A BIM-Based Automated Assessment Tool for Green Building Index

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Abstract. In Malaysia, Green Building Index (GBI) is one of the sustainability rating tools for the construction industry, focusing on six main categories including Energy Efficiency (EE), Materials and Resources (MR), Water Efficiency (WE), Indoor Environment Quality (EQ), Sustainable Site Planning & Management (SM) and Innovation (IN). Currently, the process for GBI assessment and certification is carried out manually, which requires additional time and effort for preparation of supporting documents. Since Building Information Modelling (BIM) is perceived as a holistic solution for digital integration of various construction project attributes, it is anticipated that sustainability aspects can be addressed through BIM if an appropriate approach is implemented. Therefore, GBI assessment process can potentially benefit from BIM application to transition from conventional manual approach to an automated approach. This research is aimed at developing an Automated Green Building Assessment tool (AGBIA) using visual programming (Dynamo) to run as a supplementary application to the existing BIM authoring software (Revit). The AGBIA system consists of 6 modules that automatically analyses digital BIM models in accordance to GBI requirements, and ultimately produces the necessary documentation as a final output. AGBIA is an efficient supporting BIM tool as compared to assessment and documentation of green building data manually.

1. Introduction
In Malaysia, GBI has been introduced to be the driving initiative for the construction industry to incorporate environment-friendly features that will have a positive impact in the long term. Energy Efficiency, Materials and Resources, Water Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management and Innovation are the categories that must be evaluated for GBI certification. Upon assessment of the design details and supportive documents for each category, allocated points will be granted at the design stage, followed by another round of verification upon project completion. Currently, the GBI process for green building assessment and certification is carried out manually, which requires additional time and effort for preparation of supporting documents especially with large and complex projects. Combining several building features from different disciplines demands for tools and technology that can ensure well connectivity [1]. Many researchers have highlighted the need for BIM application to overcome some of the barriers in delivering green buildings since BIM is known to be an efficient tool that integrates various building aspects digitally. Ayman, Alwan and McIntyre [2]
anticipated the direct impact of BIM utilisation on the sustainability barriers would be a reduction in time and cost due to better design coordination and effective decision making during the design phase. Based on the review conducted by Lu, Wu, Chang and Li [3], the application of popular BIM tools for green building assessment however, are limited to specific regions only. Although the GBI assessment process can be accelerated with the utilisation of existing tools and software, the available tools are based on sustainability assessment guidelines that are not entirely in line with GBI requirements in terms of local references and baselines, as well as method of calculation, analysis and documentation. Therefore, there is a need to identify appropriate methods for integration and automation of GBI assessment with available BIM authoring tool to address local standards for green building design. In order to propose an automated BIM-based approach for green buildings in Malaysia, the following objectives must be achieved:

- To design a BIM template addressing green property sets in accordance to GBI
- Automatic assessment of green data extracted from a standard BIM model
- Automatic production of documentation for green building assessment

To accomplish the above objectives, this research is aimed at developing an Automated Green Building Index Assessment (AGBIA) tool that automatically analyses BIM models in accordance to the GBI requirements, and ultimately produces the documentation/report as a final output. AGBIA is an efficient alternative as compared to assessment and documentation of green building data manually.

2. Literature Review
The application of BIM for green building assessment has been investigated by number of researchers. Revit as a widely used BIM authoring tool has been explored and evaluated for integration with various green building rating systems. Table 1 contains a summary of researchers who introduced technical strategies for integration of BIM with various green building rating systems. For instance, Azhar et al. [4] demonstrated that 17 LEED points and 2 prerequisites can be directly assessed via Revit and IES-VE default functionalities. Furthermore, Barnes and Castro-Lacouture [5] optimised a similar process in Revit by proposing an additional LEED toolbar for Revit users. Meanwhile, Wong and Kuan [6] utilised user defined Revit features such as custom parameters and schedules for BEAM-Plus assessment. Alternatively, a number of researchers opted for external tools to assess the information extracted from the BIM models [7-9]. From a regional perspective, the developed tools are limited to local green building guidelines, standards and baselines. Therefore, in terms of regional relevancy, the methods explored by Lim et al. and Khoshdelnezamiha et al. [8-9] are more applicable. In order to optimise the existing methods, an alternative approach is proposed to gain direct access to the building data and process the information rapidly without the use of any external tools.

