Energy Analysis of High Rise Building on BIM

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Abstract

Energy crisis is one the major problem in construction sector. Most of the energy consumption is being utilized in high rise building. To use energy in a most efficient way, can reduce impact of energy crisis. Following the problem Building Information Modeling (BIM) is one the platform which provide a way for efficient utilization of energy through its energy optimization processes. The BIM in high-rise construction minimizes the errors in the construction process and energy utilization. BIM technology has been accepted around in the globe to tackle or solve construction issues. BIM has brought a new revolution to the Architecture, Construction and Engineering (ACE) industry. Over time, more advancements are taking place in BIM process to the meet the present as well as future challenges. For understanding and studying the BIM process, a 16-floor building project was selected located at metropolitan city of Pakistan. There are several dimensions of BIM based on data or the requirements the user is looking for. the energy efficiency of the building was calculated by creating the Energy Model in Revit. It was found out that by implementing BIM energy saving strategies, the consumption of 79.2 kBtu/ ft^2/ yr can reduce to 14.6 kBtu/ ft^2/ yr.

Keywords

Energy Consumption, AEC Industry, High Rise, BIM, Energy Analysis

1. Introduction

As we are entering into third decade of the twenty-first century, the world is at a turning point in the energy sector (Viox, 2023). In recent times, the energy consumption has been abruptly increased. To meet energy demands in buildings and to increase efficiency of available resources there is a need of advance strategies (Huotari et al., 2024). Around 33% of global energy is being consumed solely in building sector (Liu et al., 2023). In Pakistan, the building sector consumes more than 50 % of total energy consumption and it is growing at annual rates of 4.7 % and 2.5 % in household and commercial sectors, respectively. There is a dire need of proper energy management which can be done through innovative methods, as it was revealed that 20% losses of energy are due to absence of energy management (Hossain et al., 2023). The energy problem is the biggest single economic drag on Pakistan, the Pakistan BIM Council (PBC) is attempting to implement BIM adoption in the construction industry (Maglad et al., 2023). The problems of resource depletion and climate change are becoming worse right now. Construction sites and the building industry are the primary causes of this since they utilize a lot of energy. (Sacks et al., 2018). Using and implementing Building Information Modeling (BIM) can close all of these gaps (Jung & Gibson, 1999). The building industry uses between 20 and 60 percent of the world's total energy (Han et al., 2015). One potential approach to maximizing energy use and improving the general effectiveness of building design and operations is Building Information Modeling (BIM). (Azhar et al., 2012; Borrmann et al., 2018; Petrushevski et al., 2018). Buildings have a number of adverse impacts on the natural environment, the majority of which are linked to the use of nonrenewable energy, which raises questions about how energy-efficient buildings should be.. (Carvalho et al., 2021). Building Information Modeling (BIM) is being widely used by designers and researchers in the construction sector to manage building data and enhance productivity and quality worldwide. (Santos et al., 2019). Working on large-scale projects in the past, the construction industry was frequently troubled by missed deadlines. It is mostly due to poor project integration, ineffective communication within the work team, and customer-contractor disagreements (Habib & Kadhim R., 2020). However, with the rapid expansion of technology, a fundamentally new approach to architecture design and the preparation of construction documentation is required. It is vital for a diverse variety of architects, designers, and engineers to use computerized models of structures that incorporate all information relating to the future appliance, facility, and services. (Gamayunova & Vatin, 2014). Rapid urbanization has led to the utilization of the energy resources available. Greenhouse gases have more negatively impacted our delicate environment due to the mechanical system being used to its total capacity for active cooling of the building. This issue opened people's eyes from all over the world, which promoted energy-efficient building options. The performance in hot and humid locations and how building envelope design measures should be chosen are unknown. The AEC (architecture, engineering, and construction) industry has long attempted techniques to minimize project time, increase productivity, achieve good quality, and reduce the budget of the project. (Manzoor et al., 2021). New technology has come to light in the construction industry named BIM in recent times. BIM refers to “Building Information Modelling”. It is one of the best ways for changing the approaches to project maintenance, design, and construction. Planning, designing, and construction processes are complicated in high-rise construction. The BIM in high-rise construction minimizes the errors in the construction process with the help of the nD model (Sun et al., 2015).

