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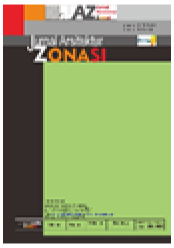

Comparison of Natural Lighting Performance in Hospital Inpatient Rooms Based on Opening Orientation

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ABSTRACT

Natural lighting plays a crucial role in supporting visual comfort and patient healing processes in hospital inpatient rooms, especially in tropical regions receiving year-round sunlight exposure. However, high solar radiation intensity can cause excessive glare and thermal loads that interfere with the healing process. This study aims to analyze the influence of opening orientation and passive element configuration on natural lighting performance in inpatient rooms at Sultan Suriansyah Regional Hospital, Banjarmasin. Simulation method using DIALux Evo 13 with Useful Daylight Illuminance (UDI) parameters was applied to 8 sample rooms covering four main orientations (Southwest, Southeast, Northeast, Northwest) in two buildings with different configurations: new building (with 2m terrace) and old building (without terrace). Simulations were conducted during equinox conditions at 15:00. West orientations (Southwest and Northwest) achieved optimal performance with UDI of 88.99-100% and adequate lighting areas up to 64.88%, while Northeast orientation demonstrated the poorest performance (UDI 22.44-24.36%) with 100% underlit areas. Terrace elements proved effective in reducing glare potential (0%) for orientations with excessive exposure but were counterproductive for orientations with minimal daylight. These findings emphasize that passive shading strategies must be designed responsively based on specific orientations to optimize natural lighting in tropical hospitals, rather than uniformly applied across all facades. Design recommendations

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include facade treatment differentiation based on orientation and dominant sun exposure time.

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1. INTRODUCTION

Natural lighting has emerged as a critical design element in modern healthcare facilities, fundamentally transforming hospital environments from purely functional spaces into therapeutic healing environments. The profound influence of natural light on human health is well-established through extensive neuroscientific and biological evidence (Hosseini et al., 2024), with empirical studies demonstrating reduced patient distress, increased satisfaction (Park et al., 2018), and accelerated recovery rates (Husein & Sazgar S.S., 2020). This therapeutic impact extends beyond psychological benefits, as Lindskov et al. (2022) found significant effects on sleep quality, circadian alignment, and daytime mood in 14 of 17 studies reviewed. The efficient use of natural light has thus become a fundamental criterion in healthcare design (Ferrante & Villani, 2022), particularly crucial in tropical climates where inadequate lighting conditions—characterized by low daytime and excessive nighttime illumination—can negatively impact both patient recovery and healthcare worker performance (Campano et al., 2024).

The mechanisms through which natural lighting accelerates healing are multifaceted and measurable. Jafarifiroozabadi et al. (2023) documented that cardiac patients with access to natural light experienced 16.8-hour shorter stays compared to those in windowless rooms, while Li et al. (2022) analysed 27,532 surgical patients and confirmed direct correlations between room lighting levels and length of stay. These benefits operate primarily through circadian rhythm regulation, as light exposure influences not only visual perception but also non-visual physiological processes affecting sleep and mood (Blume et al., 2019; Wang et al., 2024). Morning sunlight exposure has been particularly effective in reducing hospitalization duration for bipolar depression (Scott et al., 2021), emphasizing the temporal dimension of therapeutic lighting.

Contemporary evaluation of lighting quality in healthcare settings has evolved beyond simple illuminance measurements to embrace climate-based metrics that account for dynamic environmental conditions. Useful Daylight Illuminance (UDI), which measures the percentage of annual hours when illumination falls within beneficial ranges, has emerged as the most comprehensive metric for healthcare facilities, as climate-based metrics are more relevant for evaluating lighting performance in tropical hospitals by considering temporal variability and solar radiation intensity throughout the year (Tabadkani et al., 2021). Implementation studies demonstrate that appropriate UDI values correlate strongly with occupant perceptions and visual comfort (Shafavi et al., 2020), while optimized configurations using UDI parameters can reduce cooling loads by 40-80% while maintaining sufficient daylight levels (Eisazadeh et al., 2021; Sherif et al., 2015). Modern criteria must balance multiple factors including energy efficiency, visual comfort (Perumal et al., 2021), photometric characteristics of materials (Ferrante & Villani, 2022), and the diverse needs of patients, staff, and visitors in multi-functional hospital environments (Mehrotra et al., 2015).

Implementing natural lighting strategies in tropical hospitals presents unique challenges due to high solar radiation intensity that can cause excessive glare and thermal loads, potentially interfering with healing processes (Mangkuto et al., 2016). Building orientation and opening configuration become critical factors in balancing lighting needs with solar protection (Atthaillah A, Mangkuto RA, Subramaniam S, 2024), requiring integration of both active and passive strategies (Abd Rahman et al., 2021). Research indicates that a 25% window-to-wall ratio with centralized configurations optimally distributes daylight and circadian stimuli (Campano et al., 2024), though these principles must be adapted to specific

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orientations—east-west facades requiring maximum protection while north-south facades can benefit from diffuse light with minimal shading.

