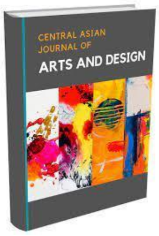

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Article

Sustainable Lighting in Iraqi Hospitals: Al Garaawe Hospital in Babylon

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Abstract: This research addresses lighting in interior design to achieve visual comfort and a sustainable environment for its users. This is done by one of the hospitals in Iraq. examining Adel Al Garaawe Hospital which is a newly established hospital in Iraq. The hospital was visited, and photographed; in addition, the hospital director and some patients were interviewed to collect the required data. Also, light intensity in the spaces was measured using a GED multi-meter, model FMM5. In addition, previous research was studied to arrive at sustainability indicators in terms of lighting and then determine the extent of their application to the sample. To analyze the collected data, the plans of the hospital were entered into a specialized environmental simulation program (namely, Design Builder) to arrive at accurate results and ultimately come up with conclusions and recommendations. The result shows that the sustainability indicators are not applied to the selected sample, and that natural lighting is insufficient and requires artificial lighting and other treatments.

Keywords: : Interior Design, Light, Sustainable Environmental Control, Sustainable Lighting, Visual Comfort

1. Introduction

1.1. The Problem and Its Significance

The research problem lies in the lack of natural lighting in some buildings due to a lack of awareness of the issue of lighting in interior design locally, especially in public buildings, including hospitals. This has led to the emergence of health, environmental, and economic problems after the building is occupied [1]. The current study offers an explanation of sustainable environmental systems from a visual perspective and their impact on interior design and its users, and the possibility of applying them in public buildings to achieve visual comfort and sustainable environment. Consequently, the study attempts to answer the following questions:

a. Is the level of natural lighting adequate for space users in hospitals?

b. Do the spaces under study not comply with the optimal natural lighting Well Building Standards?

c. How can we maximize the use of natural environmental resources to achieve visual comfort?

1.2. Research Aims

The study tries to achieve the following aims:

a. Finding out whether natural lighting is adequate for the space users in hospitals.

b. Finding out whether there is any representation of the Well Building Standards.

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c. Finding ways for maximizing the use of natural environmental resources to achieve visual comfort.

1.3. Research Limits

The current study is limited as follows:

a. Subject Limits: Sustainable lighting in public buildings, particularly hospitals.
b. Spatial Limits: The interior spaces of Adel Al- Garaawe Hospital in Babylon.
c. Temporal Limits: The study was conducted in July 2024.

1.4. Research Hypotheses

The study proposes the following hypotheses:

- The level of natural lighting in the hospital under study is inappropriate for the space's users.
- The patients' rooms in the hospital under study do not comply with the optimal Well Building Standards
- Visual comfort can be achieved by controlling the size and location of windows, the type of finish, and the colors of the space's walls.

1.5. Research Introduction

Environmental control affects human visual comfort within any space, as well as its economic and social status. Nature can be utilized to create natural methods for environmental control within interior spaces by rationalizing energy use and preserving the environment [2]. Indoor visual comfort is an important aspect of sustainable building design. Studies have shown that natural light improves user performance and productivity and plays a significant role in reducing the energy used for artificial lighting, especially in cities exposed to high levels of sunlight [3].

1.6. Light

Light is an electromagnetic radiation that can be seen with the naked eye. It is considered as the primary controller of the sense of sight, through long waves (infrared waves) or short waves (ultraviolet waves), which are called the colors of the spectrum. Light waves are reflected by the eye, which automatically transmits them to the brain to be recognized and translated into images [4].

Light is a visible ray of light from the electromagnetic spectrum that spreads in a wave motion with different frequencies and wavelengths. It spreads in a straight line within uniformly composed media that affect the retina and are called optical effects. This generates important reflections for humans, and therefore the method of distributing lighting within spaces in buildings must be taken into consideration. Good lighting relaxes the eyes and increases production efficiency. Lighting is one of the basic elements for creating the necessary healthy and psychological framework for work [5].

Understanding the basic units of light - Candela, Lux, and Lumens - is vital to achieving the desired lighting effect in any space, whether at home, in the workplace, or outdoors. These units measure the various components of lighting, and knowing how they interact can give us a more precise approach to lighting design and application. By understanding the differences between these three terms, we can optimize the lighting in our spaces, contributing to aesthetics, productivity, and overall comfort.

