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Building Information Modelling for Building Energy Efficiency Evaluation

Integration with Green Building Index (GBI) in Malaysia

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***Abstract*— Due to the arising concern for sustainability in built environment, numerous green building certification and rating systems are available throughout the world including Green Building Index (GBI) and GreenRE which were introduced in Malaysia in 2009 and 2013 respectively. However, the current methods of measuring, analysing and documenting the green building design rely on a number of disjointed processes to meet the discrete requirements for various building systems. The development of Building Information Modelling (BIM) technology has made it easier to get complicated building modelling be digitally constructed, generating all required information to support green building design and assessment throughout various design stages. Thereby the aim of this research is to integrate BIM and green building certification in Malaysia, using GBI as a unique case. Firstly, Green Building Index (GBI) and related guidelines were reviewed. Secondly, functionalities of BIM software (Autodesk Revit) were studied and compared to GBI assessment criteria. Finally a generic BIM-GBI model was developed based on the matchup of GBI credits and the functionality of Revit, focusing on the first category of GBI, which is Energy Efficiency (EE) and holds 35% of total points in GBI. The proposed BIM-GBI (EE) model was preliminarily validated by creating a use case of GBI sub-category EE1. The fundamental contribution of this research will be the unique approach it proposed to fulfil green building certification such as GBI by integrating functionalities of BIM.**

Keywords-sustainability; green building certification; Revit; OTTV

I. Introduction

Studies have shown that the building industry is one of the largest users of energy, also CO_2 emitters in the world. So, with respect to such significant influence of the building industry, a lot of efforts have been made on finding appropriate strategies and actions to decrease energy consumptions and environmental impacts of the buildings [1]. The architects, designers and green consultants who are the main decision makers in sustainable building design projects, have a great opportunity to cut down on future energy consumptions and environmental impacts of the buildings by making the right decisions in the early stages of the design.

In order to assess the success of a construction project in achieving sustainability, there should be a rating system, which the decision makers can use to analyse the interactions of the potential design variables available to them to predict the building performance trends [2,3]. With a predictive assessment of the building performance, the decision makers can put forward strategies and methods in their decisions to improve the building performance in a more cost-effective way [1]. In the past 20 years, numerous certification and rating systems such as LEED in the US; BREEAM in the UK; Green Mark in Singapore; Green Star in Australia, Green Building Index (GBI) [1] and GreenRE [2] in Malaysia are available throughout the world for sustainable building to facilitate evaluating sustainable building design and construction.

The term ‘sustainability’ comprises a wide range of components: environmental quality, society well-being, and economic stability. Ecological considerations, resource efficiency and CO_2 and other GHG emissions reduction

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should be considered in sustainable building design projects paralleled with improving the indoor environmental quality and harmonization with the environment. These components often lead to conflict; therefore, it is very difficult to integrate these components into a single green rating [4].

With the latest development of building information modelling (BIM) tools and technology, all information or data related to a building, including its physical features, performance during its life cycle, can be digitally represented in a single model. Thus, integration of BIM and green building are able to best address the unprecedented challenges in productivity and sustainability encountered by the AEC industry. Nevertheless, till today there is no standard workflow for BIM-based modelling especially for green building design and assessment in Malaysia. Thus more efforts are needed to further develop model or framework for integration of BIM and green building certification. Thereby, this study aims to integrate GBI and BIM functionalities with the consideration on the tropical climatic contexts in Malaysia. This study focuses on Energy Efficiency (EE) category which consists of 35% of the total points to achieve in GBI.

The main method applied to develop the BIM-GBI (EE) model was reviewing a vast range of literature related to the subject along with GBI and other rating systems and related guidelines, followed by studying the functionalities and capabilities of Autodesk Revit. Then, matchup and comparing GBI criteria with BIM functionalities were made to formulate the model. Lastly, validation of the model was done through modelling a hypothetical template in Revit, considering the tropical climatic context of Malaysia, to demonstrate the application of the proposed model in sustainable building design projects.

