The mediating effects of cost estimates reliability on BIM adoption: SEM model analysis

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Abstract. This paper presents the Structural Equation Modelling (SEM) analysis to evaluate the mediating effects of cost estimates reliability towards the Building Information Modelling (BIM) technology adoption. Using results from a survey by questionnaire, SEM analysis employing SPSS-AMOS application is to assess the relationships amongst the studied constructs (Improved Information, Perceived Benefits, BIM Adoption and Cost Estimates Reliability) by testing three hypotheses. The SEM model was established with its validation through the assessment on its uni-dimensionality, validity, reliability, and fitness index, prior to the hypotheses testing. There are two effects possibly involved in the constructs’ relationships, namely direct and indirect effects, in which were examined using Sobel Mediation Test. The results showed that from all mediating relationships developed amongst the constructs, only Cost Estimates Reliability construct demonstrates its role as partial mediator in the direct relationship between Improved Information and BIM adoption constructs. Whilst the other two hypotheses failed the test, indicating no mediation is possible in between the related constructs relationships. The analysis confirmed that the BIM capabilities could provide better mechanism in understanding project information to establish more reliable cost estimates. It could then improve the estimators’ skills and knowledge throughout the whole cost estimating process, hence potentially motivating them towards adopting the BIM technology.

1. Introduction

Nowadays, the use of BIM technology in the construction industry has been widely employed, claimed help improve productivity in construction practices. There are several studies acknowledged many benefits of adopting BIM especially in improving planning and design including cost and time saving, quality and performance improvement, and collaboration and communication enhancement. Particularly, in preparing construction cost estimates, the application of BIM tools also assists the Quantity Surveyors’ tasks in establishing more reliable project costs.

The innovation of BIM would possibly upgrade the traditional method of cost estimating in encountering constant errors, inaccuracies, omissions and ethical flaws [1]. With BIM 3D models visualizing the construction sequences by project stages, it allows the Quantity Surveyors to manipulate more accurate information to subsequently produce more reliable cost estimates [2]–[5]. The provision of digital database furnished by BIM platform restores the limitation of conventional 2D drawings usage, hence allowing all disciplines in project team to more effectively integrate information for cost estimating purposes [6][7]. Also, data coordination that could be accomplished by BIM tools authorizing
multiple views of building models, could help to evaluate components clashes and discrepancies in related building structure [7][8].

On the other hand, the BIM technology diffusion is designated by the perceived benefits of the professionals in the construction industry through the utilization of BIM [9]. Therefore, it could be presumed that the benefits obtained from BIM implementation in assisting the cost estimates preparation by the Quantity Surveyors might lead them to adopt the technology in their practice. Accordingly, by demonstrating SEM analysis, this paper aims to examine the mediating effects of cost estimates reliability on BIM adoption amongst the Malaysian Quantity Surveyors as cost estimators.

2. Research methods

For this paper, data were gathered through a survey using questionnaire. The pre-tested questionnaire was distributed amongst the Quantity Surveyors registered with the Royal Institution of Surveyors Malaysia (RISM). From the total of 1140 registered members on the list, 294 were chosen as samples from the overall population [10], by employing random sampling technique [11]. A satisfactory response rate was remarked at 68.5% [12][13] where 202 Quantity Surveyors responded and their feedback were usable for further analysis. Likert scale measurement was used for the questionnaire, requiring the respondents to rate their opinions towards the effects of BIM on cost estimates reliability, consequently affects the adoption of the technology amongst them. Four main constructs were assessed namely BIM perceived benefits, BIM improved information, cost estimates reliability and BIM adoption with three hypotheses incorporated: (H1) Perceived Benefits mediates the relationship between Improved Information and BIM Adoption; (H2) Cost Estimate Reliability mediates the relationship between Improved Information and BIM Adoption; (H3) Cost Estimate Reliability mediates the relationship between Improved Information and Perceived Benefits. The hypotheses were established upon few technology adoption theories from the literature namely Roger’s Innovation Diffusion Theory (IDT)[14], Theory of Reasoned Action (TRA)[15], Theory of Planned Behaviour (TPB)[16], Technology Acceptance Model (TAM)[17], and Unified Theory of Acceptance and Use of Technology (UTAUT)[18]. The SEM method engaging SPSS-AMOS was used to evaluate the studied constructs and their mediating effects relationships. Prior to testing those mediating effects, the final SEM model was developed in previous study [19] as shown in Figure 1.

