OPTIMISING ENERGY PERFORMANCE ANALYSIS USING BUILDING INFORMATION MODELLING

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DEDICATION

This thesis is dedicated to my family for their constant support with patience and encouragement.

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ABSTRACT

Construction industry is broadly recognised as a major contributor to the economy of a country however it also contributed to our rising environmental issues. The sustainability in the construction industry in the aspects of social, environment and economic is gaining more attention from the researchers. Back in 1992, Agenda 21 is proposed in the United Nations Conference to kick start program of action internationally in order to achieve sustainable development for 21st century. In order to achieve sustainability, energy performance is a crucial aspect to be considered. However, the current energy have deteriorated performance issues, loss of data greatly affect the accuracy of the analysis conducted. Thus, the implementation of Building Information Modelling (BIM) improves the energy performance measurement. The aim of this study is to investigate the potential benefits of BIM integration in Energy Performance Analysis using the case study of Eco-Home followed by three objectives which are, to identify the high energy consumption equipment in a building; to compare and contrast the simulated values from BIM with the actual measured data of electricity production; and to propose solutions and recommendations for energy optimisation. This study integrates BIM and energy analysis tools to explore the energy performance analysis using the case study of Eco-Home in UTM. The energy performance analysis conducted through Green Building Studio software with the exported Revit file in gbXML file format. In this study, the high energy consumption equipment in Eco-Home is the air conditioner. Meanwhile, the simulated and actual energy performance of Eco-Home is 7,981 kWh/year and 7,597 kWh/year respectively. Further design alternative analysis shows that Eco-Home has the potential to further improve the energy performance by implementing daylighting sensor and greywater collection system. In conclusion, the simulation using Building Information Modelling (BIM) and Green Building Studio enable the building owner to forecast the future energy usage with different design alternative to select the most suitable design with better energy performance.

ABSTRAK

Industri pembinaan secara umumnya dikenali sebagai penyumbang utama terhadap ekonomi sesebuah negara. Walau bagaimanapun, industri ini juga mengakibatkan peningkatan isu alam sekitar. Kelestrarian dalam industri pembinaan dari aspek sosial, persekitaran dan ekonomi semakin memperoleh perhatian daripada para penyelidik. Pada tahun 1992, Agenda 21 telah dicadangkan dalam Persidangan Bangsa-Bangsa Bersatu untuk memulakan program di peringkat antarabangsa bagi mencapai pembangunan lestari pada abad ke-21. Untuk mencapai kelestrarian, prestasi tenaga ialah aspek penting untuk dipertimbangkan. Walaubagaimanapun, tenaga semasa telah merosot dari segi prestasi dan kehilangan data sangat mempengaruhi ketepatan analisis yang dilakukan. Oleh sebab itu, pelaksanaan *Building Information Modeling (BIM)* dapat meningkatkan pengukuran prestasi tenaga. Tujuan kajian ini adalah untuk mengkaji potensi faedah integrasi *Building Information Modeling (BIM)* dalam Analisis Prestasi Tenaga dengan menggunakan kajian kes Eco-Home diikuti dengan tiga objektif iaitu, untuk mengenal pasti peralatan yang menggunakan tenaga yang tinggi dalam sesebuah bangunan; untuk membanding dan nilai simulasi dari *Building Information Modeling (BIM)* dengan data sebenar penghasilan elektrik yang diukur serta untuk mengemukakan cara penyelesaian dan cadangan dalam dalam mengoptimumkan tenaga. Kajian ini mengintegrasikan BIM dan peralatan analisis tenaga untuk menerokai analisis prestasi tenaga dengan menggunakan kajian kes Eco-Home di UTM. Analisis prestasi tenaga dijalankan menggunakan perisian *Green Building Studio (GBS)* dengan fail Revit yang dieksport dalam format fail gbXML. Dalam kajian ini, alat yang menggunakan tenaga yang tinggi di Eco-Home ialah pendingin hawa. Sementara itu, prestasi tenaga simulasi dan sebenar Eco-Home ialah 7,981 kWh setiap tahun dan 7,597 kWh setiap tahun. Analisis alternatif reka bentuk yang lebih lanjut menunjukkan Eco-Home berpotensi untuk memperkembang prestasi tenaga dengan menerapkan sensor pencahayaan siang hari dan greywater collection system. Kesimpulannya, simulasi menggunakan *Building Information Modeling (BIM)* dan *Green Building Studio* membolehkan pemilik bangunan meramalkan penggunaan tenaga masa depan dengan alternatif reka bentuk yang berbeza dalam usaha untuk memilih reka bentuk yang paling sesuai dengan prestasi tenaga yang cemerlang.

