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Building information modeling for sustainable design and LEED® rating analysis

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ABSTRACT

Today, there is a high level of demand for sustainable buildings. The most important decisions regarding a building's sustainable features are made during the design and preconstruction stages. Leadership in Energy and Environmental Design (LEED®) is the most widely adopted sustainable building rating system in the United States. For projects pursuing LEED® certification, designers have to conduct in-depth sustainability analyses based on a building's form, materials, context, and mechanical–electrical–plumbing (MEP) systems. Since Building Information Modeling (BIM) allows for multi-disciplinary information to be superimposed within one model, it creates an opportunity to conduct these analyses accurately and efficiently as compared to the traditional methods. In this exploratory research, a case study was conducted on Salisbury University's Perdue School of Business building to demonstrate the use of BIM for sustainable design and the LEED® certification process. First, a conceptual framework was developed to establish the relationship between BIM-based sustainability analyses and the LEED® certification process. Next, the framework was validated via this case study. The results of this study indicate that documentation supporting LEED® credits may be directly or indirectly prepared using the results of BIM-based sustainability analyses software. This process could streamline the LEED® certification process and save substantial time and resources which would otherwise be required using traditional methods.

1. Introduction

Recent studies indicate that the demand for sustainable building facilities with minimal environmental impact is increasing [1,4,7]. Rising energy costs and growing environmental concerns are the catalysts for such high demand. The environmental and human health benefits of sustainable (also called green) buildings have been widely recognized. A slight increase in upfront costs of about 2% to support sustainable design, on average, results in life cycle savings of approximately 20% of total construction costs; which is more than ten times the initial investment [12]. Hence sustainable buildings are economically viable too.

Worldwide, individuals and organizations have responded to the increased demand for green buildings. Many countries and international organizations have initiated rating systems for sustainable construction. Currently, a number of different rating systems are used to rate the environmental performance of buildings. These include but are not limited to: Australia's Green Star; Canada's LEED Canada; Germany's DGNB Certification System; India's IGBC Rating System and LEED India; Japan's Comprehensive Assessment System for Building Environmental Efficiency; New Zealand's Green Star NZ; South Africa's Green Star SA, United Kingdom's BREEAM, and the United State's LEED. Most of these rating systems' primary criteria are similar in that they evaluate a building's energy consumption, water efficiency, material use and indoor environmental quality [17].

In the United States, the Leadership in Energy and Environmental Design (LEED®) system is currently the most widely utilized method for rating a building's environmental performance. LEED® was developed by the U.S. Green Building Council (USGBC) in 1998 to provide building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operation and maintenance solutions [15]. The LEED® credits are divided into six categories (LEED® ver. 2.2) as follows: *sustainable sites*, *water efficiency*, *energy and atmosphere*, *materials and resources*, *indoor environmental quality*, and *innovation in design* [16].Under the LEED® system, a structure may earn up to 34 total credits. Sixty-nine points are available within the confines of the credits. Under certain credit categories, multiple points may be earned for higher environmental performance levels. In addition to credits, each section of the LEED® system includes prerequisites which must be earned even though they do not count towards a building's point total. Points are distributed unequally among the categories as shown in Table 1.

There are four levels of LEED® certification: *LEED® Certified*, *LEED® Silver*, *LEED® Gold* and *LEED® Platinum*. The level of LEED® certification a building earns is determined by the number of points awarded as

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Table 1
LEED® credit categories and available points [16].

Categories	Available points (LEED® ver. 2.2)
Sustainable sites	14
Water efficiency	5
Energy and atmosphere	17
Materials and resources	13
Indoor environmental quality	15
Innovation in design	5
Total	69

follows (LEED® v. 2.2): 26–32 points for LEED® Certified, 33–38 points for LEED® Silver, 39–51 points for LEED® Gold, and 52–69 points for LEED® Platinum [16]. During construction, supporting documentation and evidence are compiled and submitted to the U.S. Green Building Council (USGBC). Based on that information, the USGBC determines whether or not to award the point. No points are awarded and the certification is not received until construction is complete. Any changes made during construction require a resubmission of the supporting documentation.

