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Comparison of 250 Watt Sodium SON Lamp and 168 Watt LED for Lighting on Gading Tutuka Highway

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ABSTRAK

Tingkat pencahayaan adalah ukuran kuantitatif dari sejauh mana cahaya yang ada dalam suatu area atau ruang tertentu. Ini mengacu pada seberapa terang atau redupnya suatu lingkungan, dan diukur dalam unit cahaya yang disebut lux. Tujuan penelitian ini adalah untuk melakukan analisis tingkat pencahayaan pada lampu eksisting di ruas jalan raya Gading Tutuka berjenis SON 250 watt pada sore dan malam hari untuk mengetahui apakah sudah sesuai dengan standar BSN SNI 7391 2008 dengan data berupa jenis tiang yang akan digunakan, jenis lampu, dan jumlah total daya yang dipasang. Setelah memperoleh data intensitas cahaya, jarak antar tiang, jumlah tiang, dan intensitas cahaya didapat hasil perhitungan nilai intensitas cahaya yaitu 11,16 lux dan kemerataan sebesar 0,19 sehingga dapat dikatakan memenuhi nilai tersebut memenuhi standar. Kemudian lampu sodium SON 250 watt dibandingkan dengan lampu LED 168 watt, lampu sodium memiliki daya total sebesar 19.000 watt, sedangkan lampu LED memiliki daya total sebesar 12.768 watt. Dari sisi biay,a lampu sodium membutuhkan biaya sebesar Rp. 59.290.488 pertahun, sedangkan LED membutuhkan biaya pertahun lebih rendah yaitu sebesar Rp. 39.844.404. Namun berdasarkan nilai Tingkat pencahayaan didapat lampu LED 168 watt memiliki nilai intensitas cahaya sebesar 10,23 lux dengan kemerataan 0,44 dimana nilai ini tidak sesuai dengan standar sehingga jika mempertimbangkan hal tersebut lampu eksisting SON 250 watt dapat dikatakan masih layak untuk digunakan.

Kata kunci: *Pencahayaan, Ruas Jalan, Kemerataan, Penerangan, Intensitas cahaya*

ABSTRACT

Lighting level is a quantitative measure of the extent of light present in a given area or space. It refers to how bright or dim an environment is, and is measured in units of light called lux. The purpose of this research is to analyse the lighting level of the existing lights on the Gading Tutuka highway section of the SON 250 watt type in the afternoon and evening to find out whether it is in accordance with the BSN standard SNI 7391 2008 with data in the form of the type of pole to be used, the type of lamp, and the total amount of power installed. After obtaining data on light intensity, distance between poles, number of poles, and light intensity, the results of the calculation of the light intensity value are 11.16 lux and evenness of 0.19 so that it can be said that the value meets the standard. Then the 250 watt SON sodium lamp is compared to the 168 watt LED lamp, the sodium lamp has a total power of 19,000 watts, while the LED lamp has a total power of 12,768 watts. In terms of cost, a sodium lamp costs Rp. 59,290,488 per year, while LED requires a lower annual cost of Rp. 39,844,404. However, based on the value of the lighting level, the 168 watt LED lamp has a light intensity value of 10.23 lux with an evenness of 0.44 where this value is not in accordance with the standard so that if you consider this, the existing 250 watt SON lamp can be said to be still suitable for use.

Keywords: *Lighting, Section, Highway, uniformity, Light Intensity*

1. INTRODUCTION

Street lighting is part of a road complementary building that can be placed / installed on the left / right of the road and or in the middle which is used to illuminate the road and the environment around the road needed including road intersections, overpasses, bridges and underground roads. Public Street Lighting (PJU) is a facility that is needed in every city to improve or optimise road equipment facilities in the form of street lighting devices in order to create safety, security, order, and smooth traffic and convenience for road users in traffic so as to minimise the occurrence of accidents [1], as well as for construction workers at night [2]. This lighting is also crucial for highways that have tunnels because lighting that is not up to standard can trigger a decrease in driver concentration [3]. Due to the importance of street lighting for motorists, the handling of PJU lamp damage should be improved, because there are still many PJU lights that are not functioning or the lights are off so that the road becomes dark [4]. PJU helps road users in travelling at night and during the day. Night lighting is the most important public service because it affects human activities and can improve safety in transport and pedestrians. According to [5] 50% of road accidents occur at night due to inadequate levels of road lighting, especially at vehicle speeds exceeding 70 km/h [6]. PJU lights are very influential on visibility when driving at night, if the condition of the lights does not work it can interfere with the safety of the driver. This is a guideline for Road Supervisors in the installation and placement / arrangement of lighting as a complement to city roads that function according to their purpose [7].

