved when adopting BIM such as those described above, there are also other factors which impact negatively on the rate of uptake in the industry. A significant amount of literature has been published on the challenges of BIM adoption and implementation [7,8]. Barriers such as cost, training, interoperability, and changes in the overall design process are found often throughout the various literatures, and as such seem significant in setting back the adoption of BIM in the industry. Hence, a study is crucial to be conducted in order to understand the factors influencing its adoption within the industry. Specifically, this study focuses on identifying factors that influence organistional adoption of BIM.

RESEARCH AIM AND RESEARCH QUESTIONS

Building Information Modelling (BIM) can be defined as a set of technologies and processes to streamline the building lifecycle processes [9,10]. Its data-repository capability synchronises the construction practices from design, construct, operate, maintain to renovation/demolition thus also provides dynamic decision-making to the users. It has been claimed to have significant effects on productivity and quality within construction industry. Despite reported benefits of BIM paving the way for adoption by industry players, the rate of uptake is not as encouraging as expected [11,12,13,14,15]. Disparities of adoption rate between countries as well as industry players has motivated researchers to examine the adoption of BIM within the industry. Numerous studies have investigated the factors that influence adoption of BIM within organisations. These studies either explore the drivers [16,17], barriers [16,18] or benefits and uses of BIM adoption within organisation. However, most studies are merely listing the inhibitors and motivators of BIM adoption. In addition, those said factors are presented in an unstructured frameworks and thus, the findings are rather quite limited in assisting firms to make informed decision in adopting BIM. Hence, a study is crucial to be conducted in order to understand the factors influencing its adoption within the organisation. Specifically, this study attempts to develop a model by integrating *Diffusion of Innovation (DOI) Theory, Institutional Theory* and fit into *Technology-Organisation-Environment (TOE) framework* in order to aid in making decisions of adopting BIM within QS organisations.

The aim of this research is to facilitate the deployment of BIM/BIM-based software within QS organisations who are yet to adopt it through developing an adoption model to inform the significant factors that influence BIM adoption. Drawing from the research problem highlighted, the pertinent research questions are:

1. What are the key Technological factors influencing the adoption of BIM/BIM-based software within Malaysian QS firms?
2. What are the key Organisational factors influencing the adoption of BIM/BIM-based software within Malaysian QS firms?

3. What are the key Environmental factors influencing the adoption of BIM/BIM-based software within Malaysian QS firms?
4. How does the size of firm influences Organisational factors in the adoption of BIM/BIM-based software within Malaysian QS firms?
5. Which adoption factors have greater association with BIM/BIM-based software adoption within Malaysian QS firms?

RESEARCH MOTIVATION

This study is timely as stakeholders within the construction industry globally in general and, in Malaysia specifically are strongly urged to embrace the advent of BIM as a strategy to address its inherent issues such as wastages, inefficiencies, low quality and productivity. The Government of Malaysia has taken several initiatives concerning BIM adoption. Construction Industry Development Board (CIDB) Malaysia has set-up a BIM Portal for the usage of contractors and Public Works Department (PWD) Malaysia has initiated several BIM-based pilot projects as well as formulated BIM Roadmap which requires its key players to adopt BIM by 2016. Seeing that QS firms are the least adopters among the consultants within the construction industry, it is anticipated that this study will be used to facilitate and spur their adoption of BIM. By examining the key factors of BIM adoption, appropriate strategies can be formulated in effectively mobilising the resources within the organisations.

Theoretically, this research contributes to the existing knowledge of BIM literature which lacks organisational adoption models in general. It also extends the knowledge within BIM literature by synthesising 3 well-accepted theories which are DOI, Institutional Theory and TOE framework to enlighten the adoption of BIM within organisations. This approach may shed new insights to understand how these factors might shape BIM adoption.

LITERATURE REVIEW

Building Information Modelling

BIM is a revolutionary technology and process that changed the way buildings are designed and built [2,19]. Literature search shows that numerous definitions have been given to BIM and usually context-dependent, however, no universal definition has been attained [20]. Some authors have defined BIM as a tool for designing a facility in which all relevant data is stored and used throughout its lifecycle [21]. On the other hand, many authors have defined BIM as a process which utilize technological tools to create, illustrate, analyse, and construct a facility. They posit that BIM is more than a technology, it is a process enabled by 3D modelling. Apart from them, there are also authors who further defined BIM as an enabled technology which captures all the relevant information of a facility digitally for the different phases of the whole lifecycle of the facility [9,10,22]. In addition to the utility of technological tools, these authors suggest that BIM is meant for the whole lifecycle of the facility. In summary, BIM is a digital representation of a building to facilitate exchange and use of information throughout its lifecycle by the stakeholders. Further, [23] expresses that the significant concept behind BIM is to build the building virtually before moving to site in order to resolve any issues or problems beforehand.