The early design and preconstruction phases of a building are the most critical times to make decisions on its sustainability features [6]. Traditional computer-aided design (CAD) planning environments usually lack the capability to perform sustainability analyses in the early stages of design development. Building performance analyses are typically performed after the architectural design and construction documents have been produced. This failure to analyze sustainability continually during the design process results in an inefficient process of retroactive modification to the design to achieve a set of performance criteria [14]. To assess building performance in the early design and preconstruction phases accurately, access to a comprehensive set of data regarding a building's form, materials, context, and mechanical–electrical–plumbing (MEP) systems is required. Since Building Information Modeling (BIM) allows for multi-disciplinary information to be superimposed within one model, it creates an opportunity for sustainability measures to be incorporated throughout the design process [3].

Kriegel and Nies [13] indicated that BIM can aid in the following aspects of sustainable design:

- Building orientation (selecting a good orientation can reduce energy costs)
- Building massing (to analyze building form and optimize the building envelope)
- Daylighting analysis
- Water harvesting (reducing water needs in a building)
- Energy modeling (reducing energy needs and analyzing renewable energy options can contribute to low energy costs)
- Sustainable materials (reducing material needs and using recycled materials)
- Site and logistics management (to reduce waste and carbon footprints).

A recent survey of 145 design and construction firms in the United States indicates that the practitioners implementing BIM-based sustainability analyses are realizing 'some-to-significant' time and cost savings as compared to the traditional methods [4]. The combination of sustainable design strategies and BIM technology has the potential to change the traditional design practices and to efficiently produce a high-performance facility design. One such effort on the Columbia campus of the University of South Carolina resulted in approximately $900,000 in savings over the next ten years at current energy costs [10].

A building information model carries a wealth of information which may be utilized to produce necessary documentation for earning LEED® credits. For instance, schedules of building components can be obtained directly from the model to determine percentages of a material's reuse, recycled content, or salvage. Various design options for sustainability can be studied and tracked in a building information model [2]. Another feature of BIM for sustainability relates to how architects can choose the site of their project. Architects can input spatial data into the building information model that geographically locates the building site and imports information that helps the design team understand issues related to climate, place, surrounding systems, and resources. Designers can then edit and reorient the building on a site using real coordinates to reduce the building's impact on the surrounding environment and determine the most efficient solar orientation [11]. Many LEED® credits require that drawings be submitted to support the qualification for credit. Although most of these drawings can be prepared using conventional CAD software, BIM software produces these drawings more efficiently as part of the building information model and have the added advantage of parametric change technology, which coordinates changes and maintains consistency at all times. Thus, the user does not have to intervene to update drawings or links [3].

2. Purpose of the study, scope and methodology

The purpose of this study is to demonstrate the ways designers and planners may use BIM for various sustainability analyses in pursuit of LEED® certification. The scope of the research is limited to non-residential new building projects only. This study did not investigate the financial benefits and/or deficits of using BIM for sustainability analyses.

A two-step methodology is adopted for this study as follows:

1. Development of a conceptual framework to establish the relationship between BIM and LEED® rating processes. This framework was developed via review of existing literature and in-depth semi-structured interviews with professionals heavily involved in BIM and LEED® certification.
2. Validation of the developed framework via a case study.

Brief results of both steps are presented in the following sections.

3. Results

3.1. Conceptual framework for establishing a relationship between BIM and LEED® rating processes

Based on the review of existing literature and feedback collected from building design professionals and LEED® consultants, the following conceptual framework (Table 2) was prepared to illustrate the relationship between various LEED® credits and associated BIM-based sustainability analyses. The table also indicates the project stage at which documentation for these credits can be prepared. More details about this work can be found in Brown [8] and Carlton [9].

This framework is validated using data from a case study which is discussed in the following section. More case studies are planned for further verification and refinement. The results of these case studies shall be published separately. The presented case study also identifies the number of LEED® credits for which required documentation can be prepared using results of BIM-based sustainability analyses.

3.2. Validation of the framework

3.2.1. Description of selected project for case study

The project selected for case study is the Perdue School of Business building located on Salisbury University's campus in Salisbury, MD.