Investigation of day light levels in a room within a building

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Abstract. This work investigates natural light levels inside a room in Electrical & Information Engineering building, Covenant University, Ota, Ogun State, Nigeria. In order to reduce the amount of energy used on lighting, it is imperative to make the utmost use of natural daylight. The use of windows are one traditional solution, other solutions are skylights and light pipes; atria and light wells; domes and arches; structural glass which are all discussed. In high temperature regions, it is necessary to reduce the amount of sunlight entering the room because light produces heat. With the use of a Light Dependent Resistor (LDR sensor), results are presented to study the day light levels in a room by measuring the light levels at various parts of the room; by measuring the proportion of light entering through the window and measuring how the light level changes over a 24 hour period. The outcome of this work is the study and development of a system that can monitor light levels in a building. The application of this work extends to determining the period of the day when daylight is maximal in order to reduce energy cost, building an automation system for the automatic lighting of dark areas within a building as well as monitoring energy consumption used to light p a building. Further extension will be to make predictions on the natural light level based on the data available.

1. Introduction
Considerations in lighting approach during the design of a building can reduce the amount of energy used for lighting purposes and hence minimize monthly and annual light cost expenditure. The emphasis of this paper is on providing information on daylight distribution in a room in order to illustrate peculiar issues influencing daylight distribution in a room with the aim of minimizing the amount of energy spent on lighting. Before the construction of a given building structure, the key issues that need to be taken into consideration are the requirement for structural strength and stability [1-3]; the need to keep the building at a suitable temperature; and the provision of proper and comfortable lighting within the building. These key issues are closely allied to principles of energy transfer, forces in structures, and characteristics of different materials. This paper focuses on the need for adequate and good lighting by analysing and measuring the daylight distribution within a room. The need for adequate lighting is an important consideration in the erection of a building [4]. It is mandatory to use some form of artificial lighting at night to illuminate dark areas, but in this paper, considerations are given to solutions involving the full use of natural light. The most common traditional solution is to utilize transparent material, in most cases glass [5] on various sections of the wall or roof.
while protecting the internal structure of the building from natural elements such as dust, wind, rain or snow.

In this work, the consideration to providing adequate lighting within a building structure is studied by measuring the illuminance at different parts of a room within a building with the aim of determining the areas of the room that are exposed to more natural light compared to other areas. The gap this work aims to fill is the investigative study of natural light level in a room within a building with the goal of reducing energy cost as a result of lighting as well as to be able to make predictive models and forecast based on the data available on natural lighting. The practical implication will be in the design of an automatic lighting system which will automatically turn on artificial light when the measured natural light is insufficient to provide illumination.

2. Regulating the amount of daylight in a room

Light levels in at various parts of a building or room will vary depending on distance from the window and the colour of surfaces within the room [6]. Intuitively, the highest levels of lighting in a room will be at the window which depends on the size (length and breadth) of the window. In a location where a building is surrounded by other nearby high rise buildings (Figure 1), then the rooms on the lower levels are likely to be in shadow during peak periods of daylight, as little sun light will be able to enter.

[Figure 1. Light enters lower storey rooms at a more restricted range of angle (blue lines) compared to rooms on an upper storey (red lines) [6].]

One way to the maximizing light levels in lower storey rooms that are shaded by tall surrounding buildings is through the use of light pits. Light pits are constructed around the outside of a building and lined with light, reflective material to reflect light into the lower storey rooms [7]. Similar to light pits, light shelves are another means of improving light levels inside a room [8]. Light shelves involve the positioning of reflective stripes around window of a room with the intention of bouncing light onto the ceiling and into the depths of the room [9] as shown in Figure 2. Although light shelves produce more light levels overall, light levels at the window is obstructed by the light shelf.

On the other hand, too much light can be problematic because light produces heat. High light levels can be mitigated using shades. Shading and orientation will cause a reduction of solar radiation intensity on the outside of the window [10]. Another approach to avoiding overheating is to reduce the amount of energy transmitted through the interior of the window material by using tinted glass [11]. A tinted glass works by absorbing light energy in order to reduce the overall amount of visible light transmitted.
3. Other approaches to the boosting light levels in a building

Novel building materials that include specialist composite materials or new production processes can be used to improve sunlight into a building. Incorporation of windows are the most widely used and traditional solution. Other ways of boosting natural light levels rather than using artificial lighting include the following solutions.

Skylights and light pipes: These approaches bring additional daylight in from the sky, with the aim of either to complement insufficient window-based lighting or can be used as the only natural source of light [12]. Skylights can be likened to windows in the roof [13] while light pipes usually refer to cylindrical constructions with a reflective inner coating [14].

Figure 3 shows the schematic of a light pipe. The direction in which the top of the pipe is facing determines the amount of light that bounces into the pipe at varying times of the day. The reflector is also angled in such a way that the best range of angles of incident light is achieved.

Atria and light wells: These are similar to light pipes as they are also installed to convey light from above into the centre of a building [15]. Atria and light wells are relatively large spaces and are particularly installed in buildings which are surrounded by tall structures and would not obtain much direct light from the outside of the building via windows [16].

Domes and arches: These are normally implemented where a large amount of light is required. These structures have been used for large conservatories and greenhouses and for large public spaces such as swimming pools and railway stations [17].