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LIST OF ABBREVIATIONS

BIM	-	Building Information Modelling
GBS	-	Green Building Studio
BEM	-	Building Energy Modelling

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Construction industry is an inevitable important sector particularly in developed and developing countries. Therefore, construction industry is broadly recognised as a major contributor to the economy of a country. However, it also become a main contributor to our rising environmental issues. For instance, the increasing energy consumption worldwide leads to greenhouse gases emission (Lu et al., 2018). There is a growing concern for the construction industry to become much more sustainable in their projects and developments due to the noticeable negative effects on the environment and the rising consciousness of environmental conservation. Thus, Malaysia takes the initiatives to reduce 40% of greenhouse gas emission intensity of Gross Domestic Product (GDP) by 2020 which improved from the emission record in 2005 (Ministry of Natural Resources and Environment Malaysia, 2019). As a result, the sustainability in the construction industry in the aspects of social, environment and economic is gaining more attention from the researchers (Zhang et al., 2018). It is also worth taking note as paragraph 10.5 in Agenda 21 mentioned that the comprehensive objective is to enable the development and usage of the land to deliver the maximum sustainable paybacks.

The emissions of greenhouse gases have created a variety of issues and problems, particularly from the social aspects, global warming, lack of energy supplies, which has contributed to greater recognition and support for green and sustainable growth, leading to extensive concern towards sustainable development by policymakers and public across the globe. Green building or sustainable construction does not solely emphases on energy saving results and carbon emission control, for instance improving energy and water usage, improving indoor air quality and

reducing environmental contamination, it correspondingly concentrates on the economic and social sustainability growth and progress (Wang et al., 2020). According to Gourlis and Kovacic (2017), Green buildings as an effort of sustainability aims to reduce the environmental issues for instance climate change and global warming. These environmental issues are the consequences of surging in the usage of energy. As a result, energy consumption becomes an important issue to be emphasized across the world.

Looking into the perspective of building energy performance, the performance gap, which indicate the difference between the predicted energy performance and the actual energy performance (De Wilde, 2014). This is crucial to identify whether the designed building is truly efficient. Innovative approaches, in particularly Building Information Modelling (BIM), are increasingly expanding to implement in building and construction industry (Gholizadeh et al., 2017).

Ganiyu et al (2020) stated that the primary focus of BIM is to standardize construction works by increased effective collaboration and a provide a consistent understanding of the priorities at the initial phases of the project and development. Therefore, BIM is providing a conceptual change from the conventional model of only storing work information to a collective approach that uses the digital representation of the project and development. According to Akinade et al (2018), major elements where BIM's technologies may contribute to accomplish a circular economy in construction involve automated clash identification, design error mitigation, initial collaboration between stakeholder, simulation, waste modelling and waste management report. Furthermore, Building Information Modelling (BIM) is increasingly recognized as a great deal of interest in industry and research studies. BIM has long played a crucial role in the design and maintenance of structures, at least in building architecture (Hegemann et al., 2020). In this context, this study integrates BIM and energy analysis tools to explore the energy performance analysis using the case study of eco-home in UTM.

1.2 Problem Statement

Energy efficiency is one of the most important issues globally, as the rapid depletion of non-renewable resources due to high amount of energy consumption by the world population (Fathi et al., 2020). With this context being portrayed, it is evident that buildings do play a crucial role in improving the energy performance rather than the elements of processes or technologies (Fichera et al., 2020). However, it has also been apparent to the emergence of an issue on the accuracy of energy performance measurement and difficulties of collecting the data. As supported by Cho and Kim (2019), the limitations of assessing the energy performance of existing buildings accurately and mainly includes the physical deterioration of the building materials as time goes by. In addition, the actual working conditions of the existing building may differ from the documented as-built data. To further support this particular stand, Burman et al. (2014) stated that the lack of adequate data for further analysis largely contributed by deteriorated performance issues, loss of data which greatly affect the accuracy of the analysis conducted. Furthermore, the issues of inadequate forecast of energy consumption at the design stages and lack of method to manage the building performance at the operational stage are also identified as the issues in assessing energy performance.

