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# Performance of daylight for different room layout and window configuration for hospital rooms in hot and dry climate

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## ABSTRACT

Patient rooms contribute to the largest floor area in hospital buildings. There is a lot of research addressing the patient room layouts based on orientations, window sizes and shapes, and its effect on human health. But researches on the parameters like layout of the rooms with window configurations and their impact on the daylight performance in hot and dry environment have not been undertaken. In this research, three most common design layouts of the patients room were studied. The aim of the study was to analyze how the shape of the room influences the amount of daylight (quantity and quality) which is sufficient and comfortable. Simulation techniques were used for identifying the most effective patient room configurations with varied window to wall ratios .The research paper focuses on adequate distribution of daylight for patients and staff in the patient rooms. Study scopes down its focus on south orientation as it receives the maximum solar radiation in this climate type. Simulations were conducted using Autodesk Ecotect analysis software with the help of plug-in software radiance for accurate analysis. Results demonstrate that daylight adequacy is achieved in inboard and nested patient rooms, with higher ranges as compared to outboard patient rooms.

***Keywords:*** *Daylighting, Patient room layouts, Window to wall ratio [WWR], Hot and Dry climate*

## 1. Introduction

Adequate daylighting in indoor environment is important for architects, engineers and planners as natural daylight plays an important role in improving patients health, helps reduce stress and anxiety, lower blood pressure, reducing need of pain medication and shortens patients stay in the hospitals.

Its becomes very important to study windows, window positioning and WWRs correctly to provide adequate natural light into the patient rooms. Some patient rooms have a smaller external wall surface with a larger room depth, whereas some have larger external wall surfaces with smaller depth, which leads to inaccurate daylight penetration into the rooms. Larger the external wall it has larger range of opening can be build. Therefore the window in the patient rooms plays a significant role in minimizing solar penetration, reducing overheating, and at the same time provides adequate daylighting, minimizes the artificial energy load and increases patients view to the exteriors. Hence it becomes important to study the window to wall ratio values and window positioning on the external walls for analyzing daylight in hot and dry climate.

The main objective of the research is to address patient room layout designs and its influence by various window to wall ratios to help achieve adequate daylighting performance for each room type for both patients and staff. Three most commonly used patient room design layouts facing south orientation will be focused on, in hot and dry climate of Aurangabad, India.

## 2. Literature review:

A study linked daylighting with patients health performance, the patients illness was affected by daylight levels, which was identified. Factors which were studied were patients average stay in the hospital as the outcome, difference in environment during daylight hours, illuminance, illuminance ratio, illumination variations in the hospital patients rooms .The study proved that daylight decreases patients hospitalization stay[1].

In another study related to energy efficient building, envelope treatment was examined in patients rooms of a Thailand hospital. Parametric analysis was conducted on parameters like glazing material, window to wall ratios (WWR), thermal transfer valves and external shading devices were addressed. The results analysis focuses on daylight penetrating at different orientations, which affects the day lighting in healing patients, on the other hand reduces the artificial lighting energy consumption and their relationship to other environmental aspects [2].

A study on four main orientations with the help of simulations of various window configurations for daylight performance was evaluated for a typical intensive care unit room located in Cairo, Egypt, where effect of adding shading and daylight systems was identified to lower the artificial light load. It was identified that the south orientation receives the maximum radiation and results states that successful window configuration with window to wall ratios at four main orientations [3]. In another study windows were analyzed for optimum window design based on different window lintel levels, sill levels, width and depth of shading devices. It results in optimum window form for providing day lighting, external views, while minimizing artificial energy consumption [4].

The above literature reviews addresses daylight as an important factor in patient rooms. There are very few publications that have addressed relationship between hospital patient room layouts and its association with alternative window configurations ranging varied WWRs values to achieve accurate daylight performance. Scarce research work has been quoted explaining the relationship between room layouts and WWR especially for hot and dry climate. One can avoid glare and improve the natural daylight levels by an effective room layout design which will lead to effective healthcare facilities and thereby reducing artificial energy consumption for artificial lighting, which makes it an effective sustainable hospital design, which has a direct impact on delivering more effective healthcare facilities.

