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Building Information Modeling (BIM): A new paradigm for quality of life within Architectural, Engineering and Construction (AEC) industry

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Abstract

The adoption of Building Information Modeling (BIM) constitutes a paradigm shift in the architectural, engineering and construction (AEC) industry. Broader BIM adoption will transform construction processes to achieve greater efficiency to improve the quality of life (QOL) of construction stakeholders. This paper seeks to identify determinant factors and implementation gaps of BIM in the AEC industry. A case study was conducted through a preliminary workshop organised by CIDB among the five potential stakeholders: Public Private Partnership (PPP) Unit (UKAS), JARING, eMOST/ UMP, Greenwave Synergy (GWS) and CIDB eConstruct (EC) of the AEC industry in Malaysia. The findings suggest various determining factors and gaps existed at the national and organisational levels. Finally, the workshop suggested an *'affordable BIM concept'* with *'pay-per-use or periodical license'* method to be adopted for SMEs contractors.

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Keywords: Building Information Modeling (BIM); BIM influencing model; construction; technology

1. Introduction

Technology is changing and developing around the world at a rate and pace never experienced before. The contribution of new technology to economic growth can only be realized when and if the new technology is widely adopted and used. Adoption itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison between the uncertain benefits of the new invention and the uncertain costs of adopting it (Parente

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and Prescott, 1994). The architecture, engineering and construction (AEC) industry is often perceived as being slow in adopting technology, and was claimed to cling on to old business models and processes for decades. Nevertheless, the AEC industry has several practical applications that facilitate the technology, outsourcing and exchange of information within the industry, the roles of technology adopted are important to sustain the quality of life (QOL) to mankind. For instance Computer aided design (CAD) or drafting is a technology widely used by the AEC industry. CAD is a form of computer-aided building modulation that architects, engineers and contractors use to create and view two-and three-dimensional models. The AEC industry also uses building information modeling (BIM), a newer computerized modeling system that can create up to six-dimensional models; this software can greatly increase productivity in the AEC industry. Hence, the task of AEC industry is to be able to adopt and apply technologies in order to improve the quality and productivity of the industry (Hassan, 2012).

Much attention in the AEC industry today is focusing on Building Information Modeling (BIM). CIDB (2013) defines *BIM as a process supported by technology of computer generated model used in collaboration to populate information and simulate the planning, design, construction and operation of a facility.* BIM is now being increasingly used as an emerging technology to assist in conceiving, designing, construction and operating the building in many countries (Wong et. al., 2009). It is recognized as a new management technology that provides an integrated solution to operate businesses while improving the client satisfaction to time, cost, safety, quality and functionality of construction projects. Meanwhile, there is a great diversity in ideas about definitions on Quality of Life (QOL). Some perceive it as *the environment we live, the house and the air we breathe*, while others describe it as *safety and security, health, wealth (employment), transport infrastructures, adequate building for housing, schooling and recreation* (Mercer, 2007). In general, QOL is a subjective matter that involves a person's emotional state and personal life. To achieve any of the perceive QOL, adoption of new technology is inevitable.

This paper seeks to identify the key determinant factors and implementation gaps of BIM in the AEC industry. A Technology Acceptance Model (TAM) developed by Davis (1989) posits that human feelings, behavior and attitude are the trigger to begin adopting new technology. The study accesses the impact of *perceive usefulness* and *ease-of-use* to the broader adoption of BIM which will ultimately contribute to the improvement of QOL in the AEC industry.

2. Background

One of the Malaysian government agenda in the 12 National Key Economic Areas (NKEAs) is to enhance business growth in the AEC industry (Pemandu, 2011). For this matter, the AEC organizations have aggressively embraced new technology in order to remain competitive in the current market (Alshawi et.al. 2010). Building Information Modeling (BIM) is one of the new emerging technologies to be deployed in the design, construction, and facility management in which a digital representation of the building process is being created to facilitate the exchange and interoperability of information in digital format. Despite the advantages derived from this paradigm, local construction industry is reluctant to deploy the technology in its service delivery (Shuratman, 2012).

