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BIM-based Energy Efficiency Analysis on Regional Architecture of Pakistan

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Abstract

Adopting sustainable building practices is necessary due to Pakistan's growing energy demand and environmental concerns. The building structure must guarantee occupant safety. Furthermore, it should also ensure effective, thermal, and visual comfort. However, the buildings usually lack the above parameters. Therefore, there is a considerable need to use sustainable design techniques, especially in Asian countries. The current study investigated the application of Building Information Modelling (BIM) for energy efficiency analysis in Pakistani regional architecture. Additionally, the study analyzed the building of Shell House, Karachi and its head office as well as the warehouse building in Vehari through different software. These included Formit Pro, Revit, Insight360, and Ladybug. The study looked at how BIM-based simulation tools can be used to optimize climate-responsive design elements, such as orientation, materials, shading, and natural ventilation. Several design scenarios were assessed in various climatic zones using energy modeling platforms to determine their effects on thermal performance and energy consumption. The findings showed that combining BIM with passive design techniques can greatly lower energy consumption and enhance building performance. The study emphasized how traditional architectural knowledge and contemporary digital technologies can be combined to create sustainable, energy-efficient solutions that are specific to Pakistani regional contexts.

***Keywords*:** building information modelling, energy analysis, insight360, revit

Introduction

To construct buildings with a strong sense of place, regional architecture prioritizes the local context and makes use of regional materials, climate-

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responsive techniques, and cultural traditions. Pakistan's regional architecture has a strong foundation in climate-responsive design, making use of regional materials and conventional passive cooling methods to adapt to a variety of settings, from frigid northern mountains to hot, arid plains. Pakistan has faced a considerable population rise in recent times. Energy consumption is directly proportional to industrial expansion and population growth. In order to keep up with the pace of growth, not only have new energy sources been discovered but the focus has been on the efficient use of available energy sources (Wang, 2011).

Carbon dioxide is the main by-product of this energy consumption, and poses a threat to the environment. Therefore, energy efficiency is becoming more and more important globally. A thorough coordination is always needed between Heating, Ventilation, and Air-Conditioning (HVAC) experts and interior designers to ensure not only aesthetics are looked after but functional optimization as well along with energy efficiency. Through coordination with HVAC) engineers and building physics professionals, attention should be paid to the aesthetic appearance of the building and energy-saving measures. With rise in the scarcity of resources at the global scale, the due availability of building based materials also comes into question with respect to non-renewable resources (Wang, 2006). Therefore, it is necessary to consider energy efficiency in architectural design. Concepts and initiatives, such as the zero-energy building adopted by the European Union (EU) to reduce carbon dioxide emissions may help achieve better energy efficiency and a good environment. In Pakistan, the difference between available energy and energy demand is rapidly increasing.

Buildings consume about half of the world's electricity and cause a third of the planet's carbon emissions (Bhatti & Iftakhar, 2023). Most of the energy consumed in buildings in the form of electrical energy is used for space heating and cooling. In many countries/regions, buildings' energy consumption accounts for 25-40% of total energy consumption. Compared with the construction techniques of the existing buildings that do not consider energy-saving measures, the number of newly-built buildings using energy-saving measures is very small (1%). This shows that the existing buildings have huge energy-saving potential (Alam, 2014). According to the International Energy Agency (IEA), a large part of the total energy can be saved by improving the efficiency of the building. On the one hand, it focused on promising renewable energy; on the other hand,

research has also been accelerated in improving the energy efficiency of existing buildings to reduce emissions and energy consumption (Ahsan, 2019). When it comes to the environmental impact of wastes and materials, retrofitting has proved to be a suitable option compared to demolishing and rebuilding the existing buildings. In the simulation study, the building envelope of the office with daylighting was evaluated to obtain the best window-to-wall ratio and window glass installation method. The results showed that by reducing the window-to-wall ratio from 50% to 30%, a considerable energy can be saved. By using suitable glass windows, 83% of the heating load can be saved.

Literature Review

Building Information Model (BIM) for energy simulation is a design and simulation method that uses accurate 3D computer models to draw, define, share, and coordinate data during the design process. As an output, BIM has the physical and functional characteristics of the building, and can be used as a shared knowledge resource for building information. Architectural information model depicts geometric shapes, spatial relationship of geographic information, quantity characteristics of architectural elements, bill of materials, cost estimates, and performance schedules. The model can be used to express the life cycle of the entire building (Gondal, 2021). As a result, the number and shared attributes of the material can be easily extracted. The scope of work can be easily isolated and defined. System, sequence, and the assembly can be displayed in proportions relative to the entire facility or a group of facilities. Project documents, such as drawings, submission process, procurement details, and other specifications can be easily interrelated (Kymmell, 2007).

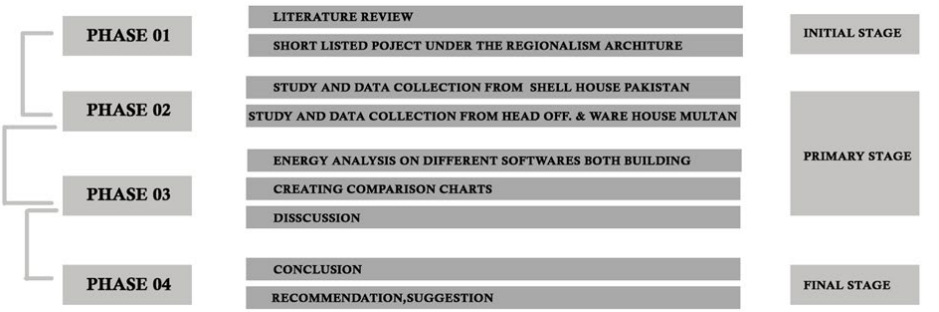
As a process, BIM can be used to construct digital models of buildings. Furthermore, its information can be exchanged and is interoperable. BIM provides the latest and effective project design information, cost information, schedule, energy simulation, and structural design required for construction projects. BIM is a method of constructing a 3D computer model for the design process, and its performance is evaluated by simulating its energy model (Ahmad, 2014). To be able to simulate building energy consumption, BIM provides accessibility. According to Slahuddin et al 2024, BIM energy simulation is quite useful to build energy assessment. Using BIM as a data source for energy analysis can make data entry more efficient, and existing data can also be modified. In addition, since BIM

allows "real-time" digital models to be connected to analysis programs, designers can more easily use and perform performance evaluations through known software interfaces (Shoaib & Islam, 2024). Moreover, design changes can be effectively merged. In this way, more design changes can be analyzed to increase efficiency and achieve sustainability goals (Borrmann, 2004). A study suggested that BIM can be used to evaluate the energy performance of a building by showing its efficiency. This is derived from a detailed study (Leon et al., 2021) that used BIM technology to optimize energy-saving design and achieved positive results. BIM is the key to analyze energy performance at different stages of the construction process. The energy simulation of the BIM model should follow the following steps:

- Use Revit software to make a 3D BIM model
- Set up the energy analysis model
- In the analysis tab, analyze the BIM model by creating an energy model
- Run the simulation and get the results

Figure 1

Research Flow Chart



Statement of Problem

Aesthetics and functionality both create beautification in architecture. In different contexts, different countries of world adopt many regional design approaches and fundamentals same as those employed in Pakistan. Furthermore, many modern and contemporary architects' practices are based on their regional architectural approaches. However, they do not have any idea regarding the designing and planning outcomes or results based on their decisions being made hypothetically without any software simulation. Hence, the current research aimed to merge originality with context. This

was done with the help of different software. BIM-based analysis is helpful in getting the outcomes of variables' exploration in energy, cost, and time efficient manner through utilization of diversified and interoperable software and their allied plugins. This ensures regional and climatic conditions be better integrated in the analysis through gathering local data and its usage in the process (Khan et al., 2024).

BIM-based analysis on different plug-ins was used to determine the output results that matched with the context of region or were just designed on own assessment of architect. This highlights only aestheticism not regionalism (Masood, 2013).