Despite extensive research on daylighting in various building types, significant gaps remain in understanding optimal configurations for tropical hospitals. Previous studies have focused on desert climates with different characteristics (Sherif et al., 2015) or examined office typologies in tropical contexts (Indarto, 2018), but none have comprehensively integrated orientation analysis, passive element configuration, and sun path considerations for vertical hospitals in humid tropical climates. This gap is critical as uniform application of shading strategies across all facades may be counterproductive, potentially reducing already limited natural light in certain orientations.

This study addresses these gaps by analyzing how opening orientation and passive element configuration affect natural lighting performance in hospital inpatient rooms using UDI parameters. The research examines two inpatient buildings at Sultan Suriansyah Regional Hospital, Banjarmasin—an old building with southeast-northwest orientation without terraces and a new building with northeast-southwest orientation featuring 2-meter terraces—to evaluate the specific influence of passive elements on light distribution and visual comfort across different orientations. Through simulation of eight sample rooms covering four main orientations at equinox conditions, this study aims to develop orientation-specific design recommendations that optimize therapeutic lighting while preventing visual discomfort in tropical healthcare environments. The findings will contribute to evidence-based guidelines for climate-responsive hospital design, supporting both patient healing and energy efficiency objectives.

The study was limited to the analysis of natural lighting simulation using DIALux Evo 13 for inpatient rooms on the 3rd and 4th floors. Evaluation parameters included UDI values, the percentage of areas with sufficient lighting (100-2000 lux), areas with potential glare (>2000 lux), and areas with insufficient light (<100 lux). The simulation was conducted at equinox conditions (March 21) at 15.00 with the assumption of clear skies to represent the critical conditions of afternoon lighting in tropical regions. The influence of external vegetation, surrounding buildings, and seasonal variations were not considered to focus the analysis on the influence of building geometry and orientation.

2. RESEARCH METHOD

2.1 Research Object

This study uses a comparative case study approach on two vertical inpatient buildings at Sultan Suriansyah Regional General Hospital, Banjarmasin, with characteristics of a humid tropical climate. The two buildings were selected based on significant differences in the orientation and configuration of their passive facade elements. The old inpatient building has a dominant southeast–northwest orientation with a simple configuration, using only a canopy without additional terrace elements. In contrast, the new inpatient building is oriented northeast–southwest and is equipped with a 2-meter-wide terrace element and a canopy as a passive strategy to regulate lighting and protect against direct solar radiation. Both buildings have an identical Window to Wall Ratio (WWR) of 17.5%, so the measured difference in lighting performance can be attributed to the orientation and configuration of passive elements, not to the proportion of openings.

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Figure 1. Old Inpatient Building (left) and New Inpatient Building (right) of Sultan Suriansyah Regional Hospital, Banjarmasin
(Source: Author's documentation, 2024)

The differences in passive element configurations between these two buildings provide an opportunity to evaluate the effectiveness of design strategies in optimizing natural lighting while mitigating potential visual discomfort in a tropical environment. Both buildings are integral parts of the same hospital complex, thus sharing identical microclimate and surrounding environmental contexts, allowing for a valid comparison of the effects of orientation and passive elements.

2.2 Sample Selection and Criteria

The research sample was selected from the function of the inpatient rooms located on the 3rd and 4th floors to maintain the consistency of the vertical position towards the potential for natural lighting. In the old building, the room on the 3rd floor has a module measuring 7.2 × 7 m², while in the new building it measures 7.2 × 7.2 m². On the 4th floor, both buildings have the exact same room module as the 3rd floor, but in the new building the module is divided by a partition due to the adjustment of the inpatient class into two equal rooms with a size of 3.6 × 7.2 m² each. This difference does not affect the entry of light because the design of the window openings is typical.

The selection of spaces was based on four main facade orientations representing variations in solar exposure throughout the day: southwest (SW), southeast (SE), northeast (NE), and northwest (NW). These orientations were chosen to analyze the influence of solar trajectories on lighting performance during the simulation. Figure 2 shows the position and orientation of the sample spaces within the context of the masterplan and building blocks of the Inpatient Ward Blocks of Sultan Suriansyah Regional Hospital.

