Sustainability and Energy Efficiency: BIM 6D for Multi-Storey Building- a Case Study

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Sustainability and Energy Efficiency: BIM 6D for Multi-Storey Building- A Case Study

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Abstract. Building Information Modelling is method of combining modelling data from many sources to produce virtual models of intelligently parameterized facilities. BIM 6D is known as the production of an energy model for sustainable building in a simple way. Unfortunately, slow adoption of BIM in Malaysia's building industry have highlighted the need to identify the significant of BIM adoption in Malaysian‘s construction industry. This study also analyse the sustainability and energy analysis for Multi-Storey Building and determine the challenges in BIM and strategies that will enhance effective. A total 51 feedbacks were received. The study found the most concerned barriers factor in implementing BIM in Malaysian construction industry is expensive software with highest means index of 4.06 while the most supported strategies in implementing BIM is related to economic which by subsiding the price of BIM software with mean score 4.73. Moreover, this study was done for Sipitang District Police Headquarters, Sabah project to better examine the benefits and limitations of 6D BIM. By minimizing Window-Wall Ratio, Infiltration, Lighting Efficiency, Daylighting and Occupancy Controls and Plug Load Efficiency could lead significant reduction about 43% in annual mean energy use which have been done by Green Building Studio (GBS) and Insight 360.

1. Introduction

In the civilized era, as the building industry expands and a growing number of sustainable construction projects are undertaken globally, the economic implications for regional development are important [2]. The majority of annual greenhouse gas emissions are caused by buildings. Buildings consume for over 40% of worldwide CO2 emissions due to energy use and will be crucial for a long-term shift [4]. As a result, converting big energy-intensive structures to energy-efficient, sustainable structures is essential, as is developing a framework for building sustainability assessments employing cutting-edge methods and technology [11]. Due to the difficulty of setting up a building model for multi-objective design optimization, advanced modelling and simulation technologies, such as Building Information Modelling (BIM), are in high demand.

BIM offers all of the necessary data to enable all life-cycle activities and is readily understandable by computer software. This research differs the case study is for an existing structure in Malaysia which are the Police Headquarters. The Police Headquarters were occupied 24/7 which typically use more energy and other resources than traditional office buildings. According to Affleck et al. [1], police headquarters could generate energy costs up to two or three times as high. Thus, BIM 6D will need to change to better depict sustainability standards and boost compatibility with sustainability simulations and software as sustainability becomes a major element of the Architecture, Engineering and Construction (AEC) industry by using Revit, a BIM package, Green building studio, a cloud based energy analysis programme and Autodesk Insight 360. In general, theories focusing on several constraints that restrict the utility of BIM or the capacity to apply it in construction were not well documented [13]. Therefore, there is a need for study on the challenges and benefits using BIM that will enhance effective BIM 6D implementation in the construction sector specifically the multi-story building.

2. Methodology

The aim of this study is to examine the development of BIM definition and advantages of BIM throughout the project life cycle particularly more on 6D BIM. This helps to create a better understanding of BIM for the reader. More specifically, the study attempts to identify the challenges of implementation of BIM 6D then aims to plot a strategy of optimizing BIM 6D to increase construction quality and sustainability.

2.1. Literature Review

In pursuit of the objectives of this study, literature review focuses on collecting all necessary data and information about BIM. To boost reader's knowledge on BIM, gathering qualitative data is vital. This helps to create awareness of BIM to readers too. Online databases available on the internet provide researcher sources to a great amount of papers on previous works [12].

2.2. Modelling

This section deals with 6D structural modelling of a Multi-Storey building. The selected building to simulate the BIM 6D was Sekolah Menengah Kebangsaan Desa Wawasan, Tambunan, Sabah. The model will be created using BIM modelling software, Revit, Green Building Studio (GBS) and Autodesk Insight 360. Using the model, the capacities of 6D in BIM will be assessed. The first stage in Energy simulation is to define the energy target [7]. The suggested goal was to illustrate the impact of reduced energy consumption, energy costs and CO2 emissions, as well as to simulate a Net Zero Energy building using software and the result will be shown [10].