BIM has existed for over 20 years; it is only over the last few years that the construction industry is aware that BIM promises to make the industry much more streamlined and efficient (Arayici, et. al., 2012). BIM applications has grown tremendously, from a tool to design in three dimensions and use of components, to a tool that is used for model analysis, clash detection, product selection, and whole project conceptualization (Weygant, 2011). BIM is now being increasingly used as an emerging technology to assist in conceiving, designing, construction and operating the building in many countries (Wong et.al. 2009). It is providing itself as a very powerful tool that allows users to create visual simulation of a project and provide a virtual prototype of a building prior to construction. However, BIM requires specialized training because of the complexity of the processes.

In view of the BIM evolution, Germany, Finland and United State (US) are regarded as the pioneering countries for this technology (Howell and Batcheler, 2005; Wong et.al., 2011 and Khosrowshahi and Arayici, 2012). Previous record indicated that, the earliest development of BIM is recorded way back in 1982 by Gabor Bojar through Graphisoft in Hungary (Graphisoft, 2013). Meanwhile, US are the biggest producer and consumer of BIM products and the flow of BIM knowledge dissemination have generally been from the US to other developing countries (Wong et. al., 2011). According to Khosrowshahi and Arayici (2012), Finland is the world leader in the BIM implementation in which the BIM software (Tekla and Vicosoft) were born. Nevertheless, apart from United Kingdom (UK) and Hong Kong (HK), Singapore, South Korea and Australia are countries that are making progress towards the endorsement of BIM at the national levels.

Despite the industry's awareness of the potential of BIM, construction organisations are yet to utilise it aggressively. According to Khosrowshahi and Arayici (2012) the UK construction sector is facing slow progressive changes in the BIM implementation. The probable reasons could be the difficulty to implement BIM, adoption could incur higher additional project cost, require a comprehensive training, and majority of the designers are still familiar in using AutoCAD in their design services instead of BIM.

3. Methodology

The study starts with literature search which reviews the determining factors in the adoption and implementation of BIM in the AEC industry. Further research has been carried out through a workshop by the Construction Industry Development Board (CIDB) to investigate the determining factors and implementation gaps of BIM movement within the five potential stakeholders: Public Private Partnership (PPP) Unit (UKAS), JARING, eMOST/ UMP, Greenwave Synergy (GWS) and CIDB eConstruct (EC) of the AEC industries in Malaysia. The data were processed by means of content analysis techniques.

4. Determinant factors of Technology Acceptance

The determinant factors of technology acceptance could be divided into three parts; categories of technology adoption; factors influencing the choice to adopt; and factors mediating technology implementation. These factors will be discussed in turn.

4.1. Categories of technology adoption

The adoption of new technology usually begins prior to an official decision made by the organisations. Most local and international organisations decide to adopt technology based on the benefits or competitive advantage that they will gain through the push factors such as regulations, policy and industry standards (Abukhzam and Lee, 2010). Similarly, in Malaysia, the AEC industry decides to regulate the technology implementation based on economic demand, advantages and global competitiveness (Parente and Prescott, 1994; Hasan, 2012). In order for the technology to be adopted conversantly, training and support in the use of the technology is inevitable due to the complexity of its processes (Suebin and Gerdsri, 2009). In this regard, technology adoption could be categorised into two levels: national and organisational/individual levels. At the national level, the adoption means the decision at the ministry to mandate or regulate the use of technology throughout the whole nation. This will result in policy making and development of national standards and enforcement acts. The organisational level is referring to the decision made by the top management of the organisations based on the push factors or the competitive needs to be champion in the respective area (Teng and Nelson, 1996). The organisational level could also include the individual's acceptance and motivation to accept changes and the ability to learn new ideas. This motivation and ability to learn are hugely dependent on the ease-of-use of the technology and its usefulness to each individual. Without the acceptance from the individuals, the organisation will not obtain any benefits from investing in new technology (Suebin and Gerdsri, 2009).