Research Objectives

The major objectives of this research are as follows:

- To evaluate the level of different design approaches incorporated in building designs regarding regionalism to achieve maximum energy efficient designs.
- To check the after-compilation stage of building in order to easily judge what is the response of respective region on building design.
- To ascertain whether a building's architectural principles align with its context, region, or user-friendliness without resorting to excessive mechanical means architectural design optimization with reference to energy based contextual and regional needs.

Research Questions

The current study aimed to answer the following research questions:

- Which software are used for simulation process to measure how the region and context effect the building design?
- How can energy efficient architectural designs be achieved and executed in respective contexts and regions, and what are the after effects?
- What are the best and cheaper materials used in different contexts of Pakistan to achieve maximum results?

Research Methodology

The current study aimed to evaluate the building of Shell House Karachi

and its head office as well as the warehouse building in Vehari. It discussed both buildings and compared them through different software. These included Revit, ladybug, Formit360, and Insight360, which judged the energy-building performance.

Shell House Karachi

Figure 2

All Plans and Elevations of Shell House, Karachi

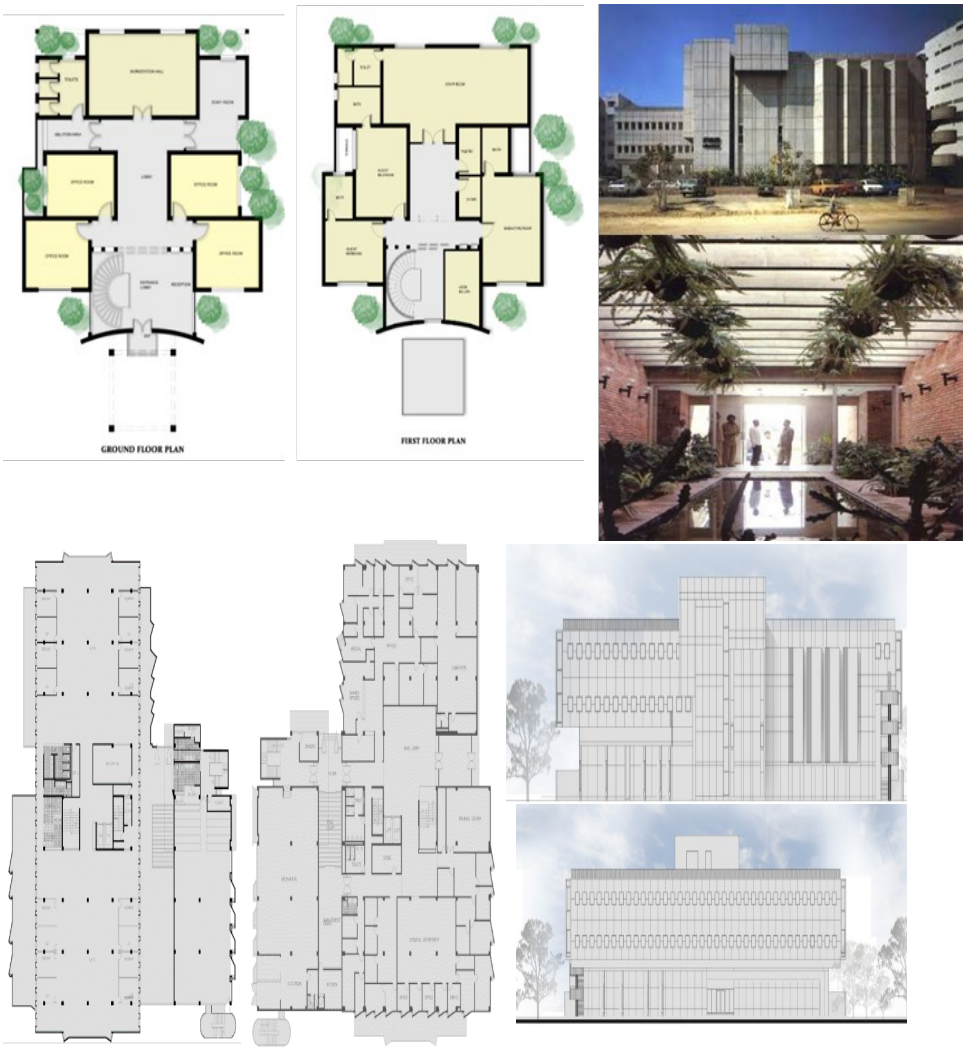


Figure 3

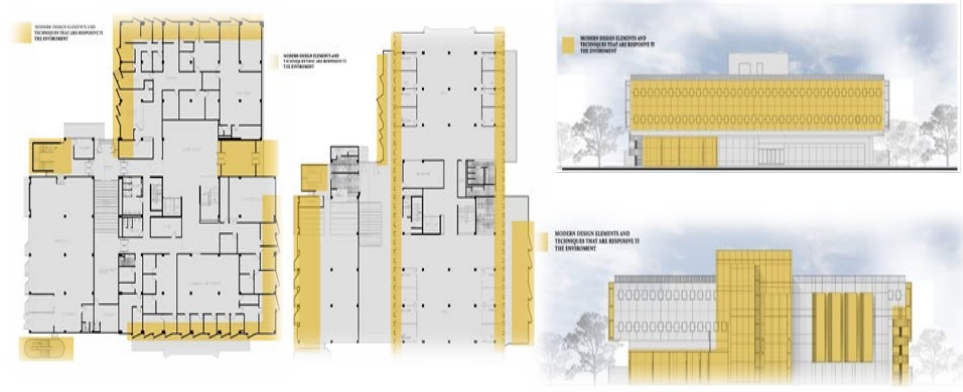
Plans and Elevations of Shell House, Karachi

Regionalism Analysis of the Shell House

Shell house was constructed in 1978 during the era of modernism. The concept, as shown, is depicted by simple and bold lines as well as functional floor plans. The truthfulness of the form, material, expression, and minimalist approach define the shell house. Habib Fida Ali used the same basic concept in the construction of Shell House. The concept consisted of three main principles including timelessness, functionality, and simplicity, which are the key points of regionalism. Moreover, the design philosophy is still based on "less is more". Furthermore, the available natural and native materials were used along with the design techniques that made the building more efficient with respect to the energy efficiency.

Figure 4

Plans and Elevations of Shell House Responsive to Environment



This building also promotes creativity with a disciplined design process that assesses, analyzes, and synthesizes a project's issues and objectives. The building form of Shell house is seemingly more functional, practical, and adorable. Straight lines and rectangular volumes have been used in the building. Moreover, blocks have been placed according to the environmental considerations as shown in Figure 8. Through these analyses, the designed openings and spaces could be configured to ensure desired natural light can be optimized while undesired or glare can be avoided. The same kind of design technique has been used in the first floor as shown in green highlights in Figure 4.

The design of the building is more responsive to the environment. This is because the environment of Karachi is not suitable for open buildings. So, HFA designed the façade to handle the environmental factors. The solid blocks have been placed to the south side in order to block the intensive sun radiation. Moreover, windows have been recessed to decrease the direct impact of radiation as well as to welcome the diffused light in the interior. Furthermore, some blocks have been placed at an angle to avoid sunlight. This is because the placement of windows is not directly exposed to the south side. That is why, windows are designed on the edges of south side to avoid sunlight. From Figure 5, the placement of windows can be analyzed that have been recessed and hidden. Due to this reason, the Shell house presents a more massive and solid appearance.

