

Social Sciences Spectrum

A Double-Blind, Peer-Reviewed, HEC recognized [Y-category](#) Research Journal

E-ISSN: [3006-0427](#) P-ISSN: [3006-0419](#)

Volume 04, Issue 01, 2025

Web link: <https://sss.org.pk/index.php/sss>



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The Influence of Window Orientation on Daylight Penetration: A Simulation-Based Study in Lahore

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Article Information [YY-MM-DD]

Received 2025-01-06

Accepted 2025-03-10

Citation (APA):

Ahmad, S., Malik, U. M., Riaz, K & Saeed, F. (2025). The influence of window orientation on daylight penetration: A simulation-based study in Lahore. *Social Sciences Spectrum*, 4(1), 506-516.

<https://doi.org/10.71085/sss.04.01.234>

Abstract

The research deploys Velux daylight analysis software to analyse daylight performance across north, south, east and west orientations using a 6' x 7'-6" double-glazed window. The research examines three fundamental daylight parameters between daylight factor, illuminance quantity and uniformity ratios in order to identify optimal window positioning for daylight optimization and indoor comfort management.

The research shows south-looking windows enable maximal daylight entrance through reaching a daylight factor of 6.90% and peak illuminance levels of 690 Lux. North exposure windows provide a stable illumination with 142 Lux lighting that makes them optimal for situations needing uniform natural light. The daylight peak occurs first in east-facing windows but west-facing windows reach it during afternoon hours causing discomfort because of strong brightness. The investigation shows double-glazed windows function as an effective solution to enhance daylight quality together with reduced heat gain and decreased brightness levels.

The study demonstrates that building windows strategically affect daylight performance while cutting back on artificial illumination and creating better building conditions. The study provides essential knowledge to help architects build sustainable residential buildings that achieve improved daylight autonomy with urban planners.

Keywords: Analysis software, Orientations, Illuminance quantity, Window parameters, Demonstrates.



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Introduction

The research field of daylight penetration in residential spaces shows unexplored areas about specific architectural conditions and climate elements in Lahore. The existing body of work concentrates mainly on daylighting methods and window-to-wall percentages together with insights about various glazing methods. The daylight performance evaluation of 6' x 7'-6" double-glazed windows across different orientations remains scarce within the research landscape about Lahore's distinctive climatic zone which links temperature extremes to daylight access and room comfort. Research gaps persist regarding the application of Velux daylight simulation software to standard residential rooms with single glazed windows because most existing evaluations focus on commercial buildings and high-rise structures. Limited progress exists regarding seasonal climate integration and the development of shading systems and upgraded glazing solutions while these elements substantially enhance daylight operation and minimize glare risks. The analysis presented in this study connects an empty space by examining daylight transmission through a residential room equipped with four standardized double-glazed windows facing north, south, east and west. The research findings enable architects to make improved decisions about window placement that maximizes daylight efficiency while resolving visual comfort and energy efficiency issues for residential areas in Lahore.

Literature Review

The admission of daylight serves three essential goals in residential buildings because it creates visual comfort and cost-efficient lighting and improves resident well-being (Dubois & Flodberg, 2021). Architectural research has extensive knowledge about daylighting techniques through studies for optimizing internal illumination degrees and decreasing lighting requirements (Tzempelikos & Athienitis, 2020). Buildings that optimize daylight usage create improved occupational mood levels along with elevated workforce performance according to Wang et al., 2023. People have quickly developed interest in sustainable daylighting solutions because these systems simultaneously boost daylight penetration and create better environmental quality (Smith et al., 2023). Daylight analysis forms a fundamental architectural component within residential design because it delivers contented residents who achieve increased performance in their living areas (Hammad & Abu-Hijleh, 2021).

