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Analysis Illumination of Public Street Lighting on Street Jenderal Sudirman in Pemalang Regency

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Abstract – Public street lighting is a complement to the road and is placed on the left or right side of the road or in the middle of the median of the road to illuminate the road. The public street lighting that has been operating is usually rarely maintained, and problems will arise in the street lighting that can reduce the illumination value. This study aims to determine the illumination value, whether it is the SNI 7391:2008 standard or not, by means of measurements and simulations on the Jenderal Sudirman Pemalang road. measurement using a digital lux meter (AS803) and simulation using the software DIALux evo 10.1. Based on simulation results with the SNI 7391:2008 standard and an illumination value of 11-20 lux, the study recommends replacing the installed lamp with a 70 W LED lamp. The result of this study is that replacing a 70 W LED lamp can reduce the cost of electrical energy consumption by Rp 3,037,338 and reduce electrical power consumption by 2,102.4 kWh.

Keywords: Public street lighting, illumination, measurement, simulation

I. INTRODUCTION

Public street lighting is an addition that is placed on the right or left side of the road, or in the middle of the road median, depending on the condition of the road and the surrounding environment, to help road users see road conditions at night [1]. Good public street lighting needs to use standards and rules that are based on (SNI 7391: 2008) regulates the specification of street lighting in urban areas. Study [3] stated that the road is an important means of transportation; all activities start from here, so the comfort and safety of road users must be considered. Public street lighting installations that are already in operation are usually not maintained often and cause problems with the street lighting, such as damage to lamps, installations that don't work, and guards that don't work. [4] so that the lighting can be dim and affect the value of the illumination. Reducing the lighting level of the lights or dimming the lights can reduce the driver's visibility, which can result in accidents for motorists or other road users [5].

Roads that are busy with traffic certainly really need lighting at a higher level. One of the roads that is quite busy with traffic is a protocol road. The protocol road is the main street in the city, which is the center of the traffic jam. One of the main roads in Pemalang Regency is Street Jenderal Sudirman, where there are economic centers, banks, supermarkets, and schools on the side of the road. The length of Street Jenderal Sudirman is 3.6 km, and the road width is 7 meters from both sides of the road..

The selection of the type of lamp also needs to be considered in street lighting, for example, such as LED and SON-T type lamps, the advantages of LED lamps according to references [6] including having good durability, a fairly high level of energy efficiency (reaching 80–90%), the color of LED lights being brighter than yellow lights, being more energy efficient, not using mercury, being environmentally friendly, having a longer lamp life, and having a smaller size. smaller. However, LED lights have some disadvantages, including the fact that they are quite expensive, cannot penetrate fog or rain, and their durability is affected by ambient temperature. While the advantages of SON-T lamps, according to reference [7] SON-T lamps have a good efficiency of around 90–120 lm/Watt, have a fairly low price, have a color that can penetrate fog and rain, and have a fairly long lamp life of between 12,000 and 24,000 hours. The weakness of the SON-T lamp is that it has a low color rendering that results in color on objects, it requires greater consumption of electrical energy, and its future performance is not that great.

Specifications for public street lighting in urban areas must be well planned for illumination to achieve harmony in planning street lighting. Illumination or lighting intensity is the amount of light that falls on an illuminated surface, measured in lux units [8]. Measurements and simulations are performed to determine whether or not the illumination value (E) on Street Jenderal Sudirman Pemalang complies with SNI 7391: 2008 standards. Measurements are performed using a digital lux meter AS803, and simulations are performed using software Dialux Evo 10.1. This study aims to analyze the value of illumination or the strength of public street lighting according to the desired standard so that the installation of street lighting on Jalan Jenderal Sudirman in Pemalang Regency is in accordance with the rules of SNI 7391: 2008.