4.2. Factors influencing the choice to adopt

When people are presented with new technology in the market, a number of factors influence their decisions on how and when to use the technology (Majid et.al, 2011). These decisions are related to their perceptions of the new technology through social communication but with fearful of changes (Suebin and Gerdsri, 2009). The use and adoption of new technology is a process that begins with awareness of the technology and progresses through a series of stages that end in appropriate and effective usages. According to BTC (2005), factors influencing the choice to adopt technology could be in five stages. These are: awareness, assessment, acceptance, learning and usage. Awareness implies the knowledge gained by potential users through one's own perceptions or by means of information about the technology, its benefits, and plan to investigate further; assessment is the potential users' evaluation on the usefulness, usability, difficulty in adopting the technology; acceptance means potential users' decision to acquire and use the technology, or decide not to adopt; learning is when users' develop the skills and knowledge to use the technology effectively; and finally, usage is when the users demonstrate the effective use of the technology and conform of the adoption. Figure 1 shows TAM theory which employs the perception towards technology usefulness and ease-of-use as determinant factors to technology adoption (Davis, 1989).

TAM theory starts with the exertion of external factors or external variables such as the stimulus from political influence, regulation and implementation process as the push factors. While, the combination of perceived usefulness and perceived ease-of-use will form the attitude and intention to use prior to full acceptance and actual use of any new system or technology in the industry. Perceived usefulness is defined as the degree to which an adopter believes the new technology would improve or enhance job performance, meanwhile perceived ease-of-use refers to the users perception of the minimum effort required for the use of new technology. Venkatesh and Davis (2001) developed the extended model of TAM called TAM2 by including social influence and cognitive instrumental processes into the equation. TAM3 is later being established by Venkatesh (2012) as an extended version of TAM2. However, the models are consistent with the basic TAM theory which defines perceived usefulness and perceived ease-of-use as key predictors of technology acceptance within the AEC industry.

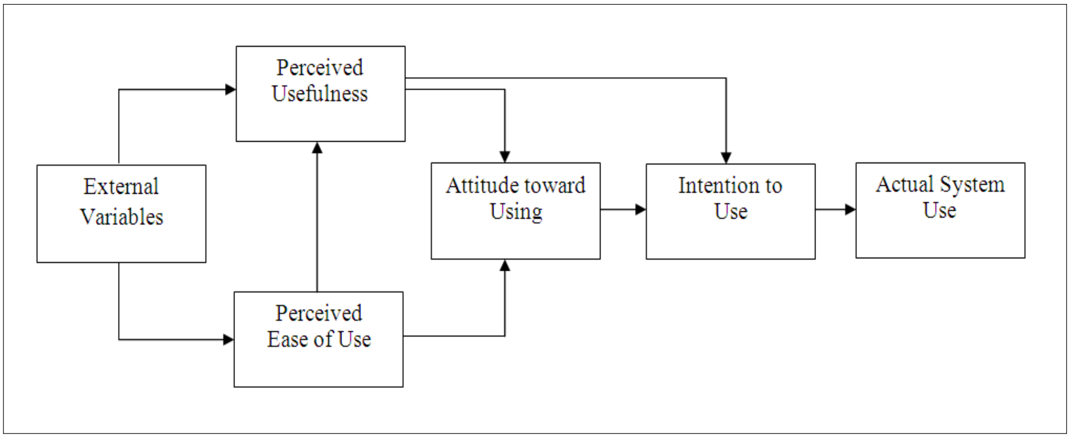

Fig. 1. Technology Acceptance Model (TAM) (Davis, 1989)

4.3. Mediating factors to technology implementation

Studies have demonstrated that the issue of technology adoption is very complex. Upon the analysis to begin accepting and the decision to adopt, the readiness of the organisations in respect to the product, process, and people is sought (Gu and London, 2010). Product refers to the capability and complexity of the selected system to fulfil the users' requirements; process means the necessity to revisit current work processes that require changes or otherwise; while people refers to users and top management awareness, involvement, sufficient training and sufficient support. These are mediating factors to technology implementation within the organisations (Khosrowshahi and Arayici, 2012). Figure 2 illustrates the general process flow of new technology adoption and implementation in the AEC industry.

