

# Hypothesis Analysis of Building Information Modelling Penetration in Malaysian Construction Industry

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## Abstract

The demand pull for a more effective construction process within architecture, engineering and construction (AEC) industry continuous to transform design techniques from 2D, 3D and building information modelling (BIM). Leverage on IT pivotal for construction industry development has been earmarked by the Malaysian construction industry master plan (CIMP). BIM uptake by stakeholders in Malaysia construction industry is on a gradual increase. BIM generates and manage building data during its life cycle via three-dimensional, real-time, dynamic building modelling. The model is dependent on collaborative contribution by project teams input at various stages. However, challenges such as people, process and technology impede an effective penetration rate in Malaysia. This paper presents a continuation of the theoretical framework developed, to further investigate the relationship for BIM penetration from perspectives of people, process and technology to strategic IT in construction and collaborative construction. The theorised hypotheses argue that strategic IT planning will invariably aid BIM penetration in the industry. The hypothesis will undergo structural equation modelling (SEM) to analyse the desired statistical power, test for close versus exact fit and complexity of the model. The findings will delineate the variables with predominant impact on BIM penetration and serves as a guide to policy making on BIM implementation in Malaysia.

**Keywords:** Building Information Modelling, Information Technology, Penetration, Malaysia Construction Industry.

## 1. Introduction

Malaysian construction industry is continually adapting to meet competitive challenges around the globe market. Thus, the need to imbibe change reaction and modernism from capacity and knowledge acquired, tapping from similar initiatives by the UK construction industry stipulated in 1998 Latham report. Hamid and Kamar (2010) recommended the construction best practice programme (CBPP) model for Malaysia construction industry involving rethinking IT programs and tools. The UK National Building Specification (NBS) National BIM 2012 Report expressed a competitive disadvantage syndrome for organisation lagging behind in BIM adoption (Malleon, 2012). The Malaysian-German Chambers of Commerce projected a 5.2% expansion in the construction industry as a result of civil

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engineering works from government stimulus package. The analysis also hinged a successful growth rate on technological investments in Information Technology (IT), similar to growth in other sectors spawn by IT. Malaysian construction industry should take a cue for a more sustainable construction growth performance. Under the 10th Malaysian plan an estimated growth of 3.7% per annum is expected compared to the nations' 6% per annum GDP (Brandt & Yong, 2011). The revolutionary BIM tool in the Architecture, Engineering, and Construction (AEC) industry presents great advantages towards the vision on Construction Industry Development Board (CIDB) master plan and the nations' 2020 vision through increase in key performance indicators (KPIs) and productivity. BIM provides sustainable assessment tool for life cycle simulations, efficient costing, improvement in engineering quality and promising a new crop of graduates (Nguyen et al, 2010; CRC, 2007; Russell et al, 2009; Ibrahim et al, 2004; Kaner et al, 2008; Smith et al, 2005; Sun & Zhou, 2010). However, every new IT tool is without inherent challenges such as inherent interoperability issues, legal and contractual aspects management BIM pedagogy, BIM training and high cost of purchasing software (Rezgui & Zarli, 2006; Taylor et al, 2007; Enegbuma et al, 2010; Tse et al, 2005; Rosenberg, 2006; PSDC, 2010). The first part of the paper introduces the current scenario in the industry, usefulness and challenges of BIM. Subsequent sections delineate the model construct and hypothesis extending previous study by Enegbuma and Ali (2012).

## **2. Building Information Modelling**

Models seek better perfection in creation of forms and buildings (Teran, 2008). Building Information Modelling is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the model to support and reflect the roles of that stakeholder. The model is a shared digital representation with open standards for interoperability (Smith & Edgar, 2008; McCuen, 2008). The process generates and manages building data during its life cycle using three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components (Lee et al., 2006). BDS (Building Design Systems) and RUCAPS (Really Universal Computer Aided Production System) formed the early parts of BIM development which were sold across UK and US, followed by SONATA in 1986 though limited to central work stationing, personalized computer CAD systems such as ArchiCAD were in developmental stages while, GLIDE (Graphical Language for Interactive Design), GLIDE-II, and CAEADS (Computer Aided Engineering and Architectural Design System) (See, 2007). Industry Foundation Classes (IFC) is open and neutral data format for openBIM borne by the increased pressure to integrate various BIM formats and software to smoothen the collaborative platform. IFC is registered with the International Standardization Organization ISO as ISO16739 and specification are developed and maintained by buildingSMART International (IFC 2002; IFC, 2012). Information Delivery Manuals (IDM) in ISO 29481-1:2010 is an initiative by BuildingSMART geared towards the capture of real life construction documentation, with several challenging test carried out to capture real life construction data which is universally accepted by the BIM support software. Timely update and quality information dissemination forms a key part and strict guideline from initiation of the process, development, application for official status with buildingSMART, approval and

