Simulation of Natural Daylighting Optimization in College Library

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Abstract. In a library’s reading area, sufficient light exposure is needed to see objects around the users’ field of vision for their activities. Regarding the case study, as an equatorial region, Indonesia also has the advantage of getting a continuous high radiation climate throughout the year. Therefore, buildings around the area need to optimize this benefit to achieve optimal energy efficiency. Meanwhile, according to the national standards of SNI 6197-2011, the simulation of the existing reading area in PGRI University’s Library has not achieved the optimized daylighting performance. This research aims to improve the lack of daylighting performance, using DIALux EVO simulations as the primary method to analyze the library’s existing condition and to evaluate each design proposal for retrofitting. The study then found that among all other options, the recommendation to add five more window openings on the north walls, setting up 0.8-meter width light shelves, and reducing the window overhang length to 0.25 meter is the most effective ways to optimize the daylighting performance in the library.

1. Introduction
Lighting is a critical factor in determining users’ productivity. The light condition throughout the space directly impacts student learning performance and physical wellbeing [1, 2]. Productivity level could increase as the effective use of natural lighting benefits physical and mental health, improving work and study [3]. Activities that focus predominantly on human visual sensory, such as reading, writing, and learning, are common activities encountered in the library that emphasize the need for good lighting exposure. This phenomenon makes the ability to provide enough light to accomplish visual tasks becomes one of the requirements needed for library lighting. The second requirement is to prevent over-contrast brightness of other objects within the field of view, so the library users can do their activities comfortably and not become visually fatigued [4].

As a part of educational spaces, the college library is mainly active during the day hours. Thus, it is essential to focus on the light’s effectiveness, especially natural lighting [5–7]. A College library needs a lighting condition that provides users with the comfort they need for essential learning tasks during the day [8]. If designed appropriately, the natural lighting penetration into the room can provide environmentally safe and sustainable lighting, such as low emission level, low energy consumption, and low maintenance cost [9].

A particular building’s geographical location is critical in deciding the sun’s positioning during the day [10]. Buildings located in places with high radiation climates can benefit from favorable
natural lighting conditions for energy savings and visual comfort [11]. This case study would be a waste if the library of PGRI Semarang University (UPGRIS) in Indonesia could not use the continuous supply of solar radiation advantage throughout the year.

Based on Indonesia’s national standards of Energy Conservation, SNI 6197-2011 [12], a library’s recommended average luminance is 300 lux. By achieving this level, it is a way of maximizing sufficient daylighting without causing visual discomfort. This research aims to assess the library’s current condition and further improve daylighting performance by conducting a set of design proposal simulations.

2. Methods

2.1. Literature Study: Optimizing Natural Lighting
The natural lighting-focused design focuses primarily on the creation of sheaths and layouts, constructed in such a way as to offer a decent amount of natural light to the interior spaces [5, 7, 10]. The literature of Panduan Pengguna Bangunan Gedung Hijau Jakarta Vol.3: Sistem Pencahayaan [13] functions as the main base to bring out a set of design proposals to optimize the daylighting performance inside the library.

2.2. Software Simulation Approach using DIALux EVO
The researcher has to calibrate the DIALux EVO program settings to fit the on-site observation situation to establish an accurate library simulation. There are a few aspects to calibrate; Active utilization profile, site alignment, and daylight setting.

![Figure 1: DIALux EVO settings for active utilization profile and daylighting](image1.png)

![Figure 2: DIALux EVO settings for site alignment](image2.png)

3. Discussion

3.1. Simulation for Existing Condition
As shown in Figure 1 and Figure 2, the simulation for UPGRIS’s library is set for Wednesday, September 8th, 2020, from 11 a.m. to 12 p.m. The existing reading area is approximately 403
sqm, with openings only on the east and south wall. Desks and chairs dominate the furniture layout in the room.

**Figure 3:** Left to right: The reading area’s existing condition, Windows on the south, Windows on the east

**Figure 4:** Simulation result of the existing condition’s daylighting performance

**Figure 5:** Perspective view of the existing condition’s daylighting performance

| Building 1 · Storey 4 · UPGRIS University Library (Light scene 1) |
|---------------------------------------------------------------|
| **Summary**                                                  |
| Results                                                      |
| Symbol | Calculated | Target | Check |
|--------|------------|--------|-------|
| Daylight | D          | 1.345 % | -     |      |
| Workplane | f    | 252 lx  | ≥ 100 lx | ×     |

**Figure 6:** DIAhux calculation result of the existing building’s daylighting performance

As stated in Figure 6, the simulation result for the existing building’s daylighting performance shows the average luminance of 252 lux. Meanwhile, according to Indonesia’s national standards
of Energy Conservation SNI 6197-201 [12], a library’s minimum average luminance is 300 lux. Therefore, the result shows that UPGRIS’s library has not reached the minimum of day-lighting performance for visual comfort.

