Faculty of Electrical Technology and Engineering

DEVELOPMENT OF A LIGHTING OPTIMIZATION SIMULATION APP USING ALPHA SOFTWARE FOR RESIDENTIAL HOUSES

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Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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DEVELOPMENT OF A LIGHTING OPTIMIZATION SIMULATION APP USING ALPHA SOFTWARE FOR RESIDENTIAL HOUSES

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DEDICATION

To my incredible parents, Suzrita bin Sulaiman and Hambali bin Omar, whose unwavering support and love have been my pillars of strength throughout this journey. Your sacrifices and encouragement have shaped me into the person I am today.

I extend my deepest gratitude to my dedicated lecturers, whose guidance and wisdom have been instrumental in expanding my knowledge and fostering my academic growth. Your passion for teaching has left a lasting impact on my intellectual journey.

A special appreciation goes to my esteemed Supervisor, Arman Hadi bin Azahar, whose expertise and mentorship have been invaluable. Your constructive feedback, patience, and commitment to excellence have been the driving force behind the success of this project.

I would also like to express my gratitude to my friends for their camaraderie and encouragement. Your shared laughter and collaborative spirit have made this academic journey memorable.

This project is dedicated to each of you, as you have played an integral role in my achievements and have been my source of strength and inspiration.

ABSTRACT

In residential houses, the optimization of lighting often remained unknown to normal residents. The adequacy of lux levels for various activities within each area of the house and the potential wastage of energy due to excessive lighting usage were typically not discernible. This project aimed to address this issue by developing an application that was widely available and accessible to all residents for download on their smartphones. Although similar applications existed, they had limitations, such as being exclusively available online, lacking energy calculators, and providing no lighting recommendations. In contrast, this application had the capability to calculate and optimize lighting by recommending the appropriate amount of light bulbs needed for each room. Additionally, it could calculate the monthly bill based on Malaysia's TNB residential tariff rates. The lighting standards adhered to in this project referred to MS1525:2007, wherein the recommended lux levels for various areas, such as the living room, dining room, bathroom, etc., were listed. Unlike traditional calculations that considered factors like room area (Width x Length), this project incorporated both room area and height (Length x Width x Height) using a comprehensive approach. To achieve this, the application utilized calculations integrating all these factors. In conclusion, this project provided residents with the means to optimize lighting within their homes through a user-friendly application accessible at their fingertips.

ABSTRAK

Dalam rumah kediaman, optimasi pencahayaan sering kali tidak diketahui oleh penduduk biasa. Kecukupan tahap lux untuk pelbagai aktiviti di setiap kawasan rumah dan pembaziran tenaga akibat penggunaan pencahayaan yang berlebihan tidak dapat dikenal pasti. Projek ini bertujuan untuk menangani isu ini dengan membangunkan satu aplikasi yang tersedia secara meluas dan boleh diakses oleh semua penduduk untuk dimuat turun ke dalam telefon pintar mereka. Walaupun terdapat aplikasi serupa, aplikasi-aplikasi tersebut mempunyai kelemahan seperti hanya tersedia dalam talian, tidak mempunyai pengira tenaga, dan tidak menyediakan cadangan pencahayaan. Sebaliknya, aplikasi ini berupaya mengira dan mengoptimumkan pencahayaan dengan mencadangkan jumlah mentol lampu yang diperlukan untuk setiap bilik. Tambahan pula, ia boleh mengira bil bulanan berdasarkan kadar tarif kediaman TNB Malaysia. Standard pencahayaan yang digunakan dalam projek ini merujuk kepada MS1525:2007, di mana tahap lux yang disyorkan untuk pelbagai kawasan seperti ruang tamu, ruang makan, bilik mandi, dan sebagainya disenaraikan. Berbeza dengan pengiraan tradisional yang hanya mengambil kira faktor luas bilik (Lebar x Panjang), projek ini memasukkan kedua-dua faktor luas bilik dan ketinggian (Lebar x Panjang x Tinggi) dengan pendekatan yang menyeluruh. Untuk mencapai ini, aplikasi menggunakan pengiraan yang menggabungkan semua faktor ini. Secara kesimpulannya, projek ini memberi penduduk cara untuk mengoptimalkan pencahayaan di dalam rumah mereka melalui aplikasi yang mudah digunakan dan boleh diakses dengan mudah.

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LIST OF SYMBOLS

Φ	-	Flux
	-	
	-	
	-	
	-	
	-	
	-	
	-	

LIST OF ABBREVIATIONS

dBA	-	A-Weighted decibels
3D	-	3 Dimension
K	-	Kelvin
E	-	Illuminance
Lx	-	Lux
Fc	-	Luminous Flux
Lm	-	Lumen
W	-	Watt

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CHAPTER 1

INTRODUCTION

1.1 Background

Lighting makes up quite a bit of the energy used in commercial buildings, which is pretty significant. Traditional lighting systems can waste a huge amount of energy, increasing electricity costs and having a negative impact on the environment when used in residential buildings. Smart lighting solutions that can optimize energy use and increase the efficiency of the building are now becoming more important.

Building automation systems have been receiving more attention in recent years for their ability for helping to increase the comfort of residents, reduce energy consumption, and improve building efficiency. Building automation systems or are known as smart building systems, automate a variety of building functions, such as lighting, HVAC, and security systems by using advanced technologies including sensors, controllers, and software.

An important component of building automation which is lighting optimization can increase indoor lighting quality, save energy costs and increase the comfort of the residents. Building owners and facility managers can use simulation programme to make smart choices about their lighting systems, leading to an increase in energy efficiency, a decrease in operating costs and a greater comfort of the residents.

Another important factor of lighting in itself is the effect it can have on the human health. Light is that part of the electromagnetic spectrum that is perceived by our eyes. The wavelength range is between 380 and 780nm. The cones come on during the day and we see colors, whereas at night the rods take over and we only see shades of grey[1].

Our vision depends heavily on light. In order to reach the retina at the back of the eye, light must first travel through the cornea and lens of our eyes. In order for us to see and understand our environment, photoreceptor cells in the retina known as rods and cones transform light into electrical signals that are subsequently transferred to the brain.

There is also something called circadian rhythm where light acts as a powerful regulator of our biological clock. This circadian rhythm helps to regulate certain bodily functions including sleep-wake cycles, hormone secretion, body temperature and metabolism. Our internal clocks are synchronized by exposure to natural light during the day, which encourages alertness and wakefulness. At night, less exposure to light tells the body to get ready for sleep.

1.2 Problem Statement

While there are all these different applications available online or on the phone that can optimize lighting and calculate cost, they all have their pros and cons. The table below will compare the different features between 4 different applications.

Table 1 Comparison of features between 4 application

Features	Omni Calculator	e-conolight (Lighitng Layout Tool)	Light Bulb Saver	Philips Hue
Compatibility (Android)	-	-	No (Older Version)	Yes (Latest Version)
Availability	Website	Website	Play Store	Play Store
Energy Calculators	Yes	No	Yes	Yes
Lighting Recommendations	No	No	No	Yes
Lighting Design and Layout	No	Yes	No	Yes
Automation and Control	No	No	No	Yes
Type of Lighting Technology	-	General Lighitng System	General Lighting System	Bluetooth / Wireless Bulbs

The Omni Calculator website are used only for calculating the amount of lightbulbs needed to meet the required lumen the user desires. The user needs to input the lighting type (desk lighting, kitchen, living room etc.) and it will give the the recommended lux needed. The user will then input the size of the area by width, length and the amount of lumen for each bulb. It does not calculate the cost of the bulb and electricity usage. It also does not have any layout design that includes factor such as lighting positioning.

The e-conolight website on the other hand only focuses on the lighting and layout design. The user can input the area size and choose the type of light bulb to use from a series of option from a very disorganize list. It will then automatically position the light bulb to it's optimal positions on the ceiling. While it has a 3D model of the space to visualize the layout, it can not do anything else other than layout design.

