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METHOD OF LIGHTING PERFORMANCE ASSESSMENT IN HERITAGE AREA: CASE STUDY OF KAYUTANGAN PEDESTRIAN CORRIDOR

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Abstract.

Outdoor lighting serves as a crucial element for visibility and plays a vital role in creating a comfortable and safe atmosphere in public spaces, particularly along pedestrian corridors. Lighting is an integral part of urban design that can enhance the identity of an area and support public activities, especially at night. This article presents a literature review aimed at identifying the most suitable method for evaluating outdoor lighting performance along the Kayutangan pedestrian corridor in Malang, following the revitalization of the Kayutangan Heritage Corridor. This review employs a literature-based approach to establish a foundation for future research on measuring light intensity at multiple strategic points along the pedestrian area. The findings from this review aim to identify methods for assessing the quality of existing lighting and determine whether the lighting meets SNI, CIE, and IESNA standards, while fostering a positive public perception. This study will further support research that selects sample measurement points based on the function of active spaces within the Kayutangan Heritage Corridor. The literature review provides insights into how outdoor lighting can support or hinder public interaction at night. The results of this review are expected to provide a comprehensive understanding of the standards and measurements applied to outdoor lighting in public areas, particularly the pedestrian zones within the Kayutangan Heritage Corridor.

Keywords: outdoor lighting, lighting measurement methods, heritage area, Kayutangan pedestrian corridor

1. Introduction

Kajoetanganstraat is a historical area and the first commercial corridor in Malang City. It has the character of an "Indische Empire" building, which was developed in 1914 (Erine et al., 2022). Between 1930 and 1940, numerous commercial buildings were constructed in this area, featuring facades in the *Nieuwe Bouwen* architectural style (Ridjal et al., 2016). Kayutangan underwent a series of fluctuations characterized by both prosperity and decline in its historical evolution. Previously, it was described as a dormant and tranquil locale during nocturnal hours, exhibiting diminished visual appeal. (Azis et al., 2019), and then revitalized again in 2020 and designated as a Heritage Area (Yusran, 2020). Drastic changes can be felt during the development of the Kayutangan Heritage Corridor, which was previously a quiet area until revitalization efforts were carried out in 2020. The area became increasingly busy, and the local economy began to recover slowly. The development of the Kayutangan area has begun to become increasingly busy at night, accompanied by the addition of lighting features along the

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pedestrian path. The nocturnal luminescence exhibits a positive correlation with economic advancement, as it indicates the magnitude of commercial undertakings. (Duan et al., 2020; Hu et al., 2023). The illumination during the nocturnal hours plays a significant role in fostering a vibrant economic atmosphere and enhancing the overall efficacy of commercial operations within metropolitan regions. (Lin et al., 2023). The right lighting design can increase visitor activity (Petty, 2007) and add to the aesthetics of urban spaces (Lin et al., 2023). Research (Traboulsi et al., 2023) found that the quality of lighting in historic areas supports the continuity of visitor activities at night. Streets with high pedestrian traffic and high activity levels, such as business districts or tourist areas, can significantly benefit from better lighting. It can also be seen that improving nighttime lighting in the Kayutangan Heritage Corridor can increase visitor and economic activity at night. However, it is essential to remember that the Kayutangan Heritage Corridor is a Heritage Area and a critical point in the study of night lighting, making it a valuable site for further research.

2. Literature Review

The effectiveness of outdoor pedestrian lighting depends on several factors, including the technical specifications of the lighting equipment, environmental conditions, and individual subjective perceptions. These variables collectively influence how pedestrians experience safety, visibility, and comprehensive comfort in outdoor environments. Understanding these components is critical to developing an effective Public Space Lighting (PSL) system.

Street lighting plays a vital role in creating pedestrian comfort and safety. The illumination and evenness of light greatly influence the perception of safety, where illumination levels of 5–17 lx are sufficient for safety, and 25–35 lx are ideal for optimal quality. (Liu et al., 2022). Additionally, a color temperature of 4000–5500 K with warm tones is preferred as it increases the perception of security. (Liu et al., 2022). Luminance from environmental elements, such as the sky and sidewalks, contributes to visual intensity and comfort. (Berardinis et al., 2015). Lighting design in heritage areas requires adaptation to local aesthetics and culture to support livability and community involvement. (Traboulsi et al., 2023). External factors, such as traffic density and vegetation, also influence road users' perception of lighting and comfort. (Liu et al., 2022). From a social perspective, lighting quality impacts perceptions of safety and visual comfort, influencing nighttime activities. (Casciani, 2020; Liu et al., 2022). In addition, effective lighting increases social interaction and a sense of safety, creating a friendlier and more comfortable environment for people. (Casciani, 2020).

