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BIM-Enabled Energy Analysis for Sustainability

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Research Article

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ABSTRACT

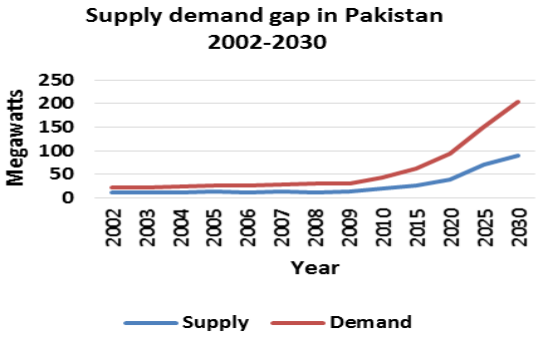
The current works aim to investigate the energy performance of the building system at the planning stage for sustainable design. Building information modeling has been adopted to simulate a high rise multi-story building in a virtual environment. The Insight has been utilized to access the performance energy in terms of kWh/m^2/yr. A case study of sixteen story building has been assessed at its current proposed location, which is at an angle of 370 from the centerline of the building along with the transverse axis and at true north. The study observed that the case resulted in an annual consumption of 282 kWh/m^2/yr and 276 kWh/m^2/yr,respectively. The study has highlighted that adopting virtual technology at design building can help to achieve the optimized sustainable design solutions by accessing energy requirements at the early stage of design inception.

INTRODUCTION

Sustainability is the avoidance of the reduction of natural resources. According to the UN Department of economic and social affairs, sustainable development encounters the essentials of the existing generation without compromising with the capacity of upcoming generations to meet their specific requirements [1]. The construction industry has become the third principal contributor of GHG emission to the environment [2]. According to the

Economist Intelligence Unit's report 2013, the prime energy usage in the building sector will increase by 19% until 2035.

Figure 1: Energy Demand and Supply



The global energy consumption unveiled that energy demand continuously rising. Steamers and Yun (2009) Reported that worldwide energy request will upsurge by over one-third in the period of 2012 to 2035. Over 70% of the greenhouse gas released from buildings. The rapid upsurge in energy usage has a direct consequence of mounting worry about supply problems, natural source reduction and environmental effects.

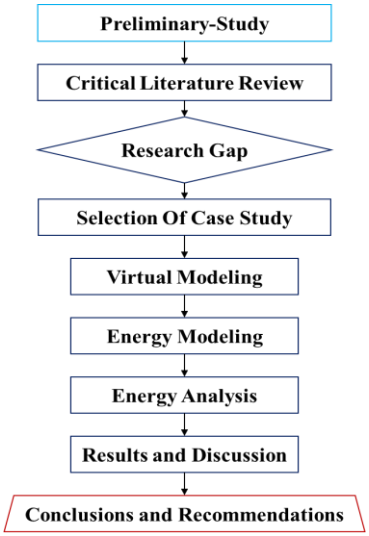
Energy analysis is a discipline to examine how building systems affect building performance. This methodology has gained momentum due to the use of Building Information Modeling that upgrades the simulation process of energy analysis. At the conceptual design phase of planned projects, BIM users assess many alternate designs and select vital energy approaches and schemes. Due to enabling BIM, the time-consuming process of re-entering the building geometry is avoided for energy analysis. For this purpose, different building performance analysis and modeling software programs are available i.e. Energy Plus, Virtual Environment, Insight, Green Building Studio, Ecotect, Trnsys, Revit Architecture, and ArchiCAD. Khasreen [3,4] suggested that new sustainability requirements have been progressed by the environmental impact from the built environment regarding the building's performance throughout life cycle cost and energy [5,6]. reported that the energy usage of the proposed structure design can be quantified with the help of Computational simulation [7]. have been instigated the research based on the Digital Project BIM software and energy analysis [5]. distributed the performance assessment of a building into five portions. During the structure life cycle, BIM arose as a resolution to assist the integration and management of information [8].

Energy savings can be maximized by the use of building optimization. Sustainability and energy performance of the high rise structures needed more attention [9,10]. Energy usage and costs can be reduced by using efficient design of buildings along with better comfort and class for the residents. Substantial energy savings can be attained if the building designs are proper along with construction and operation [11]. The trend in the world about energy usage has been mounting serious concern about supply problems, energy fatigue and hefty environmental effects [12]. The current work aims to observe energy optimization utilizing the location of the building. The case study of high rise commercial buildings with the help of energy analysis tools supported by the BIM model promotes sustainable development concerns.

METHODOLOGY

The methodology and scientific approaches adopted for the achievement of the proposed objectives is illustrated in the figure below;

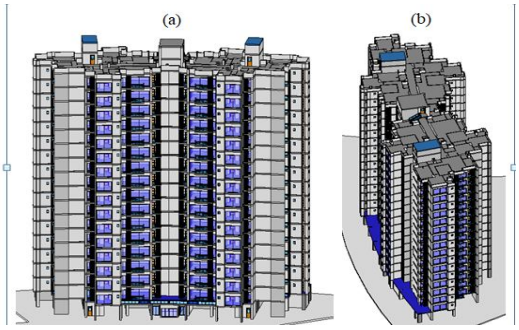
Figure 2: Paradigm of Research Design



Case Study

A case study was adopted to deliver an in-depth exploration of the BIM-based energy analysis and energy optimization of structures. A sixteen story commercial building located in the capital city of Pakistan has been analyzed. A 3-D virtual model was developed using the BIM process. The figure shows the virtual developed model.

