Lighting System Design for Commercial Buildings with Higher Energy Efficiency

by

TAN TECK YING

16228

Dissertation submitted in partial fulfilment of

the requirement for the

BACHELOR OF ENGINEERING (HONS)

(ELECTRICAL AND ELECTRONIC ENGINEERING)

JANUARY 2016

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
32610 Tronoh
Perak Darul Ridzuan
Malaysia.

CERTIFICATION OF APPROVAL

Lighting System Design for Commercial Buildings with Higher Energy Efficiency

by

TAN TECK YING

16228

A project dissertation submitted to the

Electrical and Electronic Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (HONS)

(ELECTRICAL AND ELECTRONIC ENGINEERING)

Approved by,

____

Ir. Dr. Mohd Faris Bin Abdullah

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK DARUL RIDZUAN

January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

TAN TECK YING

ABSTRACT

The power demand increasing year by year have made the worldwide in energy crisis. Therefore proper energy management is required to use the available energy wisely. Lighting system play a role of decorative or functional purposes make it become the biggest energy consumption from total energy consumption. As an engineer, we apply our engineering knowledge to increase the efficiency of current lighting system to solve the problem of inefficiency of energy usage. There were various methodology/approach to have a more energy efficient system. Author came out with the effective method to satisfy both economic and technical requirement for commercial building's lighting system. Theoretical analysis and simulation of lux level in accordance to Malaysian Standard 1525 using DIALux software have been performed. The appropriate lighting fixture had been selected for suitable usage of the room and the lux simulation were conducted to determine the minimum number of light fixtures required to achieve the minimum lux. Technically a higher energy efficiency lighting system should consume less power consumption, which draw less current from the power supply and achieve higher uniformity of lux achieved. After the lighting system fulfill all the technical requirement, analysis continued with the economic analysis to justify that the lighting system was economically acceptable. The factors that have taken into consideration including installation cost of lighting system, cost of energy usage, return of investment (ROI) and payback period. Throughout this project, justification was carried out on type of light fitting more suitable, energy saving and also cost saving in order to achieve the energy saving and also still able to compliance with the lux requirement of MS1525.

ACKNOWLEDGEMENT

To begin with I am very thankful to my supervisor, Ir. Dr. Mohd Faris Bin Abdullah for all guidance, valuable knowledge and advice that he has provided throughout the whole period of my project conducted. His exemplary advice, monitoring and constant encouragement throughout my project helped me to get my work done.

I am using this opportunity to express my gratitude to everyone who supported me throughout the period of my project. The work presented hereby would not made a possible without any of them.

I wish to express my gratitude to my parents, Mr. Tan Kian Yew, my father and Ms. Lim Pek Yok, my mother for all their encourage and support during my study at Universiti Teknologi PETRONAS especially the period I conducted this project. Other than my parents, I also would like to thankful to my sisters and friends who gave me advice and motivated me to complete my work.

Last but not lease, I would like to thanks to Universiti Teknologi PETRONAS (UTP) for providing the good learning environment for me to complete my project with all the problem encounter can be solved.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Generally, the highest amount of energy consumption of a building comes from lighting system. An electrical lighting system could consume around twenty percent to fifty percent of total electricity consumption. Therefore, by careful design, use of more efficient equipment, and effective control, it should be able to achieve enormous energy savings.

Lighting is producing heat when it operates, therefore through reducing the number of light used will reduce the heat dissipated to environment and at the same time saving the overall air-conditioning energy usage. Different configuration of lighting system will have different visual performance and visual comfort to end user. Therefore, when designing lighting system, we will focus on the average lux level achieved at workplace level.

In industry, one of their concerns is the cost of operation. This waste energy should not be part of the operating cost. Most of the management would like to decrease their cost of operation from their total power consumption. They not only go for lower cost of operation but also would like to have the higher or same efficiency or the production rate compare to before this. To fulfill their need, a system with lower power consumption and complying the lux level recommend by MS1525 are required. In this project, an economic analysis will also be carried out base on initial cost investment, payback period (in years) and return of investment (ROI) for client/end user to decide either to go for energy saving design or stay for conventional design.

1.2 Problem Statement

As an engineer, we should apply our engineering knowledge/techniques to enhance the efficiency of current lighting system to solve the problem of inefficiency of energy usage. There are various methodologies to improve the efficiency of energy. The simplest way can start from proper lighting system management by placing sticky note at lighting switch at washroom or storeroom with the kind reminder of “PLEASE SWITCH OFF THE LIGHT WHEN NOT IN USE”. However not every methodology could satisfy both economic and technical requirement for commercial building to comply with Malaysia Standard 1525.

1.3 Objectives

At the end of this project, the following objectives shall be achieved:-

(i) To study the most effective method to satisfy both the economic and technical requirement for commercial building’s lighting system.

(ii) To perform theoretical analysis and simulation of lux level in accordance to MS 1525 using DIALux software.

(iii) Establish the best method to improve energy efficiency of commercial lighting system with compliance with MS 1525.

1.4 Scope of Study

Throughout this project, we should be able to justify which type of light fitting is more suitable, energy saving and also cost saving in order to achieve the energy saving and also still able to compliance with the lux requirement of MS1525. Colour Rendering Index (CRI) and Colour Temperature will be taken into consideration when choosing a light fitting.

Author should be able to come out the details of analysis in term of technically as well as economically. At the end of this project, a lighting system with low power consumption and cost effective shall be presented.

CHAPTER 2
LITERATURE REVIEW AND/OR THEORY

Power demand has been increasing rapidly from year to year. In order to meet the demand of nationwide, one of the solutions is building up new power plant to generate more power. Building up new power plant required proper planning because it required long-term maintenance fee and cost of operating [1]. In commercial building lighting system, the lighting systems have contributed around twenty percent to fifty percent of total electrical energy usage [2]. Therefore, we could have a system with higher efficiency by using efficient equipment, control and maintenance of lighting system and correct detail design. This is to make sure that lighting system is environmentally and achieve visual comfort of end user [1].

The first step in designing a lighting system is to choose the correct light for suitable usage of the room. The light source used will affect the performance of whole lighting system or other system as well [3]. Different light fitting/light source only applicable to certain application of a room, this will be discussed more in detail later on. Nowadays there are a lot of light sources available in market. All of these lighting should be analyzed base on the following terminology:-

i) Wattage – The total amount of electricity energy consumed by a lighting source
ii) Lumens – The amount of light that a light source can produce
iii) Efficiency – Lumens per watt (lm/W)
iv) Foot-candles – The total amount of light reached on an object and/or
v) Illuminance – Total luminous flux incident on a surface per unit area (lux)

When involving lighting system efficiency, we will look into how efficient is the electrical energy converted to light [2]. Designers have to choose the proper light fitting for the most suitable purpose of the use of light for different application. The most important factor to take into consideration is lm/W when dealing with lighting system efficiency. The higher lm/W will have higher efficiency because it requires same watt to produce more luminaire.

