Measurement of Theoretical Relationships in Building Information Modelling Adoption in Malaysia

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Abstract -

Implementing Information technology (IT) in a system presents varied responses. Prior research models in IT adoption examine dimensions not limited to attitude, subjective norm, ease of use, usefulness, innovation including several moderating variables. Despite consistent blueprints on leverage on IT in the Malaysian construction industry master plan, the exponential growth rate of building information modeling (BIM) experiences various challenges in Malaysian construction industry. Hence, this paper presents results from a BIM model study. The model dimensions are people, process, technology, strategic IT planning and collaborative planning aimed at improving BIM adoption. Data was drawn from construction industry professionals (Architects, Quantity Surveyors, Contractors and Engineers). A total of 14 hypotheses were generated. The analysis was carried out with Statistical Package for Social Sciences (SPSS) to test the Chronbach Alpha while Smart PLS, a rapidly increasing Partial Least Square (PLS) software to test the hypothesized relationships in the model. The Cronbach Alpha derived was above 0.6 minimum threshold. 5 out of the hypotheses were insignificant while business process re-engineering (BPR) had the highest effect on BIM adoption. The findings points a path for major managerial decision making choices as to which areas in the construction industry to improve upon. Future research should project towards extension of the model, test other unperceived mediating variables and other varied sample population.

Keywords -

Building Information Modelling (BIM); Construction Industry; Information Technology; Malaysia; Partial Least Square (PLS).

1 Introduction

The Malaysian-German Chambers of Commerce projected a 5.2% expansion in the construction industry as a result of civil engineering works from government stimulus package [1]. The analysis hinged a successful growth rate on technological investments in Information Technology (IT), similar to growth in other sectors spawn by IT. Under the 10th Malaysian plan an estimated growth of 3.7% per annum is expected compared to the nations' 6% per annum GDP [1]. The construction industry in Malaysia remains one of the fastest growing construction industries across the globe [2]. This aids Malaysia rankings towards a newly industrialised nation and an emerging economy [3-4]. The revolutionary Building Information Modelling (BIM) tool in the Architecture, Engineering, and Construction (AEC) industry presents great advantages towards the vision of Construction Industry Development Board (CIDB) master plan and the nations' 2020 vision through increase in key performance indicators (KPIs) and productivity. BIM is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the model to support and reflect the roles of that stakeholder. The model is a shared digital representation with open standards for interoperability [5-6]. The process generates and manages building data during its life cycle using three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components [7]. BIM provides sustainable assessment tool for life cycle simulations, efficient costing, improved engineering quality, new crop of graduates, better communication in generating alternates ideas and analysing the impacts of such ideas [8-15]. However, every new IT tool is without inherent challenges such as interoperability issues, legal and contractual aspects, management, pedagogy, training and high cost of purchasing software [16-21]. The first part of this paper introduces advancements in Malaysian construction industry and BIM attributes. Subsequent sections will expatiate on the present state-of-the-art in Malaysia, present conceptual framework of the BIM adoption model, methodology and results and discussions.

2 BIM in Malaysia

Information technology (IT) continues to transform and plays a vital role in determining innovative effects on 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. 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 has also favoured BIM propagation. The Malaysian Construction Industry Development Board (CIDB) published a ten-year construction industry master plan (CIMP) in 2007 [22]. 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 [23]. In Malaysia, 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); 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 [24]. However, BIM uptake in Malaysian construction industry is still at an infancy stage [25]. BIM maturity is often defined by the level of usage [26]. From the Bew-Richards BIM Maturity Model and Succar models perceptive it can be seen that Malaysian construction industry still falls between stage 1 - 2 and pre-BIM-Modelling 1 respectively (Figure 1), although the debate on the most suitable BIM Maturity Model still exists between Bew-Richards BIM Maturity Model and Succar's BIM Maturity Stages [26]. However, irrespective of the stage of adoption, awareness levels are increasingly raised by seminars/workshops and training on BIM carried out by various bodies (Construction Industry development Board-CIDB, Jabatan Kerja Raya-JKR, Royal Institute Surveyors Malaysia-RISM). Similarly, within construction firms handle large scale projects in-house training are encouraged [27]. The unsettling precedence of such a new system in the industry faces challenges closely linked to the cultural background of the construction industry in Malaysia. The construction professionals not limited to Architects, Quantity Surveyors, Engineers and Contractors are faced with challenging tasks of comprehending new BIM definitions, technology, process and new roles. Also, dissimilarity in technical terminology and process flow of BIM as earlier studied compared in different countries contributes immensely to BIM confusion in the industry [25]. Revit, Bentley, ArchiCAD, Tekla and BoCAD are readily available object based modelling softwares [27].