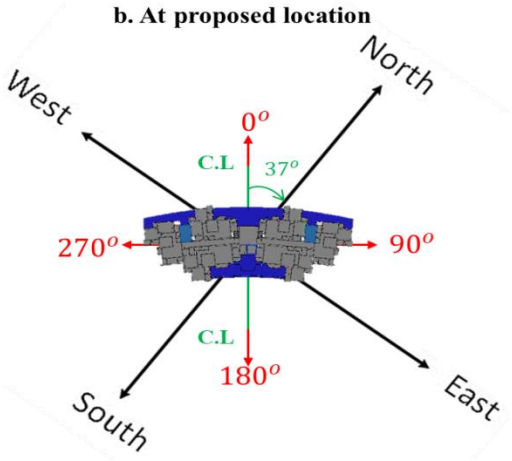
Figure 3: Perspective Views of 3-D Virtual Model



RESULTS AND DISCUSSION

The results contained here were developed by running simulations on BIM software, Revit and Insight. The 3-D virtual model is converted to Energy Model and that energy model is analyzed with the help of Insight. True North was used as baseline orientation and the results were compared with True North accordingly.

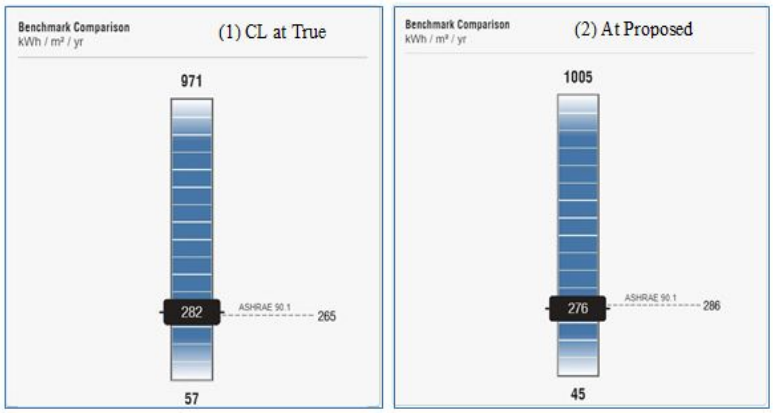
Figure 4: Scheme of Rotation for Energy Analysis



Energy analysis

Annual average energy consumption at true is 282 kWh/m²/yr and at 0o w.r.t is 276 kWh/m²/yr. Figure 3 (a) having the 57 kWh/m²/yr lower limit and 971 kWh/m²/yr upper limit while figuring 3 (b) 45 kWh/m²/yr lower limit and 1005 kWh/m²/yr upper limit was observed, respectively. According to ASHRAE 90.1 true North 265 kWh/m²/yr value and 0o having 286 kWh/m²/yr. There is an overall decrease of 6 kWh/m²/yr in energy usage. So, it is better alignment as compare to True North.

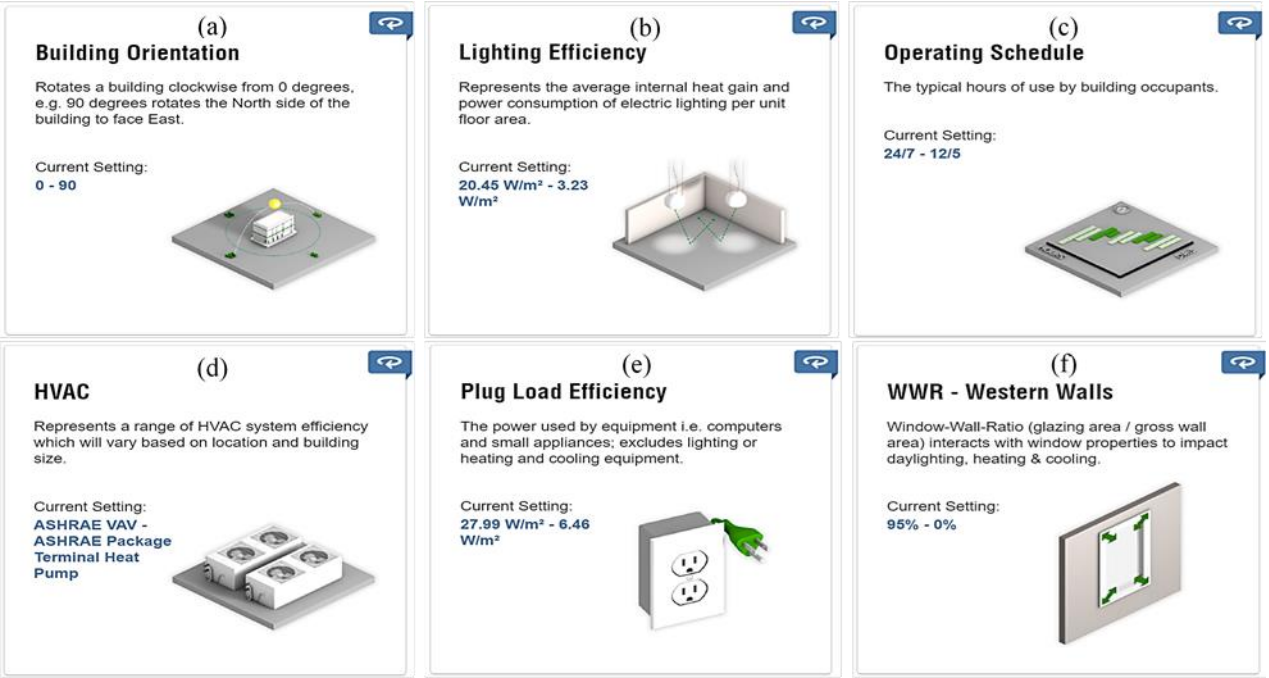
Figure 5: Annual Average Energy Consumption.



