Preliminary Study Impact of Building Information Modelling Use in Malaysia

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Abstract. The paradigm shift in the construction industry from 2D to Building Information Modelling (BIM) presents unforeseen challenges for new entrant construction industries. Experiences from advanced industry users of BIM shape the directions for future use. In Malaysia, BIM maturity is fast appreciating with increasing demand for efficiency and competitive advantages. However, adoption rate encounters resistance from several factors highlighted in previous research: people, process and technology. To improve on Information technology (IT) adoption models factors such as business process re-engineering, computer integrated construction and BIM adoption were considered for this research. This paper represents findings of an ongoing research, presenting the designed questionnaire to access perception of construction industry professionals (Architects, Quantity Surveyors, Engineers and Contractors) knowledge on BIM softwares and BIM attributes. Responses were derived from 120 construction professionals in the pilot phase of the research. The data is analyzed using SPSS for a descriptive overview of the most prominent BIM software usage. Smart PLS was utilized to analyze the path coefficient effects of each variable in the model. The Cronbach Alpha derived fell within an agreeable minimum threshold of above 0.60. The factors loaded appropriately to each variable. The path coefficient revealed people perception had the highest effect on collaborative processes, business process re-engineering (BPR) had the highest effect on BIM adoption and model variance R2 explained 24.6% of BIM adoption. The results will demonstrate the current state of BIM adoption in Malaysian construction industry complimenting current efforts to improve BIM awareness. At this stage, future research focuses on developing the second phase of the model and recommends towards extending and redefining the model with other mediating variables.

Keywords: Building Information Modelling (BIM), Construction Industry, Information Technology, Malaysia, Partial Least Square (PLS).

1 Introduction

Building Information Modeling is predominantly 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. BIM as the process of generating and managing building data during its life cycle. National Building Information Modeling Standard (NBIMS) views BIM as a digital representation of physical and functional characteristics of a facility [1]. The Malaysian Construction Industry Development Board (CIDB) ten-year construction industry master plan (CIMP) to refocuses on the strategic position and future direction of the industry breeding an innovative, sustainable, professional, profitable and world-class construction industry. Important to this study is the leverage on IT towards achieving the set vision of 2015. The dimensions to building information modelling (BIM) research is inexhaustible in fields of user perception, health and safety, costing, project management, green building, Off-Site Manufacturing (OSM), Integrated Project Delivery (IPD), self help housing and real estate [5] [6] [7] [8]. Information technology IT transforms and plays a vital role in how innovation affects project delivery in Malaysian construction sector. The Malaysian governments' aggressive drive to developed nation and exportation of construction services to India and South-East Asia intertwined with government-to-government projects favoured BIM propagation. Design technology is key to affordance of a project hence, choice and collaboration should commerce at the earliest stage. BIM implementation brings unsettling effect to technology, people and processes/policy, process and technology [9]. BIM implementation produces various impacts on both internal organisational culture and values; and external supply chain. 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, automatic building permission [10] [7] [8] [1]. Amidst such process improvement potentials through BIM also exists challenges to full system automation (knowledge; resistance; political engagement; technology capabilities; skills gaps; costs; new forms of contracts; legal issues; life cycle benefits; relevant training and data standards [11] [10] [7] [12]. This study presents pilot results for the Enegbuma and Ali [6] model aimed at plotting a path towards linking user perceptions of people, process and technology and focuses on how they react in strategic IT implementation for effective BIM penetration in the industry. Subsequent sections will delineate the variables of the BIM model, present the hypotheses, examine the data findings and discusses by re-visiting the earlier stated hypothesis.

