The Role of Nanotechnology in Energy-Efficient Lighting: Evaluating Store Building Lighting Using Dialux and MsExcel

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Planning and installing lighting systems in lecture halls is a significant issue for several reasons. Therefore, this research used a lux meter to observe and evaluate the lighting system in the new building of the Faculty of Engineering and Vocational Education, Indonesia University of Education. Data were tested using DIALux (Deutsches Institut für Angewandte Lichttechnik) software, and calculations were made through Microsoft Excel. It is important to note that the lamps produced the lux required by the room and the lumens. The calculation results showed that the lighting installed in the building has a conformity level of 70% with the SNI standard.

Keywords: Lighting, Dialux, Ms. Excel, SNI standard, Armature.

1. Introduction

Lighting is essential in the design of a building due to its ability to support the function of space and several other activities in the room, form an aesthetic visual image, and create comfort and safety for space users [1]. This means it needs to be considered in the planning phase because the activities to be conducted in a room usually affect light distribution. It is also essential for an architect to design the lighting based on the recommended lighting standards [2].

The primary function of lighting is to support the activities in a space [3]. Moreover, optimal lighting is highly desirable due to its ability to fulfill two basic human needs, including the lighting effect's visual and environmental stimulation [4]. It has been previously reported that poor lighting can make space users feel awake and very active [5]. This is a psychological effect in the physical form because the atmosphere in a space can be created from the color and intensity of the light.

Schools, as one education provider, require adequate lighting comfort to ensure smooth teaching and learning activities. Moreover, determining the lighting intensity involves the consideration of the room index, luminous flux, and the number of armatures. Its assessment also requires a match between the measured conformity of the design through theory and standards and the users' perception.

Lighting is one of the factors in achieving a safe and comfortable environment and is also closely related to human productivity. All living things, including humans, require it. It has been reported that proper lighting conditions usually allow building users to conduct their activities comfortably, efficiently, and safely [6]. Moreover, light has some unique qualities with a specific focus on its effect on the eyes and nerves because its absence can lead to eye fatigue and nerve tension [7].

Humans need natural lighting from the sun due to its quality [1]. It can minimize the use of electrical energy, which is why it must be prioritized in designs. Natural light sources are, however, sometimes considered less effective than artificial light due to their varying intensity and heat generation, specifically during the day[8]. Artificial lighting is produced by sources other than natural sources [9]. It is indispensable when a room is positioned so that it is difficult for natural light to enter from outside. The primary source of artificial lighting is electrical energy[10], mainly used at night but sometimes during the day, in addition to insufficient sunlight to light up the room [11].

Several types of lamps listed in the SNI-6197-2011 regulations are stated as follows(a)Incandescent lamp; (b)Halogen lamp; (c)Fluorescent lamp; (d) Other gas discharge lamp; and (e)LED lamp. The armature is the control of light lamp distribution through a lamp housing. It can be classified in four ways based on the direction of light distribution, protection against dust and water, protection against electric shock, and installation method [12]. The percentage of light emitted towards the bottom and top can be grouped under an armature based on the distribution of light intensity, as shown in the following table:

Table 1. Armature Classification Based On The Direction Of Light

Armature Class	Number of lights	
	Towards the bottom (%)	Towards the top (%)
1	2	3
Indirect	0 – 10	90 – 100
Semi indirect	10 – 40	60 – 90
Diffuse	40 – 60	40 – 60
Semi-direct	60 – 90	10 – 40
Direct	90 – 100	0 – 10

Source: [13]

The classification is in line with the grouping of armature into five based on the distribution direction by the ILO (International Labor Organization, 1998), including:

a. Indirect Lighting Distribution

In an indirect lighting system, as much as 90 – 100% of the light is directed to the ceiling and the upper part, which are then reflected to brighten the entire room. However, it requires good maintenance and is considered advantageous because it does not create shadows and glare but lacks total efficiency due to the light falling on the work surface.

b. Semi-Indirect Lighting Distribution

This involves directing as much as 60-90% of the light to the ceiling. It also requires appropriate attention and good maintenance. However, the system is practical because there are no problems with shadows and glare.

c. Diffuse Lighting Distribution

This method involves directing as much as 40-60% of the light to the surface required to be illuminated, with the rest headed to the ceiling and walls to reflect. In this system, the reflection value from the roof should be high to reflect enough light downwards. However, it has the problems of shadows and glare.

d. Semi-Direct Lighting Distribution

This system has as much as 60-90% of the light directed toward the objects to be lighted while the rest is reflected in the ceiling and walls. It can reduce the weakness of the direct lighting system.

e. Direct Lighting Distribution

In a direct lighting system, as much as 90 – 100% of the light is directed directly at the objects to be illuminated. This system is most effective in regulating lighting but can cause annoying shadows and glare due to direct irradiation or reflection of light.