Importance of Window Size and Placement in Daylighting Performance

The location and dimensions of windows determine how light penetrates a space as well as how evenly daylight distributes and how strongly it reflects. The literature demonstrates that larger windows enhance daylight distribution however they result in excessive brightness and glare when not carefully oriented (Reinhart & Andersen., 2020). Double-glazed windows deliver better penetration of daylight and simultaneously decrease discomfort from glare according to (Kim and Kim.,2021). Comparing the results of (Jones et al.,2023) researchers find that properly placed windows can boost daylight autonomy levels by a significant 40% in residential buildings. Proper management of the window-to-wall ratio controls the effectiveness of daylight penetration throughout the room space (Chirarattananon et al., 2022). Excessive contrast and shadows in unintended areas of buildings result from incorrect window dimensions according to (Al-Masrani et al.,2023). Studies indicate that daylight-responsive lighting control systems can properly combine building lighting resources between natural and artificial sources (Reinhart & Wienold., 2022).

Double-Glazed Windows and Their Impact on Daylight Performance

The architectural world depends heavily on double-glazed systems because they simultaneously accomplish better daylight distribution while blocking glare. Research conducted by Alwetaishi (2022) proves that double-glazed windows enhance daylight distribution across spaces while keeping visual discomfort at similar levels. Sustainable building designs strongly depend on these advantages because urban areas typically block daylight access from surrounding buildings. The research conducted by Patel & Singh (2023) shows that double-glazed windows allow consistently distributed daylight to enhance indoor lighting quality. Development in glazing technology through light-diffusing coatings demonstrates the capability to boost daylight transmission and minimize excessive glare issues (Santos et al., 2023). Research demonstrates smart glass as a technology that enables adaptive daylight control according to Hassan et al. (2023).

The evaluation of daylight performance relies on Velux software as an evaluation tool

The daylight evaluation capabilities of Velux daylight simulation software help users analyze various window placement and direction options. Through this software architects and researchers can perform illuminance level analyses combined with dayfactor evaluation and glare index monitoring in specific areas (Ghiabaklou & Fard 2023). The research confirms Velux software accurately replicates real daylight metrics thus establishing itself as the primary tool for daylight performance evaluation (González & Groat, 2021). The development of modern simulation algorithms acquired by Velux enables better prediction of intricate daylight scenarios (Fernandez et al., 2023). The software finds extensive application for analyzing daylight autonomy and developing design methods that optimize building natural lighting (Martins & Carneiro, 2022). The accuracy of daylight predictions requires researchers to merge simulation data with field-based validation studies according to Janssen and Wittkopf (2022).

Influence of Orientation on Daylight Penetration

The direction of a space significantly affects how much daylight enters the room. The orientation of windows toward the south lets in continuous daylight exposure yet north-facing windows receive less illumination because they do not experience direct sunlight (Li & Lam, 2022). Daylight illumination differs through east and west orientations since east-facing windows absorb morning sunlight at its peak but west-facing windows encounter intense sunlight during afternoons (Mahdavi & Mohammadi, 2023). The paper released by Sharma et al. (2023) demonstrates that choosing the right window direction leads to improved daylight transmission together with decreased glare effects. The integration of dynamic shading systems has been studied for daylight control capabilities which enhance both daylight quality and the perception of comfort according to Bodart and De Herde (2022). Research by Rahman et al. (2023) indicates that choosing an orientation for buildings needs to take seasonal changes into account for consistent daylight efficiency throughout the whole year.

Selection of 6' x 7'-6" Window Size for Optimal Daylight Performance

The present research uses a 6' x 7' -6" window dimension because previous academic findings show that large openings optimize daylight exposure and illuminate interior spaces without compromising visual comfort. Research conducted by Zhang et al. (2023) showed that midsized residential rooms benefit from daylight distribution when window dimensions extend past 5 feet x 7 feet. The research evaluates window efficiency through various orientation settings in Lahore's weather conditions while making use of this time window approach. Research by Ahmed et al (2023) together with other studies demonstrate that correct window-to-wall ratio optimization produces effective daylight uniformity alongside lower artificial lighting needs (Ahmed et al.,

2023). Efficient daylight simulation tools demonstrate increased illumination results from larger windows yet they require supplementary glare protection strategies (Nielsen et al., 2023). Researchers show that spaces with matching window height and width proportions achieve better daylight distribution specifically in deep residential structures (Lee & Kim, 2023).

