

FACTORS AFFECTING BUILDING INFORMATION MODELLING ADOPTION
BY MALAYSIAN CONSULTANTS AND CONTRACTORS

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Quantity Surveying)

Faculty of Built Environment
Universiti Teknologi Malaysia

MARCH 2016

To Almighty God for his guidance through all perils.

To late Sir. Andrew Maliki Enegbuma (KSJ) for the educational legacy you left
behind.

To Lady Bridget Irekpitan Enegbuma (KSJ) the ever inspirational supermom.

To Nelson, Andrew, Grace, Alexandra, Emmanuel and Vanessa Enegbuma for the
understanding and support along this educational endeavour.

To late Riwana Juhari for your support before your passing.

ACKNOWLEDGEMENT

Special acknowledgement goes to God Almighty for his blessings and guidance all through this journey. I also acknowledge my main supervisor Dr. Kherun Nita Ali and co-supervisor Dr. Uche Godwin Aliagha for their commitment, valuable guidance, mentoring and expertise which immensely assisted me to complete this thesis.

Similar acknowledgement goes to all who contributed academically in shaping the direction of this research, not excluding IPMS Johor, Dr. Clement Folorunsho, Dr. Steven Eluwe, Prof. Chris Preece, respondents to my pilot study and subsequently the main data collection.

I would also like to acknowledge Samson Tella, Dr. Joshua Olorunkiya, Helen Osebor, Izehi Omede, Omofuma Osebor, Olutayo Sosanya, Monica Obi, Nelson Obi, Salbiah Abd Samad, Dr. Kayode Ojo, Dr. Solomon Oluyinka, Dr. Akintunde Ajagbe, Dr. Yakubu Dodo, Arc. Badiru Yusuf, Abraham Arimokwu, Dr. Andrew Ologbo, Dr. Olugu Ezutah, Louisa Aiyejina, Teejay Malik, Thelma Rivera, Syarmala Sakmad, Dr. Solomon Zakwoi, Dr. Emmanuel Umaru, Dr. Abdulrahman Yusuf, Dr. Uche Chude, Dr. Oga Ejoko and Dr. Baba Adams for assistance and encouragement in times of declining moral, shelter and financial distress.

Finally, thanks to friends and colleagues who stood by me and special thanks to Bridget, Nelson, Andrew, Grace, Alexandra, Emmanuel and Vanessa Enegbuma including Syarifah NurulFasya Syed Abdullah for ushering me on with patience, love and understanding.

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 pengubalan dasar bagi meningkatkan lagi penggunaan BIM.

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LIST OF SYMBOLS

ρ	-	Correlation
ρ^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
SRI	-	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 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. This 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 (Malleeson, 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 fully 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.

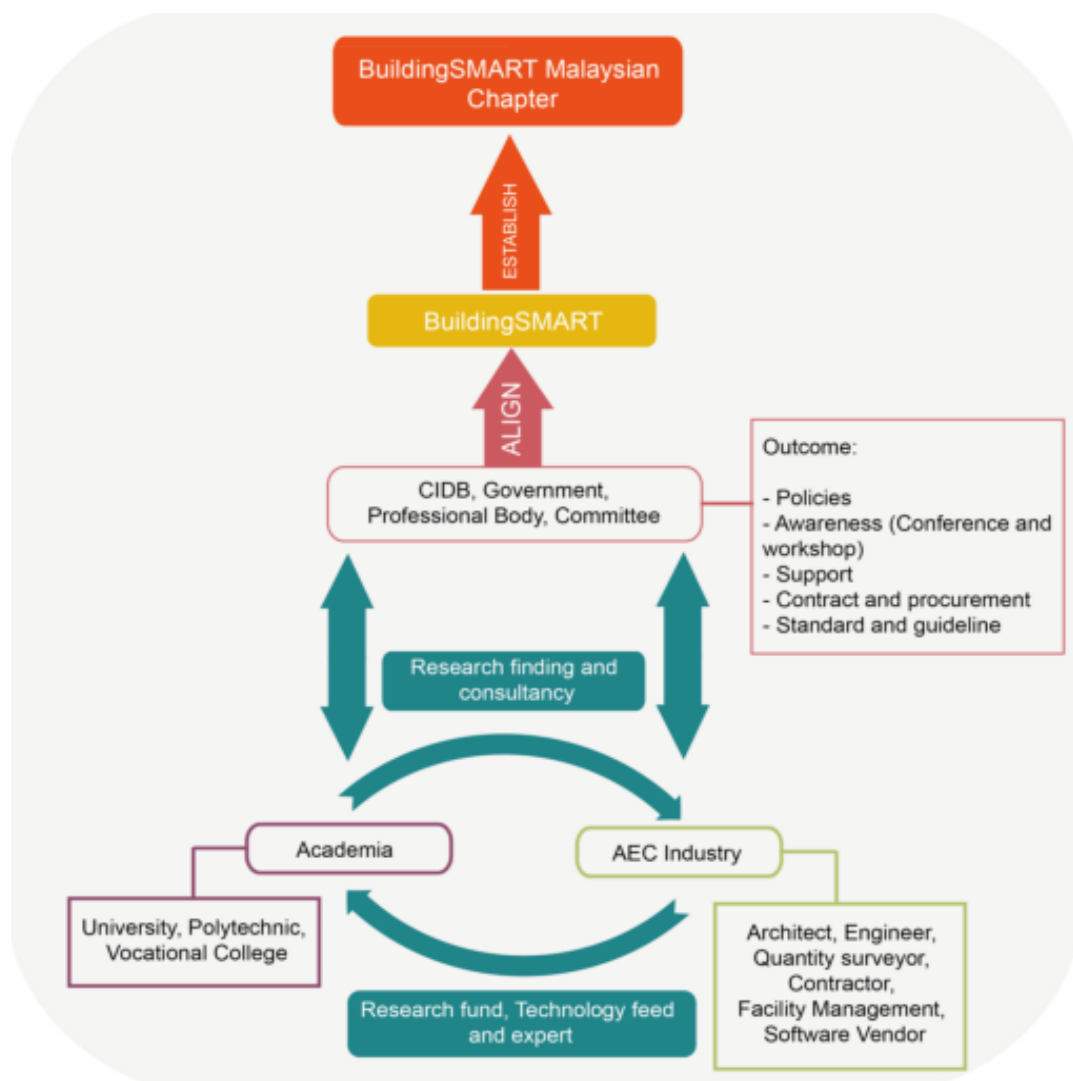


Figure 1.1: Framework of BuildSMART Malaysia (Ismail, 2014)

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), facilitating 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 necessity 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 aggressive assertion on the nature of BIM adoption 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) spurred 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 through 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 Qclassic, 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 (χ^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, data 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.

REFERENCES

- Abdul-Karrem, H. I. and Abu-Bakar, A. H. (2011). Identifying IT Benefits for Malaysian Construction Companies. *Journal of Information Technology in Construction (ITcon)*, 16: 477-492.
- ACIF (2002). Innovation in the Australian Building and Construction Industry - Survey Report, <http://www.acif.com.au/>.
- Adriaanse, A., Voordijk, H. and Dewulf, G. (2010). The Use of Interorganisational ICT in United States Construction Projects. *Automation in Construction*, 19(1): 73–83.
- AELR, Walker v Northumberland County Council [1995] 1 All ER 737.*
- Ahmed, I. U., Russell, J. S., and Abou-Zeid, A. (1995). Information technology and integration in the construction industry. *Construction Management and Economics*, 13, pp.163–171.
- AIA. (2009). *Interoperability Position Statement*. Washington, DC: American Institute of Architects.
- AIA (2010). BIM Implementation: An Owner's Guide to Getting Started. Construction User Roundtable. www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab085571.pdf.
- Alavi, M. and P. Carlson (1992). A Review of MIS Research and Disciplinary Development. *Journal of Management Information Systems: JMIS* 8(4): 4562.

- Albarq, A. N. and Alsughayir, A. (2013). Examining Theory of Reasoned Action in Internet Banking Using SEM among Saudi Consumers. *International Journal of Marketing Practices*. 1(1): 16-30.
- Ali, K. N., Al-Jamalullail, S. N. N. I. and Boon, T. C. (2013), Building Information Modeling Awareness and Readiness: Among Quantity Surveyors and Quantity Surveying Firms, Selangor: Royal Institution of Surveyors Malaysia (RISM).
- Alshawi, M. (2007). *Rethinking IT in Construction and Engineering: Organisational Readiness*. Taylor and Francis, London and New York.
- Alshawi, M. and Faraj, I. (2000). Integrated Construction Environments: Technology and Implementation. *Construction Innovation*. 2(1).
- Alshawi, M., Putra, C. W. and Faraj, I. (1996). A Structured Concept for Objects Life Cycle in Integrated Environments. *Microcomputers in Civil Engineering*, Blackwell, 12: 339-351.
- Alter, A. (1990). The Corporate Make-over. *CIO* 493: 32-42.
- Amor, R., Betts, M., Coetzee, G. and Sexton, M. (2002). Information Technology for Construction: Recent Work and Future Directions. *ITcon*, 7: 245-258.
- Amor, R. and Anumba, C. J. (1999) *A Survey and Analysis of Integrated Project Databases*. Concurrent Engineering in Construction, VTT Technical Research Centre of Finland.
- Anderson, J. C. and Gerbing, D. W. (1988). Structural Equation Modelling in Practice: A Review and Recommended Two-Step Approach. *Psychological Bulletin*, 103(3): 411.
- Anthony, R. A. (1965). *Planning and Control Systems: A Framework for Analysis*. Division of Research, Graduate School of Business Administration, Harvard University.
- Anumba, C. J., Evbuomwan, N. F. O. and Baron, G. (1997). Communication Issues in Concurrent Life-cycle Design and Construction. *BT Technology Journal*, 15(1): 209-216.

- Anumba, C. J. and Newnham, L. N. (2000). Computer-based Collaborative Building Design: Conceptual Model. *International Journal of Construction Information Technology*, 8(1): 1-14.
- Anumba, C. J., Ugwu, O. O., Newnham, L. and Thorpe, A. (2002). Collaborative Design of Portal Frame Structures using Intelligent Agents. *Automation in Construction*, 11(1): 89-103.
- Aouad, G., Marir, F., Child, T., Brandon, P., and Kawooya, A. (1997). *A Construction Integrated Databases - Linking Design, Planning and Estimating*, International Conference on Rehabilitation and Development of Civil Engineering Infrastructure Systems, American University of Beirut, Lebanon.
- Aouad, G. and Wafai, M. H. (2002), Implementation of Information Technology in the Construction Industry: The Conceptual Methodology Approach. *2nd International Postgraduate Research Conference in the Built and Human Environment*, University of Salford.
- Arayici, Y., Ahmed, V. and Aouad, G. (2005). A Requirements Engineering Framework for Integrated Systems Development for the Construction Industry. *ITcon*, 11: 35.
- Arayici, Y. and Aouad, G. (2004), DIVERCITY: Distributed Virtual Workspace for Enhancing Communication and Collaboration Within the Construction Industry. *European Conference on Product and Process Modelling in the Building and Construction Industry (ECPPM)*, Istanbul, Turkey: 415-422.
- Arayici, Y., Egbu, C. and Coates, P. (2012). Building Information Modelling (BIM) Implementation and Remote Construction Projects: Issues, Challenges, and Critiques. *Journal of Information Technology in Construction (ITcon)*, 17: 75-92.
- Arayici, Y., Coates, P., Koskela, L. J., Kagioglou, M., Usher, C. and O'Reilly, K. (2011). BIM Adoption and Implementation for Architectural Practices, *Structural Survey*, 29(1): 7-25.

