Analysis on impact of energy efficient techniques to enhance the building performance

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Abstract. A substantial share of energy goes into building air-conditioning under harsh climatic conditions. The climate control load could be decreased by several means; the proper structure and choice of the building envelope and its components are noteworthy among them. Due to the growing global warming and energy crisis, energy analysis is becoming a major factor to be considered in the industry these days. During the design process, power forecasting is on the rise and alternative energy is considered as conservation measures and considerations for creating a more energy-efficient building. To minimize the annual energy use and annual cost, the study of the commercial school building has been done by employing various alternatives in the conventional school building model. The different parameters taken for the study are (heating load, cooling load, orientation and lighting control). Analysed the alternative scenarios, and the findings were collected. Each case comparison is based on energy use and the annual cost. The result shows that from the combined use with Autodesk Revit and a Green Building Studio, the integrated energy analysis and design alternatives can provide more building with energy-efficient. The accuracy of the data can greatly affect the results obtained.

1. Introduction
Construction is the world's largest field of energy consumption. Building with energy-efficient design is the major requirement to reduce in atmospheric CO₂ emissions. Greater orientation of building is one key factors in energy efficient building design [1]. Right orientation is a minimal-cost option for improving the thermal comfort of the occupant and the cool and heat resources a proper orientation of the building with a perfect cooling sun to let the structure cool off during season facing the stream of wind during summer [2]. Portion between structure, structure form, envelope thickness, material self-efficiency and the building envelope's optical and hot temperature properties are the most serious parameters that affect thermal comfort and the building energy control [3]. From the first stage of the design process, architects and designers will take serious account of their envelope concept for energy efficiency [4]. Cutting energy use in office buildings in particular is a problem for government departments, architects and engineers alike. For that the energy fee, knowing the overall architectural design features of existing high-rise office buildings in hot tropics is important. The occupant
operation is proposed to have a direct effect on the efficiency of the buildings [5-6]. The main problem with the implementation models is the behavior of occupant in Building Energy Simulation (BES), selection for the specific case of an effective modeling complexity. Residents are blamed for an substantial proportion of the supply of energy to buildings. Occupying activity is nowadays recognized as a major source of discrepancy between the construction's expected and actual results [7]. During the design process, simulation of output formation has become an established process of evaluation, with the growing complexity of the construction design and higher performance requirements on the use of building simulation sustainability being unavoidable [8]. Throughout the work environment, in comparison to residential buildings, human and building interactions are either planned or restricted, while the usage data is easier to capture. So, occupancy information can be used in commercial building controls, particularly when the occupancy sensors are cable to building automation systems [10]. Orientation also plays a critical role in supplying occupants with thermal comfort. In order to determine the orientation of the building, it is very important to pay attention to climate factors such as solar radiation and wind in an area. The structure's angle, especially in the tropical region, must be taken very seriously in respect of all its association with radiation and wind patterns [9].

Constructing a building's orientation is crucial to the building's solar penetration. It is recommended that houses in the northern hemisphere have Southern Access Windows to improve energy efficiency. The heating load of a passive solar house can be reduced considerably when facing south [11]. Energy deprivation impacts heavily on energy demand in most tropical countries, with no access to electricity or electricity protection. While the use of power-consuming appliances like air conditioners is restricted lead to power scarcity, a proper design of the building envelope will be the only choice for achieving the necessary thermal comfort [12]. Building orientation is an essential consideration of architecture, especially in respect to solar power and the responsive design of buildings in the wind climate, not because of their comfort for users and saving of energy, although because it tends to conserve precious things on the planet earth [13]. A complex collection of factors affects the buildings' thermal efficiency and thus determines the amount of energy needed for mechanical climate control. Growing of heat produced in structure from solar energy mainly depend on factors such as latitude, location, orientation and building configuration [14]. Some devices, such as laptop computers, are also connected to the individual occupants. The portable devices move along with the occupants from room to room, absorbing energy or producing heat gains. Like most occupant activity patterns are influenced by the occupation [15]. Modern cities are made up of stable and sustainable infrastructure, where growth is an important essential. Energy of building use add around 70 per cent of city power uses that have a significant impact on electric grid operations. It is critical that operations of building provide comfort, even also rising energy costs in same time [16]. Low energy construction design requires detailed simulation software for thermal for determine heat and cool charges. These designs would provide thermal comfort to the occupants and encourage reduced energy usage over the house's life. The secret for successful design is to incorporate an element which properly embodies a radiant mirrors edge and absorption properties through a complex environment [17]. Thermal comfort is considered a key requirement that is typically expected by accommodation unit occupants including the school. A compatible indoor climate design is, in essence, a modification of the external weather system, and is intended to provide comfort to occupants. Temperature relief in college design is vital factor many consider, because it affects the well-being and efficiency of the students significantly [18]. Natural light is a significant part of household energy use. Instant building automation devices reduce use by growing working times of the lamp based on various factors such as activity, period daylight, sunlight supply. The illumination is controlled by different technologies. These technologies differ according to the source variables, process management, control method, implementation costs, commissioning difficulties, etc [19].

