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Building Information Modelling for Project Cost Estimation

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Abstract: Building Information Modelling for cost estimation (BIM 5D) was introduced to improve cost estimation accuracy that automatically generates data to provide a bill of quantity (BQ) and taking off documents. However, the utilisation of BIM 5D was still low in the Malaysian construction industry due to lack of awareness about its benefits and poor implementation because of its arisen challenges and software issues. This study aims to identify benefits, challenges, and issues during BIM implementation for project cost estimation (BIM 5D). Solutions to reduce the issues and challenges were also investigated in this study. A questionnaire survey was conducted to gather necessary data to achieve all the objectives. Descriptive analyses and mean ranking analysis were used to generate meaningful findings. This study found that BIM 5D provided a better visual representation of building models was the benefit with the highest-ranking mean value perceived by the respondents. Lack of BIM trained professionals was perceived as the most significant challenge. The most common technical issue faced by respondents was BIM 5D software could slow down computer processing speeds. Upgrading computer RAM was strongly agreed by most of the respondents to overcome the issue beside other solutions. The findings of this study could provide a basis for indicating the usage level of BIM 5D and for embarking future research works on strategies towards better BIM 5D implementation in Malaysian construction industry.

Keywords: BIM 5D, Cost Estimation.

1. Introduction

Cost estimation is one of the main tasks and critical functions of any construction project during the design phase. It allows industry players to estimate the relevant budget for the construction flow and monitor the project from a massive loss. This calculation should be made carefully by industry

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experts that have specific technical skills and cost estimating experience. Incomplete or incorrect estimates may lead to a runoff of the budget and time and a failure of the construction project [1]. Building Information Modelling (BIM) which is known as n-D modelling, virtual model, or virtual prototyping technology, can be defined as a collaborative platform to process, produce, communicate and analyze the construction projects using a digital information model throughout the project construction life-cycle [2]. Malaysia Government has given the Construction Industry Development Board (CIDB) a full mandate to encourage all stakeholders in the construction sector to apply BIM including in project cost estimation [2].

In order to improve cost estimation, BIM 5D that focuses on cost modelling and cost calculation was introduced. BIM 5D is normally aided by BIM software and available software such as Autodesk Nevis Work for visualisation, Autodesk Revit Architecture for modelling, Cost X for cost calculation and Microsoft Excel as automation generator. The software can provide acceptable, precise, and reliable cost estimates and data for construction project for the use of project team. In reality, BIM 5D can generate more accurate and realistic cost estimation and calculation in comparison to conventional cost estimation method of providing. Basically, BIM 5D can improve the incorrectness in cost estimation and allows project collaborators to easily access information of various types, greatly promoting information transparency during the life cycle of a facility [3]. However, BIM 5D also have issues that encountered by industry player. System that is not performing well to obtain cost estimation result is among the main issues. Technically, BIM 5D still has the possibility of producing an incorrect value in cost estimation work, and the taking off result generated by BIM software does not display the actual amount of material used in any construction site [4]. BIM 5D vulnerabilities should be seriously identified to ensure that the system can operate with the maximum capacity in estimating project costs.

This study was conducted to identify the benefits, challenges and issues of using BIM technology for project cost estimation (BIM 5D in particular) in realm of Malaysia construction industry, and as well as; strategies undertaken by the consultant and contractor firm in resolving the challenges and issues.

2. Building Information Modelling for project cost estimation (BIM 5D).

BIM 5D can be defined as details of the scope and amount of the necessary construction activities, including the actual cost of construction process's actual cost [2]. Then, BIM 5D has a significant impact on the construction industry, and the system has changed the workplace environment, especially relating to cost estimation work.