II. BASIC OF THEORY

Public street lighting is an addition that is placed on the right or left side of the road, or in the middle of the road median, depending on the condition of the road and the surrounding environment, to help road users see road conditions at night [1]. The function of public street lighting in urban areas is as follows:

1. Road user navigation aids
2. Increase comfort and safety at night
3. Support security and prevent crime
4. Give the street environment beauty

Several classifications of common street lamps can be divided into several classes based on SNI 7391: 2008, namely:

1. Street Lokal, public roads that are passed by vehicles with short-distance travel criteria, low average speeds, and restrictions on the number of entryways
2. Street Arteri Primer, roadways that accommodate local and regional activities, have quite dense traffic, so they must have maximum street lighting.
3. Local and regional activity reservoir roads to support primary arterial roads, such as Jalan Arteri Sekunder: traffic conditions on this route are congested.According to [9], Secondary arterial roads are also called protocol roads in urban areas.
4. Street Kolektor primer and collector paths from the surrounding neighborhood roads that will lead to primary and secondary arterial roads. Moderate, average-speed vehicles and restrictions on the number of access roads
5. Collector paths from surrounding neighborhood roads will lead to primary collector roads, primary and secondary arteries, and Jalan Kolektor Sekunder.
6. Street Lingkungan, roads in rural areas, housing or settlements.

Table 1. Illumination Value on Road Classification

Road Type/Classification	Average illumination (lux)
Sidewalk	1-4
Jalan Lokal:	
Primary	2-5
Secondary	2-5
Jalan Kolektor:	
Primer	3-7
Sekunder	3-7
Jalan Arteri:	
Primer	11-20
Sekunder	11-20
Jalan arteri dengan akses kontrol, jalan bebas hambatan	15-20
Jalan layang, simpang susun, terowongan	20-25

Dialux Evo is software used to simulate and visualize artificial or natural lighting in a room or outdoors in 2 dimensions and 3 dimensions [10].

A lux meter is a tool used to measure the intensity of lighting in a place or area [11]. The lux meter has a light sensor that is sensitive to light, allowing the lighting value in a location or area to be determined. Figure 1 shows the physical form of a digital lux meter

Figure 1. Digital Lux Meter AS803

III. METHOD AND DESIGN

A. Research methods

This study uses the observation method. The observation method is a way to collect data by observing or directly observing in the field or at the study location to find out the situation that occurred. Observations were made to collect data on the length of the road, the width of the road, the type of poles used, the distance between poles, the type of lamp armature, the type of lamp used, and the measured illumination value. The object of this research is Street Jenderal Sudirman Pemalang with a road length ranging from 3.6 km, a road width of 7 meters on both sides of the road section, a median road width of 1 meter, and a height of 1 meter, using double handlebars placed in the middle of the road or in the

road median. The distance between poles is an average of 38 meters, using SON-T and LED lamp types. The type of armature used for SON-T lamps is a type of starfruit with transparent convex glass so that it can reflect light, while the armature LED lights are already in one light package. Street Jenderal Sudirman Pemalang is one of the main roads in Pemalang Regency, which is always busy with traffic, especially at night. Data collection was also carried out through interviews with informants from DISPERKIM (Dinas Perumahan Kawasan dan Pemukiman). The interviews were conducted with the aim of obtaining the required data..

B. Calculation of Light Intensity

Luminous intensity is the light that the light source emits in the light cone [12]:

$$I = \frac{Ø}{\omega} \text{ and } K = \frac{Ø}{P} \quad (1)$$

$$I = \frac{K\ x\ P}{4\omega} \quad (2)$$

Explanation:
I = light intensity (cd)
Ø = Luminous flux (lm)
ω = steridian space angle (sr)
K = Luminous efficacy (lm/W)
P = Electrical power (W)

C. Ornament Handlebar Angle Calculation

Ornament handlebar calculations are used to determine the point of street lighting leading to the middle of the road [13]:

$$t = \sqrt{h^2\ x\ c^2} \quad (3)$$

$$\cos\alpha = \frac{h}{t} \quad (4)$$

Explanation:
h = height of the light point
t = distance of the light to the middle of the road
c = horizontal distance between the lights and the middle of the road