Figure 5

Plans and Elevations of Shell House Blocking Sunlight

The native aspect of this building is not as strong as it should be. This is because Pakistan is an Islamic state and in our culture religious values are important. In Islamic-inspired architecture, the use of arches or symbolic representation of arches is important. While in this building, no Islamic touch exists since the façade gives the straight-line experiences. The fare face concrete has been used in the construction of this building which is harmful for the environment since concrete is not an echo-friendly and natural material. So, the application of concrete contradicts with the emotional values for our environment as emotional values define the native values and surroundings. There is no doubt that the placements and treatments of the windows is efficient but the material selection is not fulfilling the requirements of energy-efficiency (Salahuddin et al., 2024). In the interior, there are some themes that depict the native or local values as shown in Figure 16. These show that there is a water body inside the lobby and the walls are finished with gutka. The experince of light is very delightful in the lobby as light represents heaven, connecting the building with Islamic philosohy. The building entrance has been made to be more elaborated and grand by placing some dramatic volumes that can also be related to the Mughal era since they used to make grand and more elaborated entrances.

Shell House Analysis on Different Software

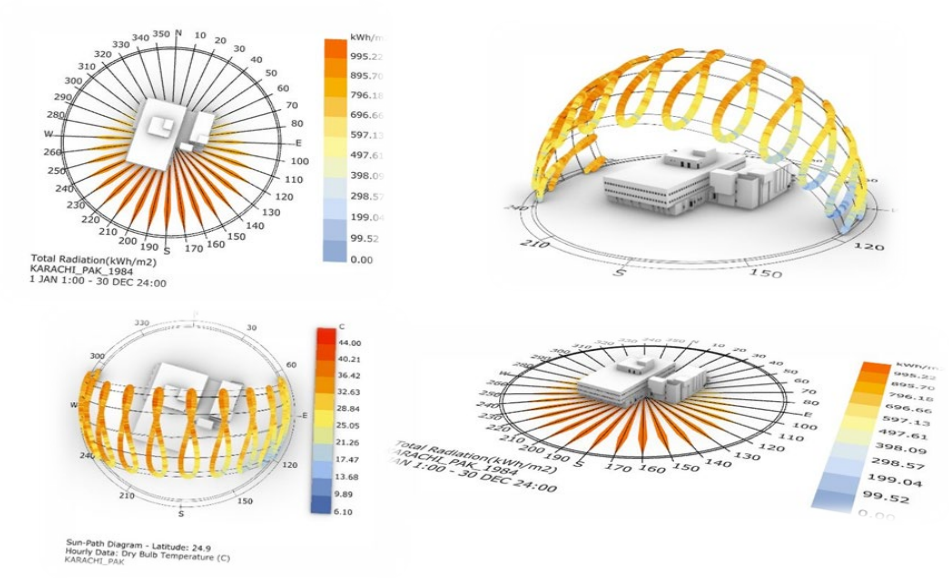
Analysis on Ladybug

Solar Radiations' Analysis of Shell House on Ladybug. Ladybug plugin is the extension in grasshopper for energy assessment of the building. This plugin is helpful in analyzing the wind direction, solar path, and radiation analysis. The figure shows the radiation charts of a specific area in which the building was analyzed.

Figure 6 shows the sun orientation in different seasons of the year. Moreover, there is a temperature bar here which shows temperature on different positions of the sun through color coding. The minimum temperature noted was 6.10 degrees, and maximum temperature noted was 44.00 degrees. This value is same for other buildings that is, head office and warehouse as shown in Figure 6.

Figure 6

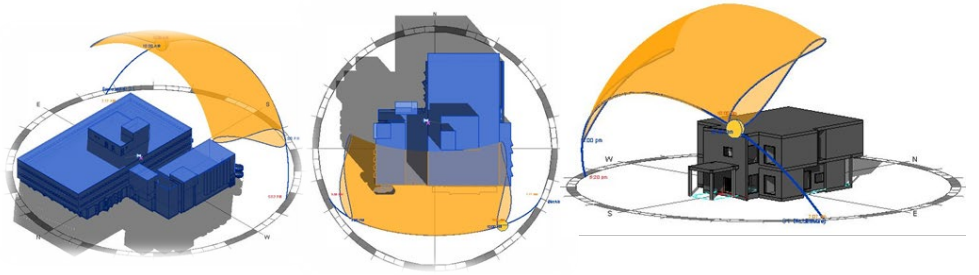
Solar Analysis of Shell House



Wind Analysis of Shell House on Ladybug. Ladybug also provides wind direction of an area in a different time interval. So, the wind direction of Karachi is shown in figure below. The figure shows that the maximum wind direction was from the west and southwest side. Additionally, the minimum speed of air recorded was 2.47 m/s and the maximum wind speed recorded was 24 m/s. Moreover, the other color coding showed different speed of air at different interval of circle. The wind speed was different at different ring intervals and can be read by different colors of cods.

Figure 7

Wind Analysis of Shell house



Shadow Analysis of Shell House on Revit

Through the Revit, the shadow analysis for the building was performed so that shadows at different time intervals and different seasons can be found. The figure shows the shadow analysis between the two time intervals from September to November and between 10 am to 3 pm. This analysis is quite useful to find the shading devices location and check the impact of shadows on surroundings.

Figure 8

Shadow Analysis of Shell House

Exterior Façade Analysis of Shell House

The areas that are used for walking inside the building are considered as the circulation spaces. These spaces are shown by white color, and black spaces are the working spaces inside the building as shown for shell house Karachi.

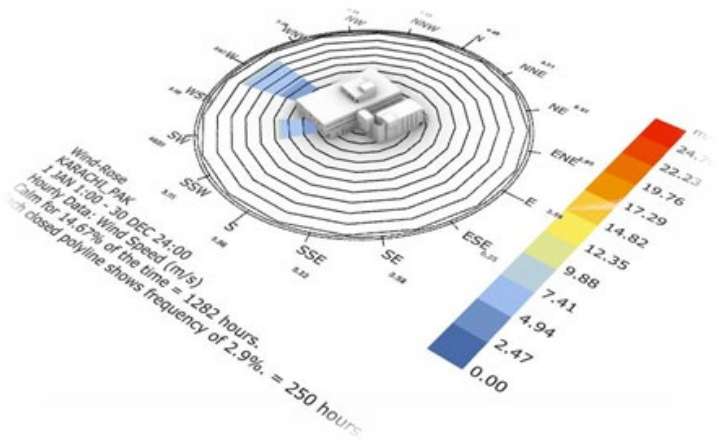
Shadow Analysis of Shell House on FormIt 360

Energy consumption in buildings plays an important role in functionality as well as in enhancing the life span of buildings. Therefore,

there must have been calculations on energy consumption and usage in buildings. This is because without these calculations we may lose money, time, and materials as well. In the current era, when technology is growing rapidly, there are many parameters to consider for the calculation of energy consumption and energy efficiency, which is by use of Revit and Rhino plug-ins. This software provides roundabout near to real values for energy saving. However, in Pakistan energy values are not calculated for consumption and energy saving. That is why most of the buildings consume more energy and increase carbon footprint day by day. The study analyzed Shell house using BIM to know factor of regionalism incorporated in buildings for energy efficiency. Moreover, the study analyzed planning, building facade, and fabric in all perspectives for calculation of energy efficiency in BIM.

Figure 9

Circulation Relationship with the Spaces of Shell House



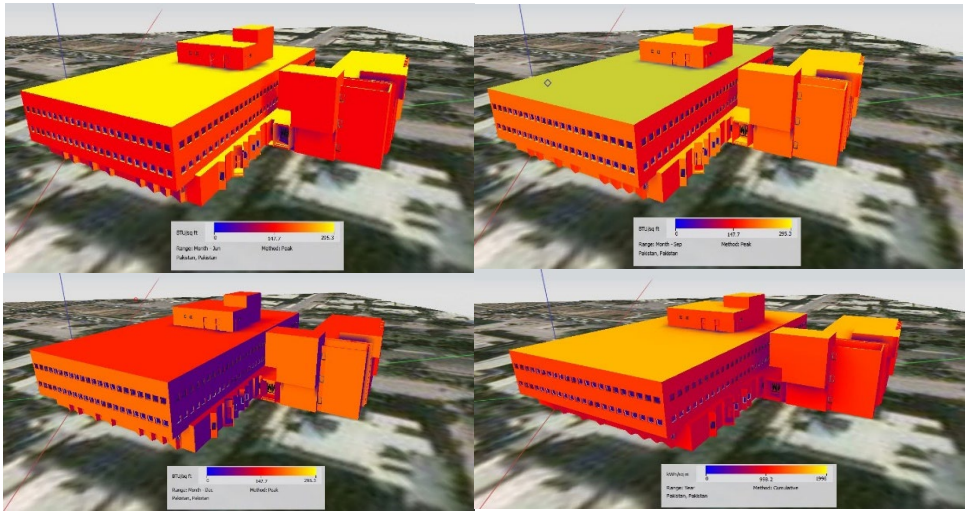
Due to the shape of the Shell house based on its architectural plan and design, that is, rectangular, most of the surface is exposed and has led to gain higher exposure to sun without optimizing its usage in any functional or energy generation.