2.1 Benefits and challenges of using BIM 5D.

A significant benefit of adopting BIM 5D is that the technology can improve the accuracy of cost estimation while also assisting in reducing project cost. Based on [5] and [3], BIM 5D can remove some issues such as human error and inaccurate drawing interpretation during calculation using automated quantification features. BIM 5D can ease any quantity surveyor or BIM user to automatically extract quantities from the BIM model and shorten the time required to generate cost plans [6]. This is because the technology can process large volumes of data very quickly and make the task more manageable. In visualisation, BIM 5D can provide graphical representations related to the project. This technology generates a simulation and animated video that aids in visualising the project's construction phases, from site management to operation. The video simulation will describe the construction process to the project team, and then help them imagine the intricate part of the building structure and make them easy to understand project flow. The use of BIM 5D can enhance collaboration and cooperation between the project team in executing up projects. The 3D modelling consumption in BIM 5D allows participants to provide design improvement input after many design iterations [7].

Although BIM 5D offers various benefits, this technology also has several challenges faced by the player industry in implementing this technology. Lack of team communication in the project team can bring a difficulty to project workflow. The reason for the scenario is that team communication conflict

can lead to the entire cost estimation wrong. Another challenge is the lack of BIM trained professional. The reliability of cost estimation data generated from BIM 5D software depends on BIM user expertise [4]. This is because any participant who lacks solid fundamental and experience in 2D paper-based measurement may have trouble recognising problems in CAD/BIM models as they did in the 2D environment. These problems will stymie project development and affect project budget management [8]. In the company view, resistance to reform has become a significant challenge to adapt BIM 5D within their work environment. This matter is because most of older staffs were comfortable with traditional methods in estimating project cost [8]. The implementation of BIM 5D also requires high expense to be adopted. This expense is encompassing software purchase, hardware equipment provision, and training programs [7]. Therefore, several construction firms cannot financially fund the implementation of BIM 5D within their organizations since it entails those factors [6].

2.2 Software issues of using BIM 5D.

Creation of BIM 5D software aims to enhance the conventional cost estimation method to achieve a better result. However, some of the software may not perfectly developed and also has brought common issues for the user. Lacks of interoperability in BIM 5D software hinders the software from achieving that performance. This matter has arisen because several data cannot be opened at other software which has different features and fields [9]. Data and result generated by BIM 5D also been checked and reviewed same goes with the conventional method. Nevertheless, according to [10] and [8], the result generated by BIM 5D software is more challenging to check for accuracy and clash detection issues than conventional methods. This matter is because the complexity of BIM software complicates the BIM user, especially for young quantity surveyor who does not have solid fundamental training in conventional measurement. BIM 5D software also can cause inaccurate data. In a previous study shows modelling mistake can cause inaccurate data to occur in the BIM environment [11]. This matter happens when an inadequate detail and missing information within BIM models could bring to design errors and inaccurate estimates [12]. BIM 5Dsoftware also causes minor issues and effect computer processing speed. For example, Autodesk Revit constantly undergoes system lagging while it used in modelling work. As a result, the issues has given bad experience to consultant firm in implementing BIM 5D in their workplace.

2.3 Strategies in resolving challenges related to BIM 5D technology.

The challenges of BIM 5D consisted of team communication, lack of BIM trained professional, resistance to reform and high expenditure. Several solutions used by BIM users have been identified to overcome these challenges. Team communication constraints appeared in the BIM environment because of the lack of experience in handling or coordinating BIM project among the project team [4]. The challenges were overcame by keeping each project member informed about any changes and issues to reduce misleading information. Lack of BIM trained professional is one of the significant challenges in achieving full of BIM 5D implementation at the workplace. In order to encounter the challenge, most of the company was sending their staff to join training programs and workshops related to BIM 5D to strengthen their fundamental knowledge and develop skill in BIM 5D coordination. Forming project team by combining younger and older staff members to overcome their respective deficiencies in knowledge or expertise and solve any upcoming issues together and employing person who has BIM certification to conduct construction project used BIM 5Dwere also strategies to overcome lacking of BIM trained professional in the company [10].

BIM users rarely use this technology to estimate cost because they prefer to use a conventional method instead of automation software [8]. In order to solve that challenge, most companies encouraged their project team to employ BIM 5D technology in an upcoming project by providing enforcement or state BIM uses in the contract during the early design stage. The firms also have convinced the client to use BIM 5D method by showing the record periodic report about BIM 5D performance. This indirectly changed their staff's negative mindset regarding BIM 5D by showing the record benefits of BIM 5D [7]. For solutions, some companies employed youth engineers in both the public and private sectors who can handle BIM 5D software at the workplace. Another challenge of BIM 5D is that every firm must invest high expenditure in implementing the technology within their job scope. In response to this challenge, the companies only purchased BIM 5D software that fits

company demand instead of marketing promotion to reduce company expense [13]. Then, in order to minimize training costs, the companies chose BIM training or workshop from any organization that offers a competitive price but can bring long term benefit to their staff [14].