## 3. Methodology:

The Methodology adopted here is to achieve daylight for adequacy performance to formulate hospital patient room modules with different shapes for south orientation in Hot and Dry climate of Aurangabad.

Three most commonly used patient room design layouts configurations were investigated (A, B, C) of a same floor area (23.4 m$^2$) i.e.an outdoor bathroom (design A), a nested bathroom (design B) and a room with inboard bathroom (design C). Using same parameters and dimensions as mentioned in Table 1 for studying these three design room layouts. Patient rooms are assumed to be located on the first floor level as higher the floor level more the lux level comes in the hospital building with annually mean sky conditions.

The spaces are assumed to have no external obstructions outside the patient rooms. 20% reflectance of external ground surface with seventeen varied window configurations ranging from (10-90%) WWR values were analyzed for each patient room design. The window to wall ratios increases from every 5% increments. Simulations techniques were conducted using the climatic data of the city of Aurangabad (19.53N, 75.21E, and 568m) in Autodesk Ecotect software with the help of radiance plug-in.

Experiments were conducted for an entire year performance using the Dynamic Daylight Performance Metrics (DDPM). Considering the avaibility of natural light during the day, simulation time is assumed to be from 7am-5pm.In this study, the patient's bed level plane (0.9m height) was used as a reference plane level. According to the Illuminating Engineering Society of North America (IESNA, 2000) and National Building Code (NBC) 300 lux is considered adequate for daylighting and as per ECBC norms 30% UDI (Useful Daylight Illuminance) or more is considered adequate.

The simulation results represent partially daylit, daylit, and overlit areas for the given room layouts. Design cases having 100% daylight area over the bed plane coupled with more than 90% daylight area of the patients room area were considered "successful" since these ensure sufficient daylighting performance at the patients bed where medical care is performed. The partly lit areas are those which do not receive daylight over half of the area of the year-round occupied time. And the over lit areas are those areas which receive daylight in excess which is not desirable. Table 1 gives parameters of hospital patients rooms where as Fig. 1 shows layout designs.

**Table 1. Parameters for hospital rooms**

| **Internal surfaces materials (Reflectance)** | |
|---|---|
| Floor to floor height of room | 4 m |
| Room area | 23.4 $m^2$ |
| Walls | 50 % (off-white colored internal walls) |
| Ceiling | 80 % (white colored ceiling) |
| Flooring | 20 % ( Vitrified floor tiles) |
| Acoustic insulation | up to 32 dB |
| Window Parameters | |
| Double glazing clear glass | Both glasses are 6 mm thick with 10 mm air gap |
| Visual light transmittance (VLT) | 80% |
| Window frame | Aluminum frame-Reflectance |
| Window shading overhang | 600 mm overhang |

