FACTORS AFFECTING BUILDING INFORMATION MODELLING ADOPTION BY MALAYSIAN CONSULTANTS AND CONTRACTORS

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To Almighty God for his guidance through all perils.

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ABSTRACT

The paradigm shift to Building Information Modelling (BIM) in the construction industry has transformed the construction process. BIM adoption requires strategic implementation and collaboration. The inherent benefits of this shift are gradually experienced in Malaysia. However, adoption of BIM in Malaysia is prone to resistance as experienced in construction industries across the globe. Construction professionals are awakened to challenges with the use of a new system which define their adaptability to the BIM push within the construction industry. This research develops a BIM adoption model which builds on people, process and technology factors affecting BIM into a higher order resource of BIM perception and strategic IT implementation (business process re-engineering and computer integrated construction) mediated by collaborative processes. Data was collected from three hundred and fifty two (352) construction professionals (architects, quantity surveyors, engineers and contractors) using questionnaires. Descriptive and multivariate analyses (Structural Equation Modelling) were used to assess the measurement and structural models developed. The model explained the variance in business process re-engineering, computer integrated construction, collaborative processes and BIM adoption. The results revealed an anathematised state of collaboration leading to significant decrease in BIM adoption rate. Seven (7) out of fourteen (14) hypothesised paths were statistically significant. BIM perception exhibited indirect effect on collaborative processes through strategic IT implementation. Business process re-engineering exhibited significant direct effect while computer integrated construction exhibited a significant indirect effect on BIM adoption. This result projects the prevalent factors affecting BIM adoption, highlights grey areas needing improvement and formulating policies to further enhance BIM adoption.

ABSTRAK

Anjakan paradigma berdasarkan Pemodelan Maklumat Bangunan (BIM) dalam industri pembinaan telah mengubah proses pembinaan. Penggunaan BIM memerlukan pelaksanaan yang strategik dan kerjasama. Manfaat yang wujud daripada perubahan ini secara beransur-ansur telah dialami di Malaysia. Walau bagaimanapun, penggunaan BIM di Malaysia adalah terdedah kepada rintangan sebagaimana yang dialami dalam industri pembinaan di seluruh dunia. Pakar pembinaan telah dikejutkan dengan cabaran oleh penggunaan sistem baru yang menentukan keupayaan bagi menyesuaikan diri mereka dalam BIM ditekan dalam industri pembinaan. Penyelidikan ini mencipta satu model penggunaan BIM yang telah dibina berdasarkan faktor-faktor (manusia, proses dan teknologi) yang memberi kesan terhadap BIM kepada sumber persepsi BIM dan pelaksanaan strategik IT yang lebih tinggi (perniagaan proses semula kejuruteraan dan pembinaan komputer bersepadu) serta diselesaikan oleh proses kerjasama. Sebanyak tiga ratus lima puluh dua (352) pakar pembinaan (Arkitek, Jurukur Bahan, Jurutera dan Kontraktor) telah ditemuramah menggunakan soal selidik. Analisis deskriptif dan multivariat (pemodelan persamaan berstruktur) telah digunakan untuk menilai tahap dan kemajuan struktur model tersebut. Model ini menjelaskan bahawa varians terbentuk dalam proses perniagaan semula kejuruteraan untuk pembinaa computer bersepadu, proses kerjasama dan kegunaan BIM. Keputusan mendedahkan bahawa pengabaian terhadap kerjasama akan membawa kepada penurunan ketara dalam kadar penggunaan BIM. Tujuh (7) daripada empat belas (14) hipotesis telah menunjukkan statistik yang signifikan. Persepsi BIM mempamerkan kesan tiada langsung terhadap proses kerjasama melalui pelaksanaan strategik IT. Rekayasa semula proses perniagaan mempamerkan kesan langsung yang ketara manakala, pembinaan bersepadukan komputer pula memperlihatkan kesan tidak langsung yang ketara terhadap penggunaan BIM. Keputusan ini menjana faktor lazim yang mempengaruhi penggunaan BIM, mengetengahkan perkara yang tidak jelas dan memerlukan penambahbaikan dan penggubalan dasar bagi meningkatkan lagi penggunaan BIM.

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LIST OF SYMBOLS

ρ	-	Correlation
$\rho 2$	-	Squared Correlation
ave $\rho_{vc(\eta)}$	-	Average Variance extracted
X^2	-	Chi-Square

LIST OF ABBREVIATIONS

AIA	-	American Institute of Architects
AMOS		Analysis of Moment of Structures
BIM	-	Building Information Modelling
BRE	-	Building Research Establishment
BREEAM	-	BRE's Environmental Assessment Methodology
BPMs	-	Building Product Manufacturers
CAEADS	-	Computer Aided Engineering and Architectural Design System
CDF	-	Common Data Format
CFD	-	Computational Fluid Dynamics
CIB	-	International Council for Innovation and Research in Construction
CIC	-	Construction Industry Council
CIC	-	Computer Integrated Construction
CIM	-	Computer Integrated Manufacturing
CIKS	-	Computer Integrated Knowledge System
CIMP	-	Construction Industry Master Plan
COBie	-	Construction Operations Building Information Exchange
CR	-	Critical Ratio
df	-	Degrees of Freedom
EFA	-	Exploratory Factor Analysis
ENERGie	-	Energy Information Exchange
ETP	-	Economic Transformation Programme
GCCB	-	Government Clients Construction Board

GFI	-	Goodness of Fit Index
GIS	-	Geographical Information System
GLIDE	-	Graphical Language for Interactive Design
GOF	-	Goodness of Fit Indices
GSA	-	General Services Administration
GTP	-	Government Transformation Programme
GUID	-	Globally Unique ID
HKIBIM	-	Hong Kong Institute of Building Information Modelling
IAI	-	International Alliance for Interoperability
IBS	-	Industrialised Building System
ICE	-	Institution of Civil Engineers
I-CMM	-	Interactive Capability Maturity Model
IDM	-	Information Delivery Manual
IFC	-	Industry Foundation Classes
IFD	-	International Framework for Dictionaries
ISO	-	International Organization for Standardization
IMVP	-	International Motor Vehicle Program
ITIL	-	Information Technology Infrastructure Library
IUK	-	Infrastructure UK
LAI	-	Lean Aerospace Industry
LEED	-	Leadership in Energy and Environmental Design
LOD	-	Level Of Detail
LUGs	-	Local User Groups
MGBI	-	Malaysian Green Building Index
MI	-	Modification Index
MRSS	-	Minimum Required Returned Sample Size
MVD	-	Model View Definitions
NBIMS	-	National Building Information Standards
NIBS	-	National Institute of Building Sciences
NBS	-	National Building Specification
NCI	-	National Cancer Institute
NEM	-	New Economic Model
NICTA	-	National Information Technology Agenda