II. LITERATUE REVIEW

A. *Green Building Index (GBI)*

In many countries, sustainable building certifications and rating systems have been developed to facilitate the pursuit of sustainability in the building projects. The first founded certificate was BREEM in UK, 1990 and after that LEED was compiled in the USA, 1996 [4]. Some other rating systems are Green Mark in Singapore and Green Star in Australia. In Malaysia, Green Building Index (GBI) [5] is one of the guidelines being adopted by the building industry since it was jointly founded and developed by Pertubuhan Akitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) in 2009. GBI and GreenRE, both are sustainable building rating systems for non-residential new construction, residential new construction, and existing non-residential buildings. Some of the criteria in GBI and GreenRE actually used the benchmarks as stated in MS 1525 such as overall thermal transfer value (OTTV) and roof thermal transfer value (RTTV).

GBI has six major parts consisting of Energy Efficiency (EE), Indoor Environmental Quality (EQ), Sustainable Site Planning & Management (SM), Materials & Resources (MR), Water Efficiency (WE) and Innovation (IN). However, its scoring priorities are very much customised for the current state of Malaysia where a lot of priority is given to energy and water efficiency scores [5]. So, the analysis and decision making in the early levels of development of a building design, are required to compare the building performance with the sustainable rating systems.

B. *Building Information Modelling (BIM)*

Currently, plenty of definitions related to BIM have emerged with different perspectives [6]. On one hand, BIM is defined as a prototype or a virtual model, of which includes precise geometry and data which are required for a design project. For example, according to the U.S. National BIM Standard in 2007 [7], BIM is “a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle” [6]. On the other hand, the term ‘BIM’ is used to describe the activity of modelling building information. Eastman et al. [8] defines BIM as “a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation”. Considering both types of the definitions, it is noted that BIM is not just a software; in fact, it is a process that runs through software [9]. So, in this study, ‘BIM’ is used to refer to both the digital and virtual representation/model of a physical building and the activity of modelling.

“Green BIM” is a term to define how BIM contributes the process of achieving green or sustainable building design and construction. Numerous studies have been conducted to show how BIM adoption in early stages of sustainable design will improve the efficiency and effectiveness of the project delivery process. One of the important factors in achieving a sustainable built environment is early collaboration and open information sharing among all team members [10]. BIM with sharing digital modelling and energy performance analysis tools can form an efficient basis for collaborations among all members, also it can reduce the work that is required to evaluate multiple design alternatives in order to improve the sustainability assessment process [11].

Previous survey finding shows that green BIM practitioners believe BIM can play a key role in achieving sustainability [10]. BIM can facilitate the major actions which green BIM practitioners deal with. Sustainable building strategies are mostly related to carbon emission, energy use, cost savings and indoor air quality, through study of building orientation, building massing, daylighting, natural ventilation, water harvesting, energy modelling and implementing renewable energy resources [12–14]. Matching design variables with the building performance by using various simulation and analysis BIM tools will allow the decision makers to refine their green building strategies. As a result, the demand for heating, cooling, ventilation and electrical loads will cut off in large scale [12], [15].

C. BIM and Sustainable Building Rating Systems

Recent progress in implementing BIM in sustainable building design and analysis has been followed by conducting much research into the potential of extracting the data from a BIM model for building performance and green rating assessment. Azhar et al. [16], Wu et al. [17] and Toroghi [18] had studied the relationship between BIM functionalities and LEED credits in the US. The findings show that BIM tools can facilitate the preparation of required documents for LEED credits directly or indirectly.

In another research, Bank et al. [11] has worked on developing a BIM-based decision-making framework for sustainable building design and operation using System Dynamics. This framework is designed to assist the design decision makers in earlier design stages based on the specific sustainability trade-off analyses conducted. However, it was specifically developed for LEED credits.

Kim et al. [19] has developed a Green BIM Template (GBT) working with Green Building Certification Criteria (GBCC) in South Korea. This template is mainly focused on environmental issues, connected to GBCC. Through this GBT, data from a BIM model can be extracted for rapid response to GBCC requirements.

