Alternative Construction using BIM in Old Educational Buildings

Case Study: The Deanship Building of the Materials Engineering Department, University of Technology, Iraq

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ABSTRACT

The current study analyzes historic educational buildings to discover the optimum combination of improvements for optimal energy cost. The analysis was conducted using BIM technology and associated programs such as Auto Desk Revit 2020 and Auto Desk Insight 360 to determine the optimal strategies by which the most applicable alternative construction materials and procedures are considered to obtain environmentally and economically sustainable old educational buildings. The analysis showed that several approaches may reduce the cost of electrical energy usage and generator fuel in aged schools. Optimal changes lead to such reductions. Altering wall and roof materials minimizes electrical energy usage. The findings reveal that altering the lighting efficiency (0.3 W/sf) in the best way decreases the cost of electrical energy consumption by about 65,575,500 Iraqi Dinars (ID), and reduces the cost of fuel energy consumption by approximately 510,000 ID.

Keywords-BIM; historic buildings; construction projects; sustainable design; energy efficiency; Autodesk Insight 360 Cloud

I. INTRODUCTION

Given the importance of the energy industry and the occurring economic downturn in Iraq, the goal of this research is to look into the possibility of using environmentally friendly alternatives in old buildings, like schools, in order to cut down the amount of money these buildings spend on electricity and generator fuel. Building Information Modeling (BIM) capabilities will be used to construct and maintain schemes that are grounded in reality via the 3D visualization of the structures. This will replace any schemes that are either missing or have not been fully explained. Rivet 2020 and Autodesk Insight 360 cloud were utilized in order to conduct an analysis of a wide variety of sustainable design options.

II. LITERATURE REVIEW

Construction projects are dissimilar in size, type, location, site conditions, inputs and outputs, something that makes each project unique and consequently the standardization of construction processes becomes extensively difficult and risky [1]. The construction industry is one of the most important industries, as it plays a significant part in the provision of buildings, public institutions, and infrastructure, as well as in the alleviation of poverty. [2].

Technology is the use of scientific effects for practical purposes. The word "technology" can also mean a group of tools and techniques that work together, like those used in construction [3]. The capacity of anything to be utilized without entirely depleting it or deteriorating is one definition of sustainability. Another definition is the capacity of something to continue existing or functioning for a significant amount of time [4]. Different kinds of goods, stakeholders, processes, and working conditions set the construction business apart from others [5]. A sustainable building is one that generates stakeholder value and contributes to the well-being of present and future generations by minimizing its environmental impact over the course of its entire lifespan. This is done by making the most of the building's economic value and improving human, natural, manufactured, and financial capital [6]. BIM [7] is an approach that is enabled by Information Technology (IT), and it requires applying and maintaining an integral digital representation of all building information in the form of a data repository throughout the various phases of a project's lifecycle [7]. The term BIM refers to a system that encompasses everything having to do with the various phases of a building project. It's a central repository of project information where stakeholders may access financial details [8]. BIM is a system that looks at every part of a construction project and uses the information to help make better decisions at every stage [9]. To increase the level of performance in a construction project throughout its life cycle, BIM is a complete and coherent system for all parts of the project. This system includes a set of effective rules, processes, and computer applications [8]. Implementing and maintaining an integrated digital representation of information across several project phases is a part of this [10]. BIM is a useful tool for simulating the conditions of a construction site in a virtual setting, where potential dangers can be found and fixed before they become big problems [11].

