EFFICIENT LIGHTING SYSTEM DESIGN

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Progress Report II
Projek Sarjana Muda

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :

Name of Supervisor: Dr. Ernie Binti Mat Tokit

Date : 14 June 2021

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

Signature :

Name of Supervisor: Dr. Ernie Binti Mat Tokit

Date : 14 June 2021

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DEDICATION

To my beloved mother and father

ABSTRACT

Lighting design is one the basic and important elements for the building design. An effective lighting can give illumination at a proper level and reduce the energy consumption and energy cost. This study investigate the comparison study between compact fluorescent lamp (CFL) and light emitting diode (LED) that commonly used for home general lighting usage in different areas in the house model. The objective of this research is to perform energy analysis of efficient lighting system design for general house. The general terrace house at Muar was taken as a case study. The comparison of these two luminaires in different areas in the house model was designed and simulated using the DIALUX software based on the illuminance value, color rendering index, luminous efficacy, lighting power density, energy consumption, energy cost and building energy index. Finally, the results showed that LED is the best lighting design system compared to CFL as it more efficiency than the CFL. It provides about 16-17% of the reduction in power consumption, electric consumption, energy cost and building energy index.

ACKNOWLEDGEMENT

I have taken a lot of effort into this project. However, the completion of this project would not have been possible without the help and advice of a lot of peoples. Hence, I would like to express our heartfelt gratitude to all of them.

Firstly, we would like to express our great gratitude towards our Dean of Faculty of Mechanical Engineering for giving us an opportunity to apply our knowledge to complete this project.

I am also highly indebted to my supervisor, Dr. Ernie Binti Mat Tokit for for giving me this opportunity to do final year project with her. She never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for her patience and advice while leading me in this project.

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Thank you for those who have willingly helped me out with their abilities. I'm appreciate the effort paid by yours.

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E - Illuminance

Φ - Luminous flux

A - Surface area

U_0 - Illuminance uniformity index

E_{min} - Minimum illuminance

E_{avg} - Average illuminance

L - Luminance value of luminaire

L_b - Background luminance value

ω - Solid angle of luminaire

p - Guth Index

W/m^2 - Watt/meter square

W - Watt

° - Degree

LIST OF ABBREVIATIONS

BEI	-	Building Energy Index
ST	-	Suruhanjaya Tenaga
CRI	-	Color Rendering Index
UGR	-	Unified Glare Rating
CIE	-	International Commission on Illumination
LEO	-	Low Energy Office
LED	-	Light Emitting Diode
VCP	-	Visual comfort probability
IES	-	Indian Engineering Services
JKR	-	Jabatan Kerja Raya
CFL	-	Compact fluorescent lamp
MS	-	Malaysian Standard

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, the development of the digital era technology provides many good impact in the field of engineering design. One of the good impact that utilized in the field of the engineering design due to the development of the digital era technology is the simulation software's or tools that use to simulate and solve some engineering problems. A simulation software or tool can be defined as a platform that provides the service for the users to access or conduct an simulation through the internet at any time and any place. Example simulation tools that can be used for the lighting design are MATLAB, Energy Plus, DIALux and etc. Lighting design in a building as one of the engineering design problems are also implemented the application of simulation software to the users or engineers for the purpose of design and analyze. According to Baloch et al. (2018), lighting design was defined as one of the significant elements of building design and considered as an essential aspect when addressing sustainability of buildings.

Energy consumption that refers to the amount of energy used also consider in the lighting systems in buildings as the building energy consumption accounts for around a third of the world's primary energy. Based on the data provided by (IEA,2006), offices and commercial buildings use the most electricity (43%), follwed by residential buildings (31%), manufacturing buildings (18%) and outdoor lighting (8%). Hence, energy efficient systems need to be developed in order to increase the energy efficiency which defined as one of the elements in building energy index and then contributes building energy savings. Building Energy Index (BEI) is a method that introduced to compare the energy use in buildings for one year and it is calculated by dividing the total floor area of the building in square meters by the number of kilowatt hours used. It is very important in the development of energy efficient systems as it not only use to improve the energy intensity of the buildings but also improve the energy performance of a building. Every buildings especially the government buildings will having a Building Energy Index label that issued by the Suruhanjaya Tenaga (ST). Figure 1.1 shows the label of Building Energy Index.