2.4 Strategies in resolving software issues related to BIM 5D technology

There are software issues associated with BIM 5D implementation. These include lack of interoperability, difficulty in evaluating processes, affecting computer processing speed slow, and inaccurate data generation. In order to encounter interoperability issues, most BIM users attempted to change data file format into Industry Foundation Class (IFC) file format as a solution to ensure the data file can be opened with other different BIM software. This approach is applied because IFC standards have been generated by the International Alliance of Interoperability (IAI) to help govern data exchange between CAD software tools, estimation software tools, and other construction application software tools by creating a neutral file format [5]. BIM users also have difficulties reviewing the result, as it takes a longer duration than conventional methods. In order to overcome the issue, Autodesk Navisworks was used to check collisions during the creation of the model because the 5D BIM software tools do not detect all the collisions [12]. The advanced function of Autodesk Navisworks is to create a multidiscipline model to simulate and optimise scheduling, identify and coordinate clashes, and establish collaboration between all project team members [13].

An input of model description must be keyed in in detail in early design to avoid inaccurate data in cost estimation. Besides that, the simplification model is widely used in the BIM modelling work environment. However, most BIM users were seriously concerned about the method with always cautious when inserting quantity data during the simplification model [4]. BIM users have also encountered inaccurate data by importing extracted quantity data from BIM design into BIM estimation software [4]. Therefore, all data that be imported would not miss and affect the accuracy of BIM 5D data. In order to overcome computer processing speed slow, upgrading computer RAM seems to be the relevant solution. Other firms also have minimised this issue using the Based Compound Element Quantity Takeoff Improvement (BCEQTI) method during the cost estimation process. This matter is because BCEQTI method does not manipulate the original BIM models, including the file size and the number of model elements that would not change. If any change for model geometries would be made, it does not slow down computer performance, and then BIM models can be smoothly edited [11].

3. Methodology

3.1 Materials and Methods.

A set of pertinent questionnaires was developed to achieve the study objectives. The questionnaire was distributed to 110 professionals from diverse firms that applied BIM in the workplace via LinkedIn platform. Based on [15], a total of 108 samples would be enough for a population size of 110 persons to be able to get the result. However, the response rate is good enough as [16] stated that the range 30% to 40% is acceptable. Most of collected data and response from each respondent are to represent each company. and the question was designed using a google form. In this study, a respondent has been selected as representing their company capacity. Table 1 show the distribution and rate of return of the questionnaire survey.

Table 1: Distribution of questionnaire

Category of respondents	Number of targeted respondents	Valid Returned Response	
		(%)	Frequency
BIM Manager	25	5	20
BIM Coordinator	20	13	65
BIM Engineer	20	9	45
BIM Modeler	20	17	85
Quantity Surveyor	5	1	20
Civil Engineer	10	6	60
Other	10	6	60

Total	**110**	**57**	**51.8**

To analyse data, descriptive analysis and mean ranking analysis were employed in this study. The descriptive analysis facilitates describing each variable's mean scores and standard deviation by providing a brief overview for each data category. This include frequency distribution to highlight information such as company background, experience using BIM, etc. Mean ranking analysis consists of using the average of the ranks to determine the rank for the expected frequency. Through this method, the level of benefit, challenges and issues of BIM 5D, as well as strategies undertaken can be determined.

