Smart Daylighting Strategies for Architectural Studios: Evaluating Louvre Angles and Time Effects Through Revit Simulations

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Abstract. This study explores the effectiveness of louvre windows in optimizing daylighting within an architectural studio using Revit simulations. The aim was to enhance natural light distribution, minimize glare, and control heat gain to improve comfort and productivity. Simulations were conducted for a 48 m² west-facing studio, testing louvre angles (0°, 15°, 30°, 45°) at different times of day (7:00 AM, 11:00 AM, 1:00 PM, and 4:00 PM). Results indicate that flatter angles (0° and 15°) maximize early morning daylight but increase glare, while steeper angles (30° and 45°) reduce glare but limit illuminance. At midday, moderate angles (15° and 30°) strike a balance between glare control and daylight distribution. In the afternoon, steeper angles (30° and 45°) effectively manage glare while maintaining adequate daylight. The study underscores the trade-off between illuminance and glare control, essential for visual comfort in studios. Optimized daylighting reduces reliance on artificial lighting, promoting energy efficiency and climate change mitigation. However, limitations such as static simulations and lack of real-world validation highlight the need for further research to confirm findings and explore advanced daylighting strategies.

1 Introduction

Daylighting plays a critical role in architectural design, particularly in educational settings where students spend extended hours. The provision of natural light not only enhances visual comfort but also contributes to the overall well-being and productivity of occupants. Fitriaty et al. [1] highlight that in tropical coastal areas, excessive sunlight can lead to overheating, necessitating strategic daylighting techniques to mitigate glare and heat gain while still allowing for adequate illumination. Similarly, Lim et al. [2] emphasizes the underutilization of abundant daylight in tropical climates and the need for empirical validation of daylight simulation tools to optimize building performance.

Designing architectural studios in these regions requires a multifaceted approach to daylighting that integrates both natural and artificial lighting systems. Yunitsyna and Toska

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[3] argue that effective daylight control mechanisms, coupled with individual lighting control features, can significantly enhance the adaptability of studio environments to varying daylight conditions. This adaptability is crucial in tropical regions where daylight availability fluctuates throughout the day and across seasons. Furthermore, Eleyan and Ariffin [4] illustrates the potential for energy savings through well-executed daylighting strategies in design studios at the International Islamic University Malaysia, reinforcing the importance of integrating daylighting into the architectural curriculum. Othman et al. [5] underscore the necessity for revitalizing daylighting strategies in educational buildings, particularly in response to rising electricity costs and the need for sustainable design practices.

Among various architectural features, the use of louvres stands out as a crucial element in enhancing daylight distribution and controlling solar gain within studios. Louvres are adjustable horizontal or vertical slats that regulate the amount of sunlight entering a space, thereby controlling both light levels and heat gain. Their strategic placement and orientation can significantly improve visual comfort and reduce energy consumption. Kunduracı and Kizilörenli [6] discuss the effectiveness of louvres in managing daylight in deep-plan classrooms, particularly in tropical climates where glare and uneven light distribution can pose significant challenges. Their study emphasizes the importance of adjustable shading systems in creating a balanced indoor environment.

The role of louvres in optimizing daylight quality is critical, particularly in spaces with large window-to-wall ratios. Lotfabadi [7] explores how different configurations of louvres and glazing systems can influence daylight factor and thermal performance, making them essential components of sustainable building design. By carefully selecting the angle and spacing of louvres, architects can maximize natural light while minimizing the negative effects of direct sunlight, such as glare and overheating.

Simulation tools play a pivotal role in enabling a more informed approach to daylighting design, allowing architects to evaluate various design options and their impacts on daylight availability and quality. Akin et al. [8] emphasize that simulation-based design maximizes a building's overall performance by allowing designers to analyze spatial daylighting performance. Brown and Mueller [9] highlight the increasing use of parametric models in early-stage design, enabling architects to explore multiple design alternatives and their respective performance outcomes. The integration of passive design strategies with advanced simulation tools further enhances daylighting outcomes. Andersen et al. [10] discuss the importance of interactive expert support in early-stage daylighting design, noting that such tools enable designers to engage with complex data sets and make informed decisions based on climate-specific analyses. Additionally, Andersen et al. [11] propose a framework for predicting non-visual effects of daylight on human health and well-being, emphasizing the need for simulation tools to account for factors like circadian rhythms and mood enhancement. Simulation tools are also instrumental in optimizing daylight performance in architectural design, as demonstrated by González and Fiorito [12] in their work on the optimization of external solar shadings. Reinhart and Fitz [13] reveal that many practitioners now routinely employ daylight simulations to assess daylight factor and interior illuminance distributions, indicating a growing trust in the reliability of these tools.