Construction of a green building is an ongoing process that begins with careful preplanning and continues long after the construction completion. The primary goal of most green construction projects is to reduce the building's energy consumption. The two main approaches to lowering energy use are active and passive design techniques [5]. A green building is one that uses sustainable methods in its planning, construction, and day-to-day operations to lessen or get rid of the impact the building has on its surroundings and the people who live there [12]. Sharing ideas and traditions makes people's lives more interesting and opens their minds to new things. Sharing cultural heritage also helps strengthen economies and communities [13]. The majority of the energy used currently by homes goes toward heating. The effects of electrical power use are expanding in commercial and industrial structures. Lighting, ventilation, and air conditioning, along with use-specific gadgets like computers and manufacturing gear, all account for a significant portion of an industrial facility's total energy consumption. This is especially true for newly built structures, since their heating needs are far less than those of older structures. Powering electronics, such as refrigerators and washing machines, use a lot of electricity. In places where heating is more important, like in the climate of central Europe, there are clear seasonal differences in how much energy the buildings use [14]. Since far-off energy and fresh-water sources would necessitate more energy for transferring electricity and water into cities, minimizing the demand for natural resources and limiting natural resource consumption is the primary challenge in the development of green buildings. To lower the ever-increasing energy demand, it is important to use new building system designs and renewable energy sources when possible [15]. A building is considered energy-efficient if its design and construction result in a considerable decrease in the amount of energy required for its operation and maintenance. Every facet of a building's development is attended to from the very beginning of each project by a dedicated staff. People who will be working and living in the building are parts of the team, along with architects, engineers, developers, owners, and, the future tenants. They collaborate to establish targets for resource conservation, productivity, and innovative space use. Buildings that use a collaborative strategy may be up to 70% more efficient than traditional commercial buildings [16]. A Net Zero or Zero Energy Building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied by renewable technologies. Energy efficiency in buildings means using less electricity, gas, and other fossil fuels. This is done by using high-performance equipment, appliances, products, and design strategies to reduce and control how much electricity is used [6]. The research on the utilization of building energy (Building Energy Efficiency) also defined as greening or modernizing of a building (Building Retrofit), or the process of modifying the structure of the building referring to changes that increase its energy efficiency [17]. One of the most energy demanding sectors in modern agriculture, the greenhouse industry is in definite need of energy consumption reduction [18]. Energy consumption in new commercial buildings may be reduced by 20% – 30% on average, and by over 40% for particular building types and locations, with the help of conventional energy efficiency technologies like thermal insulation, low-emissivity windows, window overhangs, and day lighting controls. Increasing a building's energy efficiency might raise the initial expenses, but the money saved on energy bills over the building's useful life can more than make up for it. One of the biggest advantages of sustainable design over traditional building methods is that it saves money on energy costs over the whole life of a building [5]. The energy consumption in the residential sector is very complex due to the large variety of construction types, sizes, thermal envelope materials, and the very wide variety of occupant behavior [19]. According to Green Globes, energy consumption is the single most influential factor in determining a building's overall sustainability. As such, it is given the most weight in Green Globes' three rating systems for buildings: Existing Building (EB), New Construction (NC), and Sustainable Interiors (SI) [20]. Most of a building's electricity bill goes toward running the air conditioner and lights. The energy requirements of a building can be drastically reduced through the use of passive design optimization in conjunction with building system optimization. BIM software can help architects, engineers, and building owners evaluate different design options and their effects on energy consumption, day lighting, thermal comfort, etc. [21]. Creating energy by burning fossil fuels results in the emissions of carbon dioxide. By cutting down the energy use, we may lessen that impact on the environment and cut down the human-caused causes of global warming, as well as the pollution that causes heat waves and other urban problems [22].

III. RESEARCH METHODOLOGY

The study strategy is mostly made up of two parts that are based on previous studies about BIM technology and take into account different ways to control how much energy a building uses.

A. *Part One (Theoretical Study)*

Relevant literature, including theses, books, journals, and websites was reviewed.

B. *Part Two (Practical Study)*

By examining the building in Autodesk insight 360 Cloud, a feature included in Revit 2020, sustainable design solutions were assessed. This study includes an energy audit that is completed in line with ASHRAE 90.1. The process used to conduct this analysis is outlined below.

- Autodesk Revit 2020 was used to create a three-dimensional building information model for the project.
- We made sure that each of the rooms has enough space.
- The energy settings changed and some information was provided, such as the location of the project and the kind of project it will be.
- Energy analysis was conducted in the cloud with Insight 360 by using Rivet 2020 to create an energy model and selecting the optimization panel.
- An investigation on the amount of energy that was used was conducted, with the findings being shown in the cloud by Autodesk Insight 360.
- The research results gave information about the different aspects of different design options and how those options affect the total amount of energy used (EUI).
- Using the cloud-based version of Autodesk Insight 360, the various ways in which energy efficiency may be improved via sustainable design were demonstrated and compared.

The results of the investigation were based on net-zero scenarios.

IV. CASE STUDY

The Deanship Building of the Materials Engineering Department of the University of Technology was the case study. The Department was established in 1999/2000, and the first B.Sc. group graduated in 2002/2003. In the department, evening classes first began in 2000/2001. The Deanship Building is one of Technology University's instructional buildings. This building has 4 levels and occupies a total area of 3368m^2. The segment building is made up of two structures joined together by a bridge.

