Assessment of lighting system in library room of E11 building, Universitas Negeri Semarang

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Abstract. Lighting is primary factors for visual comfort in the library. The library of Universitas Negeri Semarang had the illuminance of 97 – 672 lux. Based on SNI 6197-2011, the library must have a minimum illuminance of 300 lux. This study aims to assess the quality of lighting, design the layout and lighting system using Dialux evo 9.2 software. This research was expected for the best layout design to support the lighting system to follow SNI 6197-2011. This research used the library of E11 Building, Universitas Negeri Semarang with dimension of 8.6 m x 5.7 m x 3.4 m. This research was carried out by redesigning the layout of the furniture, replacing the type of lamp and armature and calculating the efficiency electricity cost. The results declared that the quality of lighting in the library using TL-D 36W did not achieve SNI 6197-2011. Redesigning of furniture layout and replacing of TL-D with LED tube are solutions to achieve the minimum illuminance. In addition, replacing TL-D with LED Tube can save electricity costs ranging from 64% – 69% per year.

1. Introduction
Lighting is the primary factor for visual comfort in the library. With adequate lighting, library visitors feel comfortable and can concentrate well [1]. The library of the E11 Building, Universitas Negeri Semarang is one of the rooms that still utilize artificial lighting to support lighting throughout the day. It is because daylight is insufficient for the library's lighting. Meanwhile, the minimum standard for library room lighting is 300 lux [2].

Based on the observation, the library had illuminance that did not achieve SNI 6197-2011 both daylight and artificial lighting. The illuminance from daylight in the library was around 57 – 416 lux, and the illuminance from artificial lighting was around 41-213 lux. The illuminance of the natural and artificial lighting combination was around 97 – 672 lux. The daylight can optimize the lighting system, but it cannot support because of the inappropriate layout of the furniture. Therefore, it is necessary to redesign the layout and utilize daylight that the library's illuminance can be optimal and achieve 300 lux.

Inappropriate furniture layout can affect the room's illuminance to be less than optimal [3,4]. It also can disrupt the library visitors' mobility. There have been several methods to optimize lighting systems. They are changing the layout [3,4], utilizing daylight [5–9], redesigning the layout of the luminaire [10,11], changing the type of armatures [12], and changing the type of lamps [13–16]. In addition, utilizing daylight and LEDs can reduce electricity consumption to increase efficiency electricity costs [17–19]. This research aims to assess the quality of light and design the furniture layout to support the lighting system using Dialux Evo 9.2. This research is expected for the best
layout design. So, it can support the lighting system to follow SNI 6197-2011. It is also expected to increase efficient electricity costs from the lighting system.

2. Research Method
The method of this research focused on simulation with the Dialux Evo 9.2 software. The library of Semarang State University Building E11 was a case study in this research. The library is near the gate of the E11 Building, as presented in Figure 1 (a). The library’s dimension is 8.6 m x 5.7 m x 3.4 m, as shown in Figure 1 (b). The artificial lighting in the library used the 6 TL-D 36W 2500 lumen lamps mounted on 3 Artolite RM300 M2 armatures, as shown in Figure 1 (c).

![Figure 1](image1)

**Figure 1.** 3 Dimension of (a) outdoor E11 Building, (b) outdoor of the library, and (c) indoor of the library.

The minimum standard for illuminance referred to SNI 6197-2011, which was 300 lux. The measurement point used general and task area measurements regarding SNI 16-7062-2004 [20]. Because the library had 43,548 m², the general measurement point used 3 meters for distance per point with the 1 meter height from the floor. The general measurement points were A1 and A2 points. A1 was near the tables, and A2 was near the bookshelf, as shown in Figure 2 (a). Meanwhile, the task area measurements were on the ten tables with A to J codes, as presented in Figure 2 (b).
This research used three lighting conditions. They were the daylight, artificial lighting, and a combination of daylight and artificial lighting. The daylight was simulated at 8 AM, 10 AM, 12 AM, 2 PM and 4 PM. The times of simulation have also simulated the combination of daylight and artificial lighting. Meanwhile the artificial lighting was simulated at 7 PM. In addition the empty library was simulated at 8 AM and 4 PM. This simulation aimed to determine the distribution of daylight for redesigning the layout of furniture and redesigning the lighting system. The timing simulation referred to the observation result. The result showed that the illuminance at 8 AM and 4 PM were the smallest illuminances.

The layout of the furniture has been designed following the simulation results of the empty library. The placement of the reading desk has been focused on an area with sufficient illuminance. If the illuminance did not achieve 300 lux, then the artificial lighting has been replaced. There were two types of artificial lighting, LEDTube 16W with lumen 2500 and LEDTube 26W with lumen 3900. The design recommendation was simulated in three sky conditions. They were clear sky, average sky, and overcast sky.

The new furniture layout and lighting in simulations were expected to achieve 300 lux in every weather condition. The electricity costs in this research were calculated to determine the efficiency of electricity costs annually. The operating hours were 9 hours per day. In addition, the electricity tariff was Rp. 925.00 per kWh.