Buildings business have the highest capacity to combat environment change, due to introduction of reworking and relief approaches became the significant obstacle for construction industry workers.
Both plans will be based on projections, and the Intergovernmental Panel on Climate Change (IPCC) has published a series for pollution projections to be used in global warming research focusing upon greenhouse gas emissions to analyze building efficiency in a warmer future world [20]. The basic heat and thickness of the materials, solar absorption, ground and albedo temperatures (physical uncertainties), and occupancy schedules of equipment power and number of occupants (uncertainties of user activity) were essential parameters in the study. The variables should be measured or calculated and use more precise techniques, since they often influence the efficiency of the simulation [21]. Design of resources-efficient structures needs environmental modeling systems that measure an increased air condition of both the house, which is also a significant factor in determining that energy needed for solar heating in order to accomplish ecological efficiency for all the inhabitants [22]. Choosing most effective construction alignment is among the crucial energy-saving decisions that may have an effect on the energy efficiency of the building structure, since it could be used to mitigate direct sun radiation via doors, create openings and exterior transparent partitions into the buildings. This can also be one of the most affect in full glazed house [23]. Human body responds intelligently by acclimatizing and adapting to the different climatic conditions. The unique behaviour of thermal comfort of human need under various climatic conditions and even for different seasons clearly demonstrates that the approach to building design needs to be compatible with the position of the house. Smart system can be used to provide thermal comfort [24]. Given the existence of many experimental and numerical research studies, only a small amount of research literature was performed on the study focusing on orientation and lighting regulation, in the study the innovation was mainly focusing how to minimize the annual cost and life cycle cost by taking two most important parameters such as Orientation and the lighting control of the environment, where review was performed with different alternatives.

2. Methodology
Autodesk Revit 2020 is selected as a modelling program to build, as it is the latest version with all new updates that can be used in the project. The Green Building Studio was chosen for further energy analysis of the school building, as this software provides the opportunity to import the Autodesk Revit project file into it and measure the building's energy and fuel consumption. The building's design plan is being researched, the users should be aware of the software specifics and criteria to add value to the project.

The data required for the project is collected correctly, as the accuracy of the data used in the analysis will greatly affect the results obtained. The modern classroom was chosen for the study which is mostly located in Chennai with a hot climate condition throughout the year. In a school building, a significant amount of energy is required to use various cooling equipment. The work is carried out to conduct a detailed simulation of a building including the state of the environment, the type of material used. As so many variables can influence the energy consumption of the building but one that has an important part in the actions of the inhabitants, it is difficult for empirical analysis due to its complicated characteristics.