2.1 Incandescent Bulbs

One of the most common lighting sources is incandescent bulbs. When there is an electric current passing through the filament, it will produce the light. Incandescent bulbs are commonly used because it is inexpensive and they produce the colour temperature between warm and yellow-white. The tungsten-halogen incandescent bulbs can produce the whiter and brighter light among all incandescent bulbs. Other than that it also produce more light per watt and have much longer lifespan. The disadvantage of an incandescent light is its inefficiency where most of the energy loss due to the heat produced. Therefore, in a commercial building an incandescent light would not be recommended due to energy efficiency issue. Figure 1 shows the structure of an incandescent bulb.

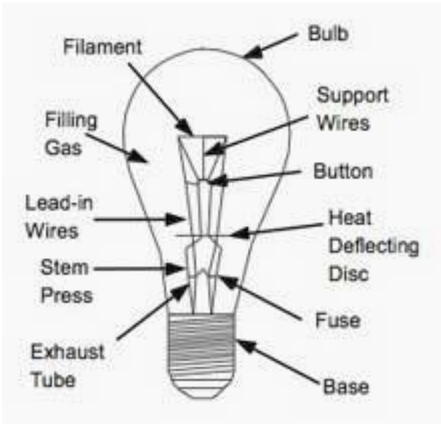


FIGURE 1: Structure of an incandescent bulb [4].

2.2 High-Intensity Discharge (HID) Lamp

Another light source that we can commonly use for outdoor or in a factory was High-Intensity Discharge (HID) lamp. The principle of HID is where a pressurize tube have an arc pass through between cathodes then the light is produced. HID has a better energy efficient but they do not pleasing light colour. Normally HID light source will be installed for street lighting purpose because it will emit some light toward the end of blue-white spectrum which is very helpful for drivers during night time [5]. Even HID can be divided into four (4) main category of light source which are low-pressure sodium, high-pressure sodium, metal halide and mercury vapor.

2.3 Fluorescent Bulbs

Fluorescent bulb is the most commonly used light source for commercial building. A radiant energy will be produced when there is an arc pass through between cathodes and the arc excite the mercury and gasses. This radiant energy will be converted to visible light using phosphor coating. Compare to incandescent lamps, fluorescent lamp has a much longer life span and much more energy efficient. From time to time, compact fluorescent lamp has been introduced to replace the fluorescent lamp. A compact fluorescent lamp will have a smaller physical size. It can be easily use in any screw-type light fitting to replace the incandescent lamps. T8 bulbs with electronic ballasts are commonly used in commercial building and residential applications. Electronic ballast will able to turn on the light instantly. However, this electronic ballast will consume energy which is not energy efficient. T5 bulbs are also introduced in the market as it can achieve the same level of illuminance with lower power consumption. Figure 2 shows that the main different between T12, T8 and T5 bulbs is their diameter sizes.

FIGURE 2: Physical difference between T12, T8 and T5 [6].

2.4 Light-Emitting Diode (LED)

Light-Emitting Diode (LED) has become commonly used for general application as it has longer lifetime and does not contain any poison mercury content [7]. When voltage applied to the negatively charged semiconductors, a unit of proton is produced when electron collide and combine together (in this case is light). Generally, LED is more energy efficient and has a longer life span. Most of the manufacturer/supplier of LED claim that LED lighting system would save up to 30% - 40% of total energy consumption. Until today, the price of LED still slightly expensive compare to T5 bulbs.

2.5 Colour Temperature

Colour temperature is defined as the colour emitted from of a light source which is warm (yellowish) or cool (bluish) [8]. A colour temperature is measured in degrees of Kelvin (°K), the higher value of colour temperature will produce a bluish colour while a lower value of colour temperature will produce a yellowish colour. Selection on colour temperature of a light source is very importance because it could affect to the end user to perform tasks. Figure 3 shows that the colour temperature emitted from different type of light source.

FIGURE 3: Colour temperature from different light source [9].

2.6 Colour Rendering Index (CRI)

Colour Rendering Index (CRI) is different from colour temperature; CRI is how a light source could effect on an object appear to a human being's eye. The important thing to remember is CRI and colour temperature is independent. Therefore, two light sources with same value of colour temperature might have two different scale of CRI. CRI is scaled from zero to hundred. This scale indicates that how good is a light source when rendering a colour. A light source with CRI scale of eighty five to ninety are considered good rendering colour.

CHAPTER 3
METHODOLOGY / PROJECT WORK

3.1 Project Works

When design a lighting system, we will consider the usage of the room. Different type of room will have different type of light fitting to be installed so that it can achieve its highest efficiency. In this project, we will consider a room which will be utilized as an office. A conventional fluorescent lamp will be used as the based design. The main challenge to make sure that our design comply with the MS 1525 recommended lux level for different services of building area.

We will look into a few aspects for different type of light fitting being used which including but not limit to:-

i) Colour Rendering Index of light fitting
ii) Colour Temperature of light fitting
iii) Total power consumption on lighting system
iv) Estimated electricity bill based on Tenaga National Berhad (TNB) tariff
v) Cost of installation for proposed lighting system
vi) Return of investment (ROI) of new system investment
vii) Payback period for new system investment

3.2 Methodology

3.2.1 Room size and function of room

Different usage of a room/space would require different level of lux. For this project, author would like to focus his work on commercial building of an office area. Accordance to MS 1525, the minimum lux required at work plane level is 300 lux. Table 1 shows extract of Malaysian Standard 1525.

TABLE 1: Lux requirement accordance to MS 1525 [10].

Task and Application	**Illuminance (Lux)**	**Minimum CRI**
b) Lighting for working interior		
- Infrequent reading and writing	200	80
- General offices, shops and stores, reading and writing	300 – 400	80
- Drawing office	300 – 400	85
- Restroom	150	80
- Restaurant, canteen, cafeteria	200	80
- Kitchen	150 – 300	80
- Lounge	150	60
- Bathroom	150	80
- Toilet	100	60
- Bedroom	100	80
- Classroom, Library	300 -500	80
- Shop/supermarket/department store	200 – 750	80
- Museum and gallery	300	80

For the simulation result to be conducted, author set the room size of this office to 24m (length), 12m (width) and 3m (height). The reason being, most of the commercial buildings especially for office area, the ceiling installed will be 1200mm (length), 600mm (width). With this size of room a number of four hundred celling pieces can be installed perfectly and nicely.

3.2.2 Light Fitting selection

When deciding the light fixture, we will take into consideration the colour rendering index and colour temperature of a light fixture. Generally for an area to be use as office area we will choose a light fixture with colour temperature of 4000K. This colour temperature selection depend on designer/engineer/end user selection. As an engineer we will proposed the colour temperature which is more suitable base on the usage of the room. While for the colour rendering index (CRI), MS 1525 recommended the minimum CRI required. Therefore, when select the CRI we have to make the CRI of light fixture achieved at a minimum eighty (for the application of an office area).