- Arendt, C., Landis, R. and Meister, T. (1995). The Human Side of Change – Part 4. *IIE Solutions*: 22-27.
- Aspin, R., DaDalto, L., Fernando, T., Gobbetti, E., Marache, M., Shelbourn, M. et al. (2001). A Conceptual Framework for Multi-Modal Interactive Virtual Workspace. *ITcon Vol. 6, Special Issue Information and Communication Technology Advances in the European Construction Industry*, p. 149–62. <http://www.itcon.org/2001/11>.
- Attewell, P. (1992). Technology Diffusion and Organizational Learning: The Case of Business Computing. *Organization Science*, 3: 1-19.
- Astebro, T. (1995). The Effect of Management and Social Interaction on the Intra-firm Diffusion of Electronic Mail Systems. *IEEE Transaction on Engineering Management*, 42(4): 319-331.
- Awang, Z. (2012). *A Handbook on SEM Structural Equation Modeling: SEM Using AMOS Graphic*, 5th. Edition, Kota Baru Malaysia: Universiti Teknologi Mara Kelantan.
- Ayub, A. R. and Eman, J. (2006). Identification of Challenges faced by Bumiputera Contractors and roles of Local Government in ensuring a Successful Completion of a Project. *Paper Presented at the International Conference On Local Government 2006*.
- Ayub, A. R., Kuan, N. W. and Abdullah, A. J. (2007). Identification of Common Problems faced by the Bumiputera Contractors (Case Study Locations: Perlis and Pulau Pinang). *Paper presented at the 1st Construction Industry Research Achievement International Conference (CIRAIC 2007)*.
- Azhar, S. (2009). BIM for Electrical Construction: Benefits and Current Trends. *Journal of Building Information Modelling*, Fall 2009 Issue: 28-29.
- Azhar, S. (2011). Building Information Modelling: Benefits, Risks and Challenges. *Leadership and Management in Engineering*. 11(3): 241-252.

- Babbie, E. R. (2007). *The Practice of Social Research*, 11th Ed. Edn, Thomson Wadsworth, Belmont, Calif.
- Bain, P. G., Mann, L. and Pirola-Merlo, A. (2001). The Innovation Imperative: The relationships Between Team Climate, Innovation, and Performance in Research and Development Teams, *Small Group Research* 32 (1): 55–73.
- Baron, R. M. and Kenny, D. A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology*, vol. 51(6): 1173.
- Bazjanac, V. (2004). Virtual Building Environments (VBE) - Applying Information Modelling to Buildings. *Proceeding of European Conference on Product and Process Modelling in the Building and Construction Industry (ECPPM)*, Istanbul, Turkey: 41-48.
- Beadnell, B., Baker, S. A., Gillmore, M. R., Morrison, D. M., Huang, B. and Stielstra, S. (2008). The Theory of Reasoned Action and the Role of External Factors on Heterosexual Men's Monogamy and Condom Use. *Journal of Applied Social Psychology*. 38(1): 97-134.
- Bell, H., Bjørkhaug, L., Bjaaland, A. and Grant, R. (2012). IFD Library White Paper. Retrieved from http://www.ifd-library.org/images/IFD_Library_White_Paper_2008-04-10_I_.pdf.
- BEM. (2011). *Statistics of Engineers*. From <http://www.bem.org.my/v3/index.html>.
- Betts, M. (1995). Technology planning frameworks to guide national IT policy in construction. *Automation in Construction*, Elsevier Science, pp.251-266.
- Betts, M. (1999). *Strategic Management of IT in Construction*. Blackwell Science Ltd, Oxford.
- Bew, M. and Richards, M. (2008), *Bew-Richards BIM Maturity Model*.
- BIWG. (2011). Strategy Paper for the Government Construction Client Group from the BIM Industry Working Group, A Report Commissioned by the Department of Business, Innovation and Skills, URN 11/948, March.

- Bjork, B. C. (1989). Basic Structure of a Proposed Building Product Model. *Computer-Aided Design*, 21(2):71–8.
- Bjork, B. C. (1994). RATAS Project – Developing an Infrastructure for Computer-Integrated Construction. *J Comput Civil Eng*, 8(4): 400–19. Available from: Available from: <http://www.vtt.fi/cic/ratas/index.html>.
- Björk, B. (1999). Information Technology in Construction Domain Definition and Research Issues. *International Journal of Computer Integrated Design and Construction*, SETO, London. 1(1): 1-16.
- Björk, B. C., Huovila, P. and Hult, S. (1993). Integrated Construction Project Document Management (ICPDM). *Advanced Technologies - Architecture - Planning - Civil Engineering. Proceedings of the Europa'93 conference*, Delft, Elsevier, Amsterdam: 135-146.
- Bjork, B. C. and Penttila, H. (1989). A Scenario for the Development and Implementation of a Building Product Model Standard. *Adv Eng Software* 11(4):176–87.
- Black, J. A. and Champion, D. J. (1976). *Methods and Issues in Social Research*. New York: John Wiley and Sons, Inc.
- Blain, D. B. (2010). Improving Your Construction Design Process Through Building Information Modeling. *Contractors Center Point* Retrieved 10th March, 2011, from <http://www.contractorscenterpoint.com/2010/04/improving-your-construction-design-process-through-building-information-modeling.html>.
- Boddy, S., Rezgui, Y., Cooper, G. and Wetherill, M. (2007). Computer Integrated Construction: A Review and Proposals for Future Direction. *Advances in Engineering Software*, 38: 677–687.
- Bohms, M., Tolman, F. and Storer, G. (1994). ATLAS, A STEP Towards Computer Integrated Large Scale Engineering. *Rev Internat CFAO*, 9(3): 325–37. Available from: <http://www-uk.research.ecorg/esp-syn/text/7280.html>.
- Booth, G., Mark J. Clayton, M. J. and Kim, J. (2013). A Framework for Designing Sustainable Real Estate Developments Using Quadruple Net Value Analysis

and Building Information Modelling. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.

Boshyk, Y. and Dilworth, R. L. (Eds.) (2009). *Action Learning: History and Evolution*, Basingstoke, U.K.: Palgrave Macmillan.

BQSM. (2011). *Members Registry*. from http://www.bqsm.gov.my/bqsm/a_public/index.asp.

Brandt, T. and Yong, J. (2011). Market Watch Malaysia 2011 - Construction Industry. *Malaysian-German Chambers of Commerce*. 1-13.

Brewer, G. and Gajendram, T. (2011). Attitudinal, Behavioural, and Cultural Impacts on E-business Use in a Project Team: A Case Study. *Journal of Information Technology in Construction*, 16; 637–52.

Brod, W. and Fardig, P. (1993). *Electronic Maintenance Data Input Standards - Level One, in Developing Data - Input Standards for Computerized Maintenance Management Systems*. Federal Construction Council Consulting Committee on Computer Applications, National Academy Press, Washington, DC.

BuildingSMART. (2010). *Terms and Definitions*. Retrieved 12 August, 2010, from http://www.buildingsmart.com/content/terms_and_definitions_0.

Bullen, C. V. and Rochart, J. F. (1981). *A Primer on Critical Success Factors*: MIT Sloan School of Management, CISR WP No. 69.

Butler Group (2003). *Workgroup and Enterprise Collaboration – Reducing the Costs and Increasing the Value of Collaborative Working*, Hull: Butler Group.

Byrd, T. A. and Turner, D. E. (2000). An Exploratory Analysis of the Value of the Skills of IT Personnel: Their Relationship to IS Infrastructure and Competitive Advantage. *Decision Sciences*, 32(1): 21.

- Byrne, B. M. (2001). *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*. Multivariate Applications Book Series, Lawrence Erlbaum Associates, Mahwah, N.J.
- Campbell, D. A. (2007). Building Information Modelling: The Web3D Application for AEC. *Web3D 2007*, Perugia, Italy, April 15-18.
- Camps, H. L. (2008). BIM, Education and the Global Economy. *Journal of Building Information Modelling*, Spring 2008 Issue: 33-37.
- Cannistraro, M. P. (2010). Savings through Collaboration: A Case Study on the Value of BIM. *Journal of Building Information Modelling*. Fall 2010 Issue: 22-23.
- Castañeda, C. (2009), Plan for Integration of Building Information Modelling - BIM - with Cost Estimation Tools and Programming Projects, Bogota: Uniandes.
- CEN. (2005). *Analysis of Standardization Requirements and Standardization Gaps for eProcurement in Europe*. Brussels: European Committee for Standardization.
- Chan, T. K. and Theong, M. C. (2013). A Review of the Performance of the Malaysian Construction Industry. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Chang, M. (1998). Predicting Unethical Behaviour: A Comparison of the Theory of Reasoned Action and the Theory of Planned Behaviour. *Journal of Business Ethics*. 17(16): 1825-1834.
- Chen, H., Lin, Y. and Chao, Y. (2006). Application of Web Services for Structural Engineering Systems. *J Comput Civil Eng*, 20(3):154–64.
- Chen, W. and Hirschheim, R. (2004). A Paradigmatic and Methodological Examination of Information Systems Research from 1991 to 2001', *Information Systems Journal*, 14(3): 197.

- Cheung, G. W. and Lau, R. S. (2008). Testing Mediation and Suppression Effects of Latent Variables: Bootstrapping with Structural Equation Models. *Organizational Research Methods*, 11(2): 296-325.
- Christensen, L. C., Christensen, T. R., Jin, Y., Kunz, J. and Levitt, R. E. (1997). Object Oriented Enterprise Modelling and Simulation of AEC projects. *Computer-Aided Civil Infrastructure Eng*, 12(1):157–70.
- Christiansson, P., Dawood, N. and Svidt, K. (2002). Virtual Buildings (VB) and Tools to Manage Construction Process Operations. *In: Agger K, Editor. Distributing Knowledge in Building*, Aarhus, Denmark, 12–14 June.
- Churchill, G. A. (1979). A Paradigm for Developing Better Measures of Marketing Constructs. *Journal of Marketing Research*, 16(1): 64.
- Chuttur, M. Y. (2009). Overview of the Technology Acceptance Model: Origins, Developments and Future Directions. Indiana University, USA. *Sprouts: Working Papers on Information Systems*, 9(37). <http://sprouts.aisnet.org/9-37>.
- CIB. (2002). Agenda 21 for Sustainable Construction in Developing Countries. *The International Council for Research and Innovation in Building and Construction (CIB)*. South Africa: UNEP-ITEC.
- CICID (2007). Workshop Summary, Enhancing Performance & Overall Value through Relationally Integrated Value Networks (RIVANS), Centre for Infrastructure & Construction Industry Development, Hong Kong, 1st Dec. 2007, available at: http://www.civil.hku.hk/cicid/3_events/63/63_summary.pdf
- CICID (2008). Workshop Summary, Boosting VALUE by Building RIVANS, Centre for Infrastructure & Construction Development, Hong Kong, 31st May, 2008, available at: http://www.civil.hku.hk/cicid/3_events/68/68_RIVANS_Workshop_II_Report.pdf
- CIDB. (2007). *Construction Industry Master Plan 2006-2015 (CIMP)*. Construction Industry Development Board (CIDB) Malaysia.

- CIDB. (2013). Issues and challenges in implementating BIM for SME's in the construction industry. Construction Industry Development Board.
- CIDB (2014). Building Information Modelling (BIM) Roadmap for Malaysia's Construction Industry (2014-2020). Consyrcion Industry Development Board Workshop Report (series 2).
- CIDB, (2015). Workshop Report (series 2) of Building Information Modelling (BIM) Roadmap for Malaysia's Construction Industry, retrieved April 18. <http://www.bimcenter.com.my/index.php/bim-information/item/bim-roadmapworkshop-report-series2>
- Clifton, J. R. and Sunder, S. S. (1997). A Partnership for a National Computer-Integrated Knowledge Systems Network for High-Performance Construction Materials and Systems: Workshop Report. *National Institue of Standards and Technology Report 6003*.
- Coates, P., Arayici, Y., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2010). The key performance indicators of the BIM implementation process. *Paper presented at the The International Conference on Computing in Civil and Building Engineering*.
- Codd, T. R. and Cohen, B. N. (2003). Predicting College Student Intention to Seek Help for Alcohol Abuse. *Journal of Social and Clinical Psychology*, 22: 168-191.
- Collis, J., Hussey, R., Hussey, J. and Inglis, R. (2003). *Business Research: A Practical Guide for Undergraduate and Postgraduate Students*, 2nd Ed. Edn, Palgrave Macmillan, Basingstoke: New York.
- Conover, D. and Lee, E. (2008). SMARTcodes. *Journal of Building Information Modelling*. Fall 2008 Issue: 22-23.
- Construction Industry Development Board (CIDB), BIM Portal: Building Information Modelling. Retrieved on December 3, 2013 from <http://bimcentre.com.my/index.php/bimnews>.