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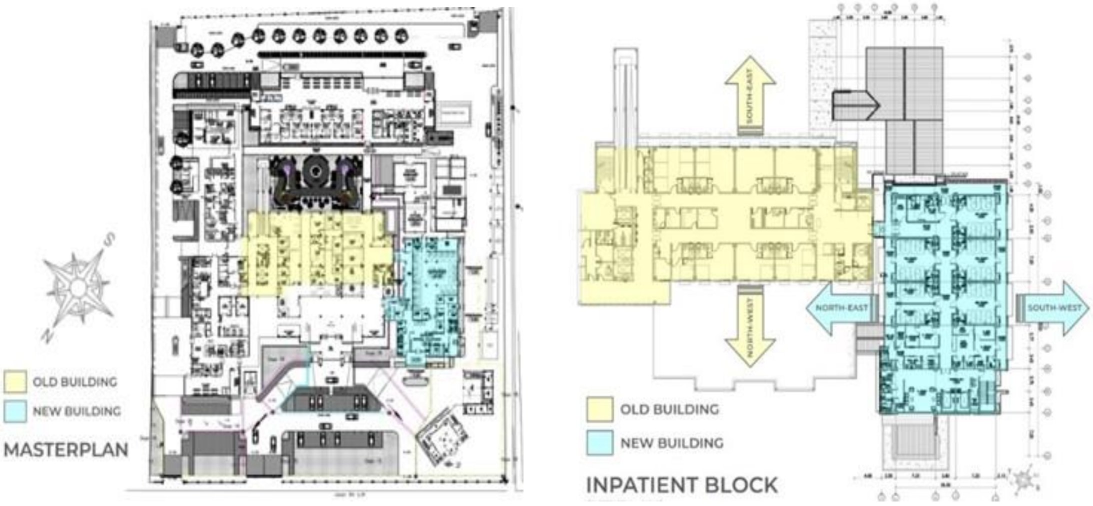
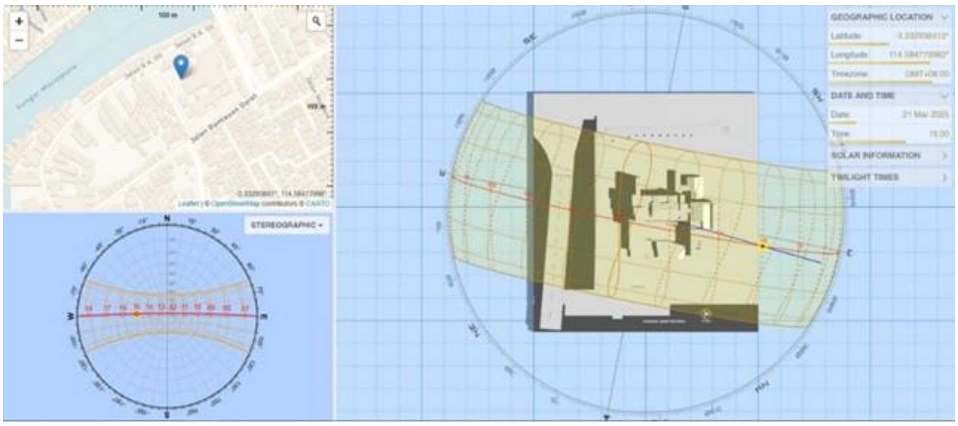


Figure 2. Position of the Inpatient Ward Blocks of the Old and New Buildings in relation to the Sultan Suriansyah Regional Hospital Masterplan
(Source: DED Image, edited by the author, 2025)

2.3 Natural lighting simulation method

This study uses a natural lighting simulation method with DIALux Evo 13 software. The evaluation parameters use Useful Daylight Illuminance (UDI) which has been explained in the introduction, with the output in the form of a percentage of the area for each lighting category (low light <100 lux, sufficient light 100-2000 lux, and potential glare >2000 lux). The three-dimensional model is constructed based on the working drawings (DED) with geometric accuracy including room dimensions, size and position of openings, wall thickness, and configuration of shading elements. Surface materials are arranged according to existing conditions with standard settings in DIALux Evo 13.

The simulation was conducted on March 21 (equinox) at 15:00 local time with clear sky conditions based on Banjarmasin climate data. This time was chosen based on the consideration that 15:00 represents the critical conditions of afternoon lighting in tropical regions when the sun is in the west with a still quite high altitude angle, potentially causing excessive light penetration on the western facade. The equinox condition was chosen to represent the neutral sun position that occurs twice a year in the equatorial region.