### 3.2. Simulation for Recommendation Design Proposals
After receiving the results on day-lighting performance in the reading room of the Library of UPGRIS. To increase the lack of natural light optimization in the room, the researcher continued the study by analyzing a set of recommendation design proposals, notably as follows:

(i) Window Orientation Optimization.
In UPGRIS’s Library’s reading area, the windows only exist on the south and east sides of the room. Although it is not recommended to install more windows to the west due to the high solar radiation in the afternoon, it is still possible to add more windows to the north [8]. A set of window addition options is suggested with a size of 0.75m x 0.4m on the north wall maximize the daylight. The study would then analyze how many windows should be added to reach the room’s most optimized luminance condition. For simulation, each window the distance is adjusted to 0.25 meter, as shown in the sequence from Figure 3 to Figure 9.

![Figure 7: Before and after applying window orientation design optimization](image)

**Table 1:** Simulation result for the addition of the windows

| Number of Windows Added | Average Luminance | Minimum Luminance Standards |
|-------------------------|-------------------|-----------------------------|
| 3                       | 289lux            | ×                           |
| 5                       | **314lux**        | ✓                           |
| 7                       | 326lux            | ✓                           |
| 9                       | 332lux            | ✓                           |

The simulation result in Table 1 reveals that among the other options, adding five windows on the southern wall increases the average luminance to approximately 314lux, which passed the minimum luminance for a library in national standards of SNI. While adding 7 or 9 windows results in higher average luminance, those options may not be the most optimized ones.

(ii) Internal Sun-Shading Device Optimization: Light Shelves
To maximize daylight penetration, the installation of light shelves could increase the possibility of extending the light transmittance to the room by reflecting sunlight from the horizontal surface (the ceilings) to make it more evenly and intensely spread throughout the room [14].

To meet the minimum average luminance requirements of 300 lux, the inclusion of 0.8 meters wide light shelves is the better choice among the four alternate width choices. By
Figure 8: Before and after the optimization of internal sun-shading device

Table 2: Simulation results of light shelves addition

| Light Shelves Width Length | Average Luminance | Minimum Luminance Standards |
|---------------------------|-------------------|-----------------------------|
| 0.4 meter                 | 278lux            | ×                           |
| 0.8 meter                 | 311lux            | ✓                           |
| 1.0 meter                 | 320lux            | ✓                           |
| 1.2 meter                 | 328lux            | ✓                           |

incorporating these light shelves, the total luminance of the reading room increases to roughly 311 lux.

(iii) External Sun-Shading Device Optimization: Solar Shading Overhang

In the case study, all windows throughout the library use egg-crated overhangs with a length of approximately 0.30m. Although the longer this shading system could prevent a higher level of solar heat, it could also block the sunlight from entering the room, resulting in a darker room [15, 16]. This circumstance is why the researcher carries out a series of simulations to determine which overhangs length is the best suited for the scenario.

Figure 9: Before and after the optimization of crated-egg style overhangs

Table 3: Simulation results of overhang length reduction recommendation

| Overhang Length | Average Luminance | Minimum Luminance Standards |
|-----------------|-------------------|-----------------------------|
| 0.3 meter       | 252lux            | ×                           |
| **0.25 meter**  | **303lux**        | **✓**                       |
| 0.2 meter       | 342lux            | ✓                           |
| 0.15 meter      | 368lux            | ✓                           |

According to the findings in Table 3, reducing the current overhang by around 0.5 meters (leaving it to 0.25 meters in length) increases the average level of luminance to 303 lux. The reduction resulted in a 0.25-meter overhang as the best fit for maximizing the library’s sun-shading system.
4. Conclusion

Lighting is a significant factor that contributes to the productivity inside a library. User activities require adequate lighting in the schoolroom to see objects within their range [17]. According to Indonesia’s national standards, the library’s recommended luminance is 300 lux. By reaching this level, it is a way to optimize sufficient lighting without creating visual discomfort. If natural lighting in the library room can meet these specific standards, visitors’ visual comfort can be accomplished [18]. The research findings have shown that natural lighting in the reading room of the PGRI University Semarang (UPGRIS) library did not meet the specified standards and is therefore not optimal. The existing building simulation shows that the reading area has an average of 258 lux. As an effort to improve the lack of optimization of natural lighting in the room according to the minimum national standards of SNI 6197-2011, a range of recommendations was made so that natural lighting within the library reading room area can be optimal (>300lux). Among them are optimization of window orientation, sun-shading devices, and solar-shading overhangs. There are five windows on the north side in the window orientation optimization so that the room’s lighting becomes 314 lux. For sun-shading device optimization with light shelves, the use of 0.8m width is best suited for the scenario to reach 311lux. Lastly, for the solar shading overhang optimization, the use of 0.25m wide could increase the average luminance to 303lux.

Acknowledgments

This research was fully supported financially by The Faculty of Engineering, Universitas Diponegoro through Strategic Research Grant 2020. The Universitas Katolik Parahyangan collaborator is supporting the operational study and presentation only.

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