2.1 Project detail
The school building selected is located near the city Chennai and the basic detail of the building used for project is provided below in table1.

| Table 1. Basic information of building. |
|----------------------------------------|
| Building type                          | Commercial School building |
| Analytical floor area m²              | 2598                       |
| Total number of floor                 | G+3                        |
| location                              | Guduvencherry              |
| Area m²                               | 10,392                     |
3. **Energy analysis**
The thermal properties of the material used in the house have a major impact on the electricity calculation. Before performing the analysis, the energy setting must be set to in the Revit device. The analysis gives the heating and cooling charge in the building when all the data are given Figure 2 shows the heating load. The refrigerating load is the amount of heat energy used to keep the temperature at home comfortable. Figure 3 indicates the cooling charge, while the refrigeration charge is the sum of energy that needs to be removed from a building to hold the temperature at ease.

![3D model of school building](image)

**Figure 1.** 3D model of school building.

![Heating load](image)

**Figure 2.** Heating load.
After which the export of the file from Revit is done by supplying the Green Building Studio with a gbXML file where the further analysis is done by applying the correct design alternatives to create an energy-efficient construction. When this is all fully converted to gbXML format. The file can be read using the green create lab. Figure 4 shows the gbXML file conversion process. The actual cost and fuel rates taken for the study was the default value in the Green building studio that Electric cost is Rs 0.08/ kWh and Rs 0.78/MJ.

![Conversion process to gbXML file](image)

Figure 4. Conversion process to gbXML file.

3.1 Orientation in building

Orientation is the orientation of a building considering seasonal shifts in the direction of the sun, as well as prevailing wind patterns. Better orientation can increase the efficiency of house, providing it easier to stay in it, and less costly in overall lifetime. The research was carried out for different orientation and lighting control on all directions. The building's energy consumption levels were calculated by rotating the base case building in circular motion each time the building rotates 45 degrees from its former position as Table 2 indicates alternatives in modelling for the orientation.
Table 2. Simulation alternatives for orientation.

| Variables | Alternatives | Description |
|-----------|--------------|-------------|
| Orientation | +45° | rotate project clockwise by 45° from original orientation |
| | +90° | rotate project clockwise by 90° from original orientation |
| | +135° | rotate project clockwise by 135° from original orientation |
| | +180° | rotate project clockwise by 180° from original orientation |
| | -135° | rotate project counter-clockwise by 135° from original orientation |
| | -90° | rotate project counter-clockwise by 90° from original orientation |
| | -45° | rotate project counter-clockwise by 90° from original orientation |

3.2 Lighting control in building
The control of lighting system is an artificial intelligent, channel-made in building automation system which help to incorporate connection with different type of inputs and outputs systems relating to control the lighting with not just one but more than one central computing devices. Lighting control devise and systems are commonly used to illuminate all indoor and outdoor economic, manufacturing, and private areas and spaces. The design of building and the living occupants often impact energy utilization (Zhun Yua et al 2012), and the use of lighting control will help us reduce the cost of building energy utilization. The alternative simulation based on the lighting control taken for the study is shown in table 3.

Table 3. Simulation alternatives for lighting control.

| Variables | Alternatives | Description |
|-----------|--------------|-------------|
| Lighting control | Occupancy sensors | Only applied to spaces in model that are 250 square feet smaller, or classrooms, storage, corridors or conference rooms of any size |
| | Daylighting sensors and controls | |
| | Occupancy/daylighting sensors and controls | |

4. Result and discussion
This segment discusses the effect of simulation and data gathered from alternatives using a Green building studio.

4.1 Orientation
The effect of the orientation on the building is evaluated in the section. Figures 7a and 7b show total annual costs and total annual energy when modelled with different orientation alternatives (+ 45 °, + 90 °, + 135 °, + 180 °, -45 °, -90 °, -135). Figures 5a and 5b represent the significant difference between the alternatives of orientation. It could be inferred that the provision of a building orientation by 135° would significantly reduce annual cost and energy as we can see the result of simulation shown in table 4.