Lumen and lux are basic units of measurement in the field of lighting. Lux is a unit of measurement used to measure illumination, i.e. the amount of light falling on a specific surface, and is known as the light level. Lux is defined as the amount of light falling on one square meter of surface, i.e. lux measures the amount of light reaching a specific area. It takes into account not only the amount of light emitted by the light source, but also the distance at which this source is located and the angle at which the light is focused [6].

The unit of measurement for lux is lumens per square meter (lm/m^2), which is a relative measurement. Lumen is used to measure the total amount of light emitted by a light source. In other words, lumen is a measure of the amount of luminous flux emitted by a light source. Luminous flux refers to the total amount of light energy emitted by a light source in all directions. Lumen does not take into account the direction or distribution of light, but rather measures only the total amount of light emitted [7].

Modern studies of vision, light and color have greatly influenced interior design, and color has become one of the properties of matter and has influenced design elements, their proportions and their relationships. Thus, the organization within the space attracts attention through the contrast of color, light value, contrast of intensity and contrast of intervals between colors. Pure color attracts attention more than dark color and the intensity of lighting calls for attention more than its dimming [5].

1.7. Natural Lighting

Daylighting is the process of light entering a building in a way that provides desirable illumination of better quality than artificial lighting sources, which leads to a reduction in the need for artificial lighting sources and thus a reduction in electrical energy consumption [8]. In addition to the important environmental and health benefits of natural lighting, given that the continuous increase in electrical energy consumption is closely linked to the phenomenon of sick buildings [9]. The continuity of space and physical movement between spaces is also achieved through openings, as well as the transmission of light, sound and heat [5]. Gefford's studies confirmed that high intensity natural lighting increases an individual's desire to engage in social interactions with others using smaller distances than interactions conducted under low lighting [10].

Therefore, natural lighting requires the correct and most appropriate placement of openings in the building to allow light to enter and then spread appropriately, avoiding glare resulting from direct sunlight and thus a feeling of discomfort and lack of vision [11]. The presence of openings in the walls is necessary as they are indispensable inside buildings and are used to light and ventilate the internal spaces in buildings [5]. Studies have shown that it is preferable for lighting to be between (50-200 lux) [12].

1.8. Natural Light Sources

Nature is considered the primary source of providing a large amount of light. The sun, the moon, and lightning are among the most prominent examples of natural sources of light [13]. Sunlight is the basis of natural lighting, which is considered as one of the cheapest and safest types of lighting for humans within interior design. Its amount in the interior space depends on the number and area of openings such as windows and ceiling openings, in addition to the location of those openings [14].

Natural lighting is of utmost importance in psychologically accepting a space and increases the people's feeling of colors and shape due to natural light, and it is possible for purposes other than housing. Natural lighting is divided into ceiling lighting and side lighting. It is noted that contemporary designs have tended towards this type of lighting, especially in public buildings, to a large extent, and for design and economic necessities, provided that this does not contradict the design requirements of the space [5].

1.9. Interior Design

It is the sum of planning and designing of interior spaces, which aims to make use of the material, spiritual and social needs of people, which in turn ensures the safety of the building. Interior design is also defined as a set of elements and foundations that are subsequently linked together within a temporal and spatial relationship in the interior space [15]. Interior design consists of technical and planning aspects, and also focuses on aesthetic and artistic aspects. Specialists, including engineers and interior designers, plan the interior design of buildings. In addition, it is possible that some amateurs design aesthetic and artistic aspects because they do not pose a danger to the user's life [14].

Francis Ching defines interior design as organizing relationships between foundations and interior elements within a harmonious and cohesive whole with the aim of achieving good functional and aesthetic aspects [16].

Interior design falls within a larger, comprehensive field, which is environmental design. The whole environmental system contains two basic parts, as indicated by the Environmental Design Research Association (EDRA), namely the physical environment and the spatial environment. Through these two directions, it is found that interior design is directly concerned with the study of the elements that constitute the space in the building, such as ceilings, walls, floors, openings, furniture, etc. Here, the designer investigates the physical composition of the material that the elements are composed of, its quality, and its visible sensory effect, such as color, texture, and shape, and determines the relationship of these elements to each other, in addition to other qualities [5].

There are architectural determinants including the ceiling, walls, floor, openings and doors that must be in proportion to the size of the space, the number of occupants, its location in relation to the building, the nature of the surface finish and colour so as not to cause glare that affects the users of that space, in addition to the texture of the surfaces being smooth rather than rough that affects the safety of its occupants, as it reduces the lighting and its distribution Degrees of rough texture can be used in places far from friction, for example in the upper part of the walls as well as the ceiling [17]. It is preferable to use warm colors in places far from natural light, and it is preferable to dilute them to prevent boring repetition and using contrast in small spaces for a color of strong intensity such as blue [18].

