



Isolux Curve and Polar Photometry of LED Public Street Lighting for Green Lighting

I Wayan Jondra¹, Putu Agus Mahadi Putra¹, Kadek Amerta Yasa¹,
I Made Purbhawa¹, Ni Made Amustini¹, and I Made Sudana²

¹ Electrical Engineering Department, Politeknik Negeri Bali, Bali, Indonesia

² Mechanical Engineering Department, Politeknik Negeri Bali, Bali, Indonesia
wjondra@pnb.ac.id

Abstract. Public Street Lighting has an important role in improving the safety, security, and comfort of road users, as well as for temple surroundings. This study aims to analyze the illuminance distribution of LED street lighting installed on a 6-meter pole height, with a 0.5-meter ornament arm and an armature tilt angle of 10°. Mathematical, statistical and photometric analysis were used in this study. Light intensity data samples were taken from 10 lamp points, there are four observation points for each lamp, namely points A, B, C, and D. The results show that the average illuminance at point A is 82.8 lux, point B is 44.8 lux, point C is 40 lux, and point D is 13.1 lux. The maximum illuminance occurred at Point A (closest to the light source center), while the minimum occurred at Point D. Based on the calculation results and visualization of the Isolux curve, the distribution of light shows an asymmetric pattern with a tendency for light to spread forward (forward throw). The peak light intensity occurs at an angle of 55° to 60° relative to nadir. These photometric characteristics make the luminaire suitable for roadway applications (Type II/III), exceeding the requirements of European Standard EN 12464-2: Lighting of work places – Part 2: Outdoor work places, as the road primarily serves to illuminate the temple environment. The results of the study found that the design is efficient and represents green lighting, as the minimum illuminance requirement of 20 lux at target point C is achieved.

Keywords: Illuminance, Lighting, Street

1 Introduction

Public Street Lighting is a vital need to improve the quality and functionality of the street infrastructure, particularly during nighttime conditions (Boyes et al., 2021; Chalfin et al., 2022; Welsh & Farrington, 2008). Street lighting significantly improves driving safety by increasing visibility for drivers, motorcyclists, cyclists, and pedestrians, thereby reducing traffic accidents (Ishak & Ayob, 2025; Braun & Lengyel, 2023; Burattini et al., 2025). Well-illuminated roads enable users to identify obstacles and other vehicles more effectively, leading to safer travel.

In addition to improving traffic safety, public street lighting enhances security by deterring criminal activities (Ishak & Ayob, 2025; Kim et al., 2024). Areas with

adequate public lighting tend to create a greater social control and sense of surveillance, helping both local communities and road users feel more secure.

Given the importance of its function and benefits, street lighting needs to be planned and evaluated carefully. Several aspects must be considered when planning street lighting, including technical, safety, economic, and environmental considerations, to ensure optimal, efficient lighting system performance and compliance with standards (Rusu et al., 2021). Lighting planning must consider the type of road to be illuminated, such as primary arterial roads, secondary arterial roads, collector roads, local roads, neighborhood roads, tourist areas, offices, or residential areas. The higher the road class, the higher the lighting level and uniformity requirements. However, this study is more specific, as the function of roads extends beyond traffic, including parking, passenger boarding and disembarkation, and the preparation of ceremonial infrastructure required within the building, thus requiring specific lighting. The level of illumination of a light source (E) in lux units is directly proportional to the light intensity (I) in candela units and inversely proportional to the square of the distance between the light source and the illuminated object (r) in meters, as explained in the formula below (Rabaza et al., 2018).

$$E = \frac{I}{r^2} \quad (1)$$

Based on Equation (1) above, it can be explained that the higher the lighting intensity required for an object, the lighting source with a stronger light intensity is needed, at a certain distance. To increase the illuminance intensity, the light source can be moved closer to the object being illuminated.

$$\Phi = I \times \Omega \quad (2)$$

Based on Equation (2) the light intensity in lux can be compared to the luminous flux in lumens (Φ), as affected by the distribution angle. For LED street lighting with illumination distribution degree of 120° , the angle of distribution (Ω) can be calculated with Equation (3) below.

$$\Omega \approx \pi \text{ sr} \quad (3)$$

To achieve stronger lighting, more electrical power is required. However, in today's increasingly expensive energy era, efforts are needed to achieve an effective and efficient lighting system. This study no longer uses street lighting such as SON-T and similar, which tend to be energy-intensive and short-lived (Kurniawan & Kurniawan, 2022; Kabir et al., 2023; Rabaza et al., 2018). The object of this research is replacing SON-T lamps with lighting-emitting diode (LED) lamps. LEDs were chosen because they produce stronger and longer-lasting light.

