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Analysis and Design of Lighting at the UNIMA Workshop Building

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Abstract— The need for natural and artificial lighting is a supporting component in daily human activities outside and inside buildings. For lighting to be carried out properly, it must meet the requirements stated in SNI and Minister of Health Regulation No. 70 of 2016 concerning Standard Requirements for Light Intensity. One of the goals of lighting in a building is to create sufficient lighting and reduce the risk of accidents. Referring to the description, the author is interested in understanding and researching further the existing lighting standards in the UNIMA Workshop building. In evaluating, the authors obtain research data by conducting case studies in which data is collected, processed, compared and analyzed. The results showed that the light intensity in the UNIMA Workshop room had an average of 144.2 lux and in the work area of 191.06 lux.

Keywords: building lighting design

I. INTRODUCTION

Several factors affect the work environment, such as physical, chemical, biological, and psychological factors. As described, physical factors can affect the work environment and workforce. One example of a physical factor is lighting. Workers carrying out all kinds of work activities always require lighting (Renita et al., 2019).

Lighting is one of the factors in getting a comfortable working environment and is related to human productivity. Good lighting lets people see the object they are working on clearly, quickly and without unnecessary effort. Poor lighting can cause eye fatigue due to reduced eye work efficiency, complaints of soreness around the eyes and headaches around the eyes. A lighting source is needed according to the room's function to meet the need for light in the room (Damayanti & Utomo, 2018).

The lighting system is one of the most essential and fundamental aspects of a building, so the building can become a building with the function we want. In its installation, attention is needed so that in its use, it will not endanger consumers or users. Therefore, in installing the lighting system, it is necessary to be careful and appropriate procedures following applicable standards.

In Indonesia, the design of electrical installations is regulated in the General Electrical Installation Regulations (PUIL) of 2011 (Kilis & Mamahit, 2021). These regulations clearly show how to install excellent and correct electrical installations (Sawenduling et al., 2022), both of which are standards for electrical installations in Indonesia (Sni Puil, 2011). According to the Decree of the Minister of Health of the Republic of Indonesia Number 1405/ MENKES/ SK/ XI/ 2002 concerning Procedures for Implementing Lighting, it is stated that natural and artificial lighting is sought so as not to cause glare and have an intensity according to their designation (Persyaratan Kesehatan Lingkungan Kerja Perkantoran Dan Industri Menteri Kesehatan Republik Indonesia, 2002).

Lighting is essential to support various human activities both indoors and outdoors. The Regulation of the Minister of Health No. 70, 2016 concerning Occupational Health Standards and Requirements states that the standard light intensity level in a factory or production area is 300 lux (Peraturan Menteri Kesehatan Republik Indonesia Nomor 70 Tahun 2016 Tentang Standar Dan Persyaratan Kesehatan Lingkungan Kerja Industri, 2016).

The Unima workshop, or in everyday life is called Bengkel UNIMA, is a place for small and medium-sized entrepreneurs who are engaged in repair services in welding techniques or wood making. The Unima workshop is also where students make handicrafts such as functional materials—related to the courses in their respective departments at the Faculty of Engineering, Unima.

The Manado State University Workshop is a place for work related to wood and iron, and many students visit to practise or learn to use existing machines such as welding or cutting machines. With workers and students who often visit to carry out work and practice, it is evident that lighting is needed to support the need for lighting in the work area in the Unima workshop. Although the lighting installation at the Unima Workshop is still relatively new, the lighting needs must still be calculated whether it is following current needs and has met the standards (Pattinasarany et al., 2022). This study aimed to analyze and design efficient and standard electric lighting at the Unima Workshop.

II. METHOD

A. *Type of Research*

The methodology used in this study is:

1. Literature study

That is the search for words taken from books, media, or the results of other people's research which aims to develop a theoretical basis that can be used as reference material in writing this report (Wahono, 2016).

2. Observation method

It is a way to collect data by directly observing an object in a certain period and relying on systematically recording specific things to be observed. In this observation, the authors make measurements and direct observations in the workshop to be able to obtain the data needed as material for preparing reports (Hasanah, 2017).

3. Interview method

Interviews are data collection carried out through direct questions and answers with the parties concerned in the workshop to provide the correct explanation to obtain data that can be used for preparing reports (Rachmawati, 2017).

4. Documentation method

Documentation is a technique for collecting data by taking pictures, in the form of photos and wiring diagrams, regarding report preparation materials (Gustiani, 2019).

