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Integrating BIM and Web Map Service (WMS) for Green Building Certification

Po-Han Chen*, Thanh-Chuong Nguyen*

*Department of Civil Engineering, National Taiwan University,
No. 1, Sec. 4, Roosevelt Road, Taipei, 10617 Taiwan (R.O.C.)*

Abstract

LEED (Leadership in Energy and Environmental Design) is one of the most popular and globally recognized green building standards. In LEED, evaluating the sustainable effects of site location and transportation to the ecosystem and human life is a critical and difficult task. Credits regarding these matters require experience, time, labor, and manual calculations. In recent years, many studies have been conducted to enhance the application of Building Information Modeling (BIM) in the LEED certification. However, the application of BIM to LEED's site location and transportation analysis is usually considered impractical due to the lack of a powerful map application in present BIM products. The aim of this research is to develop a framework for the integration of BIM and Web Map Service (WMS) technologies for LEED's location and transportation analysis. Using Autodesk Revit API and Google Maps API as the development tools, this research converts the integration model into a LEED-BIM plugin in Autodesk Revit to streamline the certification process of site location and transportation analysis in LEED.

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1. Introduction

In recent years, Green Building has become a trend in the construction industry to promote environmentally friendly and energy efficient design. More and more countries have developed their own Green Building certification systems, such as LEED in the U.S., CASBEE in Japan, BREEAM in the U.K., EEWH in Taiwan, to

* Corresponding author. Tel.: +886-2-3366-4335;

E-mail address: pohanchen@ntu.edu.tw, d00521034@ntu.edu.tw

certify buildings in terms of “green” levels. LEED (Leadership in Energy and Environmental Design) developed by the U.S. Green Building Council (USGBC) has become one of the most popular certification systems for Green Buildings in the world [1].

Project location and transportation are the critical components of a green building project. A building on developed land or near dense residential areas can make intensive use of existing infrastructure, increase development density, and conserve construction material and land resources for future use. A building near essential services, such as banks, parks, clinics, schools, restaurants and so on, can reduce the use of vehicles, save time for parking and increase the chance of walking and/or cycling. In other words, it can help reduce CO₂ emission as well as promote exercise. Convenient access to bus stops and/or rail stations can increase the use of public transportation and, hence, reduce vehicles’ gas use, pollution and maximize the use of existing transportation infrastructure. In addition, it could relieve traffic congestion and noise pollution.

In LEED 2009, project location analyses are included in credits SSc2 and SSc4.1 in the Sustainable Sites category, which is the second biggest category, only after Energy and Atmosphere. Credits SSc2 and SSc4.1 have totally four options (for projects inside the U.S.) as shown in the following table:

Table 1. Sustainable Sites Credit SSc2 and SSc4.1 (LEED NC 2009)

Credits	Intents	Options	LEED Pts
Credit SSc2: Development Density and Community Connectivity	To channel development to urban areas with existing infrastructure, protect greenfields, and preserve habitat and natural resources.	Option 1: Development Density	5 points
		Option 2: Community Connectivity	
Credit SSc4.1: Alternative Transportation - Public Transportation	To reduce pollution and land development impacts from automobile use.	Option 1: Rail station, Bus rapid transit station & ferry terminal Proximity	6 points
		Option 2: Bus stop Proximity	

Nowadays, BIM (Building Information Modeling) is widely used in LEED analyses, such as energy consumption, lighting, and sustainable material. Project site location information is usually included in most BIM software. For example, in Autodesk Revit, it is included in Project Location under the Manage tab. However, due to the complexity of LEED calculation, architects and designers usually handle LEED’s site location analysis manually.

To calculate the scores of LEED’s Credits SSc2 and SSc4.1, designers and architects usually manually extract project information (e.g., project location, building area, site area, etc.) from CAD drawings or BIM models. The data of the project site, e.g., surrounding buildings, traffic and roads, and local services are obtained from either paper maps or online maps, such as Google Maps. Moreover, it also requires the use of graphic software like Adobe Photoshop to illustrate the map image and local area for LEED submission documents. This manual process requires a lot of time and effort, as well as familiarity with document submission.