The integration of Autodesk Revit in daylighting simulation has gained significant attention in the literature, showcasing its capabilities in optimizing building design for enhanced daylight performance. Revit, as a Building Information Modeling (BIM) tool, facilitates the creation of detailed 3D models that can be used for various performance analyses, including daylighting. Eleftheriadis et al. [14] present a BIM-enabled optimization framework that integrates daylight analysis into the design process. Their research emphasizes the importance of using BIM for building performance simulations, demonstrating how Revit can be utilized to incorporate daylight analysis alongside thermal performance assessments. This integration allows architects to make informed decisions that enhance both energy efficiency and occupant comfort.

Maksoud et al. [15] conducted a study specifically analyzing the daylighting performance in architectural studios using Revit. They simulated various cases to determine the optimal daylight factor, demonstrating how Revit can be employed to analyze luminance environments and compare different design alternatives effectively. This case study exemplifies the practical application of Revit in achieving desired daylighting outcomes in educational settings. Moreover, Kota et al. [16] developed a methodology to translate BIM models created in Revit into daylighting simulation models using Radiance and DAYSIM. Their work emphasizes the importance of accurately translating both geometry and material information from Revit into these simulation tools, allowing for automated simulations without manual intervention. This advancement streamlines the process of conducting daylighting analysis, making it more efficient for architects. Additionally, Koçak and Alaçam [17] introduces an algorithm-aided design framework that utilizes Revit in the early phases of architectural design. This framework employs a performance-based design approach optimized with genetic algorithms to evaluate daylight calculations, showcasing how Revit can be integrated with advanced computational techniques to enhance daylighting design. While there is extensive research on the benefits of louvre windows and smart daylighting systems, studies specifically focusing on the integration of louvre windows with Revit for daylighting simulations are limited. This study aims to fill this gap by exploring how Revit can be used to simulate the performance of louvre windows in an architectural studio setting. By analyzing different configurations and materials, we seek to identify the most effective strategies for maximizing natural light while minimizing glare and heat gain.

This study focuses on the application of smart daylighting strategies in architectural studios, specifically through the use of louvre windows. Utilizing Revit for daylighting simulations, we aim to optimize natural light distribution, minimize glare, and control heat gain, ultimately enhancing the comfort and productivity of studio occupants. It is important to note that the scope of this paper is limited to the design and simulation of louvre windows using Revit. Validation of the simulation results through real-world measurements and comparisons is beyond the scope of this study.

2 Methodology

The study was conducted in an architectural studio located on the 4th floor of a campus building in Vocational College, Universitas Diponegoro, Semarang, Indonesia, with a total area of 48 m² (**Fig. 1**, **Fig. 2**). The studio has two key walls with windows: one facing west (**Fig. 3**) and the other adjacent to a 2-meter-wide hallway (**Fig. 4**). The west-facing wall, which directly faces the exterior, plays a crucial role in natural daylight entry, while the hallway-facing wall contributes secondary light through its windows. The primary focus of this research is on the west-facing windows, as they significantly influence the daylighting conditions within the studio.

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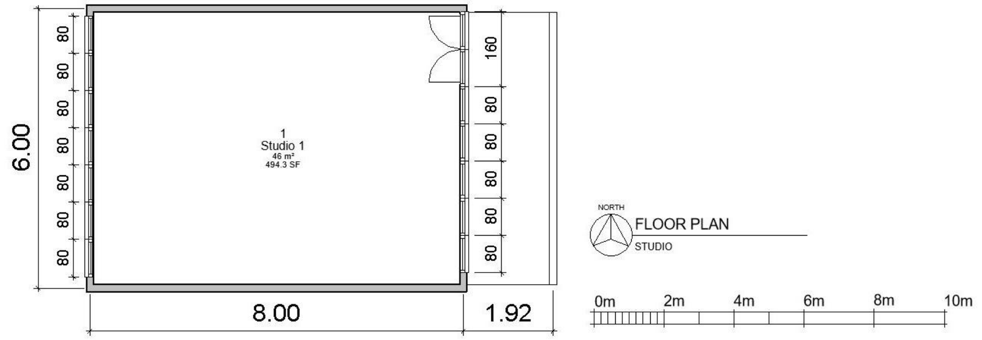

Fig. 1. Floor Plan of the Studio for Architect Students.

