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Building Information Modelling Penetration Factors in Malaysia

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ABSTRACT

The construction industry master plan in Malaysia provides ample leverage towards information technology improvements in the construction industry. Building Information Modelling (BIM) transforms the means to which the traditionally thought method is construction is carried out. Changes occur in aspects of people, process and technology during such transformation. Information technology (IT) acceptance theories of Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), Innovation Diffusion Theory (IDT), Decomposed Theory of Planned Behaviour (DTPB), Extension of Technology Acceptance Model (TAM2) and Unified Theory of Acceptance and Use of Technology stipulates underlining theories to accessing user perception to new systems such as BIM. This paper presents the linking paths to factors of user perceptions (people, process and technology) and how they react in strategic IT implementation and collaborative environment to fully support extensive BIM penetration in the industry. The study further extends the BIM penetration model by Enegbuma and Ali (2012). The model will aid industry practitioners to tackle the various challenges experienced with BIM implementation. Future research will focus on solidifying the proposal with data analysis.

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1. INTRODUCTION

The Malaysian governments' target in achieving developed nation and exportation of construction services to India and South-East Asia intertwined with government-to-government projects favours BIM propagation. Similar industries like neighbouring Hong Kong still steadily remain at a primary implementation stage despites vast amount of research on BIM [1]. Singapore similarly, has experienced such technological advancement in BIM. Design technology is key to affordance of a project hence, choice and collaboration should commerce at the earliest stage. BIM implementation brings transformation to technology, people and processes/policy [2],[3]. BIM study is not limited to modifications and innovations in various fields of user perception, health and safety, costing, project management, green building, Off-Site Manufacturing (OSM), Integrated Project Delivery (IPD), self help housing, real estate [4]–[18]. Information technology continues to transform and plays a vital role to how factors of innovation effect project delivery in Malaysian construction sector. The rise in BIM paradigm resulted from the push for better and more effective productivity in the industry hence, building better Industry Foundation Classes (IFC) open standard data model for interoperability. This study is an extension of Enegbuma and Ali [9] model aimed at plotting a path towards linking factors of user perceptions (people, process and technology) and focuses on how they react in strategic IT implementation for effective BIM penetration in the industry. Subsequent section will delineate current scenario in Malaysian construction industry, examine recent BIM research endeavours, highlight IT acceptance theories and re-visit the earlier research model to a logical conclusion.

2. MALAYSIAN SCENARIO

The Malaysian Construction Industry Development Board (CIDB) published a ten-year construction industry master plan (CIMP) in 2007. This was done to refocus the strategic position and plot the future direction of the industry breeding an innovative, sustainable, professional, profitable and world-class construction industry. The plan included seven strategic thrusts, twenty one strategic recommendations, eighty two action plans and 453 activities. Important to this study is the leverage on IT towards achieving the set vision of 2015. Chan and Theong (2013) thoroughly examined the progress of the CIDB master plan from 2006-2011 [19]. The study sort to analyse the achievements thus far, performance measures utilised retrieved from 34 performance measures used in examining similar national initiatives in Canada, Chile, Denmark, New Zealand and the UK included (a) annual construction demand, (b) percentage of projects awarded to local contractors, (c) export of construction services, (d) worker productivity (measured as value-added per worker), (e) building quality, (f) occupational safety and health, and (g) investments in IT. The study found that local contractors were able to effectively compete against foreign contractors operating in Malaysia due to 805 contract allocation earned; reduction in the industry's reliance on migrant workers to improve quality and productivity through Industrialised Building Systems (IBS); improved median score of 70-75 in 2011 though the implementation of Quality Assessment System In Construction (QLASSIC); improved design process and efficiency of the building approval process through total IT spending by construction companies. Although there was an overall increase in construction quality, areas such as occupational health and safety still needed extra improvement from data gather from Takaful Insurance Scheme organised by the CIDB and the Social Security Organisation (SOCSO) [20]-[26]. Crucial to this study also is the pace of BIM implementation in the industry necessitating the need to access the perception of industry professionals in the industry to predict and plot how BIM is currently been utilized.