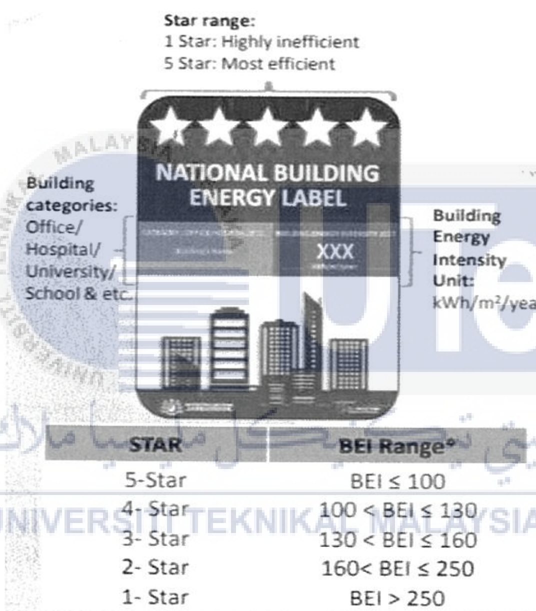

Figure 1.1: Building Energy Index Label

There are three types of design considerations that need to be consider in the effective lighting design which are lighting quantity, lighting quality and implementation. Lighting quality that considered as one of the key factors in successful lighting design, it should always take precedence over cost savings and energy savings. However, how can we define the definition of the lighting quality? According to Blaso & Pellegrino (2007), the interaction of three fields defines the lighting quality as the individual, light integration with architecture and ergonomic and environmental implications. Based on the interaction of this three fields, the elements that need to consider in the lighting quality are illuminance value, color rendering index, illuminance uniformity index, Unified Glare Rating value and effect of surface reflectance. Illuminance value is the amount of luminous flux incident on a surface, per unit area. The unit of the illuminance value is lux or lumens/m^2 and can be calculate by $E = \frac{\Phi}{A}$ where E is the illuminance, Φ is the luminous flux and A is the surface area (Febriyursandi et al,2019). Difference areas have their own value of illuminance. While the illuminance uniformity index, U_0 is define as the ratio of the minimum illumination (E_{min}) and the average illumination (E_{avg}). High value of illuminance uniformity will results high balanced of light distribution and high comfortable level of eyes feel (Wang,2015).

The Color Rendering Index (CRI) is a metric for determining the ability of a light source to expose colors of objects in relation to natural light such as daylight or incandescent light. The CRI is represented by the a range number of 0-100 in which high value of CRI will results better color rendering capacity but it is independent of color temperature. The chart for the Color Rendering Index presents in Figure 1.2. Glare that common take places in workplaces and residential area is a sensation of sight that caused by the excessive and uncontrolled brightness. Hence, a method called Unified Glare Rating (UGR) is used in order to calculate the glare from luminaires, light through windows and bright light sources. The UGR are suitable used for an indoor lighting installation only and it can be calculated either using a formula or using lighting design programmes. The equation that is used to calculate the UGR is $\mathrm{UGR} = 8\log\left[\frac{0.25}{L_b}\sum\left(\frac{L^2\omega}{p^2}\right)\right]$ where L is the luminance value of luminaire, L_b is the background luminance value, ω is the solid angle of luminaire and p is the Guth Index. Lastly, surface reflectance also effect the lighting quality like energy efficiency and visual comfortability where the lower the reflectance of surface, the lower the daylight distribution. According to Reinhart (2002), the relationship between reduced partition reflectance and reduced daylight in an open-plan office was determined through numerical simulations. Besides that, the European Standard EN 12464 recommended the ranges of useful reflectance for major interior surfaces such as walls, floors and ceilings in indoor buildings based on the occipant lighting requirements. The ranges of useful reflectance for the interior surfaces are wall (0.5-0.8), floor (0.2-0.4) and ceiling (0.7-0.9).