According to BIM Project Execution Planning Guide released by Pennsylvania University, there are 25 applications of BIM for considerations to be applied in a project such as Site Analysis, Cost Estimation, Design Analysis, Digital Fabrication and Maintenance Scheduling. However, one must be cognisant on the needs of the project to be able to decide the most appropriate applications to be employed for the intended project [2,24,25].

Benefits to QSs

A considerable amount of literature has been published on the enormous potentials of BIM to positively affect the construction industry processes in general and to QSs specifically. Some of the reported benefits are Improved Cost Estimating, Increased Efficiencies, Improved Productivity, Cost and Time Savings, Offer New Services and Enhanced Communication.

The benefits of using BIM in modern construction project management have been well recognized. When implemented correctly BIM has the potential to resolve design or drawing discrepancies between the different disciplines during the project planning phase rather than in the field. It also ensures that plans and design documents remain consistent as the documents are passed to each discipline [26]. Thereby, BIM would immensely facilitate QSs in receiving consistent drawings from the design team resulting in zero or minimal discrepancies for cost estimating. This feature would not only saves time but also reduce errors and inconsistencies [4,22].

The other key advancement to note is the automatic generation of quantities from BIM which relies on the data within BIM to extract the relevant data and process into bills of quantities [27,28]. In his survey of QS organisations, [29] state that 77% of cost consultants and 57% of general construction professionals agree that automatic quantification would enhance the accuracy of estimates. This tool would greatly assist in reducing manpower and time, two worthy commodity, and creating a more productive business processes.

Another benefit claim by proponents of BIM is its ability to produce more effective and efficient processes. BIM allows multi-dimensional manipulation of drawings thus giving better visualisation of the proposed building. BIM is also capable of detecting clashes between designs. QSs are more efficient when they are able to visualize and rotate designs in 3D which would allow them to see the details that conventional drawings unable to provide. Through clash-detection capability, they can reduce potential reworks on site production. Hence, this will result more accurate estimates prepared by them [29,30]. Based on the data of 32 major projects, the Stanford University's Center for Integrated Facilities Engineering (CIFE) reported that the accuracy of BIM-based estimates was within 3% with up to 80% time reduction in generating these estimates. From the building information models, the contractors can perform fairly accurate quantity survey and prepare detailed estimates.

Another feature highlighted by researchers and practitioners is the capability of BIM to improve on communication and information management. In his study, [29] conclude that BIM could facilitate accessibility of pertinent documents the users required through sharing of the project model.

Apart from streamlining the design phase planning, it also contributes profoundly in producing sustainable design. [2]for instance, have described the use of BIM for developing models that enable computational based analysis and simulation to be undertaken. [31]has discussed the ability of BIM to model "comforts" including thermal, visual, acoustic and air quality. This complements well roles that could be taken by QSs in the height of pushing sustainable agenda in the industry. [27]proposes with the advancement in BIM systems, the use of object orientated CAD may be able to contain information such as Green Assessment points, intelligent advice on usage, LCA with carbon, specifications and real time costing as well. With the availability of all these information in the model, gives opportunities for QSs to grasp the prospect of venturing into new services to be offered by them as proposed by [27] such as Green costing, cost and carbon management consultant and LCC/LCA. This view is supported when a research conducted in USA found that 49 percent of users say that the ability to offer new services as the result of BIM adoption is a significant business benefit in way of creating new services to be offered to the industry [32]. A BIM-based whole life cost tool can support QS to provide complex lifecycle analysis [33].