3. BUILDING INFORMATION MODELLING (BIM)

Building Information Modeling is viewed as collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the model to support and reflect the roles of that stakeholder. The model is a shared digital representation founded on open standards for interoperability. The Hong Kong Institute of Building Information Modeling (HKIBIM) defines BIM as the process of generating and managing building data during its life cycle. Similar to National Building Information Modeling Standard (NBIMS) definition which viewed BIM as a digital representation of physical and functional characteristics of a facility and it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward [27]-[29]. BIM implementation produces various impacts on both internal organisational culture and values; and external supply chain. Moderate internal project practices and external processes have also been felt through BIM usage. Changes in delivery processes shift from individual consulting to consultancy team, contractor involvement on projects, improved shared vision and trust amongst teams, rise in supply chain effectiveness from strengthened team relationships, automatic building permission system to check design solutions in advance [30]-[31],[12]-[13]. Amidst such process improvement potentials through BIM also exists challenges to full system automation such as indifference and lack of knowledge on BIM; resistance to change from entrenched business practices; lack of political engagement compared to drive for green buildings; inhibiting Software and technology capabilities; suppliers' focus on graphics rather than object data; skills gaps commercial realities of associated costs such as technology, training, and process improvement new forms of contracts; legal and copyright issues and concerns; lack of awareness of life cycle benefits; lack of relevant training and a lack of industry data standards; and new methods for on-site operations [32],[31],[12],[33].

Merschbrock (2013) in analysing the affordance of building information modelling utilised sequential analysis technique to study design routine changes due to building information usage by professionals in a building case study located in Norway [11]. The study found that effective work sharing was not achieved in actual practice, the system also did not include a support functionality to direct users on the context of production and coordination technology application. The infrastructure functionality to allow users to transfer knowledge, skills or methods to other projects or planning situations was not identified. The systems applied were void of users storage or housing information within a device. Also, actors at early project stages had a greater degree of freedom when it came to making use of their design tool affordances than actors working at later project stages. Hampson and Kraatz (2013) report on the activities of CIB Task Group 85 R&D Investment and Impact shed more light on how building information modelling transformed in Australia from the initial implementation of computer aided design and documentation (CADD); to experimentation with building information modelling (BIM); to embedding integrated practice (IP); to current steps towards integrated project delivery (IPD) including the active involvement of consultants and contractors in the design/delivery process [12]. The research was geared towards developing more efficient delivery mechanisms through the use of new technology coupled with process change. the research revealed that organisation focused on (i) strategic decision making including the empowerment of innovation leaders and champions; (ii) the acquisition and exploitation of knowledge; (iii) product and process development (with a focus on efficiency and productivity); (iv) organisational learning; (v) maximising the use of technology; and (vi) supply chain integration.

Several conflicts and apprehensions arose during BIM usage in Hong Kong, amongst issues noticed were the need for BIM interoperability significant for the interoperability among the participants. Although BIM is accepted both a new tool and a new process, changes to people, processes, communication and work culture is unavoidable. other conflicts includes computability of the design data and the information exchange among the BIM components clashes, technical barriers - poor library, low running speed of the system and lack of table customization. Also, early contractor input is still lacking in Hong Kong with most design work done independently by architects or engineers. At industry level, innovative technology such as BIM requires more efforts and time to implement, thus faces resistance in current project processes and the prevalent fast track culture. at the project level, Design-Bid-Build procurement route in Hong Kong isolates key participants within different project phases, limiting the potential benefits from BIM and finally at the organisational level, clients awareness of BIM benefits is low, architects are resistant to consider extra efforts on creating BIM model while contractors are faced with uncertainty about BIM benefits to decide setting up BIM divisions [34]-[39].