The installation of street lighting involves several important considerations, including the height of the poles, the distance between them, the angle of the emitted light, and the intensity of the lighting. Collectively, these elements influence the efficiency of lighting systems and their implications for road safety and energy utilization. The height of the pole affects the reach and distribution of light, with taller poles generally providing more uniform lighting over a larger area. Some previous research topics on this topic include the following:

a. Pole height and distance
   - The height of the lamp post affects the reach and intensity of the light. Taller light poles can cover a wider lighting area, but can cause increased light pollution if not managed properly. (Bommel, 2015; Slamet & Budiono, 2023)

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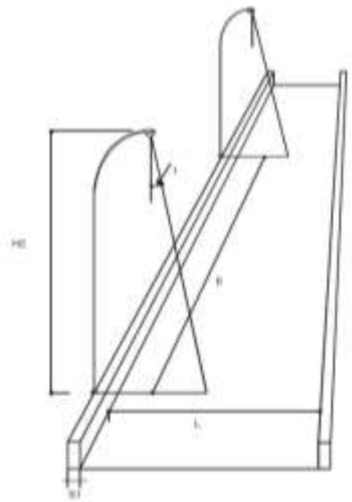
- The distance between poles must be optimized to ensure equal lighting intensity and minimize dark areas. Generally, the distance is approximately 40 meters, but this can vary depending on the road's width and the height of the posts. (Slamet & Budiono, 2023)

b. Beam angle
- The angle of the emitted light has a considerable impact on the effectiveness of street lighting and can be adjusted to reduce glare and light trespassing (Bommel, 2015).
- Adjusting the pole tilt angle can increase the uniformity and coverage of the LED luminaire (Saadouni et al., 2024)

c. Light Intensity
- Lighting intensity, measured in lux, must be adequate to ensure visibility and safety. Light intensity modifications can be applied according to traffic density and applicable environmental factors.(Slamet & Budiono, 2023)

2.1 Street lighting standards according to regulations

The Indonesian National Standard for street lighting, SNI 7391:2008, outlines specific requirements for street lighting systems to ensure adequate visibility and energy efficiency. This standard encompasses parameters such as lamp height, lamp spacing, lamp power, and illumination level.



Explanation :

H	= height of the light pole
L	= width of the roadway, including the median (if present)
E	= spacing interval between light poles
S1 + S2	= projection of the lamp's light cone
S1	= distance from the light pole to the curb edge
S2	= distance from the curb edge to the farthest illumination point
I	= lighting inclination angle

Figure 1. Planning and Placement of Street Lighting
Source: (Badan Standardisasi Nasional, 2008)

Main Parameter SNI 7391: 2008 consists of three factors: the height and distance of the light source, the lighting level, and the lamp power, as shown in Table 1 below. Setting the height and distance of the lights is very important to ensure even lighting distribution on the road. Regulations determine the height of poles and the distance between lights to support lighting efficiency, as shown in Figure 1 below. (Eriyadi et al., 2019; Zakri et al., 2023)Lighting standards also determine average and minimum thresholds to maintain visibility and safety in the road environment. (Eriyadi et al., 2019). The choice of lamp power is carefully regulated to balance energy consumption and lighting effectiveness. (Sutopo et al., 2020).

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Table 1. Basic lighting quality on sidewalks according to SNI 7391: 2008

Road type/classification	Illuminati		Luminasi			Glare Limits		Uniformity Ratio	
	E average (lux)	Uniformity	L average (cd/m2)	Uniformity		G	TJ (%)	Area	
		g1		VD	VI			Settlement	Urban
Pedestrian way	1-4	0,10	0,10	0,40	0,50	4	20	10:1	4:1

Source: (Badan Standardisasi Nasional, 2008)

Explanation:
g1: E min/E maks ;VD: L min/L maks ;VI: L min/L rata-rata ;G: glare ;TJ : Glare threshold

2.2 International street lighting standards

International street lighting standards, such as those established by the Illuminating Engineering Society of North America (IESNA) and the International Commission on Illumination (CIE), play a crucial role in providing guidelines for lighting systems that promote pedestrian safety and comfort. These standards provide guidance on regulating the distribution, intensity, and uniformity of street lighting—critical factors in enhancing visibility and minimizing glare for pedestrians.

The CIE standard is widely adopted internationally and is a foundation for regional guidelines, such as those used in Europe. It accommodates various environments, including urban areas, residential streets, and pedestrian pathways. (Bommel, 2015). CIE classifies roads into several categories based on density and traffic conditions, using a numbering system from P1 to P6. The classification considers multiple parameters, such as speed limits, traffic density, road users, parking areas, environmental lighting, and object recognition (facial recognition), as shown in Table 2 below.