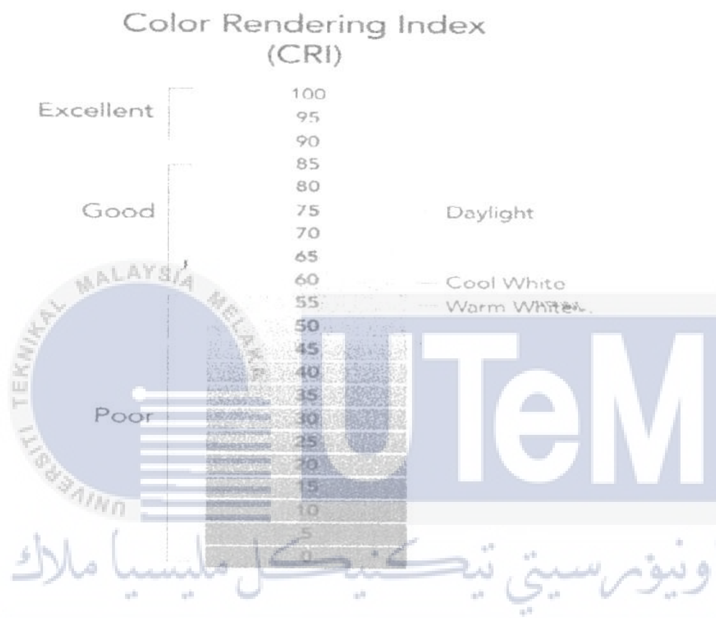

Figure 1.2: Color Rendering Index (CRI)

1.2 Problem Statement

Lighting is an essential element that use of a long time in any building hence it accounts for a significant portion of global energy use. However, the increasing of the energy consumption for the lighting system caused a lot of problems due to the increasing of population. The increasing of the lighting usage is affecting the basic living standard as the costs of the electricity increased. Besides that, the highly increase of the electricity consumption has caused the occur of pollution due to the harmful gases that released by the air conditioning and other electrical devices. Non-renewable resources such as coal and gas also reduced due the high demand of the electricity consumption.

1.3 Objective

The objectives of this research are as follows:

- To simulate the lighting level using free DIALux software.
- To propose the current lighting level using other type of light.
- To calculate the cost effect of the current and proposed lighting system.
- To analyse the light quality in term of the i) illuminance value, ii) the color rendering index, iii) the illuminance uniformity index, iv) the power intensity, and v) the effect of surface reflectance.

1.4 Scope of research

Simulate the simulation of the lighting design system using DIALux software and the model for the lighting design system is using the house at Muar, Johor.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lighting design is known as a method for providing lighting to spaces where it starts with a discussion about organizational and consumer specifications with the owner. It can be conduct through a design simulation tool or platform by considering all the considerations that might affect the efficiency of the lighting systems. Some of the previous research that related to this report will be shown in this chapter.

2.2 Illuminance value

The output of the illumination level and value could be calculated using the programs like DIALux and virtual or real building reference (Ashmore & Richens, 2001). The increased of the average illuminance value increased the illuminance uniformity index while decreased the value of the unified glare rating (Makaremi et al., 2017). A research work presented by Ahmad et al. (2020) has aimed to conduct and calculate the indoor illuminance with and without blinds based on the daylighting analysis in building under different sky condition. The proposed method applied glazed window with 0.78 optical transmitted, 90cm glazing pane width, 10cm width of window bars to get the indoor illuminance. Then, it simulated with measuring period without blinds, DOE-2 with blinds, Radlink and Radiance software that considered for with and without blinds. The sky condition during the measuring period was overcast while it was CIE standard sky condition in other softwares. During analysis and evaluation, the windows were far away from all the external obstruction. The proposed method has successfully calculated the total illuminance in term of with or without blinds. Thus, it resulted that CRI<0.2, SSP=1.0 for the clear sky and CR=1.0, SSP=0.0 for overcast sky in DOE-2 while also proved that shading coefficient was used in Radlink software where the daylight penetration can decrease by the shading effect. The results for the measured and simulated indoor illumiances without blinds were shown in Figure 2.1. This is similar to what Ashrafian & Moazzen (2019) found that the difference in average illuminance in both east face classroom and west face classroom was too high no matter the sky condition was clear or overcast. Hence, shading device shall used to enhance the indoor daylight efficiency by minimized the over-illumination that may caused visual comfort. Another study that performed by Omar et al. (2018) found that Model 2 not only offers a more equal distribution of light throughout the system but also showed 78.82% ($\rho = 6.46$) of transmission efficiency compared to model 1 that have 64.7 ($\rho = 15.60$) of transmission efficiency. The illuminance map obtained in Model 1 and Model 2 on the working plane were shown in Figure 2.2 and 2.3.

