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Optimization of Lighting Design in Office Spaces within the Framework of Energy Conservation

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ABSTRACT: The Usman Bin Affan Building first floor is an office building that serves the student. As a student service office, this building must meet lighting standart based on SNI 6197:2020 wich set minimum lighting intensity based of the room function to support visual comfort and work productivity. This research aim to design artificial lighting that complies with SNI standart using the Dialux 4.13 application. The metods used includes recalculating the number of lamps armature, and lighting installation simulation using Dialux software, and compare the lamp power requirements in the initial conditions with the conditions after simulation using Dialux software.the simulation results show that lighting intensity in all rooms of the office building dose not meet the minimum SNI standards 6197:2020. Repairs are made by simulating lamp replacement using Dialux 4.13 application. The simulation results showed that the illumination intensity in each room met the minimum standard. The implications of this study include enhanced visual comfort, increased work productivity, and compliance with lighting regulations in office buildings. After recalculated the number of lamps armature and replacement of fluorescent lamps with LED lamps obtained power consumption under existing conditions is 5440 watt and power consumption under design conditions is 3648 watt, resulting in an efficiency of 33%.

Key Word: *Lighting Intensity, Compare, Calculation, Dialux Simulation 4.13, Efficiency*

1. Introduction

Energy conservation is a series of activities that are the responsibility of the government, regional government, employers, and the community as described in Permen ESDM no. 13 Concerning the saving of electricity, that in order to further increase the use of electricity, it is necessary to use electricity efficiently and rationally without reducing safety, comfort and productivity [1,2]. The increasing issue of climate change and the energy crisis make buildings have to take energy saving measures to reduce the negative effects on the environment. GCBI has established criteria called greenship for green building, including aspects of energy efficiency and conservation that pay attention to saving energy consumption. Saving alternatives are applied with simulation to produce Greenship, this efforts resulted in EEEI savings up to 40% and the maximum achievement of Greenship with a score 36 [3]. To achieve these objectives, optimization of energy use must be done in the lighting system of the office space of building Usman Bin Affan, where the building have a 7 floors that absorbs very high electrical energy. The key to savings in high buildings is to use electricity for AC (Air Conditioner) and lighting that can be pressed as low as possible [4].

Work facilities often placed without any standard arrangement. Employees just put it based on their own comfort or follow design of their workplace. Result survey in this research is identifying work facilities arrangement that in accord to the wish from majority employees. 150 respondents are representing all employees' expectation in arranging the place of their work facilities[5]. Lighting is one of the important aspects of building, especially in the formation of a space. Lighting has an important role to support the function and continuity of activities in it [6,7]. The function of the Usman Bin Affan building first floor as office space requires lighting that is in accordance with SNI standards to provide comfort to people who are active in the room. As a student service facility, it requires a lighting system that complies with the SNI 6197:2020 standard regarding energy conservation in lighting systems, the minimum recommended lighting intensity level is based on the room's function. This standard regulates the minimum lighting level for each room based on its function [8,9]. There are four types of lighting used in office, including: *Ambient lighting* (provides lighting throughout the room and usually installed on the ceiling of the office space), Task lighting (used to illuminate employee's work are, for example a work desk), Accent lighting (provide light to the intended area, for example office coridors or other areas that require lighting so that employees or visitors do not get lost), Natural lighting (it usually comes from windows, glass doors, walls, and the ceiling. This type of light will have of positive impact on employee's but isn't always available whne the sky is cloudy or dark) [10].

The following is the standard of room lighting based on (SNI 6197:2020):

Tabel 1.1 Lighting Room Standart (SNI 6197:2020)

Function of the room	Light Intensity Standard (Lux)
Office:	
Director's Room	350
Office Space	350
Computer Room	150
Meeting Room	300
Drawing Room	750
Archive Room	150
Classroom	250
Library	350

Source : SNI 6197:2020

To calculate the armature number, the total luminous flux is first calculated to get the planned lighting level, using the equation 1.1.

$$Ftotal \quad \frac{E \ x \ A}{K_p \ x \ K_d} \qquad (1.1)$$

then the armature number is calculated using the equation 1.2.

