

## QUALITY ANALYSIS OF ROOM NATURAL LIGHTING USING SPATIAL INTERPOLATION WITH KRIGING METHOD

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### Abstract

The results of this study, where natural lighting can affect the lighting in the room, with the entry of natural lighting into the room through 4 open windows. The data retrieval process is for 1 day through special interpolation measurements using the Kriging method. The stages of data collection are in the morning, afternoon and evening with 3 windows open and 4 windows open. The intensity of light when 3 windows are open is a minimum average of -50 lux – 1350 lux in the morning and a maximum of -50 lux -1450 lux during the day, while the condition of 4 open windows is that the minimum average lighting is 0 – 1700 lux in the morning and maximum 50 lux - 1750 lux during the day. Natural lighting can make reference to the lighting schedule in the room where the condition of 4 open windows is a mix of 5 points in the afternoon and a minimum of 3 points during the day. The electric power obtained is a maximum of 36 kWh, a minimum of 21.5 kWh and the resulting cost is a maximum of RP. 51,597, a minimum of RP. 30,814.87 so that the average energy efficiency of electric power reaches 11.75%, the highest and the lowest reaches 11.58% and efficiency towards costs reaches 58%.

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### Introduction

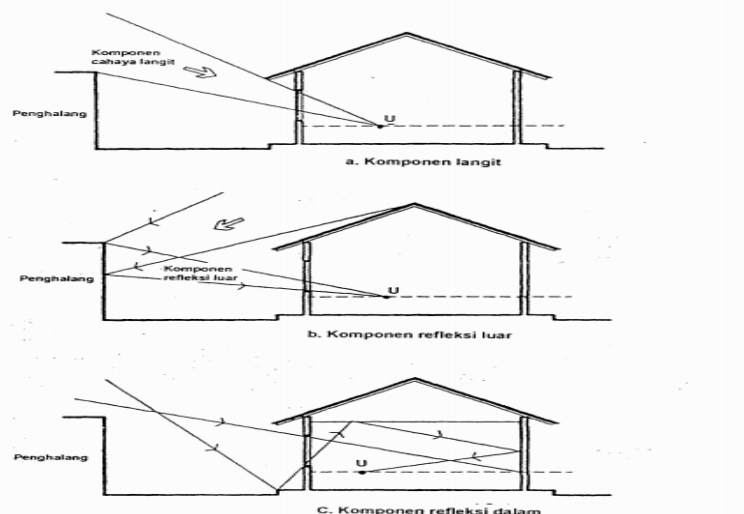
The sun is a natural light source from nature with very high light intensity (Sanders, Frago, Kehoe, Patterson, & Gaston, 2021). This natural lighting is very well used and utilized by humans lack of natural lighting that enters the room (Mahmoud, 2021), so the use of artificial lighting is more effective (Setiati & Budiarto, 2021). The study in this research is the relationship of natural lighting to the learning room (González-Zamar, Jiménez, & Ayala, 2021), where the factor causing the low natural light produced is because the sky is covered (covered) by clouds so that the sun's rays do not penetrate directly to the earth not maximally (Nicastro et al., 2021). Natural lighting is needed to support indoor activities both in industry and in high-rise buildings, office buildings, campuses and apartments in the special city in the capital Jakarta (Noviani & Jesica, 2021). The benefits of natural lighting to help lighting in the room more effectively can reduce lighting sourced from lower electrical energy by 25-35% (Ndaaru, 2021). To identify the indoor light intensity more accurately (Feng et al., 2021), the researchers conducted a simulation of the indoor lighting intensity measurement (instrument) using the kriging technique-based spatial interpolation method (Lee, Irwin, Irwin, & Miller, 2021). The measurement process was carried out for 1 day starting at 08.00 WIB - 16.00 WIB. The results of the measurement of lighting in the room are quite uniform which does not produce contrasting lighting (de Vries, Heynderickx, Souman, & de Kort, 2021) which can be seen in the lighting map image below. The level of utilization of natural lighting makes the conservation of electrical energy in the room decrease (Wei, 2021), and supports the conservation of light in the learning room and in

the environment (Boulanger et al., 2021). It is necessary to know that the glass wall in the building is very influential on the lighting in the room (Wu, Zhou, & Li, 2021) where natural light directly penetrates into the room (Li, Wu, Yuan, & Zuo, 2021) so that it can reduce lighting sourced from lighting, this is one of the savings in the use of electricity in the learning room (Avgoustaki & Xydis, 2021). The determination of the lux of indoor lighting follows the Indonesian National Standard where the standard of the room designer by producing lux brown light which is recommended by the Indonesian National is a used room of 250 Lux, office space of 350 Lux, Laboratory room of 500 Lux, Study room of 300 Lux and a hall or multipurpose building 250 Lux. The place where the researcher carried out the instrument in the design of the existing class room had 4 windows with dimensions of 3 meters x 1.8 meters, where the window was made of glass material, one of which helped the distribution of light from outside into the classroom. The location of the window is on the back and right side of the class, the classroom has 4 windows where the opening of the window researchers can take measurements and collect sample data to analyze lighting in the IT-PLN classroom using Kriging-based technology, one of the techniques of the geo-technical method. statistical is used to spatially analyze the intensity of lighting in the indoor room area. Of course, there are steps that are taken during the measurement, where before the light shelf is exposed to natural lighting, the threshold for overlapping the shape of the walecontet, before the ideal period can form three different light shelf forms, detecting the opposite energy use of the light shelf. Indoor lighting can create perspectives in different study rooms, and lighting is a fundamental that can support the learning process, indoor teaching and other activities.