Source [14].

Armature Classification Based on Protection against Dust and Water. Protection against dust and water is stated in the clarification of SNI 04-0202-1987, as indicated in Table 2 below.

Table 2. Armature Classification on Their Protection

No	Protection Level		Second Number
	Description	Description	
0	There is no protection against live touch, equipment, and the entry of objects from the outside.	No protection.	0
1	Accidental protection against touch from any part of the human body	Protection against condensed water droplets.	1
2	Protection against the touch of fingers with live parts and the entry of solid objects.	Protection against water drops that bring harmful consequences.	2
3	Protection against the entry of tools, wires, or the like with a thickness of more than 2.5 mm.	Protection against the rain.	3
4	Protection against the entry of tools, wires, or the like with a thickness of more than 1 mm.	Protection against splash.	4

5	Perfect protection against the touch of live parts and harmful dust deposits.	Protection against water spray: Water is sprayed from all directions but is non-destructive.	5
6	Ideal protection against contact with live features.	Protection against conditions on the deck of the ship (deck watertight equipment)	6

Source: [15]

Classification Based on Installation Method. This classification is divided into several groups, which include the installed in, attached to, and hung from the ceiling [12]. Minimum Lighting Standard. Lighting standards are fundamental in a situation where the level of lighting and color rendering depends on the room's function.

Table 3. Lighting Standards

Room Function	Lighting Level (LUX)	Group of Color Renderations	Color of Temperature		
			Warm white	Cool white	Daylight
Classroom	300	1 or 2		-	-
Library	300	1 or 2		-	-
Laboratorium	500	1		-	-
Picture Room	750	1		-	-
Canteen	200	1	-	-	
Room Teacher	300	1 or 2		-	-

Source: (SNI, 2011)

Table 4. Lighting Point Coefficient

Lighting efficiency for new circumstances														Depreciation factor for the maintenance period		
Indirect Direct Armature	K		rp 0,7				0,5				0,3					
			rw 0,5	0,3	0,1		0,5	0,3	0,1		0,5	0,3	0,1	1 year	2 years	3 years
			rm 0,1				0,1				0,1					
	0,5		0,26	0,20	0,17		0,22	0,18	0,15		0,19	0,16	0,14	Light fouling		
	0,6		0,30	0,25	0,21		0,26	0,22	0,19		0,23	0,19	0,17	0,85	0,80	0,70
	0,8		0,38	0,32	0,28		0,33	0,29	0,25		0,28	0,25	0,23			
	1		0,43	0,38	0,34		0,38	0,34	0,30		0,32	0,29	0,27			
GCB 2 x TL 40 W	1,2		0,47	0,42	0,38		0,41	0,37	0,34		0,35	0,32	0,30	Medium fouling		
	1,5		0,51	0,47	0,43		0,45	0,41	0,38		0,38	0,36	0,33	0,80	0,70	0,65
	2		0,56	0,52	0,49		0,49	0,46	0,43		0,42	0,40	0,38			
	2,5		0,56	0,56	0,52		0,52	0,49	0,46		0,44	0,42	0,40			
	3		0,61	0,58	0,55		0,54	0,51	0,49		0,46	0,44	0,42	Severe fouling		
	4		0,64	0,62	0,59		0,56	0,54	0,52		0,48	0,47	0,45	X	X	X
	5		0,66	0,64	0,62		0,58	0,56	0,54		0,50	0,48	0,47			

Source: P Van Harten and E Setiawan 1991

Lighting Intensity Calculation

1) Room Index (k)

Room index factor (k) can be determined through the following formula:

$$K = \left(\frac{L \text{ x } P}{h\ (L+P)}\right) \quad (1)$$

Where:

K = Room Index

h = Height of the light source above the work plane (m)

P = Length of the room (m)

L = Width of the room (m)

Source: (P. Van Harten and Ir. E. Setiawan, 1991)

The light efficiency can be evaluated by looking at the table with k, rp, rw, and rm values after the room index value (k) has been determined. Therefore, it can be calculated using the following interpolation:

$$Kp = kp_1 + \frac{k-k1}{k2-k1} \text{ x } (kp2 - kp1) \quad (2)$$

Where:

Kp = Utility factor to be found

kp1 = Lower limit utility factor

kp2 = Upper limit utility factor

k = Room Index

k1 = Index of the lower limit room

k2 = Index of the upper limit room

2) Light Flux (Ø)

The light flux can be calculated using the following equation:

$$Ø = W \frac{L}{w} \quad (3)$$

Where:

Ø = Light flux (lumen)

W = Lamp power (watt)

L/w = Lamp lumen (Lumen/watt)

(BL. Theraja, 1980)

3) Number of Armature

The number of lamps required can be calculated using the following formula:

$$nL = \frac{E \text{ x } A}{Ø arm \text{ x } Kp \text{ x } d} \quad (4)$$

Where:

nA = number of armatures

$Ø_{arm}$ = Armature light flux (lumen)

E = Required lighting intensity (lux)

A = Area of the room (m2)

Kp = Lighting efficiency

d = Depreciation factor

([13];[16]

DIALux 10.1

DIALux is a free natural, artificial lighting program overgrowing and fulfills the information needs of the latest lighting technology. In addition, it can generate automatic technical reports and visual rendering capabilities observed to be constantly improving. DIALux GmbH was created in 1989 in Germany and is still being developed to fulfill the growing lighting needs.

Microsoft Excel

The next application used was Microsoft Office Excel, and it involved using the sheet-to-sheet system in line with the SNI calculations in electrical lighting installation design.

2. RESEARCH METHOD

The stages used in this research to evaluate the lighting in a multi-story building are shown in Figure 1

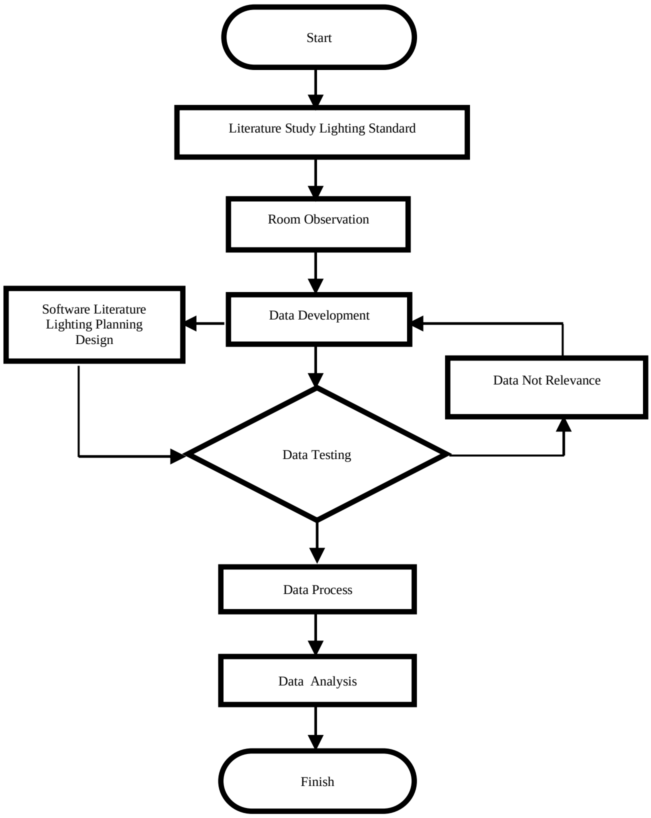

Figure 1. Research flow

The research stages in Figure 1 are explained as follows:

Several pieces of literature were reviewed, and observations were made to obtain field data on lighting design drawings, room conditions, number of lamps installed, types of lights, and lamp lumens.

The data were processed and calculated using DIAlux and Microsoft Excel software with due consideration for the coefficients listed in the SNI. The results were subsequently used to evaluate the lighting installed in the building.

3. RESULT AND DISCUSSION

Three types of LED lamps are installed in the field with different power and placements designed to their needs, as indicated below.

Table 5. Data On the Type of Lamps Installed

Lamp Type	Watt Specification	Lumen	Room
LED TL	18	1800	Laboratory Lab, Classroom, Workshop, Room Panel, Office room, Logistics room, Smoke shaft, Lobby.
LED DL	16	1600	Corridor and Hall
LED DL	13	1300	Toilet Difabel, Smoke Shaft, and Lobby
LED DL	9	1300	Toilet for Men and Women
LED DL	7	1300	Janitor room
LED DL	12	1300	Escalator room

Calculation using Microsoft Excel

The number of light points needed in a room was determined based on the following criteria:

a) Depression factor with a value of 0.8.

b) The pseudo-reflection element of r_m works using a value of 0.1.

c) Light-colored ceilings and walls using $r_p = 0.7$ and $r_w = 0.5$.

d) The number of armatures installed in the room.

e) Type of lamps used in the room.

This table shows one armature point on the 2nd floor in the electromechanical room with an area of 68 m^2 using 2 x TL LED lamps with 18-watt specifications. The calculation results showed that 9.32 armatures, approximated to 9, are required.