4. Results and Discussion

4.1 Respondents Background

Table 3 shows the information on respondents' background relates to BIM environment. For working experience with BIM part, majority of respondents (65%) respondents have 1 to 3 years of experience with BIM at their workplace. While 5% of respondents are in the category of more than nine years, have experience using BIM. With total of 48 of the respondents (44%), BIM 3D is the highest BIM level used in their companies compared to other BIM levels. Meanwhile, for BIM 4D, 30 respondents (27%) claim that this BIM dimension is use in their companies. BIM 5D was found used at encouraging 17% and BIM 6D level represent approximately 6 respondents and eight respondents. Next, in the knowledge of BIM 5D level, the Majority of respondent (46%) rate their knowledge on BIM 5D as moderate. Only 11% and 12 respondents evaluated their knowledge as very low and high respectively. This scenario occurs because the revolution of BIM has been globally diffused in the construction industry in recent years. BIM low implementation and slow development in Malaysia might cause the number of BIM 5D users to less [2].

Table 2: Respondents Background

Item	Frequency (n)	Percentage (%)
Year of experience with BIM		
1 -3 years	37	65%
4 - 6 years	12	21%
7 – 9 years	5	9%
More than 9 years	3	5%
Level of BIM Dimension		
BIM 3D	48	43%
BIM 4D	30	27%
BIM 5D	19	17%
BIM 6D	6	5%
BIM 7D	8	7%

Level of BIM 5D knowledge		
None	7	12%
Very Low	6	11%
Low	10	18%
Moderate	26	46%
High	7	12%
Very High	1	2%

4.2 Benefits of using BIM 5D

BIM 5D technology has the ability to assist and improve cost estimation works in the construction sector. The benefits of BIM 5D should be explored to fully understand the effectiveness of this technology in solving any cost estimation problems. Questions in section B were designed to meet the requirement for objective 1, which is to identify the benefits of BIM 5D. As shown in Table 3 below, there are eight types of questions related to the benefits of BIM 5D. Four questions represent the current situation (SB1, SB3, SB5 and SB7) and four more for future situations (SB2, SB4, SB6, SB8). The table also shows mean analysis and the mean ranking for BIM 5D benefits. The mean values have been arranged according to the rank from highest to lowest.

Table 3: Mean Ranking Analysis

No	**Item**	**Mean**	**Rank**
1	BIM 5D can provide better graphical representation of building models and help quantity project team understand the project view in a better way (SB5).	4.16	1
2	The graphical representation of BIM 5D can assist the project team in estimating cost in a better way for their future project (SB6).	4.09	2
3	BIM 5D can encourage collaboration among various project team when reviewing a project's costs (SB7).	4.04	3
4	BIM 5D can shorten the time it takes to estimate project costs (SB3).	4.00	4
5	BIM 5D can potentially become a main platform to provide cost estimation result precisely for the future (SB2).	4.00	4
6	BIM 5D allows all project team with different specialist to engage in cost estimation work or the future projects (SB8).	4.00	5
7	In the future BIM 5D saves quantity surveyors, estimators, etc. from spending too much time estimating project cost (SB4).	3.96	6
8	BIM 5D increase cost estimation accuracy for the current project (SB1).	3.84	7

Majority respondents agreed that BIM 5D can provide a graphical representation of building models and help the quantity project team understand the project view better (SB5) with a mean value of 4.16. This feature facilitates the project team during cost estimation work [14]. SB5 represents a current situation that becomes the most beneficial that the industry will admit while using BIM 5D. Then, the second-highest rank, the mean value, is 4.09 is (SB6), where the respondents agree that the graphical representation of BIM 5D can assist the project team in estimating the cost in a better way for their future project. SB6 is representing the future situation. Overall, most of the scores of benefits are above 3.51, which representing agreement by respondents.

4.3 Challenges and issues of using BIM 5D.

There were four challenges in BIM 5Dimplementation identified as listed in Table 4

Table 4: Mean ranking analysis of BIM 5D challenges

No	Item	Mean	Rank
1	Lack of BIM-trained professionals among project team will complicate cost estimation work when using BIM in the project.	4.26	1
2	BIM 5D adoption requires high investment from any company in the construction sector.	4.15	2
3	Most Malaysian companies feel comfortable using conventional method in cost estimation and refuse to use BIM 5D.	4.12	3
4	Team communication on is the most difficult challenge when using BIM for cost estimation.	3.91	4

