Educational Administration: Theory and Practice
2024, 30(1), 7686-7691
ISSN: 2148-2403
https://kuey.net/
Research Article

Optimization Of Window Sizes Suitable For As Green Infrastructure In Warm-Humid Climate.

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Citation: Somdeep Chakraborty, et.al (2024). Optimization Of Window Sizes Suitable For As Green Infrastructure In Warm-Humid Climate., *Educational Administration: Theory and Practice*, 30(1) 7686-7691
Doi: 10.53555/kuey.v30i1.10853

ARTICLE INFO	ABSTRACT

Windows are one of the most crucial elements of building architecture in the current period. It is well recognized that letting in natural light through windows enhances both the indoor atmosphere and the health of its inhabitants. Studies have demonstrated that more daylighting improves the happiness, well-being, and productivity of building occupants. A building's overall energy consumption can be decreased by significantly reducing the requirement for electric illumination through effective daylighting. In addition to enhancing aesthetics and visual comfort, daylighting contributes to sustainability goals in residential construction by lowering dependency on electricity generated from fossil fuels. However, there are drawbacks to maximizing daylight. In warm-humid climates, which are defined by high humidity and strong sunlight, large glass expanses can result in glare and heat discomfort. Although a wide window increases interior illumination, it can also increase cooling demands when sunlight heats the space. Larger windows allow more natural light and views, while smaller windows reduce unwanted heat absorption. In warm-humid conditions, it's especially critical to find the right window size to balance thermal performance and acceptable illumination. This essay focuses on determining the ideal window size for a livable space in a warm, humid location like Agartala city.

Keywords: Window size ; WWR; Daylight; Daylight factor; Sustainability; Lux.

I. Introduction One of the main components of sustainable architecture design is daylight, or the natural light from the sun and sky. In contrast to artificial illumination, daylight is dynamic, changing in color, intensity, and direction from hour to hour and season to season. A room with natural light can be significantly more engaging and visually pleasing than one with only artificial lighting. By making efficient use of daylight, indoor spaces can be significantly improved, lowering the need for artificial lighting, improving occupant well-being, and cutting carbon emissions. Thus the window with optimum sizes may be treated as one of the green infrastructure in habitable buildings.

1.2 Daylight Factor (DF)

The Daylight Factor is defined as the ratio of the indoor illuminance at a specific point inside a room to the simultaneous outdoor illuminance under an unobstructed overcast sky, expressed as a percentage. In simpler terms, it is a measure of how much natural daylight is available inside a room compared to the amount available outside under standard sky conditions.

The daylight factor is typically considered as the sum of three components:

1. **Sky Component (SC)** is the portion of daylight that reaches the indoor point directly from the sky through windows, without any reflection.

2. Externally Reflected Component (ERC): is the part of daylight that reaches the indoor point after being reflected from external surfaces like building façades, pavements, or ground surfaces outside. In this study this component is considered as negligible as the surrounding kept free from any external structure nearby.

3. Internally Reflected Component (IRC) is the portion of daylight that reaches the indoor point after reflecting from internal surfaces such as walls, ceiling, floors, and partitions.
A higher daylight factor means better daylight penetration into the room. However, DF has limitations: it's for a static overcast sky and does not consider sunlight or time variability. Thus, it doesn't indicate daylight performance in sunny climates or glare potential.

A daylight factor, DF of less than 2% is generally considered poorly lit, requiring artificial lighting. A daylight factor, DF above 5% is usually sufficient to avoid artificial lighting. Daylight factor, DF of more than 8% indicates high daylight may create glare and strong indicator of overheating issues.

1.3 WWR (Window to wall ratio)

The **Window-to-Wall Ratio** is a key architectural and design parameter that represents the proportion of a building's exterior wall area that is covered by windows. It plays a significant role in determining both the energy performance and aesthetics of a building. A higher WWR allows more natural daylight and views, which can reduce the need for artificial lighting and improve occupant comfort, but it may also increase heat gain or loss depending on the climate, leading to higher cooling or heating loads. Conversely, a lower WWR improves thermal insulation and energy efficiency but may limit daylight penetration. Finding the right balance in WWR is crucial for sustainable building design, as it directly affects energy consumption, indoor comfort, and compliance with green building standards.

The formula for calculating WWR is:

$$WWR = \text{Total window area} / \text{Total exterior wall area} \times 100\%$$

Where the window are means the transparent area of window which allows light to enter.
This ratio is often expressed as a percentage and serves as a critical design factor in sustainable architecture and green building standards.

