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Integration of Building Information Modelling (BIM) in Design Process to Enhance Building Energy Performance

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Abstract

The increment in building energy consumption has become a global issue that needs to be attended and curbed in order to move towards the goal of sustainability. One of the essential measures to enhance the building energy performance is by carrying out building energy analysis to understand the energy demand of a building. Unfortunately, energy analysis is very seldom performed in traditional design process and this causes the building energy consumption cannot be predicted during early design stage. Consequently, the buildings require large amount of energy to operate. BIM, an advancement of technology with various features, is believed to have the potential to overcome this trouble. The aim of this study is to examine the integration BIM in design process in relation to the enhancement of building energy performance in Malaysia. To properly tackle the problem of high building energy usage, the factors of affecting building energy consumption are identified. Then, the numerous benefits that BIM can offer to enhance the building energy performance are also determined in this study. Since this study is more relevant to design consultants, online questionnaire is distributed to architect and engineers in Selangor area to obtain their perspectives regarding this topic. The primary data collected is presented in pie chart as well as bar chart and then is analysed by statistical tools like Relative Importance Index (RII) and mean one sample t-test. The research findings show that the physical characteristic of buildings is determined as the main factor that influences the building energy consumption. Meanwhile, it is justified that the benefits of applying BIM in design process are significant in enhancing building energy performance. The most significant benefit is reducing the absorption of heat energy from the surrounding.

Keywords

BIM, design process, building energy performance.

Introduction

Building Information Modelling (BIM) is a collaborative process of generating, managing building data and it is shared across project stakeholders (Reality IMT, 2020). The BIM idea was first introduced by the Director of Public Work Department (PWD) in 2007 to be adopted by the developers, consultants and contractors in their construction projects (Ahmad Latiffi, Mohd, Kasim, & Fathi, 2013). According to the official website of the Construction Industry Development Board (CIDB), this idea was further promoted in 2012 so that the industry players are more aware of BIM and adopt BIM. Today, there are altogether seven dimensions of BIM available (BibLus, 2018). Each dimension of BIM has its own meaning and function to improve the construction projects. This study

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will only focus on the 6-dimension which is sustainability assessment in term of enhancing building energy performance.

The enhancement of building energy performance is limited in conventional design process. Since the starting of construction industry in Malaysia in the early 1990s, conventional design process has been practised to transform and illustrate the client's needs into drawings. In conventional design process, the main concern of designers is about producing buildings that can fulfil the client's needs and requirements. The up-front costs are emphasized more as compared to the operational cost of the building (Gao, Wu & Koch, 2019). As a result, energy efficiency of a building sometimes is given less attention or even neglected in conventional design. Consequently, the building will require high energy to operate.

In fact, integrating BIM in design process in a wise choice for implementing sustainable design and improving the building energy performance (Venkataraman and Kanan M, 2013). The 6-dimension of BIM which is about sustainability can overcome the flaw of conventional design in term of catering building energy performance. In the integrated design process, designers like architect, engineers, quantity surveyors, interior designers, facility managers are involved in the early design stage. The creation of a 3D model in BIM software by gathering all information from the various stakeholders enables the analysis of energy consumption to be carried out based on the model. Then, the most energy efficient design can be obtained immediately.

The natural environmental and built environmental factors that affects the building energy consumption can be classified into three major groups which are climate, physical characteristics of buildings and characteristics of building services and systems. The benefits of BIM in enhancing building energy performance include minimizing absorption of heat energy, optimising solar energy, optimising natural lighting, optimising natural air flow and optimizing building systems design. These advantages eventually lead to a more comfortable indoor environment with minimum energy usage.

According to Global Status Report 2017, construction industry specifically buildings consume around 36% of the total global energy. The energy consumption is expected to rise by 10% by the year of 2030. In Malaysia, 48% of the total electricity generated are utilized by buildings. The high energy consumption is mainly due to electrical usage for heat ventilation air conditioning system (HVAC) and lighting system (Hamid, Richard and Ramli, 2016). This issue has exerted tremendous pressure on the environment and attracted the Malaysian government's concern to promote energy efficiency (Thestar.com.my, 2019).

A study conducted by Chua and Oh states that the total electrical generation and consumption in Malaysia is predicted to rise significantly in the near future. In Malaysia, air conditioning system has become the main electric consumption, followed by lighting system (Hassan et al, 2014). Radiation from the sun increases the room temperature. This increases the demand for airconditioning equipment to cool down the indoor environment and the building cooling load is higher as well. Moreover, some rooms in a building are designed in such a way that there is very little or even no natural daylighting can penetrate into the space. In such cases, artificial lighting is required to provide visual comfort to the building users. Furthermore, mechanical ventilation system sometimes is installed in the spaces with poor airflow to ensure a health environment. All of these problems can actually be avoided if the building energy efficiency is designed properly at the early stage.