## Research Method

### Lighting Criteria

Natural lighting, namely lighting obtained from the sun, lighting can reduce the consumption of lighting in the room. Natural lighting can also be in the form of electromagnetic waves with a frequency of 380-780 manometers. The natural lighting factor is a form of irradiation of light from the sun directly to the earth. There are three elements can be seen in the image below.



Picture 1. Reflection Component Shape.

Based on Picture 1 above is the form of light rays from the sun that radiate into the room where the sky component (sky-fl) is external lighting obtained directly from sunlight with an infinite electrical peak, the external shadow component (FRL) is lighting with reflected rays and produces shadows or substances residing into the room, the inner shadow component (frd) is lighting that illuminates from the outside directly into the room and produces shadows with substances on the outer glass layer. The internal natural lighting factor is determined by the alignment of the window opening.

**Lighting**

The intended lighting is from a lamp energy source where the intensity of lighting in an indoor area is expressed as a flux with a reservoir area of m<sup>2</sup>. The refractive intensity of the light rays from the lamp is determined in general where the vertical side is 80 cm above the floor. In the colored plane and in the horizontal area, the intensity of lighting E is expressed as lux or lumen/m<sup>2</sup>, while the flux is placed with an area of A m. To find out, see the lumen equation below.

$$E = \frac{d\Phi}{dA} \dots\dots\dots(1)$$

Where :

- E = Illuminance (lx);
- Φ = Luminous flux (lm);
- A = Area (m<sup>2</sup>).

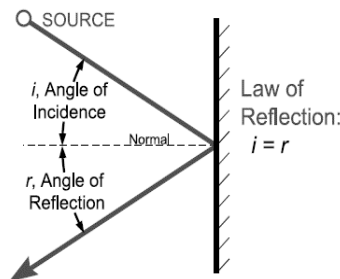
The glare index on lighting can be seen in the equation below.

$$C = \frac{E_n}{E_w} \times 100\% \dots\dots\dots(2)$$

Where :

- C = Exposure factor
- E<sub>n</sub> = lumen

Lighting from sunlight that enters the room experiences reflection where the rays come, the rays reflect on the normal line which is one of the flat planes can be seen in the image below.



Picture 2. Relationship of Lines and Lighting.

Picture 2 above explains the relationship between the vertical normal lines located in a flat plane, the source is the shape of the incident ray, namely (i), the Angle of Incidence and the reflected ray is stated (r), the Angle of Reflection and for the law of Reflection i = r, as for the glare index. on the light/lighting can be seen in the table below.

Table 1. Maximum Glare Index on Visual and Interior Tasks.

Type of Visual or Interior Tasks and Glare Control required	Maximum Glare Index	Examples of Visual and Interior Tasks
Gross visual tasks or tasks that are not performed continuously	28	Raw materials, Steel frame production, welding
Glare control required on a limited basis	25	Warehouses, cold stores, turbine and boiler buildings, machine and equipment stores, plant Rooms.
Normal Visual and Interior Tasks	22	Corridors, stairs, canteens, cafeterias, dining rooms, inspection and testing (manual work), assembly rooms, sheet metal work

**Spatial Interpolation**

Prediction of natural lighting during the day is done by spatial analysis. Kriging is a geo-statistical method with a technique used to interpolate units of random field values at a location. The lack of discrete observer values at the nearest location, with a geo-statistical approach, describes the spatial pattern and interpolates the main variables at locations that have not been sampled. geo-statistical and used to model the uncertainty of the error in the forecast area can be seen in the general interpolation equation expressed as follows:

$$Z^A(X_0) = \sum_{i=1}^n \lambda_i Z(X_i) \dots\dots\dots(3)$$

Where :

- (Xi ) = The measured value at the location point Xi
- Z(X0 ) = Estimated value on attribute X0
- $\lambda_i$  = unknown weight at location
- X0 = predicted location
- N = number of measured values.