If we discuss the facade of the Shell House in reference to heat gain, it is maximum due to the rectangular shape of the building which is simple box as per regional architecture. However, most of the energy is wasted since no energy saving device has been incorporated in the design of Shell

House. In the building, sunlight has been blocked through horizontal and vertical shading devices, which is also a regional practice. There is no decision-making for energy saving and efficiency. Additionally, there is no use of good design for wind catching, which may also save the energy consumption in building. In the month of June, most of the heat is gained through rooftop and south-side exposed walls. Direct sunlight is also blocked through the angled wall. In the month of September, heat gain decreases, which goes dead in the month of December as shown in Figure 10 below.

Figure 10

Shell House Radiation Analysis of June, September, December, and Whole Year, Respectively



Solar Radiations' Analysis of Shell House on Insight360. Solar radiation analysis as well as lighting analysis of Shell House was done on BIM, insight360, and Revit plug-in. Based on the selected months, radiation-based exposed analysis was done. In west side elevation, low radiation was found on ground's lower level. As per 1st and 2nd floors, there is no more opening in west elevation catering direct sunlight. More radiations were seen on east elevation in first half of the day except pocket space on entrance of Shell house. Lower number of radiations on north elevation and higher radiations on south side elevation on first and second floors were there.

Figure 11

Analysis Chart Strip of Shell House Radiations

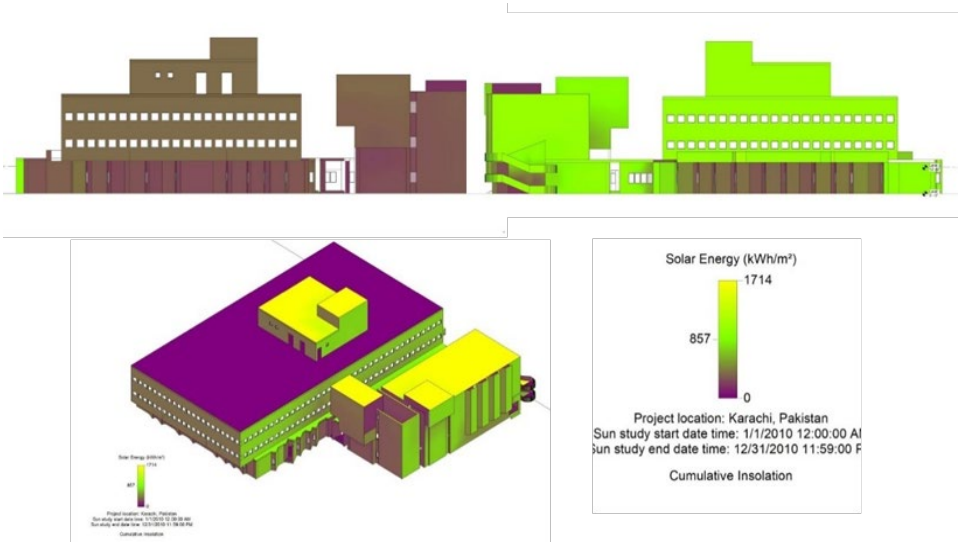
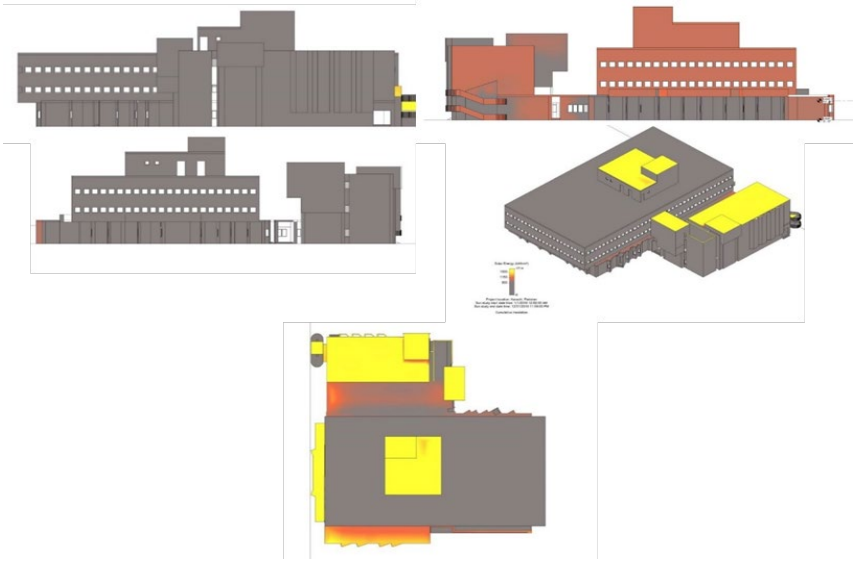


Figure 12

Radiation Analysis of Shell House Radiations on Insight360



Solar Analysis of Annual Insolation of Shell House on Insight360. In solar analysis of annual insolation, it was examined that insolation is required for the building. On the west-side facade of Shell house, it was

analyzed that there is no need of any special insolation due to blocked volumes as shown in Figure. Most of the insolation is required on the south side of upper floors and east-side of façade since these two sides are mostly exposed to sun radiations. Northside facade also requires no insolation but roof top is mostly exposed to sun. So, there is a need of insolation for roof for energy efficiency, which makes heat gain and save energy for buildings' use.

Solar Annual Photovoltaic (PV) Energy Analysis of Shell House on Insight360. This solar analysis determines from where a considerable amount of PV energy can be obtained. Maximum number of heat gain and energy comes through the roof and south side. This is because these sides are exposed to the sun. All other sides provide energy as well but less than south side and rooftop as shown in the Figure below. So, there is a need to save a large amount of energy.

Figure 13

West and East Elevation of Shell House on Insight360

Figure 14

North and South Elevation of Shell House on Insight360

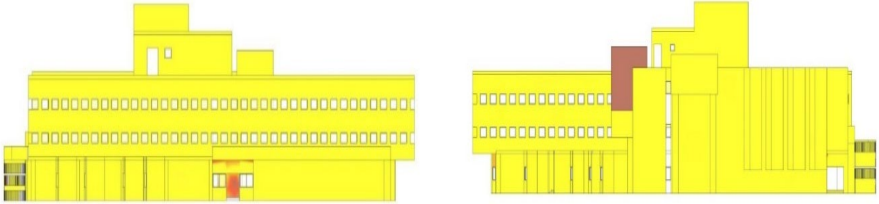
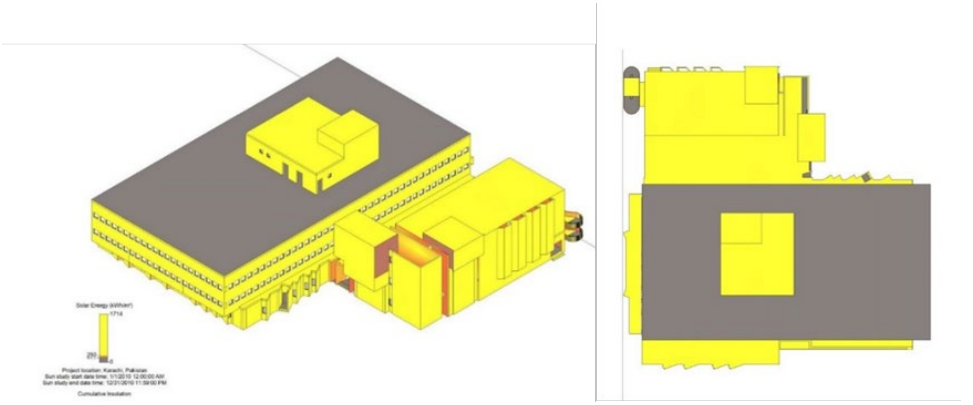