Other than that, the installation method will also taken into consideration. We should choose the proper light fitting for different usage of an area and the installation method. Author had selected a light fitting which is celling recessed type of T5 fluorescent lamp and also a surface mounted type for T8 fluorescent lamp. For LED lamp, we will use the same light casing as T8 fluorescent lamp. This is because as for now, the LED is still mainly designed for the T8 fluorescent lamp retrofit. To make sure all light fitting and lamp used in this project are comparable, all of them are selected from the same manufacturer which is OSRAM. The reason author choose manufacturer OSRAM is because among the light manufacturer only OSRAM provide more completed data for simulation work to conduct.

3.2.3 Simulation work

After we decided the type of light fixture to be used. We will use DIALux software to perform simulation to figure out how many of light fixture are required to achieve the minimum lux requirement suggested by Malaysian Standard 1525. The simulation work will be conducted for few times before obtaining final result. For the first simulation result, the distance between two light fittings is the suggested distance to achieve the minimum lux level required. But normally this distance is not practically accepted as the distance might be a weird number or cannot be installed on site later on. Therefore we would require to perform a second simulation to make sure our design (distance between two light fittings) is acceptable.

3.2.4 Technical Analysis

The simulation work will be continued until we obtain the lowest power consumption and economically acceptance. This is because sometimes we have a huge number of light fittings and low power consumption of light instead of small number of light fittings and normal power consumption of light. We have to keep in mind that the cost of installation and cost of maintenance will be taken into consideration.

Technically, we will calculate the current drawn from supply of the designed lighting system. In the calculation, considering an electrical supply in Malaysia, therefore the voltage level of three phase system is 400V, single phase system is 230V and the power factor is 0.85. Equation (1.0) gives, the current drawn from electrical supply of different configuration lighting system designed.

$$\text{Power(W)} = \sqrt{3} \text{ x Voltage (V) x Current (I) x Power Factor} \qquad (1.0)$$

Other than current drawn from electricity supply, we also concern about the average lux level achieved at work plane level. Accordance to MS 1525, the average lux level at work plane level for an office area should achieved at a minimum 300 lux. Other than the average lux level achieved at work plane level, the uniformity of lux distributed also concerned. A good lighting system should have a higher value of uniformity of lux distributed. A higher value of uniformity of lux achieved represent that the designed light system had distributed the lux equally at the desired place. The uniformity of lux achieved should be higher than 0.5 to avoid the huge variance of lux distributed between two locations.

The average wattage used per area of a lighting system also evaluated using (2.0).

$$\frac{\text{Total wattage consumed by lighting system (W)}}{\text{Total area (m}^2\text{)}} \qquad (2.0)$$

3.2.5 Economic Analysis

Apart from the technical analysis, the designed lighting system also will be analyzed on the economic factor which including the cost of installation, cost of electricity per kilowatt-hour (kWh), return of investment (ROI) and the payback period of the energy efficient lighting system proposed.

The cost of electricity per kilowatt-hour is calculated according to Tenaga National Berhad (TNB) tariff. Figure 4 shows the tariff of TNB charge for a low voltage commercial tariff.

TARIFF CATEGORY	CURRENT RATES(1 JAN 2014)
TARIFF B - LOW VOLTAGE COMMERCIAL TARIFF	
For the first 200 kWh (1 -200 kWh) per month	43.5 sen/kWh
For the next kWh (201 kWh onwards) per month	50.9 sen/kWh
The minimum monthly charge is RM7.20	

FIGURE 4: Electricity tariff accordance to Tenaga National Berhad (TNB) of low voltage commercial tariff [11].

The annual operating hours is calculated using (3.0), total annual power consumption is calculated using (4.0) and the annually cost of electricity is calculated as (5.0). The operating hour is assuming ten hours per days, five operating/working days per week and fifty two weeks per year.

Annual operating hour (hours)

$$= \text{Daily operating hours x weekly operating days x 52 weeks} \qquad (3.0)$$

Total annual power consumption (Wh)

$$= \text{total power consumption (W) x annual operating hours (hours)} \qquad (4.0)$$

$$\text{Annually cost of electricity (RM)} = \frac{\text{Total annual power consumption (Wh)}}{1000} \times \text{Electricity tariff per kWh} \quad (5.0)$$

The cost of installation cost of different lighting system is tabulated as Table 2.

TABLE 2: Cost of installation for different configuration lighting system.

Item Description	Price	
	Euro , €	MYR , RM
Section A : Price for light only		
OSRAM 1 x 36W T8 fluorescent lamp	7.00	31.29
OSRAM 1 x 14 W T5 fluorescent lamp	9.00	40.23
OSRAM 1 x 28 W T5 fluorescent lamp	9.81	43.85
OSRAM SubstiTUBE 1 x 20W LED	10.00	44.70
Section B : Price for light fitting with light		
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	61.53	275.04
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	82.29	367.84
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	64.23	287.11
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using T8 to T5 adapter)	71.85	321.17
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	70.23	313.93
Section C : Price for accessories		
T8 to T5 adapter	1.00	4.47

* Note : Currency exchange rate @ 1 Euro = 4.47 MYR

Other than that, the annual savings for the proposed lighting system can be calculated using (6.0).

$$\begin{matrix}\text{Annual saving on} \\ \text{electricity bill}\end{matrix}\text{(RM)} = \begin{matrix}\text{Electricity bill on} \\ \text{existing system}\end{matrix}\text{(RM)} - \begin{matrix}\text{Electricity bill on} \\ \text{proposed sytem}\end{matrix}\text{(RM)} \quad (6.0)$$

And finally come to the most important factor which is the Return of Investment (ROI) for the proposed energy efficient lighting system. ROI is calculating using (7.0).

$$\text{ROI (\%)} = \frac{\text{Annual saving on electricity bill (RM)}}{\text{Total cost of Installation of proposed lighting system (RM)}} \text{ x } 100 \qquad (7.0)$$

Other than the return of investment we also can look into the aspect of payback period for our investment. The payback period can be calculated using (8.0).

$$\text{Payback period (Years)} = \frac{\text{Total Cost of Installation (RM)}}{\text{Total annual saving on electricity bill (RM)}} \qquad (8.0)$$

The research methodology is describe in Figure 5.

