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A COMPARISON STUDY ON COST MANAGEMENT BETWEEN BIM AND NON-BIM PROJECTS IN THE CONSTRUCTION INDUSTRY

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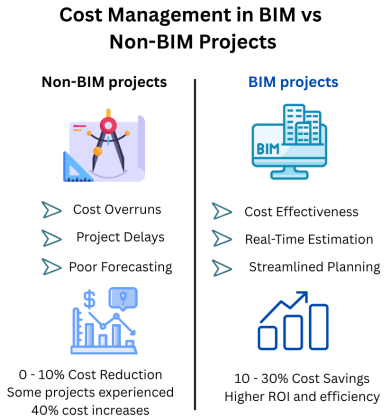
Graphical abstract



Abstract

Construction delay is one of the cost-related issues in the construction industry. Introducing Building Information Modelling (BIM) aided in the cost management of the construction project through early clash detection. Thus, BIM reduces the chances of construction delay and becomes a significant solution for cost issues in the construction industry. Therefore, this paper focuses on the cost management between the BIM and the non-BIM construction projects in Malaysia. The objectives of this paper are: (i) to study the issues of cost management and (ii) to analyse and compare the cost management between the BIM and non-BIM projects in the Malaysian construction industry. A qualitative method was adopted in this study. A semi-structured interview was conducted among the Grade 6 and 7 contractors involved in both BIM and non-BIM projects in Kuala Lumpur and Johor Bahru. The result revealed that the main cost-related issue the construction industry faces is the project's delay. With the implementation of the BIM, it contributes to the reduction of the actual cost by 10% - 30%. However, the implementation of BIM in Malaysia's construction industry is still in the infant stage, and it requires collaboration from the government sector to boost BIM implementation.

Keywords: Building Information Modelling (BIM), project delay, cost management, construction industry, contractors

1.0 INTRODUCTION

The construction industry plays an important role in a developing country like Malaysia as it creates a source of income and provides the economic balance for a nation. However, some issues inhibit the construction industry from functioning to its optimum state. Construction waste, labour issues, lack of supplies and cost overruns are some of the concerns that arise [1]. For instance, altering the design, particularly when installing prefabricated components, may result in higher costs [2].

BIM has become the preferable choice for Architecture, Engineering and Construction (AEC) consultant firms, particularly architects, due to its capability to resolve construction-related issues and provide tools for project insight and compliance [5]. On top of that, with its implementation, small construction companies can increase their staff efficiency, productivity and job satisfaction leading to operation cost reduction.

BIM provides a pivotal practice of clash detection which helps speed up construction progress with fewer errors and high productivity in return. Not to mention, BIM offers better cost control and cash flow tracking [6]. BIM is utilized in developed nations like the United Kingdom and the United States to cut unnecessary costs, schedule delays and construction waste [7].

However, not all AEC consultant firms in Malaysia adopt BIM in their construction projects, indicating their implementation is still in its infancy [8]. Similarly, Ahlam & Rahim (2021), Tanko *et al*. (2024) and Othman *et al*. (2020) confirmed that current BIM implementation in Malaysia is still in its early stages. Yet, once full implementation is applied, the industry will propel its benefit to the fullest [9,10,11].

Despite that, the major reasons for the low BIM implementation are time, cost, and experts' requirements to assist and control the projects. Furthermore, the BIM purchase requires a significant investment [9].

This paper focuses on the difference in cost management between BIM projects and non-BIM projects in the Malaysian construction industry. In general, it is possible to save money on the overall cost of the construction project by avoiding unnecessary over-design from the perspective of the architecture [12]. A construction project's cost management will also improve via BIM implementation as time passes [13] by enhancing the predictability of certain cost items such as the total project cost and labour cost.

Hence, this research aims to study the issues of cost management and analyse as well as comparing the cost management between the BIM and non-BIM projects in the Malaysian construction industry. The study focused on G6 and G7 contractors with construction projects in Kuala Lumpur and Johor Bahru.

2.0 COST-RELATED ISSUES IN CONSTRUCTION PROJECTS

Many issues in the construction project are directly and indirectly affecting the project cost. In this section, the cost-related issues found through the literature review are discussed below. A shortage of supplies can lead to price instability and eventually, an increase in total project cost, affecting not only the Malaysian contractors but the entire value chain. Additionally, the delay in permits and license renewal by the relevant authorities will disrupt the supply chain for the industry and ultimately drive up the cost of materials and total project costs [14].