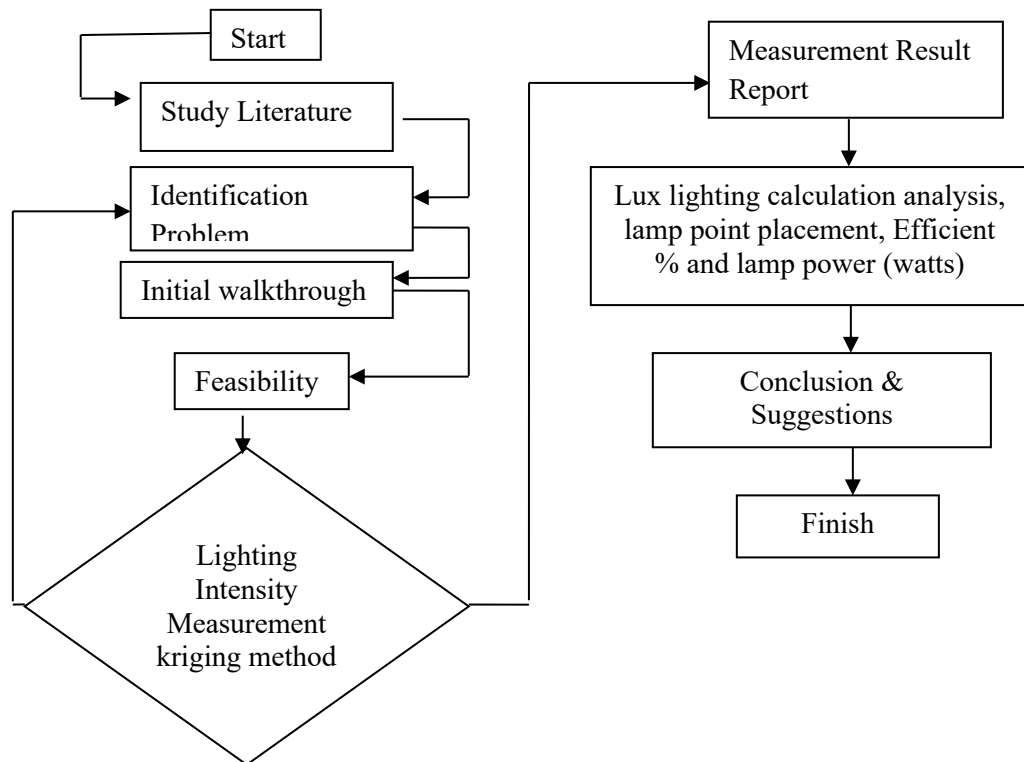
The kriging equation (simple kriging) can be expressed as follows:

$$Z^A(X_0) = \sum_{i=1}^n \lambda_i Z(X_i) + [1 - \sum_{i=1}^n \lambda_i] \dots\dots\dots(4)$$

Where:

- Z(Xi ) = Value measured at location point Xi
- Z(X0 ) = Estimated value on attribute X\_0
- $\lambda_i$  = unknown weight at location
- X0 = predicted location
- n = number of measured values
- $\mu$  = where is the known stationary mean. Parameter  $\mu$  assumed constant over the entire domain and calculated as the average of the data.

Here is the research flow.



Picture 3. Research Flowchart.

## Result and Discussion

### Measurement Scheme

The measurement scheme is carried out in the teaching and learning room 1004 at the Institute of Technology-PLN Jakarta where the light measurement uses a lux meter (Smart sensor brand), the measurement accuracy is approximately 5% with a range of 0 - 200,000 lux starting from 08.00 - 16.00 WIB. There are three stages of the measurement process, namely morning, afternoon and evening and the measurement results can be seen in each table below.

Table 2. Morning Conditions Window is Open.

No	Morning Condition	Total Lux 60 Observation Points (Lux)	Everage Lux Room	Large Window (m <sup>2</sup> )	Lux Enter Window Open (Lux/m <sup>2</sup> )
1	Condition 1 window open	1031,38	17,19	5,40	3,18
2	Condition 2 windows open	3248,11	54,14	10,80	5,01
3	Condition 3 windows open	9853,00	164,22	16,20	10,14
4	Condition 4 windows open	18838,22	313,97	21,60	14,54

Table 2 above describes the condition of the open window in the morning. The measurement results with a total lux of 60 observation points with an average Lux of 17.19, a window area of 5.40m<sup>2</sup>, the lowest total lux of 1031.38 and an entrance Lux of 3.18, the highest Lux result is in the 4th condition, which is Total lux 18838.22 with a

window area of 21.60m<sup>2</sup> and the incoming lux is 14.54 so the average Lux of the room is 313.97.

Table 3. Daytime Conditions Windows Open.