publishing (Karlshoj, 2011). International Framework for Dictionaries (IFD) was hatched to control vocabulary of construction terminology inevitably essential to support data exchange (Bell et al., 2008). Model view definition (MVD) defines a subset of the IFC schema needed to satisfy one or many exchange requirements of the AEC industry using IDM exchange requirement in its definition (Liebich et al., 2011).

## **2.1 People**

BIM offers an unsettling precedence to an already defragmented construction industry which offers less surety. New processes to enhance the construction process, electronic designs and construction professionals must acknowledge the individual risk associated with such a new technology. Boundaries of professional responsibility and work product are not clearly defined creating uncertainty for liability in a BIM model. The trend of older professionals still lagging behind while younger professionals lack experience in legal matters with a need for flexible legal form of agreement between construction teams to meet the rapid growth (Jordani, 2008; Rosenberg, 2006; Salmon, 2009). The emergence of local user Groups in various localities to discuss BIM concepts, softwares and products including information sharing on achievements has shown an adaptive response by people for BIM improvements (Lega, 2008). Owner awareness is lacking in terms of information regarding successes of BIM by other competitive companies in operation, maintenance, repair and remodeling. While, other seminar authors proposed a future expansion of current pedagogy in education of building professionals due to current challenges of constructing sustainable life cycle buildings (Edgar, 2008; Henderson & Jordan, 2009).

## **2.2 Process**

Construction industry reports such as Simon 1944, Banwell 1964 and British Property Federation 1983 except the Latham 1994 report, have ignored IT as an integral process in construction. However, emphasis on technology development alone places less attention to organisational and human issues. Furthermore, fewer staffs to regularly update BIM models and inadequate human resource training exist in the construction industry (Aouad et al., 1999; Rezgui & Zarli, 2006; Damain & Yan, 2008; Liu, 2010). For smooth BIM implementation within an organisation strict consideration must be given to the long term goals of the organisation and requirement. Similarly, managing the cost of ownership can be actualised through BIM, with diligent improvement in BIM practices owners' BIM metamorphoses into a Business Intelligence Model placing it right within corporate mission and objectives. Similar to the CAD migration from manual drawings, BIM is faced with an ever challenging bureaucracy by top management due to new risk and liability fears consummating into a lengthy list of disclaimers during model sharing (Smith, 2007; Jordani, 2008). BIM implementation in the US coast guard on subsequent Charleston Regional Strategic Plan (RSP) achieved partial success. Full success was eventually marred by people's culture and senior leadership resistance to new methodologies; workflow changes; and technological innovation (Hammond, 2008).

## **2.3 Technology**

Owner push for faster product delivery improvement, safer construction environment, reduced construction cost, lean adoption to eliminate waste and proactive drive by industry professionals to assimilate new technology such as BIM (Jordani, 2008). Malaysian construction industry grapples in advanced IT and project management techniques which forms an essential part to high-tech and capital intensive construction in line with American Institutes of Architects (AIA) push for advancement and open standards (Ibrahim et al, 2010). McGraw-Hill construction report suggests that for BIM to thrive and meet the challenges of the future, model objects needs to be readily available for smooth information extraction. Although, product library were created by software companies to represent generic components they lack enough data to represent the specifications of Building Product Manufacturers (BPMs). Knowledge of BIM software, inadequate reference material and component database provide challenges in BIM education in tertiary institutions. Inherent deficiencies in BIM specification provide inadequate differentiation between requirement for BIM deliverables and technology to deliver such information. Similarly, during hyper collaborative platforms such as BIM Storm, participants had to revert to do some manual communication (Jones & Lien, 2008; East, 2009; Onuma, 2008).