Table 4. Simulation result for alternatives of orientation.

| Alternatives | Total annual cost | Total annual usage |
|--------------|-------------------|--------------------|
|               | Energy (Rs)       | Fuel (Rs)          | Electrical (Rs) | Electrical kWh | Fuel MJ |
| 45°          | 55,709            | 2,334              | 53,374          | 6.67172        | 3.14269 |
| 90°          | 55,509            | 2,329              | 53,179          | 6.64740        | 3.13602 |
| 135°         | 55,488            | 2,210              | 53,278          | 6.65972        | 2.91633 |
| 180°         | 55,630            | 2,314              | 53,315          | 6.66443        | 3.11500 |
4.2 Lighting control

This section analyzes the impact on cost and energy by the form of lighting control provided (daylight sensor and control, occupancy sensor and occupancy / daylight sensor and control) Figures 6(a) and 6(b) show the effects of the comparison of different alternatives based on total annual cost and total annual energy use. Results of the simulation are given in table 5.
Table 5. Simulation result for alternatives of lighting control.

| Alternatives                        | Total annual cost | Total annual usage |
|-------------------------------------|-------------------|--------------------|
|                                     | Energy (Rs)       | Fuel (Rs)          | Electrical (Rs) | Electrical kWh | Fuel MJ |
| Occupancy sensors                   | 55,628            | 2,266              | 53,362          | 6.67024        | 3.05051 |
| Daylighting sensors and controls    | 53,397            | 2,278              | 51,119          | 6.38987        | 3.06728 |
| Occupancy/daylighting sensors and controls | 53,221            | 2,277              | 50,944          | 6.36800        | 3.06612 |

The collected data allows the most effective lighting control to be evaluated. Figure 6 shows the alternative that meets the criteria of energy-efficient alternatives that can be provided in the building. Although all the alternatives offered are fine, the most successful is the occupancy/daylight sensor and control, as it provides 4.35% lower annual costs and annual energy usage compared to the other two alternatives.

4.3 Summary of Recommendation
Table 6 summarizes the suggested solutions, mentioned from the simulations results.
Table 6. Simulation recommendation.

| Variables       | Run Alternatives                                                                 | Recommended Alternative          |
|-----------------|-----------------------------------------------------------------------------------|----------------------------------|
| Orientation     | +45°, +90°, +135°, +180°, -135°, -90° and -45°                                   | -90°                             |
| Lighting control| day light sensor and control, occupancy sensor, occupancy/ daylight sensor and control | occupancy/ daylight sensor and control |

After the simulation is completed the best alternative from each parameter are taken and the last simulation is done to provide a comparison between the Conventional school building and energy-efficient school building.

Table 7. Comparison of Total annual cost and total annual energy usage.

| Variables         | Total annual cost (Rs) | Variables         | Total annual energy usage |
|-------------------|------------------------|-------------------|---------------------------|
|                   | electrical             | Fuel              | Energy                    | Electrical kWh | Fuel MJ |
| Main Building     | 53,558                 | 2369              | 55828                     | 6.69479       | 3.05521 |
| Providing with the alternatives recommended | 46894                 | 2346              | 49274                     | 5.83673       | 3.40474 |

The figure 7(a) shows the comparison of main building and after providing all the recommended alternatives based on the Total annual cost. The cost with recommended alternatives is lesser.

Figure 7 (a) Total annual cost and (b) Total annual energy.
Figure 7(b) shows the comparison of main building and with recommended alternatives based on the Total annual energy usage. It was found out that after providing all the alternatives the energy usage was lesser.

5. Conclusion
This paper proposes improvements in the area of low-energy building problems. With Revit and GBS which can run multiple simulations, Autodesk can be useful on smaller projects for designers. Earlier research has proposed strategies for achieving zero emissions in existing buildings, as well as incorporating renewables into existing buildings. Base on the analysis it can be concluded that,

- Proper design and planning can help to increase energy output, and finding the best material can also make it a long-term, cost-effective house.
- The gross annual cost and cumulative consumption of energy can be reduced to 12.6% per cent and 3.7 % respectively.
- Ultimately, the different criteria evaluated for the project indicate that the energy efficiency of conventional buildings has improved making the building energy efficient.
- The goal of the thesis on performing energy conservation simulation using Revit and Green Building Studio was successfully achieved.

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