1.10. Lighting in Interior Design

Lighting is an important element in interior design and it is considered as one of the most important aspects. Without proper lighting and illumination, the aesthetics and artistry of a design cannot be achieved. Electricity can be rationalized by optimally utilizing nature to control both natural and artificial lighting [1]. Lighting design is concerned with providing the appropriate and regularly distributed light intensity for normal activities and preventing glare, which is one of the important defects that must be avoided when designing and distributing lighting for any architectural space. Glare is "a matter of proportion between the dark and light parts of a single space" [19].

1.11. Sustainable Lighting

Sustainable lighting design means "doing the right thing with the least amount of effort, in harmony with the environment and without harming it". Light-colored floors reflect the light falling on their surface and help make the interior space appear brighter, while dark floors absorb more of the light falling on them. As for walls, light-colored walls reflect light effectively. As a general rule, colors with strong intensity, which are naturally exciting and stimulating, are tiring for the eye.

The most important motivations for using false ceilings, in addition to achieving an aesthetic appearance, are the absorption and dispersion of light. Walls are equally important because the designer's solutions and ideas provide solutions that help in the process of distributing appropriate lighting parameters [20].

Based on the above, sustainable lighting indicators can be summarized in Table 1.

Table 1. Sustainable lighting indicators.

S	Indicator	Source
1	The correct and most appropriate location for openings in buildings.	[11]
2	Window height and the height of its lower edge above the ground level.	[2]

3	Using horizontal windows on facades with openness and a wide view of the external environment and using vertical windows when windows are located between adjacent buildings.	[2]
4	Adding sunbreaks to the left side of windows facing east, and to the right side of windows facing west.	[2]
5	Considering light design from the early stages of developing design ideas and plans	[3]
6	A combination of design characteristics can be employed (space shape, relying on more than one wall to illuminate the space, dividing the window space into a group of windows within the same wall, distributing windows across the walls of the space.	[8]
7	Using soft textures on surfaces (walls).	[17]
8	Using warm colors in areas far from natural light, and preferably reducing them. Using contrast in small areas for a strong color such as blue, as an example	[5]
9	Painting surfaces adjacent to openings in light colors.	[18]

2. Materials and Methods

A descriptive-Analytical Approach is followed in the current study. The study provides a description of all environmental systems and their impact on users' comfort. The study collects the required data and enters it into the analytical program (Design Builder). The study focuses on windows. It treats windows as a source of light for the space, similar to electrical sources. Determining the suitable area of the window is based on balancing the intensity of the light flux directed at the window and the amount of flux required for the space according to its function [21].

Software Design Builder (with Energy Plus engine for daylight analysis) was benefited to evaluate daylight availability using key metrics such as daylight factor, and illuminance. Also to examine the influence of room orientation (East, West, North, and South) on natural lighting levels, and compare the results with Well Building Standard (Recommends high-quality daylight exposure for health benefits) [22]. Al Garawee specialized hospital in Iraq, Babylon, was chosen as a case study. Run simulations was done for four patient rooms with different dimensions, shape, surroundings, and orientations, but with typical window size, and materials to collect daylight metrics. Analysis period was in summer season on twenty-one of June at deferent time of day according to the room orientation. This Date is important for daylight because it has maximum availability of daylight. June has the highest levels of natural light since the sun remains above the horizon for the longest [21].

2.1. Sample Description

Adel Al-Karawi Hospital was chosen as one of the modern hospitals established in Babylon, located on 60th Street in the center of the governorate. Consisting of three floors, it was first built as an ophthalmology hospital, as the hospital's owner and director is an ophthalmologist. Currently, it receives patients with various ailments, accommodates them in private rooms, and undergoes various surgical procedures.

The site was visited and photographed; also, architectural plans were obtained from the administration. The hospital director was interviewed, and some patients were met to gather information. Four models of patients' rooms were chosen because they were in different directions from one floor, the first floor, due to the identical floor plans, see Figure 1.