## **2.4 Strategic IT Planning**

As industries transform, from adversarial to cooperative thinking with more emphasis on business process, the construction industry in transforming into long term strategic planning to cope with the dynamic nature of economic, technological and social factors. Strategic IT usage though perceived with a degree of reluctance by the construction industry is currently transforming, as most business process were never designed but formed by ad hoc means. Research in labour and cost saving by Adam Smith and Fredrick Taylor provided an initiating argument towards a re-think of business process (Davenport & Short, 1990; Johansson et al., 1993; Betts, 1999). Sustainable competitive advantage is maintained though innovative process improvement and management reliant on IT to provide enabling environment (Kangas, 1999; Moingeon et al., 1998; Alshawi, 2007). ICT showed a positive and significant impact on the Malaysian economy from 1982 – 2004 which established a change from the norm of investments on agrarian economy to one of manufacturing and industrialisation (Kappusamy & Shanmugam, 2007). Technology acceptance and usage has been studied extensively, expanding Fishbein and Ajzen Model of 1975, Fred Davies formulated the technology acceptance model (TAM). Fishbein and Ajzen Model explained the theory of reasoned action, which Davies conceptualised the existence of a response predicted by user motivation and influenced by external stimulus consisting of the system features and capabilities which triggered the use of a system. Davenport (1993) perceived change to be structured and measured sets of activities designed for a specific product for various markets and clientele. In construction, process change from inception, project completion and FM stages provide benefits to clients in Malaysian construction industry. Business Process Re-engineering (BPR) drives organization to change their career paths, training, recruitment and policies (Anthony, 1965; Porte & Millar, 1985; Liang & Cohen, 1994). Factors highlighted in driving BPR are organisational training, reward, communication, research and development (Kohar et al., 2012).

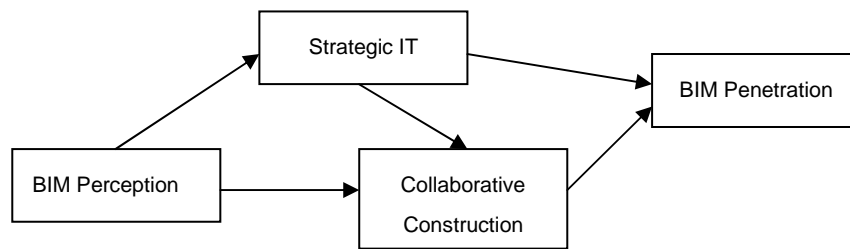
## **2.5 Collaborative Construction**

Collaboration in construction is defined as an agreement among specialist to share their abilities in a particular process, to achieve the larger objectives of the project as a whole, as defined by a client, a community, or a society at large. Collaboration can further be seen as working together in a seamless team for common objectives that deliver benefit to all. Collaboration is more effective when undertaken at the project inception stage (Hobbs, 1996; be 2004; Anumba & Newnham, 2000). The construction industry presents a rather unique approach to collaborating which when done ineffectively creates islands of automation (Kalay, 2001; Yeomans, 2005; Sun & Aouad, 2000). Major challenges to effective collaboration exist in the construction industry due to independent working and taking decisions which affects the project team (Anumba et al, 1997, 2001 & 2002; Yeomans, 2005). Issues bordering around undefined boundary between teamwork and collaboration including, unsolved issues of shared-understanding, alignment of purpose and shared meaning. Different educational upbringing, terminologies and adversarial contractual agreement further provides barriers to collaboration (Lang et al., 2002; Yeomans, 2005; Anumba et al, 2000; Kalay, 2001; Yeomans, 2005).