Table 2. Lighting Classes for Pedestrian Areas and Low-Speed Traffic Zones

Lighting Class	Average Horizontal Illuminance *Eh*.av in lx	Minimum horizontal Illuminance *Eh*.min In lx	An additional requirement if facial recognition is necessary		Uniformity Ratio (Eh.av / Eh.min)
			Minimum vertical Illuminance *Ev, min* In lx	Minimum Cylindrical Illuminance *Esc, min* In lx	
P1	15	3,0	5,0	3,0	3:1
P2	10	2,0	3,0	2,0	4:1
P3	7,5	1,5	2,5	1,5	4:1 – 5:1
P4	5,0	1,0	1,5	1,0	5:1 – 6:1
P5	3,0	0,6	1,0	0,6	6:1
P6	2,0	0,4	0,6	0,4	8:1

Notes:

- To maintain light uniformity, the **average illuminance** should not exceed **1.5 times** the value specified for each class.

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- **High color rendering** enhances facial recognition and improves overall visibility.

Source: (CIE Technical Committee 4-44., 2010)

Exceptional lighting standards for various urban settings include residential streets, communal spaces, industrial roads, central business districts, shopping centers, pedestrian pathways, access routes, and cycling routes. A methodology encompassing all of these aspects ensures that every element of urban illumination is considered and serves as a guiding framework for urban lighting that aligns with functionality, safety, and aesthetic appeal. (CIE Technical Committee, 2022).

The Illuminating Engineering Society of North America (IESNA) establishes lighting standards for public environments, emphasizing enhanced safety, comfort, and efficiency. These standards are crucial for developing lighting systems that meet technical specifications and user perceptions. IESNA standards prioritize uniformity, appropriate lighting levels, and glare mitigation to ensure pedestrian safety and comfort. The following section outlines the key components of these standards and their implications for public space lighting. (IESNA, 2000) As shown in table 3 below.

Table 2. Lighting Classes for Pedestrian Areas Based on Conflict Zones (IESNA, 2000)

Lighting Class	**Traffic composition**	**Maintained Illuminance Values for Walkways/Bikeways**			**Uniformity Ratio (Eh.av / Eh.min)**
		Average Horison illuminance E_H lx/fc	**minimum vertical illuminance at 1.5 m (4.9 ft.) E_{vmin} lx/fc**	**E_{avg} /E_{min}**	
Low Pedestrian Conflict Area	Rural/ Semi-Rural area	2.0/0.2	0.6/0.06	10.0	1: 10
	Low-density Residential	3.0/0.3	0.8/0.08	6.0	1:6
	Medium-density Residential	4.0/0.4	1.0/0.2	4.0	1:4
Medium Pedestrian Conflict Area	Pedestrian	5.0/0.5	2.0/0.2	4.0	1:4
High Pedestrian Conflict area	Pedestrian	10.0/0.1	5.0/0.5	4.0	1:4
	Pedestrian and Vehicle	20.0/0.2	10.0/1.0	4.0	1:4

Source: (IESNA, 2000)

IESNA, the Illuminating Engineering Society of North America, states that existing environmental lighting conditions will significantly influence the amount of lighting in outdoor areas, the nature of activities being performed, the speed of movement, and the materials used. Consequently, these elements must be considered when conceptualizing external lighting systems, particularly in meeting the requirements for adequate light levels.(Manurung, 2009)

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The CIE standards emphasize broader criteria and focus on aesthetics, resulting in higher energy consumption, while the IESNA standards are more centered on efficiency and conservation. (Shi et al., 2013). Nevertheless, the International Commission on Illumination (CIE) and the Illuminating Engineering Society of North America (IESNA) strive to enhance public and pedestrian lighting. Their differences highlight the balance between visibility, energy efficiency, and environmental sustainability. The ongoing harmonization of these standards suggests a future scenario where lighting techniques can achieve better universal consistency, thereby leveraging the beneficial characteristics inherent in both systems.

2.3 Outdoor Lighting in Indonesia

Most street lighting systems in Indonesia are often inefficient due to the selection of unsuitable lamps. A survey indicates that approximately half of these systems are unmeasured, resulting in excessive energy consumption that complicates energy management and cost control. (Kurniawan & Kurniawan, 2022). As cities develop, the demand for effective street lighting increases. Planning must strike a balance between urban development and ensuring that new areas are adequately illuminated, thereby supporting both residential and commercial activities. Research by (Abdullah et al., 2021) This effort aims to develop lighting solutions that minimize environmental impact while providing sufficient illumination. This research aims to enhance visibility on roads and sidewalks by optimizing the layout and design of street lighting. Using practical approaches and efficient lighting design methods, it incorporates photometric measurements, which involve analyzing light distribution and intensity to ensure optimal lighting. The design process is conducted through simulations using Dialux software, which helps visualize the impact of different lamp configuration schemes. This software can design and optimize lighting systems, including street lighting. In studying the redesign of public street lighting in Indonesia, Dialux plays a significant role in optimizing lighting design. In the study by (Hompas Jefrey I., 2018) This examined street and pedestrian lighting in the center of Manado City; actual measurements were taken using evaluations and Dialux Evo simulations. The results showed differing comparisons between technical measurements and user perceptions of lighting quality. While some areas met the SNI standards, users perceived the lighting as inadequate. The study revealed that certain zones have different lighting needs. The discrepancy between user perceptions and technical measurements can be attributed to several factors, including malfunctioning lights, the absence of lamp posts at specific points, and external light sources that affect the environment.