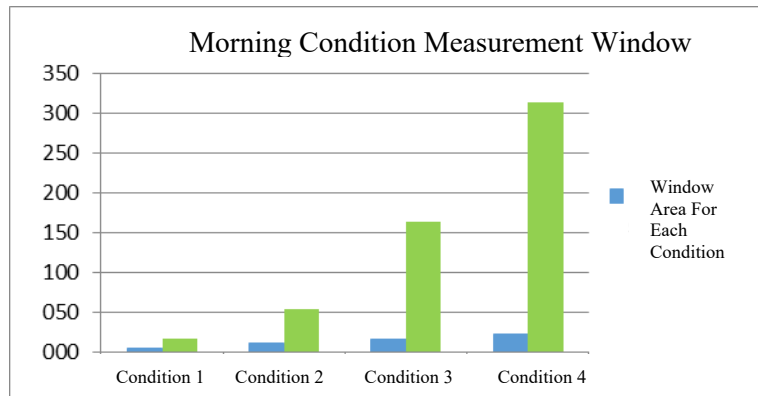
No	Daytime Conditions	Total Lux 60 Observation Points (Lux)	Everage Lux Room	Large Window (M <sup>2</sup> )	Lux Enter Window Open (Lux/M <sup>2</sup> )
1	Condition 1 Window Open	1606,89	26,78	5,40	4,96
2	Condition 2 Windows Open	3701,33	61,69	10,80	11,42
3	Condition 3 Windows Open	11842,11	197,37	16,20	36,55
4	Condition 4 Windows Open	24434,67	407,24	21,60	75,42

Table 3 above describes the conditions during the day when the windows are open. The results of the measurement of total lux at 60 points, the lowest average observation results. Total lux is 1606.89, where Lux room is 26.78 with a window area of 5.40m<sup>2</sup> Lux entry is 4.96, the highest result is in the 4th condition, namely Total lux 24434.7 The average Lux of the room is 407.24, the window area is 21.60 m<sup>2</sup> and the incoming lux is 75.42.

Table 4. Conditions in The Afternoon The Window is Open.

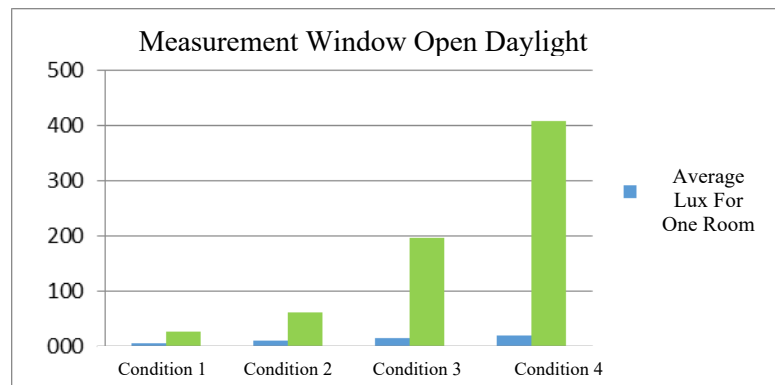
No	Afternoon Conditions	Total Lux 60 Observation Points (Lux)	Everage Lux Room	Large Window (M <sup>2</sup> )	Lux Enter Window Open (Lux/M <sup>2</sup> )
1	Condition 1 Window Open	1481,56	24,69	5,40	4,57
2	Condition 2 Windows Open	3569,89	59,50	10,80	11,02
3	Condition 3 Windows Open	8686,00	144,77	16,20	26,81
4	Condition 4 Windows Open	22153,00	369,22	21,60	68,37

Table 4 above describes the conditions during the day when the window is open, the total lux at 60 observation points is the lowest average total lux is 1481.56. The lowest value of Lux room is 24.69 with a window area of 5.40m<sup>2</sup>, the highest value is in the 4th condition, namely Total lux is 22153.00 and the Average Lux room is 369.22 with a window area of 21.60m<sup>2</sup> lux that enters is 68.37. The graph for measuring the condition of the open window in the morning, afternoon and evening. with the window area and the average lux in the room so that it can be seen more clearly in the graph below.



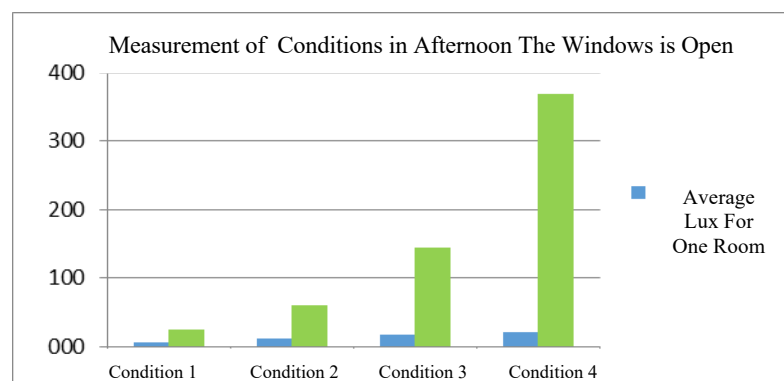
Picture 4. Morning Condition Window Open.

Picture 4 above explains the window area for each condition and the average lux value in one room where the highest lux value is 300 in the morning conditions and the lowest lux value is 025 in the 1st condition.



Picture 5. Open Window Day Conditions

Picture 5 above describes the highest lux value of 400 in the 4th condition and the lowest lux value of 025 in the 1st condition.