Upon the incursion of technology into the nation, the benefits, competitive-advantage and championship will be evaluated. In the event of no benefit or advantage is found there will be a no buy-in of the technology at the national level. Meanwhile, the regulation, policy, enforcement and awareness programs will subsequently emanated when the entire process of developing and managing could be beneficial to the nations. In this figure, two gaps of BIM adoption in the Malaysia's AEC industry are predicted. Gap 1 is to ensure the acceptance of BIM at the national level. This means to say that there is a considerable attention to the benefits, competitive advantage and championship being paid to the adoption of BIM technology prior accepting it for the National agenda (CIDB, 2013). The Gap 2; however is to ensure the internal aspect of organisational/individual acceptance or rejection prior the implementation. Gap 2 is divided into two parts; private organisation and public organisation. Private organisations are referring to companies run by private entity or individuals. It encompasses businesses that are not owned by the government. Nevertheless, it may have a business associated with the government by which regulation and policies is exerts. On the other hand, public organisation means a portion of industry managed by national or state government through several respective organisations controlled by the government.

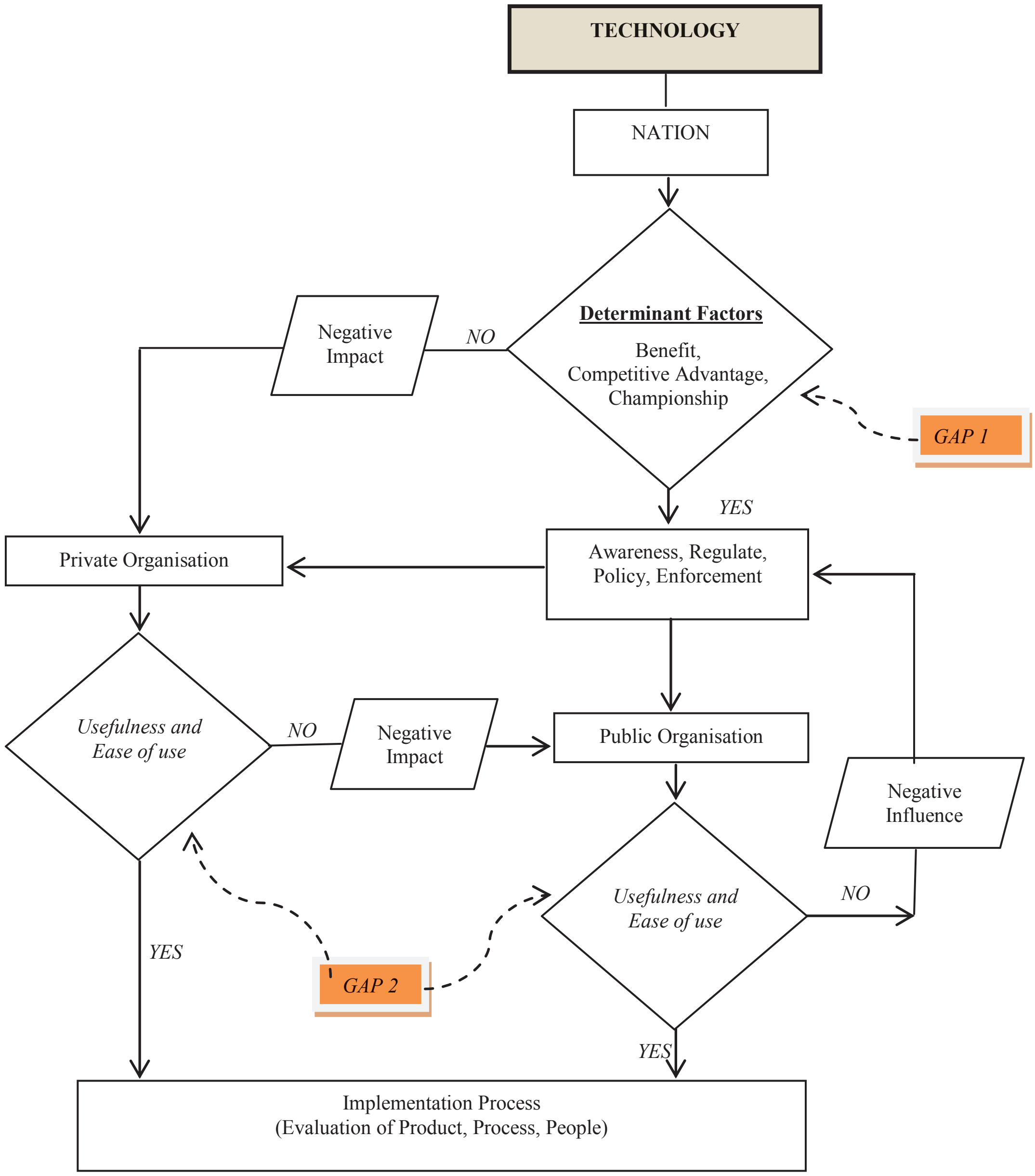

Fig. 2. General process flow of new technology adoption and implementation in the AEC industry

The usefulness and ease-of-use in implementing new technology would influence the adoption decisions at both parts (private and public organisations). In the event there is no usefulness or ease-of-use found by the private organisations, a negative influence will be asserted to the public organisations which ultimately impact the awareness program, regulation, policy and enforcement of the new technology. Gap 2 is associated to the three vital factors: BIM could increase clarity of project to all stakeholders for better decision making and reducing risk; ensuring data fidelity and continuity across project lifecycle; and providing critical foundation to business agility. Implementing BIM on public and private projects could be done in planning, design, delivery and operational areas. In Malaysia, architects are the chief consultants