The study recommends implementing regular maintenance and evaluation of the lighting system. It also suggests aligning lighting principles with each road's characteristics and specific functions to enhance users' safety and comfort. In special zones studied by (Hompas Jefrey I., 2018), particularly those with historical significance, it is recommended that specific lighting be designed that reflects the area's history and is recognized by the community, in line with the functions of historical and artistic tourist areas.

Lighting in historical areas must preserve historical and aesthetic elements while meeting visual needs. (Rakonjac et al., 2022)A historical area like Batroun, Lebanon, a

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cultural heritage site renowned for its distinctive architectural landmarks, necessitates an exploration of artificial lighting that can enhance walkability in regions of historical significance. (Traboulsi et al., 2023).

The relationship between activity and lighting in public spaces is crucial for enhancing security, comfort, and overall livability. Studies show that effective lighting encourages more frequent use of public areas and improves users' feelings of safety and comfort. (Rakonjac et al., 2022). While effective lighting can boost activity and safety, excessive or poorly designed lighting can lead to light pollution and disrupt local ecosystems. Therefore, urban lighting design must adopt a balanced approach. (Poulsen et al., 2012).

Lighting in public spaces, mainly historical areas, is crucial for preserving cultural identity while enhancing user comfort and safety. Today, lighting also plays a significant role in environmental preservation and energy efficiency. (Beccali et al., 2017; Bullough, 2013). Artificial lighting in historical areas should enhance architectural values and cultural identity, illuminating the space and creating a profound connection to the past. It helps raise awareness of the beauty and diversity of public spaces visible in the city, encouraging a rediscovery and re-examination of public and urban environments at night. (Valevičius & Levickaite, 2011).

3. Method

The method used to review this article is a systematic review aimed at identifying measurement standards suitable for pedestrians within the context of the Kayutangan Heritage Corridor. A theoretical review was conducted through existing literature and standards to discuss standards for measuring outdoor lighting, particularly in pedestrian areas. This was then compared using a comparative method between existing regulations and practices occurring in Indonesia.

The results of this analysis will be compared and evaluated, and then aligned with case studies in the pedestrian corridor area of Kayutangan, following these steps:

1) Comparing existing national and international lighting regulations to develop outdoor lighting measurement standards in Indonesia, particularly in pedestrian areas.
2) Review the measurement methods practitioners employ in planning outdoor lighting in Indonesia.
3) Unstructured direct observation of the characteristics of the Kayutangan Heritage pedestrian corridor to find a proposal for a suitable standard method for measuring outdoor lighting.

4. Result and Discussion Result

Public space lighting measurement standards are essential to investigate. In this context, several standards are commonly used to measure outdoor lighting. This article discusses the SNI (Indonesian National Standard) and international standards, including CIE and IESNA. The study reveals similarities and differences in the factors considered in outdoor

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lighting measurements. However, the lighting variables emphasized across these standards are generally consistent.

4.1 Variables for Measuring Outdoor Lighting in Pedestrian Corridors

In the outdoor lighting measurement standards set by SNI, several important variables are utilized for measuring outdoor lighting: illuminance, luminance, glare limit, and uniformity ratio. The light uniformity ratio for measuring sidewalks is divided into two classifications based on the area: residential and urban. The uniformity ratio for residential areas is more significant than urban areas, with a ratio of 10:1 indicating the difference in illumination levels between bright and dark areas in a room or specific area. In this ratio, the brightest area has a lighting level ten times higher than the darkest area. For urban lighting, a ratio of 4:1 indicates better uniformity compared to residential areas.