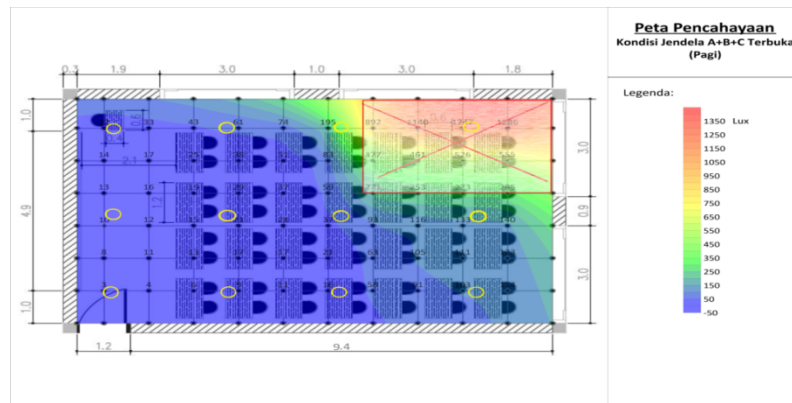


Picture 6. Conditions in the Evening Window Open.

Picture 6 above explains the highest lux value of 360 in the 4th condition, the lowest lux value of 025 in the 1st condition.

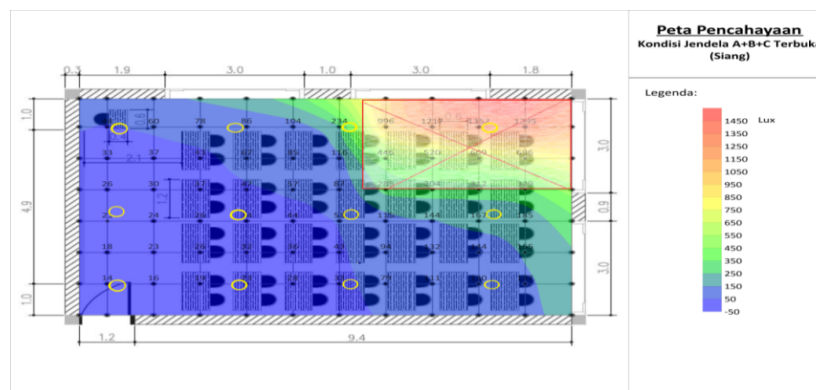
**Lighting Modeling**

From the mapping of indoor lighting carried out in every condition with existing lamps installed, namely the 36 watt TL-D lamp type in the learning room, where the natural lighting produced is not evenly distributed so it needs additional lighting from electrical energy. light is turned on. There are several images that are displayed as a result of mapping the lighting conditions in the morning, afternoon and evening as follows:



Picture 7. Condition of window A+B+C open.

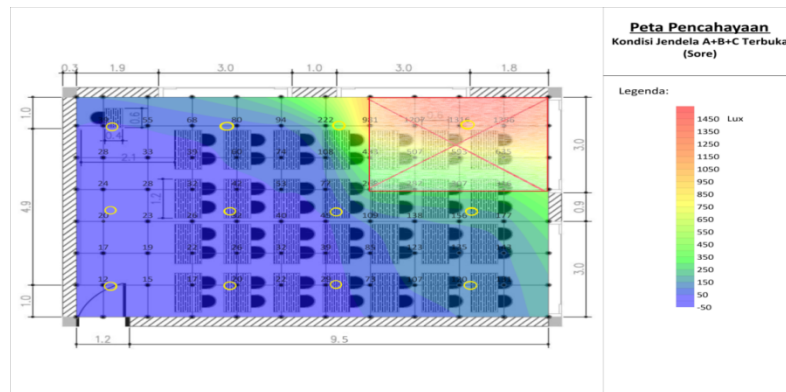
Picture 7 above describes the placement of lighting points and lighting conditions in the morning when the A+B+C window is open, where the blue light field has not yet reached the standard, namely – 50 lux - 250 lux, while the green color field for lighting reaches the standard of 350 lux – 550 lux and in the area of red mixed with yellow, the lighting exceeds the standard (maximum) i.e. 650 lux – 1350 lux. The Map of Daylighting conditions is shown in the image below.



Picture 8. Window 3 (window A+B+C opens).

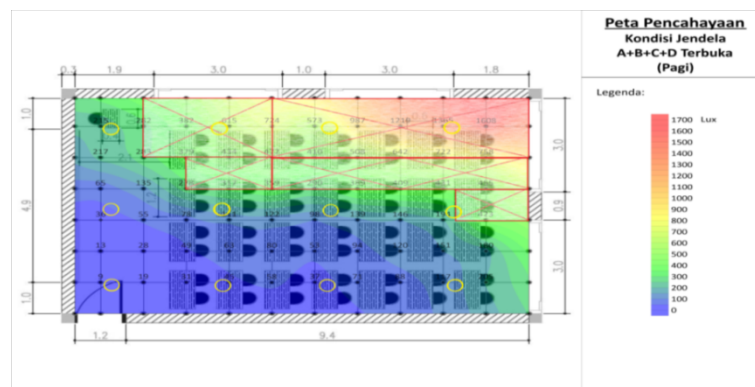
Picture 8 above describes the placement of lighting points and lighting conditions during the day when the A+B+C window is open, where the blue area of lighting has not reached the standard, namely – 50 lux - 250 lux, while the green area of lighting reaches the standard of 350 lux - 550 lux and in the area of red mixed with yellow, the lighting exceeds the standard (maximum) i.e. 650 lux – 1450 lux. Lighting Map of Afternoon conditions.