Theoretical Background

An innovation can be an idea which precede the development of new product or service, or new technologies, practices or strategies adopted to improve existing process or products by the adopting organisation[34]. [35]stated that researchers defined organisational innovation as the creation and/or adoption of new ideas or behaviours in relation to a product, service, technology, system or practice. The wealth of innovation literature discloses several typologies of Innovations for example classifications based on risks – low risks vs. high risks, nature of innovations - technological vs. administrative innovations and degree of changes resulting from innovation - radical vs. incremental innovations [36] In addition, [37] also claimed that IS innovation can be classified through degree of changes which are radical innovations and incremental innovations. While radical innovations represent dramatic divergence from existing practice, in contrast, incremental innovations are simple adjustments in current practice [38]. According to [36], technological innovation constitute of changes to organisations that are brought about by the changes in the technology deployed within the organisation. These innovations generate changes in the products, services or the related processes. Conversely, he further described that administrative innovations do not affect directly on the core activity of the organisation but more on the management of the organisation. Thus, it tends to change an organisation's structure or its administration processes. Additionally, [39] suggested IT which includes software, hardware and systems, to be another classification of innovations. [37]proposes a typology of IS innovations comprising of Type I, Type II and Type III. Type I innovation constitute IS process innovation; Type II innovation support the business administrative process and Type III innovation focus upon core business products and processes.

There are also studies that offer dual dimensions typology to enlighten the innovation phenomena. [40] proposes a dual dimension typology of innovations based on nature of innovation and significance of change and thus an innovation can be classified according to the four categories: 1) radical, technological innovation; 2) radical, administrative innovation; 3) incremental, technological innovation; and 4) incremental, administrative innovation. Drawing from the proposed typology of [40], BIM is conceptualised as a radical, technological innovation due to its nature of disrupting existing processes or practices of the adopting unit. Calls have been made to organisations to not only change their workflows and business process [41,42,43] but also to their mindset on project delivery approach [44,45] as BIM revolutionaries the way.

[46]posit that technological innovation theories are fitting to be the foundation for empirical IS adoption studies. Drawing from this, this research synthesised 3 main theories from Innovation, Information Systems and Organisational literature which are Diffusion of Innovation (DOI), Technology-Organisation-Environment (TOE) framework and Institutional Theory to explain the phenomenon of organisational IT adoption.

Technological-Organisational-Environmental (TOE) framework

TOE framework which was developed by [47] initially meant to explain innovations adoption and diffusion. The framework expounded that there are 3 contexts influencing an organisation to adopt and diffuse technology innovations. The 3 contexts are Technological, Organisational and Environmental factors. This framework has been tested and validated by many studies [48,49] and has been employed within varied IT innovations even though specific factors identified within the contexts vary across different studies.

Technological context describes both the internal and external technologies relevant to the organisation: the current in-use within the organisation as well as those available in the market [47]. [50]clarifies that the current in-use technologies may determine the scope and pace of technological change to be undertaken whereas those available technologies but not yet in-use can illustrate the possibilities the organisation could take upon.

Organisational context refers to the characteristics and resources of the organisation which includes linking structures between employees, intra-firm communication processes,firm size, and the amount of slack resources[47]. Review of the literature indicates that a large number of studies examine this context through other various constructs such as top management support [51], organisation structure [52], firm scope [53], organisation's readiness [51,54], perceived risks [55], and training [56].

Environmental contextencompasses the settings where organisations conduct their businesses which includes the structure of the industry, the presence orabsence of technology service providers, and the regulatory environment [47]. In addition, [57] identify environment context involving the industry within which an organisation embedded in, its competitors and its dealings with the government.

A growing body of literature have used TOE framework as the basis for the understanding of various IT innovations adoption. For example,[48] looks at the adoption of Electronic Data Interchange (EDI) within small firms in Hong Kong while [58] investigates the adoption of e-business usage within firms across 10 countries. Other studies explored adoption of other IS innovations such as e-commerce [59], enterprise resource planning (ERP) [49], cloud-computing [60] and inter-organisational systems (IOS) [61].

[50]stresses the need to synthesise existing adoption theories in order to formulate more comprehensive models to understand and explain technological innovations better. Hence, this study developed a conceptual research model as shown in Figure 1, by integrating TOE framework, DOI theory and Institutional Theory to explain the adoption of BIM within QS firms.

Diffusion of Innovation (DOI) Theory

DOI attempts to explain the diffusion of innovation within a social system over a period of time [62]. A large volume of published studies have applied and tested DOI theory across diverse fields such as education, agriculture, marketing and sociology and has received consistent empirical support. Moreover, recent studies have also employed DOI theory to explain IT adoption [63]. Rogers presented a few key concepts that influence the rate of adoption of an innovation: attributes of an innovation; communication channels; social system; and time. He posited that there are five attributes that affect innovation adoption which are *relative advantage, compatibility, complexity, observability* and*triability*. Numerous previous studies have adopted the attributes of innovation as the explanatory technological context to study IT adoption [46,63]. Of these, only *relative advantage, complexity* and *compatibility* are consistently found to be associated to adoption [64]. Recent studies in IT adoption also demonstrate the significance of these factors [63,64].