2 BIM Penetration Model

People perception from previous research in BIM has highlighted the seemingly increasing effect of people dimension to BIM use [14] [2] [15-19]. This paper therefore defined people as the perception towards adapting to new BIM practices in the industry. BIM emergence offers an unsettling precedence to an already defragmented construction industry which offers less surety. New processes to enhance the construction process, electronic designs and construction professionals must acknowledge the individual risk associated with such a new technology. Boundaries of professional responsibility and work product are not clearly defined creating uncertainty for liability in a BIM model. The trend of older professionals still lagging behind while younger professionals lack experience in legal matters with a need for flexible legal form of agreement between construction teams to meet the rapid growth [14] [2] [15]. The emergence of local user Groups in various localities to discuss BIM concepts, softwares and products including information sharing on achievements has shown an adaptive response by people for BIM improvements [16]. Owner awareness is lacking in terms of information regarding successes of BIM by other competitive companies in operation, maintenance, repair and re-modelling. While, other seminar authors proposed a future expansion of current pedagogy in education of building professionals [17-18]. Hence the role of people perception is taken into consideration as it affects BIM penetration in the construction industry.

Process perception changes are inherent in affecting BIM use [13] [6] [1] [20] [21-23] [14] [19]. This paper defines such process thereof as how perception related to managing process changes in adapting to new BIM practices in the industry. Previous construction industry reports except the Latham 1994 report have ignored IT as an integral process in construction. However, emphasis on technology development alone places less attention to organisational and human issues. Furthermore, fewer staffs to regularly update BIM models and inadequate human resource training exist in the construction industry [20] [4] [21-22]. For smooth BIM implementation within an organisation strict consideration must be given to the long term goals of the organisation and requirement. Similarly, managing the cost of ownership can be actualised through BIM, with diligent improvement in BIM practices owners' BIM metamorphoses into a Business Intelligence Model placing it right within corporate mission and objectives. Similar to the CAD migration, BIM is faced with challenging bureaucracy by top management due to new risk and liability fears during model sharing [23] [14]. BIM implementation in the US coast guard achieved partial success. Full success was eventually marred by people's culture and senior leadership resistance to new methodologies; workflow changes; and technological innovation [3].

Technological Perception role presents significant impact on BIM use [25] [5] [26]. Owner push for faster product delivery improvement, safer construction environment, reduced construction cost, lean adoption to eliminate waste and proactive drive by industry professionals to assimilate new technology such as BIM [14]. Malaysian construction industry grapples in advanced IT and project management techniques which forms an essential part to high-tech and capital intensive construction [24]. McGraw-Hill construction report suggests that for BIM to strive and meet the challenges of the future, model objects needs to be readily available for smooth information extraction. Although, product library were created by software companies to represent generic components they lack enough data to represent the specifications of Building Product Manufacturers (BPMs). Knowledge of BIM software, inadequate reference material and component database provide challenges in BIM education in tertiary institutions. Inherent deficiencies in BIM specification provide inadequate differentiation between requirement for BIM deliverables and technology to deliver such information. Similarly, during hyper collaborative platforms such as BIM Storm, participants had to revert to do some manual communication [25] [5] [26].

Strategic IT Planning in line with industry transformation, from adversarial to cooperative thinking places more emphasis on business process. Construction industry is transforming into long term strategic planning to cope with the dynamic nature of economic, technological and social factors. Strategic IT usage though perceived with a degree of reluctance by the construction industry is currently transforming, as most business process were never designed but formed by ad hoc means. Research in labour and cost saving by Adam Smith and Fredrick Taylor provided an initiating argument towards a re-think of business process [27].

Sustainable competitive advantage is maintained though innovative process improvement and management reliant on IT to provide enabling environment [28]. ICT showed a positive and significant impact on the Malaysian economy from 1982 – 2004 which established a change from the norm of investments on agrarian economy to one of manufacturing and industrialisation [29]. Technology acceptance and usage has been studied extensively, expanding Fishbein and Ajzen Model of 1975, Fred Davies formulated the technology acceptance model (TAM). Fishbein and Ajzen Model explained the theory of reasoned action, which Davies conceptualised the existence of a response predicted by user motivation and influenced by external stimulus consisting of the system features and capabilities which triggered the use of a system. [30] perceived change to be structured and measured sets of activities designed for a specific product for various markets and clientele. In construction, process change from inception, project completion and FM stages provide benefits to clients in Malaysian construction industry. Business Process Re-engineering (BPR) drives organization to change their career paths, training, recruitment and policies [31]. Factors highlighted in driving BPR are organisational training, reward, communication, research and development [32]. This paper considers business process re-engineering and computer integrated construction aspects of strategic IT planning.