- Construction Research Institute of Malaysia (CREAM), Issues and Challenges in Implementing Building Information Modeling (BIM) by SME's in the Construction Industry. <https://www.cidb.gov.my/cidbv3/images/pdf/announcement/BIM/bim%20seminar%20%20workshop%20for%20malaysia%20construction%20industry.pdf>.
- Cooperative Research Centre for Construction Innovation (2009), Australian BIM Guidelines Book, available at: http://issuu.com/guillermo-am/docs/bim_guidelines_book?viewMode¼magazine&mode¼embed (accessed 26 September 2013).
- Cooper, R. and Markus, M. (1995). Human Engineering. *Sloan Management Review* 36(4): 39-50.
- Cooper, R. B. and Zmud, R. W. (1990) Information Technology Implementation Research: A Technological Diffusion Approach. *Management Science*, 36: 123-139.
- CORENET (2012). CORENET. e-Submission System in Singapore. <https://www.corenetess.gov.sg/ess/>
- Cox, B. and Terry, F. (2008). Creating a BIM for Emergency Management. *Journal of Building Information Modelling*, Fall 2008 Issue: 24-25.
- Coyne, R., Lee, J., Duncan, D. and Ofluoglu, S. (2001). Applying Web-Based Product Libraries. *Automat Construct*, 10(5):549–59.
- CRC Construction Innovation. (2007). *Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House*, Cooperative Research Center for Construction Innovation, Brisbane, Australia.
- CREAM (2014). Issues and Challenges in Implementing Building Information Modelling for SME's in the Construction Industry. Construction Research Institute of Malaysia.
- Creswell, J. W. (2015). *Educational research: planning, conducting, and evaluating quantitative and qualitative research*. Boston: Pearson.

- Crisci, A. (2012). Estimation Methods for the Structural Equation Models: Maximum Likelihood, Partial Least Squares E Generalized Maximum Entropy. *Journal of Applied Quantitative Methods*, 7(2): 1-15.
- Crotty, M. J. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process*, SAGE Publications.
- Dackert, I., Loov, L. and Martensson, M. (2004). Leadership and Climate for Innovation in Teams. *Economic and Industrial Democracy*. 25(2): 301–318.
- Damanpour, F. (1991). Organizational Innovation: A Meta Analysis of Effects of Determinants and Moderators. *Acad. of Mgmt. J.* 34(3): 555–590.
- Dang, G. and Pheng, L. S. (2015). Research Methodology. In *Infrastructure Investments in Developing Economies: The Case of Vietnam*, 135-155. Springer Singapore
- Davenport, T. (1993). *Process Innovation: Re-engineering Work through Information Technology*. Harvard Business School Press. Boston, MA.
- Davenport, T. H. and Short, J. E. (1990). The New Industrial Engineering: Information Technology and Business Process Redesign. *Sloan Management Review*. 13(14): 11-27.
- Davies, R. and Harty, C. (2013). Measurement and Exploration of Individual Beliefs about the Consequences of Building Information Modelling Use, *Construction Management and Economics*, 31(11): 1110-1127, DOI: 10.1080/01446193.2013.848994
- Davis, F. D., Bagozzi, R. P. and Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, 35(8): 982-1003.
- Davis, K. A. and Songer, A. D. (2008). Resistance to IT Change in the AEC Industry: An Individual Assessment Tool. *Journal of Information Technology in Construction*, 13: 56–68.

- Davydov, M. M. (2000). *e-Commerce Solutions for Business and IT Managers: Coporate Portals and e-Business Integration*. New York: McGraw Hill.
- De-Vaus, D. A. (2001). *Research Design in Social Research*, Sage Publications, Ltd., London.
- DIBK (2012). Survey about ByggNett. Norwegian Building Authority, Oslo, Norway, www.dibk.no.
- Dimyadi, J and Amor, R. (2013). Automated Building Code Compliance Checking – Where Is It At? *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Ding, L., Velicer, W. F. and Harlow, L. L. (1995). Effects of Estimation Methods, Number of Indicators Per Factor, and Improper Solutions on Structural Equation Modeling Fit Indices. *Structural Equation Modeling*, 2(2): 119–144.
- Dobbins, J. H. and Donnelly, R. G. (1998). *Critical Success Factor Analysis for DOD Program Management*.
- Druker, P. (1988). The Coming of the New Organisation. *The Harvard Business Review*. January-February: 45-53.
- Dubois, A. M., Flynn, J., Verhoef, M. H. G. and Augenbroe, F. (1995). Conceptual Modelling Approaches in the COMBINE Project *Presented in the COMBINE Final Meeting*, Dublin, 1995. <http://erg.ucd.ie/combine/papers.html>.
- Dupagne, A. (1991). Computer Integrated Building, Strategic Final Report. *Esprit II: Exploratory Action No 5604, CE Commission D. G. XIII*, December 1991.
- East, E. W. (2009). Performance Specifications for Building Information Exchange. *Journal of Building Information Modelling*, Fall 2009 Issue: 18-20.
- East, W. E. and Brodt, W. (2007). BIM for Construction Handover. *Journal of Building Information Modelling*, Fall 2007 Issue: 28-35.

- Eastman, C. M., Chase, S. C. and Assal, H. H. (1993). System Architecture for Computer Integration of Design and Construction Knowledge. *Automat Construct*, 2(2):95–107.
- Eastman, C. M. and Siabiris, A. A (1995). Generic Building Product Model Incorporating Building Type Information. *Automat Construct* 3(4): 283–304.
- Edgar, A. (2008). Building Value Through Building Information Innovation. *Journal of Building Information Modelling*, Spring 2008 issue: 38.
- Egan, J. (1998). *Rethinking Construction: The Report of the Construction Task Force*. London: Department of the Environment, Transport and Regions.
- Egan, J. (2008). I'd give construction about four out of 10. Available at: <<http://www.building.co.uk/egan-i'd-give-construction-about-four-out-of10/3114129.article>>.
- EPU. (2006). Ninth Malaysia Plan 2006-2010. Economic Planning Unit, Putrajaya, Malaysia: Prime Minister's Department.
- Everitt, B. (2006). *The Cambridge Dictionary of Statistics*, 3rd Ed, Cambridge University Press, Cambridge, UK; New York.
- FaithfulGould. (2009). Building Information Modeling - Coming of Age? *International Construction Intelligence*, 21(2),
- Fallon, K. K. and Palmer, M. E. (2007). General buildings information handover guide: Principles, methodology and case studies. *National Institute of Standards and Technology*, NISTIR 7417, pp: 99.
- Faraj, I. and Alshawi, M. A (1999). Modularised Integrated Computer Environment for the Construction Industry: SPACE. *ITcon*, 4:37–52. Available from: <http://www.itcon.org/1999/3>.
- Faraj, I., Alshawi, M., Aouad, G., Child, T. and Underwood, J. (2000). An IFC web-Based Collaborative Construction Computer Environment: WISPER, *Proceedings of the National Conference on Objects and Integration for AEC*. UK, ISBN 186081 3771.

- Faraj, I., Alshawi, M., Aouad, G., Child, T. and Underwood, J. (2000). An industry Foundation Classes Web-based Collaborative Construction Computer Environment: WISPER. *Automation in Construction*. 10: 79–99.
- Fasel, D. (2000). *Partnering in Action – A Guide for Building Successful Collaboration across Organizational Boundaries*. Oxford: Pathways.
- Fidelman, U. (2002). Temporal and Simultaneous Processing in the Brain: A Possible Cellular Basis of Cognition. *Kybernetes* 31(¾): 432-481.
- Fellows, R. F. and Liu, A. M. M. (2003). *Research Methods for Construction*. Oxford, UK: Blackwell Science Ltd.
- Fellows, R. F. and Liu, A. M. M. (2015). *Research Methods for Construction, 4th Edition*. Wiley Blackwell. London, United Kingdom.
- Fink, L. and Neumann, S. (2007). Gaining Agility through IT Personnel Capabilities: The Mediating Role of IT Infrastructure Capabilities. *Journal of the Association for Information Systems*, 8(8); 440.
- Fischer, M. (1993). Linking CAD and Expert Systems for Constructability Reasoning. In: Cohn L, Editor. *Proceedings of the 5th International Conference on Computing in Civil and Building Engineering*, ASCE, Anaheim, California: 1563–70.
- Fisher, R. A. (1936). The Use of Multiple Measurements in Taxonomic Problems. *Annals of Eugenics*, 7: 179-188.
- Fleming, M., Gard, S., Kumarasuriyar, A. and Nielsen, D. (2009). What are Students' Understanding of How Digital Tools Contribute to Learning in Design Disciplines? *Paper presented at the Proceedings of the International Conference on Education, Research and Innovation*, Convention Centre - Melia Castilla, Madrid.
- Flórez, M., Guevara, J., Ozuna, A. and Vargas, H. (2013). The Process of Implementing Project Management and BIM In The Colombian AEC Industry. *Proceedings of CIB World Building Congress*, 5th – 9th May, Brisbane, Australia.

- French, J. R. P. and Caplan, R. D. (1973). Organisational Stress and Individual Strain. In A. J. Morrow (ed.). *The Failure of Success*. New York: Amacom.
- Froese, T. and Paulson, B. (1994). OPIS, An Object-Model-Based Project Information System. *Microcomput Civil Eng*, 9:13–28.
- Fung, W. P., Salleh, H. and Rahim, A. M. (2014). Capability of Building Information Modeling Application in Quantity Surveying Practice. *Journal of Surveying, Construction and Property (JSCP)*, 5(1).
- Fuhrman, A. (2008). Forward Thinking Organizations Invest to Convert ROI Vision Into Reality. *Journal of Building Information Modelling*, Spring 2008 issue: 27-29.
- Gaith, F. H., Khalim, A. R. and Ismail, A. (2009). Usage of Information Technology in Construction Firms; Malaysian Construction Industry. *European Journal of Scientific Research*, 28(3); 412-421.
- Geisler, C. and Rogers, E. (2000). Technological Mediation for Design Collaboration. In *IEEE IPCC 2000 / ACM 18th International Conference on Systems Documentation*: 395-406.
- Gentry, L. and Calantone, R. (2002). A Comparism of the Three Models to Explain Shop Bot Use on the Web. *Psychology and Marketing*. 19 (11): 945-956.
- Goh, B. H. and Chu, Y. L. (2002). Developing National Standards for the Classification of Construction Information in Singapore. *Proceedings of the International Council for Research and Innovation in Building and Construction CIB w78 Conference*. Aarhus School of Architecture, 12 – 14 June.
- Greening, R. and Edwards, M. (1995), ATLAS Implementation Scenario, *Proceedings ECPPM'94: Product and Process Modelling in the Building Industry*, Scherer (ed.): 467 – 472.
- Greenwood, D., Lewis, S. and Lockley, S. (2010). Contractual Issues in the Total Use of Building Information Modelling. *Paper presented at the CIB 2010 World Congress*, Salford Quays - United Kingdom.