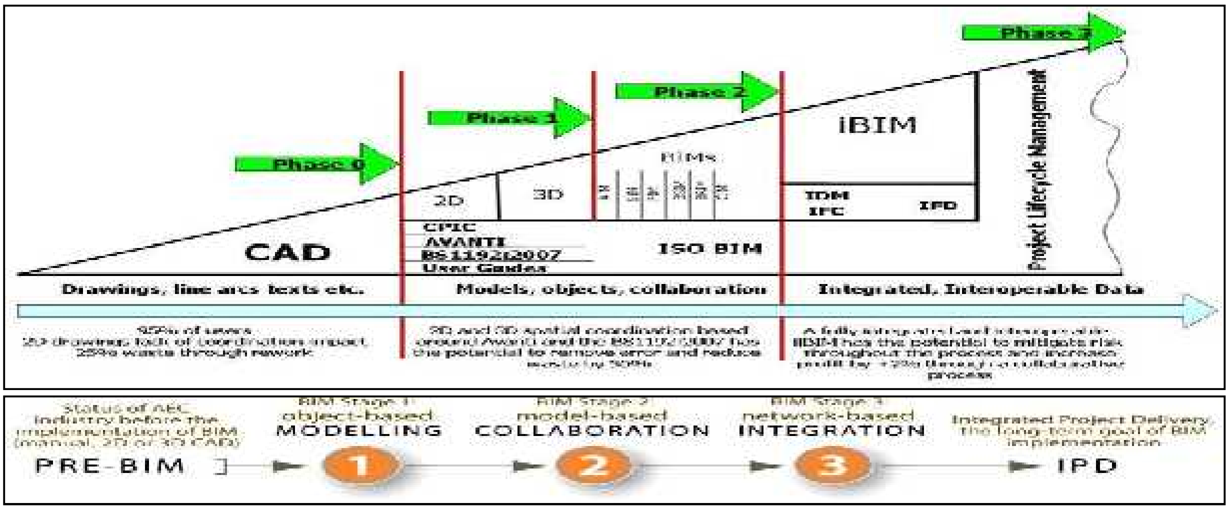

Figure 1. BIM Maturity stages [28-29]

2 BIM Adoption Model

2.1 BIM Perception and Strategic IT in Construction

IT implementation relies on the perception from people, process and technological knowhow due to inadequate artificial intelligence in software and devices [30]. Failure of stakeholders' competency leads to failure in sustaining innovations [31]. Human interaction with a new system influences the rate of implementation in an organisation. Drivers such as communication, human activity, system processing, design, specification and tradeoffs are necessary considerations [32-33][30]. Cultural change of modifying the traditional standard process present great challenges [34], where only a selected number of professionals utilize BIM model [35]. This denotes an adamant resistance to change towards new systems in the construction industry. The phenomenon known as people managers translates the importance of people in organisations adapting to new IT technologies. Hence, understanding ways to tap into individual creative energy, intelligence, initiative, managing change, alley fears to change is critical to implementation success [36-40]. Although fears arise from the perceived reduction in professional fees with

BIM, cost savings from energy savings, maintenance, informed decisions, purchasing, clash detection, reduced request for information adds value to the project for clients, hence the onus to demonstrate the level of value added to clients [41]. Australian unique BIM guideline covers the specifications for product data management (PDM) covering the issues of product libraries, addresses language and classification issues [42-43]. The report by the UK cabinet is creating demand for accurate product data and support for BIM-based PDM. There is need for future development in building product libraries and attention to functional shortcomings and data processing deficiencies which exist in the current libraries [43]. [40] argued that technological push generated more awareness on the need for improvement in business process and re-engineering. Also, incompatibility in IT applications creates island of automation challenging the normal business processes and computer integrated construction. Hence, it is hypothesized that:

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

2.2 BIM Perception and Collaborative Processes

Collaboration is a unified platform that enables interaction between various individuals or groups of individuals in the project team. This triggers a creative process and enables sharing of ideas within openness, honesty, trust and mutual respect towards achieving a common goal. Certain philosophies argues that irrespective of the manner of communication, either synchronised or asynchronised collaboration, the basic premise lies in the communication between one or more individuals. This view point was further stressed when collaboration is referred to as an activity. Emphasis is laid on technology as an enabler providing an atmosphere for various technologies to interact [44-45]. The Initial cost of acquiring the software, training personnel and technical support present great challenges. The level of detailing was not fully exploited [46]. BIM utilisation stimulated a downward trend in variation orders geared towards a zero variation order for projects. Larger construction companies demand BIM from designers in their own projects and in instances where functioning models are nonexistent they model in-house [47]. The apprehension of distrust and litigation processes often leads to ineffective collaboration [26]. The non collaborative nature of the construction industry is fuelled by the rampant silo working mode, where all intelligent, coordination and agility advantages gained in a collaborative environment are corrupted or lost [48][26]. Procurement systems in various industries often contribute to inadequate collaboration. BIM effectiveness relies on accurate and timely information from all professionals, where this is nonexistent BIM faces challenges as such softwares are intolerant to errors [49][26]. Early collaboration provide the opportunity for practical solutions for constructability complexities, owner awareness and government push also further increases BIM usage [50] thus leading lead to hypotheses:

- H6: There is significant relationship between People and Collaborative Processes
- H7: There is significant relationship between Process and Collaborative Processes
- H8: There is significant relationship between Technology and Collaborative Processes

2.3 Strategic IT in Construction, Collaborative Processes and BIM Adoption

Integrating IT systems with business processes reshapes and facilitates the organisational culture, performed task, coordinated activities [51-58][40]. However, to achieve a greater business re-engineering prompt attention is given to modelling new business processes around the implemented IT systems [59][40]. [60] expressed the need for certain project teams to provide extra effort towards achieving collaboration, however, in Malaysia current literature is void of which project team members should with the advent of BIM engage more for a push towards effective collaboration. [60] also argues that there is no resulting disadvantage from adopting collaboration practices in the industry, dependent on the commitment of the project team, merger of collaborative ideals with procurement systems and developing a means to capture and report the benefits. Gradual adoption is recommended for the supply chain to compensate for technology, training, legal and cultural changes to be effectively communicated and adopted by both supply and client side [61]. Knowledge and understanding of Project Management and BIM principles, top management support, and organizational culture are the most influential factors in formulating a BIM implementation strategy. Other factors include transparency, process efficiency and new decision making procedures [62], in some instances main contractor instruct a compulsory BIM use [63]. [30] argued that the increase usage of IT in business processes resulted from the increased awareness of the benefits of open collaborative efforts by project teams in the construction industry. The push for effective collaborative will inadvertently provide higher productivity and returns on investments for clients increased demands which led to further hypotheses of:

- H9: There is significant relationship between Business Process Re-engineering and BIM Adoption
- H10: There is significant relationship between Business Process Re-engineering and Collaborative Processes
- H11: There is significant relationship between Business Process Re-engineering and Computer Integrated Construction
- H12: There is significant relationship between Computer Integrated Construction and Collaborative Processes
- H13: There is significant relationship between Computer Integrated Construction and BIM Adoption
- H14: There is significant relationship between Collaborative Processes and BIM Adoption