The variables in international standards also measure illuminance, luminance, glare limit, and uniformity ratio. However, their road area classifications provide more detailed assessment indicators than SNI standards. The CIE classifies roads with the numbering P1-P6, where P1 has more complex lighting needs than P6. The classification is based on traffic density, road users, parking areas, ambient lighting, and the need for object clarity (facial recognition). Meanwhile, IESNA clarifies local variable factors in more detail, considering the surrounding environment, such as area density and whether it is a low, medium, or high pedestrian conflict area. Additionally, IESNA considers factors like pavement materials and surrounding environmental conditions. For a more detailed comparison of outdoor lighting standards for pedestrians, refer to Table 4 as follows:

Table 4. Comparison of Sidewalk Lighting Standards SNI, CIE, and IESNA

Standard Used	Lighting Class Classification	Measured Variables	Additional Variables	Remarks
SNI 7391: 2008 (Badan Standardisasi Nasional, 2008)	Urban	Luminance: 1 – 4 Lux Uniformity (U_0): 0,1 Uniformity (U_I): 0,5 Glare Limit: 4	Maximum Uniformity (U_I): 0,25 Threshold Glare Limit: 20%	Lighting quality on a road is measured using illuminance or luminance methods. The illuminance method is easier to use, as it can be measured directly on the road surface using a light-intensity measuring device.
	Residential	Luminance: 1 – 4 Lux Uniformity (U_0): 0,1 Uniformity m (U_I): 0,5 Batas Silau: 4	Maximum Uniformity (U_I): 0,1 Threshold Glare Limit: 20%	
CIE 115: 2010 (CIE Technical Committee 4-44., 2010)	P1 (Commercial Area)	Luminance: 3 – 15 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6:	Threshold Increment at High and moderate speed: 10% Threshold Increment at Low and very low speed: 15%	To provide for uniformity, the actual value of the maintained average 1. illuminance may not exceed 1,5 times the value indicated for the class.
	P2 (High Activity)	Luminance: 2 – 10 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6	Threshold Increment at High and moderate speed: 10% Threshold Increment at Low and very low speed: 15%	

Standard Used	Lighting Class Classification	Measured Variables	Additional Variables	Remarks
	P3 (Moderate Activity)	Luminance: 1,5 – 7,5 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6	Threshold Increment at High and moderate speed: 10% Threshold Increment at Low and very low speed: 15%	2. A high color rendering contributes to better facial recognition.
	P4 (Low Activity)	Luminance : 1 – 5 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6	Threshold Increment at High and moderate speed: 15% Threshold Increment at Low and very low speed: 20%	
	P5 (Small Roads)	Luminance : 0,6 – 3 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6	Threshold Increment at High and moderate speed: 15% Threshold Increment at Low and very low speed: 20%	
	P6 (Minimal Lighting)	Luminance: 0,4 – 2 Lux Uniformity (U_0): 0,4 Uniformity (U_I): 0,6	Threshold Increment at High and moderate speed: 15% Threshold Increment at Low and very low speed: 25%	
IESNA/ANSI RP-8-00 (IESNA, 2000)	High pedestrian conflict	Luminance: 0,5 – 18 cd/m^2 Uniformity (U_0): 0,1 Uniformity (U_I): 0,16		Discomfort glare calculations and ratings are not a part of this Standard Practice but are being actively investigated.
	Medium pedestrian conflict	Luminance: 0,4 - 14 cd/m^2 Uniformity (U_0): 0,1 Uniformity (U_I): 0,16		
	Low pedestrian conflict	Luminance: 0,3 - 8 cd/m^2 Uniformity (U_0): 0,1 Uniformity (U_I): 0,16		

Source: (Badan Standardisasi Nasional, 2008; CIE Technical Committee 4-44., 2010; IESNA, 2000)

The results of comparing these standards indicate that the lighting quality based on national standards has lower values than that based on international standards. This suggests that the expected visual quality target set by national standards is lower, possibly due to differences in social activities in Indonesia, where sidewalks are not used as intensively for daily activities because many people rely on private vehicles to travel between destinations. The IESNA and CIE standards have only slight differences in their comparative values; however, CIE places more emphasis on user comfort, while IESNA focuses more on lighting efficiency.

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4.2 Evaluation of lighting in the city center using SNI standards and user perception in pedestrian areas

The evaluation of lighting conducted by Hompas Jefrey I. (2018), indicates that the simulated measurement levels obtained from Dialux significantly differ from user satisfaction perceptions. This can be observed by comparing evaluation results obtained by simulating planned street lighting in Dialux Evo software, dividing the area into four distinct zones, and then comparing the results with SNI standards and EN (European Committee for Standardization) guidelines. This was correlated with the perceptions of road users and pedestrians based on the zoning classification. The study concluded that:

Table 5. Comparison of Lighting Evaluation Results with Dialux Evo Simulation and User Perception on Sidewalks

Area	**Compliance with Standards**	**User Perception**
Zona A	Complies with SNI/EN	Insufficient
Zona B	Complies with SNI/EN	Insufficient
Zona C	Does Not Comply with SNI/EN	Insufficient
Zona D	Complies with SNI/EN	Insufficient

Source: (Hompas Jefrey I., 2018)

The results are still not aligned based on the comparison between measurements and user perceptions. The factors contributing to this misalignment may include discrepancies between the simulation data and actual field conditions, such as malfunctioning lights, a lack of light poles in certain areas, and obstructions to lighting, including trees. If the lighting design had been executed according to the plan, the street lighting would likely meet the SNI/EN standards.