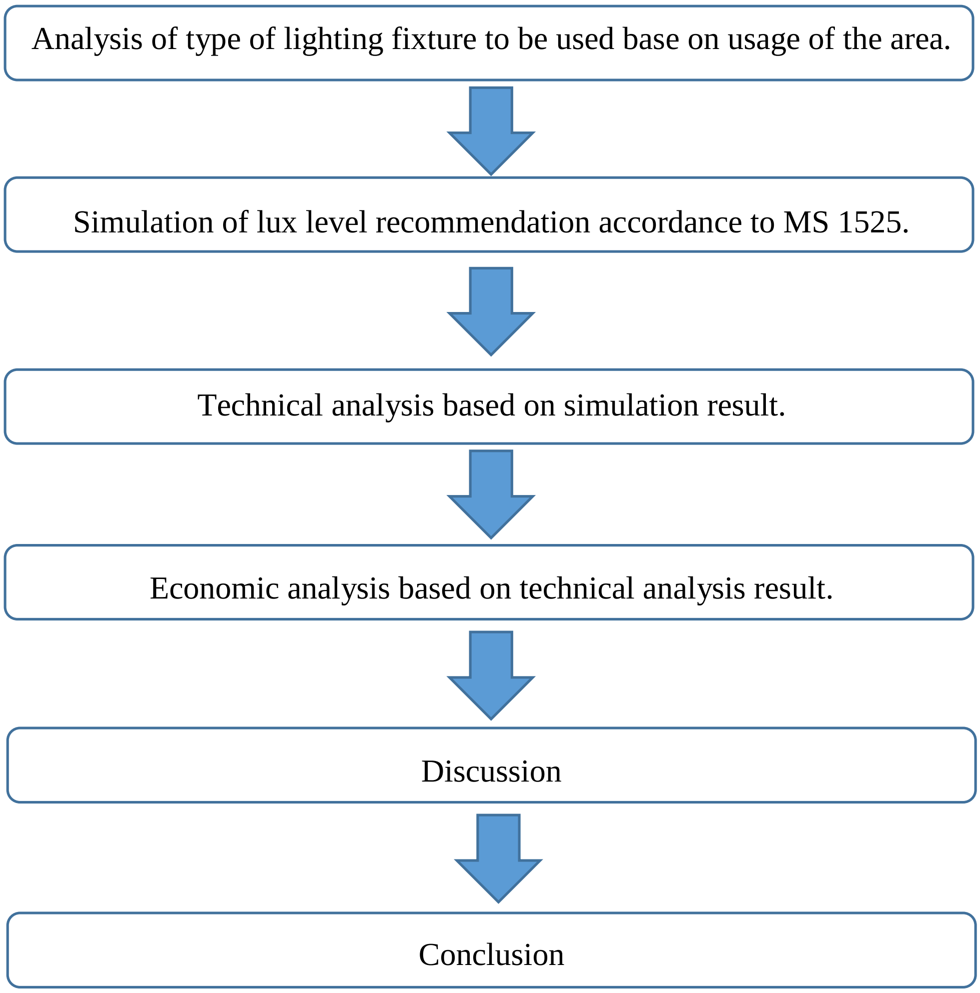
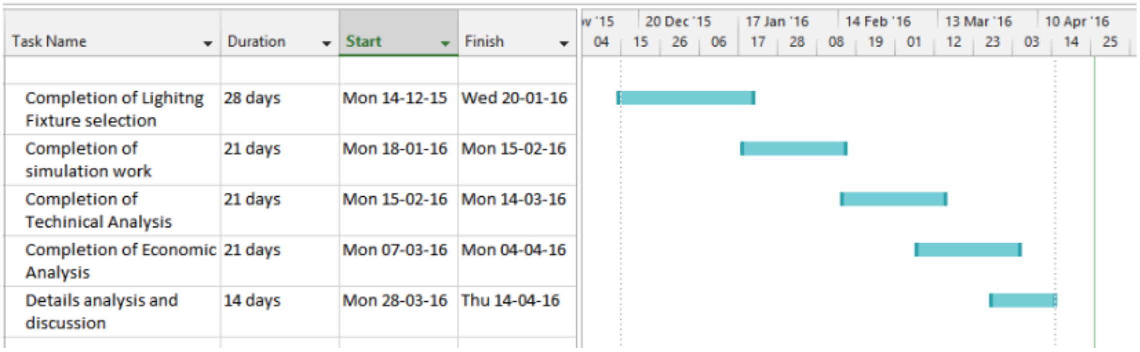


FIGURE 5: Research Methodology.

3.3 Milestone

Figure 6 shows the milestone of Final Year Project.



Task Name	Duration	Start	Finish
Completion of Lighitng Fixture selection	28 days	Mon 14-12-15	Wed 20-01-16
Completion of simulation work	21 days	Mon 18-01-16	Mon 15-02-16
Completion of Techinical Analysis	21 days	Mon 15-02-16	Mon 14-03-16
Completion of Economic Analysis	21 days	Mon 07-03-16	Mon 04-04-16
Details analysis and discussion	14 days	Mon 28-03-16	Thu 14-04-16

FIGURE 6: Milestone of the whole project.

3.4 Gantt-Chart

The project gantt-chart of this project is shown in Table 3.

TABLE 3: Gantt-Chart for Final Year Project.

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Proper light fitting selection														
Analyze selected light fitting														
Simulation of lux level using DIALux														
Theoretical Analysis														
Economic analysis on designed lighting system														

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Preliminary Simulation Work

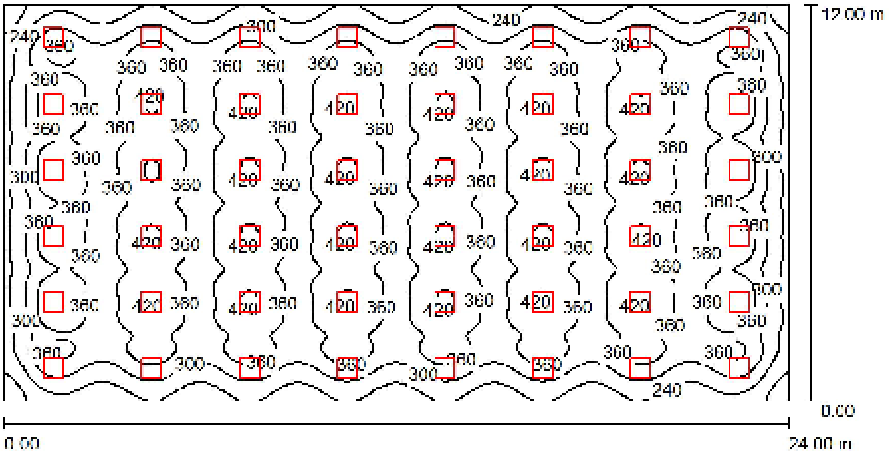
The preliminary simulation work was conducted to observe the distance between two (2) lighting fixture in order to achieve the minimum lux required accordance to MS 1525. Author has conducted his case study on commercial building with specific office area and the minimum lux required is 300 lux. From the preliminary simulation result, all technical data are tabulated in Table 4. For the result of preliminary simulation using T5 fluorescent lamp is shown in Figure 7. While the result of preliminary simulation using T8 fluorescent lamp and LED is attached in Appendix I and II. The technical data of all light fitting and lamp used is attached in Appendix III, IV and V.