- Grilo, A. and Jardim-Goncalves, R. (2011). Challenging Electronic Procurement in the AEC Sector: A BIM-Based Integrated Perspective. *Automation in Construction*, 20: 107-114.
- Grix, J. (2004). *The Foundations of Research, Palgrave Study Guides*, Palgrave Macmillan, New York.
- Groebner, D. F. and Shannon, P. W. (1990). *Business Statistic: A Decision-Making Approach* Third Edition Edn, Macmillan Publishing Company, New York.
- Gu, N. and London, K. (2010). Understanding and Facilitating BIM Adoption in the AEC Industry. *Automation in Construction*. 19: 988-999.
- Gunathilake, S. and Jayasena, H. S. (2008), Developing a Relational Approach to Contracting: the Sri Lankan Context. *Paper Presented at the Proceedings of the CIB International Conference on Building Education and Research*, Kandalama, Sri Lanka.
- Haas, C. T., Saidi, K. S. and Balli, N. A. (2002). The Value of Handheld Computers in Construction. *Report for the Construction Workforce Thrust Team*. University of Austin, Texas, USA.
- Hadzaman, N. A. H., Takim, R. and Nawawi, A. H. (2015). BIM roadmap strategic implementation plan: Lesson learnt from Australia, Singapore and Hong Kong In: *Raidén, A B and Aboagye-Nimo, E (Eds) Procs 31st Annual ARCOM Conference, 7-9 September, Lincoln, UK, Association of Researchers in Construction Management*, 611-620.
- Hagan, S. R. (2008). BIM and Stellar Architecture: Lessons from the First Three Years of the AIA TAP BIM Awards. *Journal of Building Information Modelling*. Spring 2008 Issue: 19-21.
- Hagan, S. R., Ho, P., and Matta, C. (2009). BIM: The GSA Story. *Journal of Building Information Modelling*, Spring 2009 Issue: 28-29.
- Hair, J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2010). *Multivariate Data Analysis* (7th ed.). New Jersey: Pearson Prentice Hall.

- Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E. and Tatham, R. L. (2006). *Multivariate Data Analysis*, 6th Ed, Pearson Prentice Hall, Upper Saddle River, N.J.
- Hale, J. L., Householder, B. J. and Greene, K. L. (2003). *The Theory of Reasoned Action*. In J.P. Dillard and M. Pfau (Eds.). *The Persuasion Handbook: Developments In Theory And Practice*: 259-286.
- Hamil, S. (2012). What will BIM Mean for Design Fees? *National BIM Report*: 15-16.
- Hammer, M. (1990). Re-Engineering Work: Don't Automate, Obliterate. *Harvard Business Review*. July-August: 104-112.
- Hammond, D. M. (2008). The BIM Balancing Act. *Journal of Building Information Modelling*. Fall 2008 Issue: 12-14.
- Hampson, K. and Kraatz, J. (2013). Modelling, Collaboration and Integration: A Case Study for the Delivery of Public Buildings. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Han, C. S., Kunz, J. C. and Law, K. H. (1999). Building Design Services in a Distributed Architecture. *J Comput Civil Eng*, 13(1):12–22.
- Hannus, M., Blasco, M., Bourdeau, M., Bohms, M., Cooper, G., Garas, F., et al. (2003). *Construction ICT Roadmap: Strategic Roadmap towards Knowledge-Driven Sustainable Construction (ROADCON)*.
- Haron, A. T. (2013), *Organisational Readiness to Implement Building Information Modelling: A Framework for Design Consultants in Malaysia*, PhD Thesis School of the Built Environment Faculty of Business, Law and the Built Environment, University of Salford Manchester, Salford.
- Haron, A. T., Marshall-Ponting, A. and Aouad, G. (2010). Building Information Modelling: Literature Review on Model to Determine the Level of Uptake

by Organisation. *Paper presented at the CIB 2010 World Congress*, Salford Quays - United Kingdom.

Harvey, R., Bahgat, T., Gerber, D., Kotronis, J. and Pysh, D. (2009). BIM as a Risk Management Platform Enabling Integrated Practice and Delivery. *Journal of Building Information Modelling*. Fall 2009 Issue: 14-17.

Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical Mediation Analysis in the New Millennium. *Communication Monographs*, 76(4): 408-420.

Hecht, L. (2010). Laying the Foundation for BIM Interoperability. *Journal of Building Information Modelling*. Fall 2010 issue: 19-20.

Henderson, L. and Jordan, N. L. (2009). A Modest Proposal for a Transdisciplinary Curriculum: for the Design, Construction, Management and Maintenance of Architecture. *Journal of Building Information Modelling*. Fall 2009 Issue: 35-37.

Heyck, T. W. and Klecka, W. R. (1973). British Radical M.P's, 1874-1895. New Evidence from Discriminant Analysis. *Journal of Interdisciplinary History*. 4 (Autumn): 161-184.

Hietanen, J. and Lehtinen, S. (2006). *The Useful Minimum*, Tampere University of Technology, Virtual Building Laboratory, 2006, Retrieved from <http://www.facilityinformationcouncil.org/bim/pdfs/usefulminimum.pdf>.

Hinterhuber, H. H. (1995). Business Process Management: The European Approach. *Business Change and Re-engineering* 2(4): 63-73.

Hjelseth, E. (2013). Integrated Approach for Development of Automatic Building Application Systems. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.

Ho, R. (2006). *Handbook of Univariate and Multivariate Data Analysis and Interpretation with SPSS*. Chapman and Hall CRC, Boca Raton.

- Hobbs, R. W. (1996). Leadership Through Collaboration. *AIArchitect*, 3: 11.
- Hossain, L., and Wigand, R. T. (2003). Understanding Virtual Collaboration through Structuration. *Proceedings of the 4th European Conference on Knowledge Management*, 475–484.
- Howard, R., Kiviniemi, A. and Samuelson, O. (1998). Surveys of IT in the Construction Industry and Experience of the IT Barometer in Scandinavia. *Journal of Information Technology in Construction*, 3: 45-56.
- Hox, J. J., Maas, C. J. M. and Brinkhuis, M. J. S. (2010). The Effect of Estimation Method and Sample Size in Multilevel Structural Equation Modeling. *Statistica Neerlandica*, 64(2): 157–170. DOI: 10.1111/j.1467-9574.2009.00445.x.
- Hu, L. and Bentler, P. (1998). Fit Indices in Covariance Structure Modelling: Sensitivity to Underparameterized Model Misspecification. *Psychological Methods*, 3(3): 424-53.
- Hussein, J., Hamid, Z. A., Ghani, M. K. and Zain, M. Z. M. (2009). Towards Sustainable Construction: Malaysian Construction Industry Initiatives. *The Ingenieur*, 44: 8-15.
- Iacobucci, D. (2010). Structural Equations Modeling: Fit Indices, Sample Size, and Advanced Topics. *Journal of Consumer Psychology*, 20: 90–98.
- IAI (2003). *International Alliance for Interoperability*, IFC Model: 2x3. http://www.iaiinternational.org/Model/R2x3_final/index.htm
- Ibrahim, A. R., Roy, M. H., Ahmed, Z. and Imtiaz, G. (2010). An Investigation of the Status of the Malaysian Construction Industry. *Benchmarking: An International Journal*, 17(2): 294-308.
- Ibrahim, M., Krawczyk, R. and Schipporiet, G. (2004). A Web-Based Approach to Transferring Architectural Information to the Construction Site Based on the BIM Object Concept. *Proceedings of the Association for Computer-Aided Architectural Design Research in Asia (CAADRRIA)*.
- IDM (2007). *Information Delivery Manual*, <http://www.iai.no/idm/index.html>

- IFC (2002). IFC Model Based Operation and Maintenance of Buildings (IFC-mBomb) http://cig.bre.co.uk/iai_uk/iai_projects/ifcmbomb/
- IFC (2012). *Industry Foundation Classes*. <http://buildingsmart-tech.org/specifications/ifc-overview>.
- Iguarán, A. (2010). A First Step to Implementation of BIM in State Contracts, FONADE as a Management Tool in Your Construction Project, Bogota: Uniandes.
- Ikerd, W. F. (2009). BIM in Structural Engineering: A Current View of the Profession From one of the First National Surveys in 2008 of SE's by a Non-Profit SE Organization. *Journal of Building Information Modelling*, Spring 2009 Issue: 32-33.
- Isaza, O. (2008). Plan for Implementation of Building Information Modelling (BIM) as a Tool for Planning and Control of Construction Projects, Bogota: Uniandes.
- Isikdag, U., Aouad, G., Underwood, J. and Trodd, N. (2006). *Investigating the Applicability of IFC in Geospatial Environment in Order to Facilitate the Fire Responce Management Process*. University of Salford.
- Ismail, M. H. (2014). Building Information Modelling: A Paradigm Shift in Malaysian Construction Industry. *BinaTECH*, 2:34-37.
- Ismail, M. H., Che-Ani, A. I., Haron, A. T., Preece, C. and Husain, A. H. (2014). Prioritizing Building Information Modeling (BIM) Initiatives for Malaysia Construction Industry. *25th FIG Congress*, Kuala Lumpur.
- Ismail, N. A. A., Owen, R. and Drogemuller, R. (2015). Cost estimating practice incorporating building information modelling (BIM): Malaysian quantity surveyors perspectives. *The 7th International Conference of SuDBE2015*, Reading, UK; 27-29 July.
- ISO 9735:1988. (1988). Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT). International Standards Organization. TC 154, <http://www.iso.ch/cate/d17592.html>.

- Jaccard, J. (2012). The Reasoned Action Model: Directions for Future Research. *The ANNALS of the American Academy of Political and Social Science*. March, 640: 58-80.
- Jacobsson, M. and Linderoth, H. C. (2010). The Influence of Contextual Elements, Actors' Frames of Reference, and Technology on the Adoption and Use of ICT in Construction Projects: A Swedish Case Study. *Construction Management and Economics*, 28(1): 13–23.
- Jacobsson, M. and Linderoth, H. C. J. (2012). User Perceptions of ICT Impacts in Swedish Construction Companies: 'It's not, just as it is'. *Construction Management and Economics*, 30(5): 339–57.
- Jaafar, M., Ramayah, T., Abdul-Aziz, A. R. and Saad B. (2007). Technology Readiness among Managers of Malaysian Construction Firms. *Engineering Construction and Architectural Management*, 14(2): 180-191.
- Jardim-Goncalves, R. and Grilo, A. (2010). SOA4BIM: Putting the Building and Construction Industry in the Single European Information Space. *Automation in Construction*, 19: 388-397.
- Jayasena, H. S. and Weddikkara, C. (2012). Building Information Modelling for Sri Lankan Construction Industry, *Paper presented at the World Construction Conference 2012 – Global Challenges in Construction Industry*, Colombo.
- Jayasena, H. S. and Weddikkara, C. (2013). Assessing the BIM Maturity in a BIM Infant Industry, *Proceedings of the Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction*, 14 – 15 June, Colombo, Sri Lanka.
- Jeong, Y. S., Eastman, C. M., Sacks, R. and Kaner, I. (2009). Benchmark Tests for BIM Data Exchanges of Precast Concrete. *Automation in Construction*, 18: 469-484.
- Johanssen, H. J., McHugh, P., Pendlebury, A. J. and Wheele, W. A. (1993). *Business Process Reengineering: Breakpoint Strategic for Market Dominance*. John Wiley and Sons. Chichester.