Collaboration in construction is defined as an agreement among specialist to share their abilities in a particular process, to achieve the larger adjectives of the project as a whole, as defined by a client, a community, or a society at large. Collaboration is working together in a seamless team for common objectives that deliver benefit to all. Collaboration is more effective when undertaken at the project inception stage [33]. Construction industry presents a rather unique approach to collaborating which when done ineffectively creates islands of automation [34]. Major challenges to effective collaboration exist in the construction industry due to independent working and taking decisions which affects the project team [35]. Issues bordering around undefined boundary between teamwork and collaboration including, unsolved issues of shared-understanding, alignment of purpose and shared meaning. Different educational upbringing, terminologies and adversarial contractual agreement further provides barriers to collaboration [36]. This paper adopts collaborative construction as a means improving BIM penetration in the industry.

BIM Penetration amongst other benefit derives competitive gains and future guiding policies of new systems. Communication of innovation over time amongst members of the same social systems over a period of time is often referred to as a product of complex social interaction. Social system acts as a determinant of socio-psychological processes within the social system [37]. Diffusion describes the acceptance and usage of new technology while innovation denotes a new product or process technology, or administrative. Innovation diffusion proposes new models of diffusion of new technologies with complimentary implications for increasing the rate of innovation in the industry. Furthermore, investigations identified four forces that drive innovation: competitive advantage, process problems, technological opportunity, and institutional requirements [38]. [39] argued that relative advantage, compatibility, complexity, observability and triability are determining factors for technology diffusion. The structural equation modelling path study towards improving innovation diffusion level within the architectural and engineering design (AED), delineated definitive pathways and practical strategies harnessed by the construction industry to derive outcomes from innovation via diagnosing and improving their existing innovation capability which invariably strengthen their business performance [37].

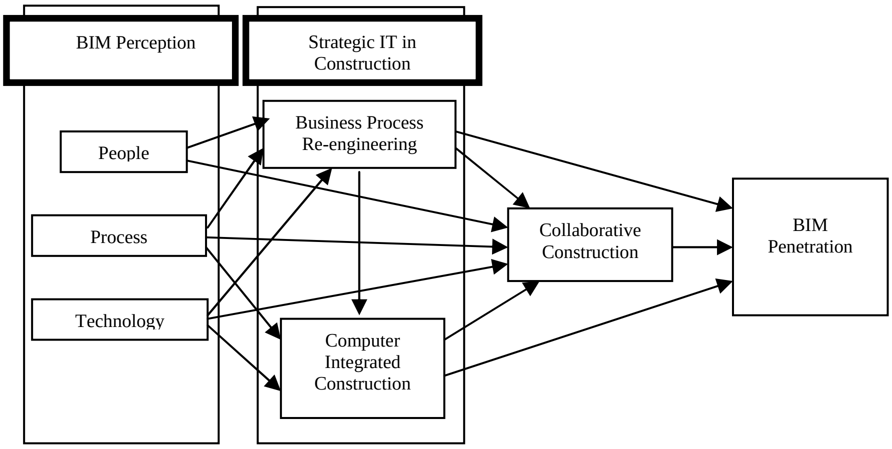

Fig. 1. Research Model and Hypothesis [1]

Table 1. Generated Hypothesis

H1	There is a positive relationship between People and Business Process Re-engineering
H2	There is a positive relationship between Process and Business Process Re-engineering
H3	There is a positive relationship between Technology and Business Process Re-engineering
H4	There is a positive relationship between Process and Computer Integrated Construction
H5	There is a positive relationship between Technology and Computer Integrated Construction
H6	There is a positive relationship between People and Collaborative Construction
H7	There is a positive relationship between Process and Collaborative Construction
H8	There is a positive relationship between Technology and Collaborative Construction
H9	There is a positive relationship between Business Process Re-engineering and BIM Penetration
H10	There is a positive relationship between Business Process Re-engineering and Collaborative Construction
H11	There is a positive relationship between Business Process Re-engineering and Computer Integrated Construction
H12	There is a positive relationship between Computer Integrated Construction and Collaborative Construction
H13	There is a positive relationship between Computer Integrated Construction and BIM Penetration
H14	There is a positive relationship between Collaborative Construction and BIM Penetration