The construction industry needs a sophisticated tool or process to manage or control all these issues. BIM technology has been accepted around in the globe to tackle or solve construction issues. BIM has brought a new revolution to the ACE industry. Over time, more advancements are taking place in BIM process to the meet the present as well as future challenges. For understanding and studying the BIM process. Specially in energy. Therefore, a study was conducted for a 11-floor building for energy analysis. The energy efficiency of the building was calculated by creating the Energy Model in Revit Insight by import from Revit 2019. It helped to increase the energy efficiency of the project with minimum cost.

2. Methodology

The methodology of the study has been divided in such a way that, initially energy analysis was carried out using Revit, Insight, and Green Building Studio. With retrofitting techniques, these instruments were utilized to investigate the thermal comfort and energy efficiency of an existing building to lessen reliance on its mechanical system. Before implementing the final design solution, the designers used the BIM tools to experiment with all viable design solutions, saving time and money and promoting more energy-efficient building design. The **Table 1** shows the project details while the **Table 2** represents material properties.

Table 1 Building Site Information

Project	Descriptions
Project Address	Karachi
Project Facing	South- Oriented
Property Type	Residential Building
Number of Floors	16 Floors
Total Built- Up Area	9000 sq.ft
Project Climatic Zone	Humid
Latitude	24°55'37.13"N
Longitude	67° 1'56.25"E
Elevation	156 ft

Table 2 Materials used in Building Components

Component	Description	Component	Description
Wall	Block Masonry	Glazing	Single Glazing
Roof & Floor	RCC	Doors	Wood

Energy setting is crucial for the attainment of better results. It is essential to clarify that the energy model does the energy simulation using the data produced by Revit for walls, doors, roofs, windows, and floors.

2.1. Energy Model Creation

The project Inputs create a new energy model which will take into consideration; new detailed design elements such as rooms, spaces, envelop thermal properties and glazing thermal properties. The energy model of the building can be seen in **Fig. 1 Energy Models**.

2.2. Heating and Cooling load of Building

The heat energy needed to be added to a place to keep the temperature within a reasonable range is known as the heating load. The cooling load is the quantity of heat energy that would need to be evacuated from a space (cooling) to keep the temperature within a reasonable range. For calculating the heating and cooling load of the building, the spaces and zones are assigned in the analysis tab to the rooms of the typical floor so that heating and cooling loads can be calculated. Assignment of spaces and zones can be seen in **Fig. 1 Energy Models** Spaces visibility also needs to be set up so that the heating and cooling load of the whole room can also be assigned. For these properties, click edit of visibility /graphics; in model categories, tab spaces boxes are ticked; to assign the whole volume of rooms. The heating and cooling load in the building is affected by the thermal input values for various building components, including the walls, roof, ceiling, slabs, floor, and glass.

2.3. Solar Analysis

The purpose of the solar analysis is to provide in-context solar radiation results to treat solar energies in design. Make sure that the location is the same before performing the analysis. The sun location is based on its location and position according to the building orientation as well as the date and daytime as it can be seen in **Fig. 1** (c). The solar analysis is performed to figure out how much sunlight is hitting the project surfaces through which we can easily find the size of the windows, put more trees or vegetation around high sun radiations, or place solar panels towards maximum radiation side facing the sun. It is necessary to be in 3D view before performing the solar analysis. Solar energy Annual PV (Which determines the annual simulation for PV energy production estimates). All Roof surfaces (On this basis it will give solar analysis results PV or insulation results) or select the outer surface of the building individual by selecting individually to know the overall cumulative insolation of the building. To achieve maximum accuracy, set the study settings based on actual data. **Fig. 1 Energy Models** represents solar radiation analysis.