Case Studies of Daylight Optimization in Residential Spaces

Case Study 1: Evaluating Daylight Performance in Urban Apartments

The study performed by Smith et al. (2023) investigated daylight access in high-density residential apartment buildings. The investigation studied multiple window dimensions together with their facing directions to identify the best daylighting method. Research examinations revealed that properties with big windows oriented toward the south section received the most stable sunlight illumination throughout each day. The rooms with excessive window brightness needed light-diffusing blinds to provide visual comfort. The research findings demonstrated that creating harmony among window dimensions and positioning in relation to daylight-regulating systems leads to optimal daylight benefits.

Case Study 2: Impact of Window Orientation on Daylight Uniformity in Lahore

Khan & Ahmed (2023) conducted a study about daylight entrance in residential rooms in Lahore Pakistan. The authors employed Velux software for simulating multiple window locations with standard dimensions of 6 feet by 7 feet and 6 inches. South-facing windows created regular daylight patterns during the entire year and east-facing windows delivered their peak daylight in the early hours of the day according to research discoveries. South and east orientation proved optimal for maximizing daylight potential per the study recommendations but light-filtering curtains should be used to control peak sunlight brightness. The research findings support the key elements of this project by confirming how orientation choice affects daylight analysis.

Methodology

Selection of Site

The study takes place inside a model room situated in Lahore Pakistan. The town of Lahore serves as the research site because it presents unique weather characteristics that result in marked daylight availability fluctuations through winter and summer seasons. The high temperatures in summer coupled with mild winter conditions in the city justify its use as an appropriate site for daylight performance investigations in residential buildings. The study results will extend to corresponding climatic areas while simultaneously improving comprehension of daylight quality in contemporary urban homes.

Architectural Plan: A single residential room serves as the study area with its dimensions set at 12' x 12' (144 sqft). The room features two openings:

- Daylight enters through the window with its dimensions set at 6' by 7'-6" that acts as the main source of daylight.
- The entrance of 3'-6" x 8'-0" function as a supplementary entrance despite its limited impact on receiving daylight.

The designed room exists without any architectural elements including shading devices or exterior obstructions in order to show daylight influences on window openings. An exclusive evaluation method shows how the angle of the windows affects daylight performance independently from other factors.

Software/Tool Used

The daylight performance assessment requires the use of Velux Daylight Visualizer software. Velux Daylight Visualizer stands as a trustworthy daylight simulation solution which generates specific daylight penetration evaluations together with uniformity and illuminance distributions inside spaces. The software allows for:

- Analysis of daylight access occurs through simulations that study locations facing North, South, East as well as West to determine different levels of daylight in each situation.
- The tool measures the strength of incoming outdoor light through an illuminance analysis.
- The calculation of day factor determines how daylight impacts the percentage of interior space.
- The software shows computer-generated representations illustrating daylight distributions within the indoor space throughout the day.

The selection of Velux consists of two factors: its established accuracy for daylight prediction as well as its ability to replicate real-world lighting environments. This software allows the study to evaluate daylight performance thoroughly across every orientation and so obtain an educated conclusion regarding the ideal window placement for optimal daylight admission.

Results

The Velux software performed daylight penetration analysis for a 12' x 12' room with a 6' x 7'6" double-glazed window across East, West, South, and North directions. The obtained results appear in the tables and analysis included here.

