Optimization of Natural and Artificial Lighting System in UPGRIS Lecturer’s Workspace using Dialux Evo

Ratri Septina Saraswati, Baju Arie Wibawa, Bambang Eko Saputra
Program Studi Arsitektur Universitas PGRI Semarang
ratriseptina@upgris.ac.id

Abstract. Semarang city in Central Java has natural lighting from sunlight, throughout the year and can be optimized when integrated with artificial lighting. It will be reduce electrical consumption. Research in lecturer’s workspace in Gedung Pusat UPGRIS performs a simulation analysis of natural and artificial lighting and their integration using the Dialux EVO version 9.0. The simulation results of the existing condition of natural lighting is 164 Lux (09.00 AM) and 225 Lux (01.00 PM), while the existing simulation results provide 201 Lux with a power consumption of 1.69 Watt/m². The results of the integration natural and artificial lighting produce 265 Lux (09.00 AM) and 256 Lux (01.00 PM) with the same electrical consumption of 0.84 Watt / m². This value shows that the existing simulations of natural, artificial and integrated of them are still less than the SNI 16-7062-2004 standard is 350 Lux. The first retrofitting by changing the type and number of lamps resulted in 393 Lux higher from SNI standard 350 Lux. The simulation produced 556 Lux at 09:00AM and 648 Lux at 01:00PM, very higher than SNI standart 350 Lux. Through this retrofitting approach, artificial lighting at night shows minimum standard because no light. The second retrofitting effort is to turn off the lights automatically Lux sensor in the workspace area near the windows the natural lighting is strong enough, the results show that the illumination strength of 402 Lux at 09:00AM and 494 Lux at 01:00PM with low electrical consumption during the day becomes 2.92 Watt/m².

Keywords: Natural light, Artificial light, Optimization, Dialux Evo

1. Introduction
The quality and quantity of lighting in a room can affect the performance and comfort of users in the room. All living things need light to function properly. If the lighting in the room is not in accordance with lighting standards, it will reduce the level of performance and productivity of the human inside.[2]

From existing empiric datas, the energy consumption for artificial lighting in office buildings is in second place after the electric consumption for artificial ventilation systems. Poorly designed artificial lighting systems can reduce energy efficiency levels. Semarang as a tropical city with the urban atmosphere has the potential for natural lighting that is available throughout the year, naturally emitted in abundance and free of charge. The results of the analysis of natural lighting will be used as the basis for optimizing the integration of artificial lighting through the installation of a lux sensor [1].
Universitas PGRI Semarang has several high-rise buildings for administrative and learning activities. The main building is located on Jl. Sidodadi Timur 24 Semarang City, is called the Gedung Pusat UPGRIS (GP), whose functions are for the center of University administration activities, the Rector’s
Office, lecturers workspace, administrative officer room, and classrooms of Faculty of Engineering and Informatics, Faculty of Management, and Faculty of Law. The Gedung Pusat UPGRIS has 8 floors. The research study is devoted to the Faculty of Engineering and Informatics lecturers workspace. That room located on the 3rd floor and on the south side of the building. (see Figure 1). The real interior condition of the lecturer workspace can be seen in Figure 2.

2. Research Methods
Research on the strength of natural lighting and artificial lighting in this room was carried out using a simulation approach using the Dialux Evo software version 9.0. Modeling is based on CAD drawings and imported into the program and then modeling is made using the drawing tools available in the Dialux Evo software.