D. Calculation of Illumination or Illumination Strength

Before calculating the illumination or lighting strength at the end of the road, it is necessary to first find the distance from the lamp to the end of the road [14]:

$$r = \sqrt{h^2 + l^2} \quad (5)$$

After getting the value of r, the calculation of the illuminance value or the strength of the illumination can be calculated:

$$E = \frac{I}{r^2}\ x \frac{h}{r} \quad (6)$$

Where:
r = distance from the light point to the end of the road
h = height of the light point
l = the width of the road from the point where the light falls to the end of the road
I = light intensity
E = illumination

E. Calculation of power consumption and cost of Electric Power

Electrical energy is the amount of electrical power used per unit of time [15], the equation to find the amount of energy used by the lamp.

$$P = Daya\ Lampu\ x\ Jumlah\ Lampu \quad (7)$$

$$E_{load} = P_{load}\ x\ t \quad (8)$$

$$Biaya\ Harian = Daya\ (kW) x\ tarif\ dasar \quad (9)$$

Where:
E_{load} = Energi yang diperlukan (Wh/Watt hour)
P_{load} = Daya beban (Watt)

F. Illumination Intensity Measurement

This study uses a measuring tool, namely the lux meter which has good results to be used as a measure of the intensity of lighting (illumination). The measuring instrument used in this study is the AS803 digital lux meter.

G. Simulation Using Dialux Evo 10.1 Software

Before carrying out the simulation, first collect the data needed. After the data is collected and calculations are performed, carry out an illumination simulation in accordance with existing rules. The simulation is carried out using the Dialux Evo 10.1 software. The simulation begins by entering the required data. The data required is the height of the poles, the distance between the poles, the length of the road, the width of the road, and the type of lamp used..

IV. RESULTS AND DISCUSSION

A. Field Conditions

Street Jenderal Sudirman Pemalang is one of the main roads in Pemalang; the situation on this road is always busy every day, especially at night because this road is used by the community for their activities. The length of this road is around 3.6 km, the road width is 7 meters on each section of the road to the west and the road to the east, and the road median is 1 meter wide. Using a type of double handlebar pole with as many as 77 poles having a pole height of 7 meters, the height of the light pole point is 7,5 meters long with handlebar ornaments and 2.1 meters. Using 150-watt SON-T lamps with 82 points of light and 60-watt LED lamps with 72 points of light The SON-T 150 W lamp uses a type of starfruit armature with transparent convex glass so that it can reflect light.

B. Illumination Intensity Measurement

Direct measurements are made to be able to determine the value of illumination at each light point; the measured illumination value is at points a, b, and c for each lamp using a digital lux meter. Power-up lamp On Jenderal Sudirman Street, Pemalang uses a timer

for LED lights and a photocell sensor for SON-T lights. The measured illumination value when the light starts using the timer at 17.30 is 1161 lux. As for the measured illumination value when the light starts up using a photocell sensor of 331 lux.