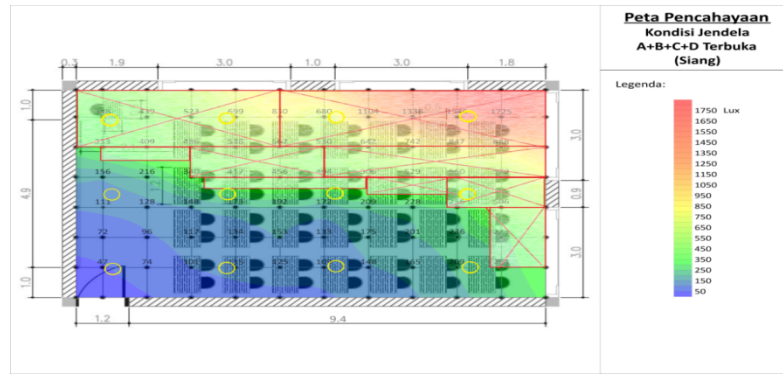
Picture 9. Window 3 (Window Condition A+B+C is open).

Picture 9 above explains the placement of lighting points and lighting conditions in the afternoon when the A+B+C window is open, where the blue area of lighting has not reached the standard, namely – 50 lux - 250 lux, while the green area of lighting reaches the standard of 350 lux - 550 lux and in the area of red mixed with yellow, the lighting exceeds the standard (maximum) i.e. 650 lux – 1450 lux. For lighting conditions, 4 open windows can be seen in Figure 3.19 below, Map of Lighting Conditions in the Morning.



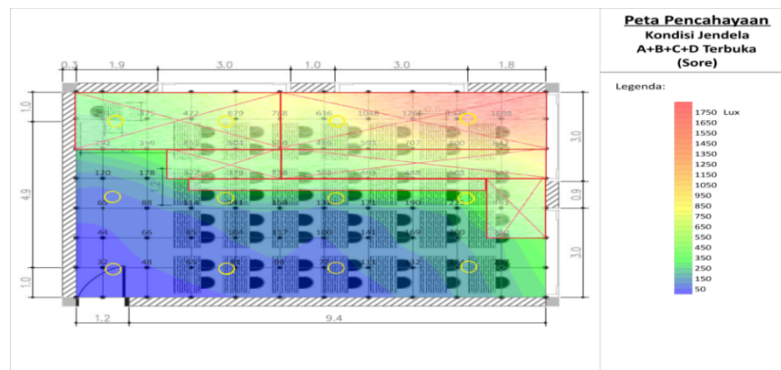
Picture 10. Window 4 ( window A+B+C+D opens).

Picture 10 above describes the placement of lighting points and morning lighting when the A+B+C+D window is open, where the blue light field has not yet reached the standard, namely 0 lux - 200 lux, while the green color area for lighting reaches the standard of 300 lux - 600 lux and at the red mixed yellow color area of the lighting exceeds the standard (maximum) which is 700 lux – 1700 lux. Map of Daylighting Conditions.



Picture 11. Window 4 ( window A+B+C+D Opens).

Picture 11 above describes the placement of lighting points and daytime lighting when the A+B+C+D window is open, where the blue area of the lighting has not yet reached the standard, namely 50 lux - 250 lux, while the green area of the lighting has reached the standard of 350 lux - 550 lux and in the area of red mixed with yellow the lighting exceeds the standard (maximum) i.e. 650 lux – 1750 lux. For a map of the lighting conditions in the afternoon, 4 windows are opened, it can be seen in picture 12 below.



Picture 12. Window 4 (window A+B+C+D Opens).

Picture 12 above describes the placement of light points and morning lighting when the A+B+C+D window is open, where the blue light field has not yet reached the standard, namely 50 lux - 250 lux, while the green color area for lighting reaches the standard of 350 lux – 550 lux and in the area of red mixed with yellow the lighting exceeds the standard (maximum) i.e. 650 lux – 1750 lux.

### Calculation Analysis

Determine the number of light points in the room.

Qualification	Unit (cm)	Unit (m)
Room Length	1070 cm	10,7 m
Room Wedth	690 cm	6,9 m
Room Area	7383 cm	73,83 m <sup>2</sup>
SNI Classroom	250 lumen/m <sup>2</sup>	250 lux

Type of lamp installed:

Brand Philips Type TL-D 36 Watt and lamp efficiency: 69 lumen/watt (lm/w), cool day light 6500 K, the results to determine the capacity and lamp point based on the calculation analysis using the formula below.