2.3. Industrial Survey

The industrial survey uses questionnaires, which will be sent out through Google Form via online communication media such as E-mail and WhatsApp. This is the most economical and easiest method to gather high validity results. The questionnaire was designed and will be distributed to 100 stakeholders in the construction sector with a covering letter explaining the background and purpose of the research [14].

2.3.1. Frequency analysis. To distinguish the variables in the questionnaire survey, frequency analysis utilized a tabular format to depict the frequency of answers to specific items in the questionnaire. The results will be tabulated in terms of frequency and percentages based on the total number of respondents. For a visual representation of the results, the frequencies may be displayed in the form of tables, pie charts, and bar charts [3].

2.3.2. Average Index. According to Khahro [6], the average index analysis for each variable was performed using the rating scale's classification:

$$\text{Average index} = \frac{\sum a1XI}{\sum Xi} \quad (1)$$

where a1 is Constant expressing the weigh given to I and x is variables expressing the frequency of responses for 1, 2, 3, 4, 5…n

2.3.3. Correlation Coefficient. To test the hypotheses, Spearman's correlation coefficient is used. According to Manzoor [8], the spearman correlation is a non-parametric test used to determine the difference in ranking between two groups of respondents' scores on a variety of topics, qualities, or variables.

$$r = \frac{\sum_{i=1}^{n} x_i y_i \frac{(\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{n}}{\sqrt{\sum_{i=1}^{n} x^2 - \frac{(\sum_{i=1}^{n} x_i)^2}{n}} \sqrt{\sum_{i=1}^{n} y^2 - \frac{(\sum_{i=1}^{n} y_i)^2}{n}}} \quad (2)$$

Using equation (2) can obtain

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2} \sqrt{\sum_{i=1}^{n} (y_i - \overline{y})^2}} \quad (3)$$

Where r is correlation coefficient, x is sum of Reponses in variable, y is sum of responses in variable 2 and n is sample size

3. Results and Discussion

Table 1 shows BIM barriers in implementing BIM in Malaysia. The most hindrance category was the time consuming. Even though BIM has proven its success to save time, it is still found to be one of the barriers that restrain BIM implementation. However, the highest mean value according to all respondents is that BIM is an expensive software with means index 4.43. While the lowest means index of 2.57 indicating to employment of additional staffs. This shows that respondents have acknowledged their awareness and knowledge about BIM, but they still face a challenging to get sufficient information.

Table 1. Barriers in Implementation of BIM in Malaysia

Barriers of BIM	Factor	Mean	Std. Deviation	Sum
Lacks Of Awareness	Not required by client	4.06	1.39	207
	Cultural barriers	2.10	1.51	107
	Lack of experience and senior management support	3.27	1.28	167
	Overall Mean	3.14		
High Cost Allocation	Expensive Software	4.43	1.10	226
	Training costs	3.43	1.19	175
	Employment of additional staffs	2.57	1.30	131
	Overall Mean	3.48		
Time Consuming	Problems of interoperability	4.29	1.22	219
	Take longer time to develop model	2.92	1.43	149
	Training the existing staffs	4.04	1.08	206
	Overall Mean	3.75		

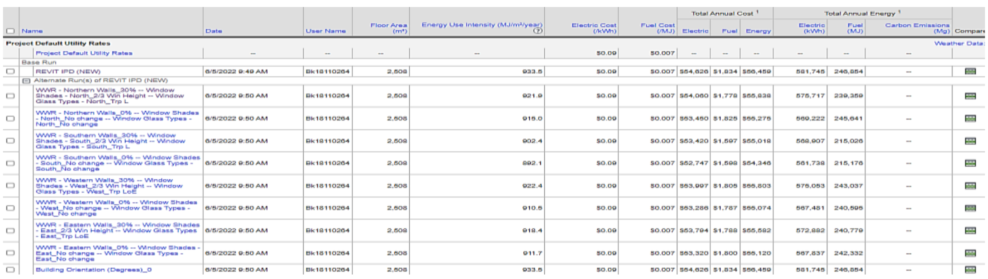
Table 2 shows that there was a total of 3 sections namely economic-related strategy, awareness- related strategy, and environment-related strategy. Each category included three factors. Result shows that the highest mean score was 4.73 which was by subsiding the price of BIM software This due to the greatest economic benefits of sustainable construction are seen in terms of subsiding the software of BIM which are mutually beneficial. Next, result shows that the highest mean score in awareness related strategy was 4.51 by introducing and integrating BIM into the curriculum in the engineering universities. According to Yusuf, Embi and Ali [15], by establishing a foundation for BIM early, it allows new graduates entering the workforce to either influence the company to move to BIM or adapt to companies that already use BIM.