Gading Tutuka highway in Soreang, Bandung Regency is a busy road with a high volume of vehicles every day, especially during peak hours such as in the morning during school or work hours, and in the afternoon during work hours. The lack of lighting can cause various problems, such as drivers not being able to see the road clearly, especially during rainy or foggy conditions. This can increase the risk of traffic accidents, especially if the driver cannot see traffic signs or vehicles in front of them [7]. Therefore, it is necessary to analyse the distribution of light on the Gading Tutuka highway in the afternoon and evening to determine how evenly light is distributed along the road. By knowing the results of this analysis, appropriate action can be taken to improve road lighting in areas that are less bright, so as to improve the safety and comfort of Gading Tutuka highway users in the afternoon and evening. According to [8] optimisation of highway lighting can be done by maximising the average illuminance level on the road surface, maximising the uniformity of lighting along the road, minimising glare on road users generated by the lighting system and minimising the operating costs of the lighting system.

Currently the lighting on the Gading Tutuka highway uses 250 Watt sodium lamps but this type of lamp has the disadvantage of high energy use, one study shows that energy consumption for lighting purposes in Iran can consume 30%-50% of total energy consumption [9] so it is necessary to look for more efficient alternative energy, one of which is with LED type lamps [1][10]–[12]. According to [13] wet road conditions also affect the level of lighting better because it can provide a lot of light reflection so as to provide additional lighting conditions.

Based on the above background, the purpose of this research is to analyse the suitability of 250 watt SON sodium lamp with lighting on Gading Tutuka highway based on SNI using digital luxmeter type YF-170. Then analyse alternative lighting on Gading Tutuka highway using LED lights in terms of energy use, lighting level and lighting uniformity so that it is expected to provide recommendations to improve the quality of the lighting system on Gading Tutuka highway.

2. METHODOLOGY

2.1. Standard Used for Lighting Quality

The lighting quality of a road is measured by either the illuminance or luminance method. However, it is easier to use the illuminance method, as it can be measured directly on the road surface using a light intensity meter. The normal lighting quality according to the type/classification of road function is determined as in Table 1 below. [7].

Tabel 1. Lighting Quality Standard

Road Clasification	Iluminance		Luminance			Glare Limitation	
	E Average (lux)	Uniformity G1	L Average (cd/m^2)	Uniformity VD	Uniformity VI	G	TJ (%)
Sidewalks	1- 4	0,10	0,10	0,40	0,50	4	20
Local roads: - Primary - Secondary	 2 - 5 2 - 5	 0,10 0,10	 0,50 0,50	 0,40 0,40	 0,50 0,50	 4 4	 20 20
Collector roads: - Primary - Secondary	 3 - 7 3 - 7	 0,14 0,14	 1,00 1,00	 0,40 0,40	 0,50 0,50	 4 – 5 4 - 5	 20 20
Arterial roads: - Primary - Secondary	11 - 20 11 - 20	0,14 – 0,20 0,14 – 0,20	1,50 1,50	0,40 0,40	0,50 – 0,70 0,50 – 0,70	5 - 6	10 - 20
Arterial roads with access control, motorways freeway	15 - 20	0,14 – 0,20	1,50	0,40	0,50 - 0,70	5 - 6	10 - 20
Freeway Elevated road, Interchange, Tunnel	20 – 25	0,20	2,00	0,40	0,70	6	10

2.2 Calculation

The data obtained is then calculated and compared with the standard using the following formulas. First, calculation conducted to obtaining line current, equation (1) is used as below [14]:

$$I = \frac{P1\,\emptyset}{VLN\ .\cos\emptyset} \tag{1}$$

I = Line Current (A)
P1∅ = Power (W)
V_LN = Neutral phase voltage
Cos ∅ = power factor

After obtaining the current results of each segment, then proceed to find the voltage drop by using equation (2) as below [14]:

$$VD = \frac{2.L.I.ZL}{VLN} \text{ x } 100\ \% \qquad (2)$$

VD = Voltage drop
L = Length (m)
I = Current absorbed by the load (A)
ZL = Impedance (Ω)
VLN = Neutral phase voltage (V)

Then proceed to calculate the light intensity using equation (3) as below [15]:

$$I = \frac{\varphi}{\omega} \qquad (3)$$

I = Light intensity
∅ = Light flux in lumen (lm)
ω = Angle of space in steridian (sr)

