Artificial Lighting Strategies On Campus Pedestrian Path In Increasing The Safety of Walking at Night (Case Study: University of Bengkulu)

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Abstract. Pedestrian path in the campus is strategic route dominated by the movement of students and other users from 06.00 AM until 20.00 PM. The unavailability of artificial lighting at night on the pedestrian paths on the campus of the University of Bengkulu causes low visibility for pedestrian path users and have an impact on walking difficulties, negative behaviour and opportunities for criminal acts. The purpose of this study is identifying frequently used pedestrian paths and examines the principles of artificial lighting must be applied pedestrian users can walk safely and comfortably in the campus at night. These conditions can increasing liveability of pedestrian paths on the campus at night. The study sites were divided into 10 zones. Each zone will be analysed using combination method of field survey methods, online questionnaires, and simulation methods using Dialux evo 9.0. Data from questionnaire and field survey result will be used to decide the artificial lighting plan on the pedestrian path. While Dialux evo 9.0 simulation are to simulate the planned light points The results of the research are determining an artificial lighting strategy is evenly distributed along the pedestrian path.

1. Introduction

The pedestrian path is one of the public facilities on campus that is used by the academic community for circulation [1]. Campus as a formal educational environment that accommodates various student activities with the existence of outside the campus has an important role [2]. Pedestrian space in the context of the campus area plays a role in creating environmental conditions that have a friendly impression of pedestrians. This is due to the relationship between the quality of the pedestrian path and the experience of the academic community as pedestrian lane users. The comfort of walking is influenced by several factors such as safety, aesthetics, convenience, and achievement.

Studies that have been conducted in the district environment in Putrajaya show that the important variables of safety, security, comfort and attractiveness affect a good walking experience [3]. A good walking experience can be achieved by increasing safety, comfort and enjoyment. The influence of the built environment has an influence on travel behavior, but currently micro-scale elements such as vegetation and street lights are still neglected and need to be studied [4]. Lighting as a supporting facility on pedestrian paths provides lighting at night so that pedestrians are safer and more comfortable [5]. Aspects of concern in improving walking safety are road design, free from fear of danger, freedom in walking so that safety with physical and aesthetic characteristics can gain comfort and attractiveness.

University of Bengkulu has a range of activities from 06.00 to 20.00 WIB, currently has a pedestrian path along ± 3116 m with conditions not yet equipped with artificial lighting in the pedestrian path area at night. The current artificial lighting on the pedestrian path at night is in the form of street lighting. Pedestrian lane lighting affects pedestrian visibility. The increased visibility of pedestrians due to the well-lit walking area helps motorists see pedestrians while driving at night thereby reducing the risk of...
accidents between motorists and pedestrians [6]. This is supported by a study that street lighting with appropriate luminance increases the visibility of drivers and road users [7]. Dark areas have psychological impacts such as fear, insecurity, fear of the unknown, which hampers one's journey [8]. The outdoor area feels comfortable at night if someone can do activities in it, supported by good lighting and the absence of shrubs that have the potential for road users to get information about their views while walking [9].

Along with the mission of UI Greenmetric on one of the ranking indicators regarding the transportation system as an important role in the level of carbon emissions and pollutants in the campus area [10]. Natural and artificial architectural lighting has contributed to increasing the safety, comfort and visual aesthetics of the area. Artificial light arrangement needs to optimize the combination of artificial lighting so that the use of electrical energy in outdoor space is more efficient. Digital simulation of lighting to help get the most out of ideas before they are applied to real situations. This study aims to identify pedestrian paths that are often used and to examine the principles of artificial lighting that must be applied to pedestrian paths using digital lighting simulations so that pedestrian users can walk safely and comfortably in the campus area at night.

2. The Content of the Extended Abstract

2.1. Study Area

The research location is a pedestrian path in the area of the University of Bengkulu, Bengkulu City, Indonesia. In figure 1 the pedestrian path is divided into 10 zones.

![Figure 1](image1.png)

Figure 1. (a) Bengkulu Province Region; (b) Bengkulu City; (c) Data collection zone

2.2. Research method

Identifying the pedestrian path lighting conditions that are often used, two series of data collection were carried out. First, conducting a survey of lighting conditions and measuring light intensity using the UNI-T series UT383 luxmeter at 10 points on the pedestrian path that is frequently traveled on July 27, 2020. Measurements were made at 19.00 WIB with the time of measurement and a review of the lighting on the pedestrian path. feet for 5 minutes. Table 1 shows the technical characteristics of the measurement instruments. The measurement results are compared with the normal lighting quality from SNI 7391: 2008.