The Light Bulb Saver application have the same features as the Omni Calculator website but it have a very big flaw in which it is only compatible with the older version of android. Thus, making it completely unusable to most users as most user have the latest version of android.

The Philip Hue application seems to be the most promising out of all the other options. It is compatible with the latest version of android and have all the other features available. The one and only flaw is that this application is specifically for Bluetooth or wireless bulbs. The means the applications can not optimize lighting for the general lighting system. Thus, making the options very limited to the user and useless for most users.

1.3 Project Objective

The objectives are as follows:

a) To calculate the minimum lux required based on room size.

b) To optimize the lighting required based on minimum lux required.

c) To include the cost, light color and luminance for each area of the house.

d) To analyze the performance and power efficiency of the formulated lux.

1.4 Scope of Project

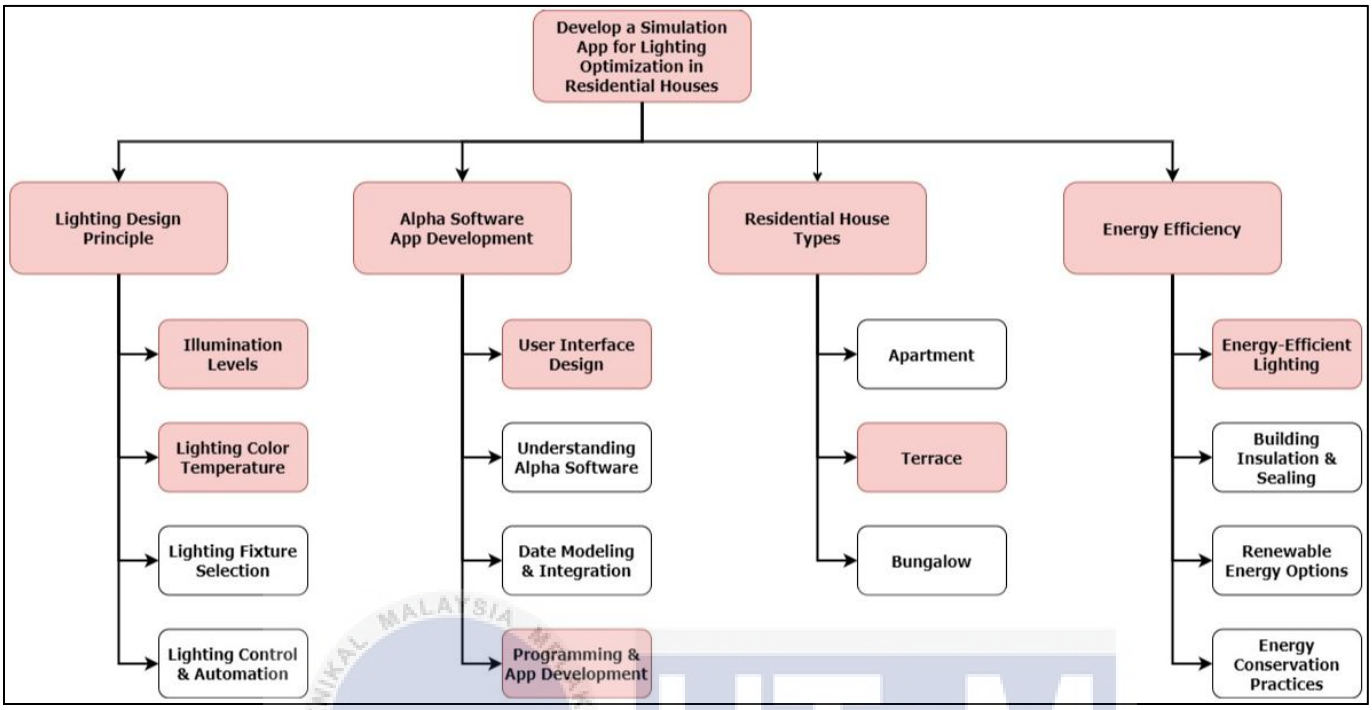

Figure 1 Scope of Project

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The increase in the number of time people spend inside buildings is significant. Both architects and engineers must think of ways to improve environmental comfort for users and, at the same time, improve energy performance in buildings. Comfort is, in fact, important since people spend around 80% to 90% of their days inside buildings.

Buildings affect people's health. There have been reports of diseases related to building use, the most relevant of which is sick building syndrome. Sick building syndrome is a term applied to buildings whose occupants experience physical discomfort just by being in them. It also describes the symptoms that show up after spending a certain number of hours in an enclosed space. These symptoms include eye, nose, and throat irritation, headaches, skin rashes, and respiratory problems.

Moreover, low-quality lighting can cause eye irritation and headaches, noise levels over 50 dBA can increase headaches and reduce concentration on tasks. Thus, it is important that we take into account the lighting conditions in houses that are the living spaces of most people. The main goal is to compare with the existing research to improve lighting conditions and reduce heath risks [2].

2.2 The Present and Future of Lighting Research

Professor Robert Boyce has summarized the key points in Lighting Research which covers the current and future technology, measurement, design, performance, and health.

There is also a lot of new knowledge on the effects of lighting being produced. The effects of illumination on the non image-forming system and the implications for health play a significant role in this. Additionally, some efforts have been made to investigate how illumination affects distant impacts beyond vision, such as mood, behaviour, and cognitive task performance. Since numerous factors other than illumination affect these remote effects, most of this has questionable validity. Focusing on the features of the intended result that can be directly related to light exposure is vital if the goal is to show lighting's advantages beyond visibility.

New colour metrics will undoubtedly be adopted soon, but completely shifting the focus of lighting from task visibility to space illumination seems unlikely to be successful unless it can be shown that doing so would significantly improve people's satisfaction with lighting without imposing additional costs. The effect of light exposure on human health is one area of research where this isn't the case. Lighting practices and regulations will need to alter regardless of cost if it can be demonstrated that lighting may have a major influence on human health. The most probable field of study to significantly alter lighting practices is this one [3].

2.3 Building's Sustainability and Energy Efficiency using Daylight

Layout design are very important when it comes to lighting as it can determine if the space is optimally illuminated during the day. A bad layout design does not fully utilize the daylight which causes a space to be dimly lit and will be dependable towards artificial lighting. Even then, the lighting position, types and brightness will play a big factor in fulfilling that role.

Lighting usually does not comprise more than 40% of the energy consumption in households but cooling and heating takes up most of it. Cooling like air-conditioner especially is used widely here in Malaysia with a hot and humid weather. Since lighting, heating and cooling techniques are deeply inter-reliant, it is now known that a too basic methodology, as well as too many limits, may hinder an efficient daylight evaluation. If not properly planned, too much sunshine can result in unwanted heat gains. Any planned energy-saving strategy must take into account electric lighting, daylighting, and shading systems all at once.

In addition to the direct energy savings, it has been well established that correct daylight evaluation can decrease lighting energy consumption. In addition, indirect energy savings can be gained in medium climates due to lower heat generation and air conditioning energy consumption [4].

2.4 Color Temperature's Impact on Task Performance

This study conducted by Yunhee Park investigated the changes in color temperature that are closely related to the visual elements that influence the performance of tasks, to present scientific evidence based on a quantitative measurement method using brainwave analysis.

The low colour temperature (2,700K, an orange color bulb) setting is effective at producing soothing conditions, such as for those generating tiredness, according to the findings of brainwave study performed before the activities. While the high color temperature (6,400K, a white color bulb) has shown to help with high degree cognitive functions, such as during waking and concentration, according to the findings of brainwave result.

Figure 2.1 Warm Colour (2700K)

Figure 2.2 Cool White (6400K)

According to the research, a low colour temperature does not necessarily guarantee stability or relaxation, while a high colour temperature does not necessarily make it easier to concentrate or think clearly. While it does affect the brainwave to a certain degree, it appears that emotional elements have a greater impact than biological or changes in brainwaves.