TABLE 4: Technical specification comparison for preliminary simulation result.

Type of Light	2 x 36W T8	3 x 14W T5	2 x 20W LED
Distance between two light fitting (m)	1.80m x 4.80m	2.00m x 3.00m	1.50m x 2.40m
Average lux level achieved at work plane level (lx)	335	345	338
Uniformity of lux distributed	0.409	0.425	0.487
Total Power (W)	2,520.00	2,016.00	3,200.00
Current drawn from supply (A)	4.2792	3.4233	5.4339
Energy consumption (W/m^2)	8.75	7.00	11.11

Operator
Telephone
Fax
e-Mail

Prelim 3 x14W T5 840 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	345	147	427	0.425
Floor	20	332	145	397	0.438
Ceiling	80	58	33	70	0.564
Walls (4)	50	117	40	305	/

Workplane:

Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.324, Ceiling / Working Plane: 0.168.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	48	OSRAM 4008321380890 DED T5 DPB KIT 3X14 W/840 WIELAN (Type 1)* (1.000)	2468	3600	42.0
			Total: 118476	Total: 172800	2016.0

*Modified Technical Specifications

Specific connected load: 7.00 W/m² = 2.03 W/m²/100 lx (Ground area: 288.00 m²)

Page 1

FIGURE 7: Preliminary simulation result using T5 fluorescent lamp.

4.2 Case Study Simulation Work

After obtain the result from preliminary simulation, the simulation work is continued with different design simulation. For each of the lighting system design, author vary the distance between two light fittings, number of light fittings used and also the arrangement of light fittings.

The simulation work of lighting system is focused on the following design:-

I. 2 x 36W T8 fluorescent lamp
II. 2 x 28W T5 fluorescent lamp
III. 3 x 14W T5 fluorescent lamp
IV. 4 x 14W T5 fluorescent lamp
V. 2 x 20W LED

The two most common design of lighting system design is the 2 x 36W T8 fluorescent lamp and 3 x 34W T5 fluorescent lamp. Therefore, these two designs will be used as the reference/base design to compare with other lighting system. The 2 x 28W T5 fluorescent lamp lighting system is replacing the 2 x 36W T8 fluorescent lamp with 2 x 28W T5 fluorescent lamp. Same as the 2 x 20W LED lighting system, it replaced the 2 x36W T8 fluorescent lamp with 2 x 20W LED.

4.3 Technical Analysis

The technical data and analysis of simulated lighting system is tabulated in Table 5. The simulation result is attached in Appendix VI, Appendix VII, Appendix VIII, Appendix IX and Appendix X.

TABLE 5: Technical Comparison between different configurations of lighting system.

Light System	2 x 36W T8	2 x 28W T5	3 x14W T5	4 x 14W T5	2 x 20W LED
Distance between two light fitting	1.80m x 4.80m	2.40m x 3.00m	1.80m x 3.60m	3.0m x 3.6m	1.20m x 3.00m
Average lux level achieved (lx)	335	298	353	312	311
Uniformity of lux distributed	0.407	0.466	0.363	0.582	0.378
Total Power (W)	2,520.00	2,240.00	2,016.00	1,568.00	2,880.00
Current drawn from supply (A)	4.2792	3.8037	3.4233	2.6626	4.8905
Energy consumption (W/m^2)	8.75	7.78	7.00	5.44	10.00

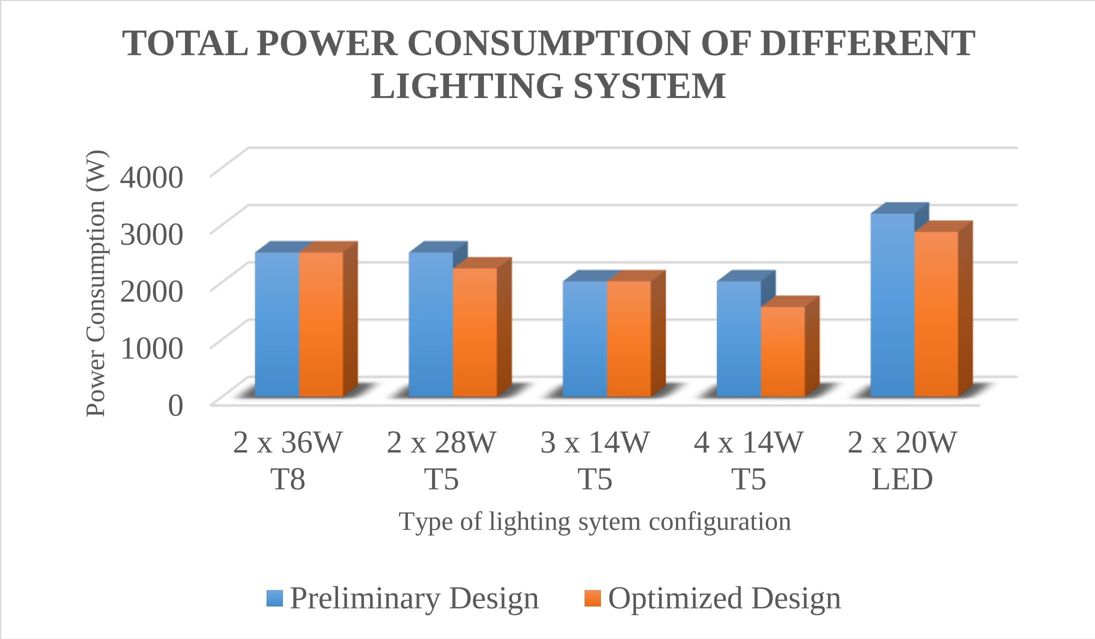


FIGURE 8: Graph of total power consumption for different lighting system.

