Lighting system evaluations of working space in educational building, Universitas Indonesia

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Abstract. This paper aims to evaluate the natural and artificial lighting systems for working space at the educational building in Universitas Indonesia. The doctoral working spaces and innovation laboratories are used as the case studies. The evaluation variables include orientation, openings, and lighting placement. The presence of variables can minimize the use of artificial lighting during the operating hours with clear sky conditions according to the SNI. The tools involved in this study are Lux meter and DIALux evo version 9.2 to perform the direct measurement and simulation. This study found that the lighting planning has fulfilled the SNI standards for doctoral working space with a minimum of 350 Lux and innovation laboratories which require 500 Lux. The direct measurement results of lighting range utilizing the natural light show output with an average of 182.8-1,278.1 Lux and the combination with artificial light from 222-1,883.8 Lux. Meanwhile, for the DIALux evo simulation, each room has exceeded the lower limit of lighting criteria between 403-3,739 Lux.

Keywords: natural lighting, artificial lighting, evaluations, DIALux evo

1. Introduction

Lighting has an essential role to support building performance and influence people's daily activities, while help to create room ambiance, as well as assist users' vision [1]. Lighting that affects building performance is classified into two different types, namely natural light and artificial light. Natural light is nature's energy that provides the source of light genuinely into a space [1]. When the natural light gradually decreases, it will be replaced by the artificial light that can make the rooms reach sufficient illuminance [2]. Furthermore, it is essential to have a better lighting, especially in the high-density activities area such as working space, where productivity can increase [3]. Nevertheless, to maximize lighting intensity efficiency, the consideration of openings, natural and artificial lighting has to be integrated into balance along with climate conditions [4].

Energy efficiency and conservation can gain equilibrium when there are adjustments between insulation orientation, building layout, massing, natural ventilation, and daylighting [5,6]. These variables affect the lighting and building performance by different kinds of factors that can manage lighting intensity. The manifest of those variables has the prospect of affecting building performance and can imply the mid-rise building located in the tropical climate country. It has dominantly a high
intensity of solar radiation throughout the year, so even the clear sky with the diffused light has a diffuseness degree of is around 20% [7,8].

This study took place in an educational building in Depok, Indonesia. This building has large openings on the North and South sides, instead of its the West and East sides. In addition, the East side is surrounded by mid-rise educational buildings, in contrast with the other sides that are less blocked. The diversity of working spaces in this building has the potential to be analysed by the light systems. It helps to evaluate and understand the effectiveness of natural and artificial lighting impact in various working spaces. Artificial lighting can provide a variety of light illumination levels based on the light scenarios in different spaces [9,10,11]. Departing from the existing study, the environmental quality influences the intensity of lighting in an educational building, which can significantly improve students’ wellbeing and performance by 21%, while creates a visual comfort [9,12,13]. Therefore, this study attempts to analyse the natural and artificial lighting systems for working space, in order to understand the impact of natural and artificial lighting on light levels, by using lighting analysis software and on-site measurement.

2. Methods

2.1. Instruments of research
The quantitative approach to evaluate the lighting systems was conducted in several steps. This research is initiated by conducting a literature review to understand the lighting systems in educational buildings and followed by sun path analysis utilizing Revit software to understand the direction and duration of on-site natural light. The data were subsequently collected by observation, providing lighting measurement points according to the SNI 7062:2019 to gather the distribution of lighting intensity using Lux meter for on-site measurement, and simulation was done by using DIALux evo version 9.2 software [14]. SNI 6197:2011 is used as a lighting standard in Indonesia. The minimum light level for the working space requires 350 Lux, while the laboratory working space requires 500 Lux [15]. These standards are applied as a parameter to analyse and evaluate the lighting systems on the fifth floor of the educational building. The data collection time was carried out at 11 am and 2 pm from Monday to Friday in May 2021, which were measured in two days for on-site measurement and two weeks for DIALux evo simulation under clear sky conditions. In order to complete the study, data collection is optimized in early May 2021, along with the chosen hours that refer to the sun path analysis for finding the light levels. Furthermore, by using DIALux evo version 9.2 software, lighting systems evaluation for natural light and the combination of natural and artificial lighting analysis is conducted which is focused on lighting analysis.