NKEAs	-	National Key Economic Areas
NTP	-	National Transformation Programme
OGC	-	The UK Government's Office of Government and Commerce
PWD Form203	-	Public Works Department Form 203
PAM	-	Pertubuhan Arkitek Malaysia
PAM 2006	-	Pertubuhan Arkitek Malaysia Standard Form of Contract 2006
RFI	-	Request For Information
RFID	-	Radio Frequency Identification
RIBA	-	Royal Institution of British Architects
RMR	-	Root Mean Residual
RMSEA	-	Root Mean Square Error of Approximation
ROI	-	Return On Investment
RUCAPS	-	Really Universal Computer Aided Production System
SDEF	-	Standard Data Exchange Format
SE	-	Standardised Estimate
SEM	-	Structural Equation Modelling
SPSS	-	Statistical Package For Social Science
SMC	-	Squared Multiple Correlation
SRIs	-	Strategic Reform Initiatives
STEP	-	Standard for the Exchange of Product Model Data
TQM	-	Total Quality Management
TPS	-	Toyota Production System
UNICLASS	-	A Coding System for Building Components
USACE	-	US Army Corps of Engineers
UTAUT	-	Unified Technology Acceptance and Use Theory
UTHM	-	Universiti Tun Hussein Onn Malaysia
VDC	-	Virtual Design and Construction

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Information technology (IT) and information communication technology (ICT) are identified as essential tools for improving communication in construction processes and creating new construction business opportunities. Walker and Betts (1997) argued that ICT technologies (e.g. Internet and the World Wide Web) expands opportunities for construction businesses to operate and excel globally. Several studies found numerous advantages and benefits of using ICT in construction (Skibniewski and Abduh 2000; Peansupap and Walker, 2005). ICT supports information integration which in turn helps to reduce the volume of information processed and reduce data re-entry by transferring information through Internet/Intranet protocols. This provides benefits throughout project phases such as design, construction, and operation (Sriprasert and Dawood 2002; Peansupap and Walker, 2005).

ICT use enhances collaboration by supporting communication among project members and sharing of information and documents, especially when team members are located in different geographical areas (Sriprasert and Dawood 2002; Peansupap and Walker, 2005). ICT use supports 'e-commerce' and create opportunities to extend business or provide improved customer service (Skibniewski and Nitithamyong 2004; Peansupap and Walker, 2005). Benefits of ICT use by construction organisations have motivated several construction organisations to adopt and invest in this technology and many recent survey results indicate an increasing trend of firms using ICT in the construction industry (Rivard 2000; Peansupap and Walker, 2005). However, the magnitude of ICT adoption in construction practices remains low compared to other industries (ACIF 2002; Peansupap and Walker, 2005).

Information technology (IT) developments have the potential to affect business strategies, organizational structures, and management processes (Li et al., 2000). New technological advancements are placing increasing demands on design and construction organizations (Ahmed et al., 1995). Love and Gunasekaran (1997) suggest that the benefits of IT were are not achieved for two reasons "Firstly, organizations in construction have been reactive to change, simply superimposing IT into hierarchical structures that are composed of ineffective and inefficient processes, which have not been designed for its support. Essentially, IT has been merely used to automate existing processes, thus exacerbating the already existing communication problems that exist. Secondly, IT has been implemented in an adhoc manner as organizations eschew devising strategic and tactical implementation strategies for its implementation" (Betts, 1995).

The construction industry philosophical shift to saving construction waste was scored four out of 10 score for its effort by Egan (2008) demonstrating the UK industry's slow pace towards continuous improvement for leaner construction. The revolution towards lean production began by demonstrating the performance difference between lean production and mass production (Womack et al., 1990; Leong et al., 2015). The International Motor Vehicle Program (IMVP) set up during the second oil crisis in 1979 investigated the problems facing motor vehicles and compared Toyota Production System (TPS) by the Japanese to Western mass production techniques. The term lean production was coined by Krafcik, a research member of the IMVP team in his Masters thesis, and popularised by the "Machine".

The system was later adopted by the aero industry. The Lean Aerospace Industry (LAI) was setup in 1993 in support of the industry lean programme. Subsequently, lean thinking is continually instrumental in transforming construction organisations (Leong et al., 2015).

Over the years, construction techniques sort to integrate and achieve high flexibility of construction systems leading to full automation process by computer integrated construction (CIC) and robotics (Koskela and Salagnac, 1990). This targeted a future increase in competitive advantage to counter the negative characteristics of low productivity, high accidents and insufficient labour (Koskela and Salagnac, 1990). Similarly, inadequate investments and R&D culture of the building site inhibit advanced technological development. To overcome this challenges, national CIC agendas focuses on calculating value added by advanced technology, plan long term survival success strategies, improve link between construction industry, research institutes/universities and information/automation system suppliers (Koskela and Salagnac, 1990).

The main challenge in the construction sector is figuring out more effective ways to improve integrated project delivery to clients which information technology advancements adequately accommodate such drive towards a more advanced construction techniques (Lee et al., 2003; 2005, Jung and Joo, 2010; Haron, 2013; Succar, 2015). The construction industry historically leans on traditional 2D CAD systems possessing the characteristics of multiple files made up of lines, arcs and circles, and the building information is contained within several document formats such as spreadsheets and word processing applications (Lee et al., 2003, 2005).