Figure 15

3D and Top View of Shell House on Insight360



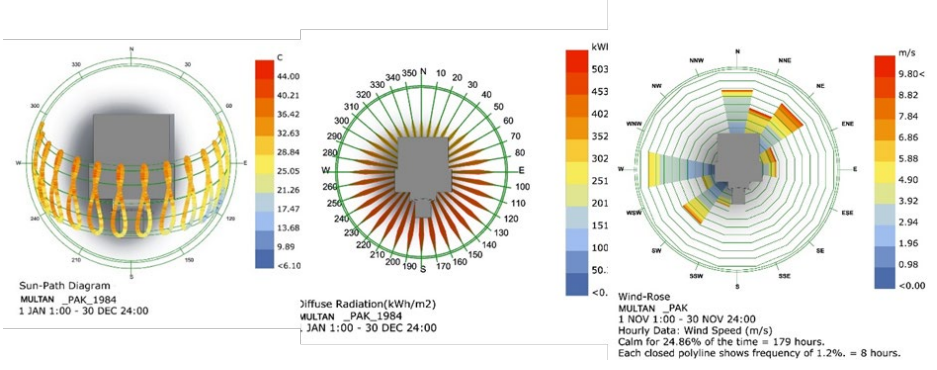
Head Office and Warehouse Building, Vehari

Solar and Wind Analysis of Head Office and Warehouse Building on Ladybug

The solar analysis shows the intensity of solar radiations on south direction and wind direction in the Multan city. This shows the different kind of behavior, that is, the minimum speed recorded in Multan was 0.98 m/s and maximum speed recorded was 9.8 m/s. Moreover, the wind speed was different at different ring intervals and can be read by different colors of cods.

Figure 16.

Solar and Wind Analysis of Head Office and Warehouse Building on Ladybug



Exterior Façade Analysis of Head Office and Warehouse Building

Black spaces being marked are working spaces, making majority in this case.

Figure 17

Circulation Relationship with the Spaces of Head Office and Warehouse Building

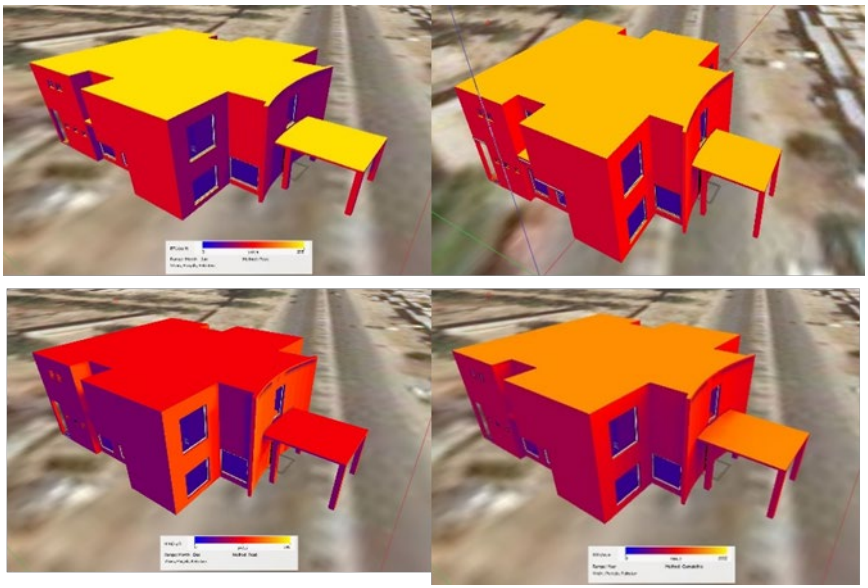
Solar Radiations' Analysis of Head Office and Warehouse Building on FormIt 360

The head office and warehouse building is situated in Vehari. Overall, the city experiences a harsh weather throughout the year. If we discuss about the facade of the building according to the energy efficiency, it is a simple rectangular box as per regional architecture. No treatment on roof for energy saving and energy efficiency can be seen, which results in waste of energy and same practice is adopted on walls. No energy saving methodology was used during the designing of warehouse building. However, if we see side elevation and back elevation of the building, then the design provides some pockets for avoiding direct light. Moreover, on back elevation, cantilever is also there to block the direct sunlight. On front elevation, a bold volume expands from building's original volumes for giving vertical device action to block the sunlight. These all parameters, for the blockage of direct sunlight, are of very high range in summers. However, the overall maximum heat gain is lost since no saving device of energy is available here. Wind aspect, a factor of energy efficiency, is not properly facilitated in the overall building but a window opening makes space livable and active. In the month of June, most heat gain comes through rooftop and south side as shown in Figure 16. In the month of September, heat gain is decreased and goes dead

in the month of December.

Figure 18

Warehouse Radiation Analysis in June, September, December, and Whole Year, respectively



Analysis of Head Office and Warehouse Building on Insight360

Solar Radiations' Analysis on Insight360

Head office and warehouse building gains maximum sunlight whole year because of the region. Due to two live openings, there are a maximum number of radiations on south side elevation. Normal radiations are on the west elevations, and there are four openings on this side. There are controllable sunlight radiations on north and eastside. Maximum radiations are calculated from rooftop but there is no technique for saving energy.

Solar Analysis of Annual Insolation on Insight360

In head office and ware house building, there is no need of insolation on north and west façade. This is because on these sides, there are very low radiations as shown in Figure below. Most of the heat gain and radiations come through the roof and south side elevation. So, insolation is required on roof for heat prevention and heat saving for building functions.