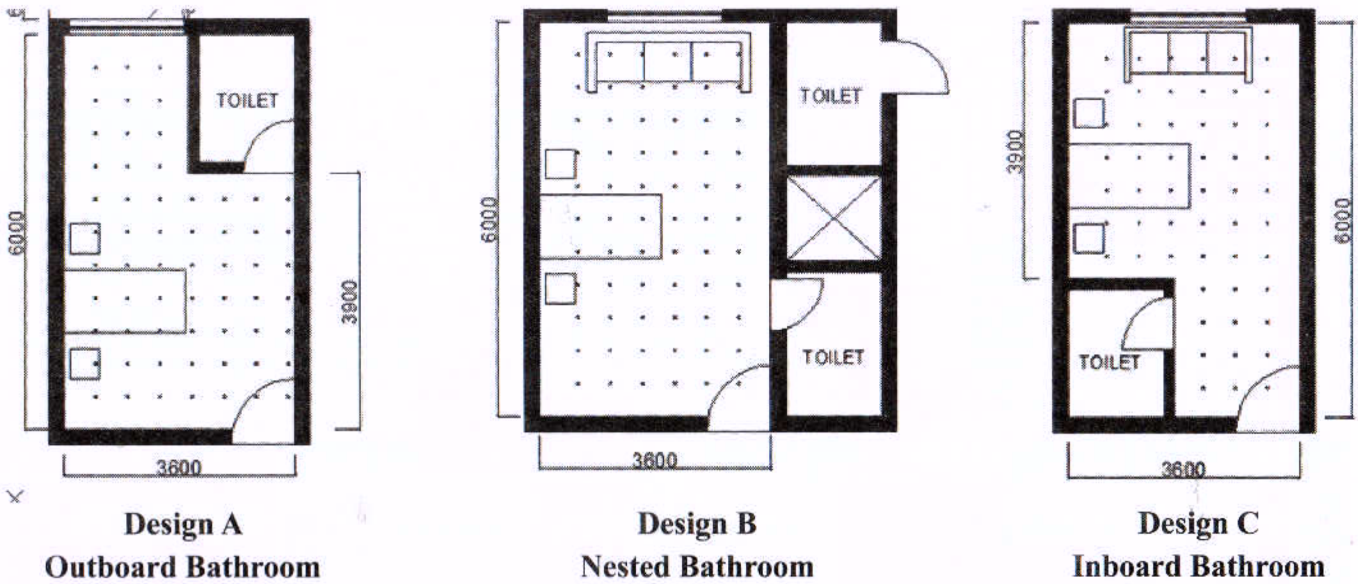
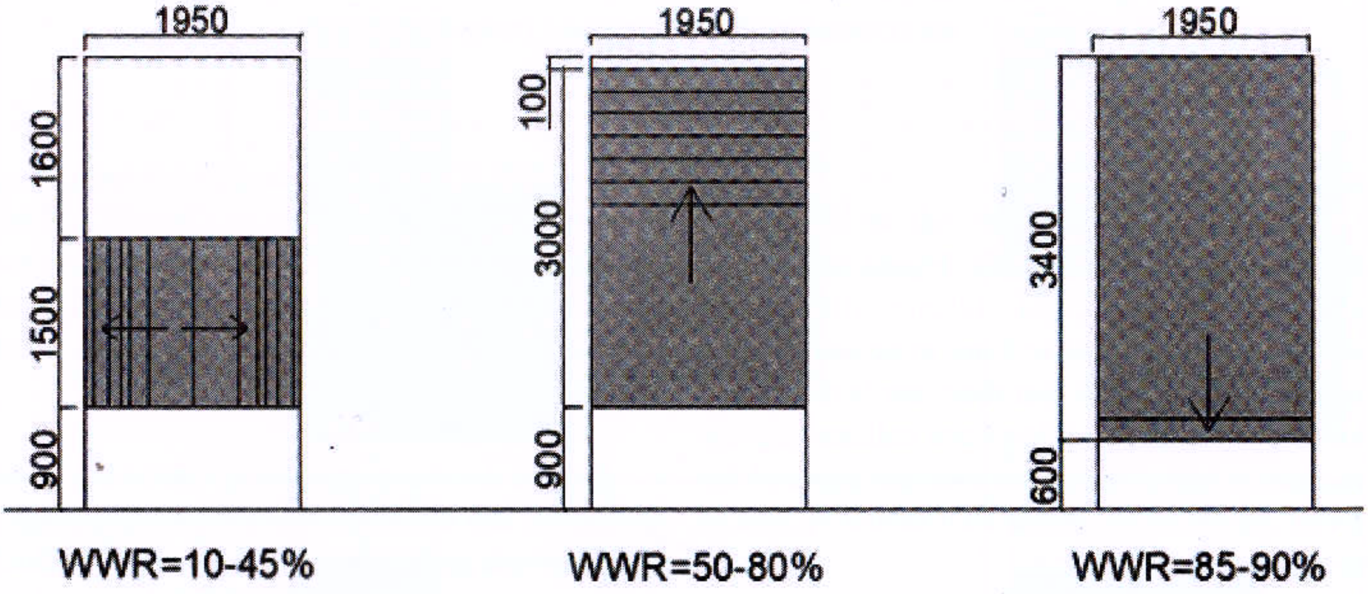