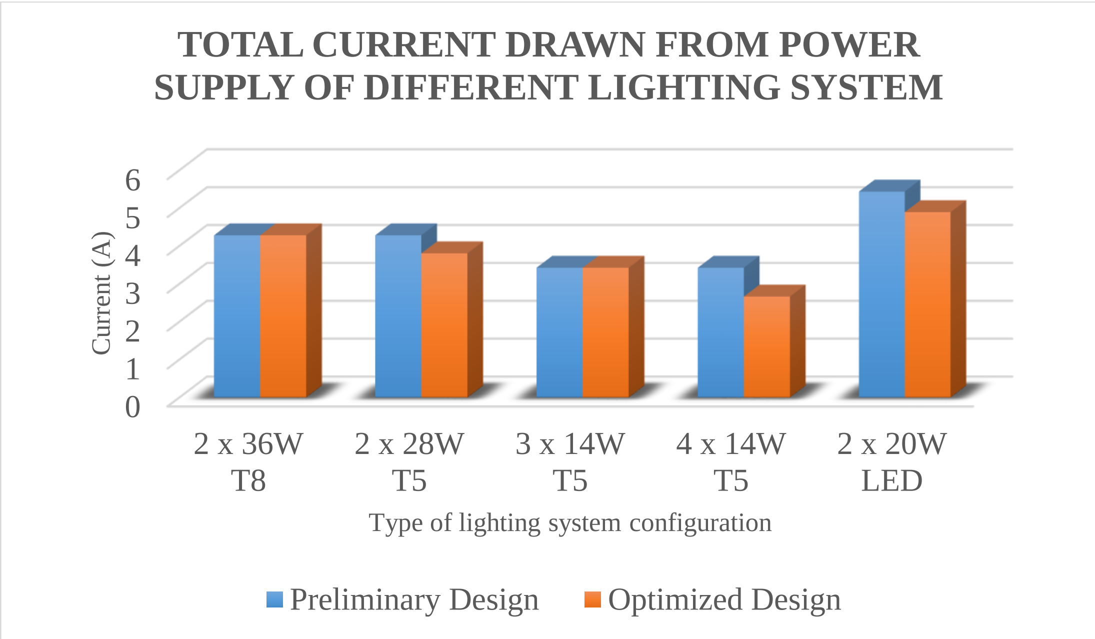


FIGURE 9: Graph of total current drawn from power supply of different lighting system.

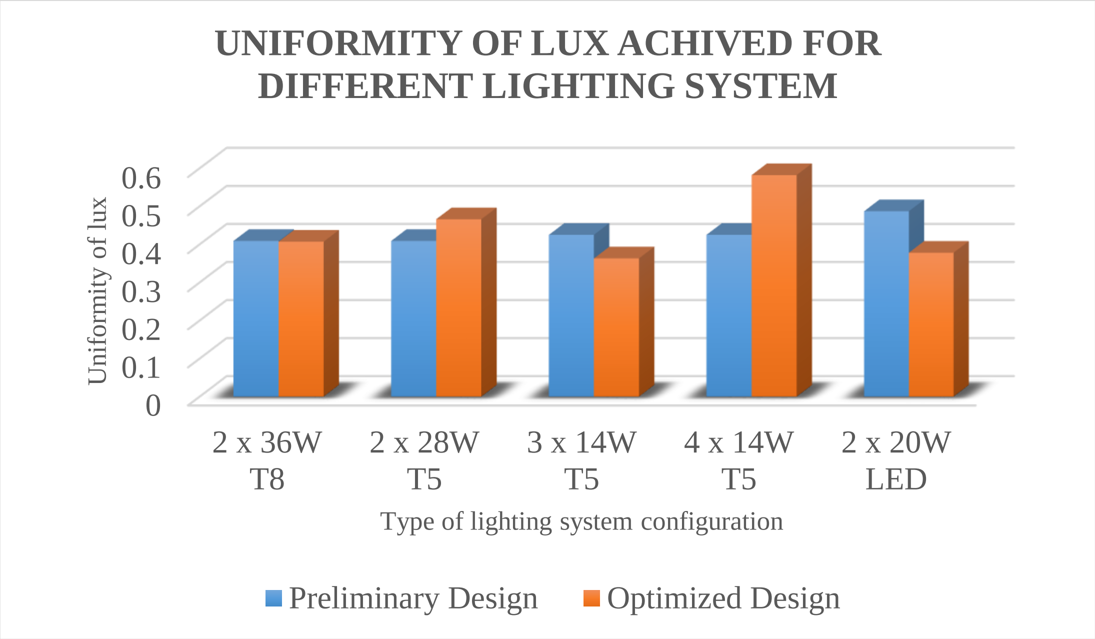


FIGURE 10: Graph of uniformity of lux achieved for different lighting system.

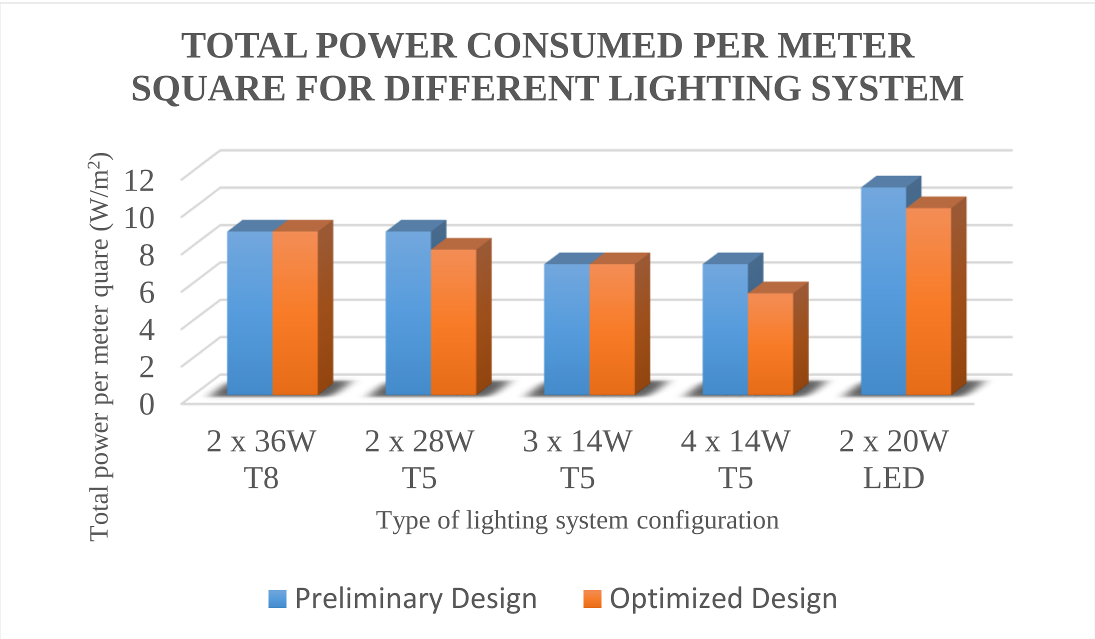


FIGURE 11: Graph of total power consumed per meter square for different lighting system.

From the simulation result, to achieve lux level at 300 lux, a LED require slightly more compare to T8 fluorescent lamp. But for T5 fluorescent lamp it require the lowest number of light fixture among all lighting system to achieve 300 lux. Although LED used the most number of light fitting compare to others, but it had achieve the highest uniformity of lux distributed in the room which the uniformity achieved is 0.484. Other than that, the LED also produced the highest lumen for each wattage consumed which is 122.22lm/W. For energy consumption, a T5 fluorescent lamp consume the less energy compare to T8 fluorescent lamp and LED.