Subsequently, construction moved on to 3D modelling/CAD which inculcates the cardinal positioning of dimensions of a point or object in physics, explained by a vector representation point in space: the x and y axes describing the planar state and the z axis depicting the height. However, 3D modelling in construction extends beyond the object’s geometric dimensions and replicates visual attributes such as colour and texture (Lee et al, 2003, 2005). The next step involves combining time sequencing and visual environments with the 3D geometric model (x, y, z) is commonly referred to as 4D CAD. The helps to simulate construction before embarking on the real life project construction. Thus, mistakes and conflicts are identified at an early stage and enable stakeholders to predict construction schedule (Kunz et al, 2002; Lee et al., 2003, 2005).

The next evolution was extended to nD modelling where the database is constructed with intelligent ‘objects’ which represent building elements like walls, doors and windows. the central database generates different views of the information which are generated automatically; views that correspond to traditional design documents such as plans, sections, elevations, schedules etc. "As the documents are derived from the same central database, they are all coordinated and accurate – any design changes made in the central model will be automatically reflected in the resultant drawings, ensuring a complete and consistent set of documentation" (Graphisoft, 2003; Lee et al., 2003, 2005).

Graphisoft (2003) stated that "nD modelling is based upon the building information model (BIM), a concept first introduced in the 1970s and the basis of considerable research in construction IT ever since. A BIM is a computer model database of building design information, which may also contain information about the building’s construction, management, operations and maintenance". There is a continuous call by leading CAD vendors such as AutoDesk, Bentley and Graphisoft to heavily promote BIM irrespective of differences in noncompatible standards where an open and neutral data format is required to ensure data compatibility across the different BIM applications (Lee et al., 2005; Succar, 2015).

The growing paradigm in the construction industry is a shift from traditional 3-Dimension (3D) computer aided design (CAD) to building information modelling (BIM) collaborative environment. The use of BIM in the United Kingdom (UK) Heathrow Terminal 5 helped shave 5% off project costs of £210million

(FaithfulGould, 2009). The McGraw Hill smart market report showed that two-third of BIM users saw positive return on investment (ROI) on their overall investment in BIM while others specified that BIM has placed them in position for better competitive advantage thereby marketing new business ideas to clients. BIM users also saw a productivity increase due to reduced rework, reduced conflict and variations during construction and clash detection for specialized M&E (McGraw Hill Construction, 2009). The Malaysian Construction Industry Master Plan (CIMP) under the critical success factor (CSF) of Knowledge Innovation aimed to improve total information and technology (IT) spending as a percentage of gross domestic product (GDP) by 50% and also, number of and revenue generated by IT companies supporting the construction industry to improve by 50% (REHDA, 2008). These improvements will in the long run counter the competitive disadvantage syndrome envisaged in organisation lagging behind in BIM adoption as stated in the National Building Specification (NBS) BIM 2012 Report (Malleson, 2012).

The goal of the CIMP is to set the industry amongst knowledge driven industries through leverage on IT (CIDB, 2007: Haron, 2013). BIM shows great prospects as a tool for sustainable assessment tool in Leadership in Energy and Environment Design (LEED) in construction (Nguyen et al., 2010) and growing utilisation in fire response facility management using geographical information system (GIS) navigation (Isikdag et al., 2006). New construction and maintenance of old works has been effective with the use of BIM (Liu, 2010). Better costing through accurate geometrical representation of the building in an integrated data environment (CRC, 2007). As built visualisation of buildings, effective communication on site and improvement in engineering quality form advantages of BIM in project management (Russell et al., 2009; Ibrahim et al., 2004; Kaner et al., 2008). BIM also promises a new crop of graduates called construction modellers whom are better equipped with adequate knowledge on collaboration working environment, detecting challenges to project and effective post-occupancy evaluation (Smith et al., 2005).

BIM adoption in the UK, USA, Finland, Singapore has shown a positive effect on key performance indicators (KPIs) increasing productivity in the construction industry (Sun and Zhou, 2010). BIM is a process of generating and managing building data during the life cycle of a building project encompassing building geometry spatial relationship, geographic information, quantities and properties of the building component (Lee et al., 2006). From an integrated project perspective, BIM is defined as the information management process throughout the building life cycle (Isikdag and Underwood, 2010). BIM thereby provides a collaborative platform for stakeholders to insert, extract, update, or modify information in a BIM model throughout the building life cycle on open standards of interoperability (Smith and Edgar, 2008). The industry foundation classes (IFC) provides reference to the totality of information within the lifecycle of a constructed facility and defines standards on interoperability of various BIM software such as IFC-ISO/PAS 16739:2005.

Recent technological advancements lays more emphasis on the entire life cycle of the building envelope from inception stage to demolition stages. Building Information Modelling (BIM) has provided an effective platform for better collaboration within the construction industry and the Malaysian construction industry is increasingly tapping into this tool in year 2014 compared to the earlier introduction stage (Ismail, 2014). Malaysian construction industry has seen a tremendous growth since the implementation of the vision 2020 and currently ICT policies under the 10th Malaysian Economic Plan has given a further boost to the construction industry. Building Information Modelling (BIM) implementation policies are in the formulation stages (Ali et al., 2013). Although efforts are geared towards sensitising the industry stakeholders about the intricacies of BIM and promote research into ways of effective implementation of BIM in the industry.

BIM is primarily driven by the private sector in Malaysia (CIDB, 2013; Haron, 2013). The word BIM was first used in 2009 in Malaysia during a two-day infrastructure and construction Asia's Building Information Modelling and sustainable architectue conference in Malaysia (Ismail, 2014). The first government project to fullly utilise BIM was launched in 2010 to build the National Cancer Institute (NCI) in Putrajaya (Ismail, 2014). In 2013, the National BIM Steering Committee was established by CIDB assisted by seven sub-committees namely; standards and accreditation, incentives, education and awareness (academia), national BIM component library, BIM guidelines, BIM special interest group and research and development (Ismail, 2014; CIDB, 2014). In 2014, the Malaysian Chapter of BuildSMART international was officially registered in support of open BIM platforms and policy push for BIM (Ismail, 2014). Figure 1.1 shows the framework for BuildSMART Malaysia.