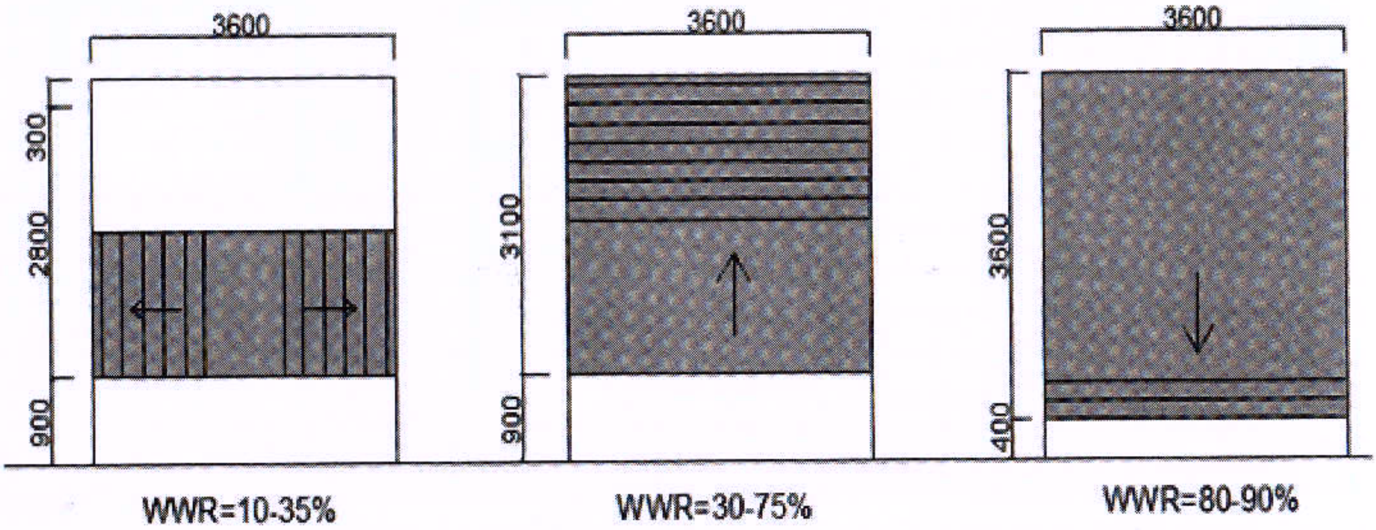