Lack of BIM trained professional in BIM is the main challenge faced by the consultant and contractor firms, with a mean score of 4.26. The companies mainly opted for teaming up together young and elder staff from different backgrounds of expertise and experience in BIM in order to overcome this challenge. This strategy can lead to continuous collaboration improvements in the BIM environment over the long term [10]. The next challenge is a high investment with a mean value of 4.15. Purchasing BIM 5D software that matches the company's needs was chosen as the main solution to minimize the problem. With a mean value of 4.12, it is clear that the companies feel comfortable using the conventional cost estimation method, resist to reform and refuse to use BIM 5D. In response to this challenge, most companies have encouraged the project team to employ BIM 5D technology. With a mean value of 3.91, the companies agree that team communication conflict also impose constraint to the project team. The companies opted for creating strong collaboration between quantity surveyor and project designers as the key strategy to minimize any misleading information and team communication conflict from occurring.

For the BIM 5D software issues, the respondents also face four major issues affecting software performance in cost estimation work i.e. lacks software interoperability, difficulty in reviewing estimation result, computer speed processing become slow and misleading result generated by BIM 5D software. Table 5 displays the results of the mean ranking analysis for BIM 5D software issues. The level of agreement towards the first three issues range with mean values within 3.51 – 4.50 (agree).

Table 5: Mean ranking analysis of BIM 5D software issues

No	Item	Mean	Rank
1	BIM 5D software causes computer processing speeds to become slow.	3.96	1
2	A process to review BIM 5D software result takes a long duration and might become more complex.	3.68	2
3	BIM 5D software lacks interoperability to upload data file in between different BIM software.	3.56	3
4	BIM 5D software often gives misleading results in cost estimation and quantity measurement.	3.30	4

BIM 5D software causes computer processing speeds to become slow, with a mean value of 3.96 become the highest for the respondent. In order to solve this issue, respondents preferred to upgrade their computer RAM to improve computer performance since BIM 5D software requires 20 times the RAM of the loaded BIM 5D software project file to avoid this to keep BIM stoked with enough RAM to prevent this performance cliff [17]. A process to review BIM 5D software results take a long duration and might become more complex, which can be considered major issues, with the mean value being 3.68. This matter is because the features of BIM 5D software was unable to detect all the collisions during the reviewing process. Therefore, Autodesk Navisworks seems to be the best alternative method for resolving this problem [11]. BIM 5D software which lacks interoperability, also contribute to software issues for the respondents. The mean value is 3.56. Industry Foundation Class (IFC) format can be used to overcome interoperability problems. In IFC format, It can help manage data interchange between CAD software tools, estimating software tools, and other construction application software tools [6]. Then, the lowest mean value is 3.30, represent BIM 5D software often gives misleading results in cost estimation and quantity measurement. A common solution is used 2 BIM software were imported extracted quantity data from BIM design into BIM estimation software.

5. Conclusion and Recommendation

In conclusion, BIM for project cost estimation (BIM 5D) technology has already been implemented by in Malaysia, although not widely. Most companies agree that BIM 5D could benefit the user whether for the current situation or future situation, especially that BIM 5D can provide a better graphical representation of building models and help the project team understand the project view better. As for the software issues, the companies agreed that BIM 5D software could cause computer processing speeds to become slow, and the most preferred solution to resolve the issue is to upgrade computer RAM to allow better performance of BIM 5D software. As for the challenges of BIM 5D, most companies agree that the lack of BIM-trained professionals among the project team becomes a big challenge when using BIM 5D, and the companies prefer to team up with younger and older staff members with various backgrounds of skill and experience in BIM.

This research has discovered that most Malaysian construction companies were fully aware of the benefits of BIM 5D despite the technology growth was slow. Further research is required to identify the most efficient way of growing BIM 5D into the construction industry. These findings revealed that sophisticated technology such as BIM 5D is also confronted with software technical issues. In this regard, future researchers should collaborate with software developers to evaluate BIM 5D in all aspects so that the software remains relevant for all time. Hence, it can be observed that most Malaysian companies face challenges implementing BIM 5D technology in their operations. In-depth research can be carried out in the future on how each challenge can be resolved among the project team without hindering the workflow.

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