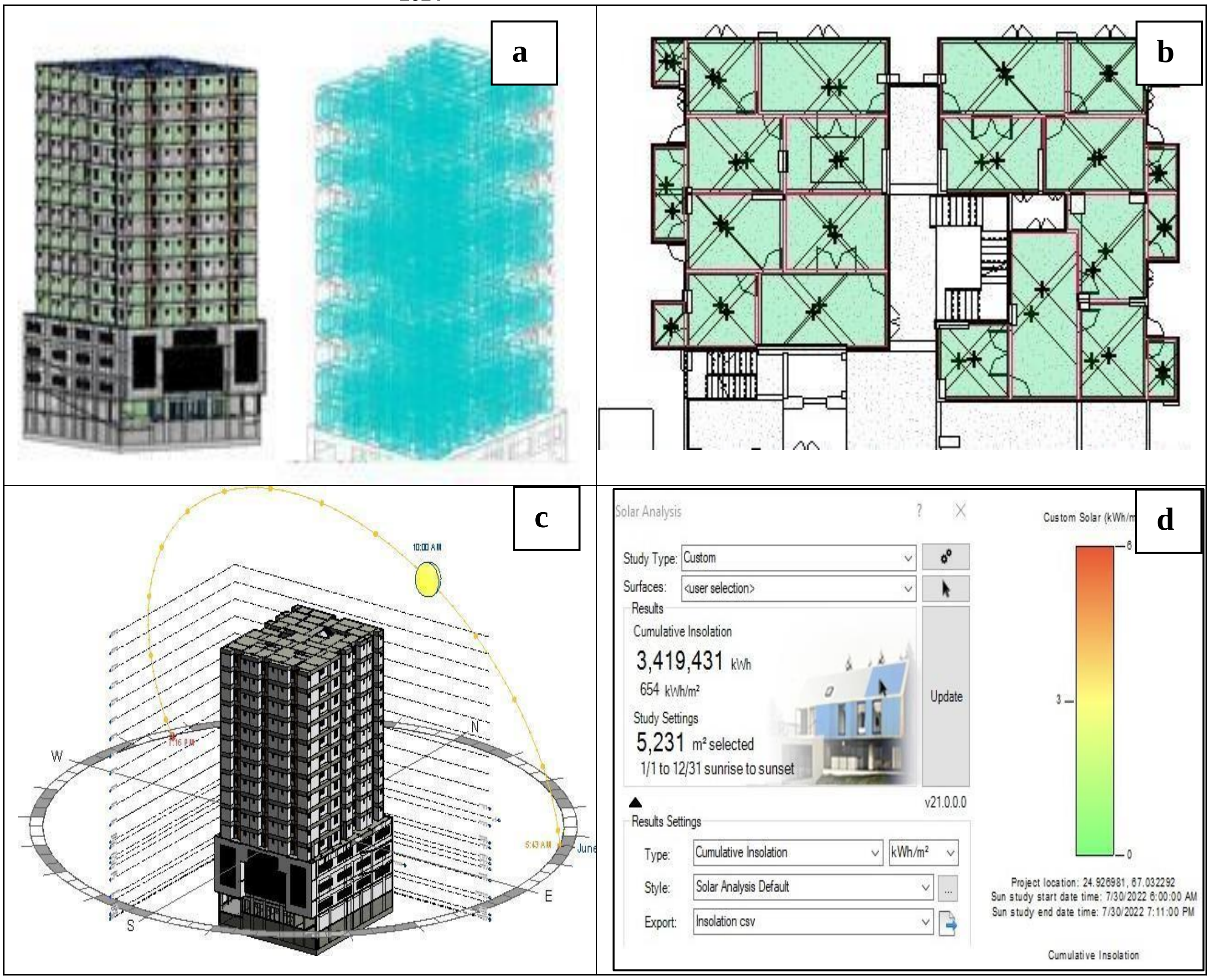

Fig. 1 Energy Models

2.8. Energy Optimization

Once the energy model is created, start optimizing the Revit model energy model by generating it in analyze toolbar. Once it is generated, a window shows that the process is completed and can be analyzed using the Revit insight plugin, which is a cloud base tool.

2.9. Working On Revit Insight

Revit insight helps to compare the performance of different model schemes and scenarios fora project. Scenarios indicate a set of factors setting. When exploring factor setting, insight can set ranges and compare potential design options. This factor sets save as a scenario and can be applied to any model for the insight. The collection page can be used to analyze all the models. The model comparison chart compares the model's performance in the insight; each bar in the model comparison graph represents one model. It can be used to see the maximum and minimum value of energy cost or UI and the scenario's name. The chart will be updated when updating scenarios. The 6D Energy Model was created by working on Revit Insight, the detailed analysis and results of the different energy analysis aspects are discussed in the results and discussions section.