Among the main criticism of this theory is the principle assumption of voluntary deployment of innovation among the individuals [34,56]. [66] criticised this theory incapable of taking into account the characteristics of complex technologies. [34]argues that DOI theory alone may not be sufficient to explain adoption of complex and multiusers technological innovations. Calls have been made to the need to complement this theory with other theories in order to investigate these complex scenarios [34]. Thus, this concept will be subsumed under the Technological context of the TOE framework.

Institutional Theory

[67]argue that organisations are becoming more similar to other organisations within the same environment not due to pressures for efficiency or performance. Institutional Theoryposits that firms resemble others due to isomorphic pressures and pressures for legitimacy. This means that firms within the same fields are prone to copy another as a result of pressures received from their institutional environment such as competitors, customers or regulatory policies. The theory emphasised that institutional environments are crucial in shaping organisational structure and actions. In contrast, [68] contend that majority of adopters are adopting innovations for greater performance and simultaneously in response to external pressures.

Isomorphism is a similarity of one organisation to another in its processes, strategies or structure which resulting from certain external pressures. On the other hand, [38] believe that organisational legitimacy is attained when one organisation is perceived to have values and actions that are consistent with the relevant social actors – competitors, customers, government bodies, trading partners or professional bodies. [67]distinguished 3 types of isomorphic pressures which are mimetic, coercive and normative pressures.

Mimetic pressures are influences imposed on organisation to imitate the practices of other competitors [67,68]. These pressures may cause an organisation to change over time to become more like the other organisations within its environment. Mimetic pressure has been included in many past studies to elucidate the adoption of IT [69,70].

Coercive pressures are a set of formal and informal forces exerted on one organisation to adopt the same processes, structure or strategies by other more powerful entities [67].[71]point out that variety of sources may be the cause for coercive pressure such as regulatory agencies, suppliers, customers, parent corporations and other keyconstituents. [72]listed legal requirements, customer requirements and owner requirements as the mechanism for coercive pressure. Coercive pressures have been found to be significant in the adoption of IT [68].

Normative pressures occur when one organisation is more likely to copy voluntarily the same process, structure or strategy if that element is prevalent within its organisational field [67,73]. Examples of normative sources are professional bodies, consultants, trade associations as suggested by [74]. Several studies included normative pressure to investigate the IT adoption [75,76].

Even though this theory has been supported to be consistent in examining the effects of institutional pressures on IT adoption but it is limited due to its narrow scope. [35]emphasized that innovation adoption is multidimensional, meaning the adoption of innovation is influenced by several interrelated contexts, not on any one dimension. Thus, it is prudent to explain the phenomenon of IT innovation adoption by synthesizing existing theories and investigate from various angles. Therefore,this concept will be subsumed under the Environmental context of the TOE framework.

