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Abstract
Green building design promotes reductions in building energy use. In most climates, the building's heating and cooling loads account for the greater portion of the energy consumed, but they are also significantly affected by the location and type of objects near the building. The presence or absence of shade on the building facade directly affects the indoor temperature. Therefore, by performing an energy analysis of a given building with and without the presence of landscape and other elements, we can quantify these effects. However, since such a practice for a real building on a real site is impracticable, a method of simulation must be employed. Building Information Modeling (BIM) integrated all the information required to construct a building and is, therefore, the best technique to conduct such simulations. This study presented the results of a series of simulations leveraging the parametric modeling capabilities of BIM, using a base test building model created in Autodesk Revit. Once the building parameters are set, BIM allows for the energy simulation to be run with various combinations of site features, which is not only advantageous in the design of the building and its systems, but also for any future changes contemplated to site features. Through BIM energy simulations, this study showed the significant effects on building energy use that can be achieved through the location, orientation, and shade density of various objects.

Keywords
Building Information Modeling, Green Building, Building Energy Modeling, Effects of tree shade, Revit Software**.**

1. Introduction

The ever-increasing resource needs of modern living have brought a greater urgency in the need to conserve the Earth's dwindling natural resources. Increasingly erratic weather patterns and natural disasters have made us more aware than ever of the impact humans have on a global scale [1]. One of the greatest sources of negative impact is the pollution caused by energy production using non-renewable sources. Since the switch to more viable clean sources has been slow, industries and governmental agencies are also trying to reduce consumption [2]. As the largest consumer of energy in the US, it is therefore important that the construction industry invests in life cycle energy reductions as well. The use of Leadership in Energy and Environmental Design (LEED) and other such green construction building certifications has led to a concerted effort in this direction [3]. Concerning building structures, one of the largest energy loads, and therefore one of the primary means to reduce energy use is heating and cooling use. It has been shown that shading, through the use of trees, has a measurable impact [4]. The advent of new technologies has led to significant changes in the design process. Ink and Mylar have been replaced by Computer-Aided Design Drafting. The next step from computer-generated 2D to 3D Building Information Modelling is already here. With all the built-in versatility of BIM, it is poised to soon become the industry standard.

Building energy consumption is a major concern, with one of the largest operational demands of any other sector of the economy [5]. The transition to energy-efficient buildings is a critical component in achieving sustainability. Najjar *et al.* (2019) developed the building information modeling, and life cycle assessment to improve the operating energy efficiency of the resulting building designs adopted, as well as to reduce the difficulties associated with the building's construction in terms of cost of construction The findings revealed that all components of building envelopes, notably outside walls and windows, have an impact on energy consumption in structures. The suggested framework can reduce yearly energy usage intensity by around 45 percent, increase life cycle energy use and expense by more than 50 percent, and minimize environmental impacts such as acidification and global warming potential by more than 30 percent.

Energy modeling techniques are also commonly utilized in the building design process to predict the energy required to ensure internal environmental comfort and to convert traditional buildings to energy efficient structures [7]. Building information modeling is a new technology that offers benefits such as time savings, analysis procedures, greater accuracy, and more rigorous design, as well as the capacity to predict environmental performance during the life cycle of a building [8]. Furthermore, the use of Building Information Modeling and energy evaluation tools could play a significant role in the selection of less energy-intensive materials and components that have a reduced impact on overall building energy usage [9].

Also, Farzaneh, Monfet, and Forgues (2019) studied Building Energy Modeling (BEM) using Building Information Modeling in design practice. The results showed that the effectiveness of BIM-BEM implementation is dependent on two key factors as follows procedure and technology. In addition, Gao, Koch, and Wu (2019) provided an overview of the building design process, as well as applications of building information modeling and building energy modeling in the design process. The results showed BIM technique -based Building Energy Modelling is recognized as being particularly useful for the early design stage, where the most appropriate and cost-effective ways for Building Information Modelling-based Building Energy Modelling is recognized as being particularly appropriate for the early design stage, when the most appropriate and cost-effective options for energy-efficient design may be integrated into the entire building design process.