Table 1. Summary of previous studies related to BIM application for green building assessment.

| Author          | Rating System | Region     | Points                  | Tool Used                     |
|-----------------|---------------|------------|-------------------------|-------------------------------|
| [4]             | LEED          | US         | 17 points and 2 prerequisites | Revit and IES-VE            |
| [5]             | LEED          | US         | 13 points and 1 prerequisite | Revit                        |
| [6]             | BEAM-Plus     | Hong Kong  | 26 points               | Revit                        |
| [7]             | BREEAM        | UK         | 14 points               | ArchiCAD and GBAT            |
| [8]             | GBI           | Malaysia   | 28 points               | Revit, Excel and BEIT        |
| [9]             | GBI           | Malaysia   | 56 points               | Revit and GBI Document Assessor |

3. Methodology
The AGBIA system design consists of 6 modules that automatically analyses BIM models in accordance to GBI requirements. Autodesk Revit was the selected BIM authoring tool for this methodology, as it is
commonly used in Malaysia. In order to achieve an automated assessment process for the users, AGBIA was designed using Dynamo, a visual programming tool. Figure 1 illustrates the process involved with developing AGBIA. The AGBIA development process began with identifying GBI assessment subcategories. Subsequently, a set of green parameters was designed to be further assigned with values either by default (using AGBIA built-in database) or by the user. Afterwards, the green data was collected and sorted to be processed through defined calculation. The processed green information was further evaluated based on conditional statements retrieved from GBI assessment guideline. Finally, the result containing provisional GBI points and summary of green building features and design calculation was exported as supporting documents for the certification.

Figure 1. AGBIA system design flowchart.
4. Verification
The practicality of the developed AGBIA was evaluated by applying it on a sample BIM model. In order to verify the results obtained, similar building was assessed via the conventional method. The conventional approach involved manual extraction and calculation to obtain benchmark values for comparison. Some GBI assessment categories were verified using the available GBI excel calculators such as Building Energy Information Tool (BEIT). Although such conventional calculators can produce rapid outputs, the user is required to manually provide several design inputs as well as general project information. This by itself can be tedious and hinders the automation process of linking design data with the calculator engines. Therefore, in this paper, it is considered as a conventional approach in relation to the fully automated process proposed.

5. Results and Discussion
A sample building model was analysed by AGBIA. The automated process eliminated the need for manual design data extraction and calculation. For demonstration purposes, the Overall Thermal Transfer Value (OTTV) was selected as one of the GBI EE subcategory. Figure 3 demonstrates the automated identification of relevant BIM elements such as external façade, external windows and shading devices required for the assessment of OTTV. The AGBIA report provided a summary of building data such as façade area, orientation, heat transfer coefficients and shading coefficients extracted from the sample BIM model (Figure 4). In order to verify the calculation carried out by the designed tool, the OTTV of the similar model was manually calculated using the BEIT tool. The BEIT calculation for OTTV was 53.83 W/m$^2$ whereby the AGBIA estimation was 51.91 W/m$^2$. The differential error of 3.57% is due to limitations in parametric inputs from the conventional method. The BEIT calculation input assumes constant values for each façade orientation which makes it more suitable for simplified designs. The AGBIA on the other hand, is intended to calculate parametric items individually and take the average values of the respective orientations, thus making it more practical for complex designs. For instance, the use of external shading devices for the east and west facades in the sample model were inconsistent which resulted in different shading coefficient values in each method.

6. Conclusion
The feasibility and potential for application of green BIM for various sustainability rating tools was demonstrated in the literature study. Similar to the well-known rating tools such as LEED and BREEAM, GBI as a Malaysian rating tool can automated and be integrated with BIM. Upon investigating the GBI assessment guideline and submission requirements, a set of standard property sets were identified as a green project template. Visual programming was incorporated to develop a
supporting tool for Revit called AGBIA to automate the process of creating Revit green project template (RGPT) as well as to extract, interpret and process green data from a BIM model [9]. The final output from AGBIA is a report containing provisional GBI rating and a set of design calculation that can be used as supporting documents for GBI assessment. Incorporating AGBIA at the design stage can optimise the utilisation of BIM authoring tool to assist designers in automatic assessment and documentation of green buildings.

**Figure 3.** Sample BIM model before and after AGBIA OTTV analysis.

**Table 1.** Heat Conduction Through Walls

| Orientation | Total Facade Area | WWR | U-factor | Thermal Transfer Value (OTTV) | A x OTTV |
|-------------|-------------------|-----|----------|------------------------------|----------|
| N          | 3128.72           | 0.47| 0.81     | 3.30                         | 10822.34 |
| E          | 527.17            | 0.47| 0.35     | 3.35                         | 1766.85  |
| S          | 2948.27           | 0.47| 0.35     | 3.35                         | 9857.81  |
| W          | 719.85            | 0.33| 0.30     | 4.23                         | 3009.38  |
| NE         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| SE         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| NW         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| SW         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |

**Table 2.** Heat Conduction Through Windows

| Orientation | Total Facade Area | WWR | U-factor | Thermal Transfer Value (OTTV) | A x OTTV |
|-------------|-------------------|-----|----------|------------------------------|----------|
| N          | 3128.72           | 0.47| 0.70     | 19.10                        | 95718.76 |
| E          | 527.17            | 0.47| 0.70     | 18.75                        | 9690.81  |
| S          | 2948.27           | 0.47| 0.70     | 18.75                        | 52204.09 |
| W          | 719.85            | 0.33| 0.70     | 13.34                        | 9226.32  |
| NE         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| SE         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| NW         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |
| SW         | 0.00              | 0.00| 0.00     | 0.00                         | 0.00     |

**Figure 4.** Sample report produced by AGBIA.

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