in the AEC industry but they do not seem to actively drive the BIM movements (RISM, 2013). The reason could be due to the limited access to capital, naïve and incapable in the system. Among others, RISM has initiated several BIM committees within the AEC industry, while the Public Works Department (JKR) has started to use BIM for selected projects. Nevertheless, the Malaysian Construction Industry Development Board (CIDB) had formed a Technical Committee of Affordable BIM to fill the Gap 2 (CIDB, 2013). The initial initiative is through a series of workshops with the purpose to discover technical limitations in the implementation of affordable BIM with centralised storage within government agencies and product vendors in Malaysia.

5. Case study

A case study was conducted through a preliminary workshop organised by CIDB in January 2013. It brought together five potential stakeholders: Public Private Partnership (PPP) Unit (UKAS), JARING, eMOST/ UMP, Greenwave Synergy (GWS) and CIDB eConstruct (EC). UKAS acts as the main stakeholder who will enforce the usage of BIM by contractors; JARING as the infrastructure-as-a-service (IAAS) provider; eMOST/UMP represents BIMs process adviser; while the GWS and EC represent the BIM product vendors to advice on system limitations and developing the 'affordable BIM' platform. The purpose of this workshop is to discover the factors influencing the choice to adopt BIM in AEC industry. The outcomes of this workshop are tabulated in Table 1.

According to CIDB, there is a need to facilitate the whole AEC industries in order to effectively implement BIM. Despite the comprehensive understanding on the usefulness of BIM, the EAC industries need to have easy access and ease-of-use on the use of BIM for their projects. Hence the concept of pay-per-use or periodical license was suggested that need to be explored further. Meanwhile, UKAS describe that BIM could incur higher project cost since the software is expensive to purchase and implemented. For that matter, cost is the biggest obstacles to effectively implement BIM to projects in particular among small and medium (SMEs) companies of sub-contractors and suppliers. Moreover, for a small contract value (i.e., less than RM 1 million), it is difficult for them to implement BIM for their projects. The concept of periodical license was suggested to support the implementation of BIM in the PPP projects.

