

## NATURAL LIGHTING OF STUDIO APARTMENT WITH EAST-ORIENTED OPENING

1,2,3) Department of Civil Engineering,  
Politeknik Negeri Jakarta, Jl. Prof.  
Dr. G.A Siwabessy, Kampus Baru  
UI, Depok 16424

Aisyah Anindya Putri<sup>1</sup>, Dyah Nurwidyaningrum<sup>2</sup>,  
Tri Wulan Sari<sup>3</sup>

Corresponding email <sup>1)</sup> :

[aisyahanindyap@gmail.com](mailto:aisyahanindyap@gmail.com)

[dyah.nurwidyaningrum@sipil.pnj.ac.id](mailto:dyah.nurwidyaningrum@sipil.pnj.ac.id) ✉

[tri.wulansari@sipil.pnj.ac.id](mailto:tri.wulansari@sipil.pnj.ac.id) ✉

**Abstract.** Less optimized natural lighting would result in apartment residents being dependent on artificial lighting, thus increasing energy consumption. Building opening orientation considerably influences the natural light intensity. This research aimed to analyze the natural lighting pattern on apartment units with east-oriented opening orientation and determine methods to support the existing condition to be optimized. This research applied the descriptive analysis research method assumed from calculation outcome of the software DIALux. Results indicated a proportion of units in The H-Residence Apartment do not meet the requirements specified by SNI 03 6197-2011, predominantly in the kitchen area. The average light intensity in a day in units with east-oriented opening reached its peak at 08.00 – 09.00 a.m. and decreased towards 16.00 p.m. following the sun path. The light intensity in numerous areas exceeded the requirements significantly. Other factors influencing the natural light distribution are layout and interior element. Several ways to optimize the natural light intensity utilization are adding suitable shading device, using dark-colored interior elements, and considering the sun path in designing building openings.

*Keywords : Apartment lighting, Opening orientation, Natural lighting*

### 1. INTRODUCTION

The building sector in Indonesia is the largest energy consumer after the industrial and transportation sector, reckoned at 24% in 2004 and still expected to rise to 39% by 2030. The energy consumption generated by the use of artificial lighting contributes about 15%– 25% to building's total energy consumption [1]. In countries with tropical climate, lighting system that depends on natural lighting from the sun could decrease the use of artificial lighting, thus reducing energy consumption. However, excessive incoming light intensity might cause visual or thermal discomfort, therefore causing apartment residents to block incoming natural light with light control devices [2]. Less optimized natural lighting intensity might result in apartment residents being dependent on artificial lighting, accordingly increasing energy consumption per unit so as affecting the expenses paid by the residents [3].

One of the factors influencing the penetration depth of natural light is window or opening orientation [4], [5]. This theory is based on the sun path throughout the day that progresses from east to west, influencing the natural lighting received by building opening depending on its orientation. The optimal opening orientation for buildings in Jakarta that is located in the equator area would be facing south or north to avoid excessive radiation and high temperature [6, 7].

This research aims to analyze natural lighting pattern on apartment units with east-oriented opening orientation and determine methods to support the existing condition to be optimized. Research simulation was run in natural lighting condition, meaning no lamps were switched on, and without assessing the glare factor. Regulation used to examine the average natural lighting intensity calculation result is SNI 03-6197-2011. This

research can be used as a recommendation in lighting system design and reference to advance the natural lighting issue on apartments or high-rise buildings so that it could be further optimized.

## 2. METHODS

This research was done on studio apartments in both empty and furnished setup in The H Residence Apartment located at Jl. MT Haryono Kav 6-7, Cipinang, Cempedak, East Jakarta. The studio unit area is 37 m<sup>2</sup> with 1.3 m<sup>2</sup> balcony and 2.7 m floor-to-roof height. Referring to **Figure 1**, the rooms inside consist of a bedroom, a kitchen area, and a bathroom.