Structural glass: This involves the use of large amounts of glass cladding on a supporting metal frame: the resulting buildings often appear to be 'glass cubes', for example, the Apple Store [18] or the Hayden Planetarium, NY [19]. The structural glass is toughened because the forces on it are considerably greater than conventional glasses used in windows. Therefore, they can endure tensional forces compared to ordinary glass [20].
Figure 3. How a light pipe channels light into a building. A transparent cover (X) fixed into the roof, along with a fixed reflector (Y) to reflect light down into the tube and subsequently into the building. A diffuser (Z) may be incorporated into the ceiling to aid the even distribution of light [12].

4. Methods
The most commonly used sensors for measuring illuminance includes photovoltaic cell, photodiode, phototransistor and Light Dependent Resistor (LDR). A photovoltaic cell, which is also being used as solar power supply, is composed of semiconductor gallium arsenide. When light falls on the photovoltaic cell, a voltage is generated. This voltage increases as the incident light becomes more intense. Another common light sensor is a photodiode which is similar in structure to a photovoltaic cell. When connected in reverse-bias to a power supply, electric current flows through. This current increases as light intensity increases. A phototransistor is a combination of a photodiode and a transistor. The transistor is used to amplify the electric current produced by the photodiode in order to increase the sensitivity of the photodiode.

Light dependent resistor is made from semiconductor material e.g. Cadmium Sulphide (CdS) or Cadmium Selenide (CdSe). A Light Dependent Resistor (LDR) was used in this work as sensor to read daylight levels. The LDR sensor works by variation in resistance such that the resistance of the sensor varies in proportion with the amount of light present at the given location and time. Using a voltage divider arrangement, resistance value from the sensor is directly converted into voltage value. These voltage values are directly logged into a data logger system to record the changes in light levels over a considerable period of time.

The specific room chosen in this work is an office room within the building. The rooms available within the building include classrooms, laboratory rooms and office rooms. An office room was selected amidst all available rooms in order to conduct the controlled experimental study which involved the monitoring of natural light level. As an office room can be closely monitored for this controlled study which involves only daylight, an office room was chosen to carry out this research.
5. Results and Discussion

In order to compare natural light levels in a room, a light sensor was used to investigate light levels within a room by recording how light levels vary with the distance from windows. The study was conducted in an office room measuring 3.2m by 4.8m at Electrical & Information Engineering Building, Covenant University, Ota, Ogun State, Nigeria within the period of February 15 to February 18, 2019. Figure 4 shows light sensor readings in ohms (Ω) as a function of distance from window.

![Figure 4. Light sensor readings in ohms as a function of distance from window](image)

A plot of light sensor readings using a light dependent resistor (LDR) against values for distance from a window is shown. From the indicated results, the brightest and dimmest places are identified. From Figure 4, the brightest place in a room is at the window; as the distance from the window becomes greater; the resistance value increased indicating that the natural light levels are reduced. Figure 5 shows daylight readings inside the building over a consecutive 24-hour period for 4 days.

![Figure 5. Daylight inside the building over a consecutive 24-hour period for 4 days](image)
Also, a daylight level inside a building over a consecutive 24-hour period for 4 days is shown in Figure 5. From sensor readings, a voltage of about 5V is indicated during dark periods while periods of maximum light intensity have a voltage reading of close to 1V.

Figure 6 provides a clear indication of the light levels in the room in voltage units at a given time of the day (hour and minute). From the plots, the brightest time of the day is between 9:00am to 10:00am in the morning.

![Figure 6. Daylight in voltage units inside the building over a consecutive 24-hour period for 4 days.](image)

This work can be further extended to include other locations within the building such as the classrooms and laboratory rooms which can be compared. As a result of the study being conducted within a room inside a building, further work is required to measure the light levels in all the rooms inside the building as well as comparing with other areas. This study is limited with regards to the amount of data as the study was conducted for 4 days. The brightest time of the day was found to be between 9:00am and 10:00am during the period of the year (February). As light levels varies according to seasons, weather
and temperature, further work will have to extend to data collection for a year in order to make predictions and forecasts using artificial intelligence methods as well as make discussions on the brightest and darkest areas of the day during a particular season; indication of specific seasons can also be inferred as a result. Also, as illuminance is directly related to heat, further work is required to simultaneously measure light and heat levels in order to identify a correlation between light and heat as the heat level from the sunlight can be investigated. While studies to investigate natural lighting would be more crucial in regions or climates that experience limited daylight compared to sub-Saharan region of Africa, a study is needed also in desert climates in order to provide adequate shading of the light in periods of the day when light intensity becomes unbearable.

6. Conclusion
Amidst other key issues paramount in the erection of a building, the need for adequate lighting is an important consideration. In this work, the requirement of natural light levels in a room was studied by measuring the intensity of light in a room for a 24-hour period for four consecutive days. Light intensity at various parts of the room was also measured in order to indicate areas with peak light intensity. This investigative study has led to the identification of structures that are used to provide adequate natural or daylight levels within a room of a building. These structures are skylights and light pipes; atria and light wells; domes and arches; structural glass; and windows which is a traditional solution. This study is limited with regards to amount of data as the study was conducted for 4 days, extension of the work can extend to data collection for a year in order to make predictions and forecasts using artificial intelligence methods. As a result of the study being conducted within a room inside a building, further work is required to measure the light levels in all the rooms inside the building which can be compared. The application of this work extends to determining the period of the day when daylight is maximal in order to reduce energy cost, building an automation system for the automatic lighting of dark areas within a building as well as monitoring energy consumption used to light a building. Further extension will be to make predictions on the natural light level based on the data available.

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