Fig. 1. The case study building.

A. *Creating the 3D Visualization for the Case Study*

Visualization is a technique that is used to the benefit of the client in order to acquire knowledge of the construction projects, and this is something that can be readily done when applying BIM. The usual techniques involve the preparation of drawings in just two dimensions, which the clients may find difficult to grasp due to the fact that it is hard to generate a realistic mental picture of the complicated projects based simply on the drawings alone. With the help of Autodesk Revit 2020, the researchers were able to make a picture of the case study.

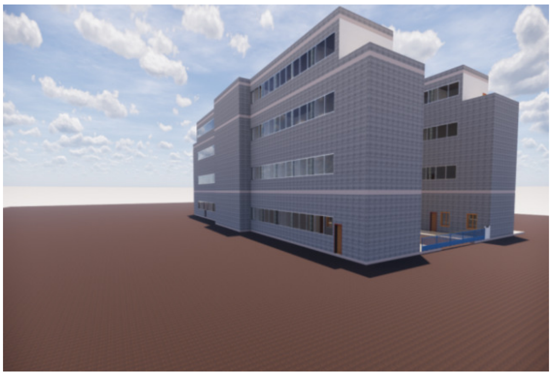

Fig. 2. Rendering of a case study in Revit 2020.

V. FINDINGS AND DISCUSSION

The findings of this study are derived from the energy settings in Revit 2020 and the scenario that was chosen from Autodesk Insight 360 on the web. Figure 2 depicts the case study model that was carried out in the Insight 360 cloud. The results showed the following:

A. *Roof Construction*

Green roofs provide a number of advantages, including shielding a building from UV radiation and temperature extremes and reducing the amount of heat that escapes and enters the structure. Roof construction demonstrates the overall resistance of roofs to heat gains and losses. This study compares and contrasts different ways to insulate a building and how well they reduce the amount of energy used. Figure 3 and Table I show that Roof Construction-R 10.25-inch SIP has fewer costs (electrical and fuel) than the other types of thermal insulation. R-value is a measure of the insulation used.

TABLE I. ANNUAL COSTS OF VARIOUS ROOF CONSTRUCTION TYPES

Roof Construction	Electric ($)	Fuel ($)
Uninsulated	228711	4568
R10	227492	4522
R19	227361	4547
R38	227310	4535
R60	227300	4572
R 10.25- inch SIP	227267	4520
R15	227347	4542

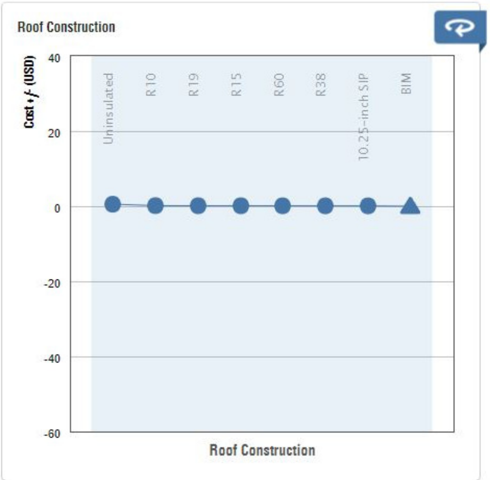

Fig. 3. Roof construction.

B. Infiltration

Holes in the building envelope are a common cause of unintended air flow into or out of climate-controlled spaces. Figure 4 and Table II shows that Infiltration ACH-2.0 has fewer costs of electricity, fuel, and energy than the other types of infiltration ratings.

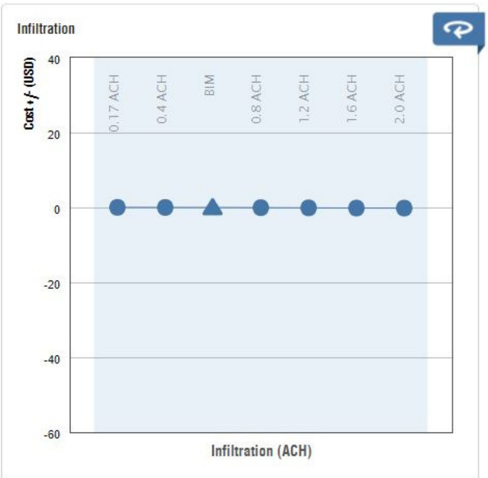

Fig. 4. Infiltration.