When it comes to the physiological response, concentration-related waves were more strongly stimulated by the white light, but when it came to task execution, the orange light, which stands for stability and relaxation, produced superior results. It appears that the orange lamp's ability to evoke a stronger emotional response led to higher task performance. Thus, from this study, we can say for certain that the color temperature does not have an absolute impact towards one action rather than a certain degree of influence [5].

2.5 Calculations

There are a few important equations and concepts that are frequently used when performing basic lighting calculations. These are some of the fundamental formulas and terms to be familiar with [8].

Illuminance (E) is the amount of light falling on a surface and is measured in lux (lx) or footcandles (fc). The formula is:

$$E = \text{Flux} / \text{Area} \qquad (1)$$

Where Flux is the total amount of light emitted by the light source:

$$\text{Flux, } \Phi = \text{Luminous Intensity} \times \text{Solid Angle} \qquad (2)$$

And Area is the surface area on which the light is falling. From the Flux equation, the Luminous Intensity (I) is the amount of light emitted in a particular direction:

$$I = \text{Luminous Flux} / \text{Solid Angle} \qquad (3)$$

And the Solid Angle is the angular extent of the light emitted by the source. And the last fundamental formula is the inverse square law formula. This inverse square law describes how the illuminance decreases as the distance from the light source increases :

$$\text{Illuminance2} = \text{Illuminance1} \times (\text{Distance1} / \text{Distance2})^2 \qquad (4)$$

The Illuminance2 is the illuminance at the new distance (Distance2) while illuminance1 is the illuminance at the original distance (Distance1).

2.6 Building Lighting Installation

Table 2 Comparison of Different Bulb Types

Room Size (length x width x height)	Lumen Requirement (lm)	Bulb Type		
		Incandescent (80 lm)	Fluorescent (800 lm)	LED (1055 lm)
		GE LIGHTING 10S11/79 Incandescent Light Bulb S11 10w	Osram Dulux-D Compact Fluorescent Lamp - 10W G24d-1 2 Pin Warm White 830	P CLAS A 75 FR 10W/2700K E27
		No. of Bulb Needed		
1x1x1	**20**	1	1	1
2x2x2	**160**	2	1	1
3x3x3	**540**	7	1	1
4x4x4	**1280**	16	2	2
5x5x5	**2500**	32	4	3

Table 2.1 shows the comparison of different bulb types which is incandescent, fluorescent, and LED. All the bulb type has a wattage of 10W and warm white (2700K) in color. It is obvious that the LED has the best efficacy while incandescent has the worst. Table 2.1 also shows that the LED requires the least amount of bulb to meet the lumen requirement of the room while the incandescent requires the most amount.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will be focusing more on the approach taken to create a user-friendly interface that users are able to simulate and optimize lighting for residential houses. It will cover an overview of the interface design, algorithms, and calculations, highlighting the underlying principles of the simulation and optimization process.

3.2 Methodology

There are three stages to this method. Stage 1 is the data collection stage where information for the input and output is important. The information needed to be obtained is the room type (living room, bedroom, kitchen, etc.), room size, the lux requirement for each room type since the lumen requirement is based on the size of the room and the lumen emitted by the light source chosen. So all in all, the information needed from the user and the information displayed will be as in figure 3.1.

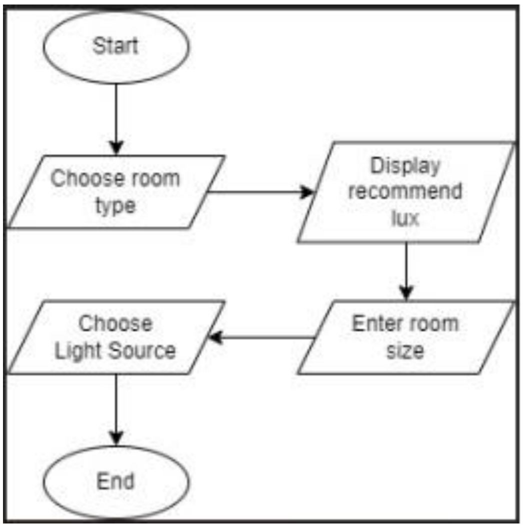

Figure 3.1 Flowchart of Stage 1

Stage 2 is calculation after collecting all the necessary data. As lux are the unit of light per meter square, it does not factor in the room size. So a formula is needed to include the room size and get the lumen requirement which is the total light needed in the room. This also includes the formula to calculate the number of light bulbs needed for the room. The process of the calculation is shown in figure 3.2.

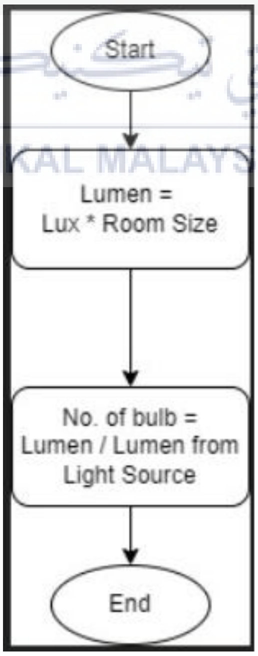

Figure 3.2 Flowchart of Stage 2

Stage 3 is App Development. After collecting data and calculating the lumen requirement and number of light bulbs needed for the room, all the necessary data and formula are adequate to start developing the app. This stage will focus on interface design and process flow of the whole app as shown in figure 3.3 and figure 3.5.

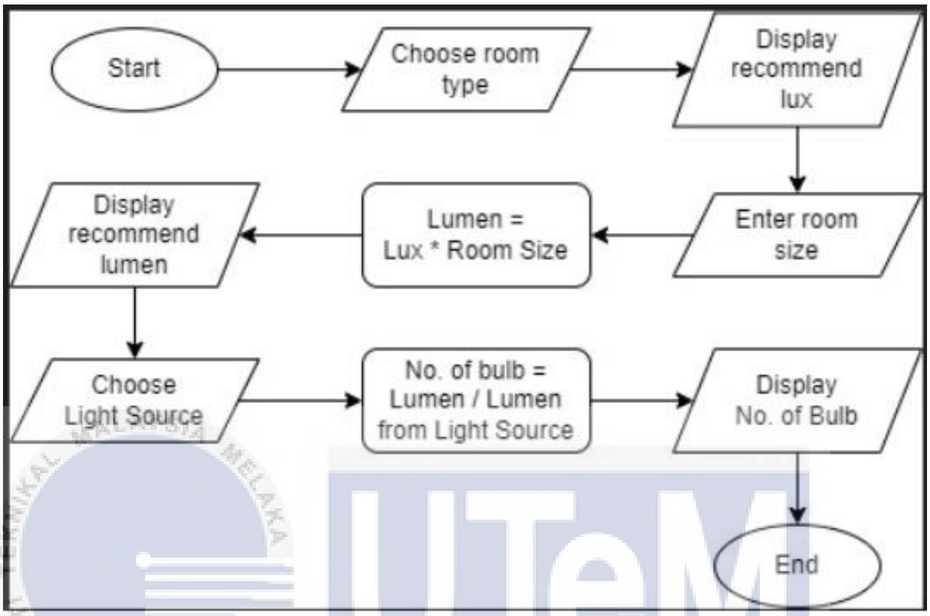

Figure 3.3 Flowchart of Stage 3

3.2.1 Selecting Application for Software Development

Figure 3.4 App Development Software Logo

Alpha Anywhere is a Rapid Mobile Application Development (RMAD) platform developed by Alpha Software Corporation. Using this, developers can build mobile applications using visual development tools and pre-built components without learning actual codes. This makes it the perfect for developers or especially students that does not have a coding background and have to build and app for their final year project. Not only is it easy to learn, it is also free to use.

The other thing is that the mobile application created can run on many different operation system such as IOS, Android, and Windows. It also offers features like data integration, offline capability, security controls, and device-specific functionality.

Alpha Anywhere is suitable for building data-driven mobile apps since it enables developers to connect to a variety of data sources, such as databases, online services, and cloud storage. Additionally, it has built-in support for responsive design, which enables apps to adjust and offer the best user experience across a variety of devices and screen sizes.