Other Factors that Affect Energy Analysis Along with Building Orientation

These factors are significantly affecting the energy usage of the building. Hence, Building Orientation, Lighting Efficiency, Operating Schedule, Plug Load Efficiency, and Window to Wall Ratio prominently affect the energy performance of a building.

Figure 6: Major factor affecting Energy Analysis



Building Orientation: The orientation of a green or sustainable building to be built in the position of the building on the site for the project according to sun and wind direction, in relation to the sidewalks, the streets, and the landscaping. Two building orientations were analyzed, one is at true north in which building alignment and true north alignment is the same as shown in the figure. Second is building alignment is at 37o from the true north.

Lighting Efficiency: The definition of lighting efficiency is a representation of the energy-saving properties of the light source. The performance of LED light sources is measured by using this important index. It represents the average internal heat gain and power consumption of electric lighting per unit area.

Operating Schedule: Operating Schedule as typical hours of use by building occupants. It can 24 hours every day in a week, 24 hours for 6 days with one holiday or two, etc.

HVAC: HVAC in short for heating, ventilation and air conditioning system. The setup provides heating and cooling capacities for buildings. HVAC framework has become the requirement for the construction of new buildings nowadays. Here, it represents a range of HVAC system efficiency which will vary based on location and size of the building.

Plug Load Efficiency: The plug load is the energy or electricity used by goods powered through plugs of electricity. Today, one of the rapidly rising sources of energy in commercial buildings is Plug loads. In offices, they account for

15-20% of the electricity consumption in the office. The power used by Equipment i.e. computers and small appliances; excludes lighting or heating and cooling equipment.

Window-to-Wall Ratio: The window area or window-to-wall ratio (WWR) is a vital variable that affects the energy efficiency of a structure or building. The window area affects the heating, cooling, and lighting of the building along with the natural environment in terms of access to daylight, ventilation, and views. The window-to-wall ratio is the amount of the percentage area that is calculated by dividing the total glass area of the building to the wall area of the outer shell. In this case study, the western wall will significantly have affected by WWR Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating and cooling [13].

Comparative Analysis

Table 1 shows the comparative analysis of results. In benchmark comparison, there is a total of 6 kWh/m2/yr decrease in energy consumption. A change in the lower and upper limit was also noticed. If we change the building orientation from True North zero degree, there is 6.77 kWh/m2/yr average energy saving as a result.

Table 1: Comparative Analysis

Description	Unit	a. True North	b. 37° w.r.t True North
Benchmark Comparison	kWh/m²/yr	282	276
Maximum		971	1005.46
Minimum		56.54	45.48
Average		282.44	275.68
Save		-	6.77

With the enlarged demand of energy and space in Pakistan with limited availability, to build a high rise structure at specific terrain with certain solar and weather conditions required a pre-estimate for natural resources that to be used. So, Energy investigation is helpful in such circumstances. The result observed an energy saving of 6.77 kWh/m2/yr by only using alignment rotation criteria with respect to True North. This orientation can help to achieve sustainability in energy consumption patterns, preservation of natural and resources like fuel and electricity [14,16].

CONCLUSIONS AND RECOMMENDATIONS

The analysis of building performance also includes the most effective way to utilize energy by using the orientation. The most effective is cost-saving calculation and time management as compared to other traditional methods. It is reasoned that BIM models are valuable and proficient in calculating the building performance. The results concluded that,

- 0o orientation of Building saves 6.77 kWh/m2/yr energy saving. This orientation is better than true north alignment according to the terrain weather and solar conditions.
- Building orientation has been observed as a vital fact to optimize the energy performance of the building.

Based on the findings of these proceedings, the building should be rotated in a circle at different alignments for energy analysis observations. However, these virtual results need to compare with a real-world example for comparison afterward.

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