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{\phi \times LLF \times CU \times n}$$

Where ,

- A = L x w (area)
- $\phi$  = Total lumens produced per 1 lamp
- Cu = Utility coefficient (0,5 – 0,7)
- LLF = Light Loss Factor ( 0,7 – 0,8)
- n = Number of lights at 1 point

**1 Point analysis Lights Window 3 opens**

1. Determine the number of lighting points in the room with 0 open windows, no natural lighting (sunlight) coming in based on the area of the room listed in table 5 below.

Table 5. Window condition 0 is open

Qualification	Unit (cm)	Unit (m)
Room Area	7388 cm	73,83 m
SNI Classroom	250 lumen/m <sup>2</sup>	250 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{250 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{6A}{P \times n} = \frac{6 \times 73,83}{36 \times 1} = 12 \text{ titik}$$

Table 6. Condition of Window 3 Open in The Morning.

Qualification	Unit (cm)	Unit (m)
Room Area	6127 Cm	61,27 m
SNI Classroom	247 lumen/m <sup>2</sup>	247 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{247 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{6A}{P \times n} = \frac{6 \times 61,27}{36 \times 1} = 10 \text{ titik}$$

Table 7. Window Condition 3 Open During The Day.

Qualification	Unit (cm)	Unit (m)
Room Area	5320 cm	53.20 m
SNI Classroom	236 lumen/m <sup>2</sup>	236 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{236 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{6A}{P \times n} = \frac{6 \times 53,20}{36 \times 1} = 9 \text{ titik}$$

Table 8. Condition of Window 3 Open in The Afternoon.

Qualification	Unit (cm)	Unit (m)
Room Area	5320 cm	53.2 m
SNI Classroom	238 lumen/m <sup>2</sup>	238 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{238 \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{6 A}{P \times n}$$

$$= \frac{6 \times 53,2}{36 \times 1} = 9 \text{ titik}$$

**1. Analyze the light point of Window 4 open**

Determine the use of the number of light points in the condition of 4 open windows, namely A+B+C+D windows in the morning.

Table 9. Window Condition 4 Open In The Morning.

Qualification	Unit (cm)	Unit (m)
Room Area	2820 cm	28.20 m
SNI Classroom	241 lumen/m <sup>2</sup>	241 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{241 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{5 A}{P \times n} = \frac{5 \times 28,20}{36 \times 1} = 4 \text{ titik}$$

Table 10. Window Condition 4 Open During The Day.

Qualification	Unit (cm)	Unit (m)
Room Area	1860 cm	18.60 m
SNI Classroom	203 lumen/m <sup>2</sup>	203 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{203 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{5 A}{P \times n} = \frac{5 \times 18,60}{36 \times 1} = 3 \text{ titik}$$

Table 11. Condition of Window 4 Open in The Afternoon.

Qualification	Unit (cm)	Unit (m)
Room Area	3498cm	34.98 m
SNI Classroom	203 lumen/m <sup>2</sup>	203 lux

$$N = \frac{E \times L \times W}{\phi \times LLF \times CU \times n} = \frac{E \times A}{P \times 69 \times 0,8 \times 0,7 \times n} = \frac{203 \times A}{P \times 69 \times 0,8 \times 0,7 \times n}$$

$$= \frac{5 A}{P \times n} = \frac{5 \times 34,98}{36 \times 1} = 5 \text{ titik}$$

Tables 5-11 above explain the area of the room with the resulting lumen with 3 open windows, the lights are turned on a maximum of 10 points in the morning conditions and a minimum of 9 points in the afternoon and evening conditions and 4 open windows conditions with lights turned on for a maximum of 5 points in the afternoon and evening conditions. at least 3 points of daylight conditions.

**3. Power Energy State Window 3 is open**

Energy consumption of lamps in condition of 3 open windows, namely A+B+C windows in 1

month in the learning room as follows

Consumption of electrical energy in the morning conditions

$$P = 10 \times 36 = 360 \text{ watt}$$

$$= 360 \times 8 \times 25 = 72.000 \text{ Wh} = 72 \text{ kWh}$$

Consumption of electrical energy in daytime conditions

$$P = 9 \times 36 = 324 \text{ watt}$$
$$= 324 \times 8 \times 25 = 64.800 \text{ Wh} = 64.8 \text{ kWh}$$

Consumption of electrical energy in the afternoon conditions

$$P = 9 \times 36 = 324 \text{ watt}$$
$$= 324 \times 8 \times 25 = 64.800 \text{ Wh} = 64.8 \text{ kWh}$$

#### **4. Power Energy State Window 4 is open**

Energy consumption of lamps when window 4 is open, i.e. window A+B+C+D in 1 month in the learning room as follows.