**Fig 1. Common patient rooms layouts**




WWR = 10-45% on the external wall and window extends towards sideways,
WWR = 50-80% extends towards the lintel levels,
WWR = 80-90% extends towards the sill level.

**Fig 2. Window shape and position of outboard room layouts on external wall (Design A)**




WWR = 10-35% on the external wall, window extends from the sideways,
WWR = 30-75% extends towards the lintel levels,
WWR = 80-90% extends towards the sill level.

**Fig 3. Window shape and position of nested and in board rooms layouts on external wall (Design B and Design C)**

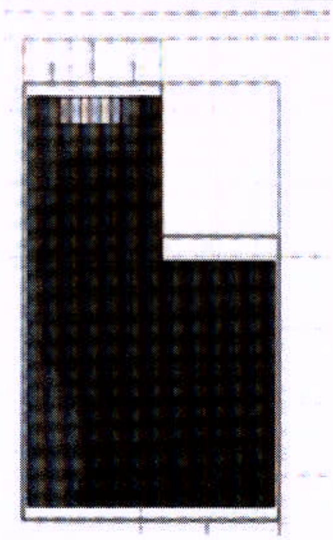
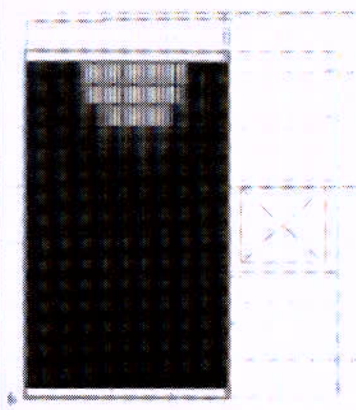
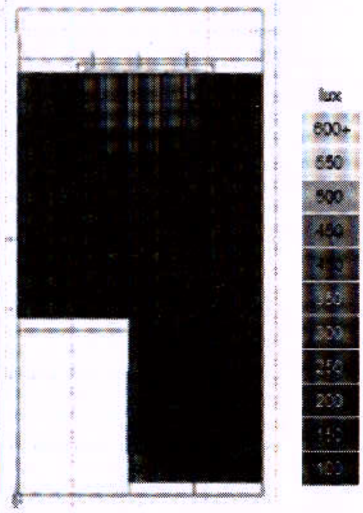
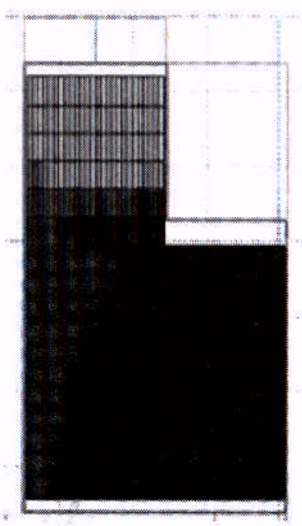
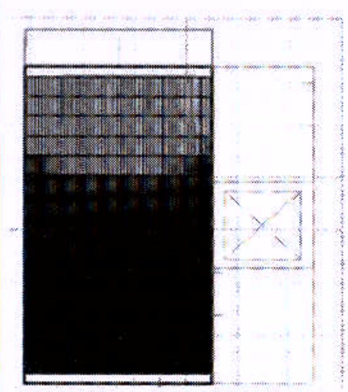
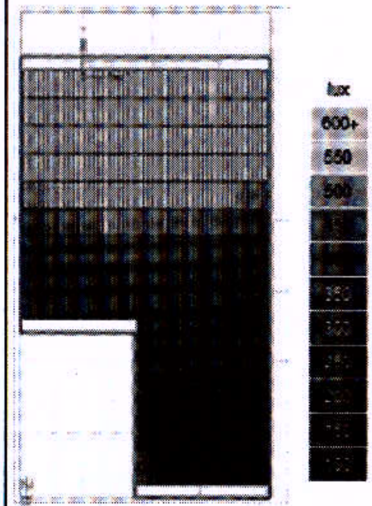
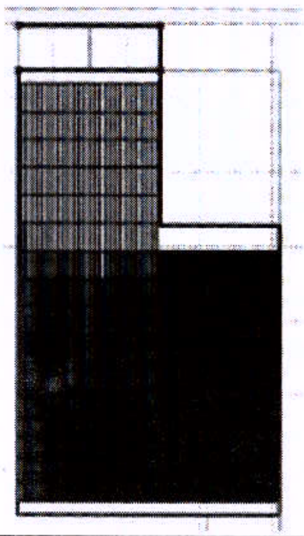
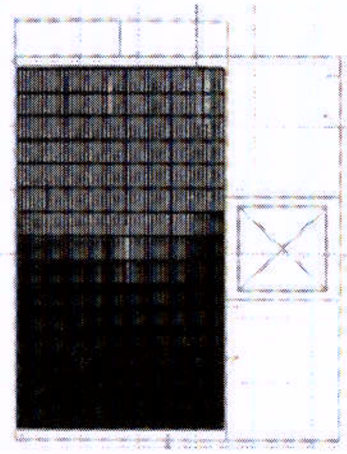
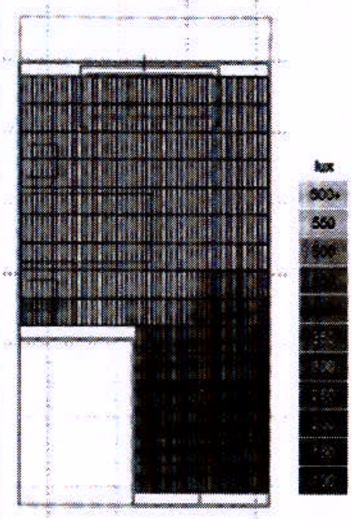
## 4. Results and Discussion :

In the below Table 2 colors indicate illuminance level falling into the room. The legend ranges from 100-600 lux. Blue color indicates illuminance which is not disirable and not even satisfactory, orange color indicates that the room is day lit and satisfactory, whereas yellow color indicates that the room is overlit (illuminance over the expected lux level). As per ECBC norms UDI should be 30% of the room area.