Web Map Service (WMS) is the process of using the web interface to request map images delivered by a map server using geographical information system (GIS) databases [2]. It has many advanced features over traditional maps by providing free online access in a browser application to maps with data associated with roads and traffic. With its strength and flexibility, WMS is a potential tool to support the map-related analysis in LEED Sustainable Sites credits.

So far, there is no comprehensive software that allows users to calculate LEED SSc2 and SSc4.1 scores directly. With the help of BIM and the WMS such as Google Maps, the calculation process can be much faster and more accurate, and, thus, save significant cost and time.

2. Literature review

Studies on the integration of BIM in to Green Building analysis have been conducted to find out the experiences of the application of BIM in Green Building analyses. Krygiel et al. [3] summarized several case studies with successful implementation of BIM in LEED® and other green projects. In his study, an in-depth analysis of BIM application was conducted in various building systems including building envelopes, water harvesting, energy modeling, renewable energy and sustainable materials. However, site location was not a subject of BIM application in his study. Wu et al. [4] revealed that Sustainable Sites was not considered having high level of BIM application compared to other categories in LEED [4]. Azhar et al. [5] presents a conceptual framework to establish the relationship between BIM-based sustainability analyses and the LEED® certification process.

Regarding site location and transportation analyses in LEED, studies also indicated that BIM has very low capability of LEED application. Unlike building performance characteristics such as lighting, thermal, energy consumption, and so on, that may potentially use BIM analyses, location and transportation has fewer direct connection with BIM software. In the survey conducted by Bynum et al. [6], most responders still regarded the Sustainable Sites category to have lower capability of BIM application than other categories. Azhar et al. [5] and Wong and Kuan [7] also discussed the application of BIM in Hong Kong's BEAM-Plus Green Building certification, which was developed based on the LEED standard. While his study concluded that 26 BEAM-Plus credits could be assisted by BIM, only 4 out of 17 credits in Site Aspect category (identical to LEED's Sustainable Sites) can be achieved by BIM. Credit SS2 Local Transport (identical to LEED's SSc4.1) and SA3 Neighborhood Amenities (identical to LEED's SSc2) are marked as not applicable to be achieved by using BIM. In conclusion, construction professionals are exploring the application of BIM in Green Building certification analysis. However, due to the missing map and calculation tools in BIM software, location and transportation analyses are impractical using BIM solutions.

3. Research objectives

The focus of this study is on the Location and Transportation analysis related to credits SSc2 and SSc4.1 of LEED for New Construction v2009. Autodesk Revit (BIM software) and Google Maps (WMS) are adopted in this study due to their popularity. Plugins for Autodesk Revit will be developed to help with credits SSc2 and SSc4.1 in Location and Transportation analysis. The plugins will automatically calculate SSc2 and SSc4.1 points (Note: These two credits are the major ones in LEED's Sustainable Sites (SS) category, accounting for 11 out of 26 points in SS), help prepare documents for LEED submittal, export proof map images with all required information marked on them, and generate an Excel file containing all location-related data. With the plugins, no manual switching between software and manual calculation of LEED points are needed.

4. Research methodology

The C# programming language together with Autodesk Revit API and Google Maps API are used for the integration of BIM, WMS and green building (GB) standards (Figure 1).

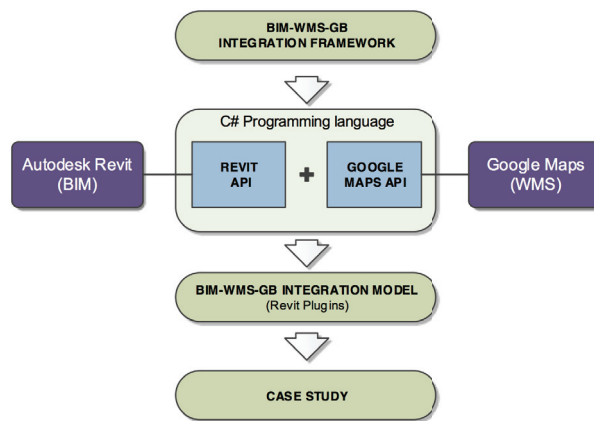


Fig. 1. Flow of BIM-WMS-GB integration

The integration model includes 3 modules (fig. 2):

- **BIM information module:** Extracts project information (location longitude/latitude, site area, building area...) from BIM model and synchronizes location information between UI and BIM model.
- **Web Map Service module:** Gets maps data from GIS server of multiple providers (Google, Bing, Yahoo...), and shows maps with buildings, traffic, local services...in the map interface. The module also draws markers, layers (density radius, services radius, route...), and exports Maps image for submission.
- **Green Building module (LEED):** Incorporates green building certification (LEED) requirements, formula and automatically calculate and show calculation results. The module also help export Excel data table for submission.