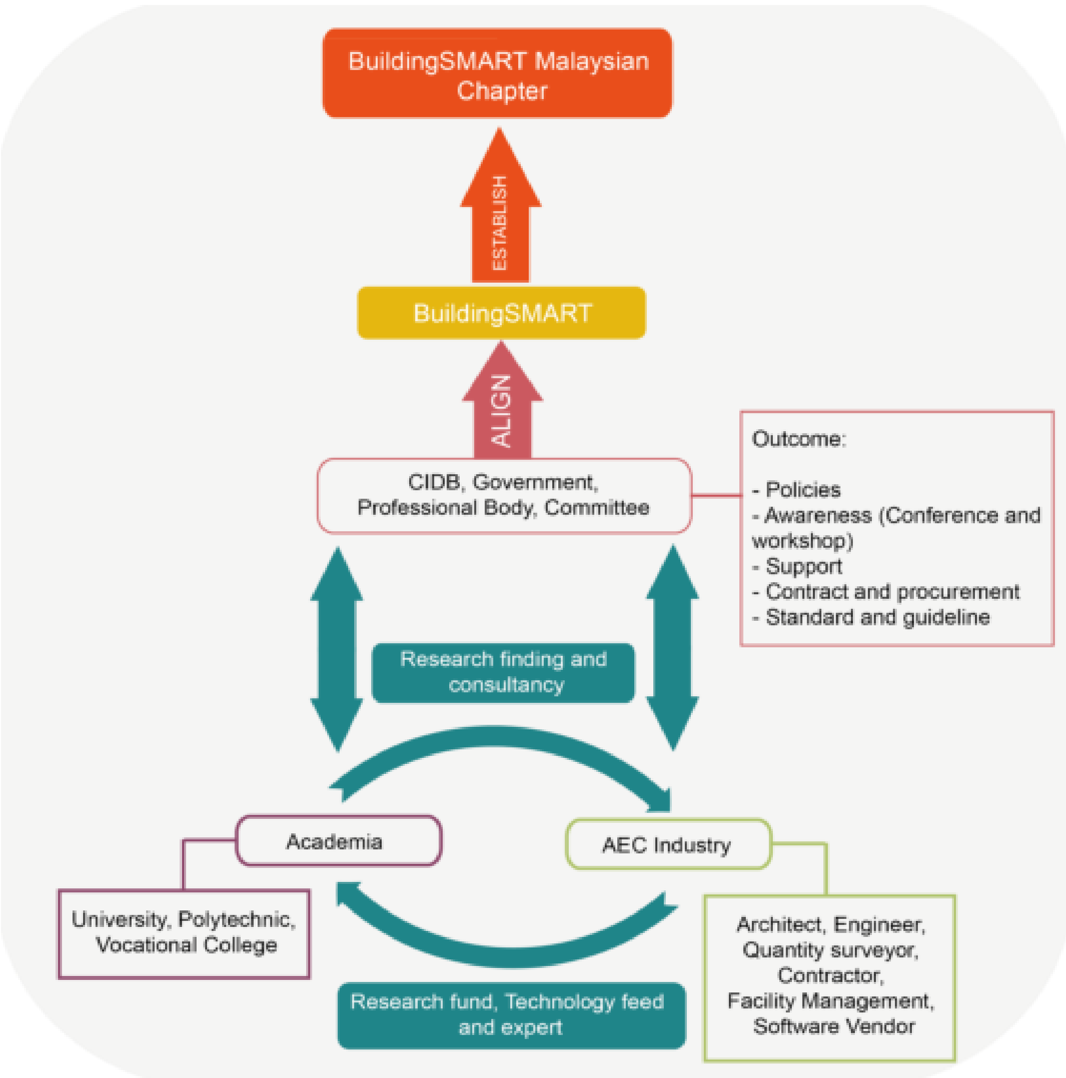

Figure 1.1: Framework of BuildSMART Malaysia (Ismail, 2014)

Remarkably, BIM successes are evident in all aspects of the construction phase for example, exposing errors and omissions in design documentation (Campbell, 2007; Memon et al., 2014), on site for verification, guidance and tracking of construction activities (Muzvimwe, 2011; Memon et al., 2014), faciliting the generation of Bills of Quantities, derivation of productivity rates and labour costs (Muzvimwe, 2011; Memon et al., 2014), increasing the speed and utility of activities by enhancing the quality of schedule and cost information throughout project lifecycle (Fallon and Palmer, 2007; Memon et al., 2014), visualization to reduce the chances of misinterpretation from any participant involved in the project (Salazar et al., 2006; Memon et al., 2014), incorporation of information from several authorities producing a better picture of the project (CRC for Construction Innovation, 2005; Memon et al., 2014). These characteristics has shown that BIM is a neccessity for future construction projects in Malaysia rather than a luxury. The future hinges on the pace of BIM adoption by Malaysian construction professionals.

1.2 Problem Statement

BIM is relatively new to the Malaysian construction industry (Zakaria et al. 2013; Keat, 2013; Latiffi et al., 2014) and promises to edge Malaysia into a world-class construction industry, innovative and knowledgeable about global solutions (Sundaraj, 2007; CREAM 2014; Latiffi et al., 2014). BIM is regarded by construction stakeholders as a potential solution for current issues pertaining to costs, quality, and time of completion (CREAM 2014). Despite initiatives such as Public Works Department (PWD) - (BIM Committee, BIM Unit Projects by PROKOM, Training in BIM, BIM Standard Manual and Guidelines, BIM Roadmap and Pilot Projects); Construction Industry Development Board (CIDB) - (BIM Portal, BIM Steering Committee and Seminars and Workshops); Multimedia Super Corridor (MSC) - (Training in BIM) and; Construction Research Institute of

Malaysia (CREAM) - (Seminars and Workshops Training in BIM) the adoption of BIM remains at a slow pace (Haron, 2013; Ali et al., 2013).