The platform provides a variety of visual development tools that speed up the creation of applications, such drag-and-drop interface builders and code editors. Additionally, it permits the usage of scripting and custom code, giving developers who need more sophisticated functionality freedom.

With an emphasis on minimizing development time and effort, Alpha Anywhere promises to equip developers to easily build robust, feature-rich mobile applications. It is made to accommodate a wide range of use cases, from modest applications to sophisticated business solutions.

3.2.1.1 User-Interface Design

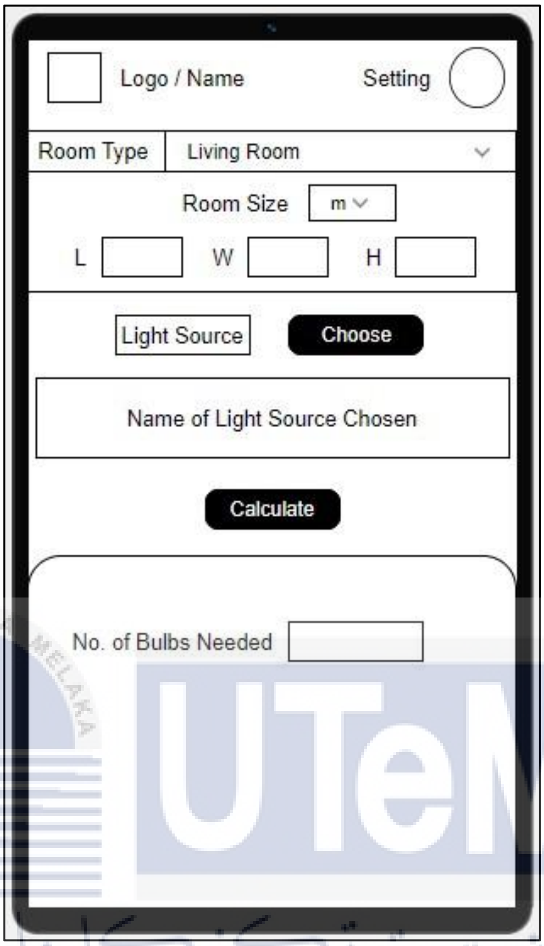

Figure 3.5 Rough Sketch Design of User-Interface

The design shown in figure 3.5 is a rough sketch design where it is the most simple and basic design intended as a baseline for future development. It is drawn using the Justinmind software and is not a finished product. It is only a sketch and does not have any functionality as it is solely for the purpose of sketching design. The design above is created with compact in mind as to show the main necessary input and output display which is the room type, room size and light source as the input and the amount of bulb needed as the output.

3.3 Limitation of proposed methodology

This project only covers residential buildings only which covers the common areas such as living room, bedroom, toilet etc. Areas such as the garage which are only present in some houses and not apartments are not covered in this project. This project also calculates the basic calculation of amount of bulbs needed as the main objective and priority. More complicated calculation such as the lighting positioning layout would only be considered as a future improvement if the project is a success.

3.4 Summary

The "Development Of A Lighting Optimization Simulation App Using Alpha Software For Residential Houses" is a methodical approach to create a system that optimizes lighting design. The process starts by gathering the required research and tools, such as Alpha Anywhere. Next, the lighting calculation method are identified and analyzed to calculate the necessary lighting conditions required. After that, the required information needed to complete the necessary calculation are identified for the input from users. Finally, everything is put together through the Alpha Anywhere platform.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis of the simulation of the app on lighting optimization, utilizing an example of a house floor plan to calculate the expected outcomes. Additionally, three case studies are conducted to demonstrate the lumen requirement of a room concerning its width, length, and height.

Within illuminated settings, numerous factors influence overall perception and functionality. This chapter delves into the outcomes derived from the experimental investigation, focusing on varying light bulb colors and their corresponding effects on lux readings. The study aims to explore how different light bulb colors contribute to ambient lighting conditions within rooms. A crucial aspect involves a meticulous comparison between actual lux readings obtained from diverse spaces and the calculated lux values derived from the application software developed in this project. This comparative analysis serves as a benchmark, shedding light on the accuracy and reliability of contemporary lux calculation methodologies.

The exploration extends to a specific case study, where two different rooms are selected for comparison. One room meets the lux requirements of MS1525, while the other falls short. By comparing the app calculations with actual measurements, this case study aims to validate the reliability of the application in optimizing lighting conditions within indoor environments.

4.2 Lumen Required vs Length, Width and Height

This case study intends to find out the relation between the minimum required lumens and the length, width, and height of a room. The room type will be the living room with a fixed minimum lux requirement of 100 lx. Figure 4.1 is an example of a house floor plan is used to calculate the expected results. Only the living area and bedroom is used to produce the result as to limit the analysis. Since the height is not mentioned, it is assumed that the height is 3 meters tall.

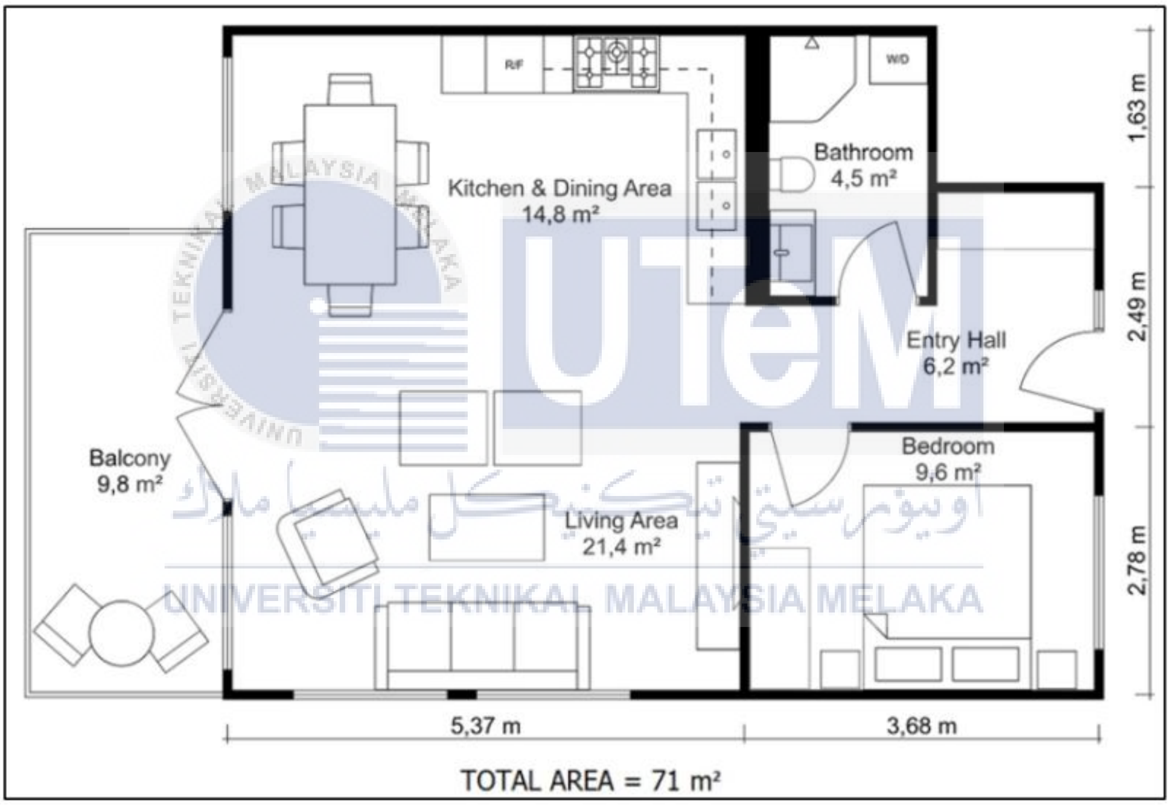

Figure 4.1 An example of a house floor plan [9]