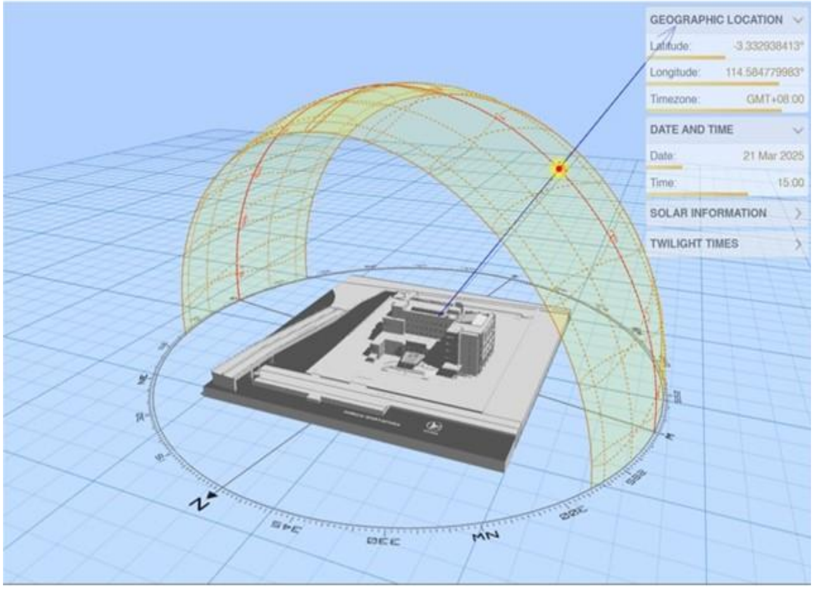


Figure 3. Sun-path Diagram of Sultan Suriansyah Regional Hospital on March 21 (Equinox)
(Source: Simulation using the 3D-Sunpath application, processed by the author, 2025)

The sun-path diagram in Figure 3 shows the sun's path at the research location to understand the distribution of lighting at various facade orientations studied.

2.4 Simulation Procedure

Simulations were performed for each sample space with consistent parameters including location settings, building orientation, simulation time, and sky conditions. The extracted simulation data included UDI values, area percentages for each lighting category, and visualizations of lighting distribution.

Figure 4. DIALux Parameter Settings in the Model
(Source: Simulation using DIALux evo 13, edited by the author, 2025)

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2.5 Data Analysis

The simulation data were analyzed using a comparative descriptive approach to identify patterns and differences in lighting performance across building orientations and configurations. The analysis focused on three main aspects that address the research problem formulation. First, a comparison of UDI values across orientations was conducted to identify the optimal orientation. Second, an evaluation of the influence of terrace elements was conducted by comparing the results between new buildings (with terraces) and existing buildings (without terraces) at the same orientation. Third, a correlation of simulation results with sun-path diagrams was conducted to validate the influence of the sun's path on lighting distribution.

Data visualization uses graphs to facilitate quantitative comparisons, while visual results from DIALux are used to analyze the spatial distribution of lighting. Interpretation of the results takes into account the tropical climate context and its implications for daylighting design strategies for inpatient wards.