From the result, we also could notice that the distance between two (2) light fittings was not a nice/whole number. The result obtain from first simulation was theoretically acceptable but not practically acceptable. This is because most of the time contractor/worker rarely to install them with the distance of 1.72m or others. Therefore there is the need for us to have a second simulation which is theoretically and practically acceptable.

From the second simulation, the number of light fittings for T8 fluorescent lamp and T5 fluorescent lamp remain the same while the number of LED used have reduced from 110 nos. to 100 nos. Therefore the power consumption of LED is reduced. We could notice that the uniformity of lux distribution had increased. This is because the light fitting have a proper arrangement according the room size so that the lux could distributed more equally. Other than that the efficiency of light fitting (lm/W) not affected by the arrangement or number of light used. The efficiency of light depend on the light itself only.

After completed second simulation, the design of lighting system using T8 fluorescent lamp is removed. The T8 fluorescent lamp consume the highest energy to achieve the minimum lux level in both simulation. And T8 florescent lamp light system also achieved the lowest uniformity of lux distributed compare to T5 fluorescent lamp and LED. All of these show that the T8 fluorescent lamp is inferior compared to the others lighting system design.

4.4 Economic Analysis

In the simulation result, the 4 x 14W T5 Fluorescent Lamp lighting system satisfied the technical requirement and it consumed the lowest power among proposed lighting system. Furthermore the economic analysis will be conducted to justify that the proposed lighting system is economically accepted. Table 6 shows the total cost of installation of different lighting system configuration. Apart from the cost of installation, the cost on energy usage (cost for electricity bill according to TNB tariff) is calculated and tabulated in Table 7.

TABLE 6: Total cost of installation of different lighting system configuration.

Lighting System Configuration	Unit Rate (RM)	Nos.	Total (RM)	Variance from lowest (%)
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	65.00	35	2, 275.00	Lowest
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	85.00	28	2, 380.00	4.62
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using (T8 to T5 adapter)	72.00	40	2, 880.00	26.59
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	62.00	48	2, 976.00	30.81
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	70.00	72	5, 040.00	121.54

TABLE 7: Cost on energy usage of different lighting system.

Lighting System Configuration	Total Energy Consumption (W)	Total Cost for Energy Usage, Annually (RM)	Variance from highest (%)
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	2, 880	3, 257.28	Highest
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	2, 520	2, 850.12	-12.5
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using (T8 to T5 adapter)	2, 240	2, 533.44	-22.22
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	2, 016	2, 280.07	-30.00
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	1, 568	1, 773.46	-45.56

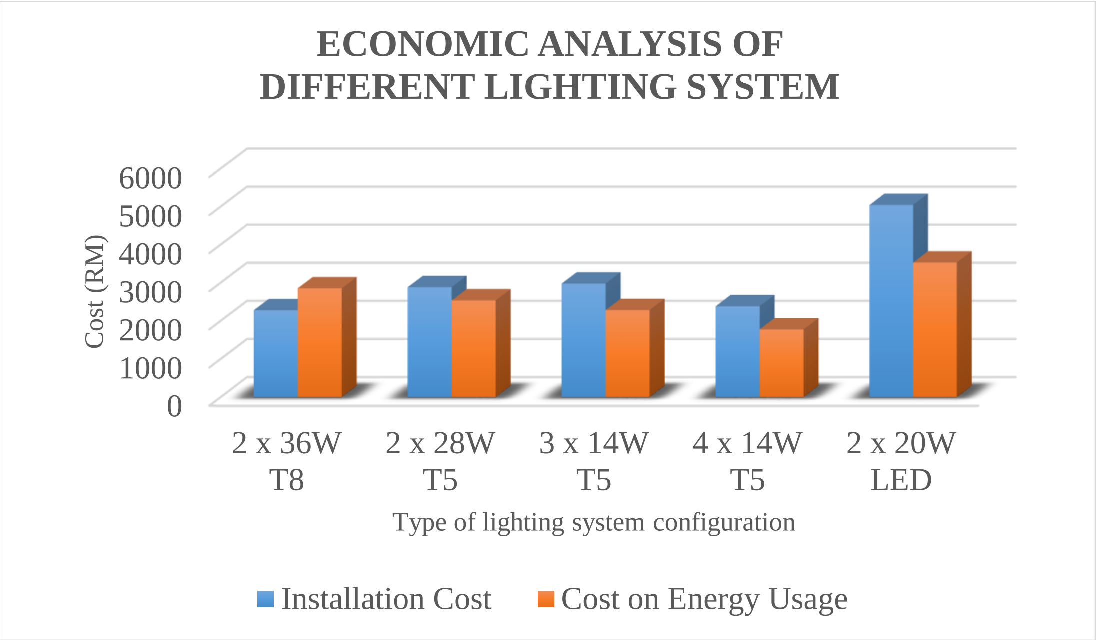


FIGURE 12: Graph of economic analysis for different lighting system.

From Figure 12, the installation cost and cost on energy usage of LED is the highest while the T5 fluorescent lighting system is the lowest. And clearly show that the LED lighting system require around double of the initial cost compare to other lighting system configuration.

4.4.1 Return of Investment (ROI)

The economic analysis is analyzed further looking at return of investment for the proposed lighting system. The 2 x 36W T8 fluorescent lamp lighting system and 3 x 14W T5 fluorescent lamp lighting system will be considered as the existing/base design, so that we could identify either the proposed lighting system have the attractive return of investment or not. The return of investment for 2 x 36W T8 fluorescent lamp lighting system as the base design is calculated and tabulated in Table 8. For the return of investment for 3 x 14W T5 fluorescent lamp lighting system as the based design is calculated and tabulated in Table 9.

TABLE 8: Return of Investment of proposed lighting system
(2 x 36W T8 fluorescent lamp as based design).

Lighting System Configuration	Total Cost for Energy Usage, Annually (RM)	Total Cost of Installation (RM)	ROI (%)
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	2, 850.12	2, 275.00	Base Design
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	3, 257.28	5, 040.00	- 8.0786
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using (T8 to T5 adapter)	2, 533.44	2, 880.00	10.9917
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	2, 280.07	2, 976.00	19.1509
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	1, 773.46	2, 380.00	45.2328

Table 8 shows the ROI of different configuration of lighting system with the 2 x 36W T8 fluorescent lamp lighting system as based design. A negative ROI represent that the investment will lead to the loss of money. This loss of money is due to the new lighting system is unable to save the cost of energy usage and lead to the extra cost compare to previous system. The highest ROI of lighting system will be the

4 x 14W T5 fluorescent lamp lighting system which is 45.2328 % and the second highest ROI will be 3 x 14W T5 fluorescent lamp lighting system which is 19.15 %.

TABLE 9: Return of Investment of proposed lighting system
(3 x 14W T5 fluorescent lamp as based design).