Table 6. Display of the DIAlux model's light point count

Armature Point Calculation				
Room Size	p	=	8,5	Meters
	I			Meters
Luman Lapm		=	3600	Lumen
Intencity Lamp		=	300	Lux
Room Efficiency		=	0,76	
Depreciacy Factor		=	0,8	
SNI Armature		=	9,32018	Armature

Calculation using DIALux

DIALux software was also used to calculate the armature point virtually. The calculation was conducted in a classroom on the 2nd floor with an area of 35 m^2. The figure shows 330 lux of light intensity was produced from 2 x TL LED lamps with a specification of 18 watts.

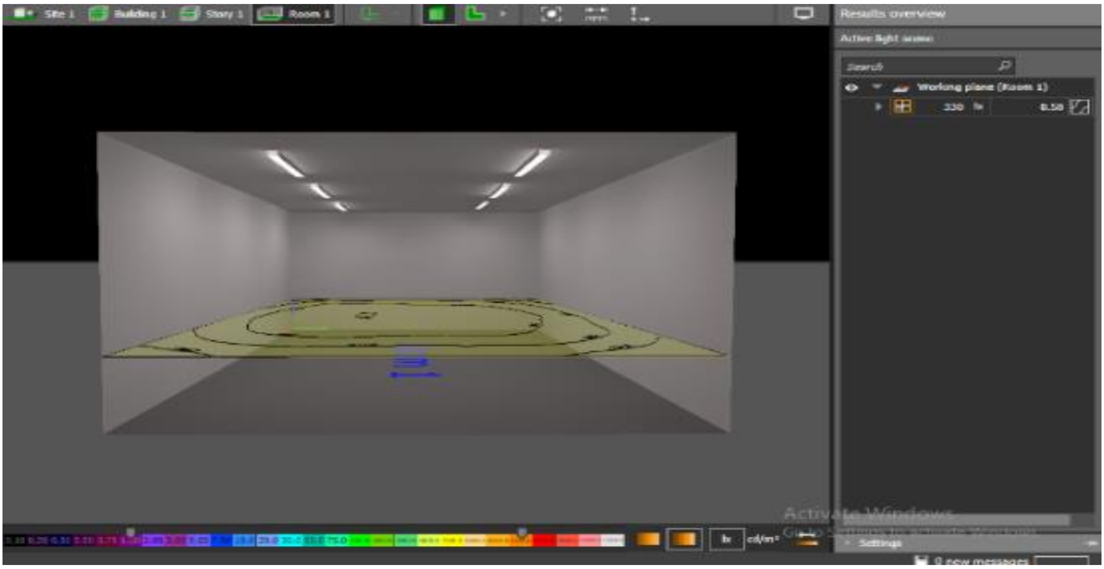

Figure 2. DIAlux lighting model

This figure models a room's lighting system and lux distribution.

Calculation Results

The observations from the field were used to generate data for the floors, including the basement, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and rooftop floors with 6, 22, 28, 34, 46, 32, 37, 31, and 5 rooms, respectively. Calculations were conducted in each room using the two software to determine their compatibility with the proposed design by the consultant using a percentage.

Table 7. Percentage Conformity Of Lighting On Each Floor

Evaluation of Lighting Installation Design		
Floor	DIALux Percentage	Ms. Excel Percentage
1	2	3
Basement floor	66%	67%
1st floor	59%	58%
2nd floor	60%	60%
3rd floor	74%	73%
4th floor	70%	71%
5th floor	90%	90%
6th floor	52%	51%
7th floor	76%	77%
Rooftop floor	80%	80%

The calculations conducted using Microsoft Excel, and DIALux software showed that the average value of conformity to the design by the planning consultant in line with the SNI standard is 70%. The disconformity observed was associated with not using the existing lumen value in the specifications set by the lamp manufacturer and not adjusting the lux in a room to the value determined by the applicable SNI. Therefore, some rooms have lighting installation that does not follow SNI recommendations

4. CONCLUSION

The analysis conducted using lighting planning software and observations at the New Building of the Faculty of Technology and Vocational Education in the Indonesia University of Education produced the following results:

1. The lighting installation design produced by the planning consultant aligns with the installations observed in the field.

2. The evaluation of the lighting installation design showed that LED lamps are used in each building room. The percentage conformity of the number of lamp armatures recommended by SNI on each floor was found to be 66%, 59%, 60%, 73%, 71%, 90%, 51%, 77%, and 80% for the basement, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and rooftop floor, respectively. The difference was caused by the fact that the planning consultant did not use the lumen value set by the manufacturer for the lamp and failed to use the lux value existing in each room with different functions.

3. The evaluation also showed that the plans made by the planning consultant and the application used had average conformity of 70%.

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