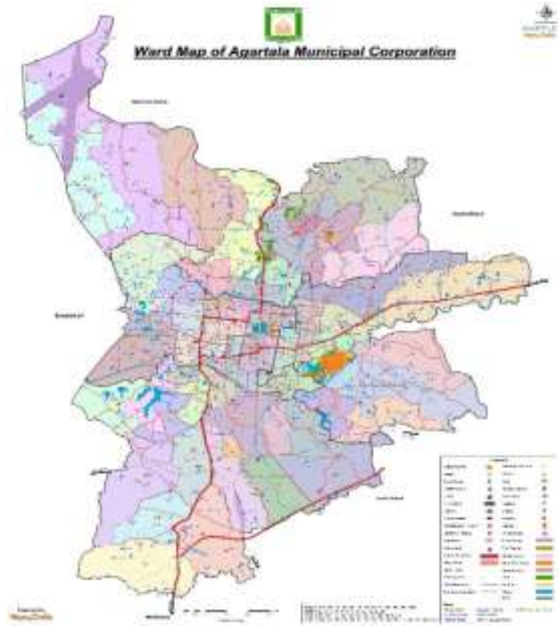
2. Objective of the study

There are significant sustainability ramifications when designing with climate-responsive window sizes. Determining the daylight-heat equilibrium is a crucial aspect of green building practices in warm-humid climates, where air cooling frequently accounts for a significant amount of energy use. Despite the fact that Tripura is supposed to have six distinct seasons, each lasting two months, there are actually four main seasons that are easily discernible all year long. Summer (March–May), Monsoon (June–August), Autumn (September–November), and Winter (December–February) are the four seasons that have an overlapping effect on each other. The insights from this chapter can inform several levels of sustainable design and policy:

- To prepare a broad data sheet of illumination levels of a rectangular interior space having different 'Window to wall ratio' (WWR) measured in different orientation
- To find the good level of WWR for uniform daylight in a habitable interior space of throughout the year
- To find the comfortable level of daylight distribution inside a room throughout the year to avoid artificial lighting during daytime using daylight factor
- Impact of the WWR on the distribution of light along its depth.
- Impact of the WWR on the cooling load of a building interior space.
- To anticipate the higher cooling load inside a interior space

3. The Study Area

The research area is situated at AD Nagar, a peri-urban area located in ward number 39 of Agartala municipal Corporation (AMC). The site is located in an peri-urban area having longitude and latitude 23°49' N and 91°15' E respectively. The climate is humid subtropical climate where the rainfall is well distributed the maximum time of the year with a yearly average rainfall of 2400 mm+. The most likely ambient temperature varies from 6 degree to 39 degree C with short winter and prolonged summer. The sky remains mostly clear in winter and extends the scope of solar energy. The international boundary of India- Even though Tripura is called to have six seasons, each lasting for two months, but practically there are four seasons seen to be prominent throughout the year. All these four seasons namely, Summer (March- May) , Monsoon (June-August), Autumn (September-November) and Winter (December- Feb) are having overlapping effect on one upon another. The rainy season, which runs from May to September here, brings with it a lot of rain, with June, July, and August seeing the heaviest rainfall. Showers, which can last anywhere from a few minutes to several hours, are the most common form of rain. The average annual rainfall is above 2400mm.



4. Methodology

To perform the experiment a rectangular model of a room was made having clear internal dimension of 1200 mm (L) x 1000 mm (W) and 900 mm (H). As it was assumed to be a part of a habitable building, one longer wall of 1200 mm x 900 mm is considered as external wall or part of the building envelop. This wall is made removable and changeable with the help of magnets around the structure. Multiple number of walls are made with different sizes of glazed opening at the centre of the walls. The glazed openings/windows are made in walls keeping the window to wall ratio 10%, 20% and 30% respe ctively.

Small rollers were fitted under the floor of the model so that it can be easily oriented in eight cardinal direction – North, Northeast, East, southeast, south, Southwest, West and Northwest for The Model has an openable part on top to allow placement of the sensors during experiments. All the windows have regular horizontal ordinary sun-shade of 150mm depth painted in white. It was checked again and again that no light was entering from any side of the model except the window/glazing on the external wall. A compass was fitted on the top of the model for proper orientation management.

Illumination levels were recorded in different orientation, time, day of month. Now daylight factor is calculated for each position assuming the average illumination of over