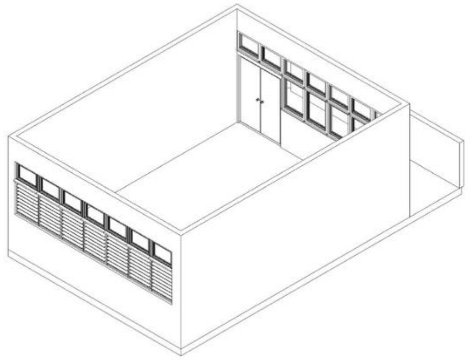

Fig. 2. Three-dimensional view of the modelled studio.

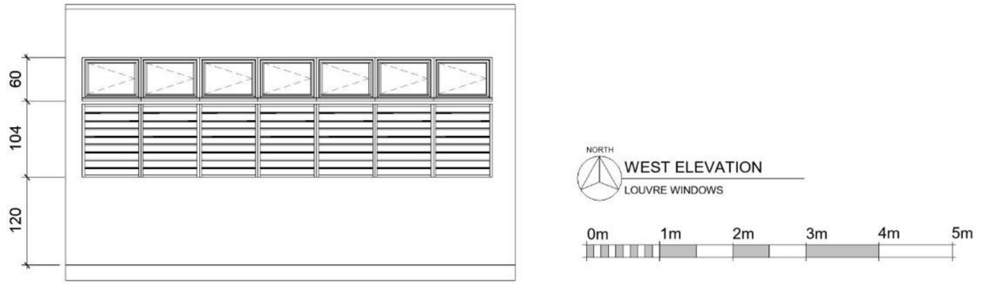

Fig. 3. Louvre window on west elevation.

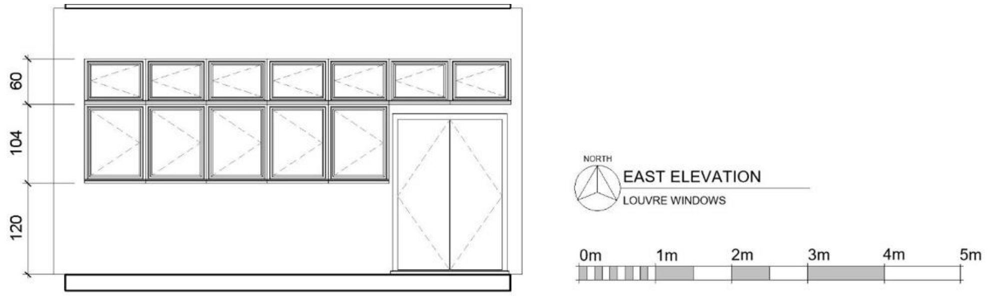

Fig. 4. Existing window from east elevation.

To assess daylighting performance, particularly at the work surface level, the Revit model was utilized to simulate various lighting scenarios. The studio was modelled in Revit with precision to accurately represent its physical dimensions, material properties, and spatial configuration. Special attention was given to the reflectance and transmittance characteristics of the materials used in the walls, floors, ceiling, and windows. Louvres were then installed on the west-facing windows, and simulations were conducted at four different angles: 0°, 15°, 30°, and 45° (Fig. **5**). The 0° angle represented a parallel alignment with the window plane, while the 45° angle indicated the maximum inclination tested.