The government PWD efforts for BIM use in pilot design and build projects such as the National Cancer Institute (NCI), Putrajaya, Healthcare Centre Type 5, Sri Jaya Maran, Pahang and Administration Complex of Suruhanjaya Pencegah Rasuah Malaysia (SPRM), Shah Alam, Selangor where BIM was utilised for site modeling, visualization, design review, clash analysis, 4D-schedule simulation and record modeling revealed that BIM implementation in Malaysia is still in the design stage but provided enabling experience and knowledge about using BIM (Latiffi et al., 2014). The maximum adoption rate is placed at stage 4 integrated project delivery (IPD) and Phase 3 project lifecycle management by Succar (2009) and Bew and Richards (2008) respectively. Hence, the pilot testing falls within stage 1 and phase 1 of both maturity yardsticks which leave more to be desired by the construction industry stakeholders.

The rapid adoption of BIM in malaysia is affected by various challenges. 65.3% of 150 construction stakeholders stated that their organizations are not well aware of BIM and have no direct involvement in BIM implementation which places implementation rate of BIM in Malaysia at a low rate (Memon et al., 2014). Similarly, lack of competent staff to operate the BIM software was listed as the most significant barrier in implementation of BIM in construction industry followed by unawareness of technology by contractors, non availability of parametric library and cost of software (Memon et al., 2014).

The practice of BIM in Malaysia when compared to other developing countries is far behind in adoption and level of use (Latiffi et al. 2013; Zakaria et al. 2013). Malaysia faces struggles in adopting BIM process which currently focuses on moving from 2D working environment to 3D working environment (Latiffi et al. 2013, and Zakaria et al. 2013). The Malaysian government decision to mandate the use of BIM for its projects beginning from 2016 against the backdrop of slow uptake in the use of BIM both within companies and to support collaboration within the Malaysian industry (Ismail et al., 2015).

Mohd-Nor and Grant (2014) took an agresive assertion on the nature of BIM adotion starting that "whilst BIM have shown promise elsewhere, it has not been the same in Malaysia. As to date, no government agencies or body has mandated the usage of BIM. Research in BIM is also at a low where none of the academic institutions have set up a unit or department that looks into BIM matters. While national scale reports or surveys on BIM usage has been conducted in many developed countries, it has not been the case with Malaysia".

Client understanding is low in BIM knowledge in Malaysia which limits the use of BIM in Level Of Detail (LOD). There is an urgent need to improve on this aspects for effective implementation of LOD for construction (Latiffi et al., 2015). LOD define how much information is inserted into the model for quantity and increases as the model progresses through the building life cycle (Leite et al., 2011; Love et al., 2013; Latiffi et al., 2015).

Construction industry has generally show that it has a conservative attitude towards adopting innovations (Sepasgozar and Davis, 2015). To fully understand new technologies, information systems (IS) discipline has over time examined technology acceptance. This domain research has taken two perspectives: a psychological perspective (Davis et al., 1989) and a social perspective (Rogers, 2003). The psychological perspective fundamentally relies on technology acceptance models (TAMs) (Venkatesh and Bala, 2008). These are theory of reasoned action (TRA) (Fishbein and Ajzen, 1975), technology acceptance model (TAM) (Davis, 1989), theory of planned behaviour (TPB) (Ajzen, 1991), innovation diffusion theory (IDT) (Rogers, 1995), decomposed theory of planned behaviour (DTPB) (Taylor and Todd, 1995), extension of technology acceptance model (TAM2) (2000) and unified theory of acceptance and use of technology (2003). These models are widely used to predict the users' behavior to accept information technologies (ITs) and information communication technologies (ICTs) (Davis and Songer, 2008; Son et al., 2014; Xu et al., 2014; Sepasgozar and Davis, 2015). There is lack of BIM adoption model in Malaysia towards highlighting key areas for improving BIM adoption.

1.3 Research Justification

ICT driven policy under the National Information Technology Agenda (NITA) in 1996 thrust Malaysia as one of the leading developing countries in the world (Kappusamy, 2007). Government and public agencies are key to policy drivers in strategic IT implementation and top management is responsible for developing strategic IT processes, a lapse in the chain inhibits IT implementation (Pamulu et al., 2004). Malaysian government transformation drive through the Economic Transformation Programme (ETP) spurned growth in the performance of several sectors, construction industry inclusive (MPC, 2013). On the back-drop of the productivity Report 2012/1013, the construction industry experienced a growth rate of 15.5% leading manufacturing (4.5%) and services (1.8%) (MPC, 2013).

The Construction and Development Board (CIDB) of Malaysia estimates a total value of contracts awarded in the building and construction industry (public and private) in 2012 at $28 billion with an estimated one million new residential units required by 2020 (AUSTRADE, 2014). In year 2010, the Malaysian Government unveiled the New Economic Model (NEM) needed to transform Malaysia into a high-income nation by 2020. The National Transformation Programme (NTP) was unveiled to implement the NEM. The NTP comprises two components: the Economic Transformation Programme (ETP) and the Government Transformation Programme (GTP). While distinct, the two programmes work in tandem towards reaching the country’s aspirations for 2020.

The ETP's targets for 2020 will be achieved through the implementation of 12 National Key Economic Areas (NKEAs), representing economic sectors which account for significant contributions to GNI. The programme is also centered on raising Malaysia's competitiveness through the implementation of six Strategic Reform Initiatives (SRIs). The SRIs comprise policies which strengthen the country's commercial environment to ensure Malaysian companies are globally competitive (LHC, 2014; ETP, 2014). Due to the nature of the construction activities in Malaysia, in terms of provision of social infrastructure such as hospitals which falls under the Health focus of NKEAs, construction in the Oil and Gas sector including transformation into more green and sustainable designs under the Oil, Gas and Energy NKEAs and subsequently the improvement of business services provided by construction firms to meet international competitive standards.

Thus, assessment of the BIM adoption challenges plays a pivotal role in improving the construction sector in line with vision 2020. Malaysian construction industry has seen a tremendous growth since the implementation of the vision 2020 and currently ICT policies under the Tenth Malaysian Economic Plan has given a further boost to the construction industry. Building Information Modelling (BIM) implementation policies are in the formulation stages (Latiffi et al. 2013; Zakaria et al. 2013; Haron, 2013). Although efforts are geared towards sensitizing the industry stakeholders about the intricacies of BIM and promote research into ways of effective implementation of BIM in the industry, this research contributes towards this actualisation for construction consultants and contractors.