Table 2. Strategies in Implementation of BIM in Malaysia

Strategies of BIM	Factor	Mean	Std. Deviation	Sum
Economic-Related Strategy	Subsiding the price of BIM software	4.73	0.70	241
	Give better information on the costs and benefits of sustainable materials	2.75	1.29	140
	Provision of trial software	4.18	0.99	213
	Overall Mean	3.88		
Awareness-Related Strategy	Mobilizing clients on the importance of BIM	4.43	0.98	226
	Introduction of BIM in University Curriculum	4.51	0.99	230
	More research on BIM toward sustainable buildings	2.67	1.51	136
	Overall Mean	3.87		
Environment-Related Strategy	Strengthened sustainable development	4.67	0.77	238
	System of environmentally friendly labelling	2.43	1.46	124
	Efficient energy forecasts in sustainable buildings	3.25	1.31	166
	Overall Mean	3.45		

Modelling analysis is done in this study to help create utilisation strategy for 6D BIM implementation in Malaysia. Revit 2021 and Autodesk Insight 360 were used to create 6D building information model of Sipitang District Police Headquarters, Sabah as shown in figure 1.

Figure 1. Modelling of Sipitang District Police Headquarters, Sabah



Name	Date	User Name	Floor Area (m²)	Energy Use Intensity (MJ/m²/year)	Electric Cost (/kWh)	Fuel Cost (/MJ)	Total Annual Cost[1] Electric	Total Annual Cost[1] Fuel	Total Annual Cost[1] Energy	Total Annual Energy[1] Electric (kWh)	Total Annual Energy[1] Fuel (MJ)	Total Annual Energy[1] Carbon Emissions (Mg)	Compare
Project Default Utility Rates													Weather Data:
Project Default Utility Rates	--	--	--	--	$0.09	$0.007	--	--	--	--	--	--	
Base Run													
REVIT IPD (NEW)	6/5/2022 9:49 AM	Bk18110264	2,508	933.5	$0.09	$0.007	$54,626	$1,834	$56,459	581,745	246,854	--	
Alternate Run(s) of REVIT IPD (NEW)													
WWR - Northern Walls_30% -- Window Shades - North_2/3 Win Height -- Window Glass Types - North_Trp L	6/5/2022 9:50 AM	Bk18110264	2,508	921.9	$0.09	$0.007	$54,060	$1,778	$55,838	575,717	239,359	--	
WWR - Northern Walls_0% -- Window Shades - North_No change -- Window Glass Types - North_No change	6/5/2022 9:50 AM	Bk18110264	2,508	915.0	$0.09	$0.007	$53,450	$1,825	$55,275	569,222	245,641	--	
WWR - Southern Walls_30% -- Window Shades - South_2/3 Win Height -- Window Glass Types - South_Trp L	6/5/2022 9:50 AM	Bk18110264	2,508	902.4	$0.09	$0.007	$53,420	$1,597	$55,018	568,907	215,026	--	
WWR - Southern Walls_0% -- Window Shades - South_No change -- Window Glass Types - South_No change	6/5/2022 9:50 AM	Bk18110264	2,508	892.1	$0.09	$0.007	$52,747	$1,598	$54,346	561,738	215,176	--	
WWR - Western Walls_30% -- Window Shades - West_2/3 Win Height -- Window Glass Types - West_Trp LoE	6/5/2022 9:50 AM	Bk18110264	2,508	922.4	$0.09	$0.007	$53,997	$1,805	$55,803	575,053	243,037	--	
WWR - Western Walls_0% -- Window Shades - West_No change -- Window Glass Types - West_No change	6/5/2022 9:50 AM	Bk18110264	2,508	910.5	$0.09	$0.007	$53,286	$1,787	$55,074	567,481	240,595	--	
WWR - Eastern Walls_30% -- Window Shades - East_2/3 Win Height -- Window Glass Types - East_Trp LoE	6/5/2022 9:50 AM	Bk18110264	2,508	918.4	$0.09	$0.007	$53,794	$1,788	$55,582	572,882	240,779	--	
WWR - Eastern Walls_0% -- Window Shades - East_No change -- Window Glass Types - East_No change	6/5/2022 9:50 AM	Bk18110264	2,508	911.7	$0.09	$0.007	$53,320	$1,800	$55,120	567,837	242,332	--	
Building Orientation (Degrees)_0	6/5/2022 9:50 AM	Bk18110264	2,508	933.5	$0.09	$0.007	$54,626	$1,834	$56,459	581,745	246,854	--	