Simulation analysis for natural lighting was taken out at September 2020 in two times: low solar altitude angle (09.00 AM) and high solar altitude angle (01.00 PM). Analysis was carried out on windows and bouwenlight conditions as the source of the entry of daylight, without attention to other
effects as glare or heat from direct sunlight. This research has not done optimization of changes or planning to add to the existing wall holes. The results of the analysis of natural lighting will be used as the basis for optimizing the integration of artificial lighting through the installation of a lux sensor. We chose the measurement time in September 2020 because in July until September is the peak of summer in the city of Semarang, along with the making of a workshop assignment on green buildings. This research uses standard workspace lighting level is 350 Lux according the SNI 16-7062-2004 Measurement of Lighting Intensity in The Workplace. [3]

In this study, the optimization of changes or additions of wall holes has not been carried out. The results of this natural lighting analysis will be used as the basis for optimizing the integration of natural light and artificial lighting through the installation of a lux sensor. Simulation of artificial lighting in the existing room and simulation using a replacement lamp Phillip LED Tube Lamp T5 15.5 Watt for existing conditions, then replaced by using the Philips TBS165 G LED type 2xTL5-28W HFS C3_840 for retrofitting. This simulation uses the SNI 16-7062-2004 standard related to the strong illumination of the general office space function of 350 lux. Replacement of the existing lamps with another type of lamps we called as ‘retrofitting lamps’.

Optimization of lighting by integrating natural lighting and artificial lighting is carried out by using an automatic light switch (lux sensor) in areas with natural light levels between 300-350 lux, then continued in areas with illumination levels below 300 lux using artificial lights. Research on the strength of natural lighting and artificial lighting in this room was carried out using a simulation approach using the Dialux Evo software version 9.0. Modeling is based on CAD drawings and imported into the program and then modeling is made using the drawing tools available in the Dialux Evo software.

| no | day     | time     | weather conditions          |
|----|---------|----------|----------------------------|
| 1  | September 20 | 09:00 AM | Clear sky, direct sunlight  |
| 2  | September 21 | 01:00 PM | Clear sky, direct sunlight  |
| 3  | September 22 | v        | Clear sky, direct sunlight  |
| 4  | September 23 | v        | Clear sky, direct sunlight  |
| 5  | September 24 | off      | Cloudy                     |
| 6  | September 25 | v        | Clear sky, direct sunlight  |

Simulations for existing artificial lighting and retrofitting were carried out using a database of lamps with the Phillip brand type LED Tube Lamp T5 15.5 Watt for the existing conditions, then replaced by the Philips TBS165 G LED lamps 2x TL5-28W HFS C3_840 for retrofitting. The simulation of attaining a strong level of lighting is based on SNI 16-7062-2004 related to the strength of lighting in the general office space levels between 300-350 lux, then carried out in areas with lighting levels below 300 lux still using artificial lights levels between 300-350 lux, then carried out in areas with lighting levels below 300 lux still using artificial lights.

3. Simulation Analysis
Simulation analysis for natural lighting was carried out at low altitude of sunlight (09.00) and high altitude (13.00). Analysis was carried out on windows and bouvenlight conditions as a source of daylight entry and had not paid attention to the effects of silhouette and heat from direct lighting of sunlight. In this study, the optimization of changes or additions of wall holes has not been carried out. The results of this natural lighting analysis will be used as the basis for optimizing the integration of natural light and artificial lighting through the installation of a lux sensor. Simulation of artificial lighting in the existing room and simulation using a replacement lamp Phillip LED Tube Lamp T5 15.5 Watt for existing conditions, then replaced by using the Philips TBS165 G LED type 2xTL5-28W HFS C3_840 for retrofitting. This simulation uses the SNI 16-7062-2004 standard related to the strong illumination of the general office space function of 350 lux.
3.1. Simulation for Existing Natural Lighting in Gedung Pusat Building

Analysis of natural lighting conditions in the lecturers’ workspace was taken in September 20, 2020 at 09.00 when the solar low altitude angle and at 13.00 WIB when the solar altitude angle is high. The simulation results show that the average natural lighting level in all parts of the room is 164 Lux, it means still far from the SNI 16-7062-2004 Measurement of Lighting Intensity in The Workplace standard is 350 Lux. (Figure 3).

Optimization of lighting by integrating natural lighting and artificial lighting is carried out by using an automatic light switch (lux sensor) in areas with natural light levels between 300-350 lux, then continued in areas with illumination levels below 300 lux using artificial lights.