To solve the challenges of BIM adoption in sustainable building projects, much research was also been conducted to develop applicable prototype workflow to apply BIM in sustainability analysis in all stages of a building life cycle [20]. Nevertheless, this research is focusing on temperate climate. Besides, they are still in preliminary stages and further study is required to develop more matured prototype or tools.

Considering the tropical climate in Malaysia, Lim et al. [21] and Lim and Shahsavari [22] had conducted research to develop a BIM-based process driven design framework for sustainable building design decision making. The proposed framework has addressed the difficulties and challenges of design decision making in schematic design and design development stages, considering the points and criteria of regional standards and certifications, such as MS1525 and GBI. The findings have been presented in a detailed framework including all design variables and objectives that need the decision makers to consider. This research has mainly addressed the design stage and further studies is needed to be conducted on the sustainable building analysis and assessment process.

III. BIM-GBI Integrated Model

A. Comparing GBI criteria and BIM functionalities

The review of several regional sustainable building certification systems and literature has highlighted the significance of building energy performance in sustainable building design. Considering GBI criteria [23], 35% of GBI points are allocated to Energy Efficiency (EE) for non-residential new construction (NRNC). Table 1 shows the overall points score of GBI NRNC.

TABLE I. GBI (NRNC) Overall Points Score [23]

Part	Item	Maximum Points
1	Energy Efficiency (EE)	35
2	Indoor Environmental Quality (IEQ)	21
3	Sustainable Site Planning & Management (SM)	16
4	Material & Resources (MR)	11
5	Water Efficiency (WE)	10
6	Innovation (IN)	7
	Total Score	100

There are 9 sub-categories of GBI energy efficiency (EE). For each of these sub-categories certain documents are required to be submitted for design assessment (DA) in order to achieve the points. The description and requirements for each sub-category of EE are summarised in Table II. The match-up between GBI criteria in EE1 and BIM (Autodesk Revit) functionalities is as shown in Table III. The findings showed that 25 out of the 35 points (or 71.4%) can be directly evaluated by BIM; while 3 points (or 8.6%) can be indirectly evaluated by BIM. The BIM process was proposed to prepare the required documents by using Revit or additional external tools. The match-up has been employed to develop BIM-GBI (EE) model with Revit templates for validation.

TABLE II. DESCRIPTION AND REQUIREMENTS OF GBI (EE) SUB-CATEGORIES [23]