Globally, project delays have become one of the primary concerns in the construction industry. Although it will increase the client's cost, nevertheless, they are still willing to compensate for the fines due to the project delay. Several reasons and causes for project delays were studied. The primary causes for project delays are the contractor's inadequate planning and inexperience, poor site management and ineffective communication among the relevant parties resulting in time extension, cost overruns, litigation risk and complete project abandonment [15].

Waste generation from construction projects will have a significant environmental effect. Due to the high demand for major infrastructure project completion in Malaysia, a substantial amount of construction could be produced [16]. Meanwhile, the incapability to reduce construction waste has led to a negative effect on the environment especially through illegal dumping acts. One of the examples that occurred was in Batu Pahat, Johor with three project sites were found to have six types of construction waste illegal dumping. They failed to fully implement the Waste Management Plan (WMP) as it will incur additional expenses [17].

In Malaysia, the shortage of labour on the construction site remains one of the cost-related issues. With the suppression of foreign workers by the Malaysian government, there is an increase in the foreign worker levy and also an upsurge in the minimum payment for foreign workers. Despite the higher cost incurred for each foreign worker to work in Malaysian construction sites, however, their presence is still in demand in the industry. All in all, many cost-related issues in the construction industry require immediate action to deal with.

2.1 Building Information Modelling (BIM)

BIM refers to the process of gathering and managing all the digital information throughout the project lifecycle. Since it is a global developing phenomenon, it has a substantial impact on the growth of the construction industry [5]. Various BIM dimensions can be discovered namely 3D (Geometry), 4D (Time), 5D (Cost), 6D (Sustainability), and 7D (Facilities Management) [18].

As this paper focuses on the costing aspect of the construction project, thus, 5D BIM which involves cost management is discussed in this section. The 5D BIM includes automated and precise quantity take-offs, real-time cost estimation analysis, value engineering as well as prefabrication solutions.

Automated construction cost estimation has gained popularity in the research area for BIM-based cost estimations. Zhiliang *et al.* (2011) introduced Industry Foundation Class (IFC) standards in their study by providing division-item property sets, cost items and mathematical relationships [19,20].

Previously, quantity surveyors conducted material 'take-offs' process conventionally which resulted in risky calculations with higher potential error. However, the presence of the BIM model, allows contractors to create the permutation of fundamental appraising data precisely and swiftly. Thus, appraising data will be altered automatically when changes are made allowing greater contractors productivity [21].

Besides, from the 'real-time' cost estimating view, expenditure data can be inserted into each object in the BIM model. This function enables the model to automatically compute the approximate estimate of material costs. This precious tool is offered to designers, enabling them to conduct value engineering. In the end, the prefabrication solution enabled the unique architectural and structural elements to comply with fewer problems encountered [22].

Although BIM is a great emerging technology which able to reduce cost effectively yet, the BIM practice in the Malaysian construction industry is still limited at a 55% adoption rate compared to the US with 80% [23]. Therefore, the benefits and barriers to BIM implementation in the construction industry are discussed in the following section.

2.2 Benefits and Barriers of BIM Implementation

In general, BIM plays a vital role in resolving clash detection conflicts while achieving cost reduction. Table 1 displays several benefits offered by BIM to the industry [5].

Table 1 BIM benefits [24]

Benefits	Description
Capture of reality	• BIM helps in real-time simulation performance
Conflict resolved	• BIM assists in early clash detection through 3D model creation
Increase client collaboration and coordination	• BIM provides better communication and collaboration through exchanging information among project stakeholders

Improve visualization details	• BIM emphasized better model creation based on actual conditions and control of the designs
Enhanced project quality and performance	• BIM helps in controlling project performance and improving project efficiency through cost and scheduling accuracy

Apart from the BIM benefits contribution, there are existing barriers which restrict the BIM implementation across the industry as shown in Figure 1.