In design A adequate daylighting was achieved with larger windows WWRs only. Only six of the seventeen tested cases got daylight availability. Simulations results reveal that the amount of daylight is directly proportionate to increase in WWR values. Only large window provide daylight adequacy in outboard bathroom design ranging from 65-90%. From 10-50% WWRs values, daylight is inappropriate as the illuminance doesn't reach the bed plane of the patient room, whereas from 50-65% values the patient room is partially daylit where patients bed plane receives daylight but the remaining room is not adequately lit.

As from the above simulations Option B (nested Bathroom) and C (inboard bathroom) layouts have better daylight performance in south orientation. Both the layouts receive daylight of 300 lux level in patients room and bed plane in maximum cases. In inboard room illuminance of 300lux level or more can be seen in thirteen cases ranging from WWR 30-90%.Inadequate daylight ranges from 10-30% values, daylit from 35-45%are considered ideal WWRs, Overlit area increases in from 70% and above.

**Table 2. Daylight performance at different WWRs and room layouts**

| WWR | OUTBOARD LAYOUT | NESTED LAYOUT | INBOARD LAYOUT |
|---|---|---|---|
| WWR=15% |  |  |  |
| WWR=45% |  |  |  |
| WWR=75% |  |  |  |

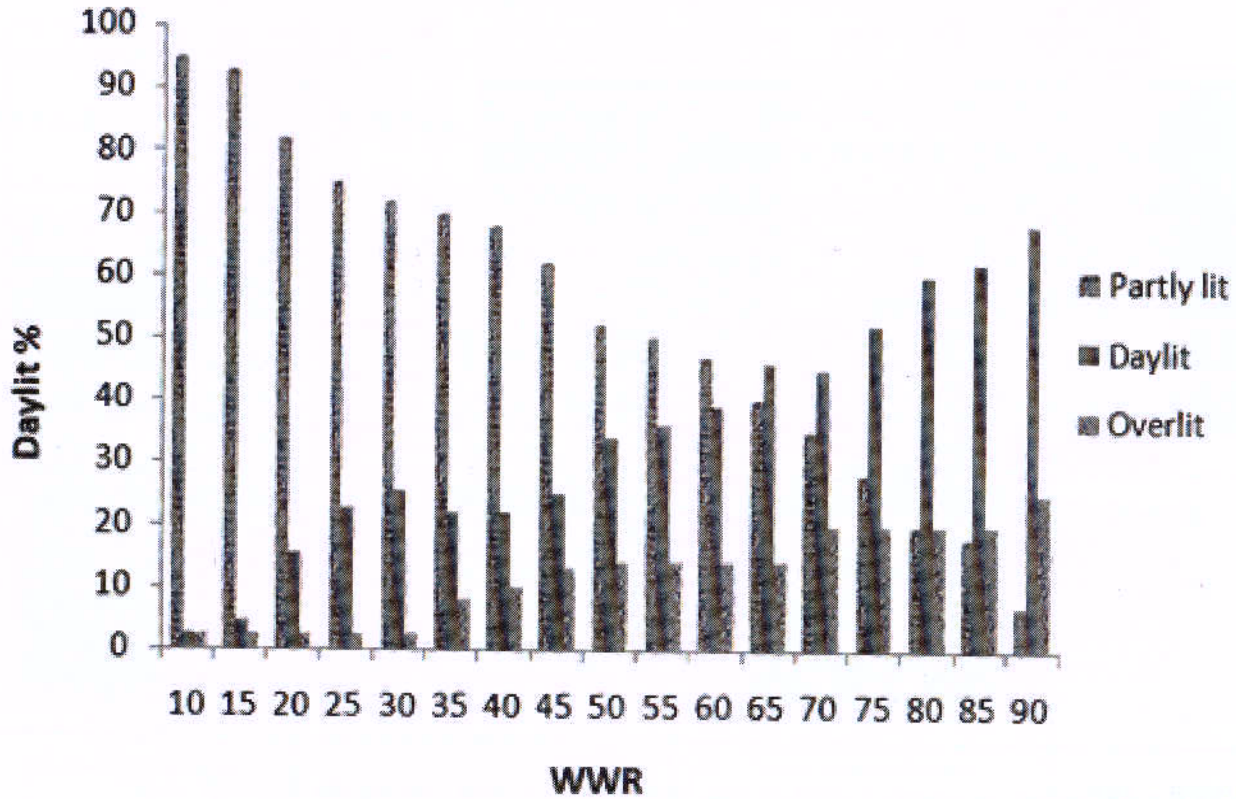



Fig 4.1 Outboard Bathroom (Design A)