BIM allows various simulations to test the design system functions including building energy use. Because of life cycle energy use reduction for a building, such a simulation can be used to compare different configurations for maximum benefit. For example, the effective use of trees, through placement and density selection, can have a lasting and continual impact. These effects are easily evaluable through BIM. Other passive means of energy use reduction, such as the usage of external louver shading devices, can also have a measurable impact on building HVAC (Heating, Ventilation, and Air Conditioning) load [12], but these devices are beyond the scope of this paper. In using BIM to model tree placement to measure the effects of shade on the building, one area of consideration is always the accuracy of the model. In a previous study, several measurements were first recorded at a specific live test site to calibrate a

BIM model before simulations were performed [13]. Hes and his team cite the complications involved with creating a representative model of trees since they vary so widely in form and dimensions even within the same species. Durdyev *et al.* (2022) studied a prioritized list of hurdles to industry-wide BIM adoption throughout the Facility Management (FM) phase. This study showed that one of the most constraining factors is a lack of competence and familiarity with BIM-related technologies, which requires special attention.

2. Objectives

The goal of this study is to demonstrate the energy use impacts of various shade items and placements under the same set of building parameters. The results will demonstrate the benefits of using a BIM tool to save energy over the course of a building's life cycle, as well as the benefits of deploying strategic shadow items. This will include examining the following objectives:

a) Investigating the influence of a large tree shading on the thermal loads and indoor temperatures of a house in a warm climate.
b) Focusing on the implementation of Building Energy Modeling and Building Information Modeling to simulate the thermal house performance.
c) Suggesting strategies allow changing the trees shading to enhance the house simulation around the year.

3. Method

3.1. Software Tools

This study was conducted using Autodesk Revit exclusively. Previous studies in this vein were conducted using multiple platforms due to the limited capabilities of BIM software [15]. Revit now integrates the capabilities of Autodesk Green Building Studio, Ecotect, and Vasari, so a designer may perform sun and shadow studies as well as energy analysis on the same model from within Revit (Panteli, Kylili, and Fokaides, 2020).

Since this study only aims to study the differences caused by variation in shade object form and location, the building’s characteristics were unimportant. Therefore, the building was created as a generic 4 story mass concept model. The various simulation configurations were created as “design options” within the same model file and the runs were performed separately for each option. The building parameters specified were as shown in Table 1.

Table 1. Building Parameters in Model

Parameter	Value
Building Type	Office
Core Offset	12’-0”
Exterior Wall	High Mass Construction – Typical Mild Climate Insulation
Interior Wall	Lightweight Construction – No Insulation
Roof	Typical Insulation – Cool Roof
Slab	High Mass Construction – No Insulation
Glazing*	Double Pane Clear – Low E Hot Climate. Low SHGC

* 40% building envelope

3.2. Location

The site for this case study is Baton Rouge, Louisiana 30.4500° north latitude, 91.1400° west longitude. Baton Rouge has a hot and humid climate with mild winters, typical of the United States Gulf Coast. Despite its proximity to oil production in the Gulf of Mexico and as a hub of oil industry-related businesses, Baton Rouge does not have any formal policy energy reduction efforts in place. An increase in LEED-certified construction projects, however, does show a growing awareness of environmental issues in light of multiple major storms that have affected the area over the last decade.

Fig. 1 shows a rendering of the model with tree objects at Location 4. Since the most sun exposure in the northern hemisphere is to the west and south, the north and east orientations were not considered for this study. It should be noted that for a location with a hot and humid climate, eastern sun exposure will have more impact on cooling loads than at more northern latitudes with mild or cold climates.