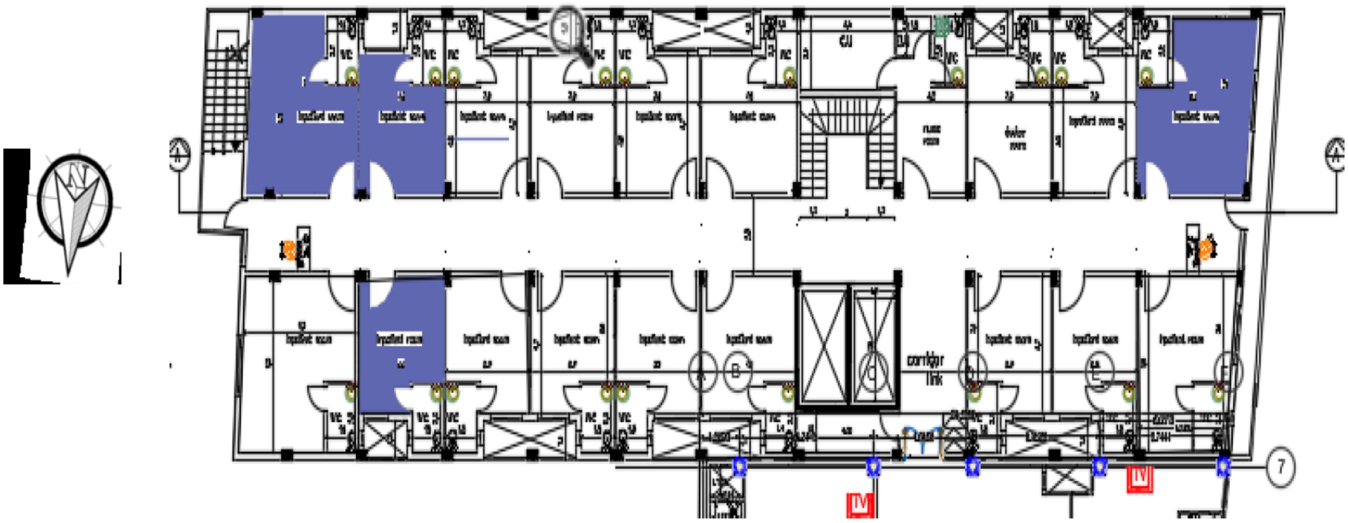

Figure 1. The location of the rooms.

It was noted that the window spaces are the same in all rooms, with a length of one and a half meters, a width of one meter and twenty centimeters, and a height of one meter from the ground. The false ceilings were made of gypsum board squares (60 × 60) in white. The walls are smooth-surfaced and collared in a light beige color for all spaces. Beds were used with blue covers and the table top in each room was blue. The room spaces are generally small. Horizontal Stripe curtains in walnut color are used in all the rooms, as shown in Figures 2-5 that shows the rooms in the four directions:

2.1.1. Description of Room No. (1)

The room is located towards the north, see Figure 2.

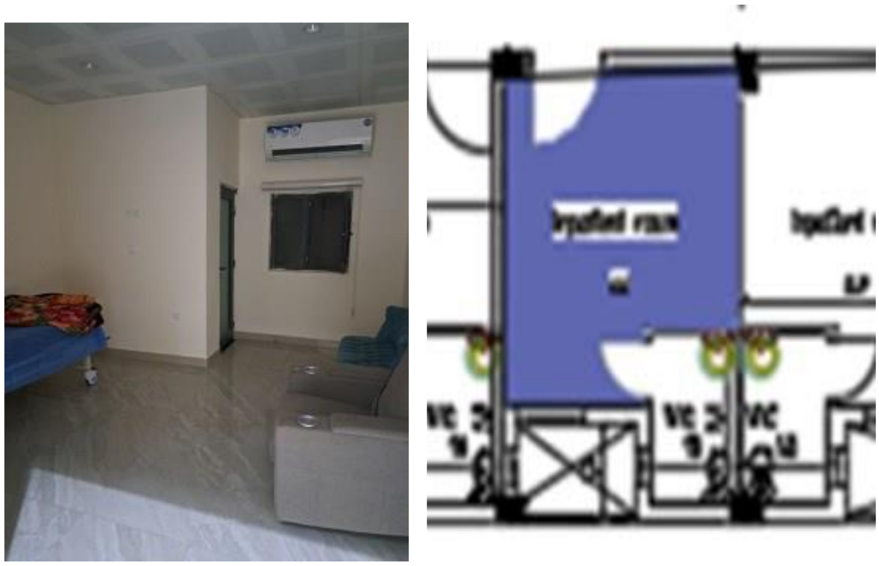

Figure 2. Horizontal projection of room no. (1).

2.1.2. Description of Room No. (2)

This room is located to the south, see Figure 3.

Figure 3. Horizontal projection of room no. (2).

2.1.3. Description of Room No. (3)

This room is located to the east, see Figure 4.