![Figure 1. SEM model [19]](image-url)
The mediating effects between the constructs were analysed to confirm the hypotheses H1, H2 and H3 within the model relationships. In analysing a mediator amongst the constructs involved, there were two effects incorporated in the relationships; direct effect and indirect effect. Direct effect exists directly between the independent construct and dependent construct, while, the indirect effect comes from the independent construct to the dependent construct but goes indirectly through the mediating construct. The mediating effects were tested using the Sobel Mediation Test. According to this test, to confirm whether mediating effects exist in the tested relationship, the value of total indirect effects must be higher that the direct effect. This is due to when the mediator enters the relationship and has an effect indirectly on the relationship; the direct effect will be reduced. Some of the direct effects have shifted to the mediator. The mediating effect acts as ‘partial mediation’ if the value of direct effect is still significant, even though it is reduced. Instead, if the value of direct effect is no longer significant, it is called ‘complete mediation’. However, no mediation occurs if the direct effect value is larger than the total of indirect effects when calculated.

3. Results and discussion

Figure 1 was simplified as Figure 2 for the mediating effects evaluation purpose. Figure 2 illustrates the direct effects and indirect effects developed from the constructs’ relationships, with their respective regression weights derived from the established SEM model [14]. The standardised regression weights and their significance for each path can be referred to in Table 1.

![Figure 2. Direct and indirect effects in the constructs’ relationships](image)

| Construct                  | Path                              | Construct                  | Estimate | S.E  | C.R. | P-value | Result     |
|----------------------------|----------------------------------|----------------------------|----------|------|------|---------|------------|
| Cost Estimate Reliability  | ---                              | Improved Information       | 0.862    | 0.067| 12.582| ***      | Significant|
| Perceived Benefits         | ---                              | Improved Information       | 0.434    | 0.117| 4.041| ***      | Significant|
| Perceived Benefits         | ---                              | Cost Estimate Reliability  | 0.382    | 0.117| 3.627| ***      | Significant|
| BIM Adoption                | ---                              | Perceived Benefits         | 0.149    | 0.054| 2.824| 0.005   | Significant|
| BIM Adoption                | ---                              | Cost Estimate Reliability  | 0.601    | 0.088| 7.685| ***      | Significant|
| BIM Adoption                | ---                              | Improved Information       | 0.219    | 0.084| 2.873| 0.004   | Significant|

*** indicate high significance at < 0.001
Table 1 shows the paths and its coefficient (in bold) which indicate the effects of every construct on its respective measuring constructs. For example, the path coefficient of Improved Information to Cost Estimate Reliability is 0.862. This value indicates that for every unit increase in Improved Information, its effects would contribute 0.862 units of increase in Cost Estimate Reliability. The effects of Improved Information to Cost Estimate Reliability are significant with P-value of less than 0.05.

There are two mediators analysed in the model; Perceived Benefits construct and Cost Estimates Reliability construct. The Perceived Benefits construct potentially gives mediating effect in the direct relationship between Improved Information as an independent construct and BIM Adoption as a dependent construct (H1). The Cost Estimate Reliability construct may influence two direct relationships between Improved Information and BIM Adoption constructs (H2), and between Improved Information and Perceived Benefits constructs (H3).

The first mediator to be tested is the Perceived Benefits construct as a mediator towards the direct relationship of Improved Information and BIM Adoption constructs (H1). The main hypothesis of this relationship is that Perceived Benefits mediates the relationship between Improved Information and BIM Adoption. Based on values and relationships in Table 1, Figure 3 describes the procedure for testing the mediating effect of Perceived Benefits towards the relationship. As presented in Figure 3, the mediation test for the Improved Information-Perceived Benefits-BIM Adoption relationship shows that no mediation occurs in the relationship because the total value of indirect effect (0.06) is lower than the value of direct effect (0.22).