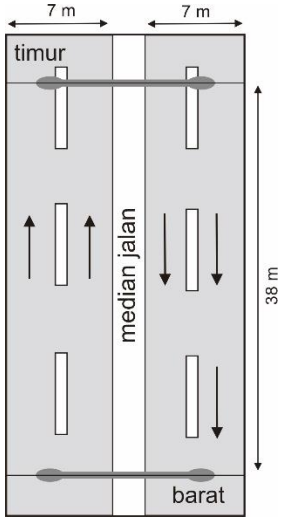


Figure 2. Street Jenderal Sudirman Pemalang Position

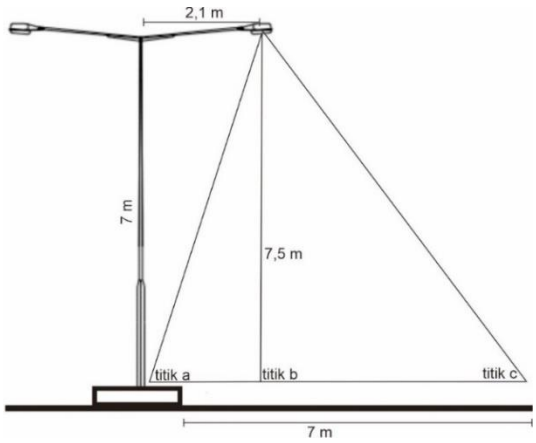


Figure 3. Illumination Measurement at Light Points

Measurements were made at 82 point lights on a SON-T lamp rated at 150 W. On the road side to the west, the highest illumination value is 28.3 lux, while the lowest value is 1 lux. On the road side to the east, the highest illumination value is 26.7 lux, and the smallest illumination value is 1.3 lux. while for the 60 W LED lamp, the measurements were carried out at 72 points on the 60 W LED lamp. On the road side to the west, the highest illumination value is 37.3 lux, and the lowest value is 1 lux; on the road side to the east, the highest illumination value is 39.7 lux, and the smallest illumination value is 1 lux. In measuring the 150 W SON-T and 60 W LED lamps, there are several lamps that meet the SNI 7391:2008 standard; some lamps have an illumination value above 20 lux, whereas under the SNI 7391:2008 rules in urban areas, the standard value is 11–20 lux.

C. Light Intensity Calculation Results

Using equation 2, it is possible to calculate the light intensity value; according to the lamp datasheet, the magnitude of the SON-T lamp flux value is 14,500 lm and the lamp power is 150 W. Previously, the light efficacy value was searched with equation 1, and the light efficacy value was 96.67 lm/w. After calculating the light intensity using equation 2, the value is 1,154.73 cd. While the LED lamp has a flux value of 7,104 lm, which corresponds to the LED lamp datasheet, with a lamp power of 60 watts, the light efficacy value is obtained using equation 1 of 118.4 lm/w, and the LED light intensity value is 568,605 cd..

D. Ornament Handlebar Angle Calculation Results

The calculation of the angle of inclination of the ornamental handlebars is meant so that the point of the light fixture can point to the middle of the road because it can affect the illumination value, so beforehand it is necessary to know the distance from the lamp to the middle of the road. From the data obtained, the handlebar ornament length is 2.1 meters and the road median width is 1 meter. Figure 4 is a calculation of the handlebar angle ornament using equations 3 and 4.

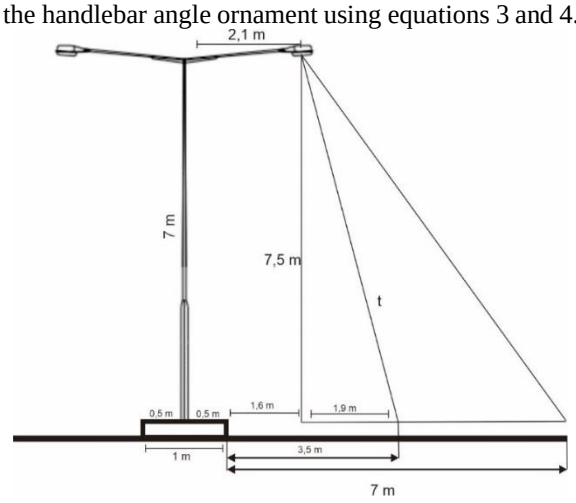


Figure 4. Ornament Handlebar Angle Calculation

In calculating the angle of the handlebar ornaments, it can be seen that the angle of inclination of the handlebar ornaments to be directed to the middle of the road is 14.06°, with t = 7.73 meters

E. Results Calculation of Illumination

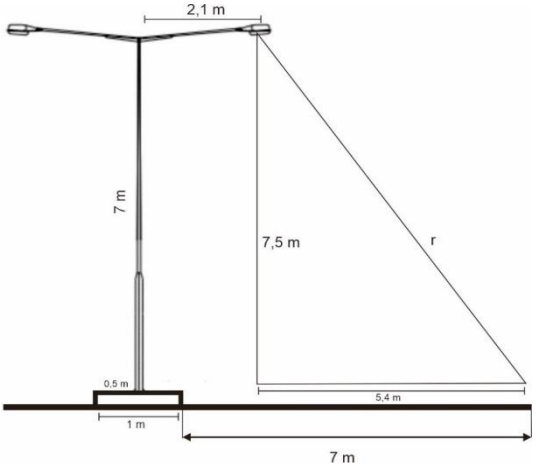


Figure 5. Calculation of the distance from the point of light to the end of the road

Using equation 5, you can calculate the illumination value at the end of the road. With h = 7.5 m and l = 5.4 m, you get an r value of 9.24 m. After getting the value of r and calculating the illumination value using equation 6, the illumination value for the 150 W SON-T lamp is 10,969 lux, while for the 60 W LED lamp it is 5,401 lux..