Figure 4. Horizontal projection of room no. (3).

2.1.4. Description of Room No. (4)

Finally, room no. 4 is located towards the west, see Figure 5.

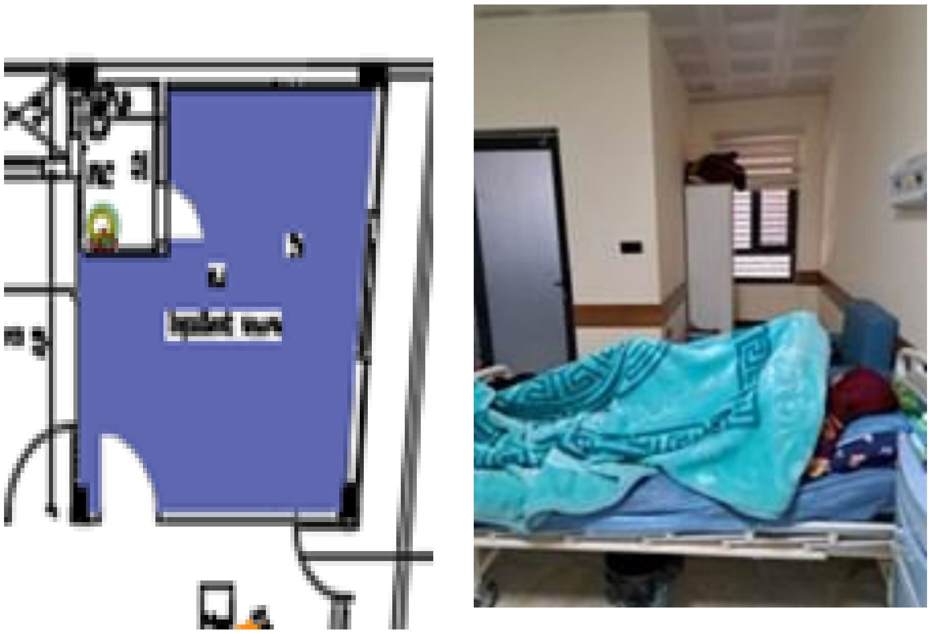

Figure 5. Horizontal projection of room no. (4).

It was noted that natural lighting in the rooms is weak because the window spaces are small, so there is greater reliance on artificial lighting.

2.2. The Analysis

The information was analyzed in two ways:

a. Comparing the sustainable lighting indicators derived from the theoretical framework and determining the extent to which they were applied to the sample, as shown in Table 2.

Table 2. The application of the sustainable lighting indicators in the rools under study.

	Indicator	Room No. 1 (North)	Room No. 2 (South)	Room No. 3 (East)	Room No. 4 (West)
1	The correct and most appropriate location for openings in buildings	✗	✗	✗	✗
2	The height of the window and the height of its lower edge above the ground level.	✗	✗	✗	✗
3	Using horizontal windows in facades with openness and a wide view of the outside environment. And using longitudinal window with the windows located between adjacent buildings	✗	✓	✗	✗
4	Adding sunbreaks to the left side of windows facing east, and to the right side of windows facing west	✗	✗	✗	✗
5	Consider light design from the early stages of developing design ideas and plans.	✗	✗	✗	✗

6	Employing a combination of design characteristics (e.g. the shape of the space, relying on more than one wall to illuminate the space, dividing the window space into a group of windows within the same wall, distributing windows across the walls of the space).	✗	✗	✗	✗
7	Using a smooth texture on surfaces (e.g. walls)	✓	✓	✓	✓
8	Using warm colors in areas far from natural light.	✓	✓	✓	✓
9	Painting surfaces adjacent to openings in light colors	✓	✓	✓	✓

b. Using GED multimeter: The light intensity was measured using a GED Multimeter, model FMM5, (Figure 6), by putting it next to the window in each of the four rooms within the sample selected. The following figures were obtained: Room no. (1) 66 lux, room no. (2) 350 lux, room no. (3) 1340 lux, and room no. (4) 550 lux (See Table 3).

c. Using simulation: The Software Design Builder (with Energy Plus engine for daylight analysis) was used to evaluate daylight availability using key metrics such as daylight factor, and illuminance. Also to examine the influence of room orientation (East, West, North, and South) on natural lighting levels, and compare the results with Well Building Standard (Recommends high-quality daylight exposure for health benefits) [22]. The operational simulation was conducted for four patients' rooms with different dimensions, shapes, perimeters, and orientations, but with a typical window size and materials to collect daylight measurements. The analysis period was in the summer season on June 21st at different times of the day according to the room orientation for the purpose of obtaining the highest light intensity. This date is important for day lighting because it has the maximum daylight availability. June has the highest levels of natural light as the sun remains above the horizon for the longest period [21]. The plans were then entered into the analytical program to determine the extent to which sustainability has been achieved in terms of light.