After obtaining the results of light intensity, then proceed to calculate the illumination at the end point of the road using equation (4) as below [15]:

$$r = \sqrt{h^2 + l^2} \qquad (4)$$

$$E = \frac{1}{r^2} x \frac{h}{r}$$

h = Pole height (metres)
l = Road width (metres)
r = Distance from the lamp to the end of the road

After obtaining the illumination results at the end point of the road, then proceed to calculate the uniformity of light using equation (5) as below [15]:

$$Light\ uniformity = \frac{E_{min}}{E_{av}} \qquad (5)$$

E_{min} = Lowest illuminance level analysed
E_{av} = Average illuminance level in the analysed area

After obtaining the results of light uniformity, then proceed to calculate the electrical energy using equation (6) as below [15]:

$$Eload = Pload \text{ x } t \qquad (6)$$

Then proceed to calculate the cost of electrical energy consumption used by using equations (7) below [15]:

Usage cost = Number of poles x lamp power x lighting hours (7)

3. RESULT AND ANALYSIS

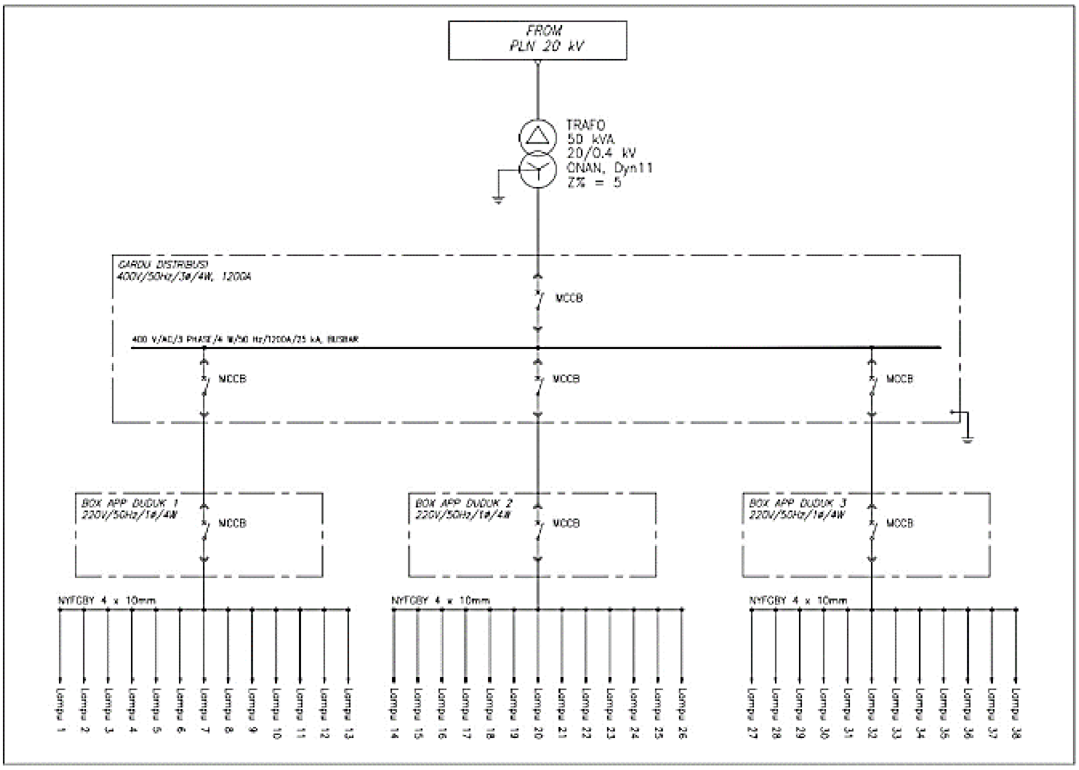

Figure 1. Single line diagram of lighting electrical in Gading Tutuka Highway

Gading Tutuka Highway has a road width of 17 metres with a road length of 1113 metres and a distance between poles of ± 30 metres. Public street lighting on the Gading Tutuka Soreang highway section has 38 poles, with a pole height of 9 metres, 76 lamps with a double arm pole type, 3 app boxes with 3 x 13200 VA electric power by having 3 panel boxes, 6 sections where each panel box includes 13 poles 26 lamps. Figure 1 showed single line diagram of lighting electrical in Gading Tutuka highway.

3.1. Calculation on 250 Watt Sodium SON Lamp

First, calculation conducted to find power of each section, the current of each section, the drop voltage, and the size of the MCB used. The results of the calculation on the 250 watt Sodium SON lamp can be seen in Table 2.