Sub-category	Description & Requirement	Required Submission for Design Assessment (DA)	Max. Point
EE 1: Minimum EE Performance	i. To create energy efficiency (EE) awareness. ii. To establish minimum EE performance in order to reduce energy consumption in buildings; thus reducing CO2 emission to the atmosphere. iii. To promote the use of MS 1525: Meet the minimum EE requirements as stipulated in MS 1525: OTTV ≤ 50, RTTV ≤ 25.	1. Plans and elevations marking out walls & apertures used for the calculation coloured blue; and walls & apertures not used for calculation coloured red. Recommended scale 1: 200. 2. OTTV calculations for each facing wall and roof. 3. Description of wall & aperture materials specified. 4. Calculations of U-values for roof and walls. 5. Proposed Glazing specifications on Shading Coefficient, R value, U-value and Visible Light Transmission. 6. Confirm provision of Energy Management System where air conditioned space ≥ 4000m².	1
EE 2: Lighting Zoning	i. Provide flexible lighting controls to optimise energy saving: More flexibility for light switching in Lighting Design Practices, making it easier to light only occupied areas.	1. Drawings of floor plans clearly showing every proposed individually switched lighting zone and its coverage area (the size of individually switched lighting zones shall not exceed 100m² for 90% of the NLA; with switching clearly labelled and easily accessible by building occupants).	1
		2. Electrical schematic drawings showing the locations and extent of switching, the area controlled by the switch and automated control sensing system detailed (provision of auto-sensor controlled lighting in conjunction with daylighting strategy for all perimeter zones and daylit areas, if any).	1
		3. Report to include the areas of all switched zones and confirmation that the total areas meet the percentage NLA requirements (provision of motion sensors or equivalent to complement lighting zoning for at least 25% NLA)	1
EE 3: Electrical Sub-metering	i. Provide sub metering for monitoring energy consumption of key building services as well as all tenancy areas by tenants or end users	1. An extract from the specification detailing the installation requirements for electrical sub-meters that meet the credit criteria (where energy use ≥ 100kVA; with separate sub-metering for lighting and separate for power at each floor or tenancy, whichever is smaller). 2. Clearly marked electrical schematic drawings showing the proposed locations of meters and the usage served by those meters.	1
EE 4: Renewable Energy	i. To promote the use of all forms of renewable energy (especially BIPV in Malaysia) so as to reduce environmental impact and emission of CO_2.	1. Plans and elevations marking out areas allocated to house renewable energy equipment. 2. Describe proposed technology to be used, including documenting total kWp or predicted equivalent energy in kWh. 3. Predicted total electricity consumption by the building and percentage of renewable energy to be generated.	5
EE 5: Advanced EE Performance - BEI	i. Exceed Energy Efficiency (EE) performance better than the baseline minimum to reduce energy consumption in the building- Mall/ retail	1. Plans and elevations marking out walls & apertures used for the calculation coloured blue; and walls & apertures not used for calculation coloured red. Recommended scale 1: 200. 2. BEI calculations for each facing wall and roof. 3. Description of wall & aperture materials specified. 4. Calculations of U-values for roof and walls. 5. Proposed Glazing specifications on Shading Coefficient, R value, U-value and Visible Light Transmission. 6. Confirm provision of Energy Management System where air conditioned space ≥ 4000m². 7. Submit predicted BEI calculations.	15
EE 6: Enhanced Commissioning	i. To ensure building's energy related system are designed and installed	1. Confirmation letter from the Commissioning Specialist (CxS) of his appointment and scope of works in accordance with the GBI CxS requirements.	3
EE 7: Post Occupancy Commissioning	i. To ensure proper design and commissioning are carried out during and after fit-outs (if any)	1. Declaration that post occupancy commissioning will be undertaken.	1
		2. After 50% Occupancy- performance verification within 12months	1
EE 8: EE Verification	i. To provide for the ongoing accountability of building energy consumption over time.	1. Declaration of commitment to carry out EE verification upon completion.	2
EE 9: Sustainable Maintenance	1. To ensure the building's energy related systems will continue to perform as intended beyond the 12 months Defects & Liability Period.	1. Identify building maintenance room and facilities in the design floor plan.	2
		2. Commitment to engage at least 50% of permanent building maintenance team before practical completion with organisation chart and staff positions identified.	1
		3. Commitment to provide evidence of documented plan for at least 3-year facility maintenance and preventive maintenance budget (inclusive of staffing and outsourced contracts).	
		Total GBI (EE) Points	**35**