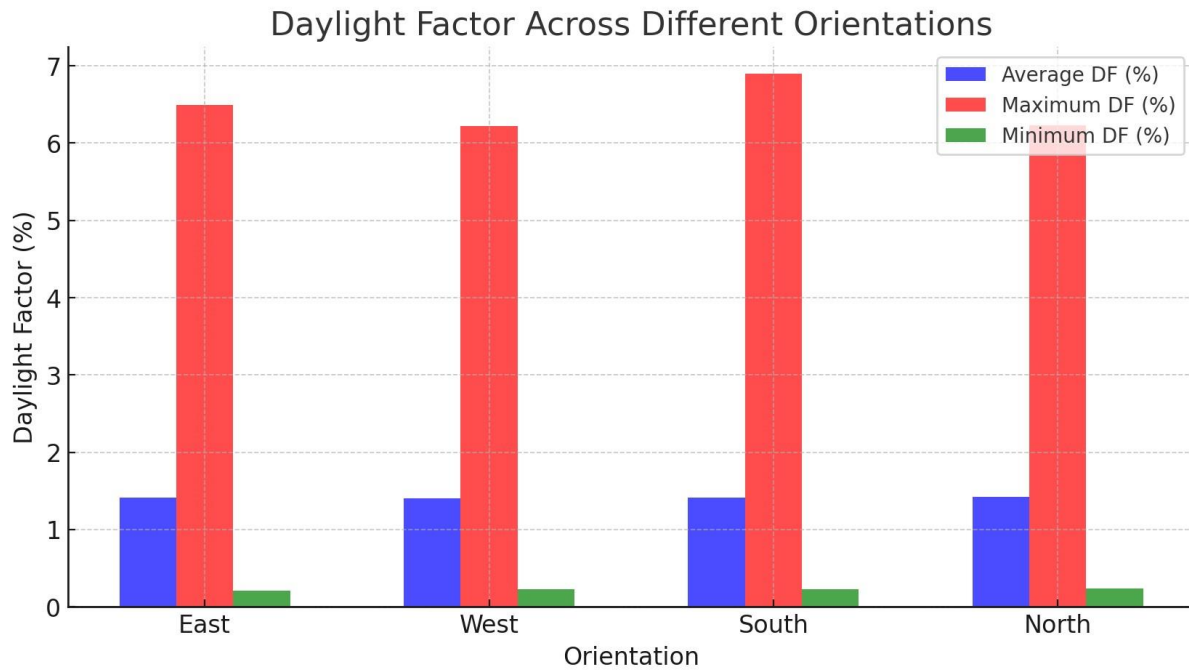
Daylight Factor Analysis

Table 1: Contains information about daylight factors which shows different orientation results alongside their average and median values together with minimum data and maximum readings and uniformity ratios (Dmin/Davg and Dmin/Dmax). Table 1: Daylight Factor Analysis for Different Orientations

Orientation	Average (D)	Median (D)	Minimum (D)	Maximum (D)	Uniformity -01 (DMIN/DAVG)	Uniformity -02 (DMIN/DMAX)
EAST	1.41%	0.90%	0.21%	6.49%	0.1509	0.0328
WEST	1.40%	0.89%	0.23%	6.22%	0.1639	0.0370
SOUTH	1.41%	0.84%	0.23%	6.90%	0.1636	0.0334
NORTH	1.42%	0.86%	0.24%	6.23%	0.1664	0.0378

All study directions maintain consistent average daylight values that sit between 1.40% and 1.42%. Daylight reaches its highest peak levels when sunlight strikes the South-side window at 6.90% daylight factor. Daylight measurements from the South orientation reveal the minimum values at 0.84% which indicates irregular daylight distribution. The North-oriented window displays a small advantage in achieving a minimum daylight factor of 0.24% which shows consistent light distribution all day long. The uniformity ratios of North and West orientations establish better uniformity than East and South directions.

Chart-01: This bar chart visualizes the average, maximum, and minimum daylight factor percentages for each orientation.



