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Integrating web map service and building information modeling for location and transportation analysis in green building certification process

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ABSTRACT

In green buildings design and construction, evaluating the sustainable effects of site location and transportation to the ecosystem and human life is a critical and difficult task. Works 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 green building certifications. However, the application of BIM to 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 location and transportation analysis in green building certifications. Using Autodesk Revit API and Google Maps API as the development tools, this research converts the integration model into the BIM-integrated plugin in Autodesk Revit. The plugin is used to streamline the certification process of site location and transportation analysis in LEED (Leadership in Energy and Environmental Design), one of the most popular and globally recognized green building standards.

1. Introduction

1.1. Location and transportation analysis in green building standards

1.1.1. Green buildings and LEED certification

It is widely perceived that the construction industry is among the heaviest consumers of natural resources and a significant contributor of CO_2 emission that leads to the global climate change [1]. According to the U.S. Green Building Council, buildings account for 38% of all CO_2 emissions, 73% of electricity consumption, 13.6% of all potable water and 40% of raw materials in the United States [2]. In response to this threat, construction professionals have embraced Green Buildings, a new trend involving environmentally friendly construction processes to reduce environmental impacts as well as building costs while conserving the earth's resources for future use [3,4].

Green Buildings is a growing trend across the globe: McGraw-Hill Construction [5] reported that 28% of architects, engineers, contractors, building owners and building consultants around the world are focusing their work on sustainable design and construction by making at least 60% of their projects green. The movement towards sustainability has brought about the development of various green building certification systems around the world. In 2000, the U.S. Green Buildings Council (USGBC) developed the LEED (Leadership in Energy and Environmental Design) certification system which has now become a popular and globally accepted standard for the design, construction, and operation of green buildings [6]. Among the various LEED systems for different types of projects, the LEED for New Construction (LEED NC) is the most adopted LEED system [7]. Under the LEED-NC 2009 (also known as LEED v3.0), buildings are judged via a 100-point credit system in five categories. The five categories and their respective points are:

- Sustainable sites: 26 possible points;
- Water efficiency: 10 possible points;
- Energy and atmosphere: 35 possible points;
- Materials and resources: 14 possible points;
- Indoor environmental quality: 15 possible points;

There are also 10 possible incentive points included in two additional categories for innovative strategies: Innovation in design (6 points) and Regional priority (4 points). Application documents and proofs can be submitted at the design phase.

1.1.2. Project site location and transportation analyses in green building standards

Project location and transportation are the critical components of a green building project as they affect the ecosystem and human life in

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Table 1
Credit SSc2 and SSc4.1 in sustainable sites category - LEED NC 2009.

Credits	Intents	Options	LEED points
Credit 2: 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 Option 2: Community Connectivity	5 points
Credit 4.1: 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 Option 2: Bus stop Proximity	6 points

many ways. First, a project location has a significant impact on the connection of the building with the surrounding area. A building in developed land or near dense residential areas can make more 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, hospitals, schools and restaurants could reduce vehicle use and increase the chance of physical activities. Easy access to public transportation helps reduce CO_2 emission, traffic congestion and noise pollution.

Project location and transportation are featured in most popular green building standards. For examples, in Australia's Green Star, they are included in "Transport" and "Land use & Ecology" categories [8]; in Singapore's Green Mark, they are included in "Environmental Protection" categories [9]; In LEED NC 2009, project location and transportation are the important parts of the Sustainable Sites (SS) category, which is the second biggest category in terms of LEED points. SS includes 17 credits and 2 prerequisites, dealing with different matters such as revitalizing and using existing infrastructure, and reducing the impacts of buildings to the neighboring environment.

In LEED, two important credits concerning location and transportation are: **Credit SSc2: Development Density and Community Connectivity** and **Credit SSc4.1: Alternative Transportation - Public Transportation.** Both of them together account for the greatest points in the SS category: 11 out of a total of 26 points. The two credits have 4 options in total (Table 1):

1.2. Conventional location and transportation analysis in green building standards

Conventionally, the certification process of project location and transportation in a green building standard includes inputs collection, map analyses, points calculation, and documents preparation and submission. For example, the certification processes of LEED credits SSc2 and SSc4.1 are shown in the following figure:

In map analyses, map-related data are usually obtained manually or semi-manually from maps (either paper maps or online maps). This results in many disadvantages. In LEED, the disadvantages are as follows:

- **Lack of a map tool for calculation:** Maps are critically needed for location and transportation analyses. Using paper maps is straightforward but has restrictions and inconvenience such as fixed scales, limited map information, no panning and zooming, and so forth. Online maps, such as Google Maps, are more convenient but do not have dedicated functions to assist with the analysis. For example, in SSc2 – option 1, a "density circle" is needed with a radius correlated to the size of the project site area. Conventionally, this credit calculation requires manual work to determine the project site area and/or calculate the density radius. Since drawing a circle on a web browser is not practical, the calculation requires screen-capturing the map from a web browser to draw the density circle, and then identify the neighboring buildings and facilities inside the circle and calculate the development density. Each of these steps has to be done separately and manually, which is tedious and error-prone.
- **Manual inputs and calculations:** Project parameters usually need to be extracted from 2D CAD drawings or 3D Revit files. Each time a building design is changed, LEED points will have to be recalculated.
- **Map image export:** USGBC requires the submission of map images and relevant information, such as a list of neighboring buildings and facilities. The extraction of map images is usually followed by map image processing and labeling using software like Photoshop, which is time-consuming.

1.3. Potential of BIM and WMS integration for green building certifications

1.3.1. BIM information for location and transportation analysis

Currently, BIM software (e.g., Autodesk Revit) is able to simulate green building performance and export IFC (Industry Foundation Class) or gbXML (Green Building XML) outputs [10]. These outputs can then be used in green building designs and certification, such as LEED, to calculate points. (See Figs. 1 and 2)

However, there are two problems with such BIM-and-Green Building standard integration: 1) BIM is mainly capable of building performance analyses and not applicable to other categories; 2) manual operation is still necessary for the switching between applications and data import and export.

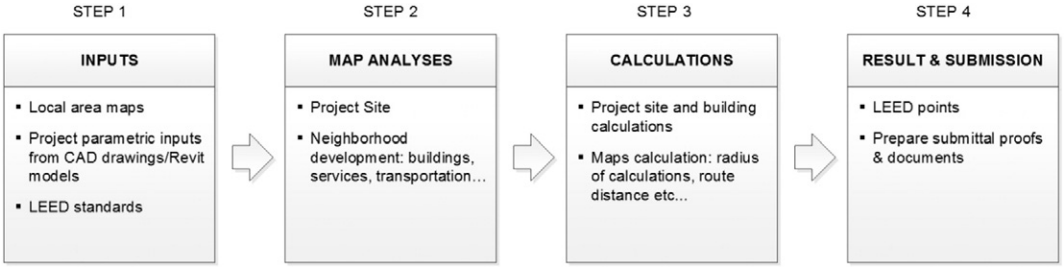

Fig. 1. Steps for conventional LEED location and transportation analysis.