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Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings

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ABSTRACT

Designing environmentally friendly buildings that provide both high performance and cost savings is of increasing interest in the development of sustainable cities. Today, we are looking at not just buildings' certification but sustainable practices that go beyond ratings to satisfy our social responsibilities. The construction industry in general will benefit from an integrated tool that will help optimize the selection process of materials, equipments, and systems at every stage of a proposed building's life. Building information modeling (BIM) has the potential to aid designers to select the right type of materials during the early design stage and to make vital decisions that have great impacts on the life cycle of sustainable buildings.

This paper describes a methodology that integrates BIM with the Canadian green building certification system (LEED©). Also, it explains how this integration would assist project teams in making sustainability related decisions while accumulating the required number of points based on the applied green building rating system. The methodology depicts the implementation of a model that automatically calculates the compiled number of LEED certification points and related registration costs for green and certified materials used in designing sustainable buildings all within the concepts of BIM. Using BIM in this methodology will help designers to invent and animate sustainable buildings in 3D mode easily and efficiently at the conceptual stage. The design information of the proposed sustainable building will be produced in a timely manner by using new plug-ins, which are developed for that reason, and which will link the BIM model with an external database that stores sustainable materials and assembly groups. A real case project is presented to illustrate the usefulness and capabilities of the proposed model.

1. Introduction

Studies indicate that the demand for sustainable buildings that have minimal environmental impacts on society is slowly increasing (Biswas, Wang, & Krishnamurti, 2008). Therefore, the construction industry needs to adopt new approaches/techniques, such as sustainability approach, for designing buildings in order to reduce pressure on the environment. Incorporating sustainability principles at the conceptual stage is attained by using sustainable design in which designers need to identify associated materials and components that potentially earn credits based on the selected green building certification system.

Lately, the Architecture, Engineering and Construction (AEC) industry has witnessed an increasing interest in using the concept of building information modeling (BIM) in conjunction with sustainability principles during the design and construction of green building projects. BIM tools have the ability to help designers explore different design alternatives at the early stage and to transfer the design information to energy and simulation tools for validation and analysis efficiently and fast. On the other hand, by using BIM tools, owners can better visualize the development of their building projects all over the different stages of their construction. The building team uses BIM models to coordinate activities, takeoff material quantities, and detect possible clashes between equipment and spaces.

Leadership in energy and environmental design (LEED), which is a recognized rating system for green buildings and homes (USGBC, 2011), has become a thriving business paradigm in promoting sustainability in the AEC industry due to governmental endorsement and the efforts of the USA Green Building Council (USGBC) and the Canadian Green Building Council (CaGBC). LEED outlines the

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following six key areas: (1) sustainable sites; (2) water efficiency; (3) energy and atmosphere; (4) material selection; (5) indoor environmental quality; and (6) innovation and design process. LEED has become an important aspect for green buildings so that some federal agencies and local governments are requiring their new and existing buildings to be at least LEED-certified. There are different types of systems under LEED that can be applied for homes, interiors, core and shell, and neighborhood development, however the focus of this paper is on LEED Canada for New Construction (LEED-NC). LEED-NC addresses the whole building and its site, which cover both the design and construction of new buildings and the major renovations of the existing ones. LEED-NC is also used for building upgrades, under the condition that less than 50 percent of the buildings' occupants remain inside it during the upgrading process.

According to Eastman, Teicholz, Sacks, and Liston (2008), developing a parametric model within BIM tool is capable of capturing project information and generating documentation. With special care taken on the software side, an enhanced BIM application could potentially resolve what used to be obstinate problems in delivering sustainable design (i.e. dealing with the complexity of conducting full building energy simulation, acoustical analysis, and day lighting design). The possibility that the design team can automatically access the green building rating system credits and associated registration and certification costs has not yet been considered into one simple model. The advantage of using BIM is its ability to act as a single source of all the project information that designers need to analyze and accordingly modify the building's design before its physical implementation. The LEED rating system is a consistent measure of how a building impacts the environment. A major aspect of LEED is the documentations and associated cost calculations that must be submitted in order to reach the required type of certification. Currently, the construction industry is using BIM tools for many tasks, such as materials quantity take off, cost estimating and documentations; however these tools lack the availability of material library that helps design professionals determine the associated LEED credits.