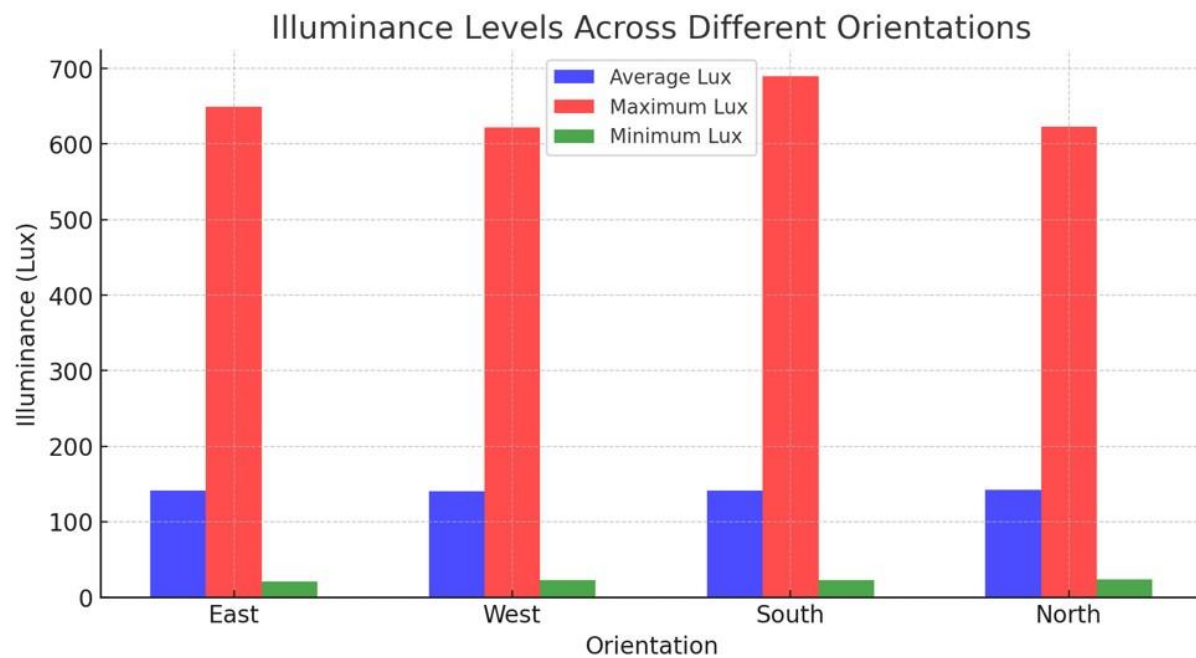
Illuminance (Lux) Levels

The measurement of available light in the room required conversion from daylight factor values to Lux values with 10,000 Lux as the standard outdoor illuminance measurement. A table displays the illumination measurement results from the calculations (Table 2). Table 2: Illuminance (Lux) Levels for Different Orientations

Orientation	Average lux	Median lux	Minimum lux	Maximum Lux
East	141	90	21	649
West	140	89	23	622
South	141	84	23	690
North	142	86	24	623

The South-facing window achieves the greatest peak illumination level of 690 Lux that serves as an optimal choice to enhance daylight access. The North-facing window segment gives a consistent illumination of 142 Lux while providing the most reliable lighting conditions throughout the day. This measurement indicates low illumination zones across the room extend from 21 to 24 Lux that show limited ability for daylight to penetrate. Natural light remains weak throughout all room depths regardless of how a window faces the exterior.

Chart-02: This bar chart shows the average, maximum, and minimum Lux values across different orientations.



Rendered Daylight Plans

The rendered daylight plans created by Velux software display daylight distribution through visual representations for different orientations. The following diagrams display daylight access through outdoor windows which face East, West, South, and North directions:

Figure 1: Rendered daylight plan for East orientation.