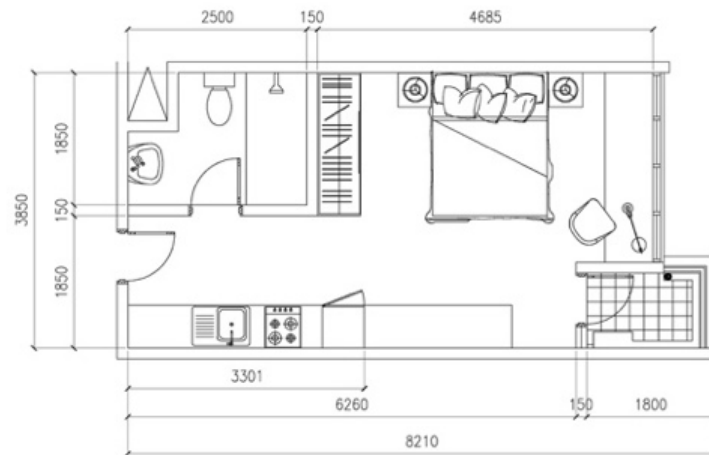
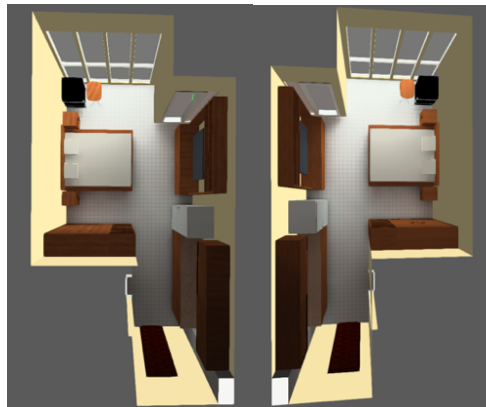


Figure 1. Studio Apartment Plan



Source : Document of The H Residence Apartment Management

Figure 2. Unit with South-corner Balcony (left) and North-corner Balcony (right)

As shown in **Figure 2**, the unit layout is divided in two types, one of them with balcony at the unit's south corner and the other at the north corner. A wall divides each unit's balcony, causing the south-corner balcony to end up with the wall on the right side, while the north-corner with the wall on the left.

This research began with searching the unit property data consist of the size and materials used for the interior elements. Then, a model was constructed using DIALux evo 9 for units with both empty and furnished setup. Afterwards, a simulation was run in various conditions namely at 8.00 a.m., 12.00 p.m., and 4.00 p.m. on June 21 and December 21 2020. Working plane was set on 0.75 m from the ground [9]. Digital simulation was chosen because of the high accuracy rate and the ability to cover plenty parameters with realistic result [10].

This research applies the descriptive analysis method that shows detailed data through words [11]. Average natural lighting intensity acquired from digital simulation was compared to requirements stated in SNI 03-6197-2011 about Energy Conservation on Lighting System, specifically 250 lux for bedroom and kitchen [12]. Further calculation was done in Microsoft Excel, with the 15th floor representing other floors due to its central position.

Table 1. Interior Elements Description

The H Residence Apartment	DIALux Evo 9
Painted Jotun	Standard Wall - white 90% 1000 (Green Beige)
Homogenous Tile - white	Tile, square, white 76%
Rustic Tile	Default floor element
Painted Ceiling - white	Default ceiling material
Concrete Table - white	Painted white 90%
Laminated Door	Lemon wood dark 9%
Aluminum & Glass Wall	Frame 9006 (white aluminum), default transparent glass
Bed	Pear dark 11% and 7044 (Silk grey)
Cupboard	Pear dark 11%
Kitchen counter	Pear dark 11% and Linoleum 1 38%
TV Set	Pear dark 11%
Night table	Pear dark 11%
Sofa	Painted black 0% and grey 32 %
Table	Pear dark 11% and default material 50%

**Table 1** shows the comparison between material used in existing apartment and digital simulation. Aside from wall, floor, ceiling, and opening, a set of furniture was added with heavy reference to actual studio apartment presented in The H Residence Apartment. All materials used in simulation model were adjusted to match the actual model, using the materials provided by DIALux evo 9 library.