TABLE III. MATCH-UP OF GBI (EE) SUB-CATEGORIES REQUIREMENT AND BIM (REVIT) FUNCTIONALITIES

Sub-category	Can it be evaluated by BIM (Revit)	BIM Process	External Tools Needed	Max. Point
EE 1: Minimum EE Performance	Yes	1. Modelling (create Floor plans and Elevations). 2. Create Material Takeoff schedule. 3. Create Wall schedule and Roof schedule. 4. Create Window schedule. 5. Create zoning to specify the A/C space area 6. Extract information from Wall schedule (absorptivity, u value, WWR, SC, OF) and Window schedule (window area, SC, U value) to Excel or key in the information in BEIT in order to calculate OTTV.	EXCEL, BEIT (mentioned in GBI).	1
EE 2: Lighting Zoning	Yes	1. Modelling (create Floor plans, showing enough evidence in the floor plans)		1
	Yes	2. Duplicating the floor plans (create Electrical floor plans, identifying controlled area by the switch)		1
	Yes	3. Checking the Electrical floor plans and conducting the report through Room Schedules.	Office Word	1
EE 3: Electrical Sub-metering	Yes	1. Modelling (create Electrical floor plans, identifying electrical sub-meters). 2. Marking locations of meters by Tags.		1
EE 4: Renewable Energy	Yes	1. Modelling (create Roof plans and Elevations); 2. Create PV families in Revit; 3. Create Roof Schedule to show Roof Area, PV area, Rule of thumb, Energy generated, OF, Actual Energy generated, Total Energy consumption, Actual Energy generated/ Total Energy % and GBI points.		5
EE 5: Advanced EE Performance - BEI	Yes	1. Modelling (create Floor plans and Elevations). 2. Extract information from Wall schedule (absorptivity, u value, WWR, SC, OF) and Window schedule (window area, SC, U value) to Excel or key in the information in BEIT in order to calculate BEI. 3. Create Material Takeoff schedule showing EE material specification. 4. Create Wall schedule and Roof schedule. 5. Create Window schedule. 6. Create zoning to specify the A/C space area. 7. Create a schedule showing BEI calculations.	EXCEL, BEIT (mentioned in GBI).	15
EE 6: Enhanced Commissioning	No	N/A		3
EE 7: Post Occupancy Commissioning	No	N/A		2
EE 8: EE Verification	No	N/A		2
EE 9: Sustainable Maintenance	Indirectly	1. Model building maintenance room and facilities in the design floor plan		3
			Total GBI (EE) Points	**35**
			Total GBI Points can be directly evaluated by Revit	**25**
			Total GBI Points can be indirectly evaluated by Revit	**3**

B. BIM-GBI (EE) Model with Revit Template

Green building design project can be assessed according to the proposed BIM-GBI (EE) model using Autodesk Revit. In this study a hypothetical building was modelled using Revit (as shown in Figure 1) with consideration of tropical climate in Malaysia. In the Revit model, EE1 was studied to demonstrate an example of the process of extracting required information from a BIM model to facilitate evaluation of a building design according to GBI criteria.

As shown in Table II, the main intent of EE1 is to create energy efficiency (EE) awareness and promote the use of MS 1525. The ultimate aim of this criteria is to minimise energy consumptions and CO_2. According to GBI NRNC V1.05 [23], the submission requirement for design assessment to achieve the EE1 credit are as follows:-

1. Plans and elevations marking out walls & apertures used for the calculation coloured blue; and walls & apertures not used for calculation coloured red.
2. OTTV calculations for each facing wall and roof.
3. Description of wall & aperture materials specified.
4. Calculations of U-values for roof and walls.
5. Proposed glazing specifications on Shading Coefficient (SC), R-value, U-value and Visible Light Transmission.
6. Confirm provision of Energy Management System where air conditioned space $\geq 4000m^2$.

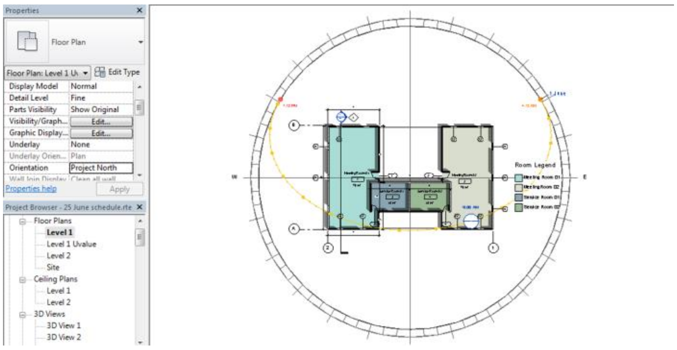

Figure 1. Revit model for GBI evaluation

To achieve EE1 criteria, Overall Thermal Transfer Value (OTTV) calculation according to MS1525 [24] shall be computed. One (1) GBI point can be earned with OTTV equal or less than 50 W/m^2. The equation to calculate OTTV is as below:-

$$OTTV_i = 15\,\alpha\,(1 - WWR)\,U_w + 6\,(WWR)\,U_f + (194 x OF x WWR x SC)$$

where:
WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;
α is the solar absorptivity of the opaque wall;
Uw is the thermal transmittance of opaque wall (W/m2 K);
Uf is the thermal transmittance of fenestration system (W/m2 K);
OF is the solar orientation factor; as in Table 1; and
SC is the shading coefficient of the fenestration system.
SHGC is solar heat gain coefficient where SHGC = SC x 0.87.