Table 2. Calculation Results on 250 Watt Sodium Son Lamp

Panel Number	Section	Number of lamps	Power of each section (W)	Current of each section (A)	Drop Voltage (%)	MCB size (A)
1	A	12	3000	5,06	0,22	10
	B	14	3500	5,9	0,25	10
2	C	16	4000	6,75	0,32	10
	D	10	2500	4,22	0,15	6
3	E	14	3500	5,9	0,24	10
	F	10	2500	4,22	0,14	6

After obtaining the data as in table 2, then the calculation of Light intensity, illumination to the end of the road, uniformity of light, and calculation of electricity consumption per year for SON lamp conducted by using equation (3) and (4).

$$I = \frac{27500}{12,56} = 2189\ Cd$$

$$E = \frac{2189}{144,96} x \frac{9}{12,04} = 11,17\ lux$$

Referring to table 1, the illumination value is in accordance with the provisions of the SNI for arterial road needs of 11-20 lux so that based on the calculation results, the 250 watt SON lamp which has an illumination value of 11.17 lux is in accordance with the standard.
To determine the value of Light uniformity, Dialux evo software was used with the results as shown in Figure 2.

Street 1

Roadway 2 (C1)

m	1.500	4.500	7.500	10.500	13.500	16.500	19.500	22.500	25.500	28.500
21.200	81.92	62.87	44.93	41.65	43.10	43.10	41.65	44.93	62.87	81.92
18.533	78.17	72.51	60.06	51.99	53.99	53.99	51.99	60.06	72.51	78.17

Maintenance value, horizontal illuminance [lx] (Value chart)

	E_{av}	E_{min}	E_{max}	g_1	g_2
Maintenance value, horizontal illuminance	31.3 lx	6.06 lx	81.9 lx	0.19	0.07

Figure 2. Dialux Evo Software Simulation Results on 250 watt SON sodium lamp

Using equation (5), the calculation of uniformity based on data obtained from dialux evo software was carried out with the results as below.

$$Uniformity = \frac{6,06}{31,3} = 0,19$$

Referring to the SNI standard, this result is in accordance with the standard for the needs of the arterial road class which is between 0.14 - 0.20 so that with an evenness value of 0.19 it can be said that the existing lights already have an evenness of light according to the standard.
The operating pattern of public street lighting has been set for 17.00 WIB - 05.00 WIB, so the lights are on for 12 hours. The following is the calculation of the energy used when using 250 Watt SON lamps.

Eload = (250 x 76) x 12 = 228.000 Wh = 228 kWh/day

In one month the electrical energy used is as follows.

Eload per month = 228 kWh x 30 hari = 6.840 kWh/month

Usage cost = Power (kW) x operation hours x tariff P-3/LV

= 38 x 0,25 kW x 12 hours x 30 days x Rp.1444,70/kWh = Rp.4.940.874,-

Usage cost per year = 12 x Rp. 4.940.874 = Rp. 59.290.488,-

The electricity cost per year that must be paid for 250 watt SON lamp is Rp. 59.290.488,-

3.2. Calculation of LED 168 Watt Lamp

The next calculation conducted to find power of each segment, the current of each segment, the drop voltage, and the size of the MCB used by LED 168 Watt Lamp. 168 Watt LED lamp was chosen because it has a lumen value specification that is close to the existing 250 Watt SON lamp. The results of the calculation can be seen in Table 3.

Table 3. Calculation Results of 168-watt LED Lamp

Panel number	Section	Number of lamps	Power of each section (W)	Current of each section (A)	Drop Voltage (%)	MCB size (A)
1	A	12	2.016	3,09	0,13	4
	B	14	2.352	3,60	0,15	6
2	C	16	2.688	4,12	0,19	6
	D	10	1.680	2,57	0,09	4
3	E	14	2.352	3,60	0,14	6
	F	10	1.680	2,57	0,09	4

After obtaining the data as in table 3, then the calculation of light intensity, illumination to the end of the road, uniformity of light, and calculation of electricity consumption per year for LED lamp conducted by using equation (3) and (4).

$$I = \frac{25200}{12,56} = 2006\ Cd$$

$$E = \frac{2006}{144,96} x \frac{9}{12,04} = 10,23\ lux$$

Referring to table 1, the illumination value of LED lamps does not comply with the provisions of SNI for arterial road needs which is 11-20 lux. To determine the value of Light uniformity, Dialux evo software was used with the results as shown in Figure 3.