In order to assess the large pool of data collected in existing building to analyse the energy performance, an effective tool is much required. Bakar et al. (2015) founded that computer technology application is a very effective tool as it is user-friendly and cost effective for energy performance analysis. In this context, BIM is an effective tool as it has the ability to store design information which are relevant to every design and management process. Therefore, BIM is introduced in this study to assist in the energy performance management as it is time and effort saving which at the same time help to prevent variations and mistakes from occurring. As supported by Utkucu and Sözer (2020), BIM is also known to be able to represent the actual condition of the building from time to time as the model is being updated accordingly. Moreover, BIM is able to offer continuous energy efficiency monitoring over the entire building life cycle.

1.3 Research Questions

This study believed that there are potential benefits of Building Information Modelling (BIM) integration in Energy Performance Analysis. In order to scope down the direction of this study, three research questions were formulated:

1. What is the highest energy consumption equipment in a building?
2. What is the differences between the simulated values from BIM with the actual measured data of electricity production.
3. What recommendations should be proposed to optimise the building energy performance.

1.4 Research Objectives

The aim of this study is to investigate the potential benefits of Building Information Modelling (BIM) integration in Energy Performance Analysis using the case study of Eco-Home at Universiti Teknologi Malaysia (UTM). In order to achieve this specific goal, three objectives are formulated:

i.) to identify the highest energy consumption equipment in a building.

ii.) to compare and contrast the simulated values from BIM with the actual measured data of electricity production.

iii.) to propose recommendations to optimise the building energy performance.

1.5 Scope of Study

The scope of research in this study is in the Universiti Teknologi Malaysia (UTM). This study concentrates on exploring the energy performance of Eco-Home using Building Information Modelling (BIM) in UTM. This study is constraint only to analyse the energy performance of existing Eco-Home building using Autodesk Revit and Green Building Studio.

1.6 Brief Research Methodology

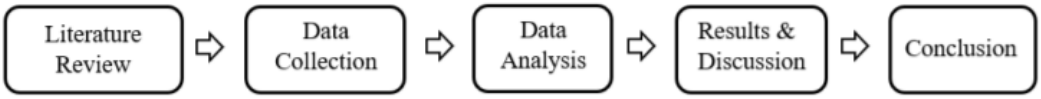

Figure 1.1 Research flow chart

Figure 1 briefly shows the flow of how this study being achieved. First, in literature review, books and journals related and associated to Building Information Modelling (BIM) and energy performance will be critically reviewed across reliable and dependable published sources. Later, data regarding to the case study of Eco-Home will be collected for the purpose of generating and creating Building Information Modelling (BIM) model through Autodesk Revit software. A site visit at Eco-Home would be carried out to collect data and information about the building and to identify the high energy consumption equipment in a building which is the first objective of this study. Autodesk Revit, a Building Information Modelling (BIM) software is used in this study to develop a Building Information Modelling (BIM) model. After completion of Revit Building Information Modelling (BIM) model, the file is exported as gbXML. file for further analysis in Green Building Studio. Then, the energy analysis will be generated in Green Building Studio. The results of the simulation will be recorded and documented. Lastly, a discussion regards to the results obtained will be carried out before making the mark to the conclusion of this study.

1.7 Significant of Study

Building Information Modelling (BIM) is now a modern technological system and strongly appreciated by the building industry and regulatory agencies. BIM is a breakthrough technique and process. It is an advancement, offering an accordingly important potential for the architectural, engineering, and construction (AEC) industry especially in this era of technology. Through the utilisation of the

BIM technology, project owners, contractors and builders will be able to enhance the sustainability of buildings throughout the lifecycle of a project.

As sustainability is gaining more attention from the public and construction sector as a main contributor to a certain extent of the global environment issues, it is important for fostering the partnership between BIM and green buildings to achieve greater benefits. Through creating an efficient and innovation work culture with BIM, a quality improvement mechanism will enhance communication between owners, managers, architects, engineers, builders, and other stakeholders. Thus, more studies about the impact of these principles will be conducted to promote the effective adoption of BIM.

1.8 Summary

This chapter covers a brief background of this research followed by defining the aim and objectives. Then, the scope of this study has been identified to achieve the aim and objectives. The outline of research methodology has stated to evaluate how this study is being conducted. Besides, thesis outline is being done to provide a basic introduction to every chapters. The next chapter in this research will be discuss about the detailed review of the topic.

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