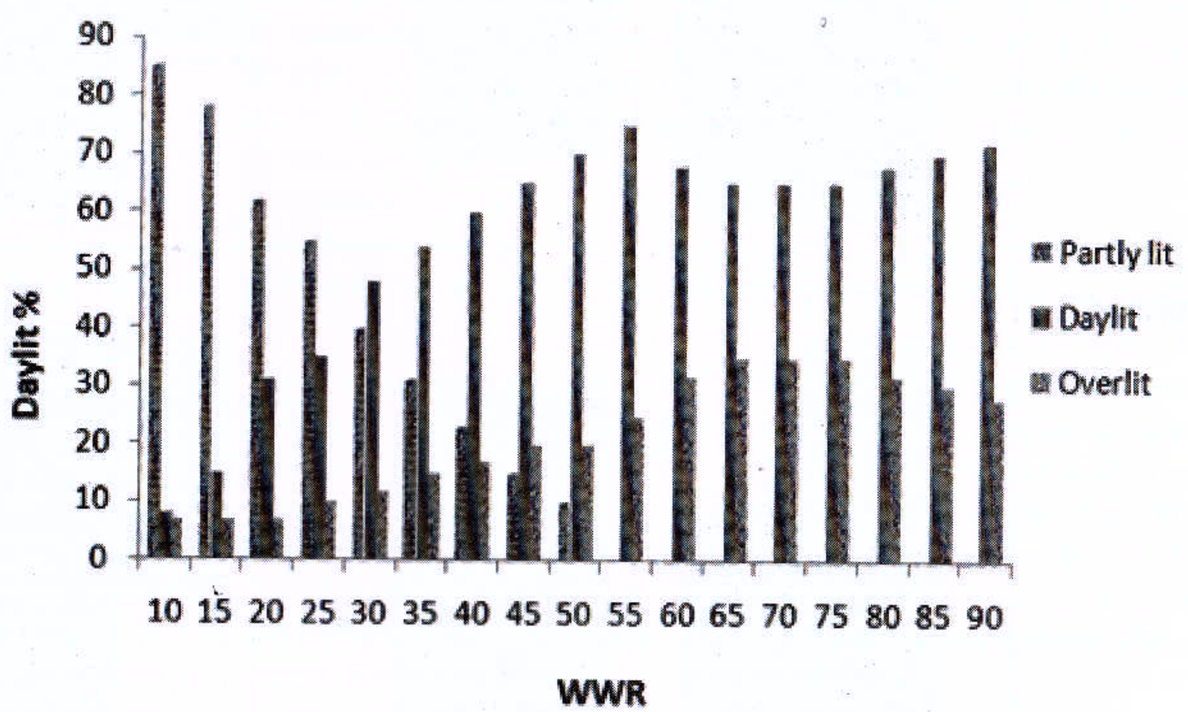



Fig 4.2 Nested Bathroom (Design B)