3. Results

3. 1 Results

The focus of the study is to optimize the efficiency of energy in a building by applying BIM based Revit Insight and Green Studio. The results obtained by performing different Energy Analysis aspects of the building are presents in such a form that initially heat and cooling load results are discussed, which represents the heat and cooling loads from all four direction of the building. After that daylight analysis is shown which basically represents the areas of a building with different colors. Every color shows different temperature of that particular area and at last it discussed the different strategies that has been applied in order to reduce the consumption of energy in a high-rise building. The details of each step are discussed below:

3.1. Heat Load And Cooling Load Results

The Energy Model created in Revit was executed and it generates different result which are shown in **Table 3.** It shows all the peak cooling total toad and peak heating load for the materials, ventilation, lighting, power, people, fan heat, roof, infiltration and for some other factors.

Table 3. Peak Cooling and Heating Load for Different Components

Cooling Components	Total (Btu/h)	Percentage	North (Btu/h)	South (Btu/h)	East (Btu/h)	West (Btu/h)
Wall	19,252.10	14.47%	4,493.90	2,442.40	7,430.00	4,885.80
Window	33.6	0.03%	0	0	33.6	0
Door	142.5	0.11%	142.5	0	0	0
Roof	9,589.80	7.21%	-	-	-	-
Infiltration	15,837.90	11.90%	-	-	-	-
Ventilation	35,066.30	26.35%	-	-	-	-
Lighting	18,983.30	14.26%	-	-	-	-
Power	27,119.00	20.38%	-	-	-	-
People	5,246.90	3.94%	-	-	-	-
Fan Heat	1,816.90	1.37%	-	-	-	-
Total	133,088.40	100%	4,636.40	2,442.40	7,463.60	4,885.80
Heating Components	**Total (Btu/h)**	**Percentage**	**North (Btu/h)**	**South (Btu/h)**	**East (Btu/h)**	**West (Btu/h)**
Wall	21,956.10	23.19%	6,791.60	4,454.10	5,645.80	5,064.60
Window	25.9	0.03%	0	0	25.9	0
Door	215.1	0.23%	215.1	0	0	0
Roof	2,065.90	2.18%	-	-	-	-
Infiltration	6,190.30	6.54%	-	-	-	-
Ventilation	12,877.80	13.60%	-	-	-	-
Lighting	-18,983.30	-20.05%	-	-	-	-
Power	-27,119.00	-28.64%	-	-	-	-
People	-5,246.90	-5.54%	-	-	-	-
Total	-8,018.20	100%	7,006.70	4,454.10	5,671.70	5,064.60

The heating loads shown above demonstrate how much heat energy must be added to the area to maintain a comfortable temperature range. Most of the top floor's ancillary rooms are cold throughout the daytime during the winter and wet seasons. Compared to apartments facing the outside environment, the areas below and the rooms facing the open courtyard are also cold. The cooling loads shown above illustrate how much heat energy must be evacuated from the area to maintain a comfortable temperature range. Most of the upper floor's ancillary rooms were hot all day. Compared to rooms facing the outside environment, the areas below and those facing the open courtyard have comparatively less heat energy. From the simulation results, the building consumes about 114 $kBtu/ft^2/yr$, as shown below:

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3.2. Results of Day Light Analysis

The primary purpose of illumination analysis is to measure how much daylight is present in a given region. For the daylight analysis, floors were chosen as the study's floor level. The spaces that are positioned in the building's peripheral are seen to receive plenty of daylight during the day, while the inside spaces receive significantly less. The **Fig. 2** Day Light Analysis represents typical 15th floor day light analysis.