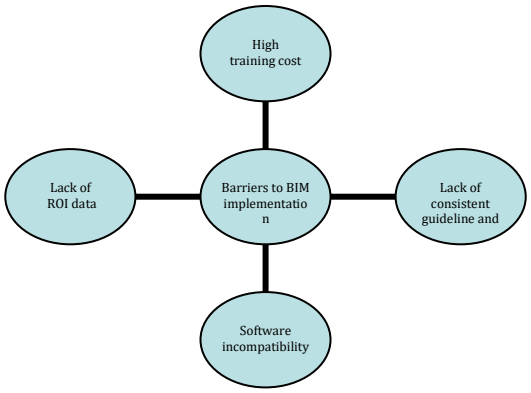


Figure 1 Barriers to implementing BIM

The primary barrier to BIM implementation is the high expenses of training. Owing to a lack of expertise and changes in the working protocols, Malaysian industry stakeholders require proper training to comprehend BIM operations. In addition, the majority of industry stakeholders are unwilling to make such significant investments in empowering their personnel with BIM training. This is due to higher BIM-related costs such as consultant and auditor fees which exceed the training cost. Additionally, initial productivity declines unless BIM has long-term advantages for its organization or the owner is willing to cover the training cost [25].

According to Ibrahim *et al.* (2019), other barriers to BIM implementation include a lack of consistent standard guidelines and software incompatibility. BIM is currently used in large projects with clients and contractors preferring their project participants who are equipped with the necessary technology capability and compatible software [26]. Consequently, pools of BIM players formed according to software compatibility and also resulted in contractors adapting different BIM processes due to inconsistent guidelines and practices.

Furthermore, the uncertain and lack of quantified BIM advantages data for the Return on Investment (ROI) report also creates a barrier for the industry in implementing BIM into their project [26,27]. As a result, conducting further research delving into 5D BIM cost management for Malaysian construction projects is essential to convince the industry stakeholders of cost-related benefits brought by BIM implementation practices.

3.0 METHODOLOGY

Qualitative research via semi-structured interviews was adopted to attain the research objectives. It fosters closer interaction with respondents, resulting in more comprehensive and high-quality information, with better influence and control throughout the interview session.

Purposive sampling was applied in this research by targeting 10 respondents from G6 and G7 contractors as they are well-versed in the usage of BIM technology in the construction industry either directly or indirectly. The selection criteria were based on: i) Complexity of BIM management on big projects and ii) Experience dealing with BIM in the construction industry.

On top of that, pilot studies were conducted with 5 academicians and industry stakeholders where the interview questions were adjusted to fit the goals of the research and make it applicable to the industry.

The information collected during the interview session was then analyzed using the Matrix Table. The Matrix Analysis method, often known as logical analysis, is one of the most common data analyses implemented in qualitative research due to the draft representation of certain sources and studies outlined in an organization chart form, map or a combination of short notes. Figure 2 demonstrates the methodology flowchart applied in this research.

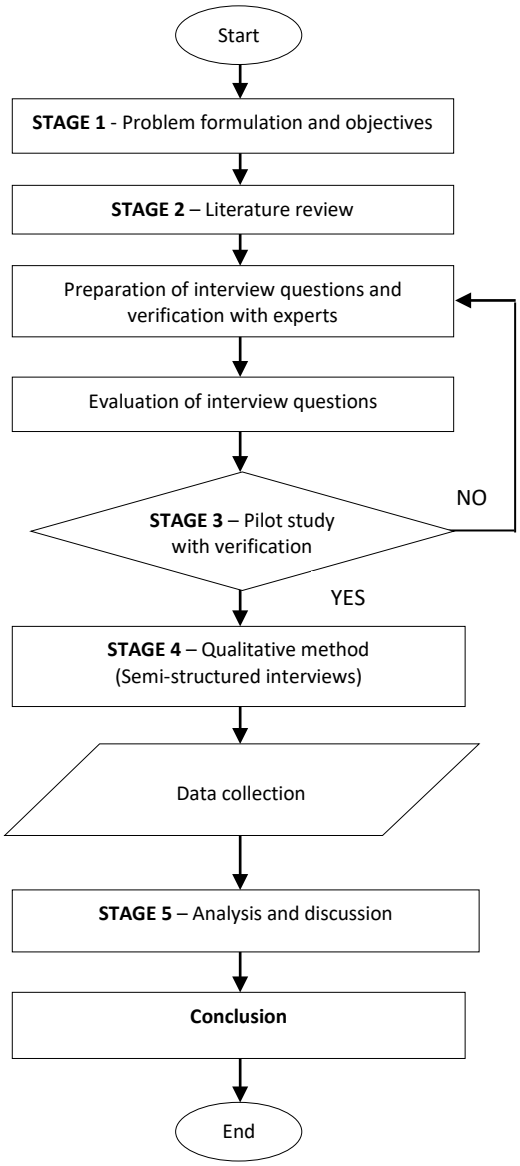


Figure 2 Methodology flowchart of study

4.0 RESULTS AND DISCUSSION

The interview session involved 10 respondents, five BIM users and the remaining 5 non-BIM users. The results obtained are stated in the sub-section below.