F. Calculation results of PJU Power Consumption and Power Rates

In general street lighting, Jalan Jenderal Sudirman Pemalang uses two types of lamps with different powers; a total of 154 points of light are used; for 150 watt SON-T lamps, there are 82 points, and there are 72 points for 60 watt LED lamps. The total consumption of electric power used by street lighting on Jalan Jenderal Sudirman Pemalang uses equations 7 and 8 as shown in the following description:.

Table 2. Power Consumption of 150 W SON-T Lamps and 60 W LED

Lamp Type	Number of Light Points	Total Energy Power Consumption Per day	Total Energy Power Consumption Per Month
SON-T 150 Watts	82 points	199,44 kWh	5.983.2 kWh
60 Watt LEDs	72 points		

Public road lighting on Street Jenderal Sudirman Pemalang is included in the P-3/TR class, so a basic usage rate of IDR 1.444,70 per kWh is based on the standards set by PT. PLN. Using equation 9, the electric power consumption on 150 Watt SON-T lamps and 60 Watt LED, the cost to be paid for one month is IDR 8.643.929,04..

Table 3. Power Consumption of 70 W LED Lamps

Lamp Type	Number of Light Points	Total Energy Power Consumption Per day	Total Energy Power Consumption Per Month
70 Watt LEDs	154 points	129,36 Kwh	3.880,8 kWh

By replacing the 150 W SON-T lamps and 60 W LED with 70 W LED lamps for street lighting on Street Jenderal Sudirman Pemalang, and Street Jenderal Sudirman Pemalang, including the P-3/TR category, a basic usage fee of IDR 1.444,70 / kWh in accordance with the standards set by PT. PLN, referring to (9) so that the consumption of electric power on a 70 Watt lamp results in a fee that must be paid for one month of IDR 5.606.591,7.

G. Simulation Results Using Dialux Evo 10.1

The simulation was carried out using Dialux Evo 10.1 software. The simulation results for a 150 Watt SON-T lamp showed an average illumination value of 18,46 lux; this value complies with SNI 7391: 2008, which is set at 11–20 lux. Figure 6 shows the simulation results of a 150 Watt SON-T lamp. The simulation results show the following illumination values::

E_{AV} = 18,46 lux
E_{min} = 3,63 lux
$E_{v.\ Min}$ = 0,26 lux

1) The average illumination value obtained is 18,46 lux, the minimum value is 3,63 lux, and the minimum average value is 0,26 lux. These results are based on the SNI 7391:2008 standard, which has a standard value of 11–20 lux for secondary arterial roads in urban areas or main roads.

The simulation results of a 60-watt LED lamp show an average illumination value of 10,70 lux. Figure 7 shows the simulation results of a 60-watt LED lamp. The simulation results show the following illumination values:

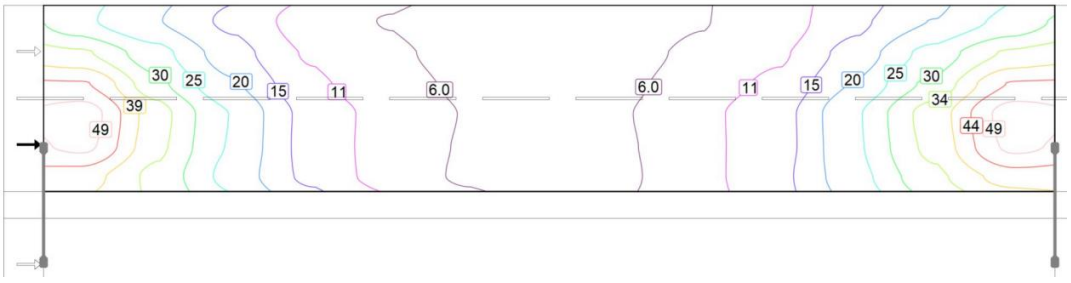
E_{AV} = 10,70 lux
E_{min} = 2,64 lux
$E_{v.\ Min}$ = 0,09 lux

2) The average illumination value obtained is 10,70 lux, the minimum value is 2,64 lux, and the minimum average value is 0,26 lux. These results are not yet based on the SNI 7391:2008 standard, which has a standard value of 11–20 lux for secondary arterial roads in urban areas or protocol roads.