Figure 19

West and East Elevation of Warehouse on Insight360

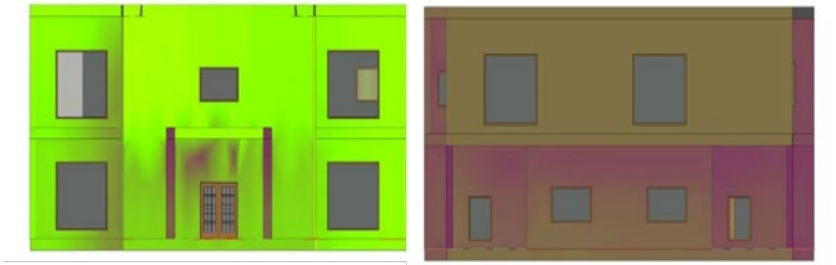


Figure 20

North and South Elevation of Warehouse on Insight360

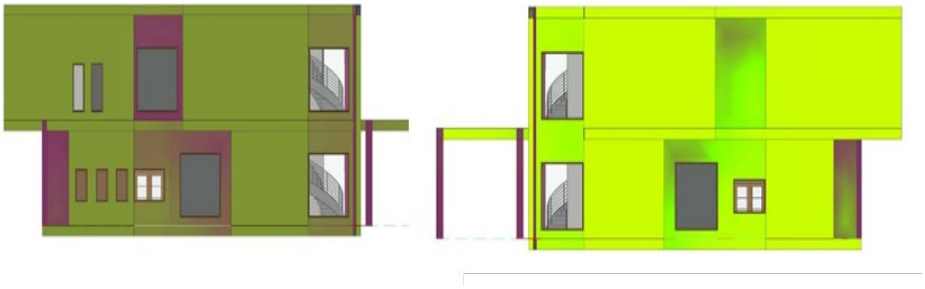


Figure 21

Top View of Warehouse on Insight360

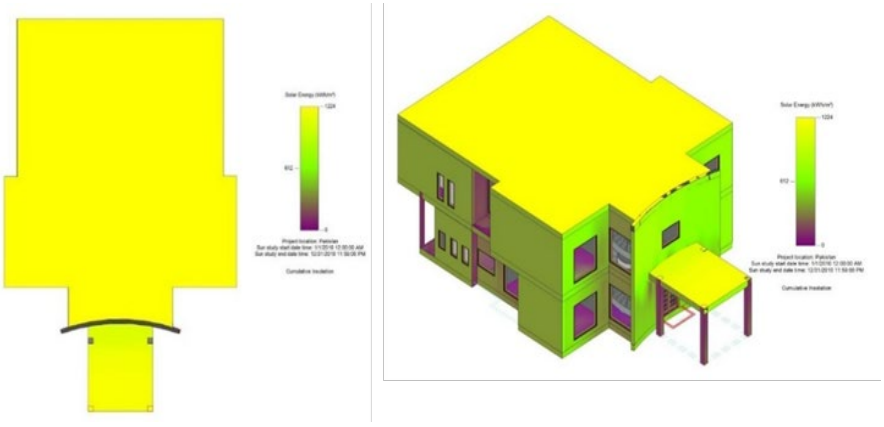


Figure 22

West and East Elevation of Warehouse on Insight360

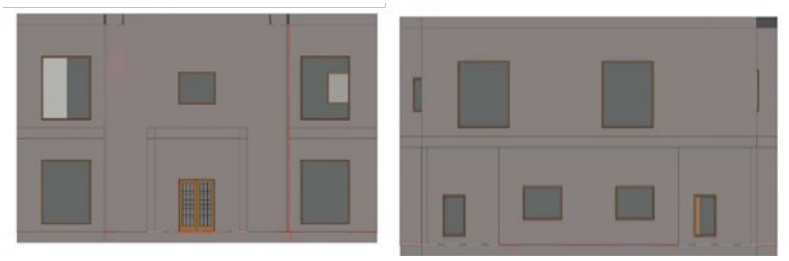
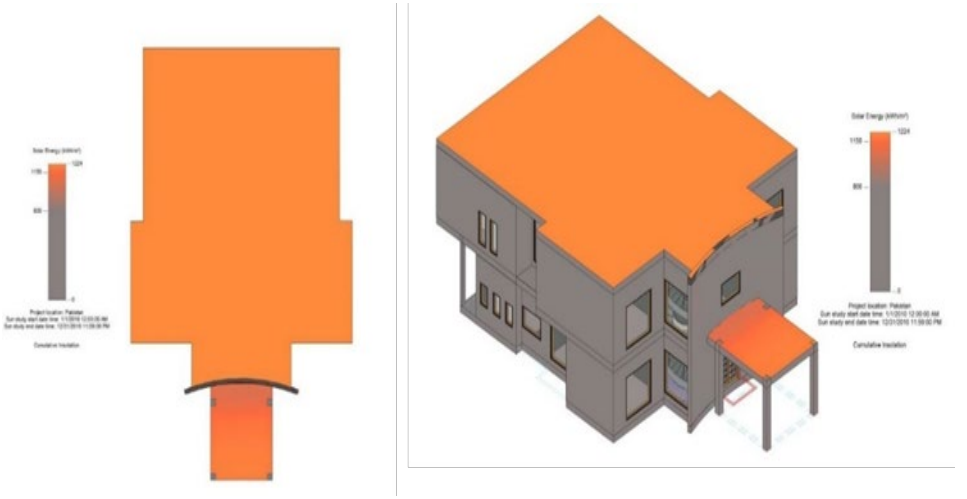


Figure 23

North and South Elevation of Warehouse on Insight360

Figure 24

Top and 3D View of Warehouse on Insight360



Solar Annual Photovoltaic (PV) Energy Analysis of Head Office and Warehouse Building on Insight360

This solar analysis determines that a considerable amount of PV energy can be found from building façade and rooftop. Maximum number of heat gain and energy comes through the roof and south side. This is because these sides are exposed to the sun, and all other sides provide energy as well but less then south side and rooftop (Figure 67-74). So, there is a need to save a large amount of energy from building fabric to use in other functions of buildings.

Figure 25

West and East Elevation of Warehouse on Insight360

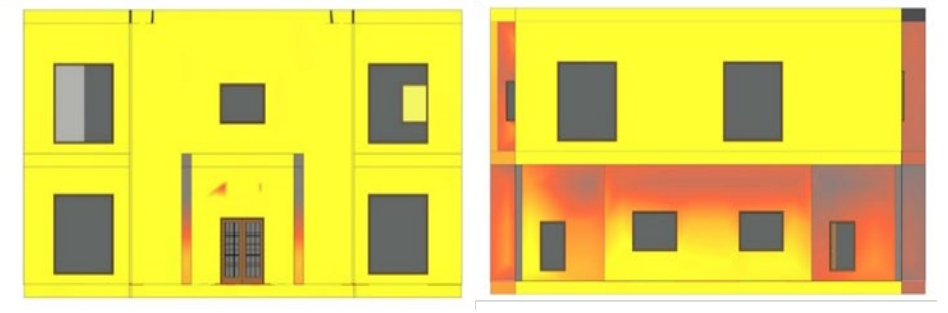
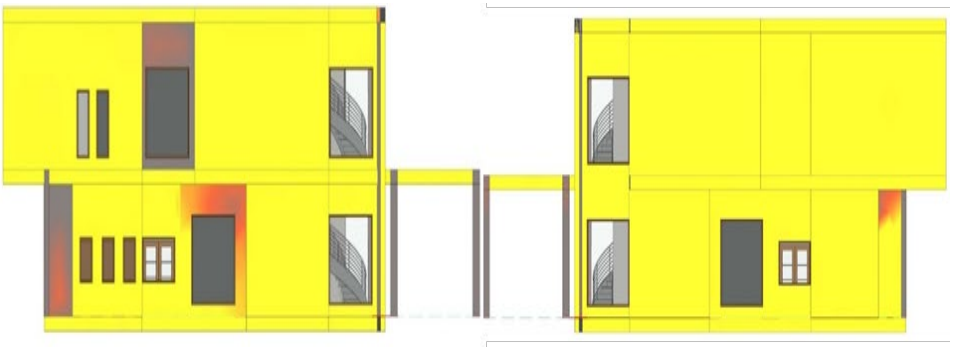


Figure 26

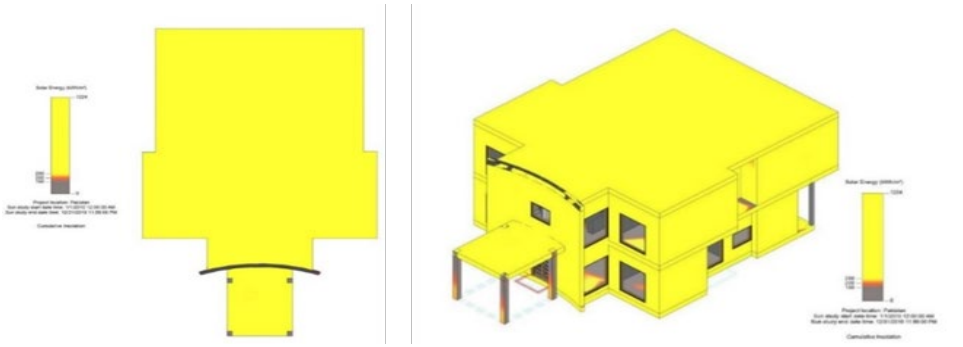
North and South Elevation of Warehouse on Insight360



In this analysis, it can be realized that how much energy is wasted without any treatment and any use in building. Only eastside of the building gives low heat gain due to cantilevered slab.