The next step involves making lighting recommendations based on evaluating user perceptions. Using Dialux Evo modeling, recommendations for lighting design will be developed in the four zones. This modeling will be tailored to the lighting needs of each zone, serving as a proposal to improve the quality of lighting in the area.

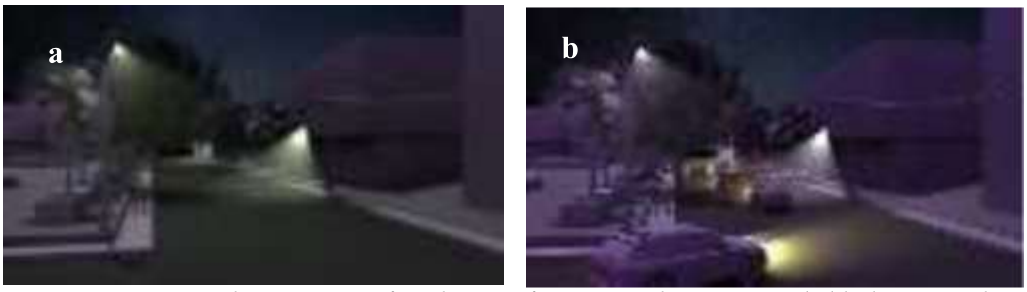

Figure 2: a. Existing simulation image of Dialux Evo for Zone C; b. recommended lighting simulation image of Dialux Evo for Zone C
Source: (Hompas Jefrey I., 2018)

From the literature review of the article above, it can be concluded that artificial lighting must be adapted to the characteristics of the existing zones. For example, urban areas require lighting that contributes to a safe and appealing pedestrian environment. Light uniformity should be maintained in urban areas to ensure no excessively bright or dark spots. Regular maintenance is also recommended. Special zones with historical

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environments require specific strategies in planning and designing lighting that aligns with their unique characteristics and community needs, especially for the specialized lighting function in historical and artistic tourist areas. In historical areas, strategies should be implemented to enhance livability and safety at night. According to theory (Traboulsi et al., 2023) Good lighting can enhance social interaction and quality of life in heritage areas. (Beccali et al., 2017) Indicates that implementing bright lighting, particularly with LED technology, improves energy efficiency and enhances the city's appearance. Furthermore,(Berardinis et al., 2015) Emphasizes the importance of preserving architectural and cultural values when planning lighting in small historic villages.

4.3 Proposed Methods for Lighting Assessment in the Kayutangan Heritage Pedestrian Corridor

The Kayutangan area, particularly within the pedestrian corridor, serves as a pathway for walking and a public space. According to SNI standards regarding light intensity (lux) for pedestrians, the existing lighting may meet the required levels, as several light fixtures have been installed along the Kayutangan road. However, the function of the pedestrian corridor as a public space necessitates further evaluation.

Pedestrian behavior often does not conform to a straight path; individuals tend to move and gather at various points due to parking areas along Kayutangan. The streetscape has already accounted for sitting groups, such as outdoor benches, at specific locations. Nonetheless, their placement needs to be re-evaluated to align better with the actual pedestrian behavior observed in Kayutangan.

Additionally, the shift in the function of storefronts to culinary spaces has transformed some areas of the sidewalk into extensions for restaurants or food vendors, inadvertently creating informal gathering spots within the public space. This evolving use of the corridor highlights the importance of adapting both the lighting and the design of the pedestrian environment to enhance safety, comfort, and usability for all visitors.

Figure 3: Lighting Kayutangan at night
Source: writer

organizing the lighting for areas with historical and heritage characteristics that also serve as commercial corridors and assessing the outdoor lighting in the Kayutangan pedestrian corridor can follow the methodology employed by (Hompas Jefrey I., 2018)

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However, this approach should be adapted to reflect the unique characteristics and functions of the roadway.

Standards set by CIE (International Commission on Illumination) and IESNA (Illuminating Engineering Society of North America) could be considered as supplementary guidelines alongside SNI (Standard Nasional Indonesia), as they provide more comprehensive points for evaluating lighting, considering surrounding environmental factors. To enhance the heritage character of Kayutangan, it is essential to adopt strategic planning for the corridor area, which features unique characteristics as a heritage and commercial tourism zone. This aligns with the theories proposed by (Berardinis et al., 2015, Beccali et al., 2017,Traboulsi et al., 2023,) Regarding the design of lighting in historical areas. Implementing these strategies can ensure that the lighting meets technical standards and supports the space's cultural significance and usability for both locals and visitors.