4.1 Respondents Background

The section below shows the general information regarding the respondents of the semi-structured interview which is divided into 2 major parts: i) Respondents for BIM projects ii) Respondents for non-BIM projects. Table 2 portrays list of respondents for BIM projects meanwhile Table 3 presents list of respondents for non-BIM projects.

Table 2 Respondents for BIM projects

Respondent	Company	Position	Working experience
1	SPC (Johor Bahru)	BIM Manager	7 years
2	KIMLUN (Johor Bahru)	Project Engineer	10 years
3	KIMLUN (Johor Bahru)	Project Director	12 years
4	SPC (Johor Bahru)	BIM Engineer	3 years
5	KIMLUN (Puchong)	BIM Manager	8 years

Table 3 Respondents for non-BIM projects

Respondent	Company	Position	Working Experience
6	ECOWORLD (Johor Bahru)	Operation Executive	4 years
7	KIMLUN (Puchong)	Project Engineer	7 years
8	ECOWORLD (Johor Bahru)	Project Manager	9 years
9	ECOWORLD (Johor Bahru)	Structural Engineer	5 years
10	KIMLUN (Johor Bahru)	Project Engineer	8 years

4.2 Cost-Related Issues in the Industry

The research conducted found that 4 major cost-related issues within the Malaysian construction industry namely project delays, poor management of the policy control practice, failure to forecast and cost overrun are the important issues in causing the cost conflicts as tabulated in Table 4.

Table 4 Cost-related issues and its causes

Respondent	Cost-Related Issues	Cause
1	• Poor management of the policy control practice	• Scope changes
2	• Project delay	• Scope changes • Complexity of project
3	• Failure to forecast • Project delay • Poor management of the policy control practice	• Inappropriate and inadequate procurement
4	• Project delay • Poor management of the policy control practice	• Inappropriate and inadequate procurement • Scope changes
5	• Poor management of the policy control practice	• Inflation
6	• Project delay	• Design error
7	• Cost overrun	• Design error
8	• Project delay	• Design error
9	• Cost overrun • Project delay	• Design error • Scope changes
10	• Cost overrun • Failure to forecast • Poor management of the policy control practice	• Inappropriate and inadequate procurement

Referring to Table 4, the majority of respondents agreed that project delays are the highest cost-related issues encountered by the construction industry as portrayed in Figure 3.

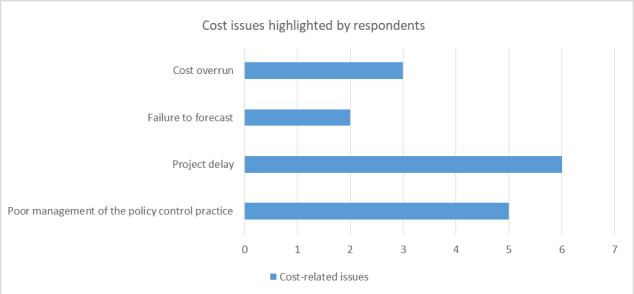


Figure 3 Cost-related issues highlighted by respondents

Undeniably, project delays are a universally acknowledged issue [1]. According to respondents, the major consequence of project delays is the requirement to pay fines. Tariq and Gardezi (2022) and Memon *et al.* (2011) agreed that time overrun is consequently a cost overrun which is one of the crucial project performance indicators [1,28]. Not just that, it also affects further related issues such as project completion time, excessive cost projection, potential legal action and total negligence towards the project [16].

Next, it is followed by poor management of the policy control practice. In the absence of proper policy control practices, the project may overspend on the unfavourable situation. For instance, the purchase of extra construction materials could lead to wastage in the construction industry.

The last two cost-related issues highlighted by respondents are failure to forecast and cost overrun. Forecasting plays an important role in project planning management. Therefore, improper project management may adversely affect the project timeline and cause time overruns [29].