As an example of the proposed BIM-GBI (EE) model application, Figure 2 shows the drawing created using the Revit model to fulfil the EE 1 submission requirement. The required data for OTTV calculation such as SC, R-value, U-value and solar absorptivity was extracted using Revit schedules as shown in Figure 3 and 4. The data can be directly exported as .txt file to calculate OTTV using other software such as Excel or BEIT.

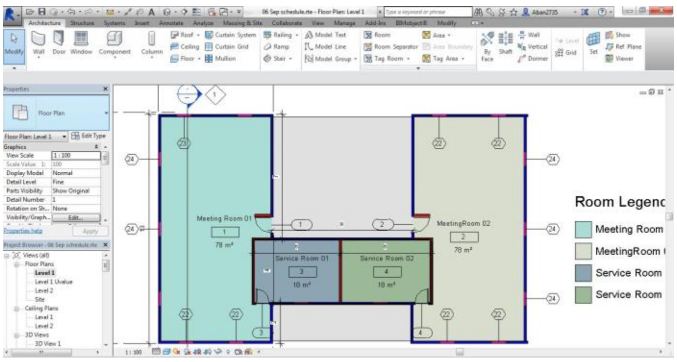

Figure 2. Revit model: EE1, requirement 1

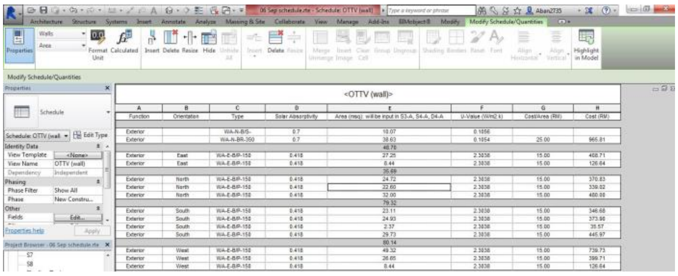

Figure 3. Revit schedule: EE1, requirement 2-1

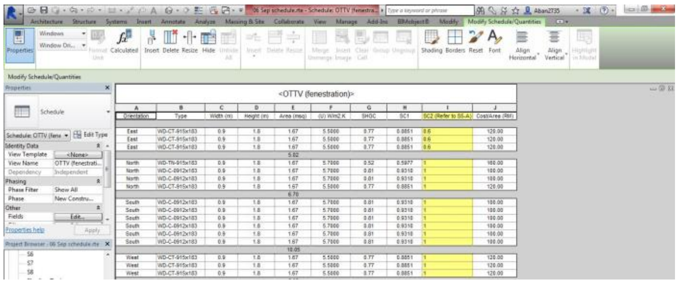

Figure 4. Revit schedule: EE1, requirement 2-2

IV. CONCLUSION

This research aims to integrate BIM in assessing building energy efficiency according to EE criteria in GBI. The objectives and requirements of the first part of this criteria, known as EE1, was considered as the main focus to develop a model in which BIM applications were compared to the requirements of each credit in GBI. The findings reveal that 25 out of 35 points scores can be directly evaluated using BIM tools and 3 more points can be assessed indirectly using BIM. This demonstrated a great potential in BIM adoption for sustainable building evaluation.

A BIM-GBI (EE) model was proposed to facilitate evaluating sustainable building design based on Green Building Index (GBI). The proposed model was validated by creating a Revit template and presenting all required information to achieve the points for EE1, focusing on OTTV calculation. However, the key note to consider is that neither of the model nor the template were developed to make the design decisions. But, they are developed only to facilitate the process of evaluating the building design based on GBI criteria, for the architects, green consultants and all members of immediate and extended design project teams. This study can be further developed for the rest of GBI points and criteria.

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