Installing street lighting requires careful planning to achieve the required lighting intensity. Selecting the right lamp will lead to achieving the desired street lighting. However, this research goes beyond planning; it also includes lamp selection and subsequent evaluation of the installed lamps to determine their performance. It is hoped

that the results of this study will shed light on green lighting efforts in line with the goal of the Politeknik Negeri Bali, a vocational education institution as a Center of Excellence for Green Tourism Technology.

In this study, quantitative data were obtained in the field by measuring the distance of objects from the lamp pole, the height of the lamp armature, the angle of the lamp armature, and the intensity of light at designated points as primary data. Secondary data were obtained from lamp specifications. The research data were processed mathematically, statistically, and graphically to obtain evaluation results for the street lighting installation at the study site.

2 Methodology

This study is applied research to solve the problem of public street lighting at Pura Luhur Dwijawarsa Temple which has been inadequate and wasteful of energy. The object of this research consists of 10 points of the public street lighting system. The measurements were conducted using a lux meter and a measuring tape.

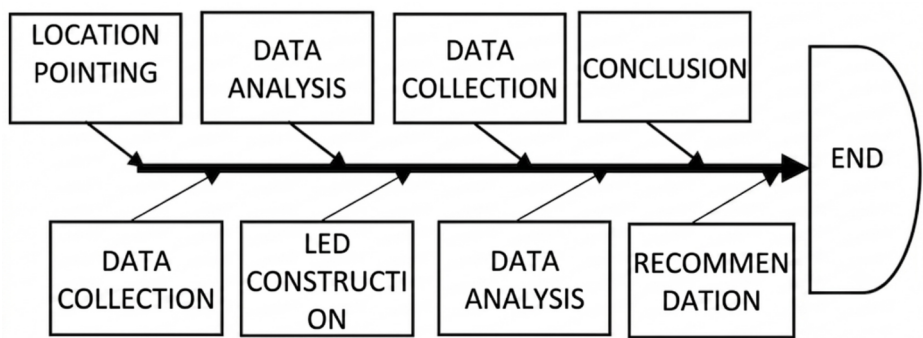


Figure 1. The Process of This Study

As shown in Figure 1, this research examines the replacement of gas lamps with LED lamps, starting from planning, construction and analysis of lighting systems with LED lamps, primary data in this study were taken by direct measurements in the field regarding distance in meters, light intensity in lux units, while secondary data were obtained from the specifications of LED lamps that have been installed (Alvarez et al., 2022; Ishak & Ayob, 2025; Kurniawan & Kurniawan, 2022; Sikora & Woźniak, 2021). The measurement data were processed and analyzed quantitatively to become a planning document, followed by construction data processed quantitatively through mathematical and statistical calculations. Finally, the research results are presented descriptively and analytically in this paper.

3 Result and Discussion

3.1 Result

Design Phase. To calculate the lumen requirements for public street lighting from a minimum target of 20 lux at point C, it can be calculated by looking at Figure 2 below. Figure 2 presents an image of a public street lighting lamp pole, which contains 1 lamp armature with a height of 6 meters and an inclination angle of 10° .

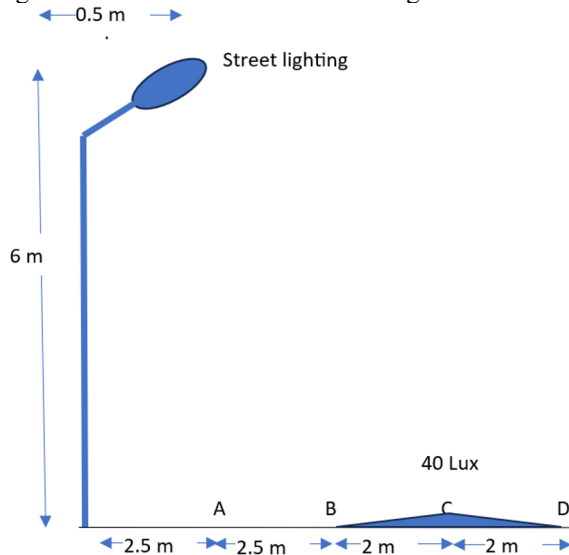


Figure 2. Schematic Setup of the LED Public Street Lighting Installation

Based on the Figure 2 and Equations (1), (2) and (3) the lighting armature can be calculated as describe at below.