### 3. RESULTS AND DISCUSSION

#### 3.1 Average Lighting Intensity Summary

**Table 2 and 3** show the calculation result summary from DIALux software in which numerous areas do not meet the requirements specified by SNI, specifically the kitchen area. The kitchen area possesses low average intensity due to its location being far from window opening and surrounded by dark-colored interior elements, namely entrance and bathroom door

Table 2. Average Lighting Intensity Summary Compared to SNI – June 21 2020

Time	Apartment Setup	Minimum Intensity Met	Minimum Intensity Not Met
8.00 a.m.	Empty	100.00%	0.00%
	Furnished	50.00%	50.00%
12.00 p.m.	Empty	58.33%	41.67%
	Furnished	50.00%	50.00%
4.00 p.m.	Empty	50.00%	50.00%
	Furnished	50.00%	50.00%

**Table 2** indicates that at 8.00 a.m. all units with empty setup meet the requirement, whereas only 50% furnished units do. At 12 p.m., 58.33% empty units and 50% of furnished units meet the requirement. At 4 p.m., both empty and furnished units only meet the requirement by 50%.

Table 3. Average Lighting Intensity Summary Compared to SNI – December 21 2020

Time	Apartment Setup	Minimum Intensity Met	Minimum Intensity Not Met
8.00 a.m.	Empty	100.00%	0.00%
	Furnished	50.00%	50.00%
12.00 p.m.	Empty	58.33%	41.67%
	Furnished	50.00%	50.00%
4.00 p.m.	Empty	50.00%	50.00%
	Furnished	50.00%	50.00%

**Table 3** indicates that at 8.00 a.m. all units with empty setup meet the requirement, whereas only 50% furnished units do. At 12 p.m., 58.33% empty units and 50% of furnished units meet the requirement. At 4 p.m., both empty and furnished units only meet the requirement by 50%.

### 3.2 False-Color Diagram

Based on false color diagram generated in DIALux for unit number 1528 (Room 7, top, south-corner balcony) and number 1530 (Room 5, bottom, north-corner balcony) with both empty and furnished setup, on June 21 and December 21 the highest lighting intensity is located at the main window and the lowest being at the kitchen area.

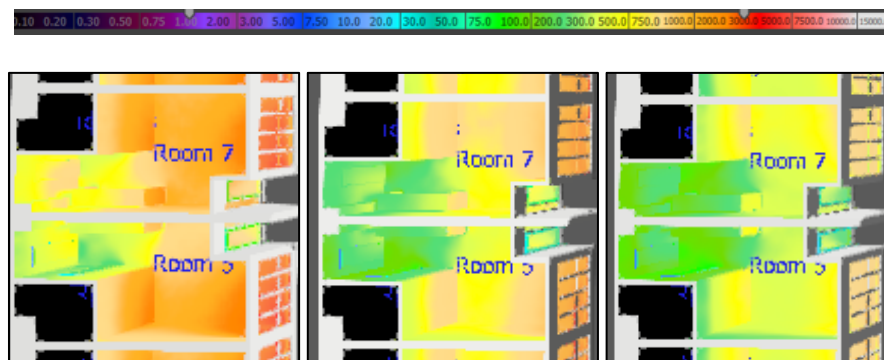


Figure 3. False Color Diagram for Empty Unit – June 21 at 8.00 a.m. (left), 12.00 p.m. (middle), 4.00 p.m. (right)

**Figure 3** shows a drastic change of natural lighting intensity with 8.00 a.m. being the time it is highest. The intensity gradually decreased throughout the day. The area with highest lighting intensity, marked by the color orange and red, ranging from 2000 – 7500 lux, is located near the window opening. While, the area with lowest lighting intensity, marked by the color blue and green, ranging from 5 – 300 lux, is located around the kitchen area.