The second mediator to be tested in the model relationship is the Cost Estimate Reliability construct. This construct potentially mediated two direct relationships; the Improved Information-Cost Estimates Reliability-BIM Adoption relationship and the Improved Information-Cost Estimates Reliability-Perceived Benefits relationship. Firstly, the Cost Estimates Reliability construct is tested as a mediator of the Improved Information-Cost Estimates Reliability-BIM Adoption relationship (H2). The standardised regression weights and their probability values are obtained from Table 1 to indicate the significance for the paths involved in the relationship. Figure 4 represents the mediation test for the relationship involving the direct and indirect effects in the paths. The mediation test for the Improved Information-Cost Estimate Reliability-BIM Adoption confirms that mediation occurs in the relationship. The total value of indirect effect (0.51) is higher than the value of direct effect (0.22). The type of mediation involved in this relationship is partial mediation, since the effect in the relationship (Improved Information to BIM Adoption) is still significant (refer Table 1) after the mediator (Cost Estimates Reliability) is included in the model.
Next, the mediating effect of the Cost Estimate Reliability construct towards the direct relationship of Improved Information and Perceived Benefits (H3) was tested. The hypothesis tested was that Cost Estimate Reliability mediates the relationship between Improved Information and Perceived Benefits. The standardised regression weights and their probability values indicating the paths’ significance are previously shown in Table 1. Based on the values and relationships in Table 1, Figure 5 below describes the procedure for testing the mediating effect of Cost Estimate Reliability towards the relationship. As presented in Figure 5, the mediation test for the Improved Information-Cost Estimate Reliability-Perceived Benefits shows that no mediation occurs in the relationship. The total value of indirect effect (0.33) is lower than the value of direct effect (0.43).

**Figure 4.** The mediation test for Improved Information-Cost Estimates Reliability-BIM Adoption relationship

**Figure 5.** The mediation test for Improved Information-Cost Estimate Reliability-Perceived Benefits relationship
The mediation test conducted on potential mediators in the model, which are Perceived Benefits and Cost Estimate Reliability, is verified. From the mediating relationships developed in the model, only Cost Estimate Reliability construct has a role as partial mediator in the direct relationship between Improved Information and BIM Adoption constructs. The mediation test confirms the hypotheses H1, H2 and H3 as described earlier. The result of the overall mediation tests is summarised as in Table 2 below.

| Hypotheses Statements                                      | Types of Mediation | Results on Hypotheses |
|-----------------------------------------------------------|--------------------|-----------------------|
| H1: Perceived Benefits mediates the relationship between Improved Information and BIM Adoption | No mediation       | Not supported         |
| H2: Cost Estimate Reliability mediates the relationship between Improved Information and BIM Adoption | Partial mediation  | Supported             |
| H3: Cost Estimate Reliability mediates the relationship between Improved Information and Perceived Benefits | No mediation       | Not supported         |

The results in overall have demonstrated significant relationships in between cost estimates reliability and BIM adoption. It has been manifested through the mediating effects in the model that the capabilities of BIM tools contributing towards improved project information to generate more reliable project costs, could possibly become the main reason why the Quantity Surveyors as estimators mechanize BIM operation in their practices.

4. Conclusion
This paper employed SEM using SPSS-AMOS application to examine the mediating effects within the relationships amongst the constructs in SEM model, namely Improved Information, Perceived Benefits, Cost Estimate Reliability and BIM Adoption. The mediating effects of the constructs were assessed through three relationships (H1, H2 and H3). Prior to testing hypotheses for the mediating effects, a SEM model was established in the previous study prescribing the possible relationships involved in the model. In conclusion, Structural Equation Modelling (SEM) approach was used to establish not only general causal effects relationships, but also to determine statistically the mediating effects amongst the constructs relationships within the model. The findings highlighted that Cost Estimates Reliability construct possesses a role as partial mediator in between the direct relationship of Improved Information and BIM Adoption constructs. Evidently, the results collaterally indicate that BIM application providing better project information, could lead towards the development of more reliable cost estimates. Subsequently, it could become the motivating factor for the Quantity Surveyors as estimators to adopt the technology in their practice, foreseeing that the BIM tools would facilitate them to perform cost estimating tasks more effectively. It has been theorised that the more the given perceived relative advantage, the better the adoption rate will be. Along the same lines as perceived benefit, TAM termed perceived usefulness to describe how the individual’s beliefs that technology could help them perform their job better may lead to the rejection or acceptance of the technology [17]. Similarly, in UTAUT, they combine the constructs of relative advantages of IDT and perceived usefulness in TAM to form the measure of performance expectancy in evaluating technology adoption [18]. They define the performance expectancy as individuals’ beliefs that using the technology at some point will assist them to increase job performance. Meanwhile, beliefs function as behavioural determinants to adopting a technology [17] and TPB reiterates that it is to be determined by a person’s intentions and actions. Accordingly, in TRA [15] added that to understand what factors contribute to people’s behaviour.
whether to adopt or not to adopt a technology, there is a need to assess their beliefs, the grounds that affect their attitudes towards behaviour. It is significant that the findings of this paper could afford some data in developing related research frameworks for further research, specifically in integrating BIM innovation with cost estimating practice within the construction industry.

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