3 Methodological Approach

In structural equation modelling, dual techniques separate the chosen method of analysis namely; covariance-based methods [40] or variance-based PLS-SEM approach [41]. Prevalent in strategic management research is the use of PLS-SEM approach, since this BIM pilot study targets a strategic approach to improving BIM penetration in the construction industry, PLS-SEM was chosen. BIM penetration construct represents a more variance-based (prediction oriented) approach [43]. Other aspects to fortify the methodology technique include increased level of statistical power in small sample size [44] and less rigid assumption [45]. Smart PLS 2.0 [46] was used in evaluating the path model and parameter estimation to evaluate the path weighting scheme [43]. The guidelines by [47] were followed in reporting the measurement model values and subsequent structural model. The constructs were measured by means of multiple items using a five-point Likert scale ranging from 1 (disagreement) to 5 (agreement) [48]. Due to inadequate specific research in contrition IT regarding BIM penetration, items to measure the constructs were reworded and some generated by the authors from previous literature. Hence the need arose to revalidate the reliability of items. Strict attention was placed on confining the multi-item measures to denote representatively the underlying construct.

4 Results and Discussion

The demographic nature of the respondents showed that Engineers made up 36.7% of the respondents. Male respondents were more with 73.3%. The age bracket of 25-35years was predominant by 66.7%. 36.7% of the respondents are originally from Federal Territory of Kuala Lumpur. 83.3% carry out their construction activities from the private sector. 53.3% represents the junior management community in the various establishments. 66.7% are qualified with a bachelor in the outlined fields of construction. 50.0% majority have been active in construction for 6-10years. 50.0% are registered in their various professional affiliations. 50.0% are of the opinion that their level of BIM involvement falls within the beginner class.

The initial pool of item amounted to 48 namely; People (RPPB) - 12, Process (RPP) – 7, Technology (RTP) – 6, Business Process Re-Engineering (RBPR) – 6, Computer Integrated Construction (RCIC) – 6, Collaborative construction (RCC) – 5 and BIM penetration (RSBP) – 6. The first stage of Alpha analysis via SPSS revealed a low Cronbach Alpha for constructs RPPB (0.606), RBPR (0.496), RCIC (0.546) and RCC (0.490). Subsequently, from the Item-Total Statistics item suggested to be deleted to raise the minimum alpha threshold were delete RPPB9, RBPR4, RCIC3 and RCC5 respectively. The final Cronbach Alpha for the constructs are above the minimum threshold of >0.60 [49].

The path diagram linking all constructs was drawn in Smart PLS and analysis initiated by PLS algorithm. The default PLS algorithm settings were utilised; weighting Scheme (Path Weighting Scheme), Data Metric (Mean 0, Variance 1), Maximum Iterations (300), Abort Criterion (1.0E-5) and Initial Weights (1.0). In Smart PLS the factor loadings are derived from the outer loading result which showed low values <0.50. Lowest value loadings were deleted. Discriminant validity holds with all factors loadings in respective variables derived from the PLS cross loading. Convergence occurred at 9 iterations from the stop criterion changes. To derive an acceptable reflective measurement model, 2 steps have to be taken into consideration namely; reliability (reliability of construct measures indicator and internal consistency reliability) and validity (convergent and discriminant). Out of 33 items, four factors loaded below 0.7 recommended thresholds for factor loading but due to the stage in the research this factors were still considered and compared to the composite reliability for any stringent effects. Thus, the measurement model achieved a considerable level of indicator reliability levels. The composite reliability values revealed that all construct measures achieved a healthy score of above 0.7 which reflects a satisfactory level of internal consistency. For the convergent validity the AVE table was assessed denoting all construct scaled the 0.5 threshold. Discriminant validity was analysed through matching the cross loading values in Smart PLS which showed no construct cross loaded more than 0.2 of the leading item. Furthermore, the [50] specifications for discriminant validity was utilised. It specifies that the construct AVE should be higher than the correlation of all opposing constructs. All construct measure according to this measurement model assessment showed reliability and validity.