Ultimately, project delay, poor management of the policy control practice, or even failure to forecast, will eventually cause cost overrun for an ongoing construction project. Thus, it demonstrates the importance of well-designed and well-planned construction projects to avoid a long-term cost overrun issue.

Apart from that, several other causes were highlighted by respondents, namely scope changes, the complexity of the project, inappropriate and inadequate procurement, inflation and design error. Changes in the project scope as well as design errors are common during the construction phase. This will cause the ongoing project to slow down until new revisions are agreed upon by all parties before it can proceed. Additionally, this will have a direct impact on or contribute to an increase in the cost [29].

Besides, the project's complexity also contributes to cost-related issues which can be measured in terms of size or design specifications. As the project complexity increases, careful planning, higher expertise, technology performance and materials are required, which necessitates more extensive planning and design before construction takes place [30]. Or else, any small error and inaccuracies will greatly affect the cost incurred.

Meanwhile, inappropriate and inadequate procurement refers to the incorrect materials selection and quantities purchased. According to the previous researcher, incorrect purchasing may cause the quality of the project to become prejudicial leading towards wastage for the environment. Besides, it will increase the construction project cost unnecessarily [31].

Last but not least, the inflation rate is one of the concerns. The role of inflation would gradually affect the construction industry and economic growth as they form a cycle which impacts each other. Various kinds of inflation in building material prices, labour wages and machinery hire rates causing the initial budget deviating from the final budget [31].

All in all, numerous cost-related issues to construction projects could be overcome through proper and detailed planning beforehand. BIM enables early planning stage collaboration among all stakeholders for successful integrated project delivery [32]. Hence, the assistance of advanced technology like BIM significantly reduces potential errors and future cost-related issues.

4.3 Cost Management in Non-BIM Projects

Table 5 displays various solutions taken by contractors to encounter cost-related issues in construction projects.

Table 5 Cost management of non-BIM projects

Respondent	Cost management	Effect on the actual cost
6	• Attempt to stay within the original planned scope • Constantly track and measure progression	• 21% to 30% reduction
7	• Pay close attention to project planning	• Less than 10% reduction
8	• Check the supplier's capabilities before hiring	• 31% to 40 % increment
9	• Pay close attention to project planning	• Less than 10% reduction
10	• Pay close attention to project planning • Check the supplier's capabilities before hiring • Attempt to stay within the original planned scope	• 11% to 20% increment

Referring to respondent 6 who encountered a project delay due to design errors, he stated 2 potential solutions in cost management with a successful rate of 21% to 30% actual cost reduction. Meanwhile, similar successful rates of less than 10% actual cost reduction were achieved by respondents 7 and 9 who applied one potential cost management solution.

Despite that, respondent 8 who experienced project delay issues due to design error, bear around 31% to 40% increment in actual cost when applied solution of checking suppliers capabilities before hiring. This is believed due to insufficient and inefficient solution being used to address the cost issues in the midst of construction phase.

Whereas, for respondent 10, who faced the highest drawbacks of cost issues such as cost overrun, failure to forecast and poor management of policy control practice applied 3 solutions in his project, which only contributed 11% to 20% cost increment, lower than the result obtained from respondent 8. To sum up, the solutions taken by respondent 10 are equivalent to addressing the cost issues that arise.

Maintaining the original planned scope resulted in cost savings since all spending for each activity was aligned with the planning scope. Besides, paying close attention to the project planning would also help save the actual cost. However, simply checking on the supplier's capability did not contribute much to cost reduction yet, increment of actual cost since the capability check only provides insight into the project resources and supplier prices. Lastly, constantly tracking and measuring progression and paying close attention to the project planning are proven to reduce redundant activities and accelerate completion time.

4.4 Cost Management in BIM Projects

Figure 4 shows positive findings where BIM projects experience a cost reduction disregarding the level of BIM usage in their respective projects.