$$N_{total} \quad \frac{F_{total}}{F_1 \ x \ n} \qquad (1.2)$$

Where :
E : Average lighting level (lux)
F_{total} : Total luminous flux of all lights that illuminate the work plane (lumen).
A : Area of work (m^2)
K_p : Usage coefficient
K_d : Depreciation coefficient (depreciation)
N_{total} : Armature Amount
F_1 : Luminous flux of one lamp
N : Number of lights in one armature

2. Methods

The amount of electricity consumption affects the monthly costs so that it is necessary to make efficient use of electricity especially the energy derived from the use of lights. In office spaces in Usman Bin Affan building , there are 2x40 watt TL lamps installed in 4 units so that the total lamp power in each room is 320 watts, this causes a large amount of energy consumption from the side of the lamp. Therefore, efforts need to be made to minimize the use of electrical energy from lights. To get an energy efficient lamp design the Dialux software is used. Dialux software is used for planning and designing light in general projects and education [11]. Dialux continues to be developed to make it easier to communicate with other image programs such as program development *Building Information Modelling (BIM)* for building energy anda comfort analysis [12]. In addition to lighting simulation in the room, Dialux can also be used to simulate outdoor light. Dialux can also be used for road reflection simulations to find evenly distributed lumen and more efficient lighting energy [13]. Dialux can also be used for renewal from old lights to new technologies, namely LED (Light Emitting Diode) [14]. In terms of spot lighting LED light sources are better than those observed in the case of specific area illumination, and almost every case tested the they occupy the second position only slightly more compared to TL lamps [15]. Comfortable office lighting is an important issue for health and work efficiency. From the research result, is was found that during the day in certain months the light is more dazzling. So need evaluate the installation of light. Office lighting is optimized by changing the light source parameters and lamp potition [16]. In addition, one way that can be taken in the context of efficiency of energy use with the Continuous Improvement approach commonly called PDCA (Plan, Do, Check, Action), known as the deming cycle [17]. The steps in the PDCA cycle on energy management systems are:

Plan	**Do**
Setting energy storage targets, determining strategies, identifying the size and responsibility of providing important resources, preparing a plan to encourage	Establish a management structure to maintain an ongoing process, increase the efficiency of technology and procedures so that

employee involvement and requiring good team work skills to be able to measure and ensure minimum energy consumption in the activities carried out.	changes can be implemented..
Action If the changes are deemed successful, they are implemented on a larger scale and the results are maintained. Optimize the strategy by consolidating new energy data and information. Evaluate progress and set new goals	**Check** Review of the level of achievement of targets and the effectiveness of the energy management system and gather ideas using data to analyze wether the changes made have or will make a meaningfull difference

In this research simulation use Dialux 4.13, the large of Fapet office space is 48 m^2 is on the first floor which is used for office building. Most educational buildings (campus) use glass windows that are generally larger than other civils building. Where the area with glass windows affect energy consumption. The parameters considered for the annual energy consumption are the cardinal orientation of the building, thermal compliance and glass quality [18]. There are three glass windows facing the outside of the building whit the size 1x2 m so that during the day some of the rooms facing the outside of the building get natural light due to the reflection of sunlight, and the color of the wall is cream so can reflect sunlight and make the room bright. In this condition during the day light source from lighting can be reduced.

To obtain optimal lighting during the simulation select 10 Philips LED lamp 1x 19 watt. Design of the armature is installated in the middle of space so that all areas in the room can receive light evenly. After the layout was completed a simulation was carried out with a maximum lumen target of 350 lux with the aim providing comfort to the occupants of the room. By replacing four fluorescent lamps 2x40 watt with ten of LED 1x 19 watt, the energy efficiency of the lamps can be calculated from the previous 4x2x40 watt totalling 320 watt to 10x1x19 watt totalling 190 watt. The saving of this room 130 watt, not including other rooms.