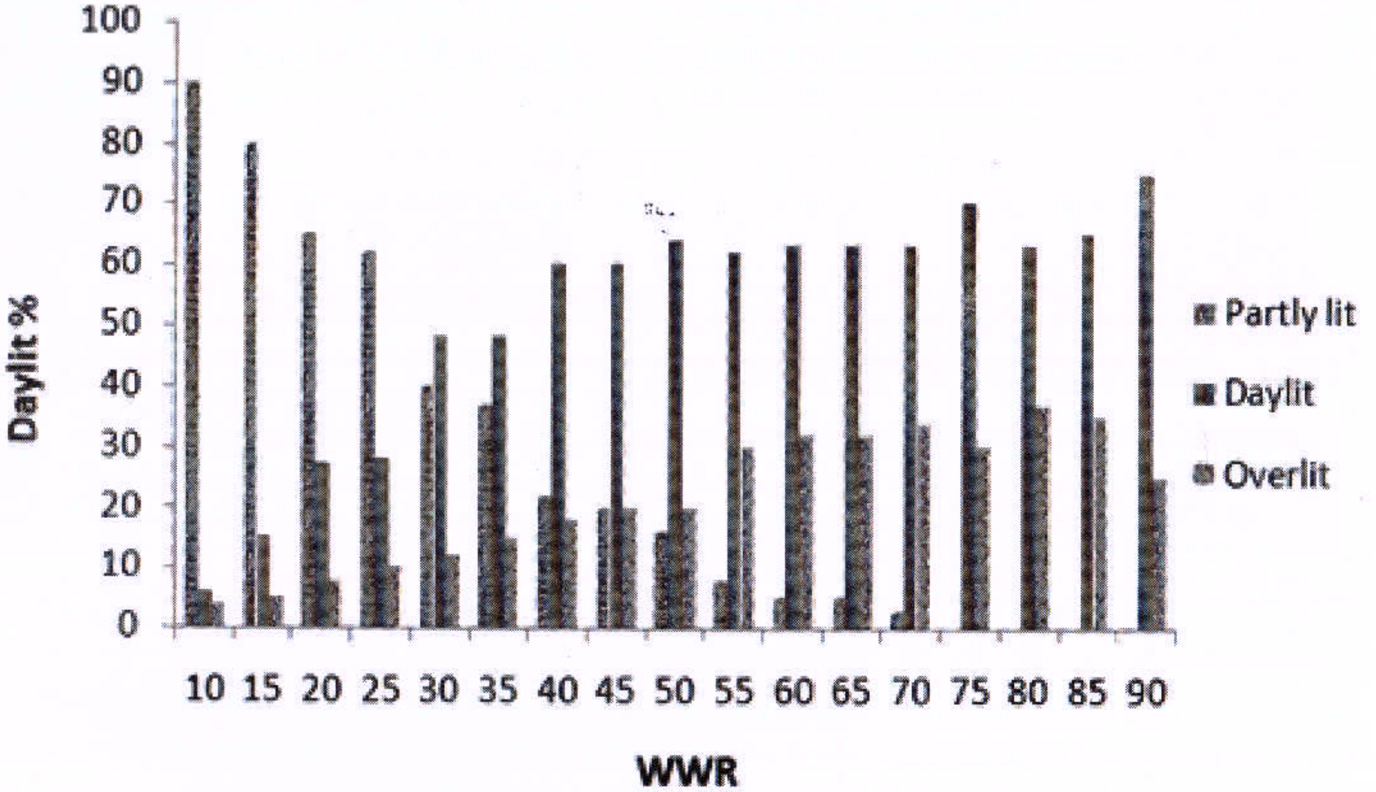



**Fig 4.3 Inboard Bathroom (Design C)**

Whereas in nested room illuminance of 300 lux level or more can be seen in thirteen cases ranging from WWRs 30-90%.Inadequate daylight ranges from 10-30% values, adequate daylit ranges from 35-45% which are considered ideal WWRs, Overlit area are from 65% valves and above.

## 6. Conclusion:

1. It is clear from Fig 4.1, 4.2, 4.3 summarizes the range of windows sizes that were recommended for each patient room design for satisfying daylighting criteria.
2. Use of outboard patient room design layout was found to the least efficient and reduces daylighting potential. Range of successful WWRs in this case is very limited. Only six out of seventeen cases achieve adequate daylight ranging from (65-90%).Therefore only large windows (65-90%) in this case are considered adequate.
3. On the other side, nested and inboard patient room design have wider cases of successful window options. Both designs have adequate daylight performance ranging from 35-45% with smaller WWRs with adequate light on the bed plane as well as in the room are considred ideal WWRs. Proper daylight can be achieved with designing a proper shading device for excessive daylight.
4. Good daylight is achieved in cases B and C as the natural light is achieved without fluctuating and in the case of design A light into the room increases with the increase in WWR values.

5. The result in the paper demonstrates the need of careful consideration of WWRs in relation to patient room designs. Further study can deal with how energy efficient the rooms can be with alternate WWRs, how visual comfort can be achieved with the same patient room layouts and same study could be conducted for each orientation type.

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