Figure 6. Multimeter (temperature - humidity - sound - light) GED – FMM5.

Table 3. Results obtained from the GED multimeter.

Sample No.	Direction	Maximum Illumination
Room No. 1	North	66 lux
Room No. 2	South	350 lux
Room No. 3	East	1340 lux
Room No. 4	West	550 lux

3. Results

The model was drawn as in Figure 7, by design builder software. then running the simulation by design builder software (with Energy Plus engine for daylight analysis), relative to Iraq climate for different orientations of room patient in the hospital, the result below has been obtained. After drawing a model of the hospital in the design builder software and running the simulation relative to Iraq climate, the following results (Figures 7-11) were obtained:

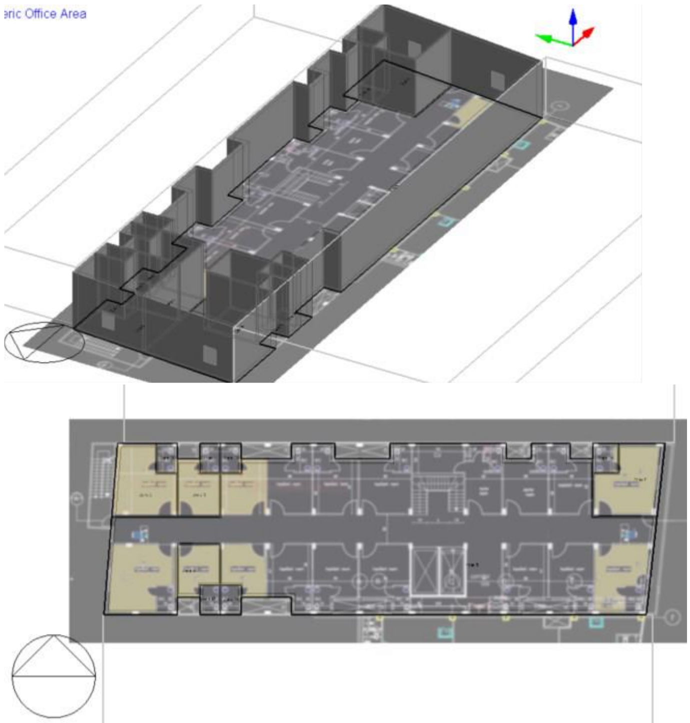

Figure 7. The model of Al Garawee specialized hospital by design builder.

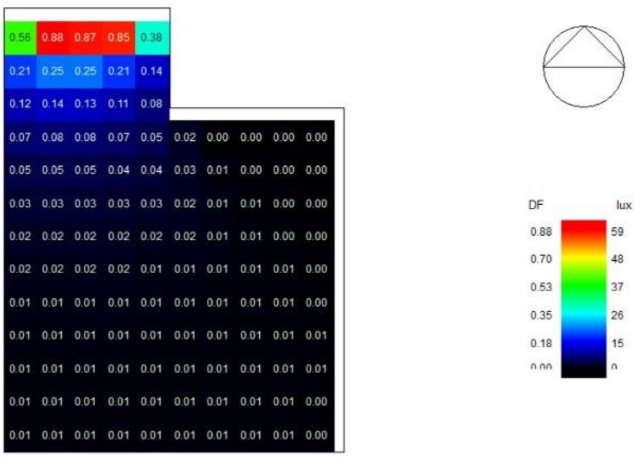

Figure 8. The daylight factor (DF%) and illuminance (Lux) distribution for northern elevation in 21 June at 5 pm.

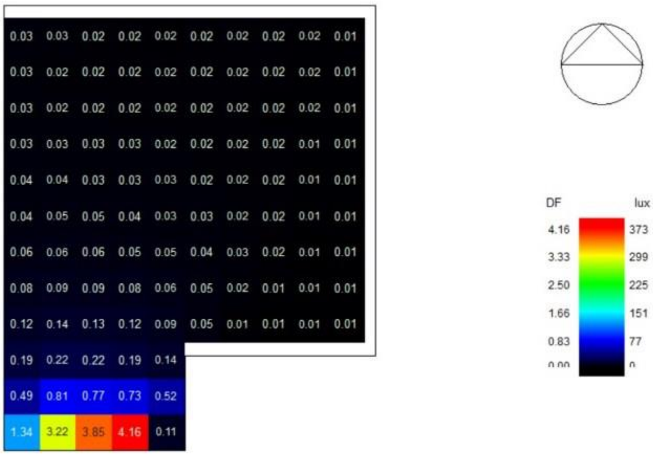

Figure 9. The daylight factor (DF%) and illuminance (Lux) distribution for southern elevation in 21 June at 1 pm.