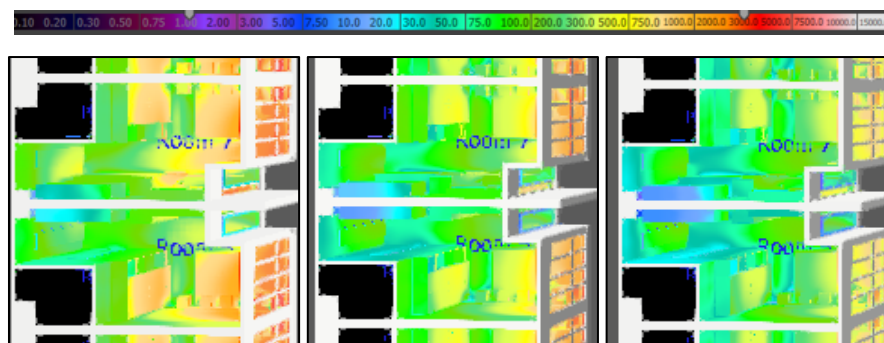


Figure 4. False Color Diagram for Furnished Unit – June 21 at 8.00 a.m. (left), 12.00 p.m. (middle), 4.00 p.m. (right)

**Figure 4** shows the same progress, although not as drastic as the empty setup, lighting intensity reaches its peak at 8.00 a.m. The area with highest lighting intensity, marked by the color red and orange, ranging from 2000 – 7500 lux, is located near the window opening. While, the area with lowest lighting intensity, marked by the color purple to green, ranging from 0 – 300 lux, is located around the kitchen area.

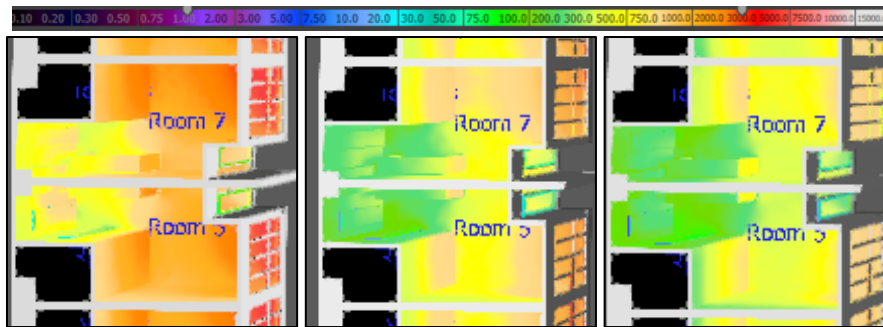


Figure 5. False Color Diagram for Empty Unit – December 21 at 8.00 a.m. (left), 12.00 p.m. (middle), 4.00 p.m. (right)

**Figure 5** shows that similar occurrence with Figure 4 happened, with the lighting intensity reaching its peak at 8.00 a.m. and gradually decreases throughout the day. However, intensity produced on December 21 is far higher than on June 21. The area with highest lighting intensity, marked by the color red and orange, ranging from 2000 – 7500 lux, is located near the window opening. While, the area with lowest lighting intensity, marked by the color blue and green, ranging from 5 – 300 lux, is located around the kitchen area.

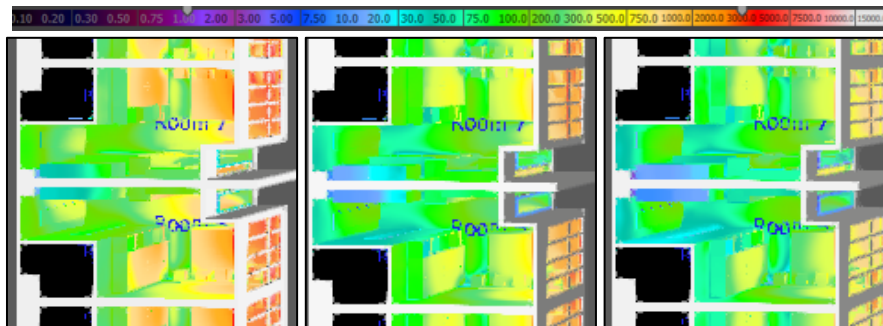


Figure 6. False Color Diagram for Furnished Unit – December 21 at 8.00 a.m. (left), 12.00 p.m. (middle), 4.00 p.m. (right)

**Figure 6** shows similar progress with Figure 5, although with far higher lighting intensity. The area with highest lighting intensity, marked by the color red and orange, ranging from 2000 – 7500 lux, is located near the window opening. While, the area with lowest lighting intensity, marked by the color purple to green, ranging from 0 – 300 lux, is located around the kitchen area.