Figure 27

Top View of Warehouse on Insight360



Lighting Analysis on Insight360 of Office and Warehouse Building

This analysis determines as to how much light in any area and any space of building enters through the windows and other openings. This analysis was generated by the BIM Insight360 lighting plugin. This analysis provides data on hourly basis. Furthermore, it gives an idea about the prime location of windows, openings, as well as the specifications of the glass to be used for more or less light. The study also found out about the lux level of the light so that the furniture could be arranged according to it in any space. In this warehouse and office building, it was analyzed in ground floor plan that maximum light comes from south side and then west side, while eastside has a long cantilever which is the reason of minimum lux.

Figure 28

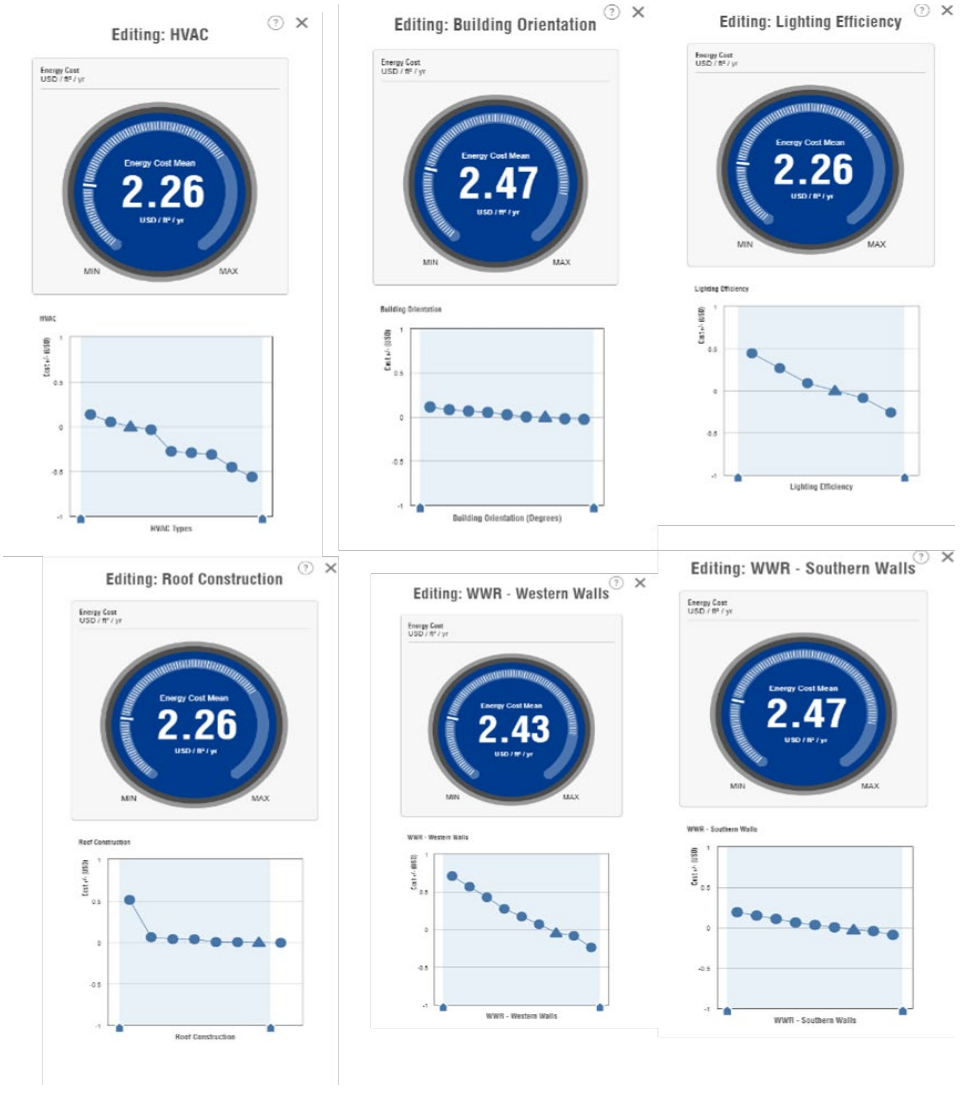
Ground Floor, First Floor, and 3D of Warehouse on Insight360

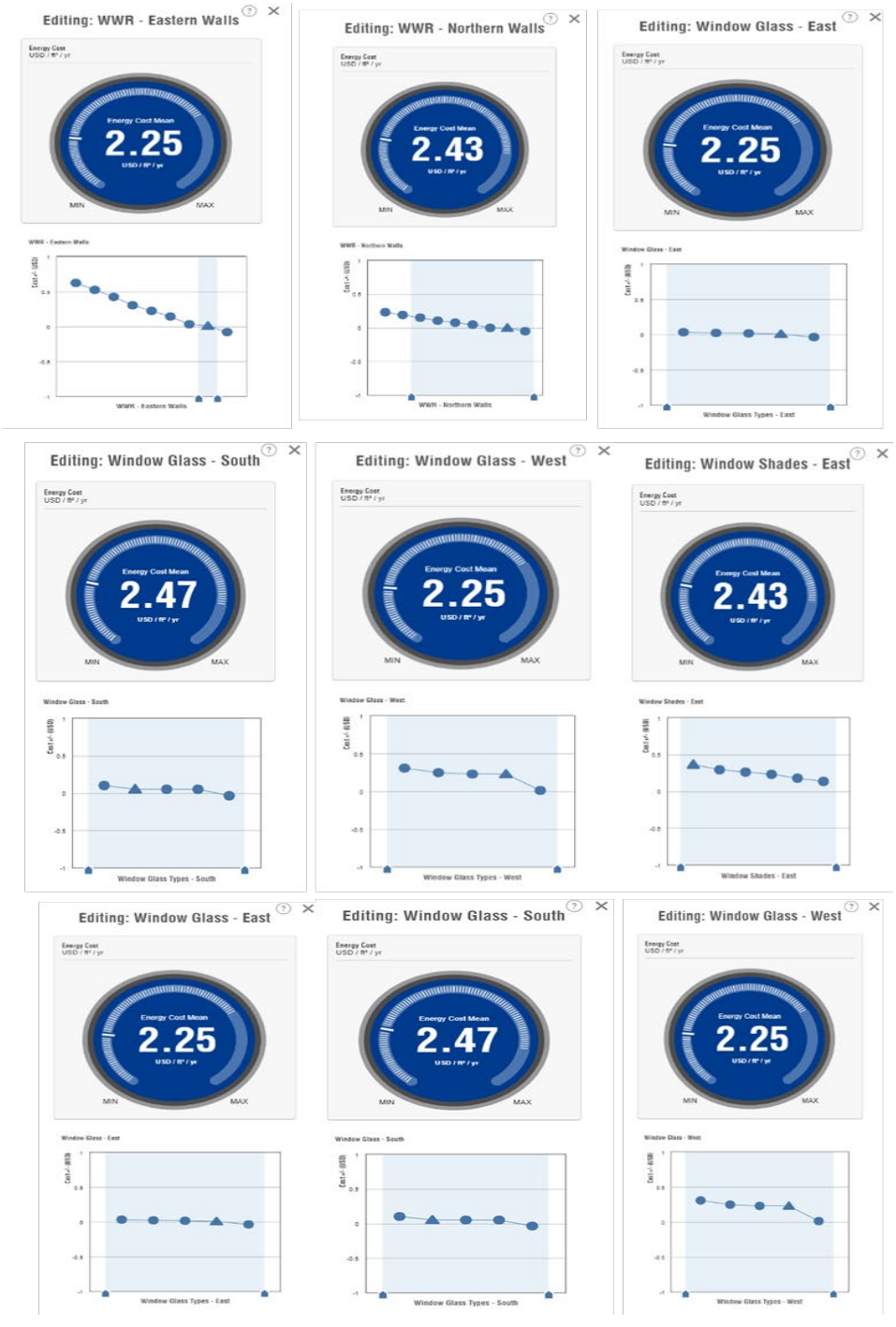
In first floor, most light comes through west side. Two openings are there on south and north side but there is no light coming through those openings. The olive green is maximum lux and whitish grey is lowest level of lux. Color coding defines the amount of light in any area.