The distance of armature lighting to point C can be calculated at below.

$$r_C = \sqrt{6^2 + 6.5^2} = 8.846 \text{ m} \quad (4)$$

The source of lighting intensity (I) can be calculated at below.

$$I = Er^2 = 20 \times 8.846^2 = 1,565 \text{ candelas} \approx 4,915 \text{ lumens} \quad (5)$$

To obtain an armature lamp with a light intensity of 4,915 lumens, an undisclosed brand, with a power of 50 watts, was chosen, with intensity up to 5,000 lumens.

Evaluation Phase. Evaluation by taking data on illumination values on objects at points A, B, C and D, which are illuminated by 10 points of 50-Watt LED street lighting armatures, measured using a lux meter. The measurement results are as stated in the Table 1 below.

Table 1. Measured Illuminance Values Across 10 Lamp Poles

Point	Illuminance (Lux) per Lamp Pole Number									
	1	2	3	4	5	6	7	8	9	10
A	83.1	82.5	83.2	82.6	82.5	82.4	83.1	82.3	83.3	83
B	44.8	44.8	45.1	45.3	44.8	43.9	44.3	45.2	44.8	45
C	42.1	43.2	38.5	40	41.2	42	40.5	36	35.8	40.7
D	13.5	12.3	11.8	12.2	13.1	12.4	13.3	14.2	15	13.2

The data as shown in Table 1 is a table of measurement results at points A, B, C, and D, resulting in 40 data sets. These 40 data sets were statistically analyzed, resulting in the results shown in Table 2 below.

Table 2. Statistical Analysis of Measured Illuminance

Point	Mean (Lux)	SD (Lux)	Min (Lux)	Max (Lux)	CV (%)
A	82.80	0.37	82.3	83.3	0.45 %
B	44.80	0.42	43.9	45.3	0.94 %
C	40.00	2.51	35.8	43.2	6.28 %
D	13.10	0.98	11.8	15.0	7.49 %

3.2 Discussion

Compliance with Standards. The results of illuminance measurements at ten armature points show an average value of 82.8 ± 0.37 lux at point A, 44.8 ± 0.42 lux at point B, 40.0 ± 2.51 lux at point C, and 13.1 ± 0.98 lux at point D. By obtaining an illumination value at point C with an average of 40 Lux with a minimum of 35.8 Lux, this has met the requirements for urban road lighting because the value is above 20 lux as European Standard EN 12464-2: Lighting of work places – Part 2: Outdoor work places, and point A with an average value of 82.8 lux with a minimum of 82.3 has met the requirements as a loading and unloading location because the value is above 50 lux(Kim et al., 2024; Raslan, 2025). The low coefficient of variation values at points A and B indicate a very good level of lighting uniformity, while points C and D show higher variations due to being in the transition area and the limit of the armature light distribution. Based on these data, point C has the largest illuminance variation (SD = 2.51 lux), while point A has the smallest variation (SD = 0.37 lux). This indicates that the most stable light distribution occurs near the center of the light distribution and varies increasingly in areas farther from the light source.

Photometric and Isolux Diagrams. The data as presented in Table 2 is reprocessed using formulas (2) and (3), then the photometric and Isolux diagrams of the 50-Watt LED armature can be drawn as shown in the image below. The 2D polar photometric

diagram of LED street lighting with Tilt 10° is made based on the average illumination at points A, B, C and D, the values of light intensity in lux units, light intensity in lux units by considering the radian angle, converted to candela, so that the light intensity is obtained at each angle. The radius indicates candela, while the direction indicates the beam angle, all measured lux values are compared with the angle (Madjidi et al., 2015; Mukherjee, 2017). All lux values that have been obtained are connected with a smooth line, thus forming a diagram as shown in the image below.

Figure 3 shows a two-dimensional polar photometric diagram, for a public street lighting LED armature installed on a 6-meter-high pole, 0.5-meter ornament length, 10-degree armature tilt, with asymmetric light distribution, the unit of light intensity is candela.

