

The relationship between cost estimates reliability and BIM adoption: SEM analysis

N A A Ismail¹, N H Idris¹, H Ramli¹, R R Raja Muhammad Rooshdi¹, S R Sahamir¹

¹Faculty of Architecture, Planning And Survey, Universiti Teknologi MARA, Shah Alam, Malaysia

*noorakmaladillah@gmail.com

Abstract. This paper presents the usage of Structural Equation Modelling (SEM) approach in analysing the effects of Building Information Modelling (BIM) technology adoption in improving the reliability of cost estimates. Based on the questionnaire survey results, SEM analysis using SPSS-AMOS application examined the relationships between BIM-improved information and cost estimates reliability factors, leading to BIM technology adoption. Six hypotheses were established prior to SEM analysis employing two types of SEM models, namely the Confirmatory Factor Analysis (CFA) model and full structural model. The SEM models were then validated through the assessment on their uni-dimensionality, validity, reliability, and fitness index, in line with the hypotheses tested. The final SEM model fit measures are: P-value=0.000, RMSEA=0.079<0.08, GFI=0.824, CFI=0.962>0.90, TLI=0.956>0.90, NFI=0.935>0.90 and ChiSq/df=2.259; indicating that the overall index values achieved the required level of model fitness. The model supports all the hypotheses evaluated, confirming that all relationship exists amongst the constructs are positive and significant. Ultimately, the analysis verified that most of the respondents foresee better understanding of project input information through BIM visualization, its reliable database and coordinated data, in developing more reliable cost estimates. They also perceive to accelerate their cost estimating task through BIM adoption.

1. Introduction

The implementation of Building Information Modelling (BIM) technology in improving the construction industry has been widely reported across the globe [1]–[5]. There are several studies that addressed many benefits of adopting BIM by the practitioners and organizations within the industry; such as cost and time saving, reduced human resource, quality and performance improvement, clash detection, improved accuracy, increased profitability, enhanced collaboration and communication, better presentation and documentation process, improved planning and design, better visualization, and improved information [6]–[12].

BIM usage also gives impact on the reliability of construction cost estimates, typically part of vital tasks of the Quantity Surveyors for any construction projects. The BIM technology is claimed to potentially enhance the traditional method of cost estimating that are constantly facing errors, inaccuracies, omissions and ethical flaws [13]. Especially towards improving project input information



supplied to the project, the application of BIM is capable of assisting the cost estimators to attain better understanding in the preparation of more accurate and reliable cost estimates. With regards to improving cost estimates reliability, BIM visualization through its 3D models, allow the demonstration of the construction sequences through simulation by project stages [14]–[17]. Additionally, the provision of digital database via BIM platform reinstates the limitations of using conventional 2D drawings; allows access to all disciplines in the team to obtain integrated project information for cost estimating purpose [18][19]. Furthermore, coordinated data generated by BIM applications permits multiple views of building models, thus helps in examining any clashes between the elements in the building system [19][20].

As interpreted by Lu et al. (2012), the diffusion of the BIM technology could be characterized by the perceived benefits of the practitioners in the industry when adopt BIM [21]. Hence, it could be assumed that the merits of BIM innovation in facilitating cost estimates preparation might influence the Quantity Surveyors as cost estimators to adopt BIM in their practice. Therefore, by utilizing SEM method, this paper aims to examine the relationship between cost estimates reliability and BIM adoption amongst the Quantity Surveyors as cost estimators.

2. Research methods

For this study, the data were collected through a survey questionnaire distributed to the registered Quantity Surveyors with the Royal Institution of Surveyors Malaysia (RISM). There are 1140 members listed, in which 294 were selected as samples from the overall population [22], upon systematic random sampling technique [23]. It resulted from the survey, the satisfactory response rate of 68.5% [24][25], where only 202 responses were usable for further analysis.

The questionnaire employed Likert scale rating in requiring the respondents to imply their point of views towards the effects of BIM technology on the reliability of cost estimates leading to adoption of the technology. Four main variables namely *BIM perceived benefits*, *BIM improved information*, *cost estimates reliability* and *BIM adoption* were evaluated through the questionnaire. Prior to the survey instrument development, six hypotheses were inferred from the relationships that might exist between the variables. The hypotheses are: (H1) Improved Information has a positive and significant effect on Cost Estimates Reliability; (H2) Improved Information has a positive and significant effect on Perceived Benefits; (H3) Perceived Benefits has a positive and significant effect on BIM Adoption; (H4) Cost Estimates Reliability has a positive and significant effect on BIM Adoption; (H5) Improved Information has a positive and significant effect on BIM Adoption; and (H6) Cost Estimates Reliability has a positive and significant effect on Perceived Benefits. The questionnaire was pre-tested amongst the experts beforehand to identify and rectify potential issues on the questionnaire setting [26]–[28].

Primarily, the inferential analysis via SEM method engaging SPSS-AMOS was used to analyse the studied variables and their relationships. Prior to the main analysis, the raw data obtained from the survey were coded, screened and cleaned in compromising with missing values in the dataset [29].