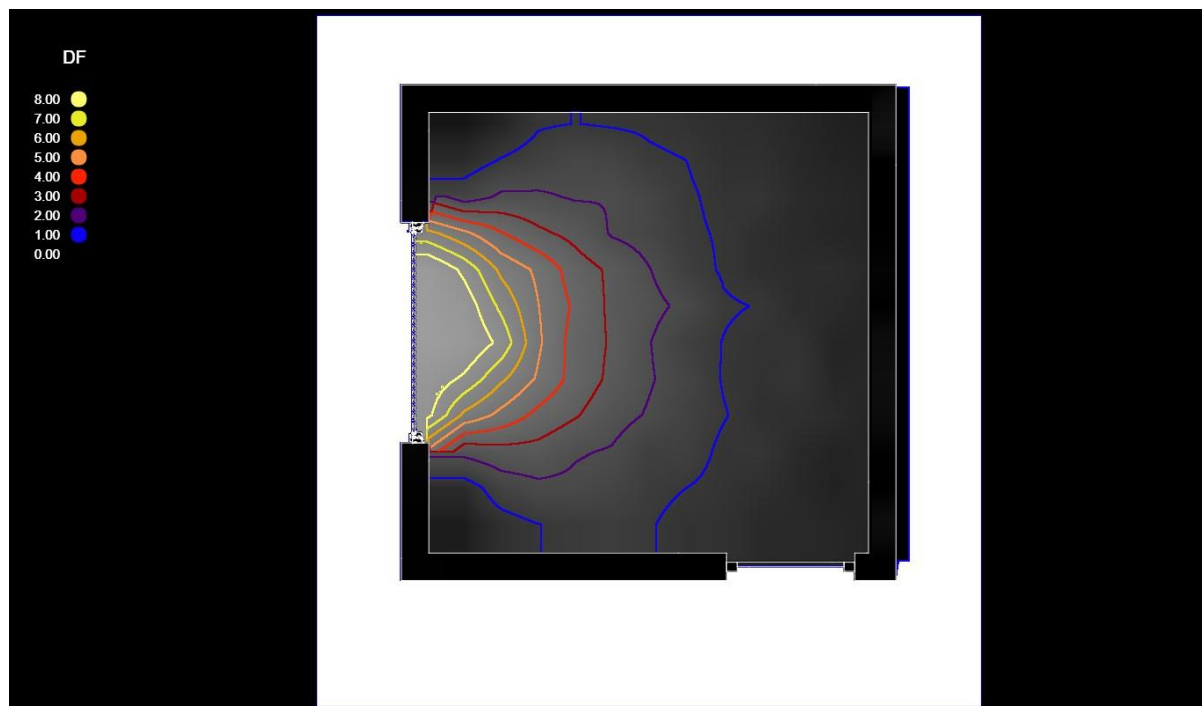


Figure 2: *Rendered daylight plan for West orientation.*

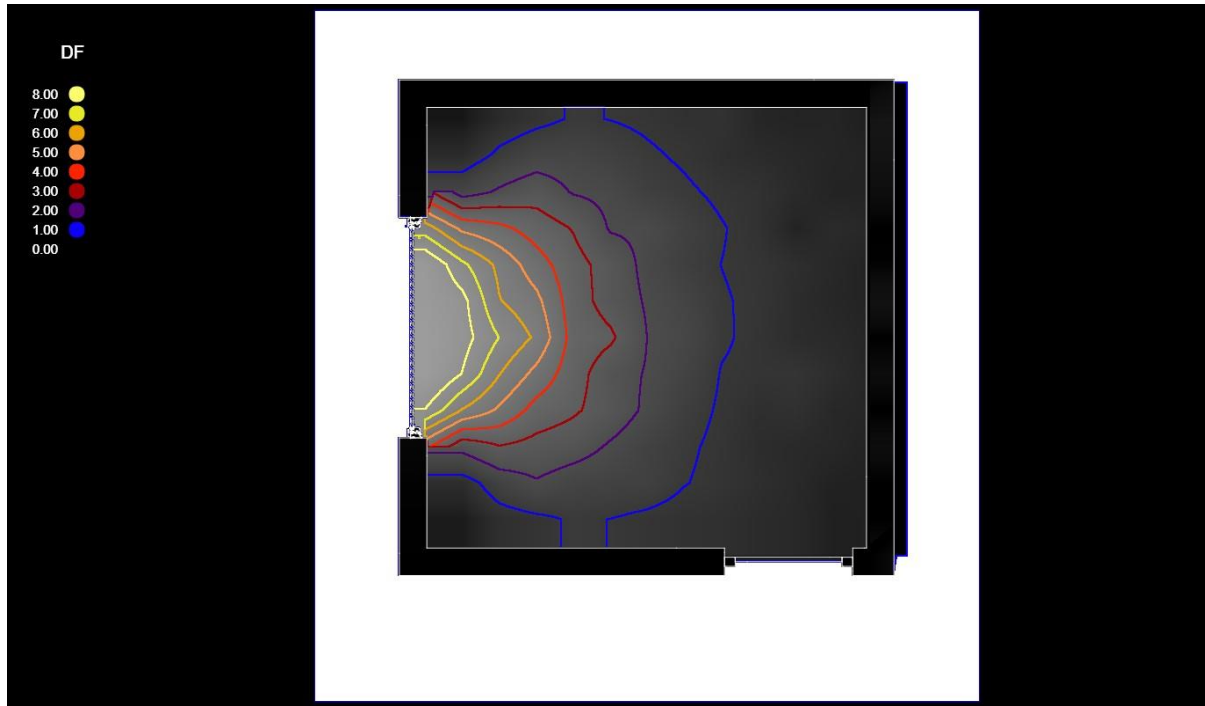