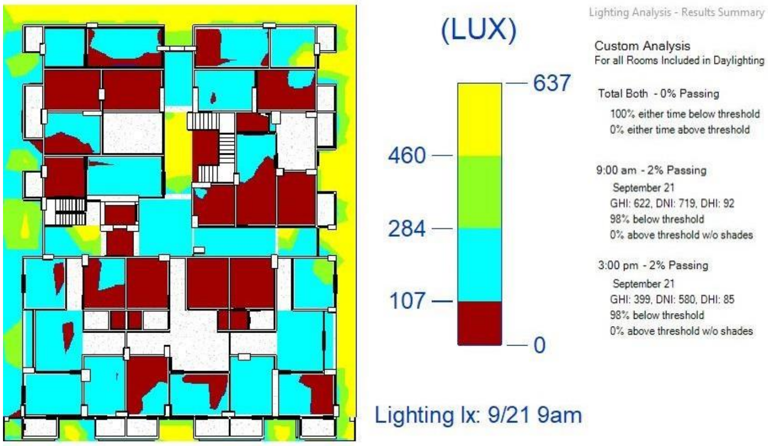

Fig. 2 Day Light Analysis

3.3. Energy-Saving Strategies

It is defined as the set of factors setting; that can select a model to apply the tool. Scenarios are for the model to be applied and help to look at factor options and guide towards designing for various energy performance goals. Click on a model in Revit insight to factor widgets which is an editor factors to reflect over desired settings for various energy performance.

3.3.1. Window to Wall Ratio

This results in a variable window-to-wall opening proportion, which further aids in lowering the building's energy usage. The graph displays the energy use intensity on an annual and incremental basis. Daylighting, heating, and cooling are all impacted by the window wall ratio (glazing area / gross wall area). The fewer windows are opened, the more energy is used in the structure. The result can be seen in **Fig. 3** (a).

3.3.2 Window Shade

It offers a wide range of window shade sizes to window height, which significantly impacts the building's energy use. HVAC energy use can be decreased by shade. The **Fig. 3** (b), represent energy savings results of window shades. The effect depends on additional elements like window size and solar heat gain characteristics. The building's minimum energy usage corresponds to window shadings of 2/3 the window's height.

3.3.3 Window Glass

It provides a wide range of glazing options, such as double glazing with low e value, double-glazed clear glass, single panel glass, and triple glazed with low e value, which can be utilized to reduce heat gain and solar heat gain in the building and to improve daylighting. The amount of daylight, heat transfer, and solar heat gain in the building are all influenced by glass characteristics, among other things. Utilizing triple-glazed low e-value glass improves daylighting by reducing glare and internal heat gain as can be seen in **Fig. 3** (c).

3.3.4 Building Orientation

It provides a variety of ideas regarding the building's best orientation, which will be best for the site and the building. This reduces the building's energy consumption by 0.26 kWh (0 degrees), 1.26 kWh (180 degrees), 1.32 kWh (270 degrees), 2.14 kWh (90 degrees), 2.89 kWh. (315 degrees), 3.84 kWh (135 degrees) and 4.52 kWh (225 degrees). The graph displays the intensity of energy use on a yearly and overall basis. This is accomplished by clockwise turning the

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structure, starting at 0 degrees so that the north side now faces east. The building's ability to conserve energy increases with improved orientation. The **Fig. 3** (d), represents energy saving result based on orientation.