Figure 2. Run list tab

In this study, GBS gave 26 alternate runs in addition to the original run. By incorporating a large number of characteristics, the most energy-efficient and least energy-efficient buildings as shown in figure 2. It found that by minimizing the window-wall ratio, Infiltration, Lighting Efficiency, using Daylighting and Occupancy Controls and Plug Load Efficiency can together reduce a large amount of annual mean energy use and annual cost.

Subsequently, different possible improvement alternatives for the building and was exported into a Green Building Studio (GBS) as shown in figure 2 which will studying the behaviour of the building from the energy and environmental point of view will be optimized from the Autodesk Insight 360 as shown in figure 3. The reduction of energy use (EUI) between Base Run Scenario and Scenario Based on GBS can be seen a decrease from 248.51kWh/m²/yr to 141.85kWh/m²/yr respectively.

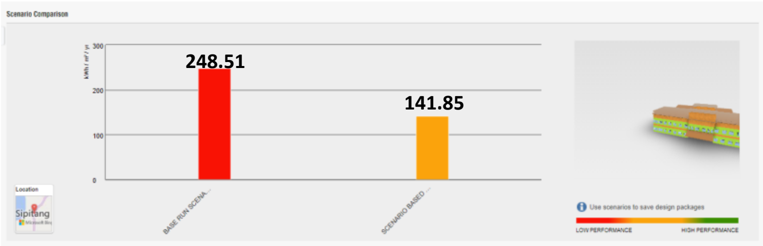


Figure 3. Scenario Comparison

In account of proposing the best solutions and recommendations which has been identified as the result on the data analysed, it can be concluded that there were three linkage of objective to outline the findings of this research work as shown in figure 4.

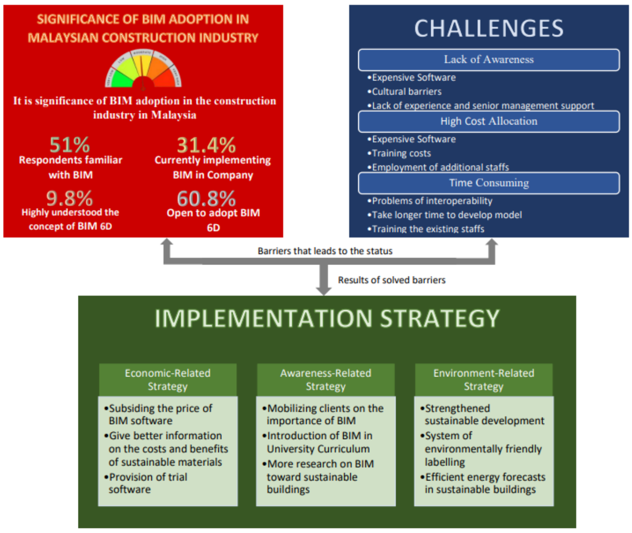


Figure 4. Link between Significance of BIM Adoption in Malaysia, Challenges and Implementation Strategy

4. Conclusion

In conclusion, the most concerned factor in implementing BIM in Malaysian construction industry is about the BIM supported software and updates cost. BIM benefits construction project time, but initial adoption of the model, problems of interoperability and time need to train existing staff, consider the most hinders of BIM. Therefore, this study also reveals that the most supported strategies in implementing BIM is related to economic in terms of subsidising price of BIM. Moreover, minimizing the window-wall ratio, Infiltration, Lighting Efficiency, using Daylighting and Occupancy Controls and Plug Load Efficiency can together reduce a large amount of annual mean energy use and cost.

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