Comparative Analysis on Software

Figure 29

Comparative Analysis of Insight360 Reports




Editing: WWR - Eastern Walls
Energy Cost Mean
2.25
USD / ft² / yr
MIN
MAX
WWR - Eastern Walls
Editing: WWR - Northern Walls
Energy Cost Mean
2.43
USD / ft² / yr
MIN
MAX
WWR - Northern Walls
Editing: Window Glass - East
Energy Cost Mean
2.25
USD / ft² / yr
MIN
MAX
Window Glass - East
Window Glass Types - East
Editing: Window Glass - South
Energy Cost Mean
2.47
USD / ft² / yr
MIN
MAX
Window Glass - South
Window Glass Types - South
Editing: Window Glass - West
Energy Cost Mean
2.25
USD / ft² / yr
MIN
MAX
Window Glass - West
Window Glass Types - West
Editing: Window Shades - East
Energy Cost Mean
2.43
USD / ft² / yr
MIN
MAX
Window Shades - East
Window Shades - East
Editing: Window Glass - East
Energy Cost Mean
2.25
USD / ft² / yr
MIN
MAX
Window Glass - East
Window Glass Types - East
Editing: Window Glass - South
Energy Cost Mean
2.47
USD / ft² / yr
MIN
MAX
Window Glass - South
Window Glass Types - South
Editing: Window Glass - West
Energy Cost Mean
2.25
USD / ft² / yr
MIN
MAX
Window Glass - West
Window Glass Types - West

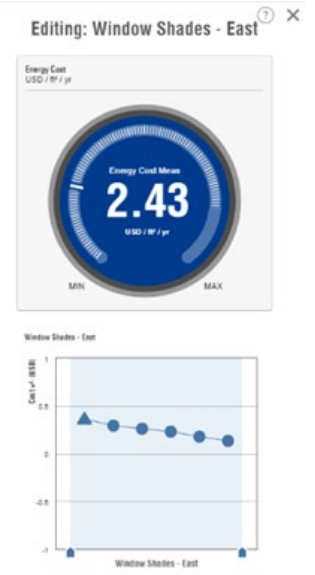


Table 1

Comparison b/w Revit(Insight360) and other Software

Software	Shadow Analysis	Solar Access	Solar Radiation	Luminance Analysis	Solar Radiation Annual Insolation	Solar Analysis Annual PV Energy
FormIt 360	FormIt 360 is more accurate than Insight360	Insight360 is more accurate than FormIt 360	Insight360 is more accurate than FormIt 360	Insight360 is more accurate than FormIt 360	Insight360 is more accurate than FormIt 360	Insight360 is more accurate than FormIt 360
Rhino (Ladybug)	Ladybug is more accurate than Insight360	Insight360 is more accurate than ladybug	Ladybug is more accurate than Insight360	Insight360 is more accurate than ladybug	Insight360 is more accurate than ladybug	Insight360 is more accurate than ladybug

Table 2

Comparison b/w FormIt 360 and other Software

Software	Shadow Analysis	Solar Access	Solar Radiation	Luminance Analysis	Solar Radiation Annual Insolation	Solar Analysis Annual PV Energy
Revit (Insight 360)	 FormIt 360 is more accurate than Insight360	 Insight360 is more accurate than FormIt 360	 Insight360 is more accurate than FormIt 360	 Insight360 is more accurate than FormIt 360	 Insight360 is more accurate than FormIt 360	 Insight360 is more accurate than FormIt 360
Rhino (Ladybug)	 Ladybug is more accurate than Insight360	 FormIt 360 more is accurate than ladybug	 Ladybug is more accurate than Insight360	N/A	 FormIt 360 is more accurate than ladybug	 FormIt 360 is more accurate than ladybug

Table 3

Comparison b/w Rhino(Lady Bug) and other Software

Software	Shadow Analysis	Solar Access	Solar Radiation	Luminance Analysis	Solar Radiation Annual Insolation	Solar Analysis Annual PV Energy
Revit (Insight 360)	 Ladybug is more accurate than Insight360	 Insight360 is more accurate than FormIt 360	 Insight360 is more accurate than FormIt 360	 Insight360 more accurate than FormIt 360	 Insight360 more accurate than FormIt 360	 Insight360 more accurate than FormIt 360
FormIt 360	 Ladybug is more accurate than Insight360	 FormIt 360 is more accurate than ladybug	 Ladybug is more accurate than Insight360	N/A	 FormIt 360 is more accurate than ladybug	 FormIt 360 more accurate than ladybug

Table 4

Comparative Results

Software	Revit (Insight 360)	FormIt 360	Grasshopper (Ladybug)
Analysis	Solar study, lighting analysis, energy analysis	Solar analysis	Shadow study, radiation analysis, wind direction
Difficulty Level	Quite complex as it requires a lot of time to learn basics, without which good results are difficult to obtain.	Very easy to operate as it requires some basic steps	Easy to operate, can get good results just following the simple results
Computer Compatibility	Requires good system	It can be operated on any system even on the web	Requires good system
Analysis Confined-ness	If the building 3D model is accurately modelled than the results are exact. Also, we put location coordinates that also give exact context	The results it gives are very specific and accurate as building model is selected itself and location gives the context	Results are not that accurate because the EPW file should be recently updated and generally it gives results based on region
Analysis result	The results show luminance and daylight factor for each level of the building separately and also give the estimated cost	The results give the accurate amount of heat gain at different times of the day	The results show that the maximum heat gain is from southeast and southwest side but does not give the amount

Conclusion

Energy efficiency in buildings has become a core issue all over the world. This is because the carbon emissions and footprint of carbon are increasing rapidly. This study showed that BIM is a very successful method to assess and enhance energy efficiency in Pakistani regional architecture. BIM facilitates well-informed decision-making at the early stages of design, resulting in more sustainable building outcomes by integrating climate data, design parameters, and performance simulations. The current study analyzed two buildings; first one was the Shell house, Karachi and the second was the head office and warehouse building, Vehari. These two buildings depict that regionalism and vernacular techniques should be used for energy saving rather than modern techniques which cause major heat loss and energy wastage (Khan et al., 2018).

The results verified that the use of passive design techniques, such as ideal orientation, suitable material selection, shading devices, and natural ventilation, can greatly lower energy consumption and improve thermal comfort in Pakistan's various climate zones. In coming years, by using these techniques, Pakistan would be able to save a large amount of energy being wasted in building functions. For this purpose, there is a need to use BIM-based software for the calculations of energy consumption and energy saving in the time of technology. This approach would make energy efficient buildings and environments which, in turn, may lead towards a carbon-free country in 10 to 15 years.

Overall, the study highlighted how BIM can help engineers, architects, and legislators create energy-efficient structures, reduce operating expenses, and solve the nation's persistent environmental and energy problems. In order to encourage a broader adoption of BIM-based sustainable design practices in Pakistan, future research can investigate more sophisticated simulation techniques and policy integration.

Author Contribution

Rifza Zahid: data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualization, writing - original draft, writing - review & editing. **Muhammad Gulraiz Zahid Awan:** investigation, methodology, project administration, resources, software, supervision, writing - review & editing. **Umair Hassan:** conceptualization, data curation, formal analysis, investigation, software, writing - original draft.

Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject

matter or materials discussed in this manuscript.

Data Availability Statement

Data supporting the findings of this study will be made available by the corresponding author upon request.

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Generative AI Disclosure Statement

The authors did not use any type of generative artificial intelligence software for this research.

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