Even though the ability of BIM in enhancing building energy performance is theoretically convincing, there is lack of initiative from the various developers in Malaysia to implement BIM in their construction projects. This statement is supported by the scenario of low adoption level of BIM in Malaysia even though many efforts had been made by the Malaysia government to promote the

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adoption of BIM. Therefore, more researches need to be conducted to prove the stakeholders how does BIM bring benefits to the industry in term of enhancing building energy performance.

The research objectives for this project were to identify the factors affecting building energy consumption in Malaysia, and to justify that the integration of BIM in design process provides significant benefits to enhance the building energy performance.

Factors Affecting Building Energy Consumption

Climate and weather

Based on the Koppen Climate Classification Map, the climate in Malaysia is considered as tropical which is represented as blue zone in the map as shown in Figure 2-1. The Malaysian climate had been classified as high humidity, harsh temperature and abundant rainfall by the Malaysian Meteorological Department (MMD) (Hassan et al, 2014). The location of Malaysia is between latitude 4o 12' N / 101o 58' E and hence it is highly exposed to solar radiation during daytime. Besides that, the large amount of average annual rainfall causes the surrounding to be humid. To survive in such harsh environment, residents usually have high demand for HVAC system to provide thermal comfort and building energy consumption rises consequently.

Physical characteristics of buildings

According to Yu et al. (2011), building energy consumption can be fluctuated significantly by a small change in some building related parameters. Examples of physical building characteristic are building envelope, orientation, size, shape, age, façade, materials and so on. The design of the building envelope shall be considered carefully because it can bring obvious effect to the building energy consumption. The three major issues of building envelope that need to be taken into account are the thermal properties of wall system, window selection and roof system (Kibert, 2005). Moreover, the floor area or building size is another physical characteristic that brings impact to the building energy consumption.

Characteristics of building services and systems

The fundamental building services required in a building for optimum building operation include HVAC system, lighting system, cold and hot water supply, energy supply and so on. The energy efficiency of building services systems can be determined by few aspects such as the type, size, age, specification, condition, operation and maintenance (De Silva and Sandanayake, 2012). Energy efficient equipment is highly encouraged in order to reduce the building energy consumption. Improper operations of systems can lead to higher energy consumption and energy wastage especially air conditioning system.

Benefits of BIM in Enhancing Building Energy Performance

From the information gathered from secondary sources, the benefits of applying BIM in design process to enhance building energy performance include:
i. reducing absorption of heat energy,
ii. optimizing solar energy,
iii. optimizing natural lighting,
iv. optimizing natural air flow,

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v. optimizing building services design.

Research Methodology

The secondary data is collected from articles, books, reports, online newsletters and websites. Meanwhile, quantitative method is chosen as the approach to assemble the architects' and engineers' perceptions regarding the benefits of applying BIM in design process to enhance building energy performance. The questionnaire is sent to 52 architect firms and 26 engineering firms in Selangor area registered under Board of Architect Malaysia and Board of Engineers Malaysia via E-mail. 33 responses received thus the response rate for this study is 42.3%. The statistical tools used for data analysis are Relative Importance Index (RII) and one sample t-test.

Data Analysis

The common factors that influence the building energy consumption are identified from secondary data sources such as articles and books. Then, the key question and hypothesis of this objective are attained by carrying out RII test on the result obtained in Section B in the questionnaire. The analysis are shown Table 1 and Table 2.

Table 1. RII and Rank based on Overall Data

FACTORS	FREQUENCY OF WEIGHTAGE			RII	RANK
	1	2	3		
Climate	15	11	7	0.586	3
Physical Characteristics of Building	3	14	16	0.798	1
Energy Inefficiency of Building Services Systems	15	8	10	0.616	2

Table 2. T-value based on Overall Data

BENEFITS	T-VALUE
Reducing Absorption of Heat Energy	10.074
Optimizing Absorption of Solar Energy	9.014
Optimizing Natural Lighting	5.600
Optimizing Natural Air Flow	6.842
Optimizing Building Services Design	4.423

Conclusions

This research regarding the integration of BIM in design process to enhance building energy performance can be concluded with the achievement of the two objectives as well as the aim of the study. The main factor that affects the building energy consumption is identified and the most significant benefit of integrating BIM in design process to enhance building energy performance is also determined. The research findings show that the physical characteristic of buildings is determined as the main factor that influences the building energy consumption. Meanwhile, it is

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justified that the benefits of applying BIM in design process are significant in enhancing building energy performance. The most significant benefit is reducing the absorption of heat energy from the surrounding. By reading this report, the design consultants are hoped to be more aware of the benefits of BIM in enhancing building energy performance.

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