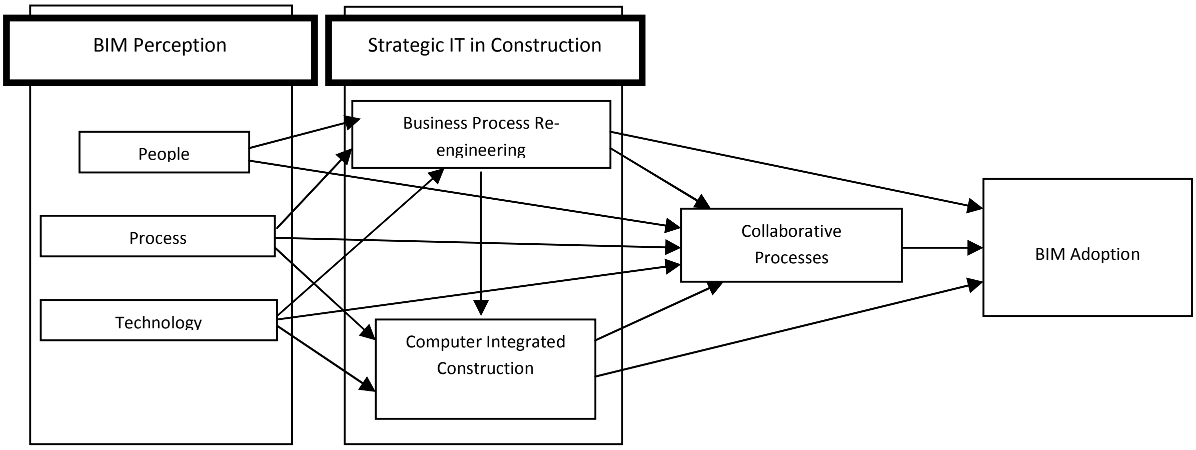

Figure 2: Research Model and Hypothesis [64]

4 Research Method

This paper considers theories/models as sets of statements or principles outlined to elucidate facts or an occurrence. For a theory to attain universal acceptance, emphasis is placed on the repetitious testing whereby in several instances the theory successfully predicts an occurrence [65]. Theory is also considered as a linkage of variables to test the casual relationship of an occurrence (Figure 2). In this research BIM adoption is been considered. Theories in-time after due supervision, examination, reasoning, testing and re-testing become standards of prediction. This standard further directs researchers on the strengths of each variables, construct relationships and situations for innovative correlation [66-67][65]. Models and Theories are often used interchangeably in various fields. The difference is established by the need to prove and verify a model, which subsequently transcends to a theory. Theories emerge from organized and prescribed illustration of previous empirical generalisations and experimental testing, while models do not follow strictly empirical generalization and testing [68-69][65]. In structural equation modelling, dual techniques separate the chosen method of analysis namely; covariance-based methods [70-71] or variance-based PLS-SEM approach [72-75]. Prevalent in strategic management research is the use of PLS-SEM approach, since this BIM pilot study targets a strategic approach to improving BIM adoption in the construction industry, PLS-SEM was chosen. BIM adoption construct represents a more variance-based (prediction oriented) approach [72][76-77]. Other aspects to fortify the methodology technique include increased level of statistical power in small sample size [78] and less rigid assumption [79]. Smart PLS 2.0 [80] was used in evaluating the path model and parameter estimation to evaluate the path weighting scheme [77]. The guidelines by [72] 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 (representing total disagreement with the items) to 5 (representing total agreement with the items) [81]. Due to inadequate specific research in construction IT regarding BIM adoption, 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-itme measures to denote representatively the underlying construct.

5 Results and Discussion

5.1 Demography

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. 60.0% are of the opinion that their level of BIM involvement falls within the beginner class.

5.2 Instrument Reliability

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 Processes (RCC) 5 and BIM adoption (RSBP) 6. The first stage of Alpha analysis via SPSS reviled 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 with People (RPPB) 0.672, Process (RPP) 0.836, Technology (RTP) 0.771, Business Process Re-engineering (RBPR) 0.639, Computer Integrated Construction (RCIC) 0.676, Collaborative Processes (RCC) 0.632 and BIM Adoption (RSBP) 0.898. The items are above the minimum threshold of >0.60 [82-86].

5.3 Measurement Model Evaluation

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 for RPPB1 (0.140), RPPB5 (0.393), RPPB6 (-0.168), RPPB8 (0.206), RPPB10 (0.261), RPPB12 (0.055), RPP6 (0.334), RTP6 (0.340), RCIC6 (0.375) and RCC4 (0.039). Hence, the lowest value loadings were deleted in order of lesser value. 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 of BPR (0.8009), CC (0.8744), CIC (0.7947), Process (0.9297), People (0.8390), BP (0.9243) and technology (0.8586). Shows that all construct measures achieved a score of >0.7 which reflects a satisfactory level of internal consistency. For the convergent validity the AVE table was assessed denoting BPR (0.5060), CC (0.6995), CIC (0.4477), Process (0.6893), People (0.5158), BP (0.6711) and technology (0.5503). 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 [87] 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 next step is the analysis of the structural model.