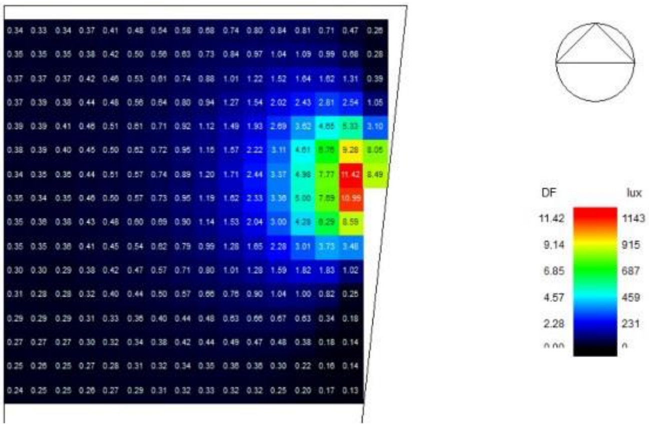

Figure 10. The daylight factor (DF%) and illuminance (Lux) distribution for eastern elevation. in 21 June at 9 am.

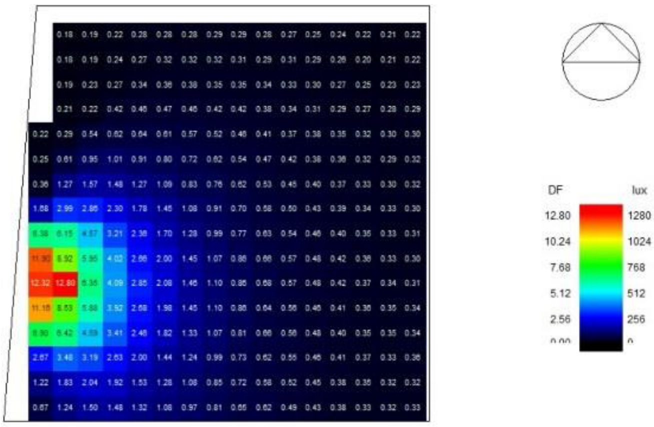

Figure 11. The daylight factor (DF%) and Illuminance (Lux) distribution for western elevation.in 21 June at 3 pm.

Figures 7-11 show the daylight factor (DF%) and Illuminance (Lux) distribution for different elevations and times of day in June. It can be seen that all patient rooms do not match the standard specifications for natural light. According to Well Building Standard the main condition for best natural lighting in hospital patient rooms can be achieve by ensuring 300-500 lux during daytime hours [12]. Accordingly, the majority of the rooms are under poor daylight conditions.

It can be seen from Figure 7, that the results of the natural lighting at 5 pm on June 21st, for northern elevation are as follows:

a. The highest DF values are (0.85 – 0.88, in red) near the window, indicating maximum daylight penetration.
b. Moderate DF values are (0.14 – 0.56, in blue-green): Light reaches a limited area inside the room.
c. Very Low DF values are (0.01 or 0, in black): The majority of the room is under poor daylight conditions.

According to Illuminance (Lux) distribution, the maximum was 59 lux (near the window). Minimum was 0 lux (farthest from the window). The gradual decrease in lux levels suggests that the daylight penetration is weak in deeper areas.

The analysis of Figure 8 shows that natural lighting at 1 pm on June 21st, for southern elevation are as follows:

a. The highest DF values (4.16 in red) located near the window, indicating strong daylight penetration.
b. Moderate DF values (0.49-1.34 in blue-yellow) spread towards the middle of the room.
c. Lowest DF values (0.01 – 0.05 in black) found deeper inside the room, where daylight is minimal.

According to illuminance (lux) distribution, the maximum was 373 lux (near the window), moderate was about 77-151 lux (middle areas), and minimum was close to 0 lux (farthest from the window).