BIM is seen as a revolutionary tool in the Architecture, Engineering, and Construction (AEC) industry. However, inherent interoperability issues exist in the BIM tools such as the manual update of Revit from Maximo for new construction (Liu, 2010). Activity based work measurement codes and standards which promise trans-disciplinary integration are still not developed (Olatunji et al., 2010). Several problems faced by the construction industry are knowledge management, total lifecycle management, quality and performance management, human aspects management and legal and contractual aspects management (Rezgui and Zarli, 2006) this invariably affect BIM adoption.

Introduction of BIM to university curricula showed improvement in the design simulated environment but was deficient in exposing students to the contribution of each professional to the model (Flemming et al., 2009). BIM pedagogy of undergraduate is a growing concern among construction industry stakeholders. Efforts to introduce BIM in school curriculum though various pedagogical methods have proven that BIM was too broad a subject to fit into one course (Taylor et al., 2007). Acceptance by faculty is also an inhibiting factor to BIM incorporation in school curriculum (Taylor et al., 2007; Smith et al., 2005). Similarly, they have a low knowledge of complex BIM tools such as Revit (Moh-Nor et al., 2009). For effective adoption an existence of a balance of supply and demand of BIM proficient graduates in Malaysia has to be put in place.

BIM training to staffs by government and private sector establishments and soft issues such as people, culture, and process factors act as inhibiting factors (Tse et al, 2005; Rosenberg, 2006; PSDC, 2010), shortage of graduate skilled and certified in BIM (Macdonald and Mills, 2010). The high cost of purchasing software license from BIM vendors (Tse et al., 2005; PSDC, 2009). There is also a call to impose mandatory usage of BIM in the Malaysian construction industry (PSDC, 2009). As BIM penetrates into the industry the need to check the level of legal maturity is pertinent (Liu, 2010). The boundaries of professional responsibility and work product have not been clearly defined creating uncertainty in terms of construction liability associated with any BIM model (Rosenberg, 2006). Currently, PAM 2006, PWD Form 203 and FIDIC guide contractual agreements, for local and international projects respectively, prompting a need for dynamic contractual agreements to cover collaborative endeavours such as BIM.

Building information modelling adoption in Malaysian construction industry is determined by factors ranging from people, process and technology under strategic IT implementation. The previously stated factors have not been adequately identified in the Malaysian construction industry. The relationship and perception of the industry stakeholders need to be established to formulate a roadmap to increase adoption rate into the industry in line with the 6th strategic thrust of the CIMP which applies to leverage on information and communication technology in the construction industry (Sundaraj, 2007). Haron (2013) highlighted the seemingly inadequacy in available literature relating to BIM practices in the Malaysian construction industry. This limitation was further echoed in CIDB Malaysian BIM roadmap which encourages research and development on BIM in the industry (CIDB, 2014). These literatures and research include empirical studies on people, process, technology, and management for both construction professionals and construction organisation within the Malaysian context. Prominent amongst construction professionals is the inertia for change from existing norms of simple CAD drawings and the entire construction management process to venturing into BIM in governing their business process which needs to be captured.

As Malaysia drives towards the 2020 target of knowledge based economy and industrialised nation, policies such as Qlassic, Green Card, Industrialised Building System (IBS) and Malaysia Green Building Index (MGBI) have been introduced, aimed at tackling deficiencies (CIDB, 2014). BIM which offers the potential for prompt collaboration amongst the construction industry professionals, effective calculation and simulation of energy requirements, reduction in conflict and construction liability, effective project management and supporting facility management (FM) life cycle will serve as a tool in actualising the industries vision. The implementation of BIM in the industry is in the infancy stages and several issues such as readiness, critical success factors (CSFs), and implementation guidelines need to be studied (Haron, 2013; Latiffi et al. 2013; Zakaria et al. 2013).

In addition to the previously mentioned IT policies in Malaysia, the Standards and Industrial Research Institute of Malaysia (SIRIM) formulated a strategic IT plan to improve productivity within the construction industry under the auspices of the Economic Planning Unit (EPU) (EPU, 2009; SIRIM, 2009; Haron, 2013). Irrespective of all the perceived policies, implementation of ICT within the construction professionals remains at disproportionate levels (Ali et al., 2013; Haron, 2013). Internet usage was found to increase efficiency and cost saving amongst Malaysian construction firm with construction professionals spending productivity time on the internet for email and information search which with BIM, such time could be channelled to model updates and collaboration (Mui et al., 2002; Haron, 2013).

Similarly, research on ICT implementation in Malaysian construction firms found a slow pace in implementation (Jaafar et al., 2007; Haron, 2013). Effective strategic implementation is inadequate in Malaysian construction industry which invariably limits the proper implementation of building information modelling (Haron, 2013). This improper strategic outlook in the long run leads to failure in implementation as most ICT implementations are as a result of peer pressure (Li et al., 2000; Mui et al., 2002; Haron, 2013). The failures are further exacerbated by the inadequate ICT training in the construction industry (Yusuf and Othman, 2008). Ismail et al. (2014) prioritised areas of improving BIM initiatives for the next five years through a four step process (global benchmarking through literatures; engagement with Local experts; prioritizing the initiatives; validation by expert panel). The eight areas are; establishment of National BIM roadmap; incentives for software and training; building capability and capacity of people; mandating BIM for public sector; BIM guidelines; compliance, accreditation and certification; research and development fund; and establish BIM reference centre.

In a prerequisite study to BIM implementation in Malaysia, Haron (2013) through a qualitative approach interviewed and observed BIM organisation in developed a framework for readiness of BIM in Malaysia highlighting people, process, technology, and management as defining variables. Latiffi et al. (2014) utilised literature review and semi-structured interviews to collect data from 2 consultants for the National Cancer Institute (NCI) Malaysia and BIM consultant for the Sultan Ibrahim Hall of Universiti Tun Hussein Onn Malaysia (UTHM). The results found that BIM in the projects improved communication and collaboration among construction players, minimized design changes, reduce request for information (RFI) during construction stage, and avoid project delay.