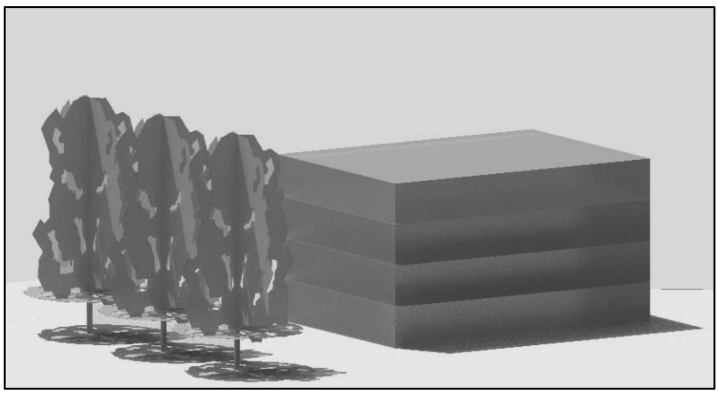

Fig. 1. Building Model with Tree Objects on the South Side at 75 ft.

3.3. Simulation

The shade simulations were differentiated into solid, partial man-made, and partial tree shade [17]. To minimize the variables in the simulations, each shade object was created to be 50'-0" tall. Solid shade was represented by a 25'-0" wide "building" block, the partial man-made shade was represented by a vertical brise soleil or screen and the tree was a generic mass shape made up of 3 flat planes with randomly placed voids, oriented along each axis, that intersect at 90°. The geometric features of the test house were entered into the Revit software, which allows for the sketching of geometry and environmental characteristics. To evaluate the influence of nearby trees shading the house, they were simulated. Due of the tree's complex shape, many geometries were tested to simulate the effect of the shading on the house.

Three sets of four simulations were then run by placing each of the three object types in four locations concerning the building as follows:

Location 1: 35'-0" West

Location 2: 75'-0" West

Location 3: 35'-0" South

Location 4: 75'-0" South

4. Results

According to the results, the shade has a measurable impact on a building's energy efficiency. The model backs up commonsense: the largest reductions are dependent on orientation (West vs. South), followed by proximity to the building (greater when the shade object is closer). The cooling demand is reduced by around 10 mBtu during the hottest month (August), but significantly more in the case of solid shade, as expected (see Fig. 7). In contrast, the presence of shadow increases cooling loads significantly, and solid shade and tree shade raise cooling loads much more. However, in the case of tree shade, this can be completely avoided by planting a deciduous tree.

The reduction in monthly peak demand has had the most impact. Though the monthly reductions are minor, the overall impact on annual electricity consumption is significant. Between the baseline model and the best scenario, the overall savings in Energy Use Intensity (EUI) is roughly 1 kBtu/SF/yr (see Fig. 2). This low figure can be attributed to the model's low fuel usage. Because heating accounts for the majority of fuel usage, a project's total consumption in Baton Rouge is expected to remain low.

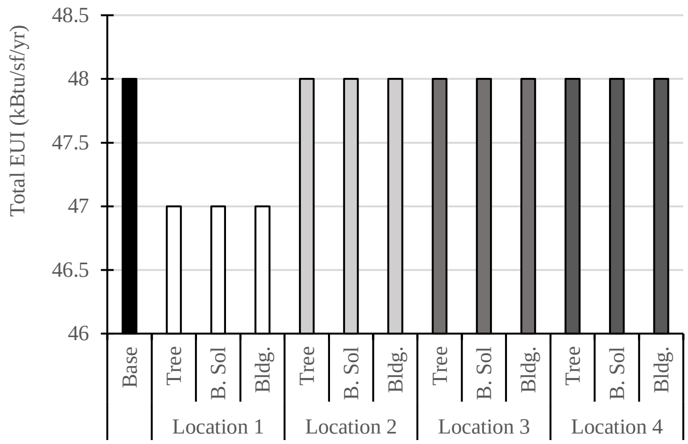

Fig. 2. Total Energy Use Intensity of Building Model.

For the same reason, the reduction in total carbon emissions (see Fig. 3) is minimal (about 6 tons.) As a comparison, the same model was used to simulate tree shade in Boston, MA, and the changes are considerably more pronounced.