3. Result and Discussion

The results of the empty library are presented in Figures 3 (a) - (b). Figure 3 (a) is a distribution of illuminance in the empty library at 8 AM. In the figure, it can be seen that the center of the library had a higher illuminance than the other parts of the library. The range of the illuminance was around 200-500 lux. It is also happened at 4 PM, as shown in Figure 3 (b). At 4 PM, the center of the room had a higher illuminance than the illuminance at 8 AM. The illuminance was around 500 - 750 lux. It happened because the daylight shines to the library room through the window on the west wall at 4 PM. By knowing the distribution of illuminance in the empty library, it was possible to redesign the layout of the furniture and lighting system.
The design of the furniture layout is carried out by changing the position of the tables, bookshelves, and cupboards in the library. Based on observations, not all measurement points had illuminance above 300 lux at table D, E, F, G, H, I, J and the general measurement point A1 had higher illuminance. It happened because the points were near the window. It was alike the tables A, B, C, and the general measurement point A2. The points had low illuminance because the artificial lighting, TL-D 36W, could not support lighting system. The points were also far from the artificial lighting. Therefore, the layout of the furniture was changed and the design was obtained, as shown in Figure 4.

Figure 3. Distribution of illuminance in the empty library (a) at 8 AM, and (b) 4 PM

Figure 4. The new layout of the library

Figure 4 is the recommended layout design. In the picture it can be seen that the table was placed in the centre of the room, while the shelves and cupboards are placed near the wall. The new layout was simulated with three sky conditions and the results are shown in Table 1. It can be seen in table 1 that only the illuminance with clear sky conditions achieved 300 lux. The illuminance in the average sky and overcast sky conditions did not achieve 300 lux. It was because the TL-D 36W lamp did not achieve the minimum lighting level in the average sky and overcast sky conditions. Therefore, it was necessary to replace artificial lighting so that the minimum illuminance can achieve if conditions were average sky and overcast sky.
The replacement of artificial lighting was carried out by applying two variations of LED Tube. The LED Tubes were LED Tube 16W 2500 lumen and LED Tube 26W 3900 lumens. The four LED Tube 16W were mounted on the Power balance RC436B armature to achieve the minimum illuminance. The layout design of the 16W LED Tube referred to reference [10] and the 1x4 design was obtained as shown in Figure 5 (a). The layout was different from the previous artificial lighting layout. It was the 1x3 layout. It was designed because the 16W LED Tube only had a luminous flux of 2500 lumens. So, it cannot achieve 300 lux if used the previous layout. On another side, the LED Tube 26W had a luminous flux of 3900 lumens. The minimum illuminance was achieved if it used the previous layout. The layout design of the LED Tube 26W can be seen in Figure 5 (b).

*Figure 5. New design of artificial lighting (a) LED Tube 16W dan (b) LED Tube 26W at the library*

The illuminance of the LED Tube 16W and 26W layouts can be seen in Table 2. The table shows that the two LED Tubes achieved the minimum luminance of SNI 6197-2011, both general measurements and task area measurements. In the 26W LED Tube, the illuminance of the library was around 335 – 669 lux. While the illuminance of the installation LED Tube 16.5W was around 303 – 579 lux. With the adequate lighting in the library room, it was visual comfort for visitors.

*Table 2. Illuminance Distribution of LED Tubes Implementation*

| Power Lamp (watt) | Illuminance Distribution (lux) |
|-------------------|---------------------------------|
|                   | General Measurement | Task Area Measurement |
| 26                | 350 - 587            | 335 - 669             |
| 16.5              | 334 - 528            | 303 - 579             |

Based on the layout and lighting system settings, a comparison of the calculation of electricity costs per year was obtained, as shown in table 3. In the table, it can be seen that the electricity cost of the library with TL-D 36W lamps for 1 year was IDR 604,195. The efficiency of electricity costs for 1 year from replacing the LED tube 26W was 64% and the LED Tube 16.5W was 69%. The two artificial lighting designs can be used as an option for the Electrical Engineering Library, Building.
E11, to achieve the minimum illuminance according to SNI 6197-2011 as well as efforts to save electricity costs.

Table 3. Comparison of The Calculation Electricity Costs Per Year

| Armatures                  | Power (Watt) | Total Lamps | Annual electricity costs (IDR) |
|----------------------------|--------------|-------------|---------------------------------|
| Artolite RM300 M2          | 36           | 6           | 604,195                         |
| Power Balance GEN2 RC463B  | 26           | 3           | 218,182                         |
| Power Balance GEN2 RC463B  | 16.5         | 4           | 184,165                         |

This research was part of the stages in the energy research in the library of the E11 Building, Universitas Negeri Semarang. Therefore, future research will focus on minimizing glare caused by daylight and artificial lighting.

4. Conclusion

This research declares that the lighting quality in the E11 building library, Universitas Negeri Semarang, using TL-D 36W did not achieve SNI 6197-2011. Redesign of furniture layout and replacement of TL-D to LED tube is a solution for achieving illuminance. In addition, replacing TL-D with LED Tube can save electricity costs ranging from 64% – 69% per year. In future research, the efforts will focus on minimizing glare caused by daylight and artificial lighting.

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