## **2.6 BIM Penetration**

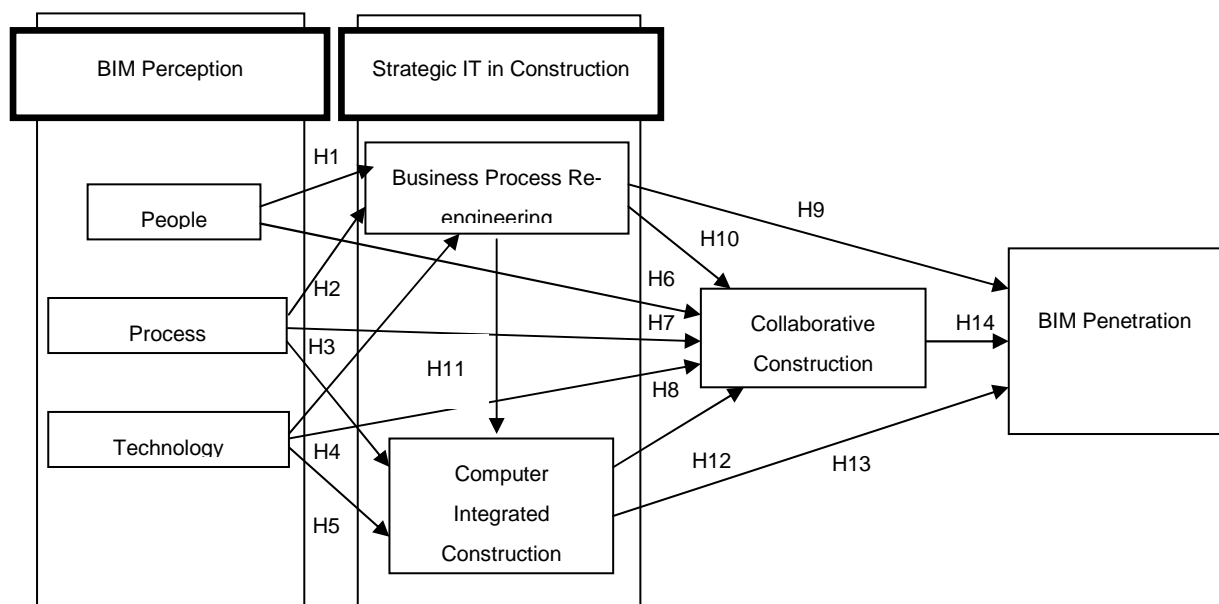
The communication of innovation over time amongst members of the same social systems over a period of time is often referred to as a product of complex social interaction. The social system acts as a determinant of socio-psychological processes within the social system (Rogers, 2003; Bain et al, 2001; Dackert et al, 2004; Kanter, 1988; West, 1990; Panuwatwanich et al, 2009). Diffusion describes the acceptance and usage of new technology while innovation denotes a new product or process technology, or administrative. This research targets the penetration of BIM within the Malaysian construction industry to foster prompt attention and improvement of grey areas within the industry. Seminar authors in innovation diffusion proposed new models of diffusion of new technologies with complimentary implications for increasing the rate of innovation in the industry. Furthermore, investigations identified four forces that drive innovation: competitive advantage, process problems, technological opportunity, and institutional requirements (Rogers & Shoemaker, 1971; Damanpour, 1991; Tatum & Mitropoulos, 2000). Rogers (1983) argued that relative advantage, compatibility, complexity, observability and triability are determining factors for technology diffusion. The structural equation modelling path study towards improving innovation diffusion level within the architectural and engineering design (AED), delineated definitive pathways and practical strategies harnessed by the construction industry to derive outcomes from innovation via diagnosing and improving their existing innovation capability which invariably strengthen their business performance (Panuwatwanich et al, 2009).

### 3. The Research Model



**Figure 1: Overview of Research Model (Enegbuma and Ali, 2012)**

The research model encompasses research gaps on BIM perceptions and the effects on penetration for construction industries adopting building information modelling. Existing literature an underlining need for adequate strategic IT planning which drew from IT acceptance models, business process re-engineering and collaborative construction. The model shown in figure 1, builds on BIM perception in the construction industry towards effective BIM penetration incorporating strategic IT implementation (Betts, 1999), technology acceptance model (Davis, 1985; Chuttur, 2009), business process re-engineering (Anthony, 1965; Porte & Millar, 1985; Liang & Cohen, 1994) and collaborative construction.



**Figure 2: Research Model and Hypothesis (Enegbuma and Ali, 2012)**

#### 3.1 BIM Perception and Strategic IT in Construction

In the research model shown in fig 2, the causative linkage between BIM Perception and strategic IT in construction as posit in literature will be discussed. IT implementation relies on the perception from people, process and technological knowhow due to inadequate artificial intelligence in software and devices (Sommerville & Craig, 2006). Human interaction with a new system influences the rate of implementation in an organisation. Drivers such as communication, human activity, system processing, design, specification and tradeoffs are

necessary considerations (Fidelman, 2002; AELR, 1995; Sommerville and Craig, 2006). The phenomenon known as people managers translates the importance of people in organisations adapting to new IT technologies. Hence, understanding ways to tap into individual creative energy, intelligence, initiative, managing change, alleviating fears to change is critical to implementation success (Towers, 1996, Cooper & Markus, 1995; Kennedy, 1994; Arendt et al, 1995; Alshawi, 2007). Although fears arise from the perceived reduction in professional fees with BIM, cost savings from energy savings, maintenance, informed decisions, purchasing, clash detection, reduced request for information adds value to the project for clients, hence the onus to demonstrate the level of value added to clients (Hamil, 2012). Alshawi (2007) argued that technological push generated more awareness on the need for improvement in business process and re-engineering. Also, incompatibility in IT applications creates island of automation challenging the normal business processes and computer integrated construction. Hence, it is hypothesized that:

- H1: There is a positive relationship between People and Business Process Re-engineering
- H2: There is a positive relationship between Process and Business Process Re-engineering
- H3: There is a positive relationship between Technology and Business Process Re-engineering
- H4: There is a positive relationship between Process and Computer Integrated Construction
- H5: There is a positive relationship between Technology and Computer Integrated Construction

### **3.2 BIM Perception and Collaborative Construction**

Collaboration is a unified platform that enables interaction between various individuals or groups of individuals in the project team. This triggers a creative process and enables sharing of ideas within openness, honesty, trust and mutual respect towards achieving a common goal. Certain philosophies argue that irrespective of the manner of communication, either synchronised or asynchronised collaboration, the basic premise lies in the communication between one or more individuals. This view point was further stressed when collaboration is referred to as an activity. Emphasis is laid on technology as an enabler providing an atmosphere for various technologies to interact (Burtler Group, 2003; Wilkinson, 2005). BIM utilisation stimulated a downward trend in variation orders geared towards a zero variation order for projects. Early collaboration provide the opportunity for practical solutions for constructability complexities, owner awareness and government push also further increases BIM usage (Cannistraro, 2010) thus leading to hypothesis:

- H6: There is a positive relationship between People and Collaborative Construction
- H7: There is a positive relationship between Process and Collaborative Construction
- H8: There is a positive relationship between Technology and Collaborative Construction

### **3.3 Strategic IT in Construction, Collaborative Construction and BIM Penetration**

Integrating IT systems with business processes reshapes and facilitates the organisational culture, performed task, coordinated activities (Davenport and Short, 1990; Hinterhuber, 1995; Hammer, 1990; Willcocks & Smith, 1994; Tapscott & Caston, 1993; Klenke, 1994; Alter, 1993; Davenport, 1993; Alshawi, 2007). However, to achieve a greater business re-engineering prompt attention is given to modelling new business processes around the implemented IT systems (Koch et al., 1999; Alshawi, 2007). Yeomans et al., (2006) expressed the need for certain project teams to provide extra effort towards achieving collaboration, however, in Malaysia current literature is void of which project team members should with the advent of BIM engage more for a push towards effective collaboration. Yeomans et al. (2006) also argues that there is no resulting disadvantage from adopting collaboration practices in the industry, dependent on the commitment of the project team, merger of collaborative ideals with procurement systems and developing a means to capture and report the benefits. Sommerville and Craig (2006) argued that the increase usage of IT in business processes resulted from the increased awareness of the benefits of open collaborative efforts by project teams in the construction industry. The push for effective collaborative will inadvertently provide higher productivity and returns on investments for clients increased demands which led to further hypothesis of:

- H9: There is a positive relationship between Business Process Re-engineering and BIM Penetration
- H10: There is a positive relationship between Business Process Re-engineering and Collaborative Construction
- H11: There is a positive relationship between Business Process Re-engineering and Computer Integrated Construction
- H12: There is a positive relationship between Computer Integrated Construction and Collaborative Construction
- H13: There is a positive relationship between Computer Integrated Construction and BIM Penetration
- H14: There is a positive relationship between Collaborative Construction and BIM Penetration

## **4. Conclusion**

As Malaysia moves towards its target vision of high income economy, BIM provides adequate IT leverage in the construction sector. This paper has presented an argument and hypothetical background of BIM penetration model formation. The model hypothesises variables of people, process, technology, strategic IT planning and collaborative construction to further enhance BIM acceptance in Malaysia construction industry. Overcoming the challenge of increasing BIM adoption and usage promises a more sustainable construction process in all ramifications. The hypothesis will undergo Structural Equation Modelling (SEM) to analyse the desired statistical power, test for close versus exact fit and complexity of the model after data collection. The structural equation modelling analyses the relationships to pin point the perception factors with higher effect on collaborative working, denoting grey area for investment and research focus in the industry.



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