4.2.1 Calculations of Expected Results

a) Room Size :

- Living Room : L x W x H = 5.37m x 2.78m x 3m = 44.79m^3
- Bedroom : L x W x H = 3.68m x 2.78m x 3m = 30.69m^3

b) Lux Requirement:

- Living Room : 100 lx
- Bedroom : 60 lx

c) Lumen Requirement :

- Living Room : 100 lx x 44.79m^3 = 4479 lm
- Bedroom : 60 lx x 30.69m^3 = 1841.4 lm

d) Light Source :

- ESS LED Bulb 9W E27 6500K HV 2PF/10 AR
- Lumen Output : 920 lm

e) No. of Bulb Needed :

- Living Room : 4479 lm / 920 lm = ~5 bulbs
- Bedroom : 1841.4 lm / 920 lm = ~2 bulbs

Table 3 Simplified Expected Result

Room Type	Room Size (m)			Lumen Required	Light Source (lm)	No. of Bulb Needed
	L	W	H			
Living Room	5.37	2.78	3	4479	920	5
Bedroom	3.68	2.78	3	1841	920	2

4.2.2 Results

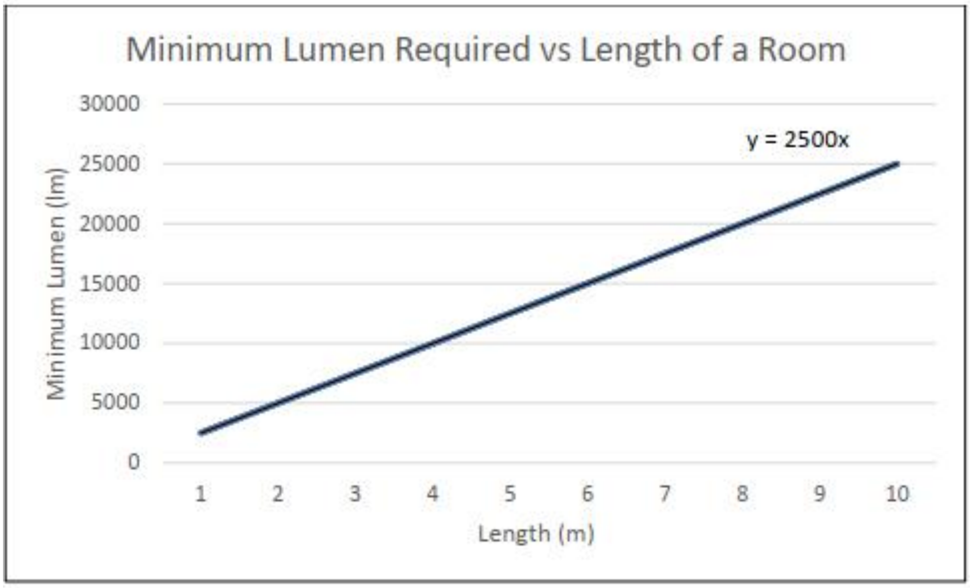

Figure 4.2 Line Graph of Lumen vs Length

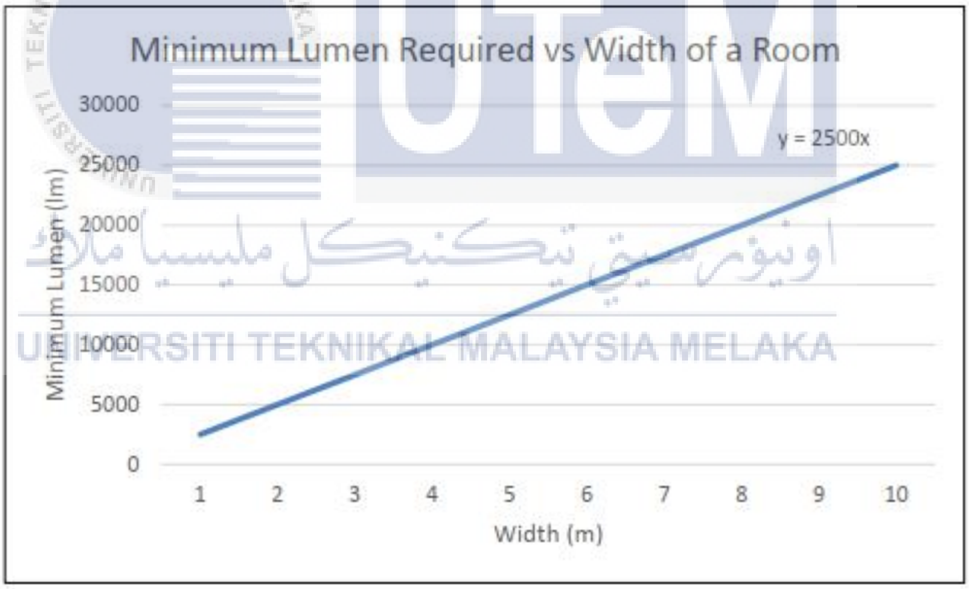

Figure 4.3 Line Graph of Lumen vs Width

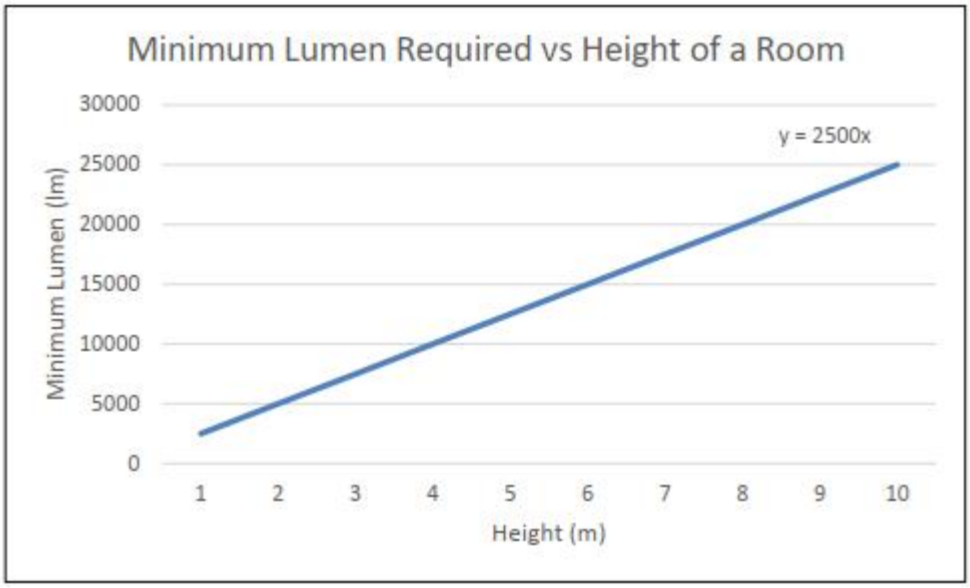

Figure 4.4 Line Graph of Lumen vs Height

From all 3 of the line graph, it is evident that the minimum lumen is directly proportional to the length, width, and height factor. Not only that, the formulation result from all 3 of the line graph is the same with 2500 being the constant value. The value 2500 is the result of the multiplication of the other 3 constant factor being the length, width, and minimum lux in the case of figure 4.4 where height is the varying factor. The formula used in the third case is:

Lumen = Length x Width x Height x Lux

Where the length and width are a constant value of 5 meters while the lux is a constant 100 lx which is the minimum lux for a living room. So, the formula would become:

Lumen = 5 x 5 x Height x 100 = 2500 x Height

4.3 Bulb Color Effects on Lux Readings

To explore the influence of various light bulb colors on lux readings, two identical fluorescent light bulbs were used with consistent specifications. Detailed information about the selected lights can be found in Tables 4.1 and 4.2. Lux measurement was gathered from two distinct spaces: the dining room and the living room. In the dining room, a 4ft LED Tube was used with a luminous output of 1800lm and a power rating of 18W. The chosen light bulb colors for this setting were Cool White (4000K) and Warm White (3000K). For the living room, a 2ft LED Tube was used with a luminous output of 1000lm and a power rating of 10W. The selected light colors for this room were Cool Daylight (6500K) and Warm White (3000K). In theory, the light bulb colors should not have any effect in the lux reading as the luminous output is the deciding factor rather than the color.