This paper describes the methodology used to implement an integrated platform to do sustainable design for proposed buildings at their conceptual stage. The methodology is implemented through the design and development of a model that simplifies the process of designing sustainable buildings and transferring their design information to an external database in order to list the potential certification points that they can earn based on the Canadian LEED Certification system. The methodology incorporates an integrated model capable of guiding users when performing sustainable design for new building projects. The integrated model uses the LEED-NC information of the buildings' components, which are stored in the external database that is, by its turn, connected to BIM tool to instantly calculate the sum of LEED points for the proposed building. The major task in developing the model is to collect lists of green products and certified materials and have them linked to the database of BIM tool. Creating and linking such a database to BIM tool helps users design and animate sustainable buildings easily and efficiently at the conceptual stage. Part of this integrated methodology is to develop new plug-ins, which are lists of instructions used to automate the transformation of information, to be inherited into BIM tool in order to aid users connect their design models with other application, which is able to evaluate the sustainability of the building's components in an efficient and consistent manner. Automating the process of identifying the potential number of LEED points that the new sustainable building must accumulate in order to comply with the desired level of certification and estimating the associated costs will minimize users' input and will increase the calculations efficiency.

2. Literature review

The main objective of sustainable design is to create buildings in sustainable cities that are livable, comfortable and safe. The sustainable design of these buildings leads to reducing the depletion of critical resources (i.e. energy, water, and raw materials) as well as preventing environmental degradation caused by infrastructure and facilities throughout their life cycle. The current challenge that the AEC industry is facing is to meet the demand for new and renovated facilities that are accessible, secure and healthy while minimizing their impact on the society, the economy and the environment. The whole building design guide (WBDG, 2012) represents the following five fundamental principles for sustainable design: (1) optimize the site design, which includes the locations of access roads, parking, vehicle barriers, and perimeter lighting; and improve the energy performance by reducing the dependence on fossil fuel-derived energy; (2) use the water efficiently and reuse or recycle the water for on-site use; (3) use the type of materials that have minimal life-cycle environmental impacts on global warming, resource depletion, and human toxicity; (4) Enhance the indoor environmental quality (IEQ) of buildings, which means maximize the day lighting and have appropriate ventilation and moisture control; (5) optimize the acoustic performance; and (6) avoid the use of materials with high volatile organic compound (VOC) emissions. Furthermore, taking into consideration the operating and maintenance issues while doing the conceptual design of a building project will contribute to enhancing the inhabitants' productivity, reducing energy costs, and improving the working environment.

Wang, Fowler, and Sullivan (2012) think that green building certification system can be used as a design and operation guide to document progress toward a design or operational performance target, to compare buildings by using the certification systems structure, and to record the design and operation outcomes and/or strategies used in the building.

As the context varies, rating systems in different countries tend to give priority to certain sustainability indicators but the general scope is quite consistent. These indicators, which are embedded in current major green building rating systems address related issues such as land degradation, biodiversity, water shortage, energy efficiency, renewable energy, carbon emission, air pollution, materials and resources, and indoor environmental quality.

Several methodologies have been developed to establish the degree of accomplishment of environmental goals, and to guide the planning and design processes of green buildings. For instance, Building Research Establishment Environmental Assessment Method (BREEAM) (Baldwin, Yates, Howard, & Rao, 1998), Green Star from Australia (GBCA, 2008), the comprehensive assessment system for building environmental efficiency (CASBEE) from Japan (CASBEE, 2008), the building and environmental performance assessment criteria (BEPAC) from Canada (Cole, 1993), and the leadership in energy and environmental design (LEED) from the United States (USGBC, 2011) are developed and are currently widely applied. Very comprehensive inventories of the available tools for environmental assessment methods can be found (Ding, 2008) such as the whole building design guide (WBDG, 2012) and the World Green Building Council (WGBC, 2008).

Although the existing methods and tools have an extended use, LEED has established strong credibility among the experts (Pulselli, Simoncini, Pulselli, & Bastianoni, 2007). The LEED system comprised 7500 company and organization members, validating its importance as the standard environmental performance measure of buildings and becoming a reference system for the design, construction, and operation of green buildings beyond the U.S. (Bowyer, 2007).

LEED encompasses a collection of sustainability indicators to holistically evaluate the building performance and to identify how