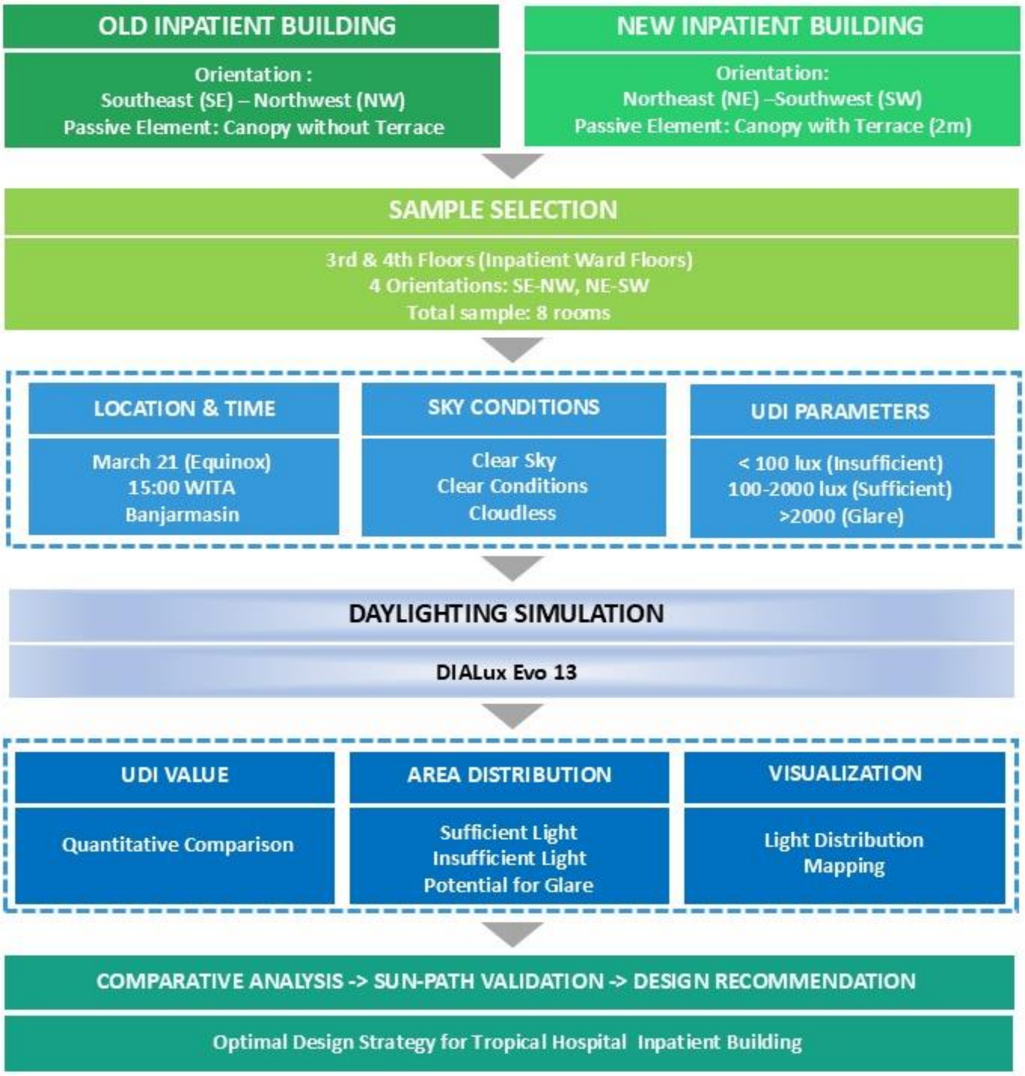

Figure 5. Schematic of the Daylighting Simulation Research Method Based on Spatial Orientation and Sunpath
(Source: Author's analysis, 2025)

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3. RESULT AND DISCUSSION

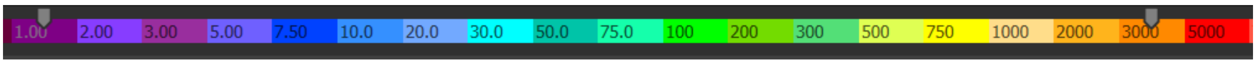
Daylighting simulation was conducted in the inpatient rooms on the 3rd and 4th floors of the old and new buildings of Sultan Suriansyah Regional General Hospital, Banjarmasin, using DIALux Evo 13 software. The modeling was adjusted to the geometric conditions of the room based on DED, with a clear sky simulation scenario on March 21 (equinox) at 15.00. The analysis focused on four main orientations of the room, namely southwest (SW), southeast (SE), northeast (NE), and northwest (NW), which represent the dominant opening facades of each building.

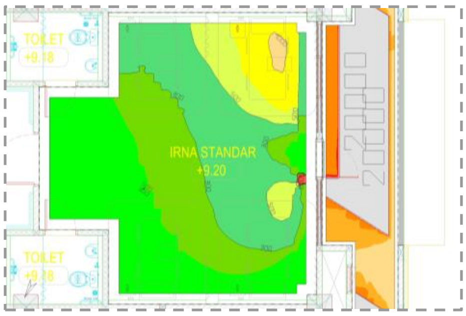
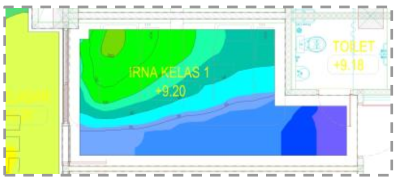
3.1 Simulation Results

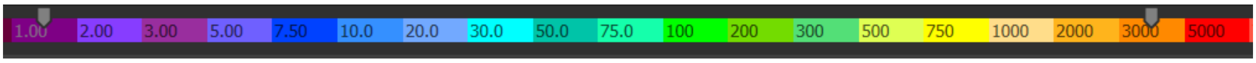
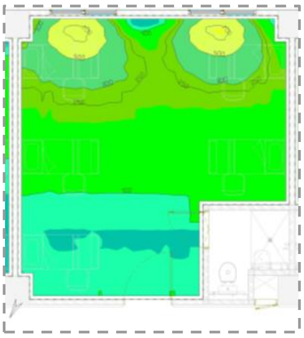
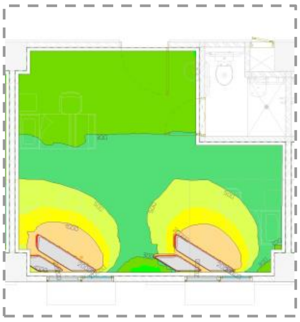
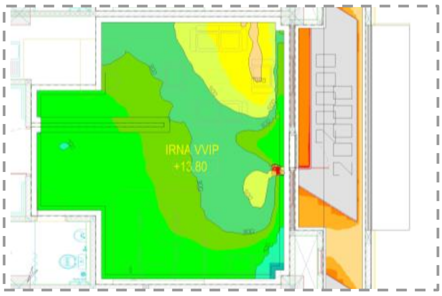
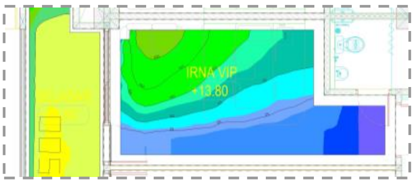
Table 1 summarizes the simulation results based on the Useful Daylight Illuminance (UDI) parameters, areas with sufficient light, areas with potential glare, and areas with insufficient light across all sample spaces. Data are presented sequentially by building category, floor elevation, and orientation.