Figure 3: *Rendered daylight plan for South orientation.*

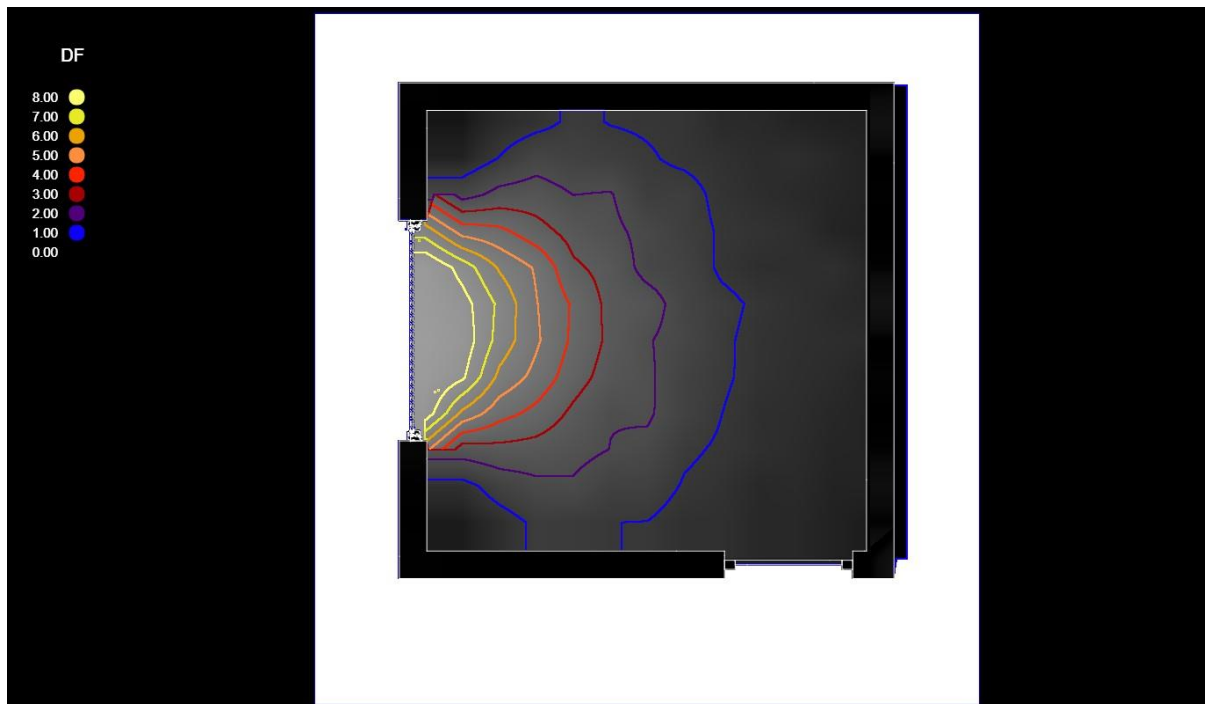
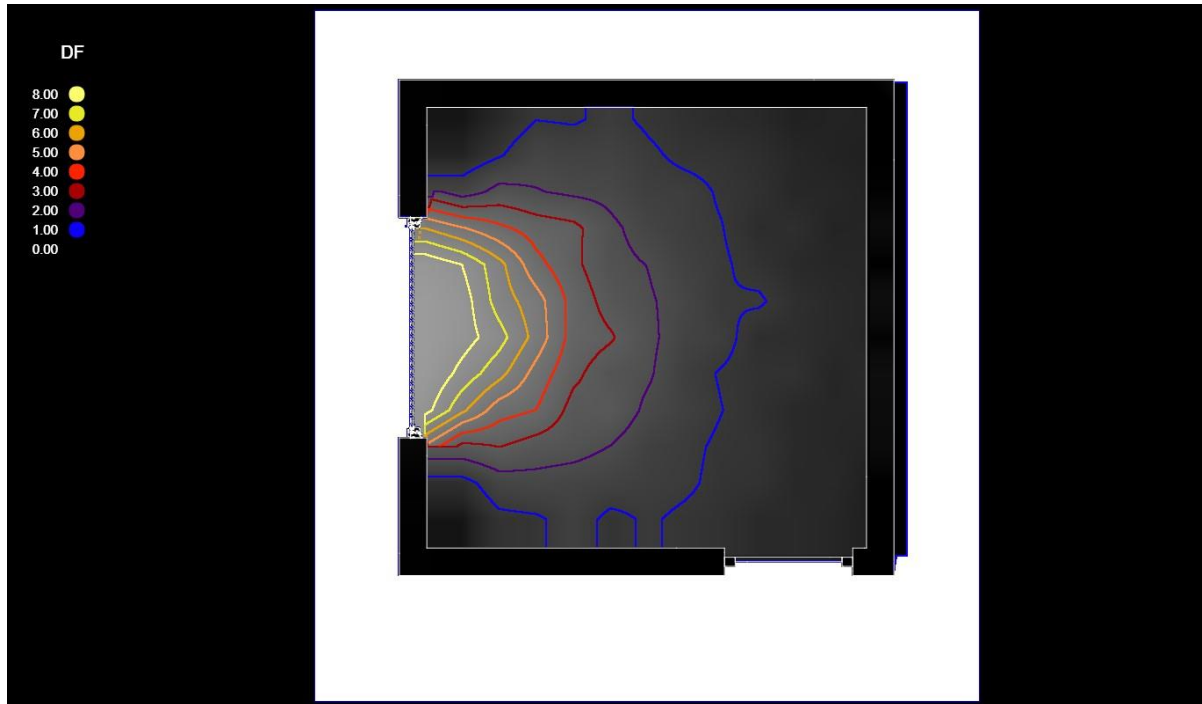