TABLE II. ANNUAL COSTS OF VARIOUS INFILTRATION TYPES

Infiltration	Electric ($)	Fuel ($)
0.17 ACH	227078	4530
0.4 ACH	226997	4540
0.8 ACH	226792	4553
1.2 ACH	226609	4559
1.6 ACH	226419	4571
2.0 ACH	226365	4529

C. Lighting Control System

This improvement included the installation of a regulation system for the building's lights, which combined presence detectors with twilight sensors in order to reduce the amount of electricity that was used. It's a typical occupancy sensor system that changes the lighting depending on how much daylight is available. In addition to day lighting apertures like skylights and windows, a day lighting management system often incorporates a lighting control system that is sensitive to the presence of daylight. When daylight alone provides enough light, this method may reduce the amount of electricity needed for electric lighting. This lighting system is able to recognize when a certain area is unoccupied and alter the level of illumination accordingly. Occupancy sensors are used in this process. The lights will either gradually dim or turn off completely in order to reduce cost. Another benefit is that it makes it easy to have the lights turn on automatically when the device detects people, which could also make the area safer. Figure 5 and Table III show that the Occupancy Control system has fewer costs (electrical, fuel, energy) than the other types of lighting control systems for buildings.

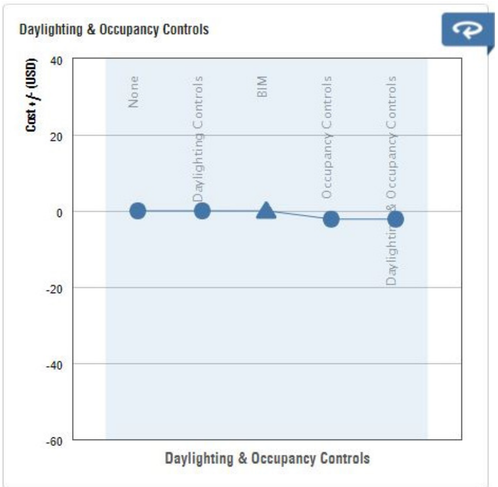

Fig. 5. Day lighting and occupancy controls.

TABLE III. ANNUAL COSTS OF VARIOUS DAY LIGHTING AND OCCUPANCY CONTROL TYPES

Day lighting and occupancy	Electric ($)	Fuel ($)
None	226997	4540
Daylighting control	226997	4540
Occupancy control	219687	4517
Daylighting and occupancy control	219689	4519

D. Lighting Efficiency

Lighting efficiency provides information on the power consumption as well as the average internal heat gain and power consumption of electric lighting per unit of floor area. In addition, it is a representation of the amount of electricity used. Figure 6 and Table IV show that a lighting efficiency system of -0.3W/sf has the lowest cost (electric, fuel, and energy) than the other considered types of lighting efficiency systems.

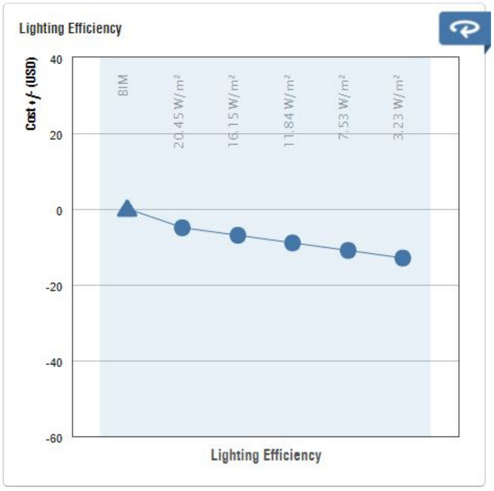

Fig. 6. Lighting efficiency.

Fig. 7. Operating schedule.