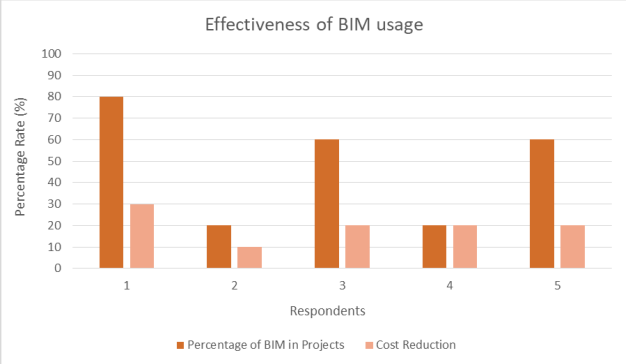


Figure 4 Effectiveness of BIM usage in the projects

The findings of this interview demonstrate that all 5 BIM respondents have shown a positive correlation between the percentage of BIM usage and cost reduction in terms of the effectiveness of BIM usage in projects. This implies that as the BIM usage increases, so does its ability for cost reduction.

The highest implementation in the BIM project was discovered by Respondent 1 for up to 80% with a 30% cost reduction achieved. Similar findings between respondents 3 and 5 were found with a 20% cost reduction despite respondent 4 having a lesser BIM percentage usage.

Respondents 1, 3 and 4 analyzed that the effect of BIM highly assists in clash detection. This finding aligned with previous research by Liao (2021), as it can help reduce actual costs through early error detection [6]. Besides, respondents 1 and 4 also highlighted that BIM did ease the planning process throughout the construction phases, eventually improving cost management.

Additionally, respondent 2 emphasized that BIM offers invaluable benefits in allowing better decision-making and construction methods before takes place by aiding in faster, more detailed and informative information of lifecycle data for the usage of the facilities management.

On the whole, BIM has significant impacts on project execution concerning cost. Among the five data listed in Figure 4, BIM implementation was claimed to bring positive benefits in enhancing cost-saving by implying shared knowledge for information within a single source.

4.5 Comparison of Cost Management between BIM and Non-BIM Projects

In light of the data collected and analysed in the previous sub-sections, several solutions were taken by the respondents in the non-BIM projects to overcome the cost-related issues encountered. Three cost-cutting strategies were proposed however, only one solution which is checking the supplier's capability before hiring was found to be ineffective and even led towards an increase in project cost.

On average, the solutions were able to reduce the project's cost by less than 10% but be mindful that the solutions adopted are only for the particular project, hence the contractors were required to adopt them in future if the issues arise again.

On the other hand, the BIM implementation can aid in the reduction of project costs by 10% to 30% as mentioned by respondent 1. By investing in long-term BIM adoption for construction projects, significant cost savings can be achieved. Acquiring BIM tools such as Revit Architectural, Revit Structural and Naviswork are all considered one-time purchase products, resulting in higher ROI to the owners.

As a result, throughout the data analysis obtained, the implementation of BIM is more cost-effective than other solutions by the non-BIM project. One of the case studies demonstrated that the ROI of the BIM is up to 36.7% once it is implemented [33]. This is encouraging evidence that the implementation of BIM yields a positive impact in return. Hence, some actions need to be taken for the construction industry stakeholders to have more awareness of BIM and also willing to implement it in their companies and projects.

In addition, one of the respondents suggested that the Malaysian government can follow the example of the Singapore Government by providing subsidies to the contractors who adopt BIM in phases. This initiative helps to reduce the high start-up cost that the contractors need to bear at first. With that, it can be seen that the Malaysian government plays an important role in enhancing the BIM implementation for the construction industry.

5.0 CONCLUSION

All in all, the study on the cost management for the BIM projects had been successfully conducted with both objectives being achieved. Despite the number of respondents involved in this study being limited, yet, significant and precise data were obtained.

Undoubtedly, BIM projects are more cost-effective as compared with non-BIM implemented projects. Nonetheless, the current Malaysian construction industry has not fully implemented BIM and the cost benefits are not attained from 5D BIM to perform automated cost estimation as early as the conceptual design phase.

Apparently, the industry is still adopting common software and tools to assist the costing management, which is inadequate and inefficient. In consequence, a higher level of BIM implementation is crucial, especially in the cost management aspect as it will enable the construction industry players to see impressive ROI changes in the projects they undertake in the future [34].

In order to maximise the benefits of BIM implementation in cost management, 5D BIM should be the main character of the BIM project. Therefore, the government must play an important role in enforcing and encouraging the implementation by creating a platform for the construction industry to promote the benefits of implementing BIM, establish policy and provide subsidiaries for the construction companies which willing to invest in BIM for their projects.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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