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A B S T R A C T

Location and transportation system are the essential parts of a green building project for the success of the LEED Certification process. LEED (Leadership in Energy and Environmental Design) is the most well-known green building rating tool worldwide. Generally, architects, engineers, and designers evaluate location and transportation systems based on conventional maps with manual estimations in LEED projects. This technique requires labor, experience, and more time and effort. However, Building Information Modeling (BIM) is an intelligent advanced technology that can reshape the construction industry in future decades. BIM (Building Information Modeling) has brought new ways to analyze location and transportation systems in the green building process. This study aims to enhance the efficiency of location and transportation systems in LEED certification by incorporating BIM. Integration of BIM model using Autodesk Revit software and LEED-based plugins with mapping tools such as google map service to develop a collaborative BIM-LEED environment which resultantly aids in performing location analysis. This technique helps planners, architects, and engineers to make informed decisions about green building performance at the early stage of a project.

K e y w o r d s: LEED, BIM, Location and Transport, Green Building

1. Introduction

In recent times, the demand for sustainable buildings raised exponentially because the world is currently facing a serious crisis regarding the environment. The post covid era has changed the entire dynamics of the world, and so people are becoming more conscious of their built environment. It has been estimated that buildings account for major energy consumption and carbon emissions and it is continuously on the rise due to the rapid growth of the population. A recent development in the construction business is the use of "green" buildings to encourage energy efficiency and environmentally friendly architecture. According to studies, the desire for environmentally friendly structures that have less effect on the population is gradually rising. To lessen the strain on the environment, the construction sector must adopt new concepts and techniques, such as the sustainability strategy. Through the use of sustainable design, which requires designers to find related materials and components that might receive points based on the chosen green building certification system, sustainability concepts can be incorporated at the conceptual stage [1].

In this regard, it is crucial to adopt such sustainable practices that make buildings energy efficient and environmentally friendly so that the demand for housing can be tackled with the rising population without compromising the ecosystem. Leadership in Energy and Environmental Design (LEED) has been considered a paramount effort to attain sustainable green building certification. It has been recognized by governmental organizations such as USA Green Building Council for its endless contribution to making buildings sustainable and green. The LEED comprises six domains that address the different components of a building to make it sustainable. These domains are sustainable sites, water efficiency, energy and atmosphere, material selection, indoor environment quality, and innovation design process. Among these, this research focuses on the location and transportation category. The reason behind selecting this category is that it is one of the most neglected categories in the building industry and it involves a rigorous planning strategy at the designing phase so that maximum errors can be reduced at the later stage of the building lifecycle [2].

2. Literature Review

Building Information Modelling (BIM) is considered to be a major technological breakthrough in the civil engineering industry. It is a digital platform that helps visualize the construction project realistically. The applications of BIM are varied and diverse. It not only helps in visualizing the project but it can be used effectively for quantity estimation, project monitoring, clash detection, and facility management [3]. Another important benefit of BIM is that it can assist markedly in sustainability [4]. Through the use of BIM, energy modeling and simulation can be done which can provide very important insights about the building at the early stage to designers, architects, engineers, and other construction industry professionals [5].

BIM and sustainability concepts are becoming increasingly popular in the architecture, engineering, and construction (AEC) sector. This is especially true when it comes to designing and constructing green buildings. BIM technologies offer the potential to quickly and efficiently communicate design information to energy and simulation tools for validation and analysis at an early point of the design process [6]. However, by utilizing BIM technologies, owners may more vividly monitor how their building projects are progressing throughout the many phases of their construction. BIM models are used by the construction team to plan activities, estimate material requirements, and identify potential equipment-space conflicts [7].

LEED encompasses a broad spectrum of green building design parameters that if implemented can make a building sustainable. The key areas of building in a LEED are sustainable sites, water efficiency, energy and atmosphere, material selection, indoor environmental quality, innovation, and design process. The geographical location of the project plays a substantial significance in the success of the green building certification process [8]. This category consists of various important factors such as land protection, site development density and diverse usage, accessibility to the quality transport system, and adoption of fuel-efficient vehicles. Each of these factors possesses a certain point which altogether helps in achieving the LEED certification. In the planning and designing phase of a project if these factors are considered on practical grounds, then it can help buildings be less susceptible to pollution [9].

3. Research Methodology

The fundamental methodology of this research is to develop a user interface UI that will act as an integration model for integration of Autodesk Revit API, Google Earth Pro, and LEED calculations as shown in figure-1. This will help us in performing LEED location calculations on the BIM model which will make the process efficient and provide accurate LEED results [2]. The integration model consists of three components which have been explained in detail as the following:

- The first component comprises of BIM model developed on Autodesk Revit. This involves project information such as geographical coordinates, longitudes, latitudes, site area, and project site area.
- The second component is the interface consisting of project information extracted with the help of BIM as stated in the previous point and project specific location data extracted using google earth pro comprising of traffic conditions, routes, density radius, and services radius.
- The third component composed of LEED guidelines based on location and transportation system. It includes formulas that automatically perform LEED calculations and generate LEED points. It can also generate LEED results into a tabular form.

Collectively, the user interface UI will display LEED location data of the project which will help architects and engineers markedly for the analyzing the green building location.