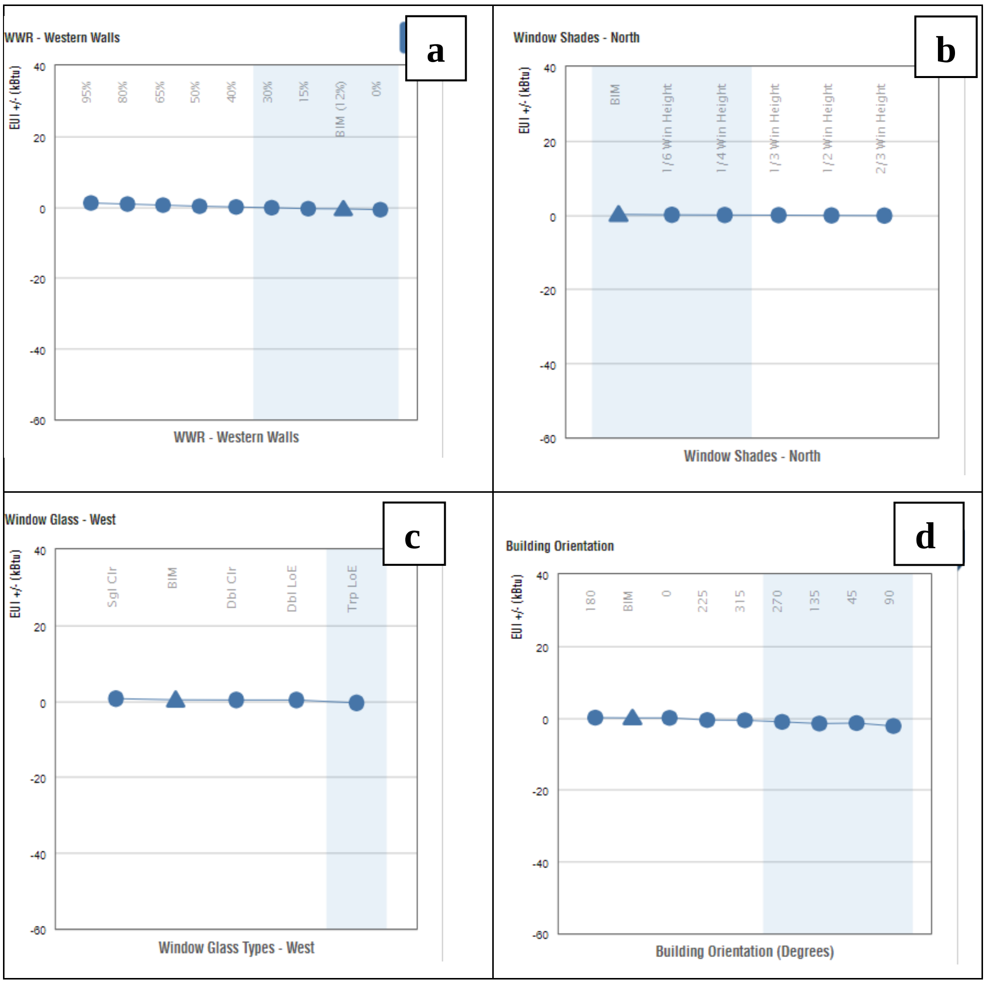

Fig. 3 Energy Saving Results

After implementing energy-saving strategies, the total energy performance was increased, as shown in the **Fig. 4**. Result reveals that BIM the consumption of 79.2 kBtu/ ft^2/ yr to 14.6 kBtu/ ft^2/ yr.