- Johnson, R. B. and Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14.
- Jones, S. A. and Lien, J. K. (2008). Towards Interoperable Building Product Content. *Journal of Building Information Modelling*, Fall 2008 issue: 36-37.
- Jordani, D. (2008). BIM: A Healthy Disruption to a Fragmented and Broken Process. *Journal of Building Information Modelling*, Spring 2008 Issue: 24-26.
- Joreskog, K. G. (1973), A General Method for Estimating a Linear Structural Equation System, in A. Goldberger and O. Duncan, eds, *Structural Equation Models in the Social Sciences*, Seminar Press, New York: 85–112.
- Joreskog, K. G. and Sorbom, D. (1993). LISREL 8: Structural Equation Modeling with the SIMPLIS Command Language, SSI Scientific Software International ; Lawrence Erlbaum Associates, Chicago, Ill.
- Jung, Y. and Joo, M. (2010). Building Information Modelling (BIM) Framework for Practical Implementation. *Automation in Construction*.
- Kalavagunta, S. (2012). *Integrated Engineering Workflow (BIM) for Design of Steel Structures*. Bentley Systems Limited, Singapore.
- Kalay, Y. E. (2001). Enhancing Multi-disciplinary Collaboration through Semantically Rich Representation. *Automation in Construction*, 10(6): 741-755.
- Kam, C., Fischer, M., Hanninen, R., Karjalainen, A. and Laitinen, J. (2003). The Product Model and Fourth Dimension Project. *ITcon Vol. 8, Special Issue IFC – Product Models for the AEC Arena*, p. 137–66. <http://www.itcon.org/2003/12>.
- Kaner, I., Sacks, R. and Kassian, W. (2008). Case Studies of BIM Adoption for Precast Concrete Design by Mid-Sized Structural Engineering Firms. *ITcon*, 13: 303-323.
- Kangas, K. (1999). Competency and Capabilities Based Competition and the Role of Information Technology: The Case of Trading by a Finland-Based Firm to

- Russia. *Journal of Information Technology Cases and Application* 1(2): 4-22.
- Kanter, R. M. (1988). When a Thousand Flowers Bloom: Structural, Collective and Social Conditions for Innovation in Organization. *Research in Organizational Behaviour*. 10: 169–212.
- Kaplan, D. 2000, Structural Equation Modelling, Sage Publications Ltd., London, New Delhi.
- Karahanna, E., Straub, D. W. and Chervany, N. (1999). Information Technology Adoption across Time: A Cross-Sectional Comparison of Pre-Adoption and Post-Adoption Beliefs. *MIS Quarterly*. 23(2): 183-213.
- Karlshoj, J. (2011). *Information Delivery Manuals. BuildingSMART International User Group*. Retrieved from <http://iug.buildingsmart.com/idms>. January, 2012.
- Katranuschkov, P., Scherer, R. and Turk, Z. (2001). Intelligent Services and Tools for Concurrent Engineering? An Approach towards the Next Generation of Collaboration Platforms. *ITcon Vol. 6, Special Issue Information and Communication Technology Advances in the European Construction Industry*, p.111–28. <http://www.itcon.org/2001/9>.
- Kazi, A. S., Hannus, M., Laitinen, J. and Nummelin, O. (2001). Distributed Engineering in Construction: Findings from the IMS GLOBEMEN Project. *ITcon Vol. 6, Special Issue Information and Communication Technology Advances in the European Construction Industry*, p.129–48. <http://www.itcon.org/2001/10>.
- Keat, Q. S. (2013). What it will take to ensure 5D BIM sustainability in Malaysia. http://www.academia.edu/4929524/What_It_Will_Take_To_Ensure_5D_BIM_Sustainability_In_Malaysia.
- Kent, D. C. and Becerik-Gerber, B. (2010). Understanding Construction Industry Experience and Attitudes Toward Integrated Project Delivery. *Journal of Construction Engineering and Management*, 136(8): 815-825.

- Kennedy, C. (1994). Re-Engineering: The Human Costs and Benefits. *Long Range Planning*. 27(5): 64-72.
- Kerlinger, F. N. (1986). *Foundation of Behaviourial Research*. New York: Holt, Rinehart and Winston.
- Kim, I. (2012). Seumter Code Checking System. SMART Geospatial Expo 2012 (The 82nd OGC TC/PC Meetings, ISO/TC 211 ans ISO/TC 59/SC 13 Joint Workshop on BIM_GIS, OGC interoperability Day, Seoul, Korea 12. Oct. 2012. www.opengeospatial.org.
- Klecka, W. R. (1973). The Clientele of Australian Parties: New Perspectives through Discriminant Analysis. *Politics*. 7: 301-308.
- Klecka, W. R. (1980). *Discriminant Analysis*. Sage University Paper Series on Quantitative Applications in the Social Sciences, 07-019. Beverly Hills and London. Sage Publications.
- Klenke, K. (1994). Information Technologies as Drivers of Emergent Organisational Forms: A Leadership Perspective in R. Baskerville, S. Smithson, O. Ngwenyama and J. Degross (eds) *Transforming Organisations with Information Technology*. Amsterdam: Elsevier Science: 323-341.
- Kline, R. B. (2005). *Principles and Practice of Structural Equation Modeling*, 2nd Ed, Methodology in the Social Sciences, Guilford Press, New York.
- Koc, T. (2007). Organizational determinants of innovation capacity in software companies. *Computers & Industrial Engineering*, 53(3): 373-385.
- Koch, C., Slater, D. and Baatz, E. (1999). *The ABC's of ERP*. London:CIO.
- Kohar, U. H. A., Senina, A. A., and Ismaila, K. (2012). The Cultivation of Organizational Innovation amongst Malaysian Bumiputera (Indigenous) ICT-Based Small Firms. *Procedia - Social and Behavioural Sciences* 40: 358 – 363.
- Kolekofsi, K. E. and Heminger, A. R. (2003). Beliefs and Attitude Affecting Intentions to Share Information in an Organisation Setting. *Information and Management*. 40: 521-532.

- Kolenikov, S. and Yuan, Y. (2009). Empirical Likelihood Estimation and Testing in Covariance Structure Models. Retrieved from: <http://web.missouri.edu/~kolenikovs/papers/SEM-EL-Yuan-Kolenikov-2.pdf>.
- Koo, B. and Fischer, M. (2000). Feasibility Study of 4D CAD in Commercial Construction. *J Construct Eng Manage*, 126(4):251–60.
- Kornberg, A. and Frasure, R. C. (1971). Policy Difference in British Parliamentary Parties. *American Political Science Review*. 65: 694-703.
- Koskela, L. and Salagnac, J. (1990). Determinants of the Development of Computer Integrated Construction. *7th International Symposium on Automation and Robotics in Construction*. Bristol, 5 - 7 June: 245 - 252.
- Koskela, L. and Salagnac, J. (2001). Determinants of the Development of Computer Integrated Construction.
- Kumar, A. (2015). Hypothesis Testing in Medical Research: A Key Statistical Application. *Journal of Universal College of Medical Sciences*, 3(2): 53-56.
- Kumar, R. (2005). *Research Methodology: A Step-by-Step Guide for Beginners*. French Forest, Australia: Pearson Education Australia.
- Kunz, J. et al (1994) Circle Integration, Computing in Civil Engineering, *Proceedings of the First Congress Held in Conjunction with A/E/C Systems 94*, ASCE: 55-62.
- Kuppusamy, M. and Shanmugam, B. (2007). Islamic Countries Economic Growth and ICT Development: The Malaysian Case. *Journal of Economic Cooperation*, 28(1): 99-114.
- Kurihara, T. Y. and Kaetzel, L. J. (1997). Computer Integrated Knowledge System (CIKS) for Construction Material, Components and Systems: Proposed Framework. *National Institute of Standards and Technology Report 6071*.

- Kurul, E., Abanda, H., Tah, J. H. and Cheung, F. (2013). Rethinking the Build Process for BIM Adoption. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Kwon, T. H. (1990). A Diffusion of Innovation Approach to MIS Infusion: Conceptualization, Methodology, and Management Strategies. *Proceedings of the Tenth International Conference on Information Systems*. Copenhagen, Denmark, 139-146.
- LACCD BIM (2009) *Building Information Modeling Standards (LACCD BIMS)*, 2.0 C.F.R., Los Angeles Community College District. http://www.viewbyview.com/html/bim_guidelines.html.
- Lada, S., Tanakinjal, H. G. and Amin, H. (2009). Predicting Intention to Choose Halal Products Using Theory of Reasoned Action. *International Journal of Islamic and Middle Eastern Finance and Management*. 2(1): 66-76.
- Laiserin J. (2003), AEC Interoperability and the BLIS Project, *CADALYST Magazine*, www.cadalyst.com/cadalyst/.
- LAM. (2011). *List of Architects*. from http://vps.lam.gov.my/lam_ims_member/index.php?module=func&op=dispList&dispCode=1&indexStart=0.
- Lang, S. Y. T., Dickinson, J. and Bucha, R. O. (2002). Cognitive Factors in Design. *Computers in Industry*, 48: 89-98.
- Latham, M. (1994). *Constructing the Team. Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry*. HMSO. London.
- Latiffi, A. A., Mohd, S. and Brahim, J. (2014). Building Information Modelling (BIM) Roles in the Malaysian Construction Industry. In Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A. Ed. *Sustainable Solutions in Structural Engineering and Construction*, 749-754.

- Latiffi, A. A., Brahim, J., Mohd, S. and Fathi, M. S. (2015). Building Information Modeling (BIM): The Level of Development (LOD) in the Malaysian Construction Projects. *Applied Mechanics and Materials*, 773: 933-937.
- Latiffi, A., Mohd, S., Kasim, N., and Fathi, M. S. (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry, *International Journal of Construction Engineering and Management*, 2(1): 1-6.
- Lee, A., Wu, S., Aouad, G. and Fu, C. (2002). Towards nD Modelling. In: *Proceedings of the European Conference on Information and Communication Technology Advances and Innovation in the Knowledge Society (E-sm@art)*, Salford.
- Lee, G., Sacks, R. and Eastman, C. M. (2006). Specifying Parametric Building Object Behavior (BOB) for a Building Information Modeling System. *Automation in Construction*, 15: 758-776.
- Lee, J. H. (2003). *Modelling Computer Integrated Construction Site Management*. M.Phil Thesis, School of Engineering Faculty of Engineering and Information Technology, Griffith University, Gold Coast Campus.
- Lee, W., Wong, A. and Tong, C. (2014). A Qualitative Study of the Software Adoption of Building Information Modelling Technology in the Hong Kong Construction Industry. *Business and Economic Research*, 4(2): 222-236.
- Lee, A., Wu, S., Marshall-Pointing, A., Aouad, G., Tah, J., Cooper, R. and Fu, C. (2005). nD modelling - a driver or enabler for construction improvement? *RICS Research paper series*, 5(6).
- Leech, N. L., Barrett, K. C. and Morgan, G. A. (2005). *SPSS for Intermediate Statistics: Use and Interpretation*. New Jersey: Lawrence Erlbaum Associates, Inc.
- Lega, A. (2008). Synergy in the Sandbox. *Journal of Building Information Modelling*, Fall 2008 Issue: 44-46.

- Leicht, R., Fox, S., Mäkeläinen, T. and Messner, J. (2007). Building Information Models, Display Media and Team Performance: An Exploratory Study. *VTT Working Paper No. 88*, Available at <http://www.vtt.fi/inf/pdf/workingpapers/2007/W88.pdf>.
- Leite, F., Akcamete, A., Akinci, B., Atasoy, G. and Kiziltas, S. (2011). Analysis of modeling effort and impact of different levels of detail in building information models. *Automation in Construction*, 20(5): 601-609.
- Lemon, M. and Sahota, P. S. (2004). Organizational culture as a knowledge repository for increased innovative capacity. *Technovation*, 24(6): 483-498.
- Leonard, L. N. K., Cronan, T. P. and Kreie, J. (2004), What Are Influences of Ethical Behaviour Intentions – Planned Behaviour, Reasoned Action, Perceived Importance, or Individual Characteristics?, *Information and Management*, 42(1): 143-58.
- Leong, M. S., Ward, S., and Koskela, L. (2015). Towards an operational definition of lean construction. *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 507-516.
- Lewicka, D. (2011). Creating Innovative Attitudes in an Organisation – Comparative Analysis of Tools Applied in IBM Poland and ZPAS Group. *Journal of Asia Pacific Business Innovation and Technology Management*, 1(1): 1-12.
- Lewis-Beck, M. S., Bryman, A. and Liao, T. (2004). *The Sage Encyclopedia of Social Science Research Methods*, 3 Vols., Sage Thousand Oaks, Calif.
- Li, H., Irani, Z. and Love, P. E. D. (2000). The IT Performance Evaluation in the Construction Industry. *Proceedings of the 33rd Hawaii International Conference on System Sciences*. DOI: 10.1109/HICSS.2000.926927.
- Li, J. and Kozhikode, R. K. (1999). Developing new innovation models: Shifts in the innovation landscapes in emerging economies and implications for global R&D management. *Journal of International Management*, 15 (3), 328-339.