Consumption of electrical energy in the morning conditions

$$P = 4 \times 36 = 144 \text{ watt}$$
$$= 144 \times 8 \times 25 = 28.800 \text{ Wh} = 28.8 \text{ kWh}$$

Consumption of electrical energy in daytime conditions

$$P = 3 \times 36 = 108 \text{ watt}$$
$$= 108 \times 8 \times 25 = 21.600 \text{ Wh} = 21.6 \text{ kWh}$$

Consumption of electrical energy in the afternoon conditions

$$P = 5 \times 36 = 180 \text{ watt}$$
$$= 180 \times 8 \times 25 = 36.000 \text{ Wh} = 36 \text{ kWh}$$

Consumption of electrical power for windows 3 open and 4 open in the learning room, large savings in electrical power are found in window 4 open, namely a maximum of 36 kWh and a minimum of 21.6 kWh.

#### **5. kWh cost.**

The cost of saving electrical energy when the A+B+C+D window is open where, Power Electrical energy per kWh x Cost.

Morning Condition

$$W (\text{savings}) = W \text{ conditions 0} - W \text{ conditions calculated}$$
$$= 86,3 \text{ kWh} - 28.8 \text{ kWh} = 57.5 \text{ kWh}$$

$$\text{Electricity Savings cost} = \text{Electrical energy} \times \text{cost per kWh}$$
$$= 28.8 \times 1.433,25 = \text{Rp. } 41.227,6$$

Daytime conditions

$$W (\text{savings}) = W \text{ conditions 0} - W \text{ conditions calculated}$$
$$= 86,3 \text{ kWh} - 21.5 \text{ kWh} = 64.8 \text{ kWh}$$

$$\text{Electricity Savings cost} = \text{Electrical energy} \times \text{cost per kWh}$$
$$= 21.5 \times 1.433,25 = \text{Rp. } 30.814,87$$

Afternoon conditions

$$W (\text{savings}) = W \text{ conditions 0} - W \text{ conditions calculated}$$
$$= 86,3 \text{ kWh} - 36 \text{ kWh} = 50.3 \text{ kWh}$$

$$\text{Electricity Savings cost} = \text{Electrical energy} \times \text{cost per kWh}$$
$$= 36 \times 1.433,25 = \text{Rp. } 51.597$$

The cost of kWh when window 4 is open, namely the daytime condition is 21.5 kWh and the cost is RP.30,814.8 and the highest value for the afternoon condition is 36 kWh and the cost is RP.51,597.

#### **6. Efficiency**

The intended efficiency is saving on the use of lamps which affect the cost of kWh of electricity in the room, because the lighting in the room has been assisted by natural lighting, namely sunlight.

1. Efficiency of lighting in the morning conditions

$$\text{Efficiency} = \frac{\text{Number of existing lights} - N(\text{light needed})}{\text{Number of existing lights}} \times 100\%$$

$$\text{Efficiency} = \frac{12-4}{12} \times 100\% = 11.67 \%$$

2. Efficiency of lighting in daylight conditions

$$\text{Efficiency} = \frac{\text{Number of existing lights} - N(\text{light needed})}{\text{Number of existing lights}} \times 100\%$$

$$\text{Efficiency} = \frac{12-3}{12} \times 100\% = 11.75 \%$$

3. Efficiency of lighting in the evening conditions

$$\text{Efficiency} = \frac{\text{Number of existing lights} - N(\text{light needed})}{\text{Number of existing lights}} \times 100\%$$

$$\text{Efficiency} = \frac{12-5}{12} \times 100\% = 11.58 \%$$

## Conclusion

Lighting is a major need in indoor environments such as homes, offices, hotels, campuses and other commercial buildings. Data were collected by measuring (instrument) the lighting in the room, by spatial interpolation using the shower kriging program method. The steps for measuring the condition of the window are closed, window 3 is open and window 4 is open, namely in the morning, afternoon and evening. The results of the measurement (instrument) that window 3 is open in the morning, large lux minimum -50 – 250 lux, maximum 650 – 1350 lux, minimum daytime -50 – 250 lux, maximum 650 – 1450 lux and minimum afternoon -50 – 250 lux, maximum 650 – 1450 lux. Then window 4 opens in the morning with a minimum lux of 0 – 200 lux, a maximum of 700 – 1700 lux, a minimum of 50 – 250 lux during the day, a maximum of 650 – 1750 lux and a minimum of 50 – 250 lux in the afternoon, a maximum of 650 – 1750 lux. the number of light points that are turned on in the condition of the open windows 3 in the morning 10 points, 4 points during the day and 5 points in the afternoon. window conditions 4 open in the morning 4 points, 3 points in the afternoon and 5 points in the afternoon. The average power consumption in 1 month is a maximum of 36 kWh, a minimum of 21.5 kWh. The resulting fee is a maximum of Rp. 51,597 and a minimum of Rp. 30,814.87 so that the energy efficiency of electric power reached 11.75 % the highest and the lowest reached 11.58%.

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