B. *Place and time of research*

The research was carried out for 3 months. This research took place at the Manado State University Workshop. Unima, Tataaran Satu, South Tondano, Minahasa Regency, North Sulawesi.

C. *Research Flowchart*

The flow chart is used to draw the flow of the process of sequential steps in research. It can be seen in the flowchart image (Figure 1).

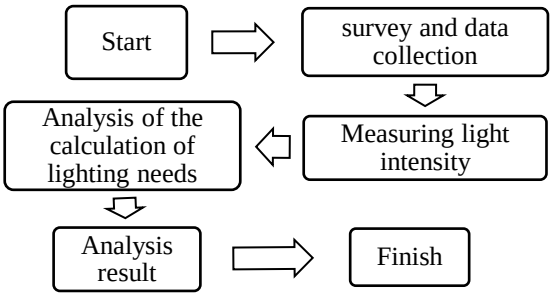

Figure 1. Research design flow chart

D. *Workshop Plan*

The Unima Workshop consists of several rooms, namely the main room used for machine work and other small rooms such as toilets. The overview of the workshop floor plan is shown in Figure 2.

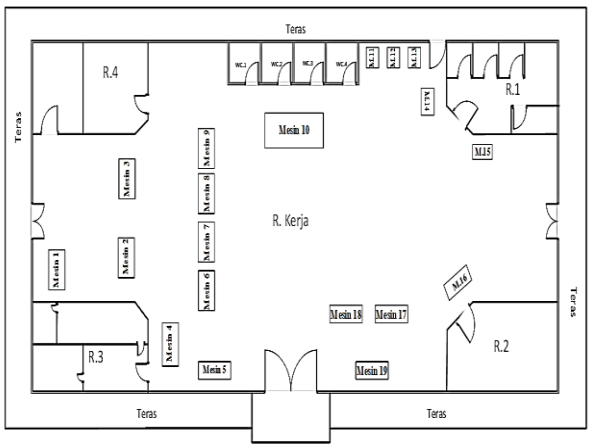

Figure 2. Workshop Plan

III. RESULTS AND DISCUSSION

A. *RESEARCH RESULTS*

In taking data or measurements, researchers use local measurements, namely calculations carried out just above the work area, which in this study is the machine. Measurements using the lux meter application through a smartphone device utilizing the existing light sensor (Nugroho et al., 2018). The steps for data collection or measurement are as follows:

1. Turn on the lux meter application, then calibrate.
2. Put the application device in the measured place.
3. Allow some time to get maximum results.
4. Record the measurement results on the measurement sheet.
5. Turn off the lux meter application immediately after use.

After local measurements and observations were made in all rooms and machines in the Unima Workshop, the data obtained are in Table 1.

Table 1. Light Intensity Existing Data in Every Room

No	Room	Area	Average Test Results
1	Room 1	64 m^2	306
2	Room 2	32 m^2	224.4
3	Room 3	32 m^2	227
4	Room 4	64 m^2	206.2
5	Room 5	64 m^2	285
6	Wc 1	2.5 m^2	116.6
7	Wc 2	2.5 m^2	116.8
8	Wc 3	2.5 m^2	119
9	Wc 4	2.5 m^2	118.6

Based on the observations made by measuring the intensity of light in each room in the Workshop when the weather conditions are sunny, it produces data as shown in Table 1. There are 5 rooms in every corner of the building, 4 toilets and work areas. Each has a different light intensity. Based on SNI and Regulation of the Minister of Health No. 70 of 2016 concerning standards and requirements for the health of the work environment, rooms 1 to 5 meet the standard, but the toilet room still does not meet the 200-250 lux. The data collection was taken with excellent or sunny weather conditions and carried out from 9:00 to 14:00. If the weather was cloudy and it was getting dark, the intensity of light received in the workshop building would decrease significantly.

Table 2. Light Intensity Existing Data

No	Room	Average
1	Machine 1	161.4
2	Machine 2	133.4
3	Machine 3	169.2
4	Machine 4	169
5	Machine 5	175.8
6	Machine 6	110.2
7	Machine 7	98.6
8	Machine 8	99
9	Machine 9	268.6
10	Machine 10	67.8
11	Machine 11	123.2
12	Machine 12	119
13	Machine 13	122.4
14	Machine 14	116
15	Machine 15	142.2
16	Machine 16	164.2
17	Machine 17	168.2
18	Machine 18	166.4
19	Machine 19	165

The workshop work area has 19 machines (see Table 2) with different sizes and positions. Some machines are almost the same size, but some are bigger or smaller. The location of the machine's placement dramatically affects the results of the light intensity test. Machines near light sources such as windows will have better light intensity than machines with blocked light sources.