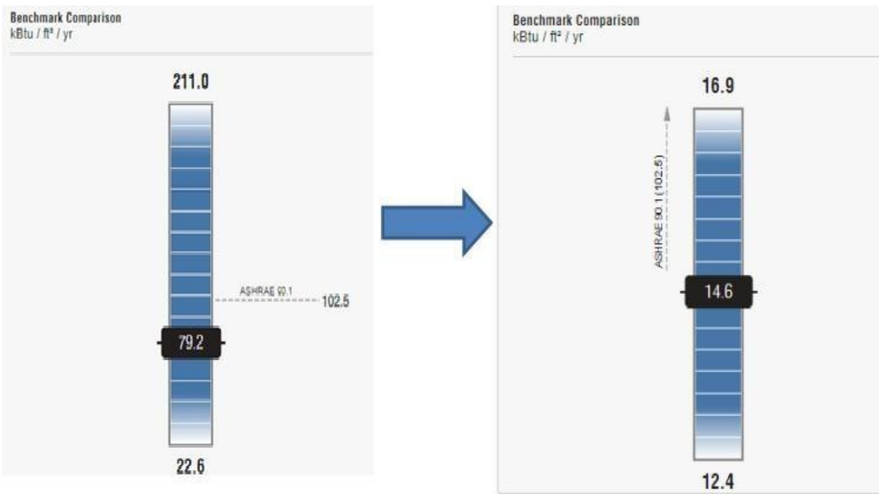

Fig. 4 Energy Performance

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4. Discussion

To reduce energy usage, buildings must be upgraded by managing heat transfers among different facilities (Stadel et al., 2011). Public goods are constructed, operated, and carried out by many utilizing BIM, which ensures these advantages in terms of the economy, society, and environment (Shoubi et al., 2015). Building efficiency can be increased by reducing energy use with the help of envelope systems. The main factors that determine a building's energy consumption are orientation, blinds, window wall ratios, plug load efficiency, and wall and roof construction. With the help of Autodesk Insight, several factors that primarily contribute to energy consumption are changed to help design the building envelope. The materials suggested by Insight according to the planning settings, when used in construction, consume less energy than buildings constructed with non-insulating materials. The thermal comfort of buildings is improved by reducing the heat build-up of the building skin. We know that sustainability is a top social requirement as pollution is on the rise. The building needs advanced capabilities to increase its energy efficiency of this building and analyze its energy performance of the building. It requires advanced software. Autodesk Revit and Insight plug-ins are the easiest and best way to assess building energy, and by changing the values of various design settings in the software, building designers can find the most efficient building model. The study can monitor the sun's energy through the design with the use of the findings from the examination of solar radiation. In addition to customized parameters, this application offers automated settings for research kinds. For solar analysis, surfaces are used. 4121 meters square was the size of the outside roof surface. A surface area's insolation was the total quantity of energy that had been accumulated there during a predetermined period. Typically, cumulative insolation was represented in (kwh/meter sq.). By following the examination of solar radiation, the total insolation was 600, 792 kwh.

5. Conclusions

The study was conducted on a high-rise building located at Karachi, Pakistan. The study focused on energy analysis on the building. BIM and Revit insight was used to see energy performances and various factors were utilized to increase the energy efficiency of the building, including location of the sun with respect to daytime, space allocation inside the building, solar radiation, building orientation, window shades, material, wall ratio was considered. After implementing energy saving strategies, energy performance of the building was increased comprehensively.

6. References

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modeling (BIM): now and beyond. Australasian Journal of Construction Economics and Building, The, 12(4), 15–28.

Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). Building information modeling: Why? what? how? Springer.

Carvalho, J. P., Almeida, M., Bragança, L., & Mateus, R. (2021). Bim-based energy analysis and sustainability assessment—Application to portuguese buildings. Buildings, 11(6), 246.

Han, B., Wang, Y., Dong, S., Zhang, L., Ding, S., Yu, X., & Ou, J. (2015). Smart concretes and structures: A review. Journal of Intelligent Material Systems and Structures, 26(11), 1303–1345.

Hossain, J., Kadir, A. F. A., Hanafi, A. N., Shareef, H., Khatib, T., Baharin, K. A., & Sulaima, M. F. (2023). A review on optimal energy management in commercial buildings. Energies, 16(4), 1609.

Huotari, M., Malhi, A., & Främling, K. (2024). Machine Learning Applications for Smart Building Energy Utilization: A Survey. Archives of Computational Methods in Engineering, 1–20.

Jung, Y., & Gibson, G. E. (1999). Planning for computer integrated construction. Journal of Computing in Civil Engineering, 13(4), 217–225.

Liu, J., Wu, H., Huang, H., & Yang, H. (2023). Renewable energy design and optimization for a net-zero energy building integrating electric vehicles and battery storage considering grid flexibility. Energy Conversion and Management, 298, 117768.

Maglad, A. M., Houda, M., Alrowais, R., Khan, A. M., Jameel, M., Rehman, S. K. U., Khan, H., Javed, M. F., & Rehman, M. F. (2023). Bim-based energy analysis and optimization using insight 360 (case study). Case Studies in Construction Materials, 18, e01755.

Petrushevski, F., Montazer, M., Seifried, S., Schiefer, C., Zucker, G., Preindl, T., Suter, G., & Kastner, W. (2018). Use cases for improved analysis of energy and comfort related parameters based on BIM and BEMS data. Advanced Computing Strategies for Engineering: 25th EG-ICE International Workshop 2018, Lausanne, Switzerland, June 10-13, 2018, Proceedings, Part II 25, 391–413.

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons.

Santos, R., Costa, A. A., Silvestre, J. D., & Pyl, L. (2019). Integration of LCA and LCC analysis within a BIM-based environment. Automation in Construction, 103, 127–149.

Shoubi, M. V., Shoubi, M. V., Bagchi, A., & Barough, A. S. (2015). Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches. Ain Shams Engineering Journal, 6(1), 41–55.

Stadel, A., Eboli, J., Ryberg, A., Mitchell, J., & Spatari, S. (2011). Intelligent sustainable design: Integration of carbon accounting and building information modeling. Journal of Professional Issues in Engineering Education and Practice, 137(2), 51–54.

Viox, A. R. P. (2023). American Deathscapes: The Ritual of the Sacred Ordinary Reimagining Approaches to Death Architecture in 21 st Century America. University of Cincinnati.