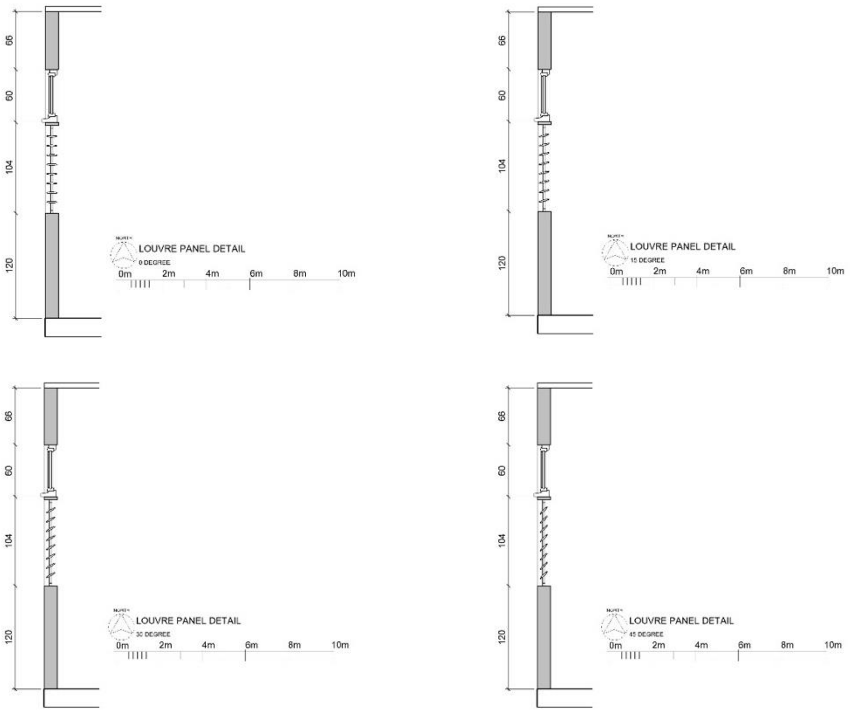

Fig. 5. Different configurations of louvre panel simulated.

The simulations aimed to evaluate the illuminance levels at a standard table height of 80 cm, corresponding to the typical work surface height used by students. The simulation settings were configured for August 1, 2024, at four specific times of day: 7:00 AM, 11:00 AM, 1:00 PM, and 4:00 PM. These times were carefully selected to capture a range of daylight conditions throughout the day.

- 7:00 AM was chosen to assess early morning light, which typically has a lower angle and can produce long shadows, influencing how light enters the room from the west.
- 11:00 AM represents late morning when the sun is higher in the sky, providing a different angle of incidence that can illuminate the space more uniformly.
- 1:00 PM was selected to examine midday sunlight when the sun is near its zenith, offering maximum daylight exposure, which is critical for evaluating potential glare and direct sunlight effects.

- 4:00 PM captures the late afternoon light as the sun begins to lower again, providing insights into how the studio's daylighting conditions change as the day progresses towards evening.

The Revit model incorporated accurate geographic location and building orientation data to simulate realistic daylight conditions at these specified times. Illuminance levels, measured in lux, were recorded across the studio at the specified height for each louvre angle configuration. The results were then compared to identify the angle that provided optimal daylight distribution while minimizing glare and excessive brightness.

The analysis focused on determining the most effective louvre angle for achieving balanced daylighting within the studio, ensuring a comfortable and well-lit environment for architectural tasks. The findings from this study are intended to inform design decisions related to daylight management in similar educational settings, providing valuable insights into the impact of louvre angles on natural light distribution. A desirable range for daylight illuminance, set between 300 and approximately 3,000 lux [18], was used as the threshold for the simulation.

3 Results and Discussions

The daylighting simulations conducted using Revit provided detailed insights into the illuminance levels within the architectural studio. The primary objective was to achieve optimal natural light distribution while minimizing the need for artificial lighting. The results (**Table 1**) suggested the simulation results that of louvre windows illuminance levels throughout the studio. Furthermore, visual rendering of the simulation is presented in the Appendix. The results of the daylighting simulations suggest that optimized louvre angles not only improve visual comfort but also contribute to significant energy savings by reducing the need for artificial lighting during peak daylight hours. These findings align with previous studies that have demonstrated the energy-saving potential of smart daylighting strategies. For instance, similar research has shown that reducing artificial lighting demand can lower a building's overall energy consumption by up to 30%. By carefully adjusting louvre angles, architects can strike a balance between maximizing daylight and minimizing glare, thus contributing to both energy efficiency and climate change mitigation.

Table 1. The results of illuminance level simulation using Revit Insights.

Louvre angle inclination degree	Time	Within threshold		Above threshold		Below threshold		Average illumination (lux)
		%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	
0	7 am	67	31	20	9	13	6	2684
	11 am	95	44	0	0	5	2	689
	13 pm	97	45	0	0	3	1	593
	16 pm	69	32	30	14	1	0.325	1624
15	7 am	64	30	20	9	15	7	1904
	11 am	94	43	0	0	6	3	669
	13 pm	97	44	0	0	3	2	578
	16 pm	81	37	17	8	2	1	1610
30	7 am	64	30	20	9	16	7	1370
	11 am	95	44	0	0	5	2	657
	13 pm	95	44	0	0	4	2	577
	16 pm	88	40	8	4	4	2	1596
45	7 am	64	29	20	9	16	7	1266
	11 am	94	43	0	0	6	3	621

13 pm	96	44	0	0	4	2	560
16 pm	85	39	8	4	8	3	1594

The daylighting simulation for the architectural studio with various louvre angles revealed significant insights into how these configurations impact the studio's lighting conditions. The study assessed the daylighting performance at four distinct times of day: 7:00 AM, 11:00 AM, 1:00 PM, and 4:00 PM, focusing on illuminance levels and glare management.

