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An Innovate and Sustainability of Green Building Design Support System Based on BIM and LEED

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ABSTRACT: The green building design movement has gained major importance in the field of architecture. Meanwhile, with the development of **Building Information Modelling (BIM)** technology, a more integrated and interactive approach for building design, construction, and operation is emerging. In this research, a BIM-based approach to automate the design assessment process has been proposed to facilitate the green building design evaluation. It proposes integrating BIM and green building rating system (i.e., LEED) to provide an automatic assessment of the design. The paper proposes an extension to BIM tools which automatically assess the design and provides real-time feedbacks. The tool also provides designers with guidelines about green building design. It is expected to help them designing high performance and sustainable buildings by making more informed decisions early in the design process. A BIM model of a villa is used as the case study to investigate the feasibility of the proposed method using a selection of LEED credits.

KEYWORDS: Building Information Modelling (BIM), LEED, Green building design, Green building assessment

I. INTRODUCTION

Building a sustainable human living environment is the fine goal of architecture, engineering and construction (AEC) industry in the 21st century. Recently, with the rising concerns about excessive energy consumption and pollution, it is of great importance to follow green practices.

Green building is a clean and sustainable building using renewable materials and energy-saving technology, and is easy to maintain and available at a reasonable cost (Smart Market Report, 2010). The development of green building is growing and it complements conventional concerns of designing buildings that are economical in energy, sustainable and comfortable (Barnes and Castro-Lacouture, 2009). The construction industry began to use Building Information Modeling (BIM) technology to support green building design analysis.

BIM technology is an integrated, interactive, virtual approach to building design, construction and operation (Eastman et al., 2011). The Industry Function Classes (IFC) data model is a BIM standard to describe building and construction data, and it is commonly used as a collaboration format in BIM systems (buildingSMART, 2013). The integration of BIM and green building design can help designers creating high performance and sustainable buildings by making informed the data stored in BIM models can facilitate numerous green building analyses, such as lighting, materials and energy. BIM technology can also support providing assessments for green building rating systems, e.g., Leadership in Energy and Environmental Design (LEED). For example, Azhar et al. (2011) developed a conceptual framework to establish the relationship between BIM-based sustainability analysis and the LEED certification process. Nguyen et al. (2015) presented a building knowledge framework representing the LEED green building criteria, which was implemented into a BIM platform to obtain an automated tool for the rating of a green building design. Zhang and Chen (2015) developed a rule-based system to automatically evaluate the energy performance of a BIM model and to assess if it satisfies sustainability goals.

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Although BIM-based green building assessment systems are developed to help designers, there are still many challenges to tackle: (1) not all of the data related to green building rating standard is stored in the BIM model; (2) extracting required data from the BIM model for the assessment needs to be automated; (3) not all credits are covered in the extraction process; (4) do not provide a revision guidance or any assistance in improving the design. Because, in addition to the assessment, it is important to inform designers how the building can be modified to become greener.

The paper describes a method that integrates the BIM with a green building rating system to help improving the building performance. LEED rating system has been selected for the green building design assessment, which has been widely accepted as the standard for sustainable building design (Nguyen et al., 2015). The method also proposes assessing LEED credits for BIM models represented in the IFC format. Hence, the data extraction process is standard and interoperable. The system calculates the LEED credits during design and provides design suggestions to help creating a greener building project. The methodology is realized by developing a prototype system called green building design support system (GBDSS).

II. PROPOSED METHOD

2.1 Process Flow

BIM tools have the ability to help designers explore different design alternatives at the early stage. Green building certification systems can be used to provide design guidance. The proposed method is to integrate BIM and LEED to help designers automatically assessing their green building design, and providing them with a real-time feedback. Users design the model using a BIM application (e.g. Revit), then the LEED rating of the model is assessed by the developed system. Depending on the calculation result, a report and revision guidance are provided. To demonstrate the approach, a prototype system (i.e., GBDSS) is developed. The process flowchart of the proposed system is shown in Fig.1 (a). First, an initial BIM model is imported to the system. Then, LEED prerequisites, such as the permits for the project plan, are checked. If the project satisfies the prerequisites, the system starts calculating the point based on the requirements of the LEED credit. At the end of the analysis, a point report is generated. If the result is not satisfying, users can request a revision guidance.