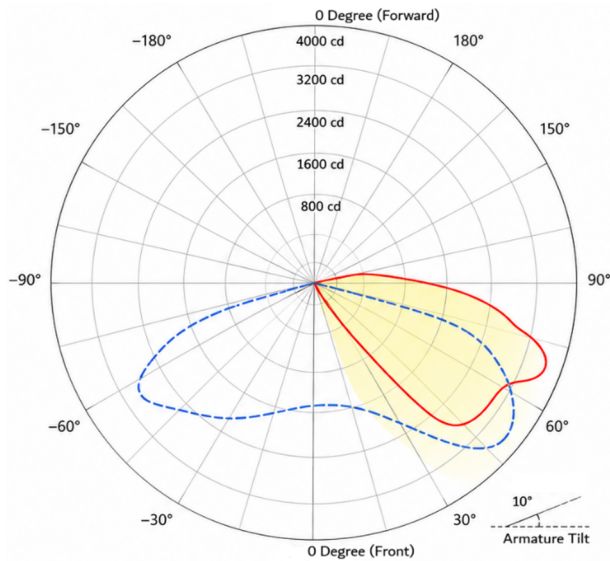


Figure 3. 2D Polar Photometric Diagram of LED Street Lighting with 10° Tilt

The red line (C0-C180) is the light distribution of the lamp that extends along the road, while the blue dotted line (C90-270) is the light distribution of the lamp across the road. The peak light intensity is at an angle of 60 degrees to front. This armature is very suitable for street lighting with the target illumination at point C. Based on Figure 3, an Isolux image can be made as presented in Figure 4 below.

The steps to draw an Isolux curve are done by placing the illumination value at point A as the midpoint, while the foot of the pole is the zero degree, which is made the Y axis with the lux value (Madjidi et al., 2015; Mukherjee, 2017). The values of points at A, B, C and D are plotted on the X axis. Create a circular image where point A is the center of the circle, each circle has a scale value range of 10 Lux, except the last circle is made with a scale of 5 Lux, so that the Isolux image is created as below.

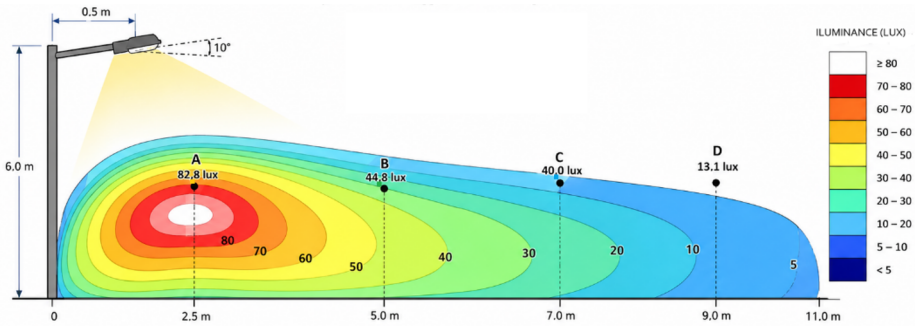


Figure 4. Isolux Diagram of LED Street Lighting with 10° Tilt

An Isolux curve is an area with the same illuminance (lux) level for the same color. Figure 4 explains this: A line of 82.8 means all points on white colors have an illuminance of approximately 82.8 lux; B line of 44.8 means all points on dark yellow have an illuminance of approximately 44.8 lux; At the center of road as C line of 40 means all points on the green area have an illuminance of approximately 40 lux, D line of 13.1 means all points on blue have an illuminance 13.1 lux.

4 Conclusion

The calculations carried out in the design have recommended a lamp with a light intensity of 4,915 lumens, so a 50 Watt LED lamp armature with a light intensity of 5,000 lumens was chosen. Post-installation evaluations revealed that the luminaire exceeded technical expectations, achieving an illuminance level of 40 lux at Point C. This value fully satisfies the minimum 20 lux threshold specified in European Standard EN 12464-2 (Lighting of Work Places – Part 2: Outdoor Work Places). The selection of a 50 Watt LED lamp provides efficient and green lighting as shown in the Isolux diagram, the optimal illuminance distribution is confirmed through both the Isolux diagram and the two-dimensional polar photometric diagram.