At 7:00 AM, the 0° louvre angle provided the highest average illumination of 2,684 lux, with 67% of the studio's area within the desired illuminance range. However, 20% of the area experienced illuminance levels above the threshold, indicating potential glare issues. The 15° louvre angle followed closely with an average illumination of 1,904 lux, while the 30° and 45° angles offered slightly reduced average illuminance at 1,370 lux and 1,266 lux, respectively. Although the lower angles (0° and 15°) allowed more light, the 30° and 45° angles were better at reducing glare. At 11:00 AM, daylight conditions improved for all louvre angles. The 0° angle still performed well with 95% of the area within the threshold, though its average illuminance dropped to 689 lux. The 15° angle also performed similarly, with an average of 669 lux. The 30° and 45° angles showed slightly lower average illuminance levels, 657 lux and 621 lux, respectively, but all configurations were effective at providing adequate daylight. At 1:00 PM, the high sun position resulted in ample daylight. The 0° and 15° angles maintained high percentages of the area within the threshold (97%) and provided average illuminance levels of 593 lux and 578 lux, respectively. The 30° and 45° angles also performed well, with average illuminance levels of 577 lux and 560 lux, respectively, suggesting that daylight distribution was well-managed across all configurations. At 4:00 PM, as daylight waned, the performance varied. The 45° louvre angle managed glare effectively, with 85% of the area within the threshold and an average illuminance of 1,594 lux. The 0° and 15° angles, while providing higher illuminance (1,624 lux and 1,610 lux), resulted in 30% and 17% of the area, respectively, receiving levels above the threshold, indicating increased glare. The 30° angle provided a balanced performance with 88% of the area within the threshold and an average illumination of 1,596 lux.

The simulation results indicate that the louvre angle has a noticeable impact on the daylighting conditions within the studio.

- Early Morning (7:00 AM): At this time, all louvre angles provided adequate daylighting, but the 0° and 15° angles offered the highest average illumination. The 30° and 45° angles reduced glare but also led to slightly lower average illuminance levels. The west-facing windows capture significant early morning sunlight, and the flatter louvre angles allowed more light to enter the space.
- Late Morning (11:00 AM): The illuminance levels across all angles fell within the acceptable range, but the 0° and 15° angles still provided the highest average illumination. The reduction in daylight intensity as the sun climbs higher in the sky made the 0° and 15° angles effective in managing the reduced light levels while maintaining high illumination.
- Midday (1:00 PM): Daylight was ample, and the 15°, 30°, and 45° angles performed similarly, with all configurations providing a high percentage of the area within the threshold. At midday, the sun's high position means that the louvre angles have less impact on light levels, and glare control becomes more crucial.
- Late Afternoon (4:00 PM): The 45° angle provided the best glare control, reducing excessive brightness in the late afternoon when the sun's angle is lower. Although the average illumination was slightly lower, the ability to manage glare effectively was a significant advantage. The 0° and 15° angles allowed more light but resulted in a higher percentage of areas receiving illuminance above the threshold.

The results demonstrated that with the optimized louvre configuration, the studio achieved a high level of daylight autonomy. This means that for a significant portion of the occupied hours, the studio relied solely on natural light, leading to substantial energy savings. The simulations showed that the studio achieved a daylight autonomy of 70%, indicating that natural light was sufficient for 70% of the time during working hours.

In summary, the illuminance levels achieved through the use of louvre windows in the architectural studio were highly effective in enhancing natural light distribution. The ability to adjust the louvre angles and select appropriate materials played a critical role in optimizing the daylighting performance. These findings underscore the potential of louvre windows as a smart daylighting solution in architectural design, contributing to energy efficiency and occupant comfort.