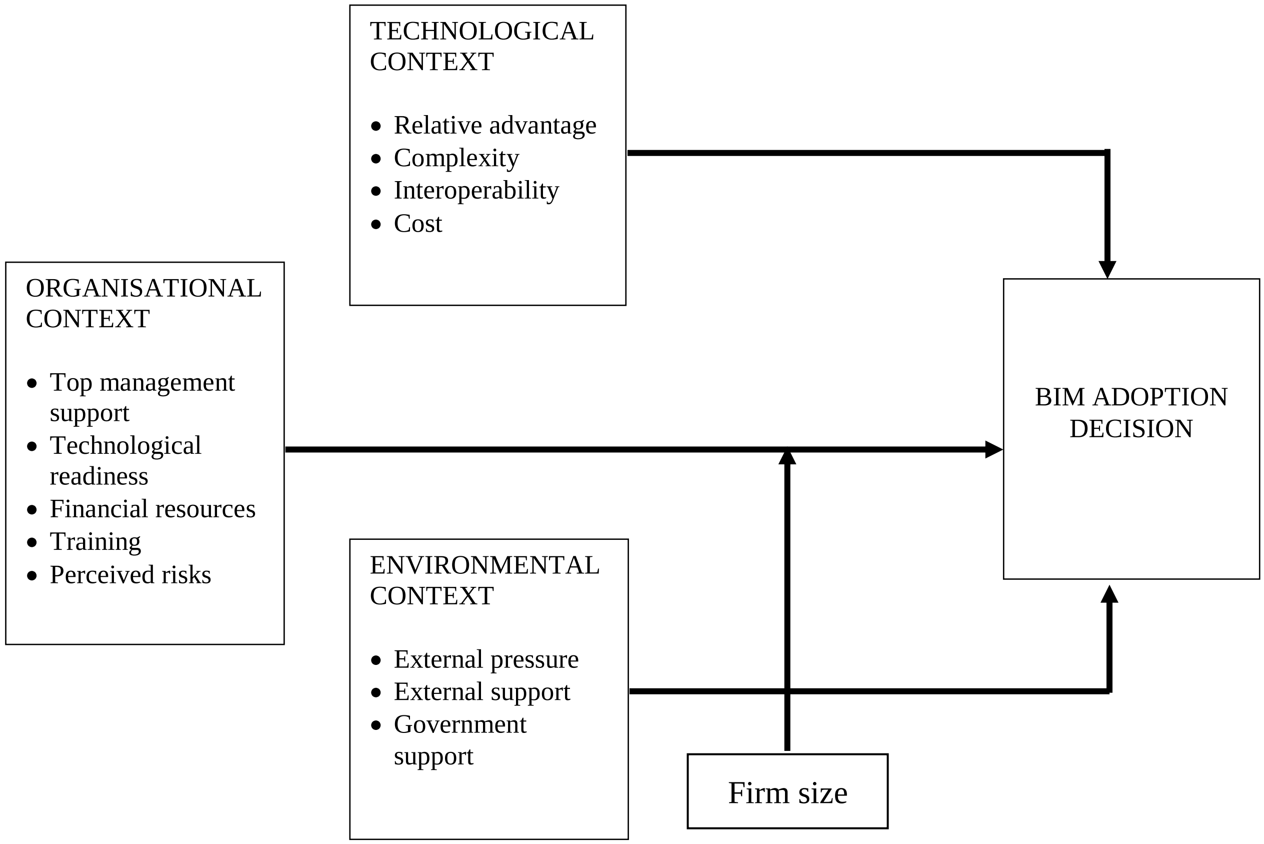

FIGURE 1. Conceptual Framework

RESEARCH METHODOLOGY

Research Design

This research employs Quantitative strategy which applies a deductive approach in which moving from theory to data. In addition, [77] argues that quantitative approach is more appropriate to determine the extent of a phenomenon or issue. The method selected is cross sectional survey using questionnaire as the research technique.

Sampling

Unit of analysis for this study is QS organisations. The key informants will be the decision-makers of the organisations. However, in order to avoid the deficiency of single key informants, two or more questionnaires were sent to each organisations.

The target population for the study is QS firms within Malaysia. However, in order to gather relevant and valid response, two requirements are imposed on the respondents, i.e. the respondents are i) the decision-makers of the firm and, ii) has some knowledge of BIM.

A list of QS firms in Malaysia was obtained from Board of Quantity Surveying Malaysia for the year 2015. The list showed there are 340 firms throughout Malaysia.

Nonetheless, to fulfil the second requirement, another list was required to imply that the respondents have some knowledge of BIM. Thus, a list of attendees to BIM workshops, seminars and/or conferences were compiled. Such activity was facilitated by having Royal Institute of Surveyors Malaysia (RISM) as the champion of BIM and has organised several meaningful events since 2011. The two lists were cross-referenced and the final list was created. The final sampling frame consisted of 189 firms throughout Malaysia.

By applying the formula published by *National Education* Association (1960), the sample size required is 127 for confidence level of 95% and margin of error at 5%.

Data Analysis

Analyses will be conducted to achieve 3objectives:

1) Getting a feel for data through descriptive statistical analysis using the SPSS. The analysis included an examination of the respondent profiles and data screening.

2) Testing the goodness of the measurement scale by measuring reliability and validity of the constructs. The construct reliability will be measured using 'Cronbach's alpha' which will indicate the consistency of responses across items within the scale. On the other hand, validity of the construct will be measured through Exploratory Factor Analysis using principal component analysis with VARIMAX orthogonal rotation.

3) Assessing and refining the model through Structural Equation Modelling (SEM). SEM is used to determine the validity of theoretical model by specifying, estimating and evaluating the relationships among a set of constructs.

CONCLUSION

This paper presents a new BIM adoption model to assist QS organisations in making decision for its adoption within their organisation. Organisations need guidance and appropriate strategies in order to increase the rate of successful adoption. By understanding the key factors for BIM adoption, QS organisations will be better able to allocate sufficient resources to achieve its goal.

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