The simulation results of a 70-watt LED lamp show an average illumination value of 14,18 lux. Figure 8 shows the simulation results of a 70-watt LED lamp. The simulation results show the following illumination values:

E_{AV} = 14,18 lux
E_{min} = 3,37 lux
$E_{v.\ Min}$ = 0,35 lux

The average illumination value obtained is 14,18 lux, the minimum value is 3,37 lux, and the minimum average value is 0,34 lux. These results are in accordance with the SNI 7391:2008 standard, which has a standard value of 11–20 lux for arterial secondary roads in urban areas or protocol secondary roads.



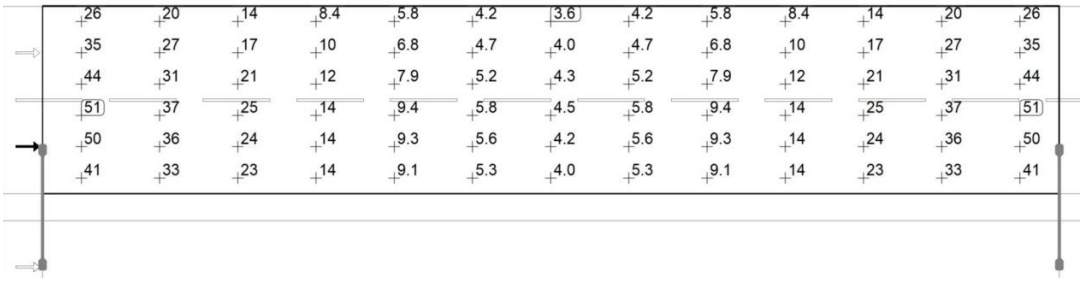


Figure 6. SON-T 150 W Lamp Simulation Results

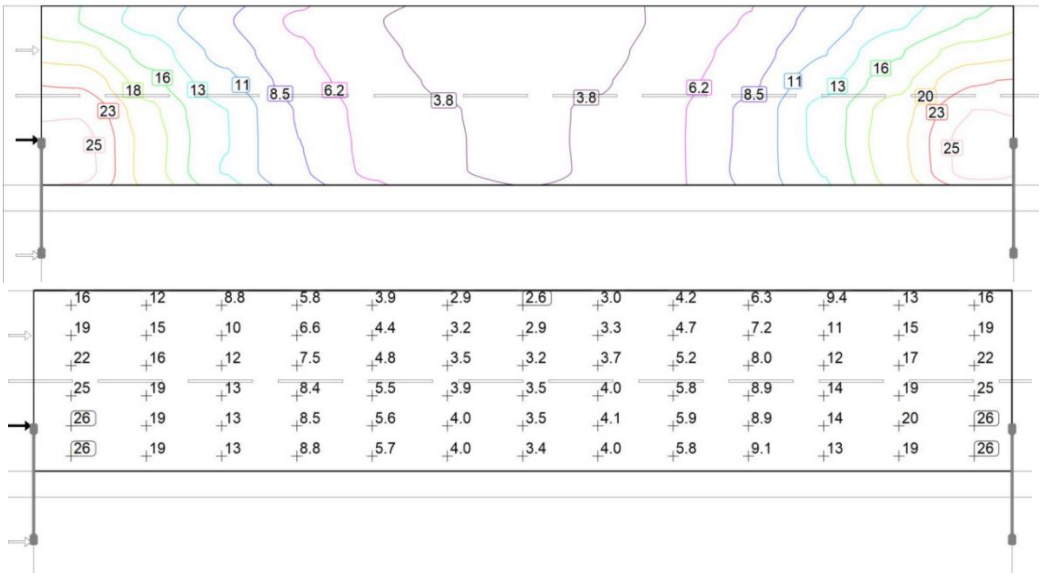


Figure 7. 60 W LED Lamp Simulation Results

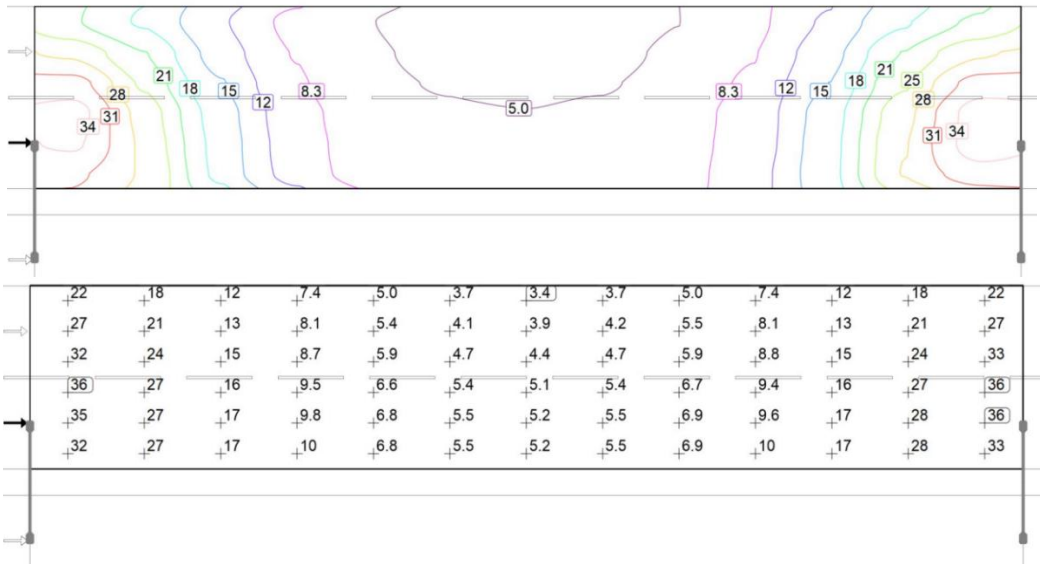


Figure 8. Simulation results of a 70 W LED lamp

Comparison of the results of calculations and simulations of illumination or lighting strength can be seen in table 4 below:

Table 4. Comparison of Simulation and Calculation of Installed Lights

Lamp Type	Simulation	Calculation
SON-T 150W	18,46 lux	10,969 lux
60W LED	10,70 lux	5,401 lux