Through the integration UI, LEED results can be automatically calculated and shown on the UI to help designers and architect have a good assessment of the Green Building location.

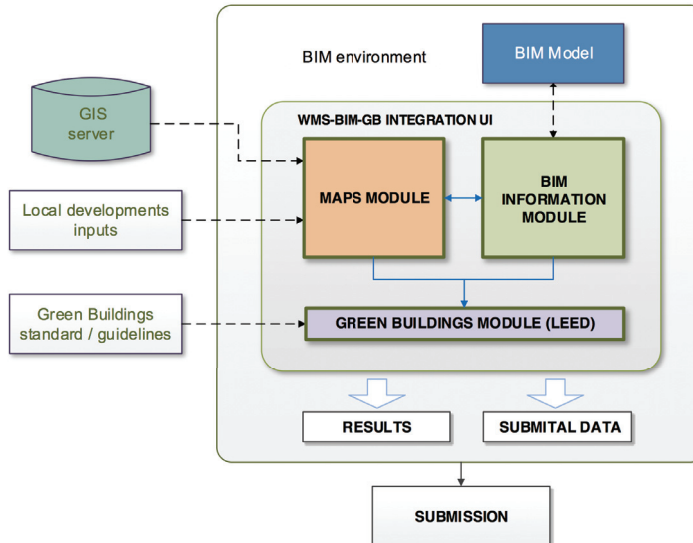


Fig. 2. BIM-WMS-LEED integration framework

5. Integration model demonstration

5.1. SSc2 credit – Option 1

This option requires the project building to be constructed or renovated on a previously developed site and in a community with a minimum density of 60,000SF/acre [8, p. 3]. The integration model can get the project location information from Revit model and show it on the map interface. The project gross area and site area can be obtained automatically through Revit Gross Area schedule and Site's Property Line area. The density circle is drawn with the radius calculated using the formula:

$$\text{Density Radius (lf)} = 3 \times \sqrt{\left[\text{Site Area (acres)} \times 43,560 \text{ (sf/acre)} \right]}$$

The user can mark different building locations on the map and enter site area and gross area data. Development Density is calculated by the formula:

$$\text{Development Density (sf/acre)} = \frac{\text{Gross Building Area (sf)}}{\text{Site Area (acres)}}$$

If Development Density of the area within the circle $\geq 60,000$ then the credit is earned, and the LEED result is automatically shown on the interface.

The following figure demonstrates the user interface of LEED SSc2 – Option 1 location analysis in Autodesk Revit:

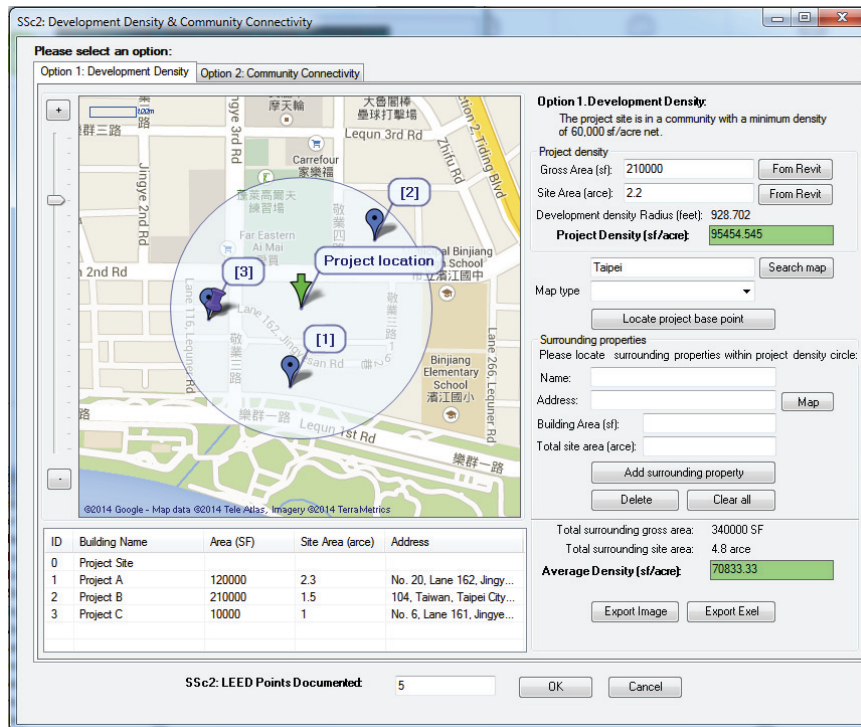


Fig. 3. BIM integration model in LEED credit SSc2 – Option 1: Development density

5.2. SSc2 credit –Option 2:

This option requires the project building to be constructed or renovated on a previously developed site within half a mile of at least 10 basic services with pedestrian access between the building and the services. The density circle is generated by the WMS module, with the density radius fixed at half a mile, as specified in LEED.

$$SR = 0.5 \text{ (miles)}$$

Combining the map and the generated density circle, the user can input each of the surrounding services, such as school, laundry, etc., by placing a marker on the map. If Number of Services ≥ 10 , then LEED points are earned.

The following figure demonstrates the user interface of LEED SSc2 – Option 2 location analysis in Autodesk Revit:

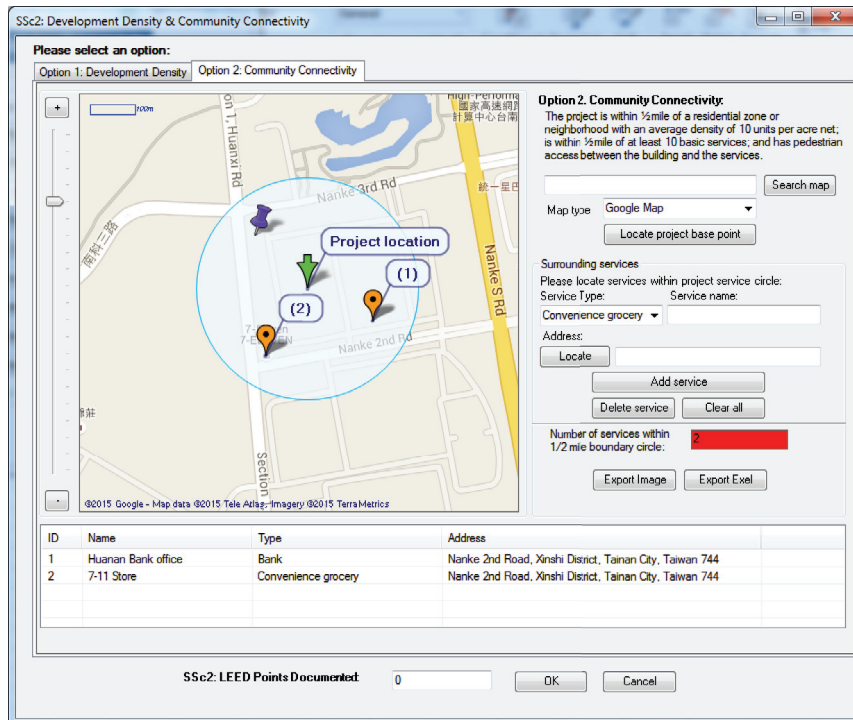


Fig. 4. SSc2 Option 2 user interface

6. Conclusions and recommendations

Green building and BIM are rapidly transforming the design and construction industry in the world. However, application of BIM in LEED certification, especially location analysis, is still by and large in its infancy. In this paper, a new and handy system was developed to integrate BIM and Web Map Service (WMS), such as Google Maps, for LEED's location analysis, so as to simplify and shorten the process of green building planning schedule.

Presently, most countries are promoting the use of new technology in sustainable construction. If the integration of BIM and green building certification (e.g., LEED) could be further extended, manual operation would be significantly minimized, and time and cost would be saved.

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