| Variable          | Equipment | Measurement range | Accuracy                      |
|-------------------|-----------|-------------------|-------------------------------|
| Illuminance (Lux) | UNI-T UT383 | 0~199,900Lux 0~18,500Fc | 0~9999Lux/ 0~9999Fc: (4%+8) |
|                   |           |                   | ≥10000Lux≥1000Fc: ±(5%+10)   |
| Illuminance (Fc)  |           |                   | ≥100000Lux≥9999Fc: ±(5%+10)  |

Table 1. Measurement Tool Characteristics
The conditions of the pedestrian paths can be reviewed objectively, the second data collection is to distribute online questionnaires to respondents who pass through the research location on July 27, 2020 at 18.30-20.00. Questionnaire questions using Likert scale [11], answers contain four alternative answers and neutral alternative answers are eliminated with the answer value having a score of 1 (disagree) to 4 (Strongly agree). This technique is used to measure the perceptions of pedestrians passing through the research location on existing lighting conditions that are compared with measurement data. The percentage of the questionnaire results is obtained using the formula:

$$\% = \frac{n}{N} \times 100\%$$

Information:

- $n =$ total score of respondents
- $N =$ maximum number of scores

1. In data processing, researchers simulate existing data using instruments to analyse data with Dialux Evo 9.0. Dialux is a natural and artificial lighting program to meet the rapidly growing information needs of the latest lighting technology and has the capability of visual rendering and automatic technical reporting [13]. To get the most out of the ideas before they are applied to the real situation of artificial lighting ideas on pedestrian paths on the campus of the University of Bengkulu, it is simulated in the DIALux Evo 9.0 program. The next analysis leads to a comparison of the calculation results in the DIALux Evo 9.0 simulation compared with the results of the pedestrian online survey and questionnaire in the research area and the next step is to analyse the advantages and disadvantages of street and pedestrian lighting to apply lighting principles in accordance with existing conditions. research sites.

2.3. Result and data analysis
This research is located on 10 pedestrian paths within the Bengkulu University campus area. In figure 2 it is a natural lighting condition when conducting interviews and measurements. The results of the interviews regarding the lighting conditions of the pedestrian paths obtained from the data on the online questionnaire of the passing respondents stated that the perceptions of pedestrians on aspects that affect walking are shown in Figure 3. The pedestrian paths that the respondent crosses are in zones 1, 2, and 3 while on other lines during research. In Figure 2, (A) the visibility of pedestrians at night has a value of 1.667, (B) comfort and barriers in walking with a value of 2.15; (C) pedestrian safety with a score of 2.58; and (D) pedestrian lane lighting uniqueness with a value of 2.25.
Figure 2. (above, from left to right) promenade conditions for zones 1-5 (bottom, from left to right) pedestrian path conditions for zones 6-10

Figure 3. Aspects affect for walking

Based on the overall assessment of respondents' perceptions in Figure 3, 7 out of 12 respondents stated that the assessment of the pedestrian path lighting conditions at night was still below <56%.
Figure 4. Assessment of lighting conditions based on respondents' perceptions

The lighting conditions on the pedestrian path are measured using a luxmeter. The width of the existing pedestrian path is between 60 cm-205 cm with the length of the path as in table 2.

### Table 2. Physical condition of pedestrian path

| Physical condition | Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------------------|------|---|---|---|---|---|---|---|---|---|----|
| pedestrian path width (centimetres) |      | 205| 205| 145| 100| 127| 200| 205| 60 | 155| 100 |
| length of the pedestrian path (metres) |      | 777,6| 294,5| 402,71| 161,27| 262,72| 481,9| 424,91| 427,48| 130,74| 215,8 |

Based on SNI 7391: 2008 for normal sidewalk lighting quality which must have an average illumination level requirement of 1-4 lux and a uniformity level (lumination / L) that must be met is 0.10 cd as in table 3.

### Table 3. Normal lighting quality

| Road classification | Illumination | Luminance | Glare limit |
|---------------------|--------------|-----------|-------------|
|                     | E | Uniformity | L (cd/m2) | Uniformity | TJ (%) | G |
| Pedestrian path     | 1-4| 0,10 | 0,10 | 0,40 | 0,50 | 20 | 4 |

The main street lighting is constructed at a distance of 50 meters with a single position on one side of the road. The lights installed have a pole height of 6 meters, a road width of 6.0 meters, a shoulder width of 1.0 meters, a length of ornament (horizontal) of 1.0 meters, and a tilt angle of 150 ornaments. From the measurement results in table 4, it shows that the lighting intensity conditions on the current pedestrian lane, 10 lanes are not yet equipped with artificial lighting specifically for pedestrian paths. However, of the 10 lanes, there are 5 lanes that have lighting from PJU lights (public street lighting), while on the other lines there is no lighting at night.
Table 4. Pedestrian path lighting conditions in the campus area

| Observed elements | Zona | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------------|------|---|---|---|---|---|---|---|---|---|----|
| There are street lights |      | √ | √ | - | - | - | - | √ | - | - | √ |
| Light intensity (lx) |      | 11 | 9 | 32 | 0 | 0 | 7 | 0 | 0 | 0 | 32 |
| Measurement distance from the lamp point |      | 1-2 | 1-2 | 1-2 | - | - | 1-2 | - | - | - | 1-2 |
| Distance between street lighting poles (m) |      | 50 | 50 | 50 | - | - | 50 | - | - | - | 50 |
| Pedestrian path dimensions are in accordance with SNI |      | √ | √ | - | - | √ | √ | - | √ | √ | √ |
| Pedestrian path surface material |      | Paving |