4.3.1 Data Acquisition Overview

Since the area of each room is wide and varied, 4 or 5 locations will be chosen to take the lux measurement to get an average read of the lux in the entire room. Detailed configurations of the lighting setups for each room, along with the specific locations for lux measurements, are illustrated in Figure 4.1 and 4.2. An app on mobile called "Lux Light Meter Pro" was used measure the lux in this experiment.

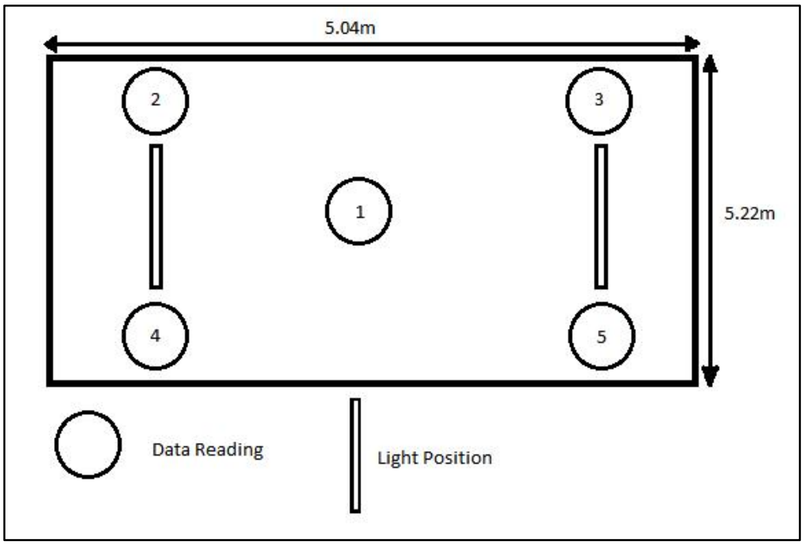

Figure 4.5 Living room lux reading position

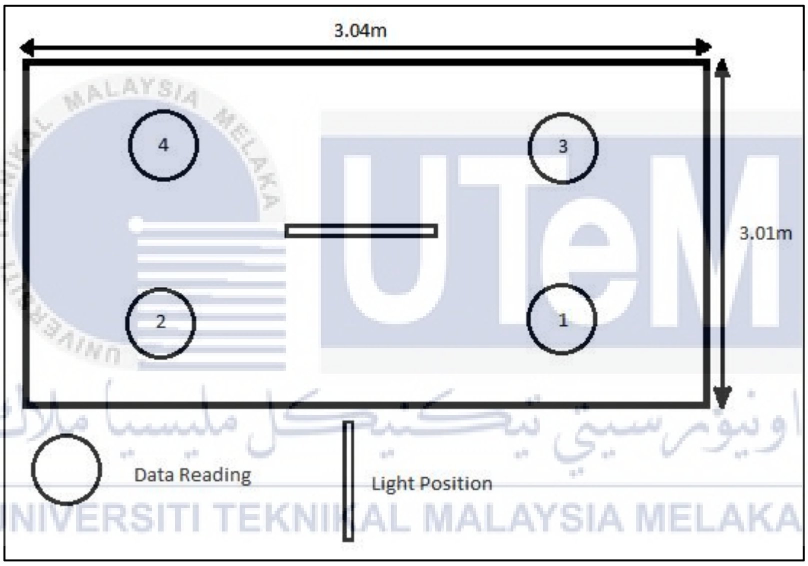

Figure 4.6 Dining room lux reading position

4.3.2 Living Room

Table 4.1 shows the data collected for the living room. The data is used to create the graph in figure 4.3. Based on the result, it shows that the more intense colors (4000K) have a higher average lux than the less intense colors (3000K).

Table 4 Lux Measurement vs Calculated (Living Room)

Location	Data Type	Bulb Colour	L (m)	W (m)	H (m)	Lux Reading 1	Lux Reading 2	Lux Reading 3	Lux Reading 4	Lux Reading 5	Avg Lux	No. of Bulb Installed	Lux Required	No. of Bulb Needed
Living Room	Measured	4000K (Cool White)	5.04	5.22	2.83	91	134	86	75	79	93	2	150	
		3000K (Warm White)				90	78	55	67	52	68.4			
	Calculated	4000K												7
		3000K												7

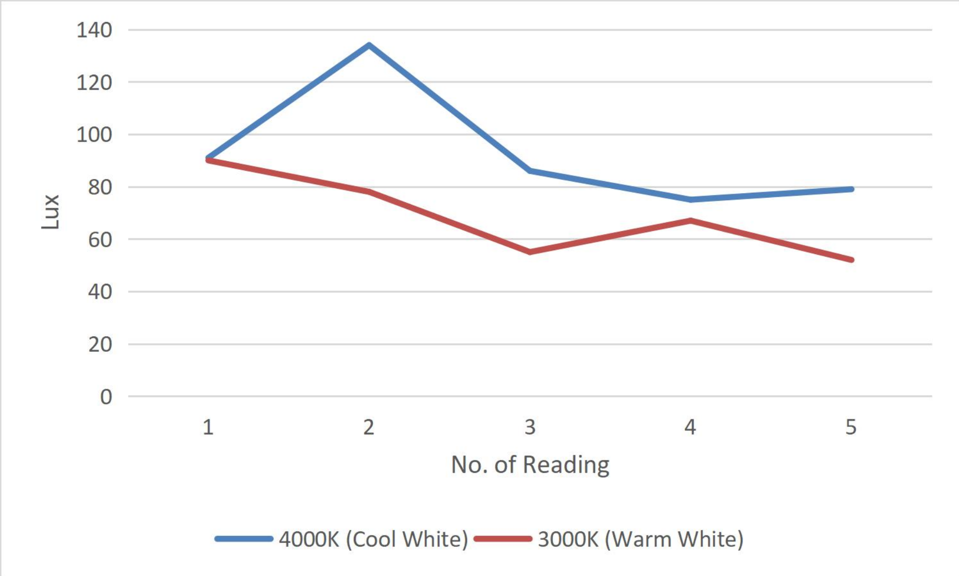

Figure 4.7 Cool White vs Warm White

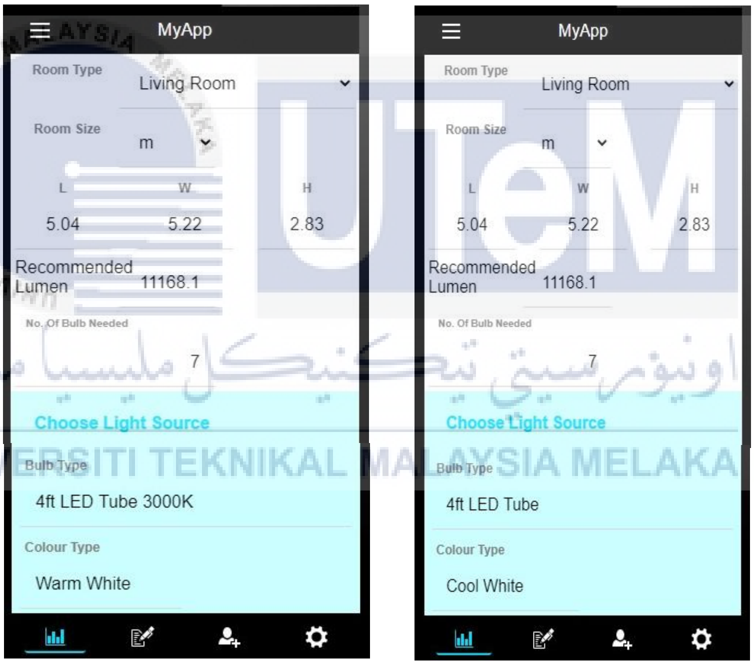

Figure 4.8 Living Room Apps Calculations (Warm White vs Cool White)

4.3.3 Dining Room

Table 4.2 shows the data collected for the dining room. The data is used to create the graph in figure 4.5. Based on the result, it shows that the more intense colors (4000K) have a lower average lux than the less intense colors (3000K).