m	1.500	4.500	7.500	10.500	13.500	16.500	19.500	22.500	25.500	28.500
14.417	67.75	62.99	50.72	39.18	31.08	31.08	39.18	50.72	62.99	67.75
13.250	73.42	69.04	54.49	40.36	31.04	31.04	40.36	54.49	69.04	73.42
12.083	77.92	74.28	56.20	39.72	30.31	30.31	39.72	56.20	74.28	77.92
10.917	77.62	73.34	52.79	36.66	28.37	28.37	36.66	52.79	73.34	77.62
9.750	67.12	61.71	44.57	31.33	25.32	25.32	31.33	44.57	61.71	67.12
8.583	52.39	46.22	32.87	24.94	21.85	21.85	24.94	32.87	46.22	52.39

Maintenance value, horizontal illuminance [lx] (Value chart)

	E_{av}	E_{min}	E_{max}	g_1	g_2
Maintenance value, horizontal illuminance	49.2 lx	21.8 lx	77.9 lx	0.44	0.28

Figure 3. Dialux Evo Software Simulation Results on 168 watt LED Lights

$$Uniformity = \frac{21,8}{49,2} = 0,44$$

Referring to the SNI standard, this result does not comply with the standard for arterial road class requirements which is between 0.14 - 0.20.

The following is the calculation of the energy used when using 186 Watt LED lights.

Eload = (168 x 76) x 12 = 153,216 Wh = 153 kWh/hari

In one month the electrical energy used is as follows.

Eload per month = 153 kWh x 30 days = 4590 kWh/month

Cost usage per month = 38 x 0,168 kW x 12 hours x 30 days x Rp.1444,70/kWh
= Rp.3.320.267,-

Cost usage per year = 12 x Rp. 3.320.267,- = Rp. 39.844.404,-

The electricity cost per year that must be paid for LED 168 watt lamp is Rp. 39.844.404,-

3.3 Comparative Analysis of the calculation results of 250 Watt SON lamps and 168 Watt LED
Table 4 is a comparison of the existing conditions of 250 Watt SON lamp with 168 watt LED lamp.

Table 4. Comparison of 168 watt SON lamp with 168 watt LED lamp

Parameters	SON 250 watt Lamp	LED 168 watt lamp
Lighting power	250 Watt	168 Watt
Lamp brightness level	27.500 lm	25.230 lm
Efficacy	100 lm/watt	150 lm/watt
Overall power of the section	19.000 watt	12.768 watt
Current of the whole section	32,05 A	19,55 A
Drop voltage	1,32 %	0,79 %
Cable type	NYY 1,5 mm^2/per section	NYY 1,5 mm^2/ per section
Light intensity	2.188 cd	2.005 cd
Illumination at street endpoints	11,17 lux	10,23 lux
Uniformity of light	0,19	0,44
Electrical energy	228 kWh/day	153 kWh/day
	6.840 kWh/month	4.590 kWh/month
Usage cost per month	Rp. 4.940.874	Rp. 3.320.267
Usage cost per year	Rp. 59.290.488	Rp. 39.844.404

The existing lighting conditions of Jalan raya gading tutuka soreang Bandung Regency have 76 points with 38 poles using 250 watt SON lamps. The light intensity of 250 watt sodium SON lamps has a value according to SNI standards with a value of 11.17 lux, comparison between 250 watt sodium SON lamps on the Gading Tutuka highway section with 168 watt LED lights, 250 watt sodium lamps have a power of 19,000 watts, while 168 watt LED lights have a lower power of 12. 768 watts and sodium lamp costs have a total price of Rp. 59,290,488 per year, while LEDs have an annual cost of Rp. 39,844,404 with a cheaper difference than sodium lamps, resulting in savings in electrical energy consumption of Rp. 19,446,084. However, in terms of light intensity and uniformity of light obtained in 168 watt LED lamps are not in accordance with SNI standards so that in this case 168 Watt LED lamps are not suitable to be applied in Gading Tutuka highway section.

4. CONCLUSION

Based on the results of the analysis that has been done, it can be concluded that the existing 250 Watt SON type lamp obtained the results of the calculation of the lighting level of 11.7 lux and the uniformity of light of 0.19 where these results are in accordance with the specified standards. However, the drawback of this type of lamp is the use of energy which is quite high, causing a cost of Rp. 59,290,488 per year so that in this study a comparison was made with 168 Watt LED lamps which have lumen value specifications that are close to existing lamps. In 168 Watt LED lamps, it is obtained that energy use causes lower costs, namely Rp. 39,844,404. However, in terms of the results of the calculation of the lighting level obtained by 10.23 lux and evenness of light of 0.44 where the results are in accordance with the specified standards so that it can be stated that the existing SON 250 Watt lamp is still recommended for use when compared to the 168 Watt LED lamp.

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