- Liang, Y. and Cohen, E. (1994). Business Process Re-engineering: An Overview. *South-Central Small College Computing Conference*. Amarillo, April 15-16; 130-136.
- Liebich, T., Geiger, A., Katranuschkov, P., Linhard, K., Steinmann, R. and Weise, M. (2001). *mvdXML Schema*. Retrieved from <http://buildingsmart-tech.org/downloads/accompanying-documents/formats/mvdxml-documentation/MVD%20formal%20schema%20proposal%20V0-5.pdf/view>. January, 2012.
- Liker, J. K and Sindi, A. A. (1997). User Acceptance of Expert Systems: A Test of the Theory of Reasoned Action. *Journal of Engineering and technology Management*. 14: 147-173.
- Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology*, 140, 1–55.
- Lim, Y. W. (2015). Building Information Modeling for Indoor Environmental Performance Analysis. *American Journal of Environmental Sciences*, 11 (2): 55-61.
- Linderoth, H. (2010) Understanding Adoption and Use of BIM as the Creation of Actor Networks. *Automation in Construction*, 19(1): 66–72.
- Liu, Z. (2010). *Feasibility Analysis of BIM Based Information System for Facility Management at WPI*. Worcester Polytechnic Institute, Worcester, Massachusetts, US.
- Love, P. E., Simpson, I., Hill, A. and Standing, C. (2013). From justification to evaluation: Building information modelling for asset owners. *Automation in Construction*, 35: 208-216.
- Love, P. E. D., and Gunasekaran, A. (1997). Process re-engineering: a review of enablers. *International Journal of Production Economics*, 50(2/3), pp.183-197.
- Lowry, G. (2002) Modelling User Acceptance of Building Management Systems. *Automation in Construction*, 11(6): 695–705.

- Lozano, L., Garcia-Cueto, E. and Muniz, J. (2008). Effect of the number of response categories on the reliability and validity of rating scales, *Methodology*, 4 (2), 73-79.
- Lu, W. and Li, H. (2011). Building Information Modelling and Changing Construction Practices. *Automation in Construction*. 20: 99-100.
- Maamar, Z., Benatallah, B. and Sheng, Q. Z. (2002). Towards a Composition Framework for E-/M-Services. In: *The Proceedings of the 1st International Workshop on Ubiquitous Agents*, Bologna, Italy, July.
- Maccallum, R. C. and Austin, J. T. (2000). Applications of Structural Equation Modeling in Psychological Research. *Annual Review of Psychology*, 51: 201.
- Macdonald, J. A. and Mills, J. E. (2010). *Can BIM be Used to Improve Building Design Education*.
- Mcdonald, R. P. and Ho, M. H. R. (2002). Principles and Practice in Reporting Structural Equation Analyses. *Psychological Methods*, 7(1): 6482.
- MacPherson, D. L. (2009). Where Does All This Information Belong? *Journal of Building Information Modelling*, Spring 2009 issue: 24-25.
- McLeod, S. A. (2008). Likert Scale. Retrieved from www.simplypsychology.org/likert-scale.html.
- Mahalanobis, P. C. (1936). On the Generalised Distance in Statistics. *Proceedings of the National Institute of Sciences of India* 2 (1): 49-55.
- Malleson, A. (2012). BIM Survey: Summary of Findings. *National BIM Report*: 8-15.
- Marir, F., Aouad, G. and Cooper, G. S. (1998). OSCONCAD: A Model-Based CAD System Integrated with Computer Applications. *ITcon*, 3: 26-46 Available from: <http://www.itcon.org/1998/3>.
- Memon, A. H., Rahman, I. A., Memon, I. and Azman, N. I. A. (2014). BIM in Malaysian Construction Industry: Status, Advantages, Barriers and Strategies

- to Enhance the Implementation Level. *Research Journal of Applied Sciences, Engineering and Technology*, 8(5): 606-614.
- McAdam, B. (2010). Building Information Modelling: The UK Legal Context, *International Journal of Law in the Built Environment*, 2(3): 246–259.
- McCuen, T. and Suermann, P. E. (2007). *The Interactive Capability Maturity Model and 2007 AIA TAP BIM Award Winners*, Viewpoint #33, AECbytes, December 6, 2007. Retrieved from http://www.aecbytes.com/viewpoint/2007/issue_33.html.
- MDeC. (2010). MSC Malaysia Annual Industry Report 2009-2010, Multimedia Development Corporation Cyberjaya.
- Md-Nor, K. (2005). *An Empirical Study of Internet Banking Acceptance in Malaysia: An Extended Decomposed Theory of Planned Behaviour*. PhD Thesis, Department of Management, College of Business and Administration, Southern Illinois University Carbondale.
- Merschbrock, C. (2013). Affordances of Building Information Modelling in Construction: A Sequential Analysis. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Meziane, F. and Rezgui, Y. (2004). Document Management Methods Based on Similarity Contents. *Inform Sci*, 158:15–36.
- Miller, A., Radcliffe, D. and Isokangas, E. (2009). A Perception-Influence Model for the Management of Technology Implementation in Construction. *Construction Innovation*, 9 (2): 168–83.
- Miller, D. (2012). BIM from the Point of View of a Small Practice. *National BIM Report*: 6-7.
- Mitchell, M. L. and Jolley, J. M. (2010). *Research Design Explained*, 7th Ed, Wadsworth Cengage Learning, Belmont CA, US.
- Mitropoulos, P. and Tatum, C. B. (2000). Forces Driving Adoption of New Information Technologies. *J. Constr. Eng. Manage.* 126: 340-348.

- Miyatake, Y. and Kangari, R. (1993): Experiencing Computer Integrated Construction, *Journal of Construction Engineering and Management, ASCE*, 119(2): 307-322.
- Mohd-Nor, M. F. I. and Grant, M. P. (2014). Building Information Modelling (BIM) in the Malaysian Architecture Industry. *WSEAS Transactions on Environment and Development*, 10(1): 264-273.
- Mohd-Nor, M. F. I., Usman, I. M. S. and Mazlan-Tahir, M. (2009). The Professional Practice and the Architecture Education in Malaysia is Catching Up with the Development of CAD. *European Journal of Social Sciences*, 4: 677-683.
- Moingeon, B., Ramanantsoa, B., Me'tais, E. and Orton, J. D. (1998). Another Look at Strategy-Structure Relationships: The Resource-based View. *European Management Journal* 16(3): 298-304.
- Molina, J. M. and Martinez, M. (2004). XML Based Data Model for the Spanish AEC Sector. *Proceeding of European Conference on Product and Process Modelling in the Building and Construction Industry (ECPPM)*. Istanbul, Turkey: 149-154.
- Moore, G. C. and Benbasat, I. (1991). Development of an Instrument to Measure the Perception of Adopting an Information Technology Innovation. *Information Systems Research*, 2(3): 192-222.
- Morgan, G. A., Leech, N. L., Gloeckner, G. W. and Barrett, K. C. (2004). *SPSS for Introductory Statistics: Use and Interpretation* 2nd Ed. Lawrence Erlbaum Assosiate Inc. Mahwah, New Jersey.
- Morrell, P. (2011). BIM to be Rolled Out to all Projects by 2016. *The Architects Journal*. 233(23): 10.
- Mui, L. Y., Aziz, A. R. A., Ni, A. C., Yee, W. C. and Lay, W. S. (2002). A Survey of Internet Usage in the Malaysian Construction Industry. *Journal of Information Technology in Construction*, 7: 259-269.
- Multimedia Super Corridor (MSC), MSC Malaysia MyProCert Programme. <http://kdi.mscomalaysia.my/DisplayProgramme.action?>p=MPC>, 2013.

- Muthén, L. K. and Muthén, B. O. (2004). *Mplus User's Guide*. Los Angeles: Authors.
- Muzvimwe, M. (2011). 5D BIM Explained. <http://www.fgould.com/uk-europe/articles/5d-bimexplained>.
- Napier, B. (2008). Wisconsin Leads by Example. *Journal of Building Information Modelling*, Fall 2008 Issue: 30-31.
- NBIMS (2007). *National Building Information Model Standard*, Version 1, Part 1. http://www.facilityinformationcouncil.org/bim/pdfs/NBIMsv1_ConsolidatedAppendixReferences_11Mar07_1.pdf.
- NBIMS (2006). *National Building Information Model Standard*, <http://www.facilityinformationcouncil.org/bim/>.
- Neuman, W. L. (2006). *Social Research Methods: Qualitative and Quantitative Approaches*, 6th Ed. Edn, Pearson/AandB, Boston.
- Nguyen, T. H., Shehab, T. and Gao, Z. (2010). Evaluating Sustainability of Architectural Designs Using Building Information Modeling. *The Open Construction and Building Technology Journal*, 4: 1-8.
- Nikas, A., Poulymenakou, A. and Kriaris, P. (2007). Investigating Antecedents and Drivers Affecting the Adoption of Collaboration Technologies in the Construction Industry. *Automation in Construction*, 16(5): 632–41.
- NO-REST. (2006). *Integrated Deliverables 05 and 06 - Report on Demand Factors and on the Supply Side for Standards for Networked Organisations*. Brussels - Belgium: Networked Organisations – Research into Standards and Standardisation.
- Nummelin, J., Sulankivi, K., Kiviniemi, M. and Koppinen, T. (2011). Managing Building Information and Client Requirements in Construction Supply Chain – Constructor's View, *Paper Presented at Conference Proceedings, CIB*, Sophia Antipolis, France.

- Oakey, R. (2003). Technical entrepreneurship in high technology small firms: some observations on the implications for management. *Technovation*, 23(8): 679-688.
- OED. (2016). *Oxford English Dictionary*. Available at: <http://www.oed.com/> (assessed 10 September, 2015).
- Olatunji, O. A., Sher, W. D. and Gu, N. (2010). Building Information Modeling and Quantity Surveying Practice. *Emirates Journal for Engineering Research*, 15(1): 67-70.
- Olatunji, O. A., Sher, W. D., and Ogunsemi, D. R. (2010). The impact of Building Information Modelling on Construction Cost estimation. *Paper presented at the CIB 2010 World Congress*, Salford Quays - United Kingdom.
- Olsson, U. H., Foss, T., Troye, S. V. and Howell, R. D. (2000). The Performance of ML, GLS, and WLS Estimation in Structural Equation Modeling under Conditions of Misspecification and Nonnormality. *Structural Equation Modeling*, 7(4): 557-595.
- Onuma, K. (2008). Integration Today Using Open Standards: BIMStorm™, Rotterdam to Los Angeles and Beyond. *Journal of Building Information Modelling*, Spring 2008 Issue: 14-18.
- OSMOS. (2001). *Proposed OSMOS Inter-Company Interaction Process Model*. OSMOS Project Web Site at <<http://cic.vtt.fi/projects/osmos/main.html>>.
- Owen, R., Amor, R., Palmer, M., Dickinson, J., Tatum, C.B., Kazi, A.S. and East, B. (2010). Challenges for Integrated Design and Delivery Solutions, *Architectural Engineering and Design Management*, 6: 232-240. doi: 10.3763/aedm.2010.IDDS1.
- Oye, N. D., A.Iahad, N. and Ab.Rahim, N. (2012) A Proposed Guideline for ICT Acceptance and Usage for Universities in Developing Countries. *International Journal of Computer Science and Information Technology and Security*. 2(1): 30-39.