The results of data analysis in zone 1 to zone 10, there are 5 zones, namely zones 1,2,3,6,10 which only have street lighting of the same type that illuminates pedestrian paths. Whereas in zone 4,5,7,8,9, the pedestrian path does not yet have lighting in the form of street lighting or artificial lighting specifically for pedestrian paths.

Table 5 shows the simulation results with Dialux Evo 9.0 in zone 1,2,3,6,10 with illumination conditions P6 which is a category within walking distance of the UNI 11248: 2016 standard. The measurement values in the Dialux simulation are as shown in table 4. Measuring distances between 1-2 meters have different measurement values. It is important to consider the lighting that is blocked by tree leaves because in a zone that has a high light intensity value, the light is not obstructed by shrubs under the light.

Table 5. The results of the analysis with Dialux Evo 9.0

| Uniformity | Standar EN 13201 | SNI 7391: 2008 | The results of the analysis with Dialux Evo 9.0 |
|------------|-----------------|----------------|-----------------------------------------------|
| E_m (lx)   | 2-3             | 1-4            | Zone 1 | Zone 2 | Zone 3 | Zone 6 | Zone 10 |
| Kemerataan (gl) | ≥ 0,40 | 0,10           | 2,49   | 2,91   | 4,79   | 2,52   | 3,15   |

2.4. Discussion

Based on the results of interviews through filling out online questionnaires, it was found that the lowest score that was related to the experience of walking on the pedestrian path in the Bengkulu University campus was the pedestrian visibility aspect. The existing lighting conditions have not helped the respondent's visibility when walking. Meanwhile, the aspect that has the highest value is security on the pedestrian path. This aspect has the highest value compared to other aspects. The sense of security obtained by respondents is due to lighting even though it is dim, it can still illuminate the pedestrian...
path. In addition, the pedestrian path that was traversed by the respondents was guarded by security guards / night guards who patrolled approximately every hour so that the respondents felt safe. Respondents need adaptation in walking to the pedestrian path zones that have street lights due to the damaged pedestrian paths.

Based on the Dialux Evo 9.0 analysis, the pedestrian lane area if based on lighting strength, the lanes 1,2,3,6,10 which are on the side of the road have met the standard of light strength, but in some zones the pedestrian paths are lit by public street lighting there is vegetation under the lamp so that the vegetation leaves cover the light. This reduces the light intensity on the walkway surface. The distance of public street lighting which is 50 meters and the height of the light point is 6 meters from the surface of the pedestrian path is related to the difficulty of respondents to see at a long viewing distance because the light point is far from the eye.

Planning related to the arrangement and use of vegetation types in the area around street lighting so as not to block light from reaching the pedestrian path. The artificial lighting strategy that can be done in this condition is by closing the distance between pedestrian light points that do not have artificial lighting. Light points are planned every 15 meters to create an even distribution of light. The height of the lamppost is planned to be 4 meters high and only shrub vegetation <1.00 meters high is planted in the pedestrian path area so as not to obstruct the view of pedestrians and not block the glow of the lights. The type of lamp used has a light distribution with the selection of luminaires that provide evenness of light as shown in Figure 6.

![Figure 6. Artificial lighting point strategies](image)

### 3. Conclusion

The lighting system that is used for outdoor areas has an impact on visibility, safety, pedestrian comfort. To meet the lighting needs at night without the help of sky light, it is necessary to have artificial lighting that is recommended for 1-4 lux based on SNI 7391: 2008. Based on the evaluation results of Dialux evo 9.0 and the perceptions of road users and pedestrians, there is a big difference, where the perception value shows less value in 4 zones, while the results of Dialux evo 9.0 zone 3 have exceeded the SNI light strength standard, this is because at the time of data collection There are several points of street lighting in zone 3 that are not obstructed by vegetation. For zones 4,5,7,8,9 which do not have artificial lighting, the strategy that needs to be done is to place light points every 15 meters with a light height of 4 meters from the pedestrian surface. This is due to the equal distribution of the light points to a distance of four meters from the light points. The placement of light poles should be placed between the boundary of the pedestrian path and the road so that it allows drivers to see pedestrians more clearly.
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