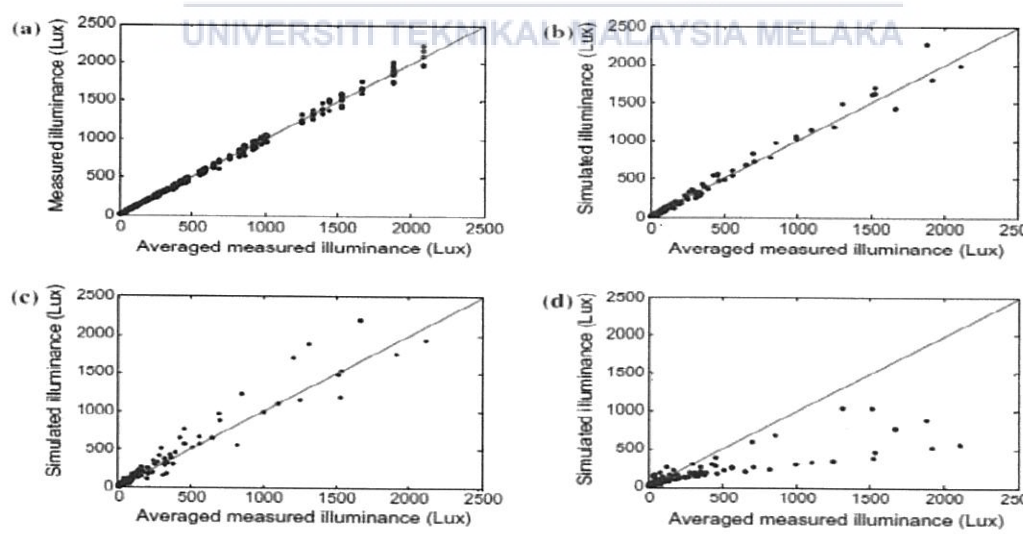

Figure 2.1: Measured and simulated indoor illumiances without blinds (a) Measured illuminance (b) Radiance simulation (c) Radlink simulation (d) DOE-2 simulation