5.4 Structural Model Evaluation

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 adoption. Figure 3 shows the results from SmartPLS using the earlier stated parameters. Following [77] recommendations, the central criterion for the structural model assessment is given by the coefficient of determination R^2. The R^2 for BIM adoption derived 0.246 from 3 variables BPR, CIC and CC. R^2 for CC derived 0.467 from 5 preceding variables. R^2 for BPR derived 0.362 from 3 preceding variables. R^2 for CIC derived 0.480 from 3 preceding variables. The average value of R^2 depicts the models predictive [72]. From the path weights, 0.564 of technology represents the highest variable affecting BPR in the industry. 0.470 of process has d highest impact in CIC while a negative of -0.528 from BPR affect CIC denoting a lower order construct relationship. 0.436 of BPR represented the highest impact on BIM adoption in the industry. The bootstrapping technique (Figure 4) was later carried out to derive the level of significance [72]. The hypothesized relationships are significant except for the following; process –> CC (1.325, $p < 0.05$), process –> BPR (0.863, $p < 0.05$), BPR -> BP (0.7989, $p < 0.05$), People -> BP (1.4773 $p < 0.05$), Technology -> BP (1.4973 $p < 0.05$) and Technology -> CIC (0.9951 $p < 0.05$). The highest significance values occurred between technology and BPR (9.871, $p < 0.05$) (Table 1).