Lim (2015) proposed the use of BIM which allows extraction of building information directly models for performances analyses such as solar study, daylighting, building energy use and Computational Fluid Dynamics (CFD) during early or pre-design stage of the building to improve the building performances. The challenge in implementing BIM-based sustainability analyses is determine by lack of well-defined transactional process models and practical strategies for integration of information.

Ismail et al. (2015) conducted an interview with 4 quantity surveyors bordering on traditional cost estimating practiced by the quantity surveyors in Malaysia. The results revealed that they had little extensive knowledge of BIM. Proposing increase in awareness to improve better understanding of the cost estimating practice incorporating BIM. Similarly, Fung et al. (2014) shared the same conclusion that lack of awareness, resistance to change and lack of capabilities awareness of BIM in their practice.

Mohd-Nor and Grant (2014) carried out a quantitative survey on all the 535 architectural firms in Malaysia registered under the Malaysian Institute of Architects or Pertubuhan Arkitek Malaysia (PAM). Electronic mails were sent to respondents and although 80% of architecture firms in Malaysia are aware of BIM benefits, only 20% of the architects firms in Malaysia are currently using the technology. Hadzaman et al. (2015) adopted an ontological position towards constructionism that examines the BIM roadmap strategies and providing insights on the strategic analysis elements. Through a formal workshop of expert panels, strategic analysis elements (i.e., capacity, support, and value) need to be embedded in the existing pillars. Suggesting that a "continuous support within all parties involved is essential to drive the successful mission of BIM in Malaysia". This highlights the need for more collaboration in the Malaysian construction industry.

Zahrizan et al. (2013) literature review and interview found that for there to be changes in Malaysian construction industry "top management of the organisations must play a major role especially during the transition time from the previous workflows to BIM workflows, convincing people about the potential of BIM, developing education and learning strategies and understanding new roles". Similarly, "due to the lack of knowledge of BIM and the low level of BIM uptake by the Malaysian construction players, the implementation of BIM in the Malaysian construction industry thus lies between BIM level 0 and BIM level 1".

Previous technology acceptance model such as theory of reasoned action (TRA) (Fishbein and Ajzen, 1975), technology acceptance model (TAM) (Davis, 1989), theory of planned behaviour (TPB) (Ajzen, 1991), innovation diffusion theory (IDT) (Rogers, 1995), decomposed theory of planned behaviour (DTPB) (Taylor and Todd, 1995), extension of technology acceptance model (TAM2) (2000) and unified theory of acceptance and use of technology (2003) have been modified to cover dimension of BIM adoption in the construction industry (Davis and Songer, 2008; Son et al., 2014; Xu et al., 2014).

Davis and Songer (2008) developed a social architecture factor model (SAFM) for construction organisations in United States of America (USA) through variable reduction of theory of reasoned action (TRA), theory of planned behaviour (TPB) and technology acceptance model (TAM). Factor Analysis, Pearson correlations, Spearman correlations, ANOVA tests, Kruskal Wallis tests, and Chi-square tests ($\chi 2$) were used in analysing the model. Davies and Harty (2013) developed a BIM model for the measurement of beliefs in the BIM system for large construction contracting organisations in the UK. The model in a bid to counter the theoretical limitations in technology acceptance model (TAM) selected variables of performance expectancy, effort expectancy, social influence, facilitating conditions, compatibility, and attitude toward using technology from unified technology acceptance and use theory (UTAUT). The findings focused on the measurement reliability of the research instrument, correlation of the variables and factor loading.

The research further recommended exploring into the interrelationship between technology and process in the construction industry.

Similar to Haron (2013), Lee et al. (2014) also took a qualitative approach to studying BIM adoption in Hong Kong and interviewed five construction industry experts. The authors limited their variable models to technology acceptance model (TAM) and extension technology acceptance model (TAM2) while recommending a diverse respondents' structure within the construction industry. Son et al. (2014) developed a BIM adoption model for organisations involving architects in South Korea. The model involved variables reduction and addition surrounding technology acceptance model (TAM). The model refinement involved addition of top management, compatibility, technical support, computer self-efficacy into TAM. The model was affected by low sample size and the need to replicate the study in a different country. Meanwhile, Succar (2013) highlighted that though, BIM is a technology-driven solution which can be analysed by TAM, there exists an inherent deficiency in analysing the relationships within an organisational framework.

Xu et al. (2014) developed a BIM adoption model for Chinese construction industry by compressing technology acceptance model (TAM) and innovation diffusion theory (IDT) into one model. The model incorporated perceived usefulness (BIM standards, compatibility, interoperability, monitoring, visualisation, advantage) and perceived ease of use (complexity, support, professionals, training, willingness, interest, perceived cost) to explaining the adoption of BIM in China. The model posit that lack of BIM standards effected BIM adoption while suggesting an extension into other dimension of BIM adoption in a broader context and future use of qualitative approach.

Whyte (2012) revealed an upward shift in research into building information modelling by creating a comprehensive review of building information modelling pattern of research. The review showed that in the first half of 2012, 160 articles were available on Google Scholar. The emerging themes were divided into (1) BIM, Lifecycle and Sustainability, (2) BIM in Design and Construction, (3) BIM Technologies, (4) Using BIM and (5) Professions and BIM. Recommending BIM research from the strategic view point of the client, GIS modelling, date capture over the life cycle of a building and prevalence of studies split along professional lines rather than as a collaborative unit.

To overcome the current challenges in BIM adoption in Malaysian construction industry, this research examines the development of a building information adoption model for Malaysian construction industry from a strategic IT perspective. The quantitative empirical gap on how Malaysian construction professionals react with the adoption of BIM in the construction industry will be derived. Subsequently, technology acceptance models are refined to accommodate the characteristics of BIM adoption. Invariably, a broad perspective from a strategic IT implementation perspective draws attention from the current research on diverse application usage in built environment/engineering fields and implementation frameworks. The research questions in the preceding section provide an insight into the research path.