National policies are increasingly geared towards automated checking and submission systems. Hence, regulations such as law, act, code, directive, and standards are written for human/professional interpretation. Thus, for automatic checking systems to be effective adequate integration of between legal building authority, informatics and construction needs to be achieved. the analysis of the new Norwegian public project called “ByggNett” compared favourably with other existing code checking system such as CORENET” e-Submission System in Singapore, Planning portal UK Government's online planning and building regulations resource for England and Wales, Seumter Code Checking System on South Korea but promised to be a more sophisticated version from the old ByggSøk - Building Application [40]-[43],[13]. Yenerim and Clayton (2013) opined that BIM techniques utilisation by US Colonias resident for will improve self help housing [14]. The residents with little knowledge of design can appreciate and innovate more affordable, more sustainable, and faster built homes when viewed from the BIM model kit. There exist lack of explicit agreement on software and strategic management of the BIM implementation [11]. Booth, et. al. (2013) proposes the use of BIM in Quadruple Net Value Analysis to structure evaluation of a project [15]. BIM capabilities provide modelling and visualization, rich models, analysis and simulation, parameterization, and software extension which allows development of the platform. The system combines sustainable development (economic, environmental, and social sustainability) with sensory value that measure the appeal of the project with respect to sight, sound, touch, taste and smell. BIM creates a data-rich 3D model of an alternative scheme with the ability to allow for rapid scheme analysis, permitting the exploration and comparison of many alternatives. Ezcan, et.al (2013) research found that providing an improved design, facilitating collaboration and covering accurate and extensive amount of information seem to be the most useful benefits of BIM for bridging the Off-Site Manufacturing (OSM/OSP) implementation gaps, avoiding longer lead-in times, high costs and modification problems [16].

Ren, et.al. (2013) proposed the utilisation of BIM through information exchange between two or more project phases in linking Design & Construction (D&C) and Operation & Management (O&M) [44]. The system Relationally Integrated Value Networks (RIVANS) was proposed through the Centre for Infrastructure & Construction Industry Development (CICID) of The University of Hong Kong. RIVANS aims to develop a "holistic conceptual framework for relational integration of hitherto mutually suspicious project participants into cross-linked value networks" [45]-[46]. Dimyadi and Amor (2013) examined the development of a computer interpretable representation of New Zealand’s performance-based codes using an open standard legal data exchange protocol [47]. This will be integrated into a web-based BIM compliance checking framework. New Zealand Building Code (NZBC) is a performance-based code and consists of two preliminary clauses and 35 technical clauses covering aspects such as fire safety, structural stability, health and safety, access, moisture control, durability, energy efficiency, services and facilities. Souza, et.al. (2013)

proposed a Design Manager Responsibilities Guide (DM Guide) comprising of Integrated Design and Delivery Solution (IDDS) four pillars: Collaborative Process; Enhanced Skills, Integration and Automation Systems and Knowledge Management [48]. The research was carried out to cope with the collaboration scenario from implementation of BIM which changes current management and communication practices in Brazilian construction industry. The document went through a series discussion by a panel of specialists comprising construction players, facilitated by the academy through regular meetings. IPD can be attained without BIM but BIM can serve facilitate IPD in their analysis for collaborative BIM (cBIM) inclusion in framework for the delivery of standardised schools in the UK. These five components of the proposed framework are BIM technology, sustainability considerations, actors or people, processes (i.e. procurement and project life cycles) and project performance measures. The framework will help access the technical challenges related to nature of the BIM technologies and non-technical related to the human and industry practices. The push to re-evaluate BIM emanates from UK Government announcement on compulsory BIM on all public sector projects from 2016 coupled with the Ministry of Justice announced in April 2011 announcement to mandate contractor BIM usage on its framework by the middle of 2013 [17]-[18].

4. STRATEGIC IT IMPLEMENTATION

4.1 Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) is a product of Fishbein and Ajzen research programme that began in the late 1950s. The product attempts to predict, explain, and influence human behavior. They unfolded the theory of reason action in 1967. The theory was based on the postulation that individuals are rational and will make systematic use of information available to them to take decision. The major variables of TRA are: Attitude towards the behavior (the degree to which performance of behavior is positively or negatively valued); Subjective Norms (the influence of social environment on behavior); Intention (an indicator of a persons' readiness to perform certain behavior) [49]-[50].