Figure 9 illustrates the analysis of the natural lighting at 9 pm on June 21st, for eastern elevation are as follows:

a. The highest DF values (11.42 in red): Located near the window, indicating very strong daylight penetration.
b. Moderate DF values (4.57 – 9.14 in yellow-green): Spread toward the middle of the room.
c. Lowest DF values (0.27 – 1.49 in dark blue): Found deeper inside the room, where daylight is minimal.

According to the illuminance (Lux) distribution, the maximum was 1143 lux (near the window), the moderate as about 231–687 lux (middle areas), and the Minimum was Close to 0 lux (farthest from the window).

Figure 10 shows the analysis of the natural lighting at 3 pm on June 21st, western elevation are as follows:

a. The highest DF/ lux (red to yellow), could be in the range of 7-12% DF or 700–1200+ lux near the window. This level of daylight is excellent but can also lead to glare if unshaded.
b. Moderate (green to light blue): values around 3–6% DF or 300–600 lux, which are generally comfortable for many daytime activities.
c. The lowest (dark blue to black): Often below 1% DF or under 100–200 lux, indicating insufficient daylight for typical tasks without additional artificial lighting.

The results obtained are listed according to what the researchers have reached from the above and are summarized in Table 4.

Table 4. The degree of illumination in the four rooms under study

No. of the room	Direction	Maximum illumination according to the Design Builder environmental simulation program	Illumination according to the figures obtained from the GED	A comparison to the typical illumination which ranges between 300-500 lux
Room no. 1	North	59	66	Limited daylight and low day light levels
Room no. 2	South	373	350	strong daylight penetration
Room no. 3	East	1143	1340	Provides strong daylight causing glare
Room no. 4	West	600	550	Excellent light but causes glare.

4. Discussion

The northern-facing façade does not receive strong direct sunlight at 5 PM, leading to low daylight levels deeper inside the room. Daylight penetration is limited, and artificial lighting may be needed for proper visibility. For southern elevation has good daylight availability, especially near the window. Potential glare and heat gain issues due to direct sunlight at midday. Strong daylight availability is for eastern elevation, especially near the window, which might cause glare issues. There is also a gradual reduction in daylight penetration towards the back of the room. Potential over-illumination risk near the window (>1000 lux can cause discomfort).

A western-facing façade usually benefits from abundant sunlight, which can reduce electric lighting needs during midday. High daylight levels can be therapeutically beneficial in hospital settings (patient rooms, for example). On the other hand, high solar angles in summer can cause uncomfortably bright light and heat gain near the window. Uneven Light distribution, the large contrast between bright zones (near the window) and dim zones (room interior) may require design adjustments

5. Conclusion

The evaluation of daylight factor (DF%) and illuminance (lux) distribution in patient rooms with various orientations reveals that none of the examined spaces fully comply with the Well Building Standard for optimal natural lighting. According to these standards, patient rooms should achieve a daylight factor between 2% and 5% and maintain natural daylight levels of 300–500 lux during daytime hours. However, most rooms fall short of these requirements, resulting in inadequate daylight conditions. A key issue across all orientations is the uneven distribution of natural light, with excessive brightness near windows and insufficient illumination in the deeper areas of the rooms. This imbalance highlights the need for design interventions such as light shelves, shading systems, or optimized window configurations to improve daylight uniformity while mitigating glare and visual discomfort.

Recommendation

At the end of the current study the researchers recommend the following strategies to improve natural lighting conditions in hospital patient rooms and meet the Well Building Standard:

a. Optimizing Window Design: Prioritizing taller windows rather than wider ones to facilitate deeper daylight penetration and utilizing high-performance glazing to maintain adequate daylight levels while minimizing glare and excessive heat gain.

b. Implementing Shading Solutions: Installing external shading elements, such as louvers or overhangs, to regulate sunlight exposure on southern and western façades using interior shading options, like adjustable blinds or light-diffusing curtains, to control glare and enhance visual comfort.

c. Enhancing Light Distribution: Introducing light shelves to reflect and distribute daylight more evenly throughout the room incorporating reflective interior finishes to maximize natural light diffusion.

As for the hospital under study, the researchers propose the following recommendations for the hospital management:

a. Changing some openings (windows) to allow adequate lighting into the room.

b. Removing the horizontally lined soffits, which reduce light penetration, and replacing them with more appropriately designed soffits, and adding sunbreaks to the left side of east-facing windows and to the right side of west-facing windows.

c. Curtains should be in cheerful, light colors, and plants should be placed to bring vitality to these spaces.

Implementing these measures can help create a more balanced daylight environment in patient rooms, ensuring compliance with lighting standards while enhancing patient comfort and well-being.

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