The structural model focuses on the relationships between the hypothesized various in the construction industry namely; BIM Perception (people, process and technology), Strategic IT Implementation (business process re-engineering and computer integrated construction), collaborative construction and BIM penetration. Figure 2 shows the results from SmartPLS using the earlier stated parameters. Following [42] recommendations, the central criterion for the structural model assessment is given by the coefficient of determination *R2*. The *R2* for BIM Penetration derived 0.25. *R2* for CC derived 0.47. *R2* for BPR derived 0.36. *R2* for CIC derived 0.48. The average value of *R2* depicts the models predictive validity [42]. From the path weights, 0.56 of technology represents the highest variable affecting BPR in the industry. 0.47 of process has d highest impact in CIC. 0.44 of BPR represented the highest impact on BIM penetration in the industry. The bootstrapping technique was later carried out to derive the level of significance [41] [42]. Figure 3 shows that most hypothesized relationships are significant except for the following; process –> CC (1.33, p < 0.05), process –> BPR (0.86, p < 0.05), BPR -> BP (0.80, p < 0.05), People -> BP (1.48 p < 0.05), Technology -> BP (1.50 p < 0.05) and Technology -> CIC (0.99 p < 0.05). The highest significance values occurred between technology and BPR (9.87, p < 0.05).

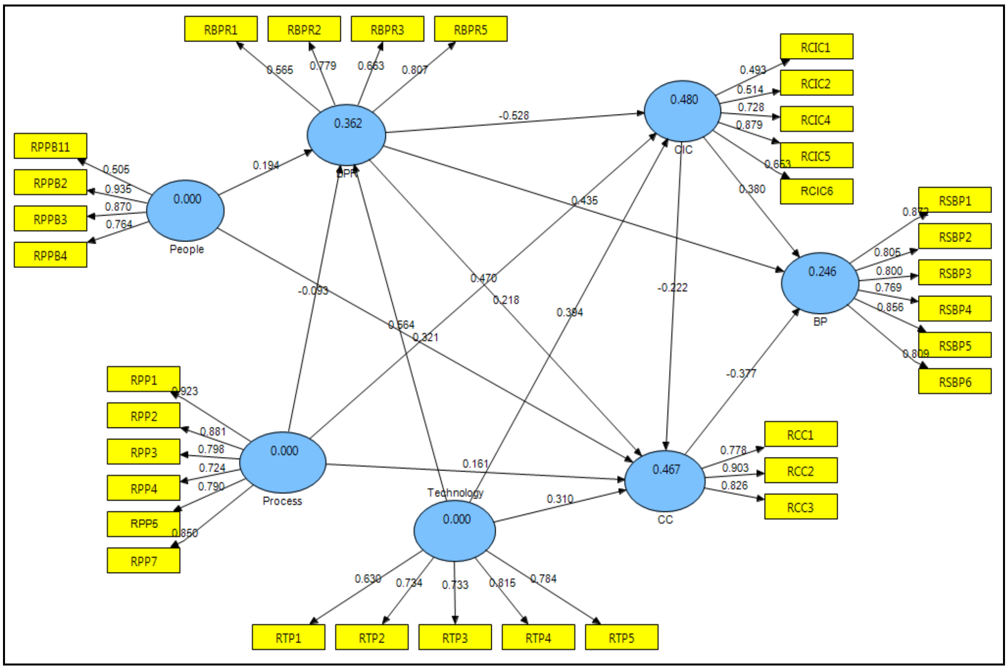

Fig 2. Measurement Model

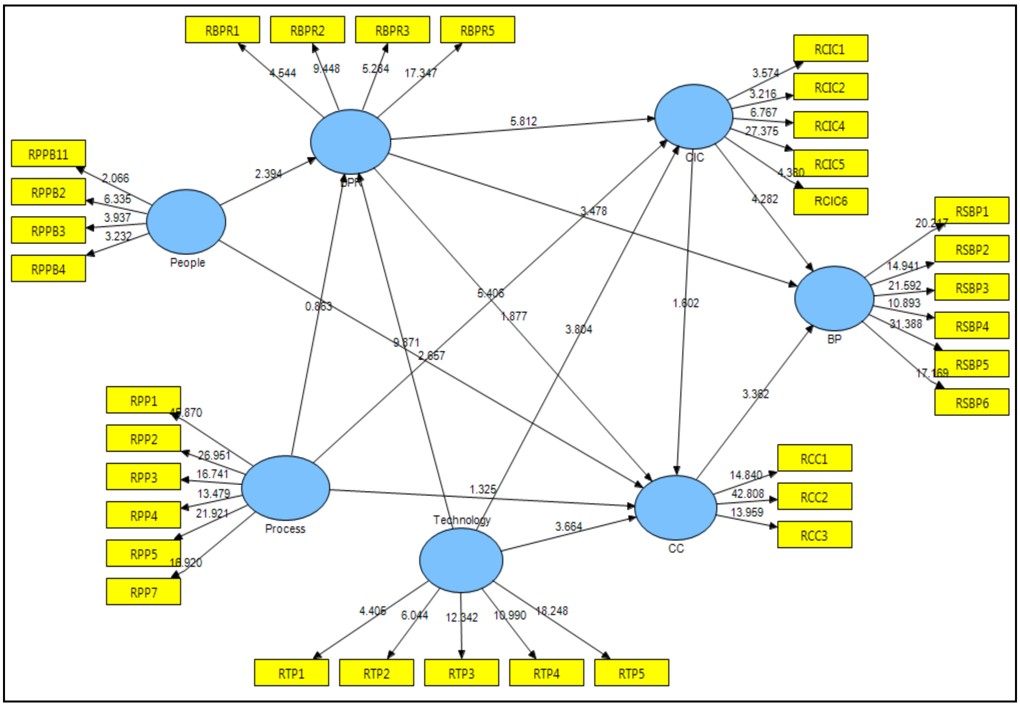

Fig 3. Bootstrapping (T statistics, >1.96 significant at 0.05 at 95% confidence level)

5 Conclusion

This paper set out to examine the varying factors affecting BIM penetration in the industry, accomplished through an extensive literature study to define the key variables. The hypothesized model and subsequent hypothesis was presented. The instrument for the main study showed a healthy Cronbach alpha including achieving discriminant validity amongst the model variables. A test of the hypothesized variables showed most importantly that 24.6% of BIM penetration can be explained by the model considering the sample size. Seemingly, the effects of technology had a highest influence on BPR, conforming with previous standpoint that technology enabler's drive towards strategic innovation and leads to changes to traditional