From this observation, it can also be seen that the results of the intensity test on the machine have similarities with other machines. This is because the locations of the machines are close to each other. For example, machines 1 to 3, machines 4 to machines 9, machines 11 to machines 14, and machines 16 to machines 19. The placement and area of the room are shown in Figures 3 and 4.

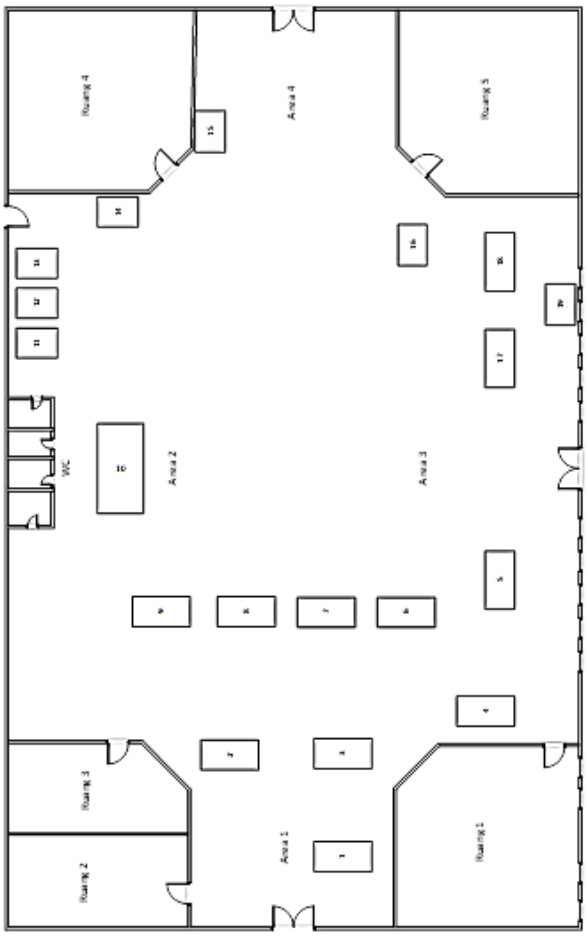

Figure 3. Machine location sketch

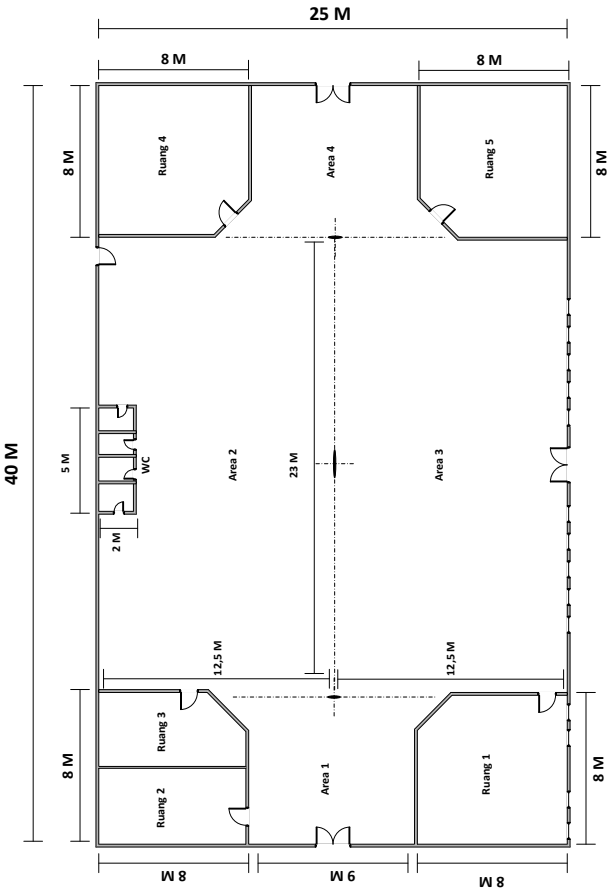

Figure 4. Floor plan of the workshop building

Table 3. Existing lamp used

No.	Machine	Area	Lamp	Total Load (Watt)
1	Working Room	10	450 W	740 W
2	Room 1	4	40 W	
3	Room 2	1	10 W	
4	Room 3	1	10 W	
5	Room 4	6	60 W	
6	Room 5	1	10 W	
7	WC 1	1	10 W	
8	WC 2	1	10 W	
9	WC 3	1	10 W	
10	WC 4	1	10 W	
11	Terrace	10	120 W	

Based on the observations made on the lighting system of the workshop building, data on the number of lamps were obtained according to Table 3. The lamps used in the room and work area amounted to 27 lamps. Consists of 10 leading lights in the work area and 13 10W lights in each room, and 4 10W lights to illuminate the toilet.