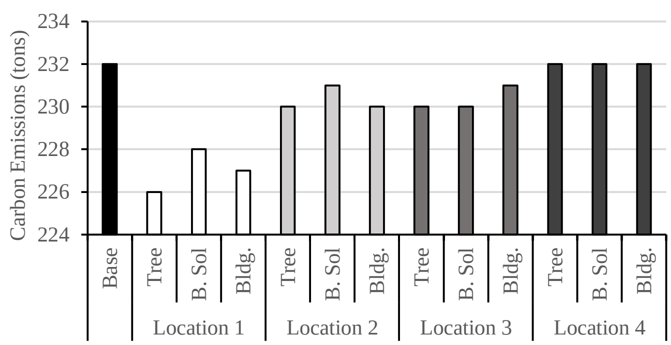

Fig. 3. The Reduction in Total Carbon Emissions of Building Model.

For the same model, Boston's Fuel EUI is 27 kBtu/sf/yr, while Baton Rouge's is 4 kBtu/sf/yr. From the base model, Tree Location 1 (best case) results in a 48-ton reduction in total carbon emissions. This is similar to the average miles driven by nearly 9 passenger automobiles in the United States, according to Environmental Protection Agency (EPA) figures.

The annual power use/cost and entire life cycle energy use/cost for this model are shown in Fig. 4 and 5. Monthly peak demand and monthly cooling loads for tree shade at Locations 1, 2, 3, and 4 vs. the base model are shown in Fig. 6 and 7. As expected, extensive shadow close to the building's west façade reduces cooling loads and related energy usage the most. Even with the least shade (Tree Location 4), the life cycle energy use is reduced by 42876 kWh. For a mild climate site like Boston, the overall losses are expected to be significantly more substantial for each of the twelve model changes.

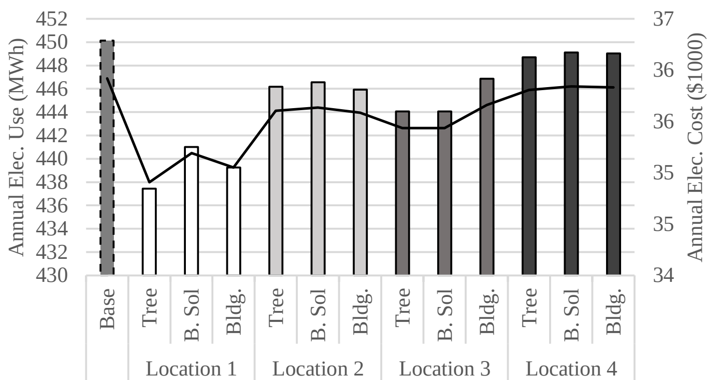

Fig. 4. Annual Electricity Use/Cost.

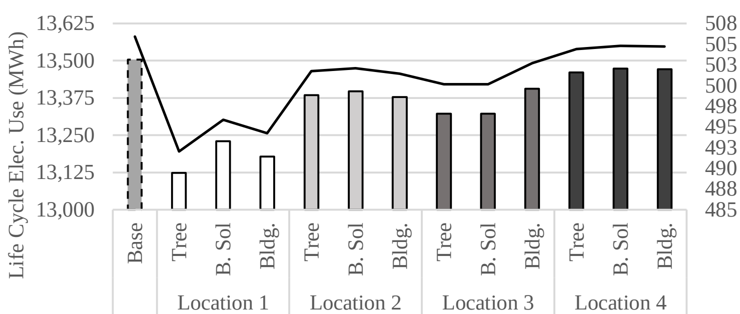

Fig. 5. Life Cycle Electricity Use/Cost.