Table 1. Summary of Daylighting Simulation Results in both Inpatient Building of Sultan Suriansyah Regional Hospital

Lux Indicator Bar



No	Sample	Simulation Results	Information
1	Space Category: **NEW INPATIENT BUILDING** Elevation: **3rd Floor** (+9.20) Opening Orientation: **Southwest (SW)**		UDI : **100%** Sufficient Light : **43,54%** Glare : **0%** Insufficient Light : **56,46%**
2	Space Category: **NEW INPATIENT BUILDING** Elevation: **3rd Floor** (+9.20) Opening Orientation: **Northeast (NE)**		UDI : **22,44%** Sufficient Light : **0%** Glare : **0%** Insufficient Light: **100%**

Lux Indicator Bar 			
3	Space Category: **OLD INPATIENT BUILDING** Elevation: **3rd Floor** (+9.20) Opening Orientation: **Southeast (SE)**		UDI : **72,60%** Sufficient Light :17,35% Glare : **0%** Insufficient Light: **82,65%**
4	Space Category: **OLD INPATIENT BUILDING** Elevation: **3rd Floor** (+9.20) Opening Orientation: **Northwest (NW)**		UDI : **88,99%** Sufficient Light : **64,88%** Glare : **5,06%** Insufficient Light: **30,06%**
5	Space Category: **NEW INPATIENT BUILDING** Elevation: **4th Floor** (+13.80) Opening Orientation: **Southwest (SW)**		UDI : **100,00%** Sufficient Light : **38,28%** Glare : **0,00%** Insufficient Light: **61,72%**
6	Space Category: **NEW INPATIENT BUILDING** Elevation: **4th Floor** (+13.80) Opening Orientation: **Northeast (NE)**		UDI : **24,36%** Sufficient Light : **0%** Glare : **0%** Insufficient Light: **100%**

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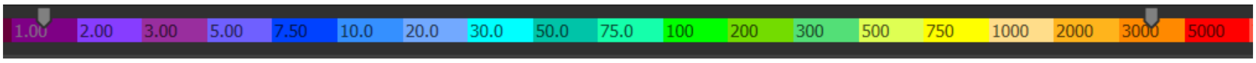
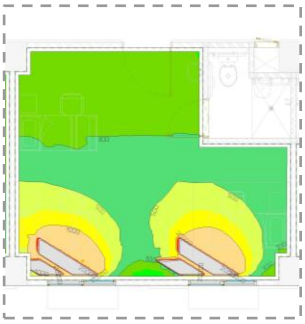
Lux Indicator Bar



7	Space Category: **OLD INPATIENT BUILDING** Elevation: **4th Floor** (+13.80) Opening Orientation: **Southeast (SE)**		UDI : **72,60%** Sufficient Light : **18,04%** Glare : **0%** Insufficient Light: **81,96%**
8	Space Category: **OLD INPATIENT BUILDING** Elevation: **4th Floor** (+13.80) Opening Orientation: **Northwest (NW)**		UDI : **91,67%** Sufficient Light : **56,25%** Glare : **3,57%** Insufficient Light: **40,18%**

Source: Simulation results using DIALux Evo 13, processed by the author, 2025

Simulation results on the third floor show significant variations in daylighting performance between orientations. The southwest-oriented space in the new building (Sample 1) achieved an optimal UDI of 100%, while the northeast-oriented space in the same building (Sample 2) only achieved 22.44%. The existing building showed more consistent performance with a UDI of 72.60% for the southeast orientation (Sample 3) and 88.99% for the northwest orientation (Sample 4).

On the 4th floor, the lighting distribution pattern shows consistency with the 3rd floor. The southwest orientation still achieves a UDI of 100% (Sample 5), while the northeast orientation slightly increases to 24.36% (Sample 6). The old building maintains the same UDI value for the southeast orientation (Sample 7) and experiences an increase for the northwest orientation to 91.67% (Sample 8).

3.2 Discussion

Simulations of natural lighting in inpatient rooms show that the orientation of openings and the presence of terrace elements significantly influence the quality of natural lighting. With an identical Window-to-Wall Ratio (WWR) of 17.5% in both buildings, the measured differences in lighting performance can be clearly attributed to the orientation and configuration of passive elements. The following discussion analyzes the simulation results based on floor and room orientation.

3.2.1 Analysis of Floor 3 Simulation Results

On the 3rd floor, the southwest orientation (Sample 1, new building) shows optimal performance with a UDI value reaching 100% and a well-lit area of 43.54%. This result is

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consistent with the sun's position at the simulation time (15:00) which is in the west, providing direct lighting to the southwest facade. The presence of a 2-meter-wide terrace element in the new building is proven to be effective in regulating light penetration, preventing excessive glare (0% glare area) while still maintaining adequate lighting.