Table 2. Material lamps for simulation

| Lighting Simulation | Type / Serie                  | Lots                                      |
|---------------------|-------------------------------|-------------------------------------------|
| Existing lamps      | Philips Lighting T5 15.5 W LED| 24 lamps; 12 armaturs = 6x2 rows          |
| Retrofitting lamps  | Philips RC484BLED 78S LED     | 12 lamps; 12 armaturs = 3x4 rows          |

Figure 3. Analysis of natural lighting conditions was taken at Sept 20-09.00 AM
Figure 4. Analysis of natural lighting conditions was taken at Sept 20 - 01.00 PM

3.2. Simulation for Artificial Lighting in Gedung Pusat Existing Building

The simulation of the artificial lighting system is taken in September 21, 2020 at 09:00 by turning off natural lighting sources that come from wall holes. The type of lamp used in the artificial lighting simulation is using 24 units of Philips Lighting T5 15.5 W LED lamps installed on 12 armatures and installed in 6 x 2 rows. (Figure 5)

Figure 5. Analysis of lamp installation with a minimum SNI 16-7062-2004 standard in 350 Lux
The result of simulation of the artificial lighting power in the existing condition is 201 Lux, still below from the SNI 16-7062-2004 standard value in 350 Lux. (Figure 6).

The simulation of the artificial lighting system is using 12 units of LED Philips RC484BLED 78S lamps installed on 12 armatures in 3 x 4 rows taken in September 22, 2020 at 09:00. (Figure 7)

The result of simulation of the retrofitting artificial lighting is 392 Lux, has reached the SNI 16-7062-2004 standard value in 350 Lux. (Figure 8).
The analysis of lamp installation has reached the standard value SNI in 350 Lux.

### 3.3. Integration of Artificial Lighting and Natural Lighting

The simulation was taken in September 22, 2020 at 09:00. Integration analysis of natural lighting at 09:00 AM by existing lamps resulted in 256 Lux, below SNI 16-7062-2004 standard value in with an energy power of 0.84 watts / m2 (Figure 9).

The analysis of the integration of natural lighting at 1:00 p.m. with artificial lamps produced a power illumination in 356 Lux, above the SNI standard in 350 Lux by 0.84 watts/m2 (Figure 10).
The result of analysis for retrofitting the integration of natural lighting was taken in September 23, 2020 at 09.00 AM with artificial lighting, produce the power illumination in 556 Lux, above the SNI 16-7062-2004 standard in 350 Lux, with a power of 5.01 watts/m2 (Figure 11).

The result of the integration of natural lighting at 01.00 PM with artificial lighting analysis, produce the power illumination in 556 Lux, above the SNI 16-7062-2004 standard 350 Lux, with a power of 5.01 watts/m2 (Figure 12).
3.4. Optimization of Artificial Lighting and Natural Lighting using Lux Sensor

Analysis of illumination, which is an integration between artificial and natural lighting, uses the approach of utilizing natural lighting as the main source that must be utilized, so that the work desk area located near the window (with natural lighting > 350 Lux) does not need to use artificial lighting. This results in savings in lamp power usage during the day.

The first simulation was taken in September 25, 2020 at 09.00 AM by turning off 5 lights which are positioned near the window. The simulation results show that the average illumination in this workspace room is 402 Lux, slightly above the SNI 16-7062-2004 standard value 350 lux, with a smaller power of 2.92 watts / m² (Figure 13).
Figure 13. Analysis of luminance performance with automatic LUX sensor at Sept 25 - 09.00 AM

The second simulation is taken at 01.00 PM by turning off 5 lights which are positioned near the window. The simulation results show that the average illumination in this workspace room is 492 Lux, slightly above the SNI 16-7062-2004 standard value 350 lux, with a smaller power 2.92 watt/m² (Figure 14).