5. Conclusion

According to the review article analysis, the lighting standards—SNI (Standard Nasional Indonesia), CIE (International Commission on Illumination), and IESNA (Illuminating Engineering Society of North America)—have a major impact on how much lighting is measured in public areas, especially in pedestrian corridors. Similar characteristics including illuminance, brightness, glare limitations, and uniformity ratios are shared by these three standards; nevertheless, there are notable distinctions in the classification and level of information in the lighting evaluation.International standards like CIE and IESNA offer a more comprehensive approach by considering environmental factors and user characteristics, in contrast to SNI, which recommends lighting quality with lower values.

The evaluation results of urban center lighting, There is a disparity between simulation measurements and user perceptions, which emphasizes the necessity of design suggestions that take into account the features of pedestrian routes in order to improve illumination quality and user safety.

Therefore, for future studies assessing pedestrian corridors in heritage regions like Kayutangan, particular lighting design solutions must be used. This is essential for maintaining cultural and architectural values while fostering social interactions. The lighting design in these locations can enhance social interaction and user experience in public spaces while considering CIE and IESNA guidelines.

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It is hoped that this study's findings will contribute positively to the development of knowledge regarding public lighting and assist in better planning in the future.

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References

Abdullah, A., Aziz, M., & Huda, M. (2021). Redesigning Public Street Lighting Using Photometric Method. *Indonesian Journal of Computing, Engineering and Design (IJoCED)*, *3*(1), 54–67. https://doi.org/10.35806/ijoced.v3i1.153

Azis, B., Santosa, H., & Ernawati, J. (2019). Assessing Public Perception for Illumination of Building in Kayutangan Street, Malang, Indonesia. *DIMENSI (Journal of Architecture and Built Environment)*, *46*(1), 11–22. https://doi.org/10.9744/dimensi.46.1.11-22

Badan Standardisasi Nasional. (2008). SNI 7391:2008 Spesifikasi penerangan jalan di kawasan Perkotaan. *SNI 7391:2008 Spesifikasi Penerangan Jalan Di Kawasan Perkotaan*, 12.

Beccali, M., Bonomolo, M., Galatioto, A., & Pulvirenti, E. (2017). Smart lighting in a historical context: a case study. *Management of Environmental Quality: An International Journal*, *28*(2), 282–298. https://doi.org/10.1108/MEQ-06-2015-0109

Berardinis, P. De, Marchionni, C., & Capannolo, L. (2015). The urban lighting in the rehabilitation of the minor historical center. The design scenarios for the architectural valorization and the energy efficiency improvement of the urban environment. *Vitruvio*. https://doi.org/https://doi.org/10.4995/vitruvio-ijats.2015.4473

Bommel, W. van. (2015). *Equipment and Design Aspects*. https://doi.org/10.1007/978-3-319-11466-8_18

Bullough, S. D. (2013). Historic Streetscape Lighting: Integration Of Aesthetic Concerns With Modern Technology. *Transportation Research Board Annual Meeting*, *489*(5), 1–19.

Casciani, D. (2020). *The Human-Scale Urban Lighting Experience BT - The Human and Social Dimension of Urban Lightscapes* (D. Casciani (ed.); pp. 21–41). Springer International Publishing. https://doi.org/10.1007/978-3-030-57165-8_2

CIE Technical Committee. (2022). *CIE 136-2000 Guide to the lighting of urban areas*. CIE. https://doi.org/https://cie.co.at/publications/guide-lighting-urban-areas

CIE Technical Committee 4-44. (2010). *CIE 115 - Lighting of roads for motor and pedestrian traffic*. 37.

Duan, X., Hu, Q., Zhao, P., Wang, S., & Ai, M. (2020). An Approach of Identifying and Extracting Urban Commercial Areas Using the Nighttime Lights Satellite Imagery. *Remote Sensing*, *12*(6), 1029-. https://doi.org/10.3390/RS12061029

Erine, K. N., Rimasari, S., & Sapto, A. (2022). Eksistensi bangunan gaya kolonial Belanda di kawasan Kayutangan, Kota Malang pada tahun 1900-2021. *Historiography*, *2*(4), 588. https://doi.org/10.17977/um081v2i42022p588-602

Eriyadi, M., Abdullah, A. G., Mulia, S. B., & Hasbullah, H. (2019). Street lighting efficiency with particle swarm optimization algorithm following Indonesian standard. *Journal of Physics: Conference Series*, *1402*(4). https://doi.org/10.1088/1742-6596/1402/4/044009

Hompas Jefrey I., M. M. . K. (2018). Pencahayaan Penerangan Jalan Dan Pedestrian Pada Pusat Kota Manado. *Fraktal : Jurnal Arsitektur, Kota Dan Sains*, *3*(Vol 3, No 1 (2018): Volume 3 Nomor 1, Maret Tahun 2018), 1–10. http://ejournal.unsrat.ac.id/index.php/fraktal/article/view/20160