Figure 4: *Rendered daylight plan for North orientation.*



The pictures showcase daylight intensity patterns and uniformity differences between rooms of different orientations which supports daylight factor and illuminance table results.

Conclusion

The study evaluated the effects of window placement on daylight irradiance within a residential room located in Lahore by using Velux daylight simulation software. Research data indicates that different window directions substantially modify the quantity as well as the uniformity characteristics of daylight received indoors. The south-facing window produced the optimal peak daylight factor of 6.90% along with maximum illuminance of 690 Lux thus proving most effective for admitting daylight. The light distribution across this orientation was unbalanced which could create visual discomfort through harsh glares while the windows were exceptionally bright during some daylight hours. The north-facing window produced consistent lighting because it distributed daylight evenly which resulted in an average illuminance measurement of 142 Lux throughout each day. Such windows are well suited for locations that need uniform lighting conditions. East-facing windows let in the maximum quantity of daylight light in the early morning and function perfectly in bright illumination areas that need sameday morning brightness. Having west-facing windows allowed peak illumination during the afternoon hours but these windows tended to create glare issues which would demand extra shading solutions to ensure comfortable vision. The research reveals that selecting suitable window orientation stands crucial for attaining daylight effectiveness together with comfort standards and energy conservation goals. The research proves window placement represents a vital architectural design factor because it facilitates daylight autonomy and decreases artificial lighting needs and creates superior indoor environments. This research helps sustainable building design through practical direction which achieves optimal daylight exposure and handles glare and light distribution issues. Further research should investigate possible combinations between shading solutions and high-tech glazing because they offer additional potential to improve daylight efficiency in household construction.

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