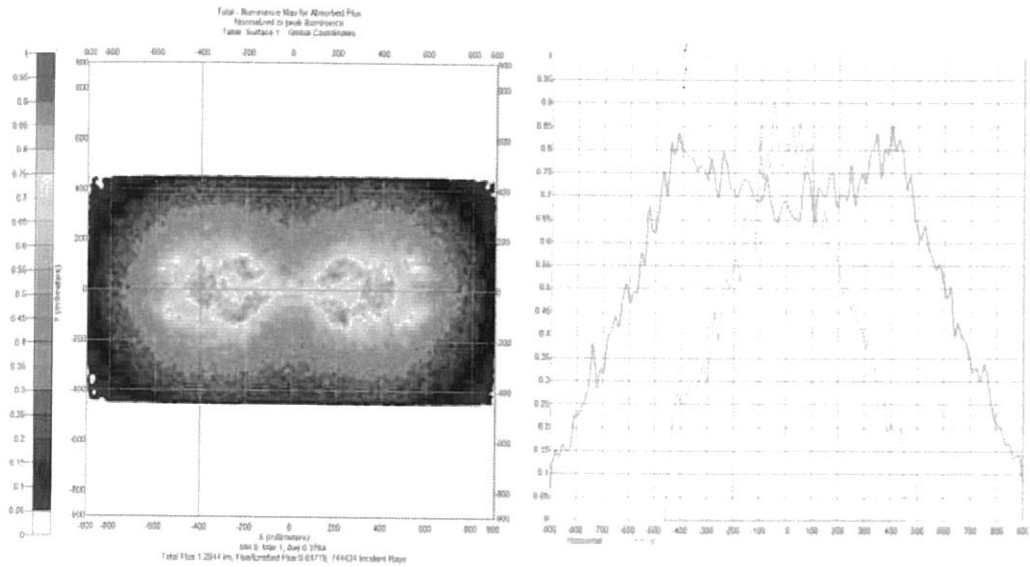

Figure 2.2: Illuminance map in Model 1 on working plane

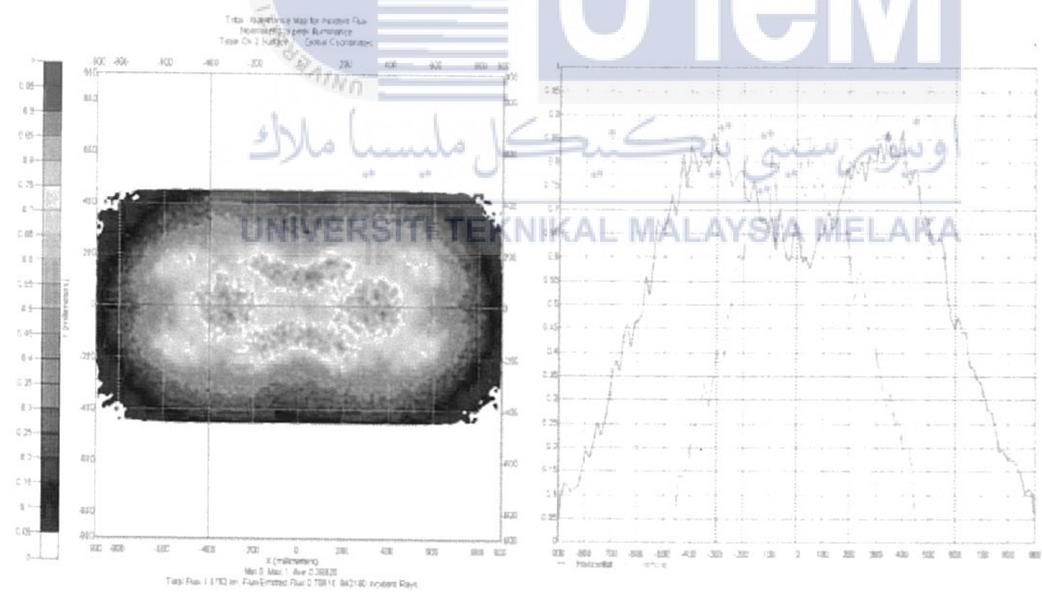

Figure 2.3: Illuminance map in Model 2 on working plane

In order to design an efficient lighting system, the lighting system design must according to the standard. In the study that performed by Wagiman & Abdullah (2018), the lighting system designs that used the T5, T8 and LED luminaires were according to the European

Standard EN12464-1 (500 lx) and Malaysian Standard MS1525 (maintained illuminance level:300-400 lx) in general office. The finding of this study stated that the illuminance values for the MS1525 were smaller compared to the EN12464-1 and LED that contributed high performance showed the potential to replace fluorescent lamps. Sun et al. (2011) and Gosende (2019) proposed a method to provided energy saving illumination of the building lighting by simulated and compared between the twist-shape compact fluorescent lamp and LED light source with the same required standard illuminance. The result showed that the simulated average illuminance of the LED used was in the range of the required standard average illuminance and the power consumption of the LEDs was lower than the twist-shape compact fluorescent lamps. This is very similar to what Kamaruddin et al. (2016), Sarsour et al. (2017) and Ridjian (2016) found that LED reduced more cost and energy consumption than CFL for the lighting system design as it's illumination at proper level.