Table 5 Lux Measure vs calculated (Dining Room)

Location	Data Type	Bulb Colour	L (m)	W (m)	H (m)	Lux Reading 1	Lux Reading 2	Lux Reading 3	Lux Reading 4	Lux Reading 5	Avg Lux	No. of Bulb Installed	Lux Required	No. of Bulb Needed
Dining Room	Measured	6500K (Cool Daylight)	3.01	3.04	2.7	49	71	66	79		66.25	1	200	
		3000K (Warm White)				57	81	73	79		72.5			
	Calculated	6500K												5
		3000K												5

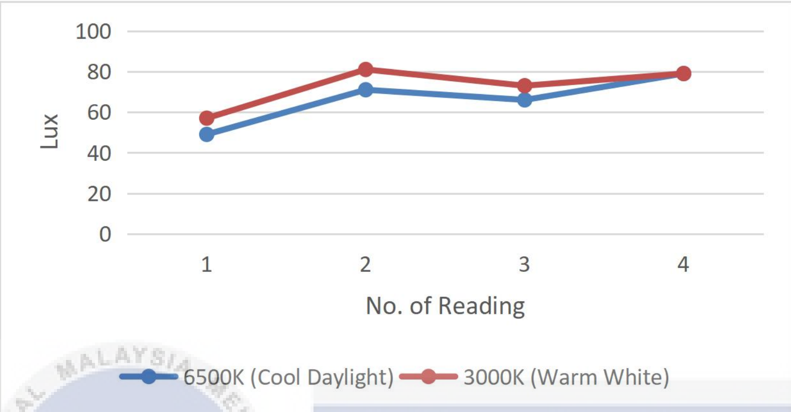

Figure 4.9 Cool Daylight vs Warm White

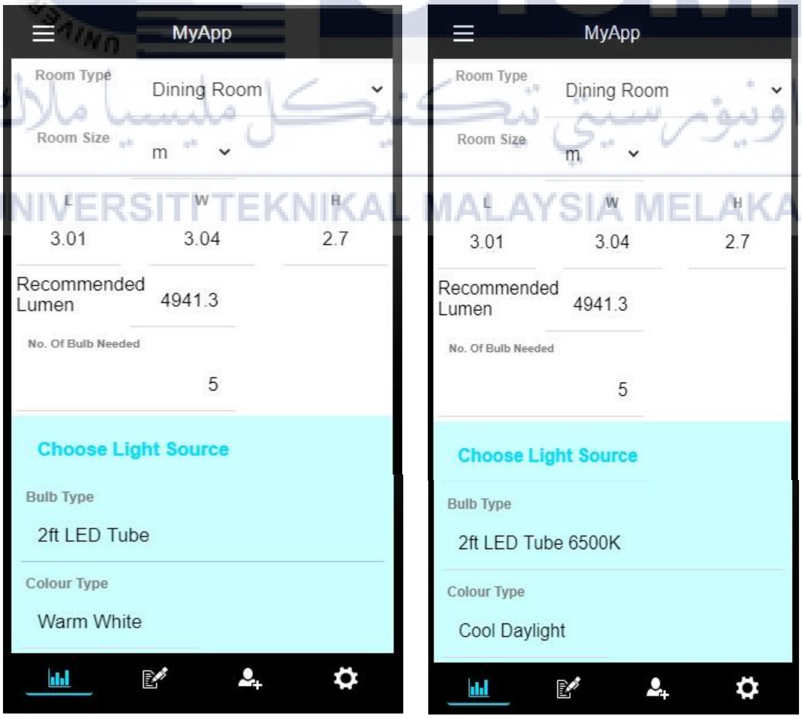

Figure 4.10 Dining Room Apps Calculations (Warm White vs Cool Daylight)

Based on both results in the dining room and living room, it is clear that even though individually the result for each room shows a big significant between different colors but when both result are combined the result shows no correlation between the intensity of the color (6500K, 4000K, 3000K) to the average lux measured.

4.4 App vs Actual : Room Lighting Assessment Comparison

The reliability of the application will be demonstrated through a comparison between the app's calculations and actual measurements in two different rooms, namely the bathroom and living room. One room will represent a scenario where the lux reading meets the requirements of the MS1525 judgment, while the other room will simulate a situation where the lux reading falls short of the specified requirements. Subsequently, the results from both scenarios will be compared with the app's calculations to assess their similarity. A total of 5 lux readings will be taken for each room, and the average lux will be determined.

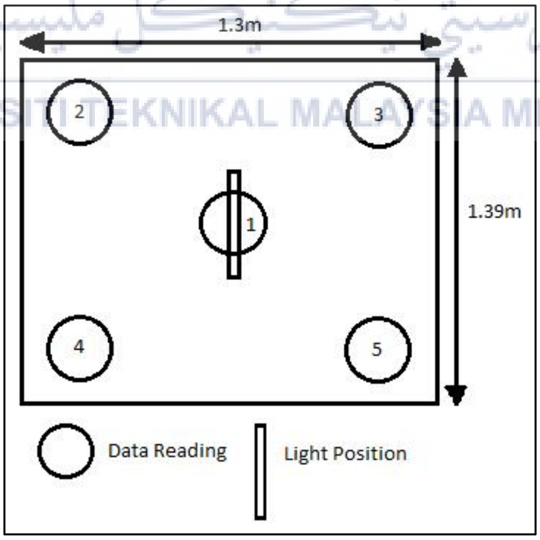

Figure 4.11 Bathroom lux reading positions

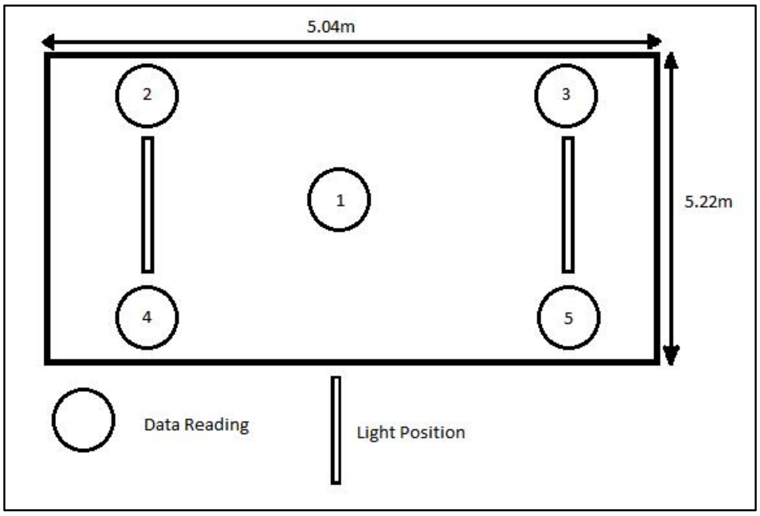

Figure 4.12 Living Room lux reading positions

4.4.1 Bathroom

Room Size : 1.3m x 1.39m x 2.88m (L x W x H)

Bulb Type : LED Surface Downlight 12W 960Lm 4000K

Table 6 App Result vs Actual (Bathroom)

Location	Data Type	Lux Reading					Avg Lux	No. of Bulb	Lux Required	No. of Bulb
		1	2	3	4	5				
Bathroom	Measured	210	163	152	159	143	165.4	1	100	
	Calculated									1