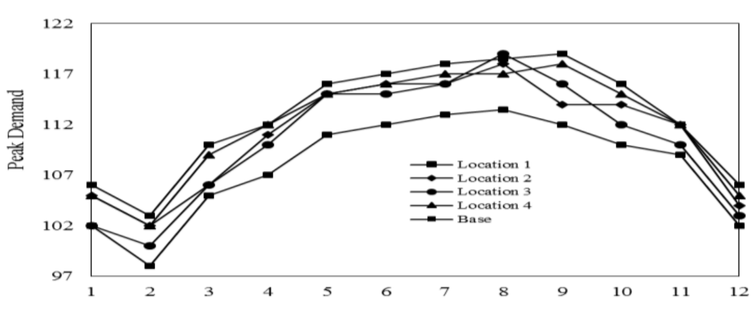

Fig. 6. Monthly Peak Demand for Tree Shade vs. Base Model.

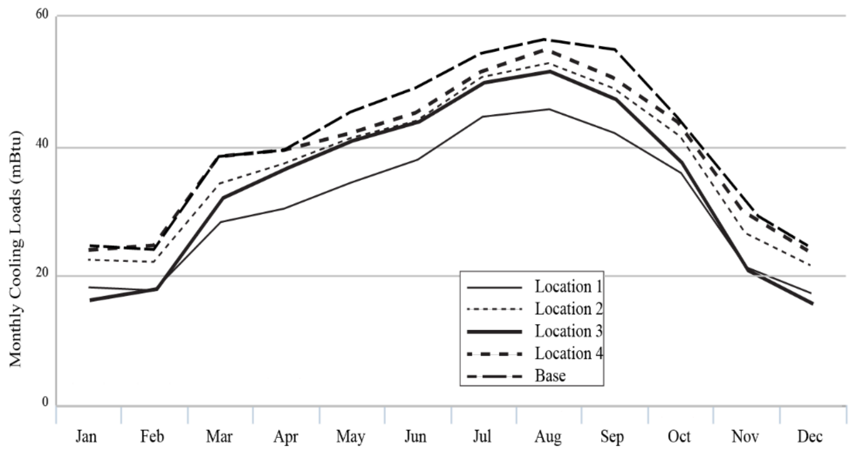

Fig. 7. Monthly Cooling Loads for Tree Shade vs. Base Model.

5. System Limitations

The use of Revit, while simple, is not very smooth. Previously, any model created in Revit had to have its files exported to other software, such as Green Building Studio (GBS), to have a certain analysis performed (Rahman, Mim, and Oshin, 2021). Newer Revit versions offer this as an Autodesk 360 feature. The software uploads the model to the GBS system and the result is returned to Revit. This leads to frequent run failures.

Another inefficient system limitation is that the pre-loaded objects within Revit are not "seen" by GBS. These objects must therefore be modeled especially as mass objects. This can be time-consuming, especially for something as complex as a tree and the resulting object file can become very large [19].

Once an analysis can run, Revit does report its results in an easily understood manner, and running data comparisons is fairly straightforward. However, the ability to export the results to software like Excel would make the process smoother, especially for larger models with many more simulation runs.

6. Conclusions

The type of testing performed by this project can only be performed with capable and robust BIM software. It is neither practical nor possible to change a building's landscape and adjacent environment while controlling for all other variables, to determine energy savings, but with software, this testing is practical, repeatable, methodical, and measurable.

The results of this project can serve as a starting point for other real-world projects. The base model for this study is a conceptual mass block, which proves that concerns about energy efficiency (or any other green measure) can be addressed from the very initial stages of design. The post-construction measurements might not tally absolutely with the initial simulation results, but the simulation will have predicted the best possible configuration for the design. According to the results, tree shading in hot climes can lower indoor air temperatures, achieving or approaching thermal comfort in non-air-conditioned homes. Tree shading can save a lot of cooling energy in air-conditioned homes. Thus, we recommended strategies allow changing the trees shading to enhance the house simulation around the year.

The added advantage of this method is that it can also be deployed for existing conditions. For example, when a change in landscaping or an addition to an existing building or complex is contemplated, this type of simulation will predict the resulting impact on the energy performance of the existing building. The implications of such a system are manifold and are deserving of more study.

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