### 3.2 Lighting Intensity Pattern

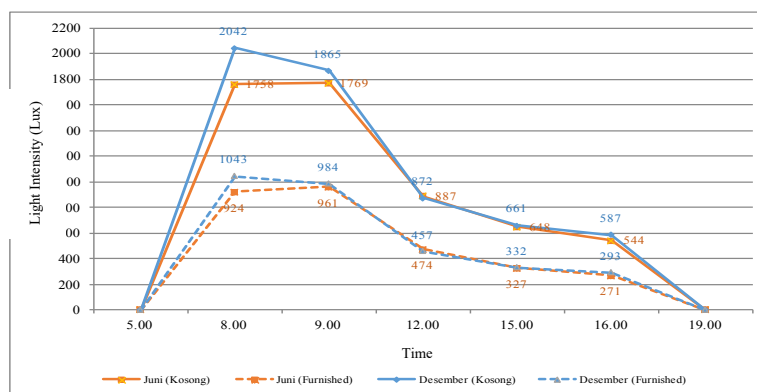


Figure 7. Daily Natural Lighting Intensity – Unit No. 1528



**Figure 7** shows that on June 21, the initial lighting intensity was 1758 lux for empty setup and 924 for furnished setup then it increased by 0.63% for empty setup and 4% for furnished setup towards 9.00 a.m., being the time it reached its peak at 1769 lux and 961 lux. A decrease of 49% took place towards 12.00 p.m. where lighting intensity became 887 lux and 474 lux. Towards 4.00 p.m., there was a decrease of 38.67% for empty setup to 544 lux and 42.83% for furnished setup to 271 lux. On December 21, highest lighting intensity was at 8.00 a.m. namely 2042 lux for empty setup and 1043 lux for furnished setup. A decrease of 57% took place towards 12.00 p.m. where lighting intensity became 872 lux and 457 lux. Towards 4.00 p.m., there was a decrease of 32.68% for empty setup to 587 lux and 35.89% for furnished setup to 293 lux.

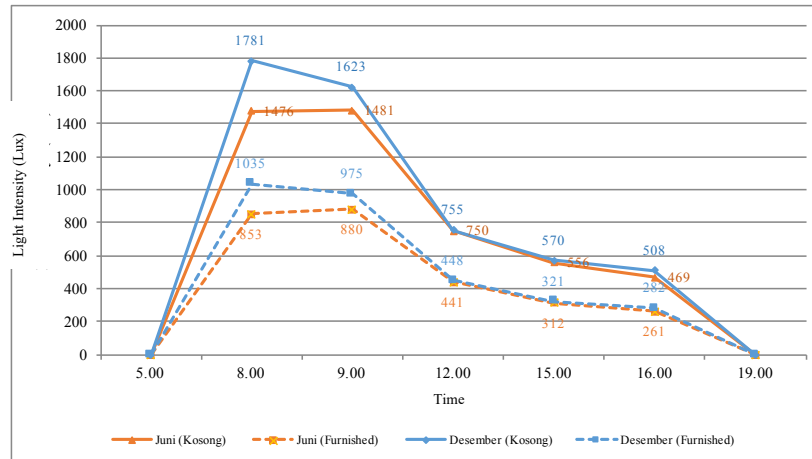


Figure 8. Daily Natural Lighting Intensity – Unit No. 1530

**Figure 8** shows that on June 21, the initial lighting intensity is 1476 lux for empty setup and 853 lux for furnished setup then it increases by 0.34% for empty setup 481 lux to 3.17% for furnished setup to 880 lux. A decrease of 49% takes place towards 12.00 p.m. where lighting intensity becomes 750 lux and 441 lux. On December 21, highest lighting intensity is at 8.00 a.m. namely 1781 lux for empty setup and 1035 lux for furnished setup. A decrease of 57% takes place towards 12.00 p.m. where lighting intensity becomes 755 lux and 448 lux. Towards 4.00 p.m., there is a decrease of 32.72% for empty setup to 508 lux and 37.05% for furnished setup to 282 lux.