3. Structural Equation Modelling (SEM) approach

SEM approach was deployed to model relationships amongst the variables involved in this study [30]. As described by Kaplan (2009), the SEM method incorporates the processes of: model specification to fit the theory; gathering samples and measures of variables; estimation of the model to obtain parameters; modification to fit the assessment done; and interpretation and discussion of reported results [31]. Two types of SEM models which are measurement model (also known as Confirmatory Factor Analysis (CFA) model) and full structural model were developed throughout the analysis. The Confirmatory Factor Analysis (CFA) assessing uni-dimensionality, validity and reliability, and fitness index were carried out for all measurement models representing each variable respectively. According to Awang (2015), uni-dimensionality in the measurement models is achieved with the factor loading value of ≥ 0.60 [32]. Whereas, the validity evaluated by Average Variance Extracted (AVE) must attain ≥ 0.50 and reliability assessed by Composite Reliability (CR) must range ≥ 0.60 in term of

values. Table 1 shows the AVE and CR formula, and Table 2 tabulates the values of Fitness Index based on categories that need to be achieved for model fit. Eventually, the finalized measurement models that have been evaluated accordingly, were combined and further analysed as SEM full structural model until it reached the model fit requirement.

Table 1. AVE and CR formula [32]

$AVE = \frac{\sum K^2}{n}$	$CR = \frac{(\sum K^2)}{ (\sum K^2) + (\sum 1 - K^2) }$
K = factor loading of every item	
n = number of items in the model	

Table 2. Categories of Fitness Indexes and Level of Acceptance [32]

Name of Category	Name of Index	Index Full Name	Level of Acceptance
Absolute fit	Chi-Square	Discrepancy Chi Square	P-value > 0.05 (not applicable for large sample size more than 200)
	RMSEA	Root Mean Square of Error Approximation	RMSEA < 0.08
	GFI	Goodness of Fit Index	GFI > 0.90
Incremental fit	AGFI	Adjusted Goodness of Fit	AGFI > 0.90
	CFI	Comparative Fit Index	CFI > 0.90
	TLI	Tucker-Lewis Index	TLI > 0.90
	NFI	Normed Fit Index	NFI > 0.90
Parsimonious fit	Chisq/df	Chi Square/Degrees of Freedom	Chi-Square/df < 3.0

4. Results and discussion

Four measurement models were developed for each variable involved in this study. Items in the questionnaire were exploited as indicators to measure the variables accordingly. Initially, those measurement models were assessed and all undervalued items that failed the related tests were eliminated from the model. Analysis was continuously done with items for every variable were tested until all measurement models achieved model fit. The final results of CFA validation for each measurement model are shown in Table 3. Finally, Figure 1 portrays the SEM full structural model combining all evaluated measurement models for all variables.

Table 3. CFA validation final results

Measurement models (variables)	AVE (≥ 0.5)	CR (≥ 0.6)	P-value > 0.05	RMSEA < 0.08	GFI > 0.90	AGFI > 0.90	CFI > 0.90	TLI > 0.90	NFI > 0.90	ChiSq/df < 3.0
Improved Information	0.877	0.955								
	0.893	0.944	0.052	0.062	0.974	0.935	0.995	0.990	0.988	1.777
	0.785	0.879								
Perceived Benefits	0.851	0.966	0.527	0.000	0.992	0.975	1.000	1.001	0.997	0.832
Cost Estimates Reliability	0.941	0.970								
	0.931	0.964	0.098	0.062	0.983	0.941	0.997	0.993	0.994	1.781
	0.912	0.954								
BIM Adoption	0.884	0.968	0.589	0.000	0.997	0.987	1.000	1.002	0.999	0.530