The lighting source in the workshop building is not only lights but natural lighting sources. The lighting source is supported by many windows and a wide and open workshop area, making it easier for light to enter (Atthaillah et al., 2019).

Table 4. Overall condition of the room in the Unima Workshop building

No	Observation Results	Category	Suitability
1	Surface types of objects in space	Absorb because it does not reflect light	Suitable
2	Wall Color	Bright, white and red	Suitable
3	Indoor air	Fresh no smoke in the room	Suitable

From the observations made, the researchers also looked at the condition of each room in the workshop building. So that the results obtained are observations based on Table 4, by looking at the condition table of the workshop building, it can be concluded that the colour conditions on the walls, indoor air, work surfaces and object surfaces are unacceptable conditions so that they do not interfere with activities and do not interfere during measurements (Budiman & Indrani, 2012).

B. Discussion

In the analysis of this calculation using a simple formula by ignoring the ceiling height but still paying attention to other factors such as the effect of the wall, the standard unit of lux is based on needs assuming the lamp used is an LED lamp with a size of 1 Watt = 120 lumens and also pays attention to the size of the area and work area. The formula used is as follows:

$$E = \frac{\Phi \times N \times Cu \times LLF}{A} \quad (1)$$

$$N = \frac{E \times A}{\Phi \times n \times Cu \times LLF} \quad (2)$$

Formula description:

E = strong lighting (lux)
Φ = light flux (lumen), 1 watt is equivalent to 100 lumens
N = number of mounting points
Cu = Coefficient Utilization, in this calculation, using 50% or equivalent to 0.5
LLF = lost light factor, the coefficient value is 0.7 - 0.8 based on room conditions
A = room area (m^2)

1. Room 1

Room 1 is divided into 4 rooms. The first room is a living room, the second room is an office, and the third and fourth rooms are used as file storage or warehouse. Overall, the room has an area of 8 m long and 8 m wide and is divided into room A, which has an area of 22 m^2, room B, has an area of 22 m^2, and room C, which has an area of 15 m^2, room D has an area of 5 m^2. With bright walls and lights, 20 watts of LED will be used in rooms a, b and c, while room d uses 10 watts. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Furthermore, lux is around 150-250 lux based on SNI. Then the number of lamps needed can be calculated by equation 2 as follows:

$$N = \frac{120 \times 22}{2400 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{2640}{840}$$

$$N = 3.14$$

Once rounded, the lights needed in this room amount to 3 lamps. Following these calculations, the results obtained are room B 3 lights, room C 2 lights, and room D 3 lights.

2. Room 2 and 3

Room 2 is a combination of room 3 but is separated from the wall. Rooms 2 and 3 each have an area of 32 m^2 with bright walls, and 22Watt LED lights. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Furthermore, lux is around 150-250 lux based on SNI. Then the number of lights needed can be calculated by equation 2 as follows:

$$N = \frac{120 \times 32}{2640 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{3840}{924}$$

$$N = 4.1$$

Once rounded, the lights needed in this room amount to 4 lamps. Using the same calculation, the results for room 3 are 4 lamps.

3. Room 4

Just like in room 1, room 4 is divided into several parts; 1 part of the room, the main room, has an area of 40 m2 using 22 Watt LEDs and 4 small sections where the 3 parts have the same size of 4 m^2 using 10 Watt LEDs. The last part of the room has an area of 12 m^2 using a 20 Watt led. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Furthermore, lux is around 150-250 lux based on SNI. Then the number of lamps needed can be calculated by equation 2 as follows:

$$N = \frac{120 \times 40}{2640 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{4800}{924}$$

$$N = 5.1$$

After rounding up, the lights needed in this room are 5 lamps, using the same calculation for room b, which has 4 rooms, each with 1 lamp and room c with 2 lamps.

4. Room 5

This room has a room area of 64 m^2 because this room only consists of 1 whole room. The lamp used is a 40Watt LED with a lumen of 4,800. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Furthermore, the lux is around 150 250 lux based on SNI. Then the number of lights needed can be calculated by equation 2 as follows:

$$N = \frac{120 \times 64}{4800 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{7680}{1680}$$

$$N = 4.57$$

After rounding, the lights needed in this room are 5 lamps.