- Paltridge, B. and Phakiti, A. (2015). *Research Methods in Applied Linguistics: A Practical Resource 2nd Ed.* Bloomsbury Academic. London, United Kingdom.
- Palos, S., Kiviniemi, A. and Kuusisto, J. (2014). Future Perspectives on Product Data Management in Building Information Modelling, *Construction Innovation*, 14(1): 52-68.
- Palvia, P. C. (1996). A Model and Instrument for Measuring Small Business User Satisfaction with Information Technology. *Information and Management*, 31: 151-63.
- Pamulu, M. S. and Bhuta, C. (2004). Managing Information technology in Construction Industry: The Indonesian Experience. *Paper Presented at the CIB World Building Congress.*
- Panuwatwanich, K., Stewart, R. A. and Mohamed, S. (2009). Critical Pathways to Enhanced Innovation Diffusion and Business Performance in Australian Design Firms. *Automation in Construction*. 18: 790–797.
- Parasuraman, A. (2000). Technology Readiness Index (TRI): a Multi-Item Scale to Measure Readiness to Embrace New Technologies. *Journal of Service Research*, 2(4): 307-320.
- Parasuraman, A. and Colby, C. L. (2001). *Techno-Ready Marketing: How and Why Your Customers Adopt Technology*. New York: The Free Press.
- Paschke, J. (2009). Adaptive IT Capability and its Impact on the Competitiveness of Firms: A Dynamic Capability Perspective. PhD Thesis. School of Business Information Technology Business College RMIT University.
- Pavlou, P. A. and El-Sawy, O. A. (2006). From IT Leveraging Competence to Competitive Advantage in Turbulent Environments: The Case of New Product Development. *Information Systems Research*, 17(3): 198.
- Peansupap, V. and Walker, D. H. T. (2005) Factors Enabling Information and Communication Technology Diffusion and Actual Implementation on

- Construction Organisations. *Journal of Information Technology in Construction*, 10: 193–218.
- Peansupap, V. and Walker, D. H. T. (2006) Innovation Diffusion at the Implementation Stage of a Construction Project: A Case Study of Information Communication Technology. *Construction Management and Economics*, 24(3): 321–32.
- Penttil, H., Peter, M. and Elger, D. (2008). Evaluating VBE and BIM-frameworks: A Cost Estimation Case Study and Reflections to Environmental Issues. *Paper Presented at the Beyond Computer-Aided Design CAADRIA 2008*.
- Peyret, F., Jurasz, J., Carrel, A., Zekri, E. and Gorham, B. (2000). The Computer Integrated Road Construction Project. *Automation in Construction*. 9: 447–461.
- PKK. (2011). *Contractor Directory*. from <http://smpkk.kkr.gov.my/subpkk/msDir/user/index2.php>.
- Planning Portal (2012). Planning Portal. UK Government's Online Planning and Building Regulations Resource for England and Wales. www.planningportal.gov.uk/.
- Porter, M. E. and Millar, V. E. (1985). How Information Gives You Competitive Advantage. *Harvard Business Review*. July-August. 63(4): 149-160.
- Powell, T. C. and Dent-Micallef, A. (1997). Information Technology as Competitive Advantage: The Role of Human, Business, and Technology Resources', *Strategic Management Journal*, 18(5): 375.
- Prowler, D. (2012). Whole Building Design: The Role of Buildings and the Case for Whole Building Design. *National Institute of Building Sciences*. http://www.wbdg.org/wbdg_approach.php.
- Przybyla, J. (2010). The Next Frontier for BIM: Interoperability with GIS. *Journal of Building Information Modelling*, Fall 2010 Issue: 14-18.
- PSDC. (2009a). *Statistics on Professionals*. from http://www.mypsdc.com/information_Statistics_on_Professional.asp.

- PSDC. (2009b). *Finding of the Survey on Degree of Adoption and Interest of 3D Software among Professionals*. Kuala Lumpur: Professional Services Development Corporation (PSDC) Sdn. Bhd.
- PSDC. (2010). *Finding of the Survey on Degree of Adoption and Interest of 3D Software among Professionals*. Johor Bahru: Professional Services Development Corporation (PSDC) Sdn. Bhd.
- Public Works Department (PWD), Unit Building Information Modeling (BIM). http://www.jkr.gov.my/prokom/index.php?option=com_content&view=article&id=84&Itemid=435&lang=ms.
- Rao, G. N., Grobler, F. and Ganeshan, R. (1997). Interconnected Component Applications for AEC Software Development. *J Comput Civil Eng* 11(3):154–64.
- Raymond, L. and St-Pierre, J. (2010). R&D as a determinant of innovation in manufacturing SMEs: An attempt at empirical clarification. *Technovation*, 30(1): 48-56.
- REHDA. (2008). Construction Industry Master Plan (CIMP) 2006-2015: The Way Forward for the Construction Industry. *REHDA Bulletin*, PP9309.
- Ren, A. and Kumaraswamy, M. M. (2013). Exploring the Conflicts between BIM and Existing Project Processes in Hong Kong. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Ren, A., Kumaraswamy, M. M., Wong, K. and Ng, S. T. (2013). Application of Relationally Integrated Value Networks in the Implementation of BIM for Better Life Cycle Considerations of Buildings. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.
- Rezgui, Y. and Zarli, A. (2006). Paving the Way to the Vision of Digital Construction: A Strategic Roadmap. *Journal of Construction Engineering and Management*, 132(7): 767-776.

- Rezgui, Y., Cooper, G., Zarli, A., Marache, M., and Samad-Kazi A. (2001). Web Based Generic Services for the Construction Virtual Enterprises in the OSMOS Project. In: *Proceedings of the CIB – W78 conference*, South Africa.
- Rivard, H. (2000). A survey on the impact of information technology on the Canadian architecture, engineering and construction industry, *ITCON*. 5, 37-56, <http://www.itcon.org/>.
- Rockart, J. F. (1979). Chief Executives Define Their Own Data Needs. *Havard Business Review*, 57: 81-93.
- Rogers, E. M. (1983). *Diffusion of Innovations*, Free Press, New York, NY.
- Rogers, E. M. (2003). *Diffusion of Innovations*. New York: Free Press.
- Rosenberg, T. L. (2006). *Building Information Modeling*. Retrieved from <http://www.ralaw.com/resources/documents/Building%20Information%20Modeling%20-%20Rosenberg.pdf>.
- Russell, A., Staub-French, S., Tran, N. and Wong, W. (2009). Visualizing High-Rise Building Construction Strategies Using Linear Scheduling and 4D CAD. *Automation in Construction*, 18: 219-236.
- Russell, R. S. and Taylor, B. W. (2003). E-Business. *Operations Management*: 271-272.
- SABLE. (2006). *SABLE Web Site*, <<http://www.blis-project.org/~sable/>>.
- Salazar, G., Mokbel, H., Aboulezz, M. and W. Kearney, W. (2006). The use of building information model in construction logistics and progress tracking in the Worcester trial courthouse. *Proceeding of Joint International Conference on Computing and Decision Making in Civil Building Engineering*, Montreal, Canada.
- Salmon, J. L. (2009). The Legal Revolution in Construction: How collaborative Agreements, BIM and Lean Construction Methods Support Integrated Project Delivery. *Journal of Building Information Modelling*. Spring 2009 issue: 18-19.

- Samuelson, O. (2011). Adoption Processes for EDM, EDI and BIM in the Swedish Construction Industry. *Paper Presented at the CIB W78-W102 2011 International Conference*. Sophia Antipolis, France, 26–28 October.
- Sánchez, C. and Valencia, J. (2011). Design Organizational Process Maps for Implementation of BIM in a Construction Company, *Bogota*: Uniandes.
- Sanvido, V. E. and Medeiros, D. J. (1990): Applying Computer-Integrated Manufacturing Concepts to Construction. *Journal of Construction Engineering and Management*, ASCE, 116(2): 365-379.
- Sarantakos, S. (2005). Social Research, 3rd Ed. Edn, Palgrave Macmillan, New York.
- Sarshar, M., Christiansson, P. and Winter, J. (2004), Towards Virtual Prototyping in the Construction Industry: The Case Study of the DIVERCITY Project, *World IT for Design and Construction (INCITE) Conference, Designing, Managing and Supporting Construction Projects through Innovation and IT Solutions*. Langkawi Malaysia: 581-8.
- Sarshar, M., Tanyer, M., Aouad, G. and Underwood, J. (2002). A vision for Construction IT 2005-2010: Two Case Studies, Engineering. *Construction and Architectural Management*. 9(2).
- Sattineni, A. (2010). Real-Time Management in a BIM Model with RFID and Wireless Tags. *Paper presented at the CIB 2010 World Congress Salford Quays - United Kingdom*.
- Schnitt, D. L. (1993). Reengineering the Organisation Using Information Technology. *Journal of Systems Management*. January: 14-21.
- See, R. (2007). Building Information Models and Model Views. *Journal of Building Information Modelling*. Fall 2007 issue: 20-24.
- See, R. (2008). Building Information Models and Model Views – Part 2. *Journal of Building Information Modelling*. Fall 2008 issue: 32-35.
- See, R. (2009). Building Information Models and Model Views – Part 4. *Journal of Building Information Modelling*. Fall 2009 issue: 30-33.

- Sepasgozar, S. M. E. and Davis, S. R. (2015). Decision Framework for Advanced Construction Technology Adoption. *94th Annual Meeting of Transportation Research Board*.
- Senge, P., Kleiner, A., Roberts, C., Ross, R., Roth, G. and Smith, B. (1999). *The Dance of Change: The Challenges of Sustaining Momentum in Learning Organizations*. London, Nicholas Brealey Publishing.
- Shari, Z. and Soebarto, V. (2014). Investigating Sustainable Practices in the Malaysian Office Building Developments. *Construction Innovation*, 14(1): 17-35.
- Simonen, J. and McCann, P. (2008). Innovation, R&D cooperation and labor recruitment: evidence from Finland. *Small Business Economics*, 31(2): 181-194.
- Singh, H., Smith, D. K. and Przybyla, J. M. (2009). Reducing Facility Management Costs through Integration of COBIE and LEED - EB. *Journal of Building Information Modelling*. Spring 2009 issue: 21-23.
- SIRIM (2010). Corporate Profile. Standards and Industrial Research Institute of Malaysia (SIRIM), Kuala Lumpur.
- Skibniewski, M. J. and Abduh, M. (2000). Web-based project management for construction: search for utility assessment tools. *Proceedings of the INCITE 2000 Conference on Implementing IT to Obtain a Competitive Advantage in the 21st Century*. Hong Kong Polytechnic University Press: 56-77.
- Skibniewski, M. J. and Nitithamyong, P. (2004). Web-based Construction Project Management Systems: Practical Advantages and Disadvantages. *Proceedings of the 4th International Conference on Construction Project Management (ICCPM)*, Singapore, Nanyang Technological University.
- Smith, D. K. (2009). The USC School of Cinematic Arts: The Arrival of Spring in the Facilities Industry. *Journal of Building Information Modelling*. Spring 2009 issue: 16-17.

- Smith, D. (2007). An Introduction to Building Information Modeling (BIM). *Journal of Building Information Modelling*. Fall 2007 issue: 12-14.
- Smith, D. and Edgar, A. (2008). *Building Information Modeling*. Retrieved 12th August, 2010, from <http://www.wbdg.org/bim/bim.php>.
- Smith, D., Wall, J. and Betts, M. (2005). A45 ICT Curriculum Design to Bridge the Gap between Industry and Academia. *Paper Presented at the The Construction Research Conference of the RICS Foundation - the Australian Universities' Building Educators Association Conference*.
- Solomon, M., Bamossy, G., Askegaard, S. and Hogg, M. K. (2006). *Consumer Behaviour: A European Perspective*, 3rd edition, Prentice Hall-Financial Times, Harlow.
- Someya, S. (1992). *The Role of R&D in Construction Firms*. M.Sc. Thesis, Department of Civil Engineering, Massachusetts Institute of Technology.
- Sommerville, J. and Craig, N. (2006). *Implementing IT in Construction*. Taylor and Francis, London and New York.
- Son, H., Lee, S., Hwang, N. and Kim, C. (2014). The Adoption of Building Information Modeling in the Design Organization: An Empirical Study of Architects in Korean Design Firms. *Proceedings of the 31st ISARC*, Sydney, Australia: 194-201.
- Son, H., Park, Y., Kim, C. and Chou, J. S. (2012). Toward an Understanding of Construction Professionals' Acceptance of Mobile Computing Devices in South Korea: An Extension of the Technology Acceptance Model. *Automation in Construction*, 28: 82–90.
- Souza, F., Wyse, M. and Melhado, S. B. (2013). The Brazilian Design Manager Role and Responsibilities after the BIM Process Introduction. *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.