Hu, S., Huang, S., Hu, Q., Wang, S., & Chen, Q. (2023). A commercial area extraction approach using time series nighttime light remote sensing data——Take Wuhan City as a case. *Sustainable Cities and Society*. https://doi.org/10.1016/j.scs.2023.105032

IESNA. (2000). IESNA- American National Standard Practice for Roadway Lighting. In *The Standard Practice Subcommittee of the IESNA Roadway Lighting Committee*. IESNA Roadway Lighting Committee. https://doi.org/10.1080/00994480.1972.10747677

Kurniawan, I. W., & Kurniawan, R. (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

Lin, Q., Zhang, C., Cai, H., Li, X., & Xiao, H. (2023). Urban night lighting evaluation system and case study: blending popular contemporary elements, cultural traditions, and advanced lighting technologies. *Engineering, Construction, and Architectural Management*.

Liu, M., Zhang, B., Luo, T., Liu, Y., Portnov, B. A., Trop, T., Jiao, W., Liu, H., Li, Y., & Liu, Q. (2022). Evaluating Street Lighting Quality in Residential Areas by Combining Remote Sensing Tools and a Survey on Pedestrians' Perceptions of Safety and Visual Comfort. *Remote Sensing*, *14*(4). https://doi.org/10.3390/rs14040826

Manurung, P. (2009). Desain Pencahayaan Arsitektural Konsep Pencahayaan Artifisial pada Ruang Eksterior. In *Andi Offset*.

Petty, M. M. (2007). *Light and the Urban Nightscape*. Hanley Wood, LLC.

Poulsen, E. S., Andersen, H. J., Jensen, O. B., Gade, R., Thyrrestrup, T., & Moeslund, T. B. (2012). Controlling urban lighting by human motion patterns results from a full-scale experiment. *MM 2012 - Proceedings of the 20th ACM International Conference on Multimedia*, 339–347. https://doi.org/10.1145/2393347.2393398

Rakonjac, I., Zorić, A., Rakonjac, I., Milošević, J., Marić, J., & Furundžić, D. (2022). Increasing the Livability of Open Public Spaces during Nighttime: The Importance of Lighting in Waterfront Areas. *Sustainability (Switzerland)*, *14*(10), 1–25. https://doi.org/10.3390/su14106058

Ridjal, A. M., Antariksa, A., Suryasari, N., & Santoso, J. T. (2016). Building Form berdasarkan Sejarah Kawasan Bangunan pada Jalan Basuki Rahmat Malang. *Review of Urbanism and Architectural Studies*, *14*(2), 34–46. https://doi.org/10.21776/ub.ruas.2016.014.02.4

Saadouni, I., Samoudi, B., Bendaou, O., & Hanafi, I. (2024). *4. Maximizing Performance of Light Emitting Diode Luminaires for Road Illumination*. International Conference on Electrical Systems & Automation. https://doi.org/10.1007/978-3-031-51796-9_30

Shi, L., Chen, W., Liu, X., & Lai, W. (2013). Quantitative comparison of photometric quantities for road lighting between CIE and IESNA standards. *Nonimaging Optics: Efficient Design for Illumination and Solar Concentration X*, *8834*, 88340S. https://doi.org/10.1117/12.2022565

Slamet, P., & Budiono, G. (2023). *Kajian teknis uneven lighting pada pemasangan pju*. https://doi.org/10.30736/je-unisla.v8i1.990

Sutopo, W., Mardikaningsih, I. S., Zakaria, R., & Ali, A. (2020). A model to improve the implementation standards of street lighting based on solar energy: A case study. *Energies*, *13*(3), 1–20. https://doi.org/10.3390/en13030630

Traboulsi, C., Hassoun, A., Rabea, M., & Felix, M. (2023). Outdoor Artificial Lighting Effects on Livability of Pedestrian Paths in Urban Heritage Context. *BAU Journal - Creative Sustainable Development*, *4*(2). https://doi.org/10.54729/2789-8334.1108

Valevičius, M., & Levickaite, R. (2011). Lighting of cultural heritage as a tool to exhibit historical architectural values in the context of creative industries (the case of ukmergė). *Limes*, *4*(2), 162–176. https://doi.org/10.3846/20290187.2011.639097

Yusran, Y. A. (2020). *Contextualizing Modernization in the Kayutangan Towards Its Images as a Heritage Town Area of Malang*. *195*(Hunian 2019), 97–106. https://doi.org/10.2991/aer.k.200729.016

Zakri, A. A., Fauzan, M., Sunanda, W., & Kurniawan, R. (2023). The Design of Solar Cell-Based Street Lighting for School Area. *Jurnal Ecotipe (Electronic, Control, Telecommunication, Information, and Power Engineering)*, *10*(1), 131–141. https://doi.org/10.33019/jurnalecotipe.v10i1.3964