4 Conclusion

This study explored the application of smart daylighting strategies in an architectural studio, with a focus on optimizing natural light distribution, minimizing glare, and controlling heat gain using louvre windows and Revit simulations. The primary objective was to enhance the comfort and productivity of studio occupants by achieving an effective balance between daylight and glare control. This study demonstrates that optimized louvre windows can significantly improve daylight distribution, reduce glare, and decrease the need for artificial lighting, contributing to more energy-efficient building designs.

The simulation results highlight key strategies for optimizing louvre angles and timings to balance daylighting and glare control. In the early morning (7:00 AM), flatter angles (0° or 15°) effectively maximize daylight but increase glare, suggesting the need for adjustable louvres or supplementary glare control measures. During midday (11:00 AM and 1:00 PM), moderate angles (15° or 30°) provide an ideal balance, offering sufficient daylight while minimizing glare. By late afternoon (4:00 PM), steeper angles (30° or 45°) are most effective for glare management while maintaining adequate daylight levels. Flatter angles generally allow more light but pose a higher glare risk, while steeper angles prioritize glare reduction at the expense of illuminance. Midday proved the most favorable period for daylighting, with all angles delivering adequate light. However, early morning and late afternoon showed greater performance variability, requiring careful angle adjustments. The 45° angle was particularly effective for glare control in the morning and afternoon, demonstrating its suitability for visual comfort. These findings emphasize the trade-off between achieving high illuminance and minimizing glare, underscoring the importance of tailored louvre adjustments for different times of day to enhance comfort and efficiency.

Despite the promising insights, the study has limitations. Static simulation conditions excluded dynamic variables like cloud cover, seasonal weather changes, and pollution, which influence daylighting. The evaluation focused solely on specific times of day (7:00 AM, 11:00 AM, 1:00 PM, and 4:00 PM) without intermediate intervals and considered only a single west-facing orientation. Simplified assumptions, such as generalized material properties and the absence of furniture or occupant activity, may also have impacted accuracy. Furthermore, the study did not integrate user feedback to evaluate practical comfort and lighting quality. Future research should address these gaps by validating findings in real-world, dynamic settings, testing additional orientations and louvre configurations, and incorporating advanced metrics and thermal analysis. Such studies could further refine smart daylighting strategies and broaden their application in energy-efficient architectural design.

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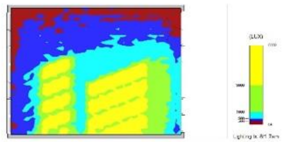
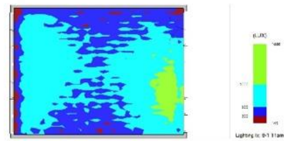
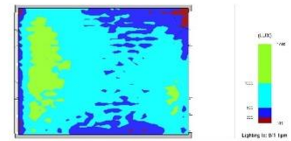
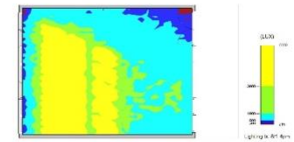
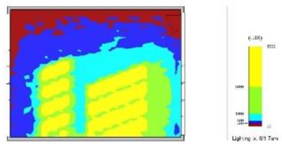
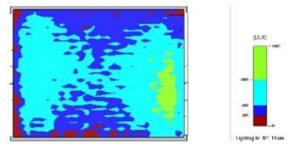
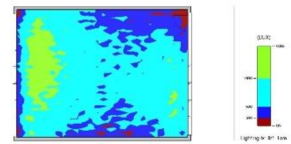
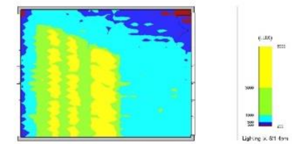
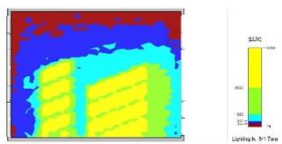
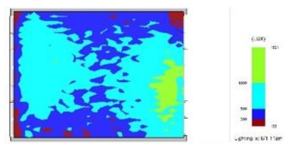
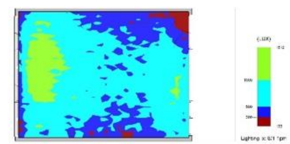
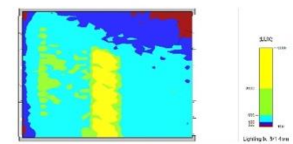
Appendix

Table 2. The visual contour of illuminance analysis on different configuration of louvre panel inclination angle on different time of a day.

Inclination Angle	Visual contour of illuminance level on different time			
	7 pm	11 am	1 pm	4 pm
0° 				
15° 				
30° 				
45°