- Steinkamp, N. (2009). Amara's Law: How BIM's Future Benefit can be measured today. *Journal of Building Information Modelling*, Spring 2009 issue: 30-31.
- Steinman, R. (2004). MOBIKO, Mobile Cooperation in the Construction Industry Based on Wireless Technology. *Proceeding of European Conference on Product and Process Modelling in the Building and Construction Industry (ECPPM)*. Istanbul, Turkey: 521-526
- Stone, W., Reed, K., Chang, P., Pfeffer, L. and Jacoff, A. (1999). NIST Research Toward Construction Site Integration and Automation. *Journal of Aerospace Engineering* 12(2).
- Straub, D., Boudreau, M. C. and Gefan, D. (2004). Validation guidelines for IS positivistic research', *Communications of the Association for Information Systems*, 13: 380-427.
- Straub, D., Gefen, D. and Boudreau, M. C. (2004). *The ISWorld Quantitative, Positivist Research Methods*. Website. <http://dstraub.cis.gsu.edu:88/quant/>.
- Sriprasert, E. and Dawood, N. (2002). Requirements Identification for 4D Constraint-based Construction Planning and Control System. *International Council for Research and Innovation in Building and Construction Council For Research And Innovation In Building And Construction Working group 78 Conference*, Aarhus School of Architecture, 12 – 14 June.
- Succar, B. (2010). The Five Components of BIM Performance Measurement. *Paper Presented at the CIB 2010 World Congress*, Salford Quays - United Kingdom.
- Succar, B. (2011). BIM Industrial Transformation in Australia. IBS/BIM Roundtable: Mechanisation of Industrialised Building System (IBS) Building Information Modelling (BIM), Cyberjaya, Selangor. ChangeAgents AEC Pty Ltd.
- Succar, B. (2013). Building Information Modelling: Conceptual Constructs and Performance Improvement Tools. PhD Thesis. School of Architecture and Built Environment, Faculty of Engineering and Built Environment, University of Newcastle, Australia.

- Suermann, P. C. and Issa, R. R. A. (2007). BIM Effects on Construction Key Performance Indicators (KPI) Survey. *Journal of Building Information Modelling*, Fall 2007 issue: 26-27.
- Suermann, M. P. and McCuen, T. (2009). AIA-TAP BIM Repeat Award Winners: Strengths and Opportunities. *Journal of Building Information Modelling*. Fall 2009 issue: 21-24.
- Sun, M. and Aouad, G. (2000), Integration Technologies to Support Organisational Changes in the Construction Industry. *7th ISPE International conference on Concurrent Engineering*. Lyon, France: 596-604.
- Sun, W. Z. and Zhou, G. Q. (2010). KPIs: Analysing the Impact of Building Information Modeling on Construction. *Proceedings of the Industrial Engineering and Engineering Management (IE&EM) IEEE 17th International Conference*. Xiamen - China: 354-356. DOI: 10.1109/ICIEEM.2010.5646595.
- Sundaraj, G. (2013). The Way Forward: Construction Industry Master Plan 2006-2015. <http://woulibrary.wou.edu.my/library/pdf/CIMPlan.pdf>. 2007.
- Szigeti, F. and Davis, G. (2003). *Portfolio and Asset Management: Performance Requirements and the IAI-NA PAMPer+ED project*, International Centre for Facilities.
- Tabachnick, B. G. and Fidell, L. S. 2007, *Using Multivariate Statistics*, 5th Ed, Pearson/Allyn and Bacon, Boston.
- Tammy, L. and McCuen, T. L. (2008). *Building Information Modeling and the Interactive Capability Maturity Model*. Retrieved from <http://ascpro0.ascweb.org/archives/cd/2008/paper/CPRT276002008.pdf>.
- Tapscott, D. and Caston, A. (1993). *Paradigm Shift: The New Promise of Information Technology*. New York: McGraw-Hill.
- Teng, J. T. C., Grover, V. and Guttler, W. (2002). Information Technology Innovations: General Diffusion Patterns and its Relationships to Innovation

- Characteristics. *IEEE Transactions on Engineering Management*, 49(1): 13-27.
- Tse, T. K., Wong, K. A. and Wong, K. F. (2005). The Utilisation of Building Information Models in nD Modelling: A Study of Data Interfacing and Adoption Barriers. *Journal of Information Technology in Construction*, 10: 85-110.
- Tatsuoka, M. M. (1971). *Multivariate Analysis*. New York: John Wiley.
- Taylor, J. M., Liu, J. and Hein, M. F. (2007). *Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum*. Auburn University.
- Taylor, S. and Todd, P. A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research* 5(2): 144-176.
- Teran, J. F. (2008). Building Modeling From Antiquity to Our Day. *Journal of Building Information Modelling*, Fall 2008 issue: 42-43.
- Thornhill, S. (2006). Knowledge, innovation and firm performance in high- and low-technology regimes. *Journal of Business Venturing*, 21(5): 687-703.
- Tiedeman, D. V. (1954). Discriminant Analysis. *Review of Educational Research*. 24: 402-420.
- Tieman, M. (2011). The Application of Halal in Supply Chain Management: In-Depth Interviews. *Journal of Islamic Marketing*. 2(2): 186 – 195.
- Too, E. and Tay, L. (2003). Implementing Construction and Real Estate IT Education: Needs and Strategy. *In Proceedings the 10th European Real Estate Society Conference*, Helsinki, Finland.
- Towers, S. (1996). Re-Engineering: Middle Managers are the Key. *Asset Management Services* 40(12): 17-18.
- Treacy, M. (1990). The Ubiquitous Machine. *The Economist*. June 16.

- Tse, K. T. C., Wong, A. K. D. and Wong, F. K. W. (2005). The Utilization of Building Information Models in nD Modelling: A Study of Data Interfacing and Adoption Barriers. *ITcon*. 10: 110.
- Turk, @. (1991). *Building Model Standard as a Foundation for Computer Integrated Design. Computers and Building Regulations*, VTT-Technical Research Centre of Finland, Espoo: 181-194.
- Turk, @. (1994). Three Prototype CDDM Systems. *V: CIB W78 Workshop on Computer Integrated Construction*: Helsinki, Finland August 22-24: 1-11.
- Turner, J. (1988). *AEC Building Systems Model*. Working Paper ISO/TC/184/SC4/WG1, October.
- Riese, M. and Shelden, D. (2008). Comprehensive International BIM with Full Owner Involvement. *Journal of Building Information Modelling*, Fall 2008 Issue: 28-29.
- Regan, E. A. and O'Connor, B. N. (2000). *End-user Information Systems: Implementing Individual and Work Group Technologies*. Upper Saddle River, NJ, Prentice Hall.
- Rogers, E. M. (1983). *Diffusion of Innovations*, Free Press, New York.
- Rogers, E. M. (2003). *Diffusion of Innovations*, 5th Ed. Free Press, New York.
- Rogers, E. M., and Schoemaker. (1971). *Communication of Innovations: A Cross Cultural Approach*, Free Press, New York.
- Vaquero, L. M., Rodero-Merino, L., Caceres, J. and Lindner, M. (2009). A Break in the Clouds: Towards a Cloud Definition ACM. *Computer Communication Reviews*, 29(1): 50-55.
- Van-Hooft, E. A. J., Born, M. P., Taris, T. W. and Van der Flier, H. (2006). Ethnic and Gender Differences in Applicants' Decision-Making Processes: An Application of the Theory of Reasoned Action. *International Journal of Selection and Assessment*, 14, 156-166.

- Van-Nederveen, S., Beheshti, R. and Willems, P. (2010). Building Information Modelling in the Netherlands: A Status Report. *Paper presented at the CIB 2010 World Congress*, Salford Quays - United Kingdom.
- Venkatesh, V. and Bala, H. (2008). Technology Acceptance Model 3 and a Research Agenda on Interventions. *Decision Sciences*, 39(2): 273-315.
- Vogt, C. A., Winter, G. and Fried, J. S. (2005). Predicting Homeowners' Approval of Fuel Management at the Wildland–Urban Interface Using the Theory of Reasoned Action. *Society and Natural Resources* 18(4): 337-354.
- VTT. (2002). *IFC Model Server*, 2002. <http://ve.cic.vtt.fi/IMSvr/index.html>.
- Wade, M. and Hulland, J. (2004). Review: The Resource Based View and Information System Research: Review, Extension and Suggestions for Future Research. *MIS Quarterly*, 28(1): 107.
- West, M. A. (1990). The Social Psychology of Innovation in Groups, in: M. A. West, J. L. Farr (Eds.), *Innovation and Creativity at Work*, John Wiley and Sons, Chichester: 309–333.
- Weston, R. and Gore, P. A. (2006). A Brief Guide to Structural Equation Modeling. *Counseling Psychologist*, 34(5): 719.
- Whyte, J. (2012). Building Information Modelling in 2012: Research Challenges, Contributions, Opportunities, *Design Innovation Research Centre Working paper 5, v1.0*.
- Whyte, J. and Bouchlaghem, D. (2001). IT Innovation within the Construction Organisation. *Proceedings of the IT in Construction in Africa 2001 conference*, Mpumalunga South Africa, 30 May - 1 June.
- Wilkinson, P. (2005). *Construction Collaboration Technologies: The Extranet Evolution*. Taylors and Francis. London and New York.
- Willcocks, L. and Smith, G. (1994). *IT-Enabled Business Process Re-Engineering: From Theory to Practice*. Oxford: Oxford University Working Papers.

- Williams, J. (2008). Implementing BIM to Drive Fabrication. *Journal of Building Information Modelling*. Fall 2008 Issue: 38-41.
- Wilson, I., Harvey, S., Vankeisbelck, R. and Kazi, A. S. (2001). Enabling the Construction Virtual Enterprise: The OSMOS Approach, *ITcon Vol. 6, Special Issue Information and Communication Technology Advances in the European Construction Industry*: 83–110. <http://www.itcon.org/2001/8>.
- Wix, J. and Karlshoj, J. (2010). *Information Delivery Manual Guide to Components and Development Methods IDMC 004 version 1.2*. Retrieved from <http://iug.buildingsmart.com/idms/methods-and-guides>. January, 2012.
- Womack, J. P., Jones, D. T. and Roos, D. (1990). *The Machine that Changed the World*. New York: Rawson Associates.
- Wong, K. A., Wong, K. F. and Nadeem, A. (2011). Government Roles in Implementing Building Information Modelling Systems: Comparison between Hong Kong and the United States. *Construction Innovation*, 11(1): 61-76.
- Wong, K. A., Wong, K. F. and Nadeem, A. (2011). Building Information Modelling for Tertiary Construction Education in Hong Kong. *Journal of Information Technology in Construction (ITcon)*, 16: 467-476.
- Wu, I. L. (2003). Understanding Senior Management's Behaviour in Promoting the Strategic Role of IT in Process Reengineering: Use of the Theory of Reasoned Action. *Information and Management*, 41(1): 1-11.
- Yang, J., Lie, H. and Skitmore, M. R. (1996) Expert Systems in Construction Management: Is the Hype Over? *In Proceedings INCIT 96, International Construction Information Technology Conference*, pages pp. 131-136, The Institution of Engineers Australia, 11 National Circuit, Barton, ACT 2600.
- Yenerim, D and Clayton, M. J. (2013). Improving Self-Help Housing in Texas Colonias Using Spatial Agents and Building Information Modelling (BIM). *Proceedings of International Council for Research and Innovation in Building and Construction (CIB) World Building Congress 2013*, 5th – 9th May, Brisbane, Australia.

- Yeomans, S. G., Bouchlaghem, N. M. and El-Hamalawi, A. (2006). An Evaluation of Current Collaborative Prototyping Practices within the AEC Industry. *Automation in Construction*. 15: 139-149.
- Yoshihiko, F. (1994). *Animation for Computer Integrated Construction*, M. Thesis; Massachusetts Institute of Technology, Cambridge, USA, May, 1996.
- Yusuf, S. and Osman, O. (2008). An Evaluation of the Use of Information Technology in the Malaysian Construction Industry. *Proceedings of International Conference on Project Management*, University of Malaya, Kuala Lumpur: 710-718.
- Zakaria, Z., Mohamad-Ali, N., Haron, A.T., Marshall-Ponting, A., and Abd Hamid, Z. (2013). Exploring the adoption of building information modelling (BIM) in the Malaysian construction industry: A qualitative approach, *International Journal of Research in Engineering and Technology*, 2(8): 384-395.