The difference in results between the simulation and calculations for installed lamps or 150 W SON-T lamps and 60 W LED is caused by several factors, including decreased lamp performance, lamp life, lamp evaporation, and a dull armature, which can affect street lighting. Therefore, it is recommended to replace the 70 W lamp because, based on the simulation results, the 70 W LED lamp is in

accordance with the SNI 7391:2008 standard with an illumination value of 14, 18 lux, while the standard illumination value in urban areas is between 11 and 20 lux.

V. CONCLUSION

The results of the analysis and simulation of public street lighting on Street Jenderal Sudirman Pemalang can be concluded. Measuring the intensity of illumination using a digital lux meter (AS806), a SON-T 150 Watt lamp, and LED 60 Watt lamps, there are only 21 lamps with an illumination value between 11 and 20 lux that meet standard SNI 7391: 2008, while 133 lamps have an illumination value above 20 lux. The calculation of the angle of the handlebar ornaments to point to the middle of the road is 14.06°, the light intensity of the SON-T 150 Watt lamp is 1.154,73 cd, and the 60 Watt LED lamp is 568,605 cd. The electric power consumption of 150 W SON-T and 60 W LED lamps for one month is 5.983 kWh; the electric power consumption of 70 W LED lamps for one month is 3.880 kWh. Simulation using Dialux Evo 10 software.

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