In the application of the PDCA cycle for the 'do' and 'act' steps, which have not yet reached the stage of replacing the lights, the results of the research are recommended to be followed up by the authorities in the context of energy conservation, which will have a positive impact in the form of energy savings that will be obtained if the results of this study are implemented. Meanwhile, in the 'check' step, it is hoped that these results can be followed up with SOPs for the use of electrical equipment in each room so that occupants can be more prudent in using the available electrical equipment. The final stage after replacing the lights is to recalculate the power consumption and conduct a survey on the comfort and productivity of the room occupants as a result of the energy conversion that has been carried out.

3. Result

Based on the PDCA cycle (plan, do, check, action), the following steps are taken::

Plan (Planning) Analyze the installation of lights using Dialux software. Before conducting the simulation, mathematical calculations are carried out first by taking samples of the Fapet office space. For the calculation of room lamp needs, use the following assumptions:

- The value of the use coefficient is set at 0,84 whit the value of the coefficient of use for fluorescent lamps in office space (General Electric, 210)
- Depreciation coefficient (Kd) is set at 0,8 according to SNI 03-6575-2000 guidelines for artificial lightings
- The room is form of Fapet office with the following information :
  - Value E = 350 lux.
  - Value A = 48 m^2 (P x L = 6 m x 8 m = 48 m^2)
  - The lamp installed is TL 2x40 Watt.
  - The planned lights are LED Philips 1x19 Watt.
  - Value of luminous flux (F_1) one lamp is 2.300 lumen.
- Mathematical calculations are obtained using the formula :

$$F_{total} = \frac{E\ x\ A}{K_p\ x\ K_d} = \frac{350 \text{ x } 48}{0.84 \text{ x } 0.84} = \frac{16800}{0.672} = 25000\ lumen$$

$$N_{total} = \frac{F_{total}}{F_1\ x\ n} = \frac{25000}{2.300} = 10 \text{ Lamps}$$

The following are the result of Dialux Software simulation:

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(a)Early Condition


(b)Design Condition

Figure 1.1 Simulation Results of the Fapet Office Space


(a)Early condition

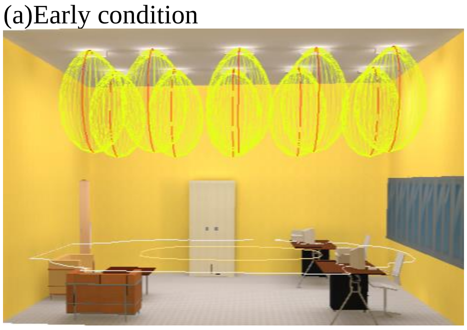
(b) Design Condition

Figure 1.2. Simulation Results of Light Distribution in the Fapet Office Space

In figure 1.2 (a) show the simulation results in the Fapet office space using a 2x40 Watt TL lamp. The number of lights in office space is 8 pieces and the distribution of light intensity in office space ranges from 45 lux to 382 lux. For lux office rooms too large, the standard lighting for office space is a maximum of 350 lux. Therefore the use of this lamp causes waste of energy. In figure 1.2 (b) the simulation results of the design conditions using a 1x19 Watt LED light. The number of lights in Fapet office space is 10 pieces and the distribution of light intensity in the room ranges from 113 lux to 354 lux, so that it has been in accordance with predetermined standards.

Table 1.2. Comparison of Existing Lighting Systems and Design Lighting

No	Office Space	Room Size (m^2)	Excisting Condition	Dialux Design Condition
			Number of Lights Installated (Units)	Number of Lights Installated (Units)
1	Lecture Office of FAI	120	4 2 xTL 40 watt	14 1 xLED 19 watt
2	Administratif Office of FT	120	4 2 xTL 40 watt	14 1 xLED 19 watt
3	IKA Unisma	30	1 2 xTL 40 watt	4 1 xLED 19 watt
4	Iqtishod Office	30	1 2 xTL 40 watt	4 1 xLED 19 watt
5	Unisma Cafe	60	2 2 xTL 40 watt	8 1 xLED 19 watt
6	Administratif Office of FIA	120	4 2 xTL 40 watt	14 1 xLED 19 watt
7	Administratif Office of Faperta	120	4 2 xTL 40 watt	14 1 xLED 19 watt
8	Administratif Office of Fapet	48	4 2 xTL 40 watt	10 1 xLED 19 watt
9	Lecture Office of Fapet	48	4 2 xTL 40 watt	10 1 xLED 19 watt
10	Dean's Office of Fapet	48	4 2 xTL 40 watt	10 1 xLED 19 watt
11	Departemen Chair's Office of Fapet	48	4 2 xTL 40 watt	10 1 xLED 19 watt
12	Departemen Chair's Office of FAI	48	4 2 xTL 40 watt	10 1 xLED 19 watt
13	Dean's Office of FAI	48	4 2 xTL 40 watt	10 1 xLED 19 watt
14	Administratif Office of FAI	48	4 2 xTL 40 watt	10 1 xLED 19 watt
15	Lecture Office of FAI	48	4 2 xTL 40 watt	10 1 xLED 19 watt
16	Dean's Office of FH	48	4	10