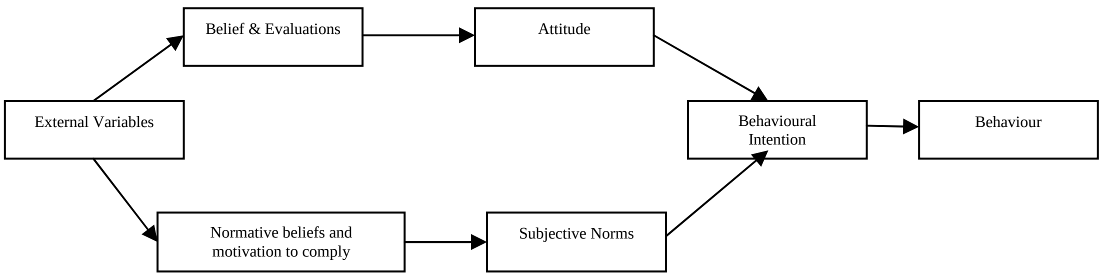

Figure 1. Theory of Reasoned Action [49]

4.2 Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) is an extension of TRA. Davis (1986) proposed the technology acceptance model, which explains an individuals' acceptance of information technology [51]. The expectation of TAM is to provide an explanation of the determinants of computer acceptance among users. TAM replaced TRAs' attitude beliefs with two technology acceptance measure: Perceived Usefulness (PU) referring to the degree to which a person believes that using a particular system would enhance his/her job performance; and perceived ease of use (PEOU) referring to the degree to which a person believe that using a particular system would be free from effort [52]. TAM does not include TRAs' subjective norms (SN) as a determinant of behavioral intention. The most commonly reported limitation of TAM is the measurement of usage by relying on respondents' self-reporting and assuming that it reflects actual usage. Limitations to this model are TAM provides only limited guidance about how to influence usage through design and implementation and the type of respondents, which in the same study, of a university student sample or professional users made generalization difficult [53]-[55],[50].

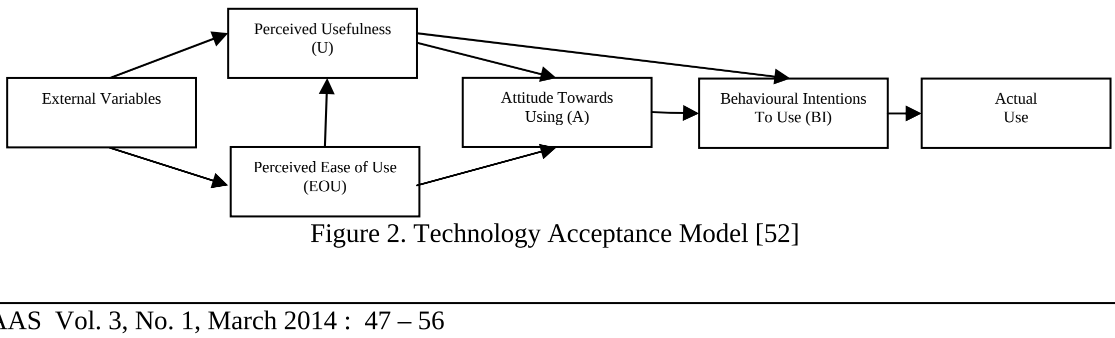

Figure 2. Technology Acceptance Model [52]

4.3 Theory of Planned Behaviour (TPB)

TRA presented some deficiencies prompting [56] to propose the Theory of Planned Behavior an extension of the theory of reason action. The principal factor of the theory of Planned Behavior differs from TRA in its addition of perceived behavioral control (PBC). PBC is held to influence both intention and behavior. Perceived Behavioral Controls' effect on behavior can be direct or interactive (through behavioral intention). When prediction of behavior from intention is possible to be blocked by actual decisional control, the PBC should facilitate the implementation of behavioral intentions into action and predict directly [57]. PBC and behavioral intention, can be employed directly or indirectly to predict behavioral achievement. The efficiency of any effort to build up a behavioral plan count on the efforts invested and the persons' control over factors such as needed information, skills, abilities, availability of a feasible plan, willpower, presence of mind, opportunities [56],[50]. Ajzen (1991) [58] assumed that PBC is most compatible with [59]-[60] concept of self-efficacy. While TPB as a replacement for volitional control limitation of TRA suggests behaviors as deliberate and planned, yet TPB does not show how people plan and how planning strategies does relate to TPB. This serves as part of the drawback of TPB. Eagle and Chaiken (1993) acknowledge evidence of other variables such as habit, perceived moral obligation and self identity, that may predict intentions and behavior in the context of TRA model, yet the TPB did not talk about such variables [61]. Taylor and Todd (1995) proposed decomposing the construct of TPB as an enlargement, which was an improvement of theory of reason action [53]. The decomposed theory of planned behavior (DTPB) enlarged the TPB by including constructs from innovation diffusion theory perspective.