2.2. Location
The research was conducted on the fifth floor of the educational building at Universitas Indonesia (Figure 1). This particular floor has a diversity of room functions compared to the other floors. The building has great potential of natural lighting intensity on the North and South sides due to the use of windows as openings. The observed area consists of the innovation laboratories 1 – 5 with a room area of 64 m² on the North and doctoral working space of 230 m² on the South (Figure 2). On-site measurements of natural lighting, including the natural and artificial lighting are conducted in two days, starting on Monday, May 3, 2021, and Thursday, May 6, 2021, at 11 am and 2 pm under clear sky conditions. Due to the pandemic of COVID-19, the amount of building visitors are limited, that the direct measurement duration took shorter time than the software analysis. Meanwhile, the lighting software analysis conducted from May 3-7, 2021 and May 10-14, 2021 is focused on finding the significant measurements of the lighting system on the fifth floor of the building. On-site measurement lighting analysis is started on Monday with all lights turned off and on Thursday all the lights are turned on with no curtains at the openings. On the other hand, the lighting analysis uses DIALux evo in two terms, namely the natural light and a combination of natural and artificial lighting effects in the fifth-floor area (Table 1). This software is used to evaluate the probability in the lighting standard as it meets
the requirements of SNI 6197:2011 and SNI 7062:2019 for natural lighting and the combination of natural and artificial lighting [14,15].

Figure 1. The section of the educational building

Figure 2. Observation area
Table 1. Lighting types and scenarios for the fifth floor of the educational building, UI

| Rooms             | Lighting types          | On-site measurement (11 am and 2 pm) | DIALux evo (11 am and 2 pm) | Weather condition |
|-------------------|-------------------------|---------------------------------------|-----------------------------|-------------------|
| Doctoral working space | Philips LEDtube 1200m HO 14W865 T8 14 Watt | May 3, 2021 | May 6, 2021 | May 3-7 and May 10-14, 2021 |
| Innovation laboratories 1-5 | Philips LEDtube 1200m HO 14W865 T8 14 Watt | Natural lighting (Openings without curtains) | Natural and artificial lighting | Natural and artificial lighting | Clear sky |
| Corridor          | Philips LEDtube IA 600mm HO 7W865 T8 8 Watt | Natural lighting (Openings without curtains) | Natural and artificial lighting | Natural and artificial lighting | Clear sky |

3. Results and discussion

Based on the natural light intensity from DIALux evo software, the higher floor of the educational building in Universitas Indonesia absorbed more lighting into the building (Figure 3). In addition, the direct sunlight dominantly comes from the North. The fifth floor has sufficient natural lighting. The artificial light that is used in this entire floor consists of Philips LEDtube 1200mm HO 14W865 T8 14 Watt and Philips LEDtube IA 600mm HO 7W865 T8 8 Watt with the color temperature of 6500 K and the color designation is cool daylight. Some spaces have specific lighting concepts such as the corridor lighting which applies recessed louvered luminaires that contribute to creating a uniform and efficient lighting. Working space and laboratories have a staggered arrangement of louvered lamps with a linear position at the center point to distribute the light while avoiding reflected glare and allowing flexibility in the furniture layout [11]. The use of TL LED armature for all of the artificial lighting on the fifth floor of the educational building can support an even distribution of light to the entire area [16]. As seen in Figure 4, all armatures on this floor are of TL LED armature type, which efficiently distributes the light in the rooms.