			2 xTL 40 watt	1 xLED 19 watt
17	Departemen Chair’s Office of FH	48	4 2 xTL 40 watt	10 1 xLED 19 watt
18	Lecture Office of FH	48	4 2 xTL 40 watt	10 1 xLED 19 watt
19	Administratif Office of FH	48	4 2 xTL 40 watt	10 1 xLED 19 watt
20	Dean’s Office of FMIPA	48	4 2 xTL 40 watt	10 1 xLED 19 watt
17	Departemen Chair’s Office of FMIPA	48	4 2 xTL 40 watt	10 1 xLED 19 watt
18	Lecture Office of FMIPA	48	4 2 xTL 40 watt	10 1 xLED 19 watt
19	Administratif Office of FMIPA	48	4 2 xTL 40 watt	10 1 xLED 19 watt
Power Total (Watt)			5440	3648

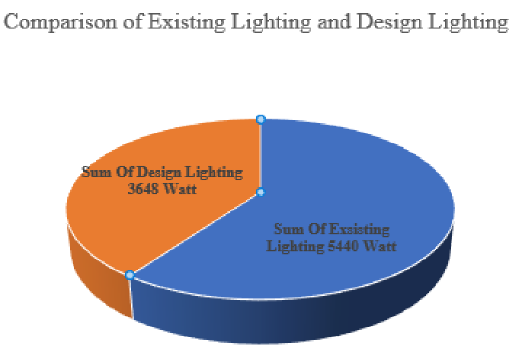

Figure 1.3. Comparison of Existing Lighting and Design Lighting

After calculating the electricity consumption under existing conditions, the power consumption on the first floor of the Usman Bin Affan building was found to be 5440 watts an then power consumption after calculation under design conditions is 3648 watts, resulting of efficiency 33%. The use of LED lights results in savings in electricity consumption and even light distribution.

4. Conclusions

Dialux software provides significant benefits in optimising electricity usage in office buildings. This software is equipped with a selection of lamps from several brands, one of which is Philips, known for its energy-efficient lamps. Simulation with Dialux software under initial conditions with 2x40 watt fluorescent lamps obtained the distribution of light intensity in office space ranges from 45 lux to 382 lux,for lux office rooms too large, the standard lighting for office space is a maximum of 350 lux. After conducting simulations under conditions using a 1x 19 watt Philips LED the distribution of light intensity in the room ranges from 113 lux to 354 lux, so that it has been in accordance with predetermined standards. The importance of lighting optimization is to obtain lighting conditions that are in accordance with SNI standards so as to provide comfort to employees. Comfortable conditions will make employees able to carry out their work to the fullest.

After simulation used Philips LED 1x19 watt achieved power efficiency of 33%. SOP for the use of electrical equipment is very important for controlling the use of electrical equipment in each office space that must be adhered to by all employees and supervised by the person in charge of the local space. If the energy-saving movement is adhered to by all employees, the optimal energy usage conditions will be obtained, resulting in reduced expenditure on electricity costs. These results show that the implementation of LED lighting not only improves the quality of room lighting but also has a positive impact on energy efficiency and reduced operational costs. Therefore, the application of LED technology is the right solution for improving lighting quality and energy efficiency.

This research can be developed to achieve efficient use of electrical energy in all buildings at Unisma, thereby saving electrical energy.

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