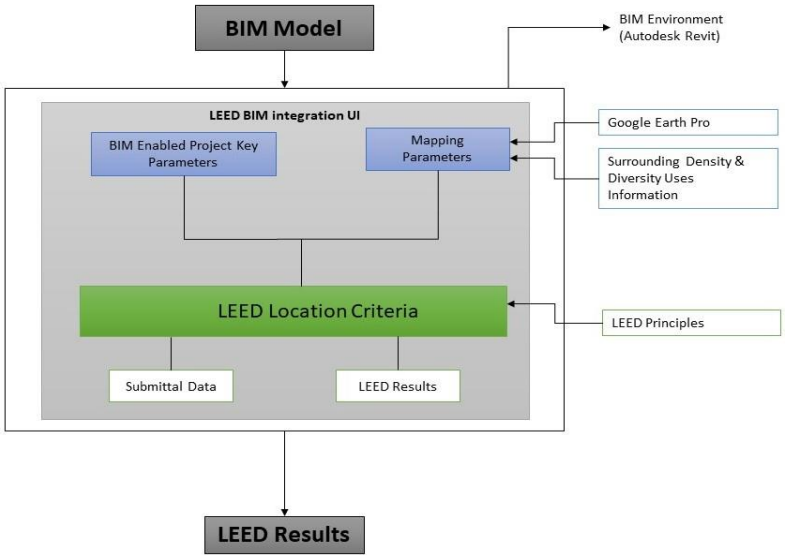

Fig.1. BIM – LEED Integration Model

4. Analysis and Discussion

The LEED location and transportation system are based on two options. The first option deals with development density and the second option deals with diverse uses. The integration model can provide the relevant project location data from the Revit BIM model, and it can be displayed on the map correspondingly [10]. As far as the project gross area and the surrounding site area is concerned, they can be calculated within the Revit. The interface has a backend formula to calculate density radius as follows.

$$Density\ Radius = 3x\sqrt{Site\ Area}$$

Similarly, the development density can be calculated based on the following formulas.

$$Development\ Density = \frac{Project\ Gross\ Area}{Site\ Area}$$

The density calculation comprises all planned and existing buildings that exist within the boundary of a project. However, it excludes all those areas that are specifically designated for parking facilities. According to LEED, the specific density should be attained within five years from the date any type of building has been occupied. During the analysis, if one part of the project, either residential or non-residential, qualifies for the minimum density criteria but the other does not fulfill the criteria then it is suggested that only the qualifying density should be included.

Surrounding Density

The points about the surrounding density of a project are earned based on calculation guidelines given by the LEED. Primarily, there are five major steps in the process. The first step is the identification of building sites and buildable land within the periphery of the project boundary which can be done with google earth pro. Once the site has been identified, the next step would be to gather the required information which includes the number of building units that already existed on the site. Afterward, specific calculations for residential and non-residential projects are performed. The formula for residential land use in a category of mixed-used projects are:

$$Mixed\ Used\ Residential\ Land = \%\ Residential\ Floor\ Area\ x\ Total\ Mixed - Use\ Land\ Area$$

Similarly, the equation for non-residential land use is following.

$$Mixed - Use\ Non\ Residential\ Land = \%\ Non - Residential\ Land\ x\ Total\ Mixed - Use\ Land\ Area$$

For calculating combined density (excluding parking areas), the following equation can be used respectively.

$$Combined\ Density = \frac{Total\ Floor\ Area}{Total\ Buildable\ Land}$$

Units Used:

Combined Density: Ft^2/acre or m^2/hectare

Total Floor Area: Ft^2 or m^2

Total Buildable Land: Acres or Hectares

The last step will be to assign the points the project has achieved which will be given with respect to reference provided by the LEED.

Diversity of Uses

In this option, basic facilities are counted within a radius of 400 meters. This also includes calculating the distance traveled by walking and indicating these routes on maps. As a result, based on this, credit is awarded to the project.

The user interface will encompass all the calculations and scenarios related to project location as discussed above. Once these steps are successfully incorporated into the user interface, it will be integrated with the BIM model in a Revit platform. As a result, LEED calculation for location and transportation system can be generated. This will reduce the time drastically as well as more accurate results will be generated.

5. Conclusion

The concept of BIM and sustainable building are the two major milestones that the construction industry is currently experiencing. The adoption of BIM and sustainable building practices can lead to achieving sustainable development goals. However, the rate of progression of these concepts is very slow. Furthermore, the LEED calculations are generally conducted manually or by some methods which are not efficient enough. This research addresses this concern and provides an efficient yet digital transformative way to tackle this issue which has not been addressed yet so widely around the globe. The benefits of developing a such BIM-LEED interface are not limited to calculations that are involved in the process, but it also fosters a concept of sustainable construction in a more structured manner. By integrating BIM with LEED, designers and planners will be able to make informed decisions about the design of a building at the very initial stage of the project. This will resultantly reduce the cost that may be incurred if the same analysis would be carried out at the later stage of the building lifecycle. Therefore, the advantages of this integration model are two-fold. However, it can be concluded that this effort requires further research and investigation to check the credibility of the BIM-LEED integration interface to confirm that the results generated are accurate as it was done manually as well as the interface is capable enough to perform calculations on various types of projects.

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