1.4 Research Questions

1. What are the factors affecting building information modelling adoption?
2. What is the relationship and significance of the factors affecting building information modelling adoption?

1.5 Research Hypothesis

Hypothesis testing is vital to research methodology irrespective of the research fields from medical science, social science and other related fields (Kumar, 2015). The Oxford English Dictionary defines hypothesis as "a proposition or principle put forth or stated (without any reference to its correspondence with fact) merely as a basis for reasoning or argument, or as a premise from which to draw a conclusion; a supposition" (OED, 2016). The research outcome is reliant on the statistical validity of the appropriate testing technique to answer the above stated research questions (Paltridge and Phakiti, 2015). This shares a profound relationship to the set values for rejection and acceptance of the null hypotheses or alternate hypothesis (Paltridge and Phakiti, 2015). Quantitative methods involves the statistical analysis of data to answer research questions which measure, predict, explain and analyse causal relationships between variables (Johnson and Onwuegbuzie, 2004; Dang and Pheng, 2014). Hypothesis works in conjunction with the research objectives and directs the focus of this research (Fellows and Liu, 2015). Alternate hypotheses are utilised to derive the relationship between the variables in this research (Creswell, 2015).

1.6 Research Aim and Objectives

The aim of this research is to develop a building information adoption model for Malaysian construction industry from a strategic IT perspective. The underlying importance of this model lies in the unison of various factors affecting the adoption rate of BIM in Malaysia in a bid to increase the adoption rate. Construction professionals are identified as key elements to foster BIM adoption. To achieve this aim, the following objectives were outlined:

1. To identify the factors affecting building information modelling adoption

2. To scrutinize the relationship of factors and construction industry stakeholders perception affecting building information modelling adoption
3. To validate the significant antecedent factors of strategic IT implementation and collaborative processes on building information modelling adoption
4. To propose recommendations towards improving building information modelling adoption

1.7 Research Methodology

This research began with an extensive literature study on the subject building information modelling. This derived the variables of people, process, technology, business process re-engineering and collaborative processes affecting BIM adoption. Previous research studies on BIM (Blain, 2010; Coates et al., 2010; Haron et al., 2010; Jardim-Goncalves and Grilo, 2010; Jeong et al., 2009; Jung and Joo, 2010; Kaner et al., 2008; Lee et al., 2006; Liu, 2010; Olatunji et al., 2010; Hamil, 2012; McCuen and Suermann, 2007; Rosenberg, 2006; Succar, 2010, 2011; Suermann and Issa, 2007; Sun and Zhou, 2010; Wong, 2011; Ren and Kumaraswamy, 2013; Kurul et al., 2013; Latiffi et al., 2014; Lim, 2015; Ismail et al., 2015; Hadzaman et al., 2015; Mohd-Nor and Grant, 2014; Zahrizan et al., 2013) within and outside the context of Malaysia. However, there is a disparity in the methodological approach.

This research draws from technology acceptance models in developing a BIM adoption model for Malaysian construction consultants and contractors. Two pilot studies were carried out. The first was done by interview and the second by questionnaire for the purpose of exploring the research justification and to test the survey instrument (Shuttleworth, 2008; Creswell, 2012). Survey instrument was chosen to get responses from consultants and contractors due to the ability to get in-depth feeling and sensation of the respondents (Mitchell and Jolley, 2010). The survey instruments constructs are: people Perception, process perception, technology perception, business process re-engineering, computer integrated construction, collaborative processes and BIM adoption. A total of 352 useable responses from construction professionals (Architects, Quantity Surveyors, Engineers and Contractors) was utilised. This met the adequate sample frame from previous research.

The data derived was screened via; Data recording, data screening, analysis of "user-missing" data, identifying pattern of "system missing" data, EM imputation for "system missing" data, normality test, outlier identification, multicollinearity check and non-response bias test. The data was further analysed using Statistical Package for Social Science (SPSS) for descriptive analysis while, Analysis of Moment of Structure (AMOS) was used to assess the significant relationships of the factors affecting BIM adoption. AMOS is a rigorous software which analyses structural equation modelling and used in BIM models outside Malaysia. An analysis involving the simultaneous analysis of several variables within a single analysis is described as multivariate in nature. Contrary to previous univariate and bivariate techniques of analysis, multivariate analysis provides better understanding and harnesses more knowledge from data provided from respondents (Hair et al., 2006). The research is based on a premise that the respondents provide accurate and unbiased data about the perception on BIM in the industry and also limited interference from the division in professional designations due to the fact that BIM adoption pushes for prompt collaborative processes from the onset.

1.8 Research Scope and Limitations

The limited number of research done on BIM in Malaysia is recognized by this research. The sampling frame took into account to adequately capture considerable sized responses from construction stakeholders (architects, quantity surveyors, engineers and contractors) within medium to large public and private organization with knowledge on BIM. The sampling is carried out within Peninsular Malaysia. The potential for bias has considerably been reduced by the chosen methodological approach of structural equation modelling to initiate generalization within this context. Hence, these scopes were all considered in delivering the research findings.

1.9 Thesis Organisation

This thesis is divided into five chapters, including this chapter which introduces the research background and justification. Chapter 2 discusses literature on the background state-of-the-art of BIM, global BIM adoption, maturity and BIM perception (people, process and technology), strategic IT implementation, technology acceptance models, business process re-engineering and collaborative processes. The research model is formulated linking BIM perception, strategic IT implementation, collaborative processes and BIM adoption. Chapter 3 presents the methodological approach to test the research questions, data cleaning and preparation and instrument validity. Chapter 4 presents the results, findings and discussion. The descriptive analysis and multivariate analysis are measured. Several measurement models are presented and evaluated. The final structural model is examined including hypotheses testing and discussions. Chapter 5 concludes the thesis by revisiting the research objectives, presenting the research contributions and recommendations including several areas for future research.

1.10 Summary

The chapter introduced the research background on the current trend in BIM research and outlines the justification for adequate research into ways of improving BIM adoption as a means towards increased productivity and higher competitive advantage through the use of strategic IT implementation. The research objectives, methodology and thesis outline were delineated to depict the research procedures from start to a logical conclusion.

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