5. Toilet room

There are 4 toilet rooms in this building. Each toilet has the same area of 2.5 m^2. The lamp that will be used is a 10Watt LED lamp with 1000 lumens. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Furthermore, lux is about 250 lux based on SNI. Then the number of lights needed can be calculated by equation 2 as follows:

$$N = \frac{250 \times 2.5}{1000 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{625}{420}$$

$$N = 1.48$$

After rounding, the lights needed for each room are 1 lamp.

6. Working area

The calculation of the work area is slightly different from the previous rooms. Due to the large and open area and to save the energy needed for lamps and others, the area used in each machine's calculation is based on each machine's work surface area. The location of the machine is also taken into consideration.

1. Machine 1

It has a work surface area of 2.89 m^2. The lamp that will be used is a 40Watt LED lamp with a lumen of 4800. For a direct lighting system with the bright ceiling and wall colours, the coefficient value (CV) is 50%. Assuming the light loss value is 0.7. Based on the Regulation of the Minister of Health Number 70, 2016 concerning standards and requirements for the health of the work environment, it is stated that the standard level of light intensity in a factory or production area is 300 lux. Then the number of lights needed can be calculated by equation 2 as follows:

$$N = \frac{300 \times 2.89}{4800 \times 1 \times 0.5 \times 0.7}$$

$$N = \frac{867}{1680}$$

$$N = 0.51$$

After being rounded up, the lights needed on machine 1 are 1 lamp. The results of calculations for 19 machines can be obtained using the same calculation, as shown in Table 5.

Table 5. The calculation results

No.	Machine	Area	Lamp
1	Machine 1	2.89	1
2	Machine 2 and 3	9	2
3	Machine 4	2.89	1
4	Machine 5	3.24	1
5	Machine 6 and 7	9	2
6	Machine 8 and 9	9	2
7	Machine 10	3.75	1
8	Machine 11, 12 and 13	9	2
9	Machine 14	3.24	1
10	Machine 15	3.24	1
11	Machine 16	3.24	1
12	Machine 17, 18 and 19	15	3

After doing calculations in each room and determining the number of lamps used based on the recommendations of SNI and Minister of Health Regulation No. 70 of 2016, the results of the design recommendations are shown in Figure 5.

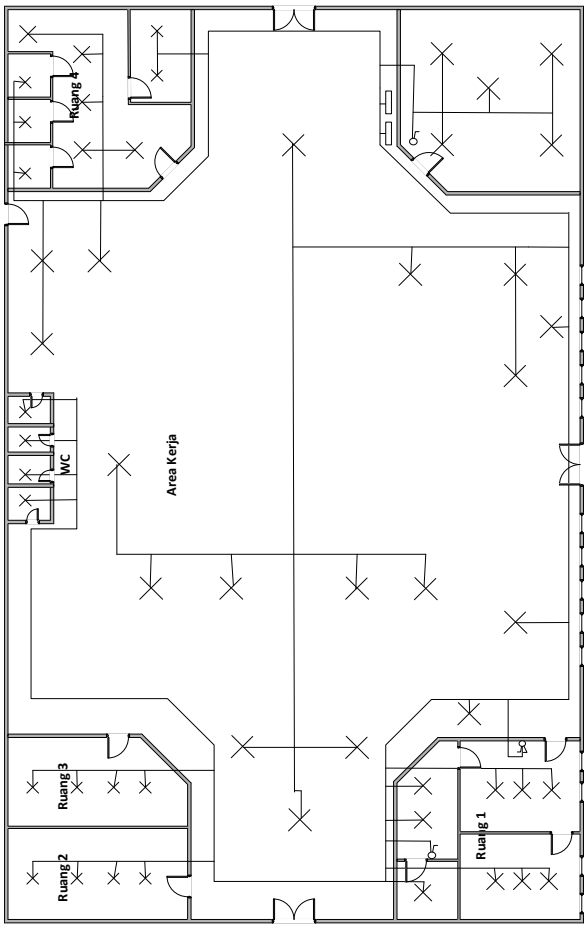

Figure 5. Workshop lighting design recommendations

IV. CONCLUSSION

The light intensity in the UNIMA Workshop building has an average of 144.2 lux in the work area and 191.06 lux in an ordinary room. So, the light intensity is still not seen from the SNI standard and the Regulation of the Minister of Health No. 70 of 2016 concerning standards and requirements for the health of the work environment with a value of 250 lux for an ordinary room and 300 lux for a work environment area.

From the calculations and analysis of the number of lamps used to meet the existing SNI standards, 54 LED lamps with variations in wattage of 10, 22, 20 and 40 were obtained.

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