Figure 14. Analysis of luminance performance with automatic LUX sensor at Sept 25-01.00 PM
3.5. Comparison of Simulation Results
The results of all simulations that have been taken out can be compared in the Table 1 below:

Table 3. Comparison of Simulation Results

| No. | Lighting system | Illumination (Lux) | Electrical power (Watt/m²) | Note |
|-----|-----------------|--------------------|---------------------------|------|
|     |                 | Result | Standard | Note | Hasil | Standar | Note |
| 1   | Natural Lighting  |        |          |      |       |         |      |
|     | 1. 09.00 AM     | 164    | 300      | x    | 0    | 0        | v    |
|     | 2. 01.00 PM     | 225    | 300      | x    | 0    | 0        | v    |
| 2   | Artificial lighting |      |          |      |       |         |      |
|     | 1. Existing     | 201    | 350      | x    | 1.69 | 12       | v    |
|     | 2. Retrofitting | 392    | 350      | v    | 5.01 | 12       | v    |
| 3   | Integration natural-artificial by retrofitting | | | | | | |
|     | A. Existing |        |          |      |       |         |      |
|     | 1. 09.00 AM     | 256    | 350      | x    | 0.84 | 12       | v    |
|     | 2. 01.00 PM     | 356    | 350      | v    | 0.84 | 12       | v    |
|     | B. Retrofitting |        |          |      |       |         |      |
|     | 1. 09.00 AM     | 556    | 350      | v    | 5.01 | 12       | v    |
|     | 2. 01.00 PM     | 648    | 350      | v    | 5.01 | 12       | v    |
| 6   | Integration natural-artificial by retrofitting and lux sensor installation | | | | | | |
|     | 1. 09.00 AM     | 402    | 350      | v    | 2.92 | 12       | v    |
|     | 2. 01.00 PM     | 494    | 350      | v    | 2.92 | 12       | v    |

4. Conclusions and Suggestions
Based on the simulations that have been taken in the Faculty of Technology and Informatics lecturers' workspace was taken in September 2020, there are several results that can be concluded as follows:

1. The simulation results obtained in the existing conditions show that the strong level of light from natural lighting gives an average value of 164 Lux at 09.00 AM, and 225 Lux at 01.00 PM. The simulation results for the strong value of illumination for the installed artificial light gives a value of 201 Lux with electric power consumption 1.69 Watt / m². The simulation results of the integration of natural and artificial lighting produced a strong value of 265 Lux at 09.00 AM, and 256 Lux at 01.00 PM with the same electric power consumption 0.84 Watt / m². This value shows that the simulation of natural light strength is natural, and the integration of natural and artificial lighting is still less than SNI 16-7062-2004 standard 350 Lux, except for the integration at 01.00 PM. The problem occurs in conditions that occur at night, when there is no natural lighting or when the sunlight is low.

2. The first retrofitting effort is on artificial lights by changing the type and number of lamps so that it produces an average lighting strength of 393 Lux. If we show the SNI standard of at least 350 Lux but with an increase in power consumption to 5.01 watts / m². The simulation of its integration with natural lighting produces a strong illumination of 556 Lux at 09.00 AM and 648 Lux which is much higher than 350 Lux, the standard of SNI 16-7062-2004. Through this retrofitting approach, artificial lighting at night can show minimum standards, but its use in conjunction with natural lighting during the day provides very excessive lighting levels with very large power consumption.

3. The second retrofitting effort is to turn off the artificial lighting automatically with a lux sensor in the segment of workspace near the windows where natural lighting is strong enough, so that the lighting strength is not too high and it can reduce the electrical power during the day. The simulation results show that the lighting strength is 402 Lux at 09.00 AM, and 494 lux at 01.00 PM with a low electrical power consumption during the day to 2.92 Watt/m².

The results of this research suggest that the integration of artificial lighting and natural lighting using Lux Sensor system could be optimizing quality and quantity of lighting needs with a low electrical power consumption during the day. Using the sensor system, the area that receive natural lighting does
not need artificial lighting. The lamps will light up in areas with inadequate lighting, so that it can save the consumption of electrical power during the day.

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