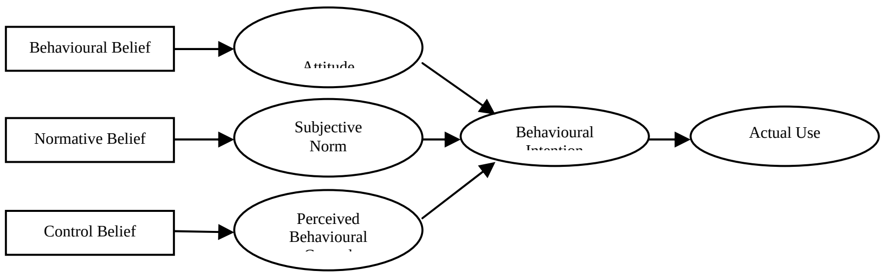

Figure 3. Theory of Planned Behaviour [56]

4.4 Innovation Diffusion Theory (IDT)

Diffusion is a process in which an innovation is communicated through certain routes overtime among members of a social system. On the opposite innovation is a concept, perceived as new by an individual or other unit of adoption. New concepts possess a degree of insecurity and thus are perceived as precarious. The limitation of IDT is that, the theory does not make available evidence on how attitude evolves into accept/reject decisions, and how innovation features fit into this process. On the other hand this uncertainty can be minimized by acquiring information. There are four elements of diffusion thus: Innovation; Communication channels; Time and; Social system [62]-[64],[50].

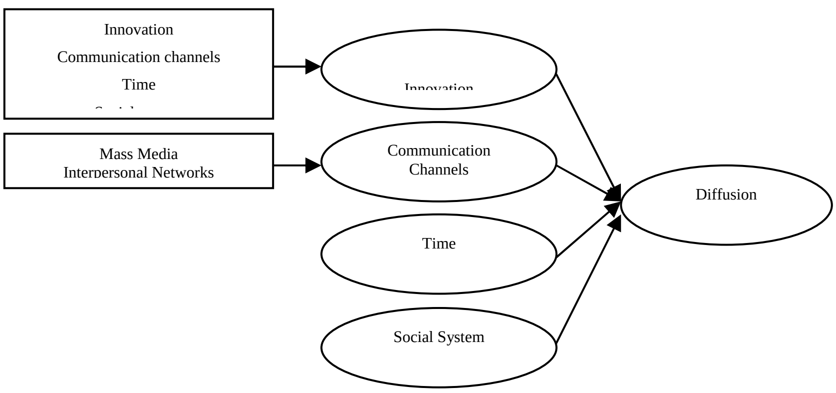

Figure 4. Innovation Diffusion Theory [62]

4.5 Decomposed Theory of Planned Behaviour (DTPB)

While the decomposed theory of planned behavior based on the work of [53], and combined aspects of the theory of planned behavior [58] with aspects of innovation diffusion theory [65]. The theory postulate that attitude, subjective norm and perceived behavioral control will influence the intention to use a technology. Taylor and Todd (1995) extended the theory by decomposing the attitudinal, normative, and perceived control beliefs into multi-dimensional constructs this provided higher explanatory power and a more precise understanding of the antecedents of behavior [53]. In their empirical test, the DTPB was found to provide a moderate increase in the explanation of behavioral intention when compared to the theory of planned behavior [53],[50].