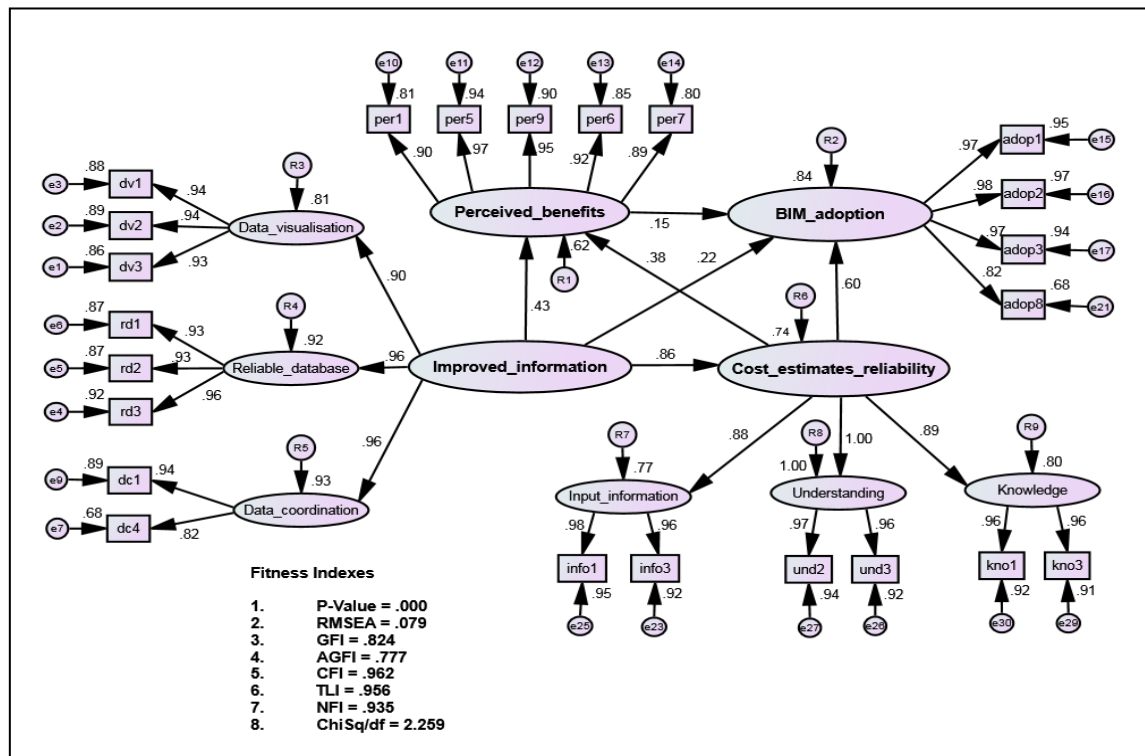


Figure 1. The SEM full structural model

Table 4. The results of hypotheses testing for variables

Hypotheses Statements	Estimate	P-value	Results on Hypotheses
H1: Improved Information has a positive and significant effect on Cost Estimate Reliability	0.862	<0.001	Supported
H2: Improved Information has a positive and significant effect on Perceived Benefits	0.434	<0.001	Supported
H3: Perceived Benefits has a positive and significant effect on BIM Adoption	0.149	0.005	Supported
H4: Cost Estimate Reliability has a positive and significant effect on BIM Adoption	0.601	<0.001	Supported
H5: Improved Information has a positive and significant effect on BIM Adoption	0.219	0.004	Supported
H6: Cost Estimate Reliability has a positive and significant effect on Perceived Benefits	0.382	<0.001	Supported

The final results as shown in Figure 1 indicate the overall fitness measure for the final SEM structural model: P-value=0.000, RMSEA=0.079, GFI=0.824, AGFI=0.777, CFI=0.962, TLI=0.956, NFI=0.935 and ChiSq/df= 2.259. All values demonstrated in the model have achieved the required level of Fitness Index except for GFI =0.824<0.90 and AGFI =0.777<0.90 which might be due to sensitivity of the values towards sample size [33][34]. With the majority of the values reached the level of acceptance for Fitness Index, the final SEM structural model was considered fit for the study. Following the full structural model, the results of hypotheses also yielded the significance p-value (<0.05) for all variables tested, hence all hypotheses are supported (refer Table 4).

The results further consummated that there are significant relationships exist between cost estimates reliability and BIM adoption. Information is improved via BIM platform through its data visualization, reliable database, and coordinated data throughout the construction projects. Evidently

by the BIM procedures establishing those aspects, it accommodates better understanding of construction project information amongst the cost estimators. It will then lead towards knowledge improvement in the cost estimates preparation. The mechanism subsequently serves the perceived benefits towards cost decision making incorporating BIM technology by the Quantity Surveyors as cost estimators. For the BIM innovation to be useful within the estimator's roles, it is anticipated that the BIM tools could accelerate the cost estimating tasks, in concurrent with increasing the accuracy of the cost estimates. With the BIM operation manifesting its capabilities of data visualization, reliable database and data coordination, that could improve their cost expertise, it ultimately motivates the cost estimators to adopt the BIM technology.

5. Conclusion

Conclusively, Structural Equation Modelling (SEM) method was statistically used to model relationships and estimate its values, which exist between variables in the study dataset. Hypotheses were formulated that preceded the development of the SEM models. There were two parts of SEM models, namely measurement model and structural model. All measurement models were established individually representing every variable that were further validated through CFA validation assessing uni-dimensionality, validity, reliability and fitness index; to be next combined as a structural model. Subsequently, the full structural model was established following the confirmation on its model fit. Some key points were highlighted upon the verification of the final model for this study. It was acknowledged that the BIM-improved information through its data visualization, reliable database and coordinated data, could provide accurate data to better understand and interpret project data, leading towards improving knowledge in estimating process. These factors become the drivers that motivate the respondents to adopt BIM in their practice, in anticipating that it would assist in performing cost estimating tasks more quickly. The conducted SEM analysis in establishing SEM full structural model in this study could become a guideline to further develop a framework in strategizing the cost estimating practice incorporating BIM technology.

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