In contrast, the northeast-oriented space (Sample 2, new building) demonstrated the lowest performance with a UDI of only 22.44% and the entire space (100%) experiencing a lack of light. The northeast orientation does not receive direct lighting in the afternoon, and the presence of a terrace further reduces the already minimal diffuse light penetration. This indicates that shading elements need to be selectively designed based on the room's orientation.

In the old building, the southeast orientation (Sample 3) recorded a UDI of 72.60% but with a dominant area of low light (82.65%). Without a terrace element, this space receives natural light directly, but its distribution is uneven within the space. The northwest orientation (Sample 4) in the old building showed better performance with a UDI of 88.99% and a well-lit area of 64.88%, as well as the appearance of a glare area of 5.06% indicating the need for shading elements in this orientation. The following is a comparison graph of the simulation results on the sample room on the 3rd floor of Inpatient Building of Sultan Suriansyah Regional Hospital which shows the percentage of light intensity in Figure 7.

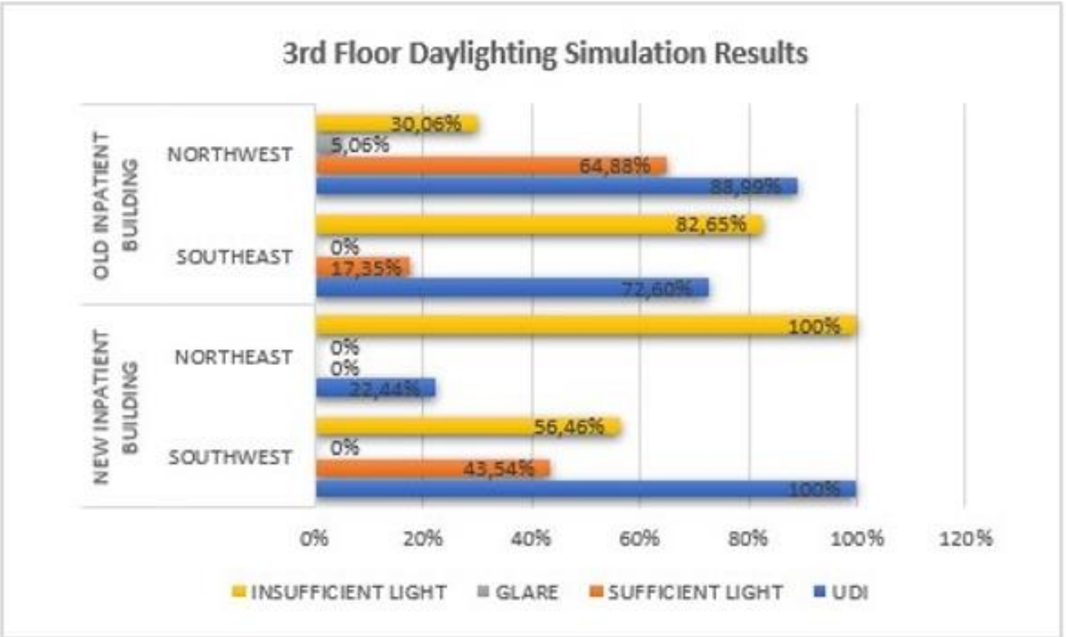

Figure 7. Daylighting Comparison Chart for Sample Rooms on the Third Floor Based on Opening Orientation
Source: Author's Analysis, 2025

3.2.2 Analysis of Floor 4 Simulation Results

The lighting distribution pattern on the 4th floor shows consistency with the 3rd floor. The southwest orientation (Sample 5, new building) maintains a UDI of 100%, although the well-lit area decreases slightly to 38.28%. This decrease is likely due to the space partition on the 4th floor that divides the space into two units, affecting the overall light distribution.

The northeast orientation (Sample 6, new building) continued to show the weakest performance, with a minimal increase in UDI to 24.36%, but the entire area remained in the

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low-light category. This consistency of results confirms that the northeast orientation with its terrace configuration is less than optimal for afternoon lighting in tropical regions.

The existing building on the 4th floor shows a similar pattern to the 3rd floor. The southeast orientation (Sample 7) maintained a UDI of 72.60% with a slight increase in the well-lit area to 18.04%. The northwest orientation (Sample 8) recorded an increase in the UDI to 91.67% with a well-lit area of 56.25%, but the glare area decreased to 3.57%, indicating that the higher elevation slightly reduces the direct light intensity. The following is a comparison graph of the simulation results on the sample room on the 4th floor of Inpatient Building of Sultan Suriansyah Regional Hospital which shows the percentage of light intensity in Figure 8.