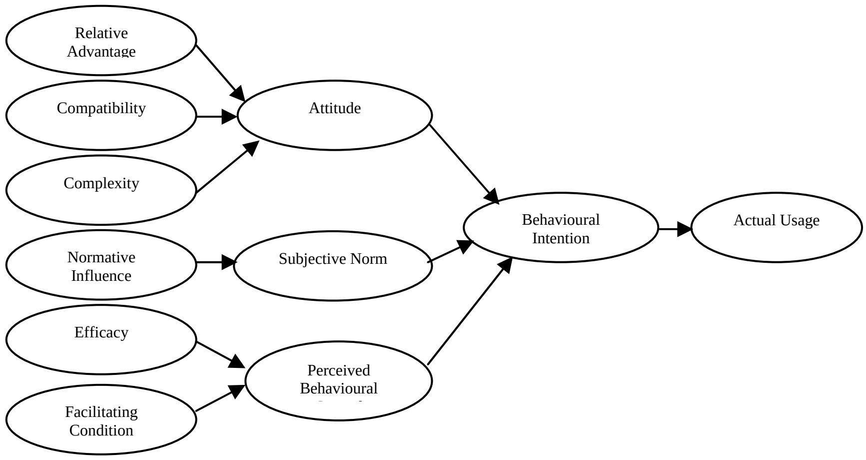

Figure 5. Decomposed Theory of planned Behaviour [53]

4.6 Extension of Technology Acceptance Model (TAM2)

Venkatesh and Davis (2000) extended the original TAM model to explain perceived usefulness and usage intentions in terms of social influence and cognitive instrumental procedure [66]. TAM2 includes additional key determinants, perceived usefulness and usage intention constructs which are meant to elucidate the changes in technology acceptance over time as individuals gain experience in using the technology. TAM2 incorporates new constructs covering social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (Job relevance, output quality, result demonstrability, and perceived ease of use) [50].

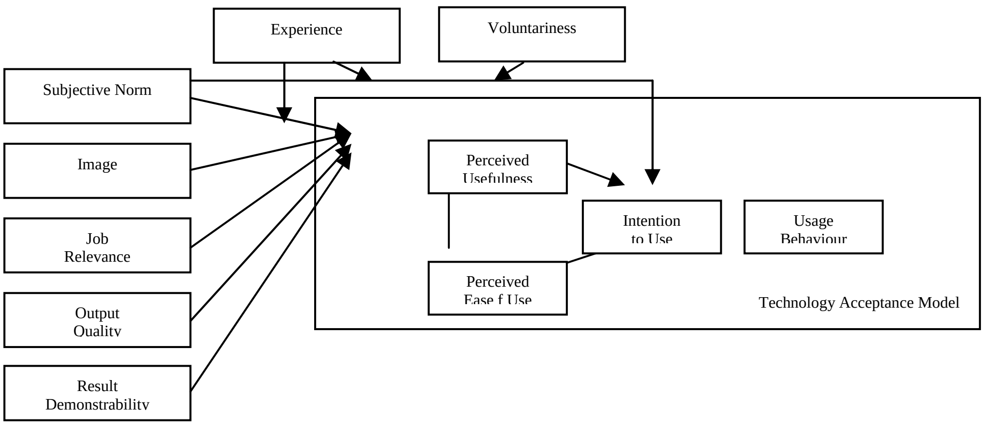

Figure 6. Extension of the Technology Acceptance Model [66]

4.7 Unified Theory of Acceptance and Use of Technology

Technology is of little value, unless it is accepted and used. The understanding of technology acceptance and usage is vital and cannot be over emphasized. Unified Theory of Acceptance and Use of Technology, is an important model for studying IT acceptance and usage. The model was produced by Venkatesh and his team basing it upon the conceptual and empirical similarities among eight competing technology acceptance models: TRA, TAM, MM, TPB, C-TAM-TPB, MPCU, IDT, and SCT [67]-[69],[66]. The UTAUT model effectively combines main elements from the initial set of 32 main effects and four moderators from eight different models [70],[66]. According to Venkatesh and his team, the theoretical perspective of UTAUT model provides a refined view of how the determinants of intention and behavior evolve over time. Consequently the model proposes three indirect determinant of new technology usage (Performance expectancy, Effort expectancy, and Social influence), and two direct determinants of usage behavior (Intention and Facilitating conditions). The model shows that four moderator, gender, age, voluntariness, and experience were identified to play specific moderating roles to the indirect and direct determinants of technology use behavior [50].