On the other hand, eMOST /UMP suggest conducting a specialized training of BIM among PPP contractors. Through a comprehensive training, the usefulness and ease-of-use in using BIM could be discovered. Despite BIM training could incur a substantial cost for the project at the early stage, the overall cost saving could be realised in the long run. The eMOST/UMP has asserted that, the cost saving throughout the project life-cycle will outweighed the up-front additional cost of implementing BIM in the construction projects. To BIM product vendors, the GWS and EC; an 'affordable BIM concept' is suggested for further discussion. The workshop has derived two important action plans: the first is to explore the possibility of providing a pilot BIM pay-per-use concept for Public Private Partnership (UKAS) projects; and the second is to investigate further the concept of 'affordable BIM' to be implemented for SMEs projects.

Table 1. Factors and implementation gaps influencing the adoption of BIM in EAC industry

	CIDB	UKAS	eMOST/UMP	GWS (Vendor)	EC (vendor)
Determining factors	Perceived usefulness Ease of use Championship	Economic demand People acceptance	Technical support Process change	Product limitation Product interoperability	Product limitation Product interoperability
Implementation Gaps	BIMs as multi-representational, multi-dimensional and integration of information carried out for project implementation.	1. Small and Medium (SMEs) companies are reluctant to use BIM due to the *expensive cost of software* and could increase the total amount of project cost. 2. PPP Contractor *transfers the cost* in implementing BIM onto the Government, defeating the idea of cost saving.	1. *Specialized training* is required for BIM among PPP contractors. PPP contractors are to appoint BIM manager to coordinate the training and estimate the cost incurred.	Plan to *propose affordable BIM* concept in the next workshop	Plan to *propose affordable BIM* concept in the next workshop
Suggestion	To explore on the platform of *pay-per-use method* or periodical license, where SMEs able to utilized during their short tenancy in the project.	The concept of *periodical license* may benefit the PPP contractors and SMEs in which they are able to implement BIM without incurring additional cost onto the project	*Specialised training to be embedded* To *propose process change*	Majority of software *companies are not ready* on the method of *pay-per-use* but will try to explore further	To suggest a *special discount* for those who want to implement BIM, registered through CIDB portal
Conclusion	The workshop suggested an *'affordable BIM concept'* with *'pay-per-use or periodical license'* method to be adopted for SMEs contractors.				

6. Conclusion

Building Information Modeling (BIM) is the use of computer generated model to simulate the planning, design, construction and operation of a facility; a technology that allows users to create visual simulation of a project with a digital prototype of a building prior to construction. The deployment of BIM in construction can make the industry more efficient, effective, flexible, and innovative. Based on the literature search and data from the preliminary workshop, it can be deduced that three (3) vital determining factors in adopting BIM at the national level are: regulation, policy & industry standards; benefit, competitive advantage & championship; and economic demand in the AEC industry within the perceptions of perceived usefulness and ease-of-use. To ensure the acceptance of BIM (G1) by the Government is the fundamental gap that exists at this level. Meanwhile five (5) vital determining factors captured in adopting and implementing BIM at the organisational level are: clarity of the project; fidelity and continuity across project lifecycle; business agility; training and support; and cost of implementation within the perceptions of perceived usefulness and ease-of-use. Once again the acceptance or rejection (G2) by public and private organisations is the essential gap at this level.

The workshop held by CIDB has suggested an 'affordable BIM concept' to be explored with the method of 'pay-per-use or periodical license' for SMEs contractors. The purpose is to investigate further that expensive cost of implementing BIM could give a negative impact on the ease-of-use of BIM in the AEC industry. Nevertheless, this concept will require further discussion and brainstorming in the future workshops.

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