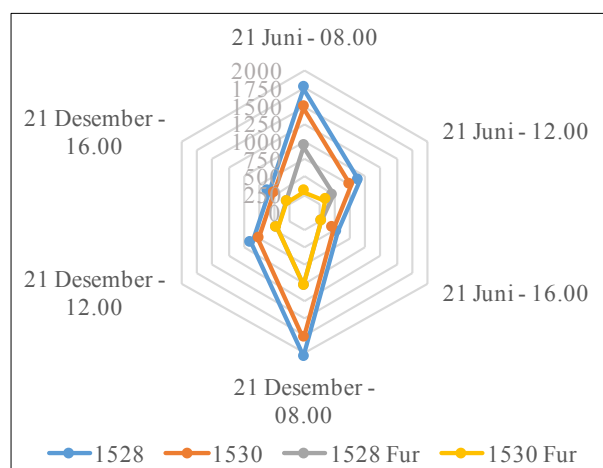


Figure 9. Radar Diagram of Natural Lighting Intensity for East-Oriented Unit

Based on **Figure 9**, both units reached peak lighting intensity between 08.00 – 09.00 a.m. in accordance with the sun path moving from east to west causing the culmination to happen in the morning. The average natural lighting intensity declines in the evening following the sun moving west [13]. Apartments with opening not meeting the requirements might result in unit receiving sufficient lighting intensity for only half a day since there will be a drastic decrease after noon.

Apartment number 1528 with south-corner balcony possesses higher average lighting intensity in comparison with apartment number 1530 with north-corner balcony. This occurrence is caused by a 3° deviation to the south on the building, therefore making apartment number 1528, with a wall dividing each studio located at the right side of the balcony, to receive more light from the sun.

Average lighting intensity from both units far exceeded the minimum requirements stated in SNI. While maximum requirements are not mentioned, requirements of maximum 300 lux for bedroom and 750 lux for kitchen area are mentioned in IESNA [14]. Excessive average lighting intensity might cause visual discomfort such as glare and thermal discomfort or high temperature, causing the residents to block incoming light and using artificial light instead [15]. High average intensity might be caused by the area of window opening, creating visual discomfort [16].

Bigger opening area causes the window-to-wall-ratio (WWR) to exceed reasonable limit. While there is a research that states the energy used for artificial lighting increases as WWR decreases, it is possible for residents to cover openings instead to avoid glare and heat, thus increasing the use of energy for artificial lighting [17]. Other previous research states energy use will decrease as WWR decreases [18].

In both units, average intensity on December is considerably higher compared to June. Because the building coordinate is located at 6°14'S and 106°52'E, lighting intensity will differ between the two solstices. This happens because sun's latitude on June 21 is situated at 23.5°N and on December 21 at 23.5°S.

**Figure 9** also indicates that empty unit possesses higher average lighting intensity compared to furnished unit caused by the dark-colored interior elements where the reflection factor is lower. Interior elements with dark colors might cause 50% decrease of lighting intensity [19]. Furthermore, the materials used also influence visual discomfort. Materials such as glass and wood can be used for interior wall, gypsum board can be used for ceiling and ceramic for tiles [20].

#### 4. CONCLUSION

East-oriented opening possesses higher average of natural lighting intensity in the morning and decreasing throughout the day given the sun path moving from east to west. Average intensity received by all units exceeds the requirement stated in SNI 03-6197-2011 and SNI 03-6575-2011. Several ways that can be applied to optimize unit's natural lighting state are adding horizontal shading device and using dark-colored interior elements. Preliminary to designing building opening, a suitable opening orientation in accordance with the sun path must be considered. Further similar research to concern the unit layout aspect and external factors from surrounding environment.

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