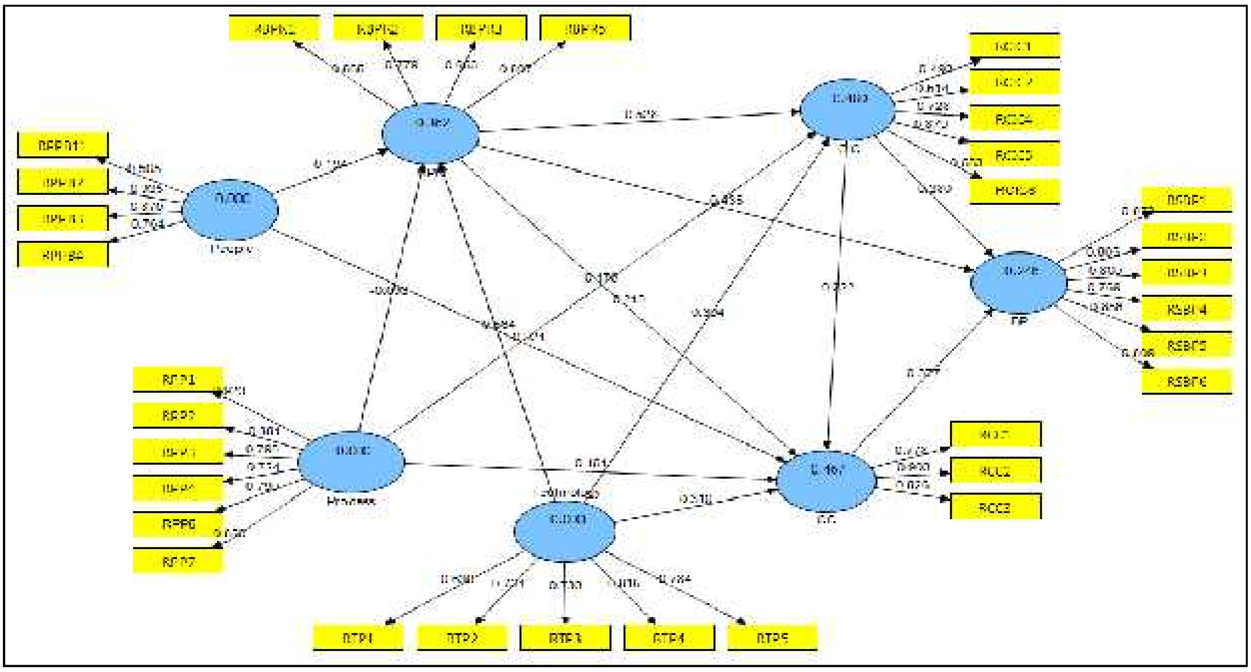

Figure 3: Measurement Model

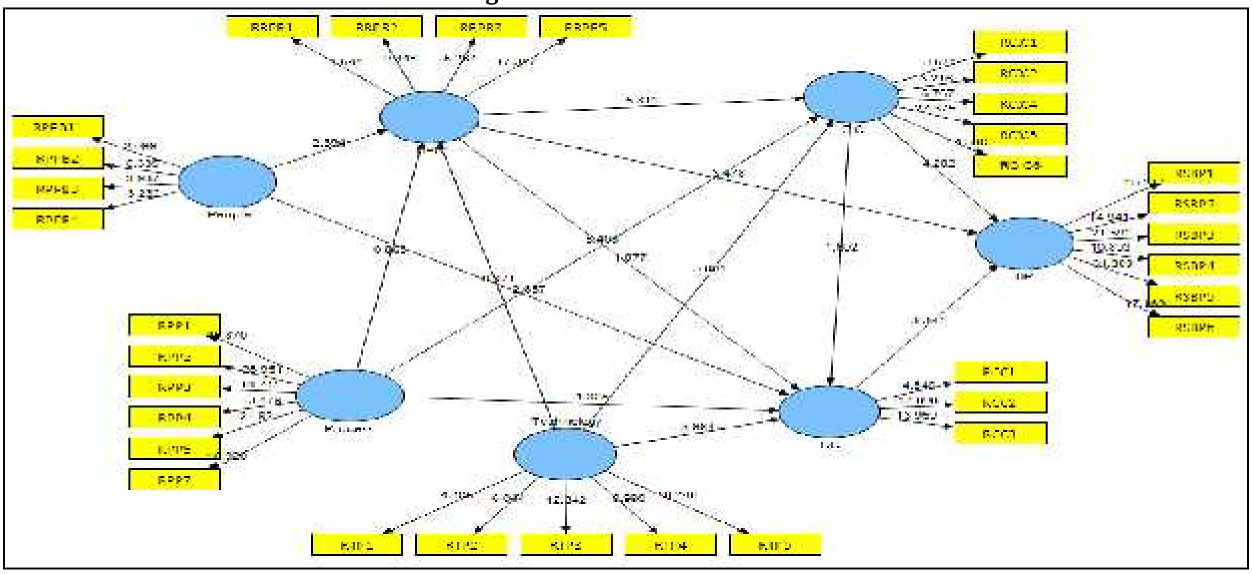

Figure 4: Bootstrapping (T statistics, >1.96 significant at 0.05 at 95% confidence level)

Table 1: Summary of Hypothesis Testing

	T Statistics (|O/STERR|)	**Supported?**
BPR -> BP	0.7989	Insignificant
BPR -> CC	4.4945	Significant
BPR -> CIC	5.8120	Significant
CC -> BP	3.3618	Significant
CIC -> BP	4.3226	Significant
CIC -> CC	1.6023	Significant
People -> BP	1.4773	Insignificant
People -> BPR	2.3935	Significant
People -> CC	3.1592	Significant
People -> CIC	2.2800	Significant
Process -> BP	1.9917	Significant
Process -> BPR	0.8633	Insignificant
Process -> CC	0.2734	Significant
Process -> CIC	6.1257	Significant
Technology -> BP	1.4973	Insignificant
Technology -> BPR	9.8714	Significant
Technology -> CC	7.0389	Significant
Technology -> CIC	0.9951	Insignificant

6 Conclusion

This paper set out to examine the following research questions: Is BIM perception (factors affecting BIM) a source for effective BIM adoption; Is collaborative processes mediating the relationship between strategic IT planning and BIM adoption; which factors exhibit a higher influence in BIM perception in Malaysia; Which factors exhibit a higher influence in strategic IT planning in Malaysia. The first part was accomplished through an extensive literate study. The hypothesized model and subsequent hypothesis was presented [88]. 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 adoption 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 [58][89-92]. In the long run therefore BPR weighed heavily on BIM adoption 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 [93]. 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 [94-97]. 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 adoption 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 [98-102], further studies define technology adoption [103-107] similar to such limiting factors while this research combined other factors. [27] 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 in Putra Jaya) will push for future changes in BPR in Malaysia [108][27]. Since saturation has not been achieved in the field of BIM research, future research will not only look into extension of the model but also seek to test various mediating variables and varied sample population testing. In conclusion, this research paves the path towards future research aimed at developing a better understanding of what drives BIM adoption in the construction industry.

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