Mathematically,

- Daylight factor, $DF = (E_i / E_o) \times 100$

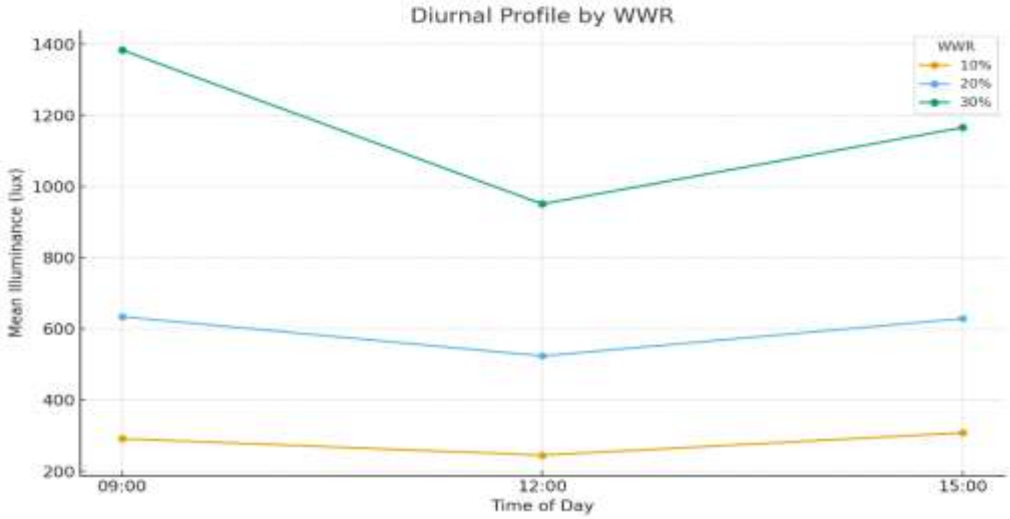
Where:

- DF = Daylight Factor (in %)
- Ei = Indoor illuminance at a point (in lux)
- Eo = Outdoor illuminance on a horizontal plane under an unobstructed sky (in lux)

The value of E_o of an overcast sky is considered as 10000 lux for the North eastern region of India. A small part of data set for 'WWR30% with NORTH orientation' is given in Table 1 for understanding the pattern of the study. Such 8 data set for each WWR10%, WWR20%, and WWR30% has been collected separately and tabulated for analysis.

5. Result and discussions

After thorough analysis of the available dataset the results found are categorized for systematic understanding.



Daylight factor (DF) is another important indicator for understanding the amount of suitable illumination level in any interior space. Chart 1 shows the orientation share of DF share for throughout the year in case of WWR10% is quite uniform and similar to the case of WWR20% in all cardinal direction but average value is less than 4% which shows deficiency in illumination level. It further explains the DF share of WWR30% throughout the year is not uniform and the average value of DF is excessively high which indicates unwanted glare & heat load in specific orientation of SE, SW & glare & heat load in any of the directions. The heatmaps shown in chart 8 gives a clear indication of irregular illumination & heat **load in the specific time of the day**

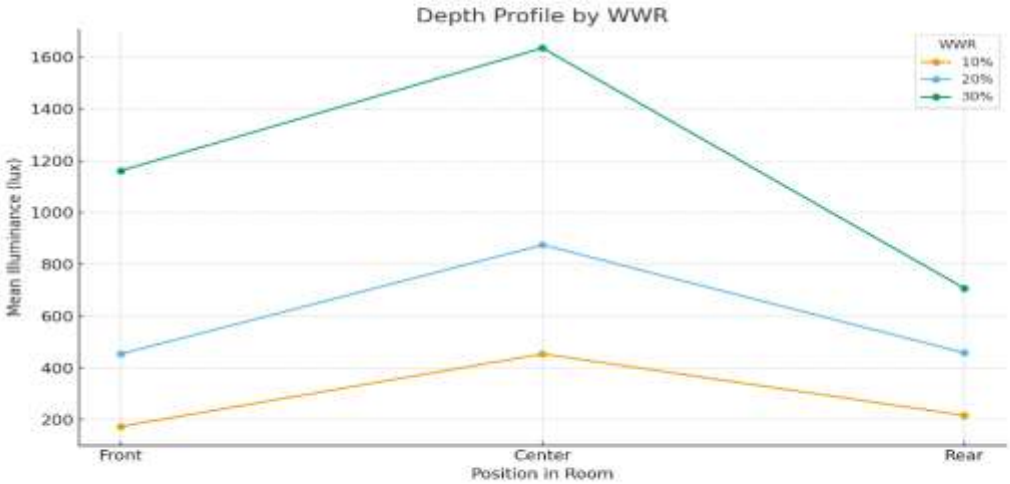


Chart 1 – Diurnal Profile of WWR

6. Finding of the Study

Based on the results and data analysis it has been found that for a place like Agartala situated in a warm humid climatic zone the best value of WWR is near 20%.