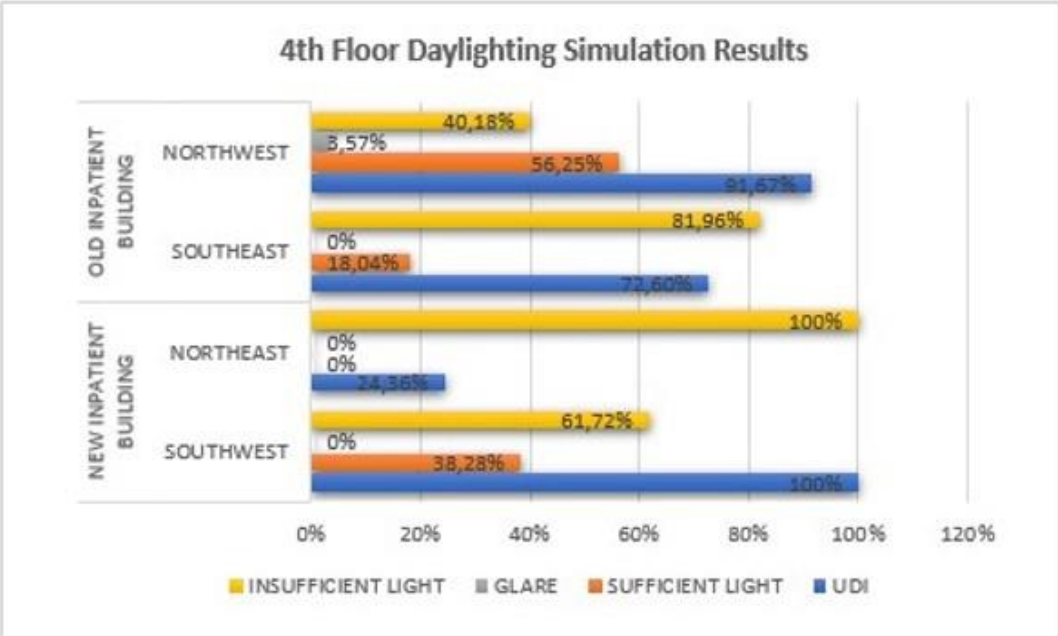

Figure 8. Daylighting Comparison Chart for a Sample Room on the 4th Floor Based on Opening Orientation
Source: Author's Analysis, 2025

3.2.3 Comparative Reflection and Design Implications

Comparative analysis shows that western (southwest and northwest) orientations consistently provide superior daylighting performance compared to eastern orientations during simulated afternoons. This finding aligns with the solar path in equatorial regions, where the sun is in the west at 15:00, as shown in the sun-path diagram in the methods section. The western facade receives direct radiation during this period, while the eastern facade receives only diffuse light.

A comparison of buildings with and without terraces reveals a paradox in the design of shading elements. In orientations that receive excess light (northwest in the older building), terraces effectively reduce potential glare. However, in orientations with minimal light (northeast), terraces further reduce already limited lighting conditions. This indicates the need for a design approach that is responsive to specific orientations, rather than a uniform application of shading elements across the entire facade. The consistency of the results between the 3rd and 4th floors indicates that variations in elevation within a single floor span do not significantly affect the lighting distribution pattern. However, the partitioning of

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spaces on the 4th floor was shown to slightly reduce the effectiveness of light distribution, emphasizing the importance of considering interior configuration in optimizing daylighting.

The practical implication of these findings is the need to differentiate design strategies based on the orientation of inpatient rooms. For west-facing rooms, shading elements such as terraces with appropriate dimensions (2 meters in this case) effectively create a balance between adequate lighting and glare prevention. For east-facing rooms, minimizing shading elements or using more transparent elements can enhance the limited penetration of diffuse light. This strategy aligns with the principles of climate-responsive design, which optimizes site-specific environmental conditions.

4. CONCLUSION

This study concludes that the natural lighting performance of inpatient rooms is significantly influenced by the opening orientation and passive element configuration. A westward orientation consistently demonstrates superior lighting performance compared to an eastward orientation in afternoon simulations, consistent with the sun's path in tropical regions. The presence of terrace elements demonstrates a paradoxical function: effectively reducing glare in orientations with excessive exposure but counterproductive in orientations with minimal lighting. This emphasizes that shading element design strategies must be responsive to specific orientations, rather than applied uniformly to the entire building facade.

These findings support the importance of a climate-based simulation approach from the early stages of tropical hospital building design. Integrating sun-path understanding with modern simulation technology has been shown to produce spatial designs that are more adaptive to local conditions. Validating building orientation principles through the UDI metric provides a strong scientific basis for design decision-making.

A practical recommendation for designing inpatient rooms in tropical climates is to implement facade treatment differentiation based on orientation and dominant sun exposure time. Further research is recommended to examine lighting performance at different times (morning and afternoon) and the influence of variations in shading element dimensions to produce more comprehensive design guidelines. Further research is recommended to examine lighting performance at different times (morning and afternoon) and the influence of variations in shading element dimensions to produce more comprehensive design guidelines. Exploration of adaptive solutions such as dynamic shading elements can also be an alternative to accommodate lighting variability throughout the day in tropical regions.

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