Figure 3. Natural lighting intensity comparison between the low and high floor
3.1. Lighting systems evaluation by direct measurement

The lighting system in the working space of an educational building is quantified by on-site measurement under some terms and conditions and also scenarios (Figure 5). Dominantly, the rooms provide wide glass window openings facing the North and South side, with the innovation laboratories having higher natural light intensity than the doctoral working space. The first scenario which started on Monday, May 3, at 11 am, under clear sky conditions and focused on natural lighting, showed the highest average of 1,278.1 Lux in innovation laboratory 5, and lowest average of 557.2 Lux in innovation laboratory 1 (Figure 6). Meanwhile, 2 pm observation showed a high average in doctoral working space of 483 Lux, and the lowest natural lighting of 182.8 Lux in innovation laboratory 4.

Additionally, the second scenario conducted on Thursday, May 6, which combined natural and artificial lighting revealed higher lighting intensity than the first scenario (Figure 7). The highest average lighting at 11 am reached 1,883.8 Lux in innovation laboratory 2, and the lowest average in the corridor was 442.7 Lux. Furthermore, at 2 pm, it showed that innovation laboratory 3 gained the highest average at about 1,113.8 Lux and lowest average at the corridor of 222 Lux. Based on the result of direct quantification, the first and second scenarios have significant differences as the first scenario only used natural light, while the second scenario combined natural and artificial lighting.
3.2. Lighting systems evaluation by simulation software

Based on the simulation results, two graphs show the intensity of natural lighting at 11 am and 2 pm (Figure 8). First scenario took place on May 3-7, 2021, natural lighting simulation shows that the highest average light intensity at 11 am has reached 3,367 Lux in the innovation laboratory 5 and the lowest average is 403 Lux in doctoral working space. Second scenario that took place on May 10-14, 2021, showed that natural lighting intensity at 2 pm reached the highest average of 2,942 Lux in the innovation laboratory 2 and the lowest average was about 431 Lux in the doctoral working space. Furthermore, the combination of natural and artificial lighting analysis revealed that on May 3-7, 2021, the highest average lighting intensity was 3,739 Lux at 11 am in the innovation laboratory 2 and the lowest average of over 573 Lux in the corridor. However, on May 3-7, 2021, the simulation exhibited the highest average natural and artificial lighting of over 3,187 Lux at 2 pm in the innovation laboratory 2 and the lowest average of over 906 Lux in doctoral working space (Figure 9).

The simulation results of natural lighting distribution show lighting intensity range of the doctoral working space and innovation laboratories. It describes that the average intensity of light income was about 2,062.14 Lux at 11 am, and 2,160.29 Lux at 2 pm. Meanwhile, the combination of natural and artificial lighting shows an average in those areas up to 2,453.86 Lux at 11 am and 2,449.29 Lux at 2 pm. The average results show that natural lighting (Figure 10), has uneven light distribution to the area far-off from the openings, while the combination of natural and artificial lighting shows wider light spread to the area away from the openings (Figure 11).
Figure 8. DIALux evo simulation graph for natural lighting

Figure 9. DIALux evo simulation graph for natural and artificial lighting

Figure 10. DIALux evo simulation for natural lighting
Figure 11. DIALux evo simulation for natural and artificial lighting

3.3. Lighting systems evaluation
The results of direct measurement and simulation with DIALux evo show that the average illuminance levels exceeded the SNI lighting standard [15]. The highest illuminance levels occur at 11 am, either natural lighting or the combination of natural and artificial lighting. However, each room has an uneven light distribution, which reveals that there is an excessive amount of natural light in the areas near the openings. Therefore, the areas gain more vision and have the possibility to imply a full natural lighting system, under the clear sky condition.