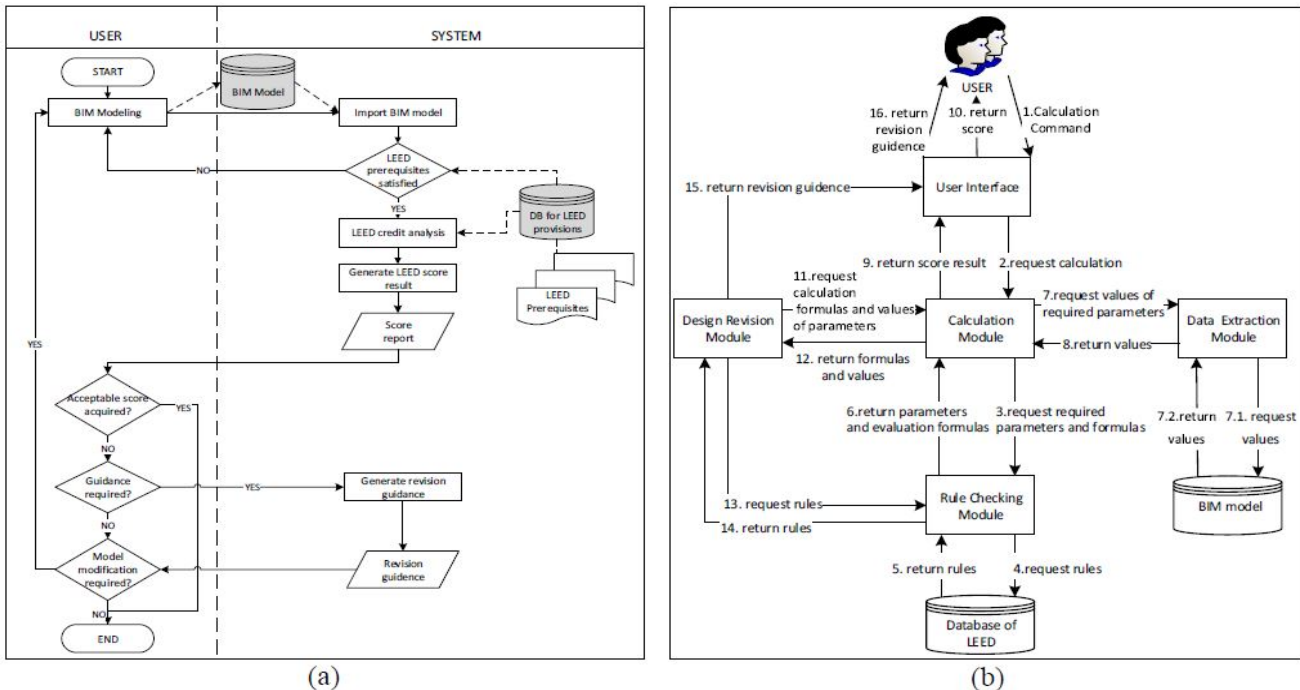


Figure 1. Green building design support system (a) The process flowchart, (b) The system architecture

Fig. 1(b) shows the system architecture for GBDSS. The system is composed of a User Interface (UI), a Calculation Module, a Data Extraction Module, a Rule Checking Module, a Design Revision Module, and Databases. The user

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interacts with the system using the UI. The data extraction module is responsible for data mapping and extraction process. It retrieves required data values from the BIM model. The calculation module acquires the extracted data and calculates the LEED point. The design revision module recommends improvement suggestions based on calculated data and LEED credits. The rule checking module provides specific required parameters of the LEED credit to the calculation module, and provides LEED credit requirements to design revision module.

2.2 System Development

The following two steps are necessary for the development of the system: (1) the LEED credits need to be analysed to identify the required data items for the point calculation; (2) the required data items have to be mapped with parameters in BIM so that the system can extract the data from the BIM model. Three credits were selected as examples for the IFC data mapping: Site Assessment, Open Space, and Heat island reduction. The required data items for these credits are identified and mapped with IFC entities in Fig.2. Using data mapping, the system queries the data from the BIM model. However, not all of required data items exist in the BIM model. Hence, new parameters should be added. For example, not all of the required IFC elements or types exist in the current version of the IFC. In our case, the vegetated area, vegetated roof area and high-reflectance roof area are new required space types in the model.