According to Vishesh et al. (2016), the simulation result showed that the obtained LUX for the conventional lighting system not met the Indian standard (minimum=300 lux, maximum= 750 lux). Cellular arrangement of lamps in the classroom was the best arrangement that met the CIE norm of no less than 500LX average illumination by extended the efficient lighting area and enhanced the lighting power quality (Wang, 2015). LEDs as the artificial light sources can be used as an illuminative substitute when the internal illumination is less than the minimum illumination value (Ji et al., 2016). This also proved when the study conducted by Ivana et al. (2018) found that artificial lighting replaced with the daylight as daylight cannot provided the required lighting intensity. Climate change was exacerbrated by a significant portion of global energy consumption and carbon emissions (Vincent et al., 2020). Case studies that performed by Roy et al. (2005) has proposed to introduce the project Low Energy Office (LEO) building that optimized using Energy-10 computer software and aimed to developing the Malaysian construction industry's potential in energy efficiency building design. This building design has considered the site & climate, comfort & indoor air quality, daylight, building envelope, office appliances, cooling, lighting & transport and energy management in order to achieve or surpass expectations of the standard of MS 1525: Code of Practice for Energy Efficiency and Renewable Energy on non-domestic building. The illumination level for the building is 300-400 lux and the installed lighting and small power loads which 15 – 20W/m^2 were replaced by 8 W/m^2. Hence, this study concluded that with Malaysia's current electricity price of 0.29 RM/kWh, the expected payback period was less than ten years as the energy savings for the energy efficient building was about 100 – 150kWh/m^{2}year.

Apart from the general building, Doekar et al. (2016) conducted a study of efficient lighting system design for power plant by comparing the mathematical analysis and software analysis. This study found that the software's outputs were more correct and accurate than the mathematical analysis as the illuminance value, minimum and maximum illuminance value, uniformity ration, 3D rendering and object reflectances could be considered by using software analysis like DIALux software. According to the study of LED street light optic designs that performed by Prommee & Phuangpitak (2016), the small lenses have better light output than big lenses as the beam angle of the small lens (150°) was wider than the beam angle of a big lens (120°) which was parallel to the street. The light performance results of LED street light with small and big lens were shown in Table 2.1 and 2.2.

Table 2.1: Light performance results of LED street light with small lens

Street Type	I	II	III	V
LED (watt)	70	70	70	120
placement	120	120	120	180
Illuminance, $E_{av} \geq 9.7$ lux	9.7	8.7	7.7	17
	12	11	9.96	29
Luminance, $L_{av} \geq 0.75$ cd/m^2	0.54	0.51	0.45	0.94
	0.75	0.65	0.58	1.61
Uniformity U_o, E_{min} / E_{av} ≥ 0.40	0.60	0.47	0.33	0.26
	0.21	0.25	0.26	0.48
Uniformity $E_{min}E_{max}$ ≥ 0.17	0.40	0.28	0.18	0.16
	0.11	0.11	0.10	0.33

Table 2.2: Light performance results of LED street light with big lens

Street Type	I	II	III	V
LED (watt)	70	70	70	120
placement	120	120	120	180
Illuminance, $E_{av} \geq 9.7$ lux	15	14	13	31
	20	19	17	53
Luminance, $L_{av} \geq 0.75$ cd/m^2	0.76	0.80	0.75	1.57
	1.04	0.97	0.86	2.71
Uniformity U_o, E_{min} / E_{av} ≥ 0.40	0.80	0.77	0.56	0.34
	0.34	0.36	0.39	0.51
Uniformity E_{min} / E_{max} ≥ 0.17	0.31	0.30	0.28	0.20
	0.14	0.14	0.15	0.33

2.3 Color Rendering Index

Color rendering Index (CRI) is the most commonly used metric for comparing and quantifying light source colour rendering efficiency (Guo & Houser, 2004). According to the Sirim Standard, the minimum color rendering index for the general building areas were shown in Table 2.3 which was in the range of 40-80. In the study of Sun et al. (2020), the color rendering index was 86 which can defined as an excellent color rendering index that provided high quality of vision. Based on the research that conducted by Gosende (2019),