Increasing WWR from 10% → 20% reliably improves daylight across the room (front, centre, rear) and boosts UDI without a dramatic jump in glare exposures. Moving further to 30% WWR is not recommended as it continues to raise illuminance above 2000

Lux and glare —, especially for southern

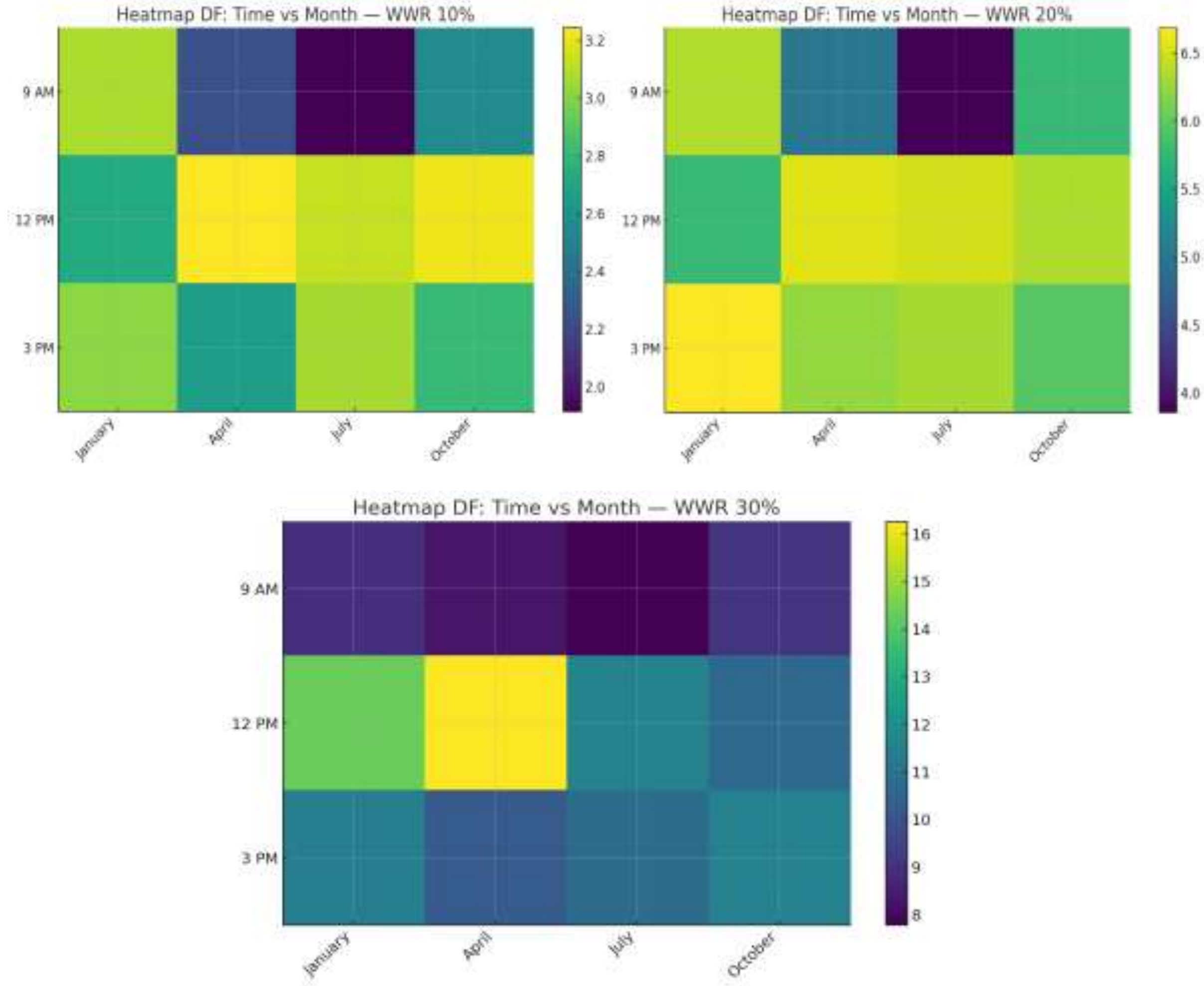


Chart 2 – Heatmap of DF

and western exposures and at low sun angles

Window size: ~20% WWR is the best option for energy efficiency for warm humid climate — more uniform distribution of illumination levels, high UDI, low glare.
Orientation (comfort-first): NE best overall; South next (with overhang); SE great for morning; SW/West only with strong shading; North/NW if you prefer very uniform, low-glare light (consider slightly larger WWR and sheers).

Timing: Use morning-oriented rooms on E/SE, daytime work on S/NE, and avoid unshaded W/SW uses after 15:00.
Put regular visual tasks (reading chair, desk) in the center-front half of the room, not at the extreme corners. Reserve the rear wall for storage or low-demand uses.

7. Conclusion

The warm-humid residential design that maximizes window sizes for daylight has two benefits: it improves living conditions and drastically lowers energy use. Designers may take use of the abundance of natural light in the tropics while avoiding the tropical heat by carefully balancing window space, glazing type, and shade. Even high-performance buildings can be attained using relatively basic means: the correct windows in the proper placements, as this chapter illustrated. Future communities will be more robust, comfortable, and sustainable if these ideas are incorporated into mainstream home design in warm-humid climates.

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