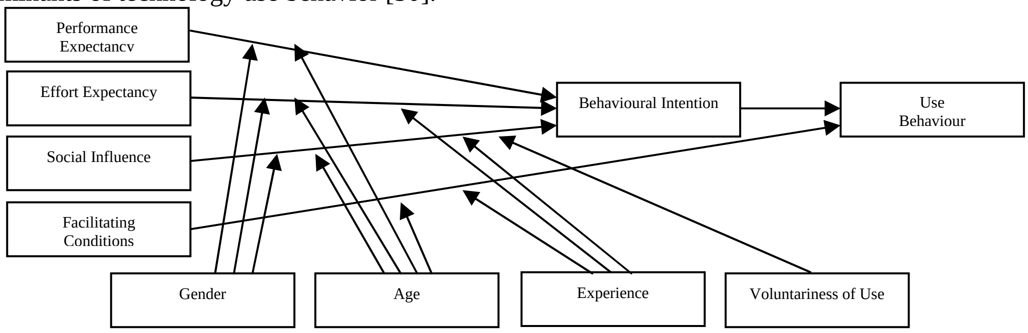

Figure 7. UTAUT Model [66]

5. CONCLUSION

This paper set out to exmine the strategic IT implementation factors of BIM penetration which was achieved thorugh literature studies on IT theories in human system interaction. As Malaysian construction industry moves towards its target vision of high income economy, BIM provides adequate IT leverage in the construction sector. The professionals' perception towards BIM needs assessment. The model shown in figure 8, builds on BIM perception in the construction industry towards effective BIM penetration incorporating strategic IT implementation [71], technology acceptance theories [51],[72], business process re-engineering [73]-[75] and collaborative construction. Information technology (IT) acceptance theories of Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), Innovation Diffusion Theory (IDT), Decomposed Theory of Planned Behaviour (DTPB), Extension of Technology Acceptance Model (TAM2) and Unified Theory of Acceptance and Use of Technology, points to various ways of assessing and predicting user perception on new IT systems. This was synthesized to the model presented in this study. Study plots a path towards linking user perceptions of people, process and technology and how they react in strategic IT implementation and collaborative environment to fully support extensive BIM penetration in the industry. The study forms an extension of the BIM penetration model by Enegbuma and Ali [10],[76]. The research model in encompasses research gaps on BIM perceptions and the effects on penetration for construction industries adopting building information modelling. Existing literature an underlining need for adequate strategic IT planning which drew from IT acceptance models, business process re-engineering and collaborative construction. The model will aid industry practitioners to tackle the various challenges experienced with BIM implementation.

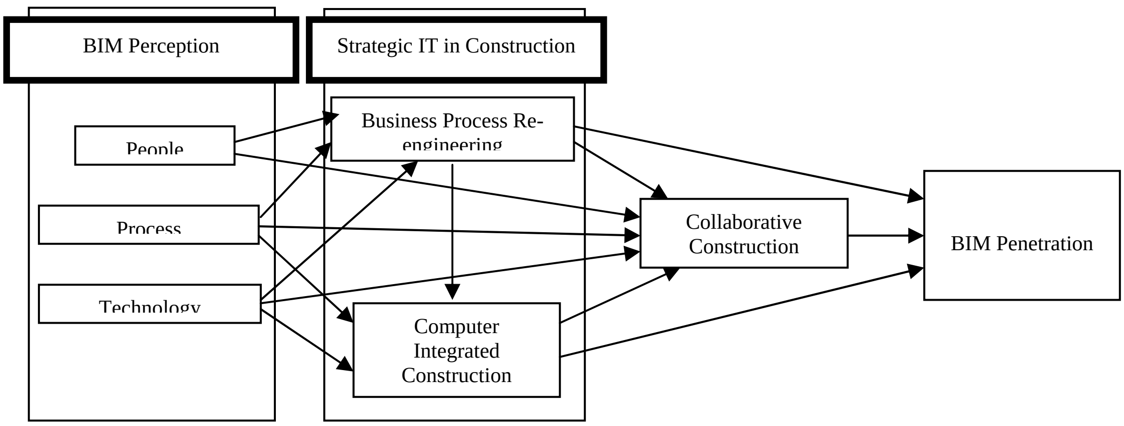

Figure 8. Research Model and Hypothesis [10]

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