business processes [30] [27] [31] [51] [32]. In the long run therefore BPR weighed heavily on BIM penetration in the industry. Efforts such as seminars and conference to promote BIM by organisations such as CIDB, BQSM, RISM and software vendors sponsored by individual firms shows there is indeed a drive towards change [13]. How Malaysian construction industry professional view process change weighed heavily on CIC, thus follows prior research linking CIC to improvement in communication, planning, collaboration, and databases [52] [20]. These findings contribute immensely to the body of knowledge in the field of global BIM study as it present a total outlook on several variables determining BIM penetration in the industry. Prior research studied presented a division in various aspect of BIM research pointing to key limiting factors as people, process and technology [22] [14] [54] [5], further studies define technology adoption [55], similar to such limiting factors while this research combined other factors. [19] recommended a follow up research on BIM readiness in Malaysia from a more quantitative approach. This research provides numerical figures though with limiting sample size still in a pilot phase. The findings points a path for major managerial decision making choices as to which areas in the construction industry to improve upon. These bodies are not limited to Construction Research Institute of Malaysia (CREAM) and Construction Industry Development Board of Malaysia (CIDB), Malaysian BIM committee, Malaysia Engineer Boards actively in the fore-front for BIM total implementation. The interrelationship found in the model denotes that prompt attention be given to areas such as BPR in the industry. The successes from JKRs BIM pilot project (National Cancer Institute) will push for future changes in BPR in Malaysia [56] [19]. The results of this research explicate the strategic role of BIM and the ability of construction professionals to deal with the dynamics of BIM adoption and use. This research contributes to both theory and practice on BIM and technology adoption by developing and validating the research instrument. Future research will not only look into extension of the model but also seek to test various mediating variables and varied sample population testing.

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