4. Conclusion
The illuminance levels in the doctoral working space and innovation laboratories of educational building in Universitas Indonesia have exceeded the SNI standard under clear sky conditions. Furthermore, there are several findings as conclusions, namely: 1) Overall, the entire rooms lighting have exceeded the lower limit of the lighting criteria according to the SNI standard; 2) Orientation and openings are significantly affecting the lighting activities in the doctoral and laboratory working space. Additionally, the North side has high lighting intensity, which is notably different from the South side that fulfils the SNI standards with higher lighting intensity; 3) Lighting placements for team-based office type allow more possibilities to create various of the furniture layouts in the working spaces; 4) Natural lighting has great potential to be fully implied during the operation hours in the rooms with openings without using any artificial light; 5) The artificial lighting can play a role as a support system for distributing light intensity when the sky is cloudy or less natural lighting floods into the rooms.

Further research should be able to measure rooms only by activating artificial lighting and conduct in a longer duration. Such research should also consider re-grouping switch sources to activate artificial lights to increase the efficiency. Lastly, it is recommended to add components related to light distribution in the rooms, such as shading, fin, or other forms.

References
[1] Phillips D 2004 Daylighting: Natural Light in Architecture, 1st ed. (Oxford: Architectural Press)
[2] Sun Y Liu X Qu W Cao G and Zou N 2020 Analysis of daylight glare and optimal lighting design for comfortable office lighting Optik (Stuttg). 206 164291
[3] Kralikova R 2018 The methodology and survey on energy saving and greening illumination for application in the automobile industry IOP Conf. Ser. Mater. Sci. Eng. 393 012081
[4] Buratti C Palladino D and Franceschini C 2016 Natural and artificial lighting in glazed buildings: Energy balance 16th CIRIAF Natl. Congr. Sustain. Dev. Hum. Heal. Environ. Prot. November
pp 1–13

[5] Bucking S Zmeureanu R and Athienitis A 2014 A methodology for identifying the influence of design variations on building energy performance J. Build. Perform. Simul. 7 pp 411–426

[6] Mandala A 2019 Lighting Quality in the Architectural Design Studio (Case Study: Architecture Design Studio at Universitas Katolik Parahyangan, Bandung, Indonesia) IOP Conf. Ser. Earth Environ. Sci. 238 012032

[7] Binarti F and Satwiko P 2018 Assessing the energy saving potential of anidolic system in the tropics Energy Effic. 11 pp 955–974

[8] Obradovic B and Matusiak B S 2019 Daylight transport systems for buildings at high latitudes J. Daylighting 6 pp 60–79

[9] Salata F Golasi I di Salvatore M and de Lieto Vollaro A 2016 Energy and reliability optimization of a system that combines daylighting and artificial sources. A case study carried out in academic buildings Appl. Energy 169 pp 250–266

[10] Wijaya D D A Utami S S Adi G S and Prayitno B 2019 Optimization of Natural and Artificial Lighting System Design in the Library of the Faculty of Economics and Business, Universitas Gadjah Mada ICETAS 2019 - 2019 6th IEEE Int. Conf. Eng. Technol. Appl. Sci.

[11] Ganslandt R and Hofmann H 1992 Handbook of Lighting Design, 1st ed. (Germany: Vieweg)

[12] Sun B Zhang Q and Cao S 2020 Development and implementation of a self-optimizable smart lighting system based on learning context in classroom Int. J. Environ. Res. Public Health 17 1217

[13] Barrett P Davies F Zhang Y and Barrett L 2015 The impact of classroom design on pupils’ learning: Final results of a holistic, multi-level analysis Build. Environ. 89 pp 118–133

[14] Badan Standardisasi Nasional 2019 SNI 7062: 2019 Pengukuran Intensitas Penerangan di Tempat Kerja Standar Nas. Indones. pp 1–17

[15] Badan Standardisasi Nasional 2011 SNI 6197: 2011 Konservasi Energi pada Sistem Pencahayaan Standar Nas. Indones. pp 1–38

[16] Hangga A Nisa A M Pratama D and Apriliyanto M 2020 Simulasi Pencahayaan Buatan untuk Ruang Kelas dengan Tipe Armature TL LED dan Bohlam LED J. Tek. Elektro 11 pp 61–66