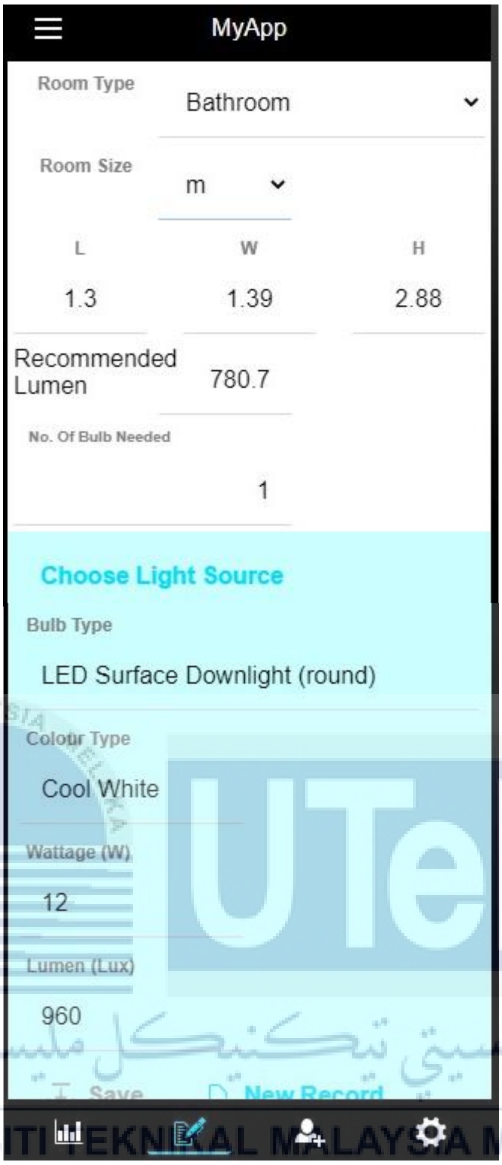

Figure 4.13 Bathroom Apps Calculation

4.4.2 Living Room

Room Size : 5.04m x 5.22m x 2.83m (L x W x H)

Bulb Type : 4ft LED Tube 18W 1800lm 4000K

Table 7 App Results vs Actual (Living Room)

Location	Data Type	Lux Reading					Avg Lux	No. of Bulb	Lux Required	No. of Bulb
		1	2	3	4	5				
Bathroom	Measured	91	134	86	75	79	93	2	150	
	Calculated									7

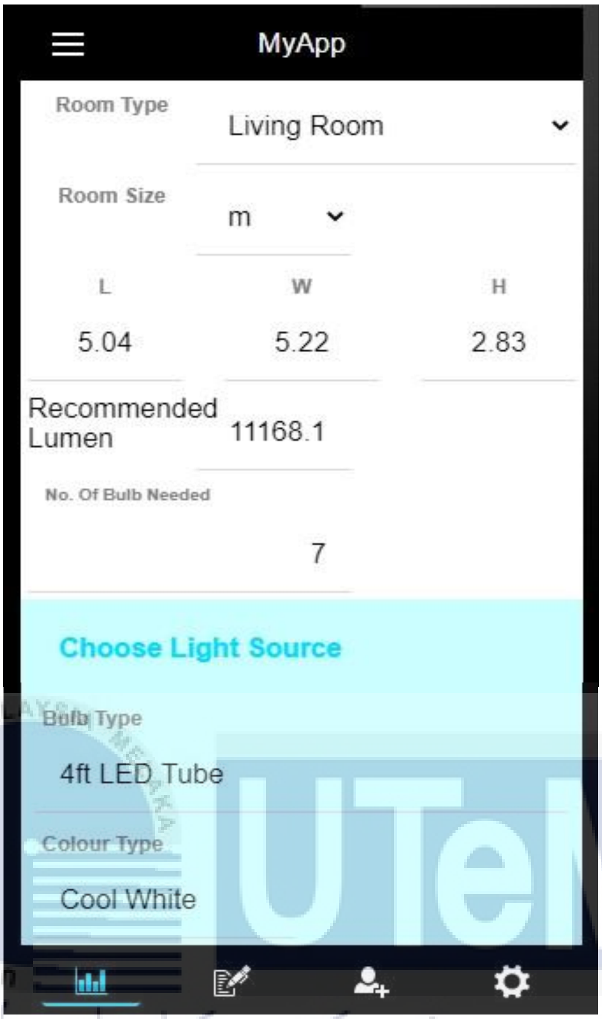

Figure 4.14 Living Room Apps Calculations

As observed, the average lux from the actual measurements in the bathroom meets the MS1525 requirement of approximately 100lx, with a recorded value of 165lx, slightly exceeding the specified threshold. The app calculations also indicate the need for one specific light bulb in the bathroom, aligning precisely with the actual measurement results.

In contrast, the living room's actual measurement results reveal an average lux of 93lx, falling below the MS1525 requirement of around 150lx. The app calculation suggests a requirement of 7 bulbs with a specific light bulb for the living room, in stark contrast to the actual scenario where only 2 bulbs are present.

This demonstration establishes that the app calculations are, at the very least, reliable in assessing whether the current bulb is sufficient for illuminating the room.

4.5 Summary

The analysis of three line graphs reveals a direct proportional relationship between the minimum lumen and the factors of length, width, and height. Notably, the consistent formulation across all graphs results in a constant value of 2500, obtained through the multiplication of length, width, and minimum lux factors.

Despite significant differences in lux readings for different colors in individual rooms, the combined results for the dining and living rooms show no correlation between color intensity (6500K, 4000K, 3000K) and average lux measured.

Observations from the bathroom and living room highlight notable variations. The bathroom's lux measurements surpass the MS1525 requirement, aligning closely with app calculations. Conversely, the living room falls short of the specified lux threshold, with app calculations indicating a need for more bulbs than present in the actual scenario. This demonstrates the app's reliability in assessing whether the current lighting is adequate for a room.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the lumen requirement is directly affected by the length, width and height of the room, the color of the lighting does not affect the lumen requirement or lux and the application have proved to be reliable. This means that the project have achieved its objectives as a lighting optimization simulation application since it is able to calculate the minimum lux required based on the room size, optimize the lighting required based on the minimum lux required, include the cost, power efficiency, light color and luminance for each area of the house, and analyze the performance of the formulated lux.

5.2 Potential for Commercialization

The Lighting Optimization Simulation App harbors significant potential across diverse domains, notably in the realm of construction planning. Architects and designers tasked with formulating the blueprint of a building confront multifaceted decisions, including the strategic placement of lighting fixtures and the selection of appropriate lighting types. In this context, the application emerges as a valuable tool, providing indispensable insights into the optimal layout and configuration of lighting elements.

Through the application's capabilities, professionals engaged in construction planning can seamlessly ascertain and calculate the requisite number of lighting fixtures essential for specific areas within a structure. Moreover, the app facilitates a comprehensive evaluation of the sufficiency of the chosen lighting solutions. By leveraging the app's functionalities, designers can gauge the effectiveness of the proposed lighting layout, ensuring that it aligns seamlessly with the intended purpose and ambiance of each space within the building.

This technological advancement not only expedites the decision-making process but also enhances the precision and efficiency of lighting design in construction projects. As the demand for sustainable and energy-efficient solutions continues to rise, the Lighting Optimization Simulation App emerges as an invaluable asset, contributing to the creation of aesthetically pleasing and functionally optimized built environments. Its integration into the construction planning workflow signifies a paradigm shift towards more informed and resource-conscious architectural practices.

5.3 Future Works

For future improvements, the Lighting Optimization Simulation Application could be enhanced as follows:

i) Incorporate an alternative method for entering the area dimensions, allowing users to delineate the space within a 3D simulation. This accommodates irregular-shaped areas, moving beyond conventional box or rectangular configurations.

ii) Integrate a 3D visualization feature depicting the user-inputted area, coupled with intelligent recommendations for optimal lighting fixture placement within the designated space.

iii) Revise the formula to optimize it according to the specific lighting type utilized, recognizing that different lighting sources exhibit distinct areas of illumination, consequently yielding varying lux levels.

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APPENDICES