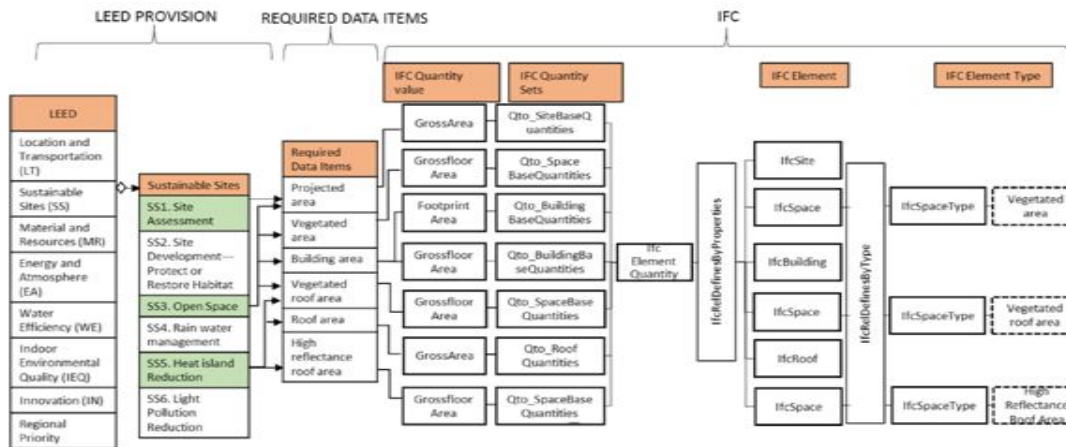


Figure 2. The example of LEED-based BIM model data mapping process

When the required data is identified and mapped with the BIM entities, the calculation of LEED point can be performed. The assessment algorithms embedded in the calculation module are essential parts of the system. In order to develop assessment algorithms, creating flowcharts of credit calculation process is useful. Pseudo codes can be developed based on the flowcharts. Fig.3 shows an example of computer algorithm development process for the Open Space, which acquires one point in LEED V4. The basic calculation formulas of open space are as follow: (1) Outdoor area $\bullet T \times$ gross area; (2) Vegetated outdoor area $\bullet 25\% \times$ outdoor area. Additionally, when the Floor Area Ratio (FAR) of the project is greater than or equal to 1.5 and the roof is physically accessible, the vegetated roof area can be considered as vegetated area.

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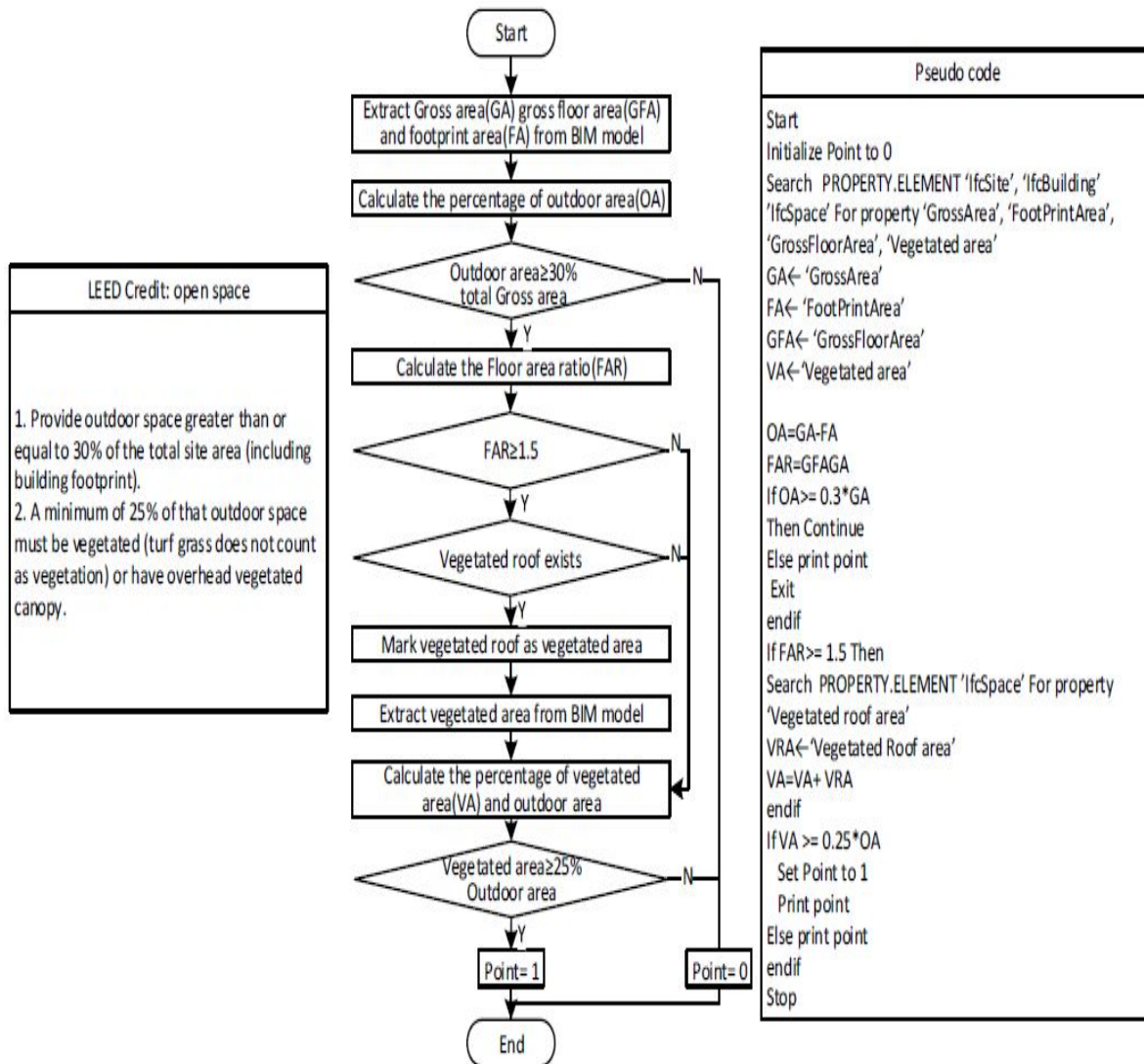