TABLE IV. ANNUAL COSTS OF VARIOUS LIGHTING EFFICIENCY TYPES

Lighting efficiency	Electric ($)	Fuel ($)
0.3 W/sf	183228	4496
0.7 W/sf	190027	4587
1.1 W/sf	196789	4507
1.5 W/sf	203557	4505
1.9 W/sf	210262	4498

TABLE V. ANNUAL COSTS OF VARIOUS OPERATING SCHEDULE TYPES

Operating schedule	Electric ($)	Fuel ($)
24/7	319692	11251
12/7	277194	7351
12/6	264673	6636
12/5	235477	6631

E. Energy Operating Schedule

This study highlights the many different operating schedules that may be used in buildings, as well as the degree to which different operational schedules can affect energy consumption and the intensity of energy use. Figure 7 and Table V show that the (12/5) operating schedule has less cost (electric, fuel, energy) than the other types of operating schedule systems (12 means that there are 12 working hours in total every day, while 5 means that there are 5 working days in total).

VI. ENERGY SIMULATION

After the 3D BIM model has been finished in Revit 2020, it was transferred to Green Building Studio (GBS) by using the Green Building XML (gbXML). This allowed coming up with different design options and give information about how much energy and water are being used efficiently. gbXML is an open schema that was developed to make simpler for engineering analysis tools to utilize BIM to access building data. The file was imported from the website of Autodesk Green Building Studio (the GBS cloud).

TABLE VI. ANNUAL COST SAVINGS

Alternative Type	Alternative Name	Annual electric cost of the alternative (ID)	Annual electric cost Savings (ID)	Annual fuel of alternative (ID)	Annual fuel cost saving (ID)	Annual energy cost saving (ID)
Roof construction	R 10.25- inch SIP	226267* 1500 = 340,900,500	678* 1500 = 1,017,000	4520* 1500 = 6,780,000	316* 1500 = 474,000	1,491,000
Infiltration	2.0 ACH	226365* 1500 = 339,547,500	580* 1500 = 870,000	4529* 1500 = 6,793,500	307* 1500 = 460,500	1,330,500
Lighting Efficiency	0.3 W/sf	183228* 1500 = 274,842,000	183228* 1500 = 65,575,500	4496* 1500 = 6,744,000	340* 1500 = 510,000	66,085,500
Day lighting and occupancy	Occupancy controls	219687* 1500 = 329,530,500	7258* 1500 = 10,887,000	4517* 1500 = 6,775,500	319* 1500 = 478,500	11,365,500
Operating Schedule	12/5	225477* 1500 = 353,210,500	1468* 1500 = 2,202,000	4631* 1500 = 9,946,500	205* 1500 = 307,500	2,509,500

*1500 represents the factor of converting the ID to $

VII. CREATE DESIGN ALTERNATIVES

GBS allows producing a variety of design options that have the potential to enhance the building's overall energy performance. Many different options, which are provided by GBS, were chosen based on an analysis by Autodesk Insight 360 and their impact on the amount of energy used and the amount of carbon emissions produced by the case study. Some of these options are orientation, window ratio, window shades, lighting control for the HVAC system, type of window glass, and type of wall. Equations (1)-(2) will be used to compute the yearly energy savings.

Annual Electric Cost saving (ID/year) = Annual Electric Cost of Building – Annual Electric Cost of Alternative (Researcher) (1)

Annual Fuel Cost saving (ID/year) = Annual Fuel Cost of the Building – Annual Fuel Cost of Alternative (Researcher) (2)

For example, the current yearly cost of electricity was 340,422,000 ID and the annual cost of fuel was 7,254,000 ID (Maintenance division / University of Technology). Table VI illustrates the annual cost savings for fuel and electricity.

VIII. CONCLUSIONS

This article gave a summary of the procedure that was used to establish a set of assessment criteria for historical structures. These criteria were utilized in the evaluation of historical and archaeological buildings. By using modern research methods, the authors of this study are making an effort to define relevant instruments and procedures that may be of assistance in the energy management. The main conclusions from the current research are:

- BIM is a very useful tool for a wide range of assessments, each of which helps find new ways to improve the energy efficiency of a project.
- Lighting efficiency of 0.3 W/sf has the greatest annual electric cost saving of 65,575,500 ID and infiltration of 2.0 ACH has the lowest with 870,000 ID.
- Lighting efficiency of 0.3 W/sf has the greatest annual fuel cost saving of 510,000 ID and 12/5 Operating Schedule has the lowest annual fuel cost savings with 307,500 ID.
- The results indicate that there is a clear difference between the estimated and the actual consumption of electricity and fuel energy. This is shown by the fact that there is a plain separation between the two. Based on these results, it seems that using BIM during the design stage is a great way to figure out how well a building uses energy.

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