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References

- Alvarez, R., Duarte, F., Frenchman, D., & Ratti, C. (2022). Sensing lights: The challenges of transforming street lights into an urban intelligence platform. *Journal of Urban Technology*, 29(4), 25–40. <https://doi.org/10.1080/10630732.2022.2082825>
- Boyes, D. H., Evans, D. M., Fox, R., Parsons, M. S., & Pocock, M. J. O. (2021). Street lighting has detrimental impacts on local insect populations. *Science Advances*, 7(35), Article eabi8322. <https://doi.org/10.1126/sciadv.abi8322>
- Braun, F., & Lengyel, J. (2023). Energy saving potential of traffic-regulated street lighting. *Sustainability*, 15(8), Article 6750. <https://doi.org/10.3390/su15086750>

- Burattini, C., Bisegna, F., & Santoli, L. D. (2025). Street luminance and night-time walking comfort: A new perspective for the urban lighting design. *Journal of Urban Design*, 30(1), 52–70. <https://doi.org/10.1080/13574809.2024.2351914>
- Chalfin, A., Kaplan, J., & LaForest, M. (2022). Street light outages, public safety and crime attraction. *Journal of Quantitative Criminology*, 38(4), 891–919. <https://doi.org/10.1007/s10940-021-09519-4>
- Ishak, S. N. A. N. M., & Ayob, M. F. (2025). LED street lighting in Malaysia: Performance evaluation and barriers to implementation. *Journal of Architecture, Planning and Construction Management*, 15(2), 211–219. <https://doi.org/10.31436/japcm.v15i2.1032>
- Kabir, H., Noman, A. A., Afiq, A. A., Raju, R. H., & Hasan, M. N. (2023). Design and implement IoT-based intelligent manageable smart street lighting systems for future smart city. *Engineering Proceedings*, 56(1), Article 147. <https://doi.org/10.3390/ASEC2023-15535>
- Kim, K. H., Hwang, T., & Kim, G. (2024). The role and criteria of advanced street lighting to enhance urban safety in South Korea. *Buildings*, 14(8), Article 2305. <https://doi.org/10.3390/buildings14082305>
- Kurniawan, R., & Kurniawan, I. W. (2022). Fostering energy efficiency through street lighting system improvement: A case study of city-level in Indonesia. *Indonesian Journal of Energy*, 5(2), 96–104. <https://doi.org/10.33116/ije.v5i2.146>
- Madjidi, F., Mohammadi, J., Khosravi, Y., & Abasi, F. (2015). Application of geospatial information system for the study of illuminance in carpet weaving workshops in Bokan, Iran. *Journal of Human, Environment, and Health Promotion*, 1(1), 12–18. <https://doi.org/10.29252/jhehp.1.1.2>
- Mukherjee, S. (2017). Simulation of daylight and artificial lighting integration and energy savings. *Environmental and Earth Sciences Research Journal*, 4(1), 17–22. <https://doi.org/10.18280/eesrj.040104>
- Rabaza, O., Molero-Mesa, E., Aznar-Dols, F., & Gómez-Lorente, D. (2018). Experimental study of the levels of street lighting using aerial imagery and energy efficiency calculation. *Sustainability*, 10(12), Article 4365. <https://doi.org/10.3390/su10124365>
- Raslan, H. M. (2025). Optimizing street lighting design of new cities to enhance the health and wellness of inhabitants. *Sustainable Transport and Livability*, 2(1), Article 2413559. <https://doi.org/10.1080/29941849.2024.2413559>
- Rusu, A. V., Gălățanu, C. D., & Livinț, G. (2021). Average luminance calculation in street lighting design: Comparison between BS-EN 13201 and RP-08 standards. *Sustainability*, 13(18), Article 10143. <https://doi.org/10.3390/su131810143>
- Sikora, P., & Woźniak, M. (2021). Intelligent street lighting in a smart city concepts—A direction to energy saving in cities: An overview and case study. *Energies*, 14(11), Article 3018. <https://doi.org/10.3390/en14113018>
- Welsh, B. C., & Farrington, D. P. (2008). Effects of improved street lighting on crime: A systematic review. *Campbell Systematic Reviews*, 4(1), 1–51. <https://doi.org/10.4073/csr.2008.13>

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