Figure 3. An example of computer algorithm development process

III. CASE STUDY

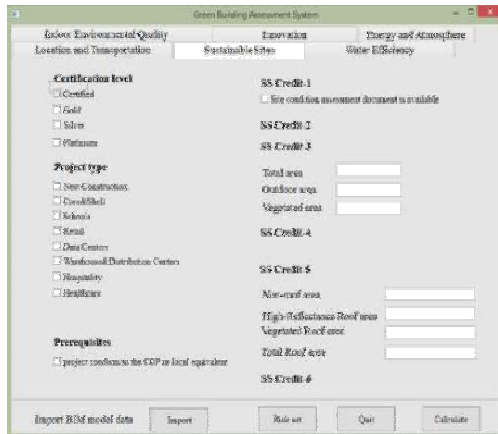
The proposed system is developed as a plugin of the BIM authoring software using available Application Programming Interface (API). The user interface of the prototype system is shown in Fig.4 (a) and the BIM model for the case study is shown in Fig.4 (b). The credit Open Space was chosen for the case study. Part of the required data, such as gross area and gross floor area, are extracted directly from the BIM. The vegetated area and the vegetated roof area are added in the BIM, the outdoor area and the FAR value were calculated accordingly. The system calculates the LEED rating point using the flowchart shown in Fig.3. Besides, the system lists credits and the obtained points for each one (Fig.5a) and provides the revision guidance for Open Space (Fig.5b). For example, it shows the current vegetated area, the minimum required vegetated area to obtain full points.

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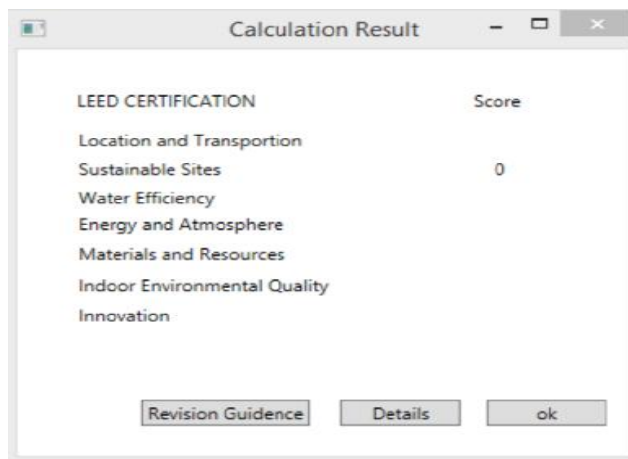
Vol. 8, Issue 3, March 2019



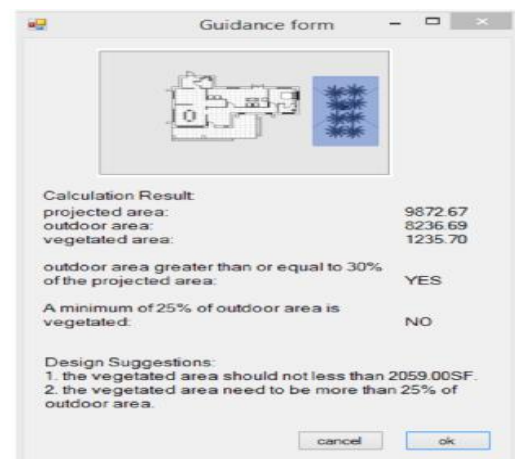
(a)

(b)

Figure 4. (a) User Interface of GBDSS (b) The example BIM model for case study



(a)



(b)

Figure 5. (a) The calculation result (b) The revision guidance

IV. CONCLUSIONS

This research investigated the integration of BIM and sustainability analysis based on LEED to assist designers and architects to make informed decisions early in the design stage. The green building design support system was developed that calculates the acquired point of LEED rating and proposes practical revision guidance. Three LEED

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credits were added to the system and their required data items were identified and mapped in the BIM authoring software. Additionally, the required data for credits was mapped to their associated IFC entities.

Green building rating systems are complex, hence, identifying and adding all required parameters and mapping them with IFC entities are big challenges for this research. Moreover, other green building rating systems, such as **Building Research Establishment Environmental Assessment Method (BREESM)** and **Comprehensive Assessment System for Built Environment Efficiency (CASBEE)** can be adopted by the proposed system. In the future, more LEED credits will be added to the system, and an optimization extension will be developed to provide more efficient revision guidance to designers

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