Lighting System Configuration	Total Cost for Energy Usage, Annually (RM)	Total Cost of Installation (RM)	ROI (%)
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	2, 280.07	2, 976.00	Base Design
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	2, 850.12	2, 275.00	-25.0571
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	3, 257.28	5, 040.00	-19.3891
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using T8 to T5 adapter)	2, 533.44	2, 880.00	-8.7976
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	1, 773.46	2, 380.00	21.2861

Table 9 shows that ROI of different configuration of lighting system and the 3 x 14W T5 fluorescent lamp lighting system is the based design. We noticed that most of the lighting system configuration have the negative value of ROI which indicated that actually 3 x 14W T5 fluorescent lamp is more energy efficient. The negative ROI is due to lighting system could not help in saving the cost of energy usage to recover back the cost of installation of lighting system. Only the 4 x 14W T5 fluorescent lamp lighting system have a ROI of 21.2561 %.

From the tabulated result in Table 8 and Table 9, we noticed that the lighting system of 4 x 14W T5 fluorescent lamp have the highest ROI in both type of based design. This shows that 4 x 14 W T5 fluorescent lamp is profitable.

4.4.2 Payback period

Apart from the ROI, another important factor is payback period of investment for proposed lighting system also taken into consideration. This is to make sure that the payback period should shorter than the lifespan of the lamp used. The payback period (in years) for 2 x 36W T8 fluorescent lamp as the based design is calculated and tabulated in Table 10. For the payback period for 3 x 14W T5 fluorescent lamp as the based design is calculated and tabulated in Table 11.

TABLE 10: Payback period of proposed lighting system
(2 x 36W T8 fluorescent lamp as based design).

Lighting System Configuration	Total Cost for Energy Usage, Annually (RM)	Total Cost of Installation (RM)	Payback period (years)
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	2, 850.12	2, 275.00	Base Design
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	3, 257.28	5, 040.00	- 12.4
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using T8 to T5 adapter)	2, 533.44	2, 880.00	9.1
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	2, 280.07	2, 976.00	5.2
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	1, 773.46	2, 380.00	2.2

TABLE 11: Payback period of proposed lighting system
(3 x 14W T5 fluorescent lamp as based design).

Lighting System Configuration	Total Cost for Energy Usage, Annually (RM)	Total Cost of Installation (RM)	Payback period (years)
3 x 14W T5 OSRAM DEDRA plus T5 double parabolic	2, 280.07	2, 976.00	Base Design
2 x 28W T5 OSRAM LUMILUX DUO T8 louver (using T8 to T5 adapter)	2, 533.44	2, 880.00	-11.4
2 x 20W LED Substitube OSRAM LUMILUX DUP T8 louver	3, 257.28	5, 040.00	-5.2
2 x 36W T8 OSRAM LUMILUX DUO T8 louver	2, 850.12	2, 275.00	-4.0
4 x 14W T5 OSRAM DEDRA plus T5 double parabolic	1, 773.46	2, 380.00	4.7

The payback period indicates that how long does the investment will be paid back. The negative value of payback period indicates that lighting system will never get the paid back due to there is no saving/profit compared to based design. From Table 10 and Table 11, the lighting system 4 x 14W T5 fluorescent lamp is the most economic saving due to its less power consumption. Again, from economic analysis, the 4 x 14W T5 fluorescent lamp is having the advantage compare to other lighting system configuration.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

When involving lighting system efficiency, we will look into how efficient is the electrical energy is converted to light. This is the main reason why we had omitted the halogen light fixture which only convert 10% of the electric energy to light and the 90% of electric energy into heat energy. As a designer/engineer, we have to choose the proper light with the most suitable purpose for the use of light for different application.

From author work, the recommended lighting system with higher energy efficiency is T5 fluorescent lamp lighting system. It achieved the lowest power consumption in order to achieve the minimum lux recommended in Malaysian Standard 1525. This lighting system have fulfill the technical requirement as well as the economic analysis. From economic analysis, the T5 fluorescent lamp show that it have the highest return of investment (ROI) and the fastest payback period as well. A lighting system with low power consumption and cost effective is presented.

5.2 Recommendation

The work of author can be implemented in real case study which can be started in Universiti Teknologi PETRONAS (UTP). The work can be continued to study the energy efficiency of existing lighting system used in UTP and propose a more energy efficient lighting system so that UTP could able to cut down their operating cost on the electricity bill.

REFERENCES

[1] P. Sathya and R. Natarajan, "Design of energy efficient lighting system for educational laboratory," in *Green Computing, Communication and Conservation of Energy (ICGCE), 2013 International Conference on*, 2013, pp. 428-432.

[2] W. N. W. Muhamad, M. Y. M. Zain, N. Wahab, N. H. A. Aziz, and R. A. Kadir, "Energy Efficient Lighting System Design for Building," *Uksim-Amss First International Conference on Intelligent Systems, Modelling and Simulation*, pp. 282-286, 2010.

[3] (20 Oct). *Types of Light Sources and Light Bulbs*. Available: https://www.americanlightingassoc.com/Lighting-Fundamentals/Light-Sources-Light-Bulbs.aspx

[4] (2015, 1 December 2015). *Incandescent Lamps Information*. Available: http://www.globalspec.com/learnmore/optics_optical_components/light_sources/incandescent_lamps

[5] G. Gardner. (2015, 22 Oct). *Pros and Cons of HID Lights*. Available: http://www.ehow.com/info_8076148_pros-cons-hid-lights.html

[6] (2015, 10th December 2015). *WHEN ARE YOUR FLUORESCENT LIGHTS BEING DISCONTINUED?* Available: http://blog.retrofitcompanies.com/blog/bid/242603/When-Are-Your-Fluorescent-Lights-Being-Discontinued

[7] C. Huang-Jen, L. Yu-Kang, C. Jun-Ting, C. Shih-Jen, L. Chung-Yi, and M. Shann-Chyi, "A High-Efficiency Dimmable LED Driver for Low-Power Lighting Applications," *IEEE Transactions on Industrial Electronics*, vol. 57, pp. 735-743, 2010.

[8] (22 Oct). *Color Temperature & Color Rendering Index DeMystified*. Available: http://lowel.tiffen.com/edu/color_temperature_and_rendering_demystified.html

[9] M. Maher. (2015, 13th August 2015). *Understanding Set Lighting and Color Temperature*. Available: http://www.premiumbeat.com/blog/understanding-set-lighting-and-color-temperature/

[10] D. o. S. Malaysia, "Energy efficiency and use of renewable energy for non-residential buildings - Code of practice (Second revision)," in *Lighting*, ed, 2014.

[11] (2015, 9th December 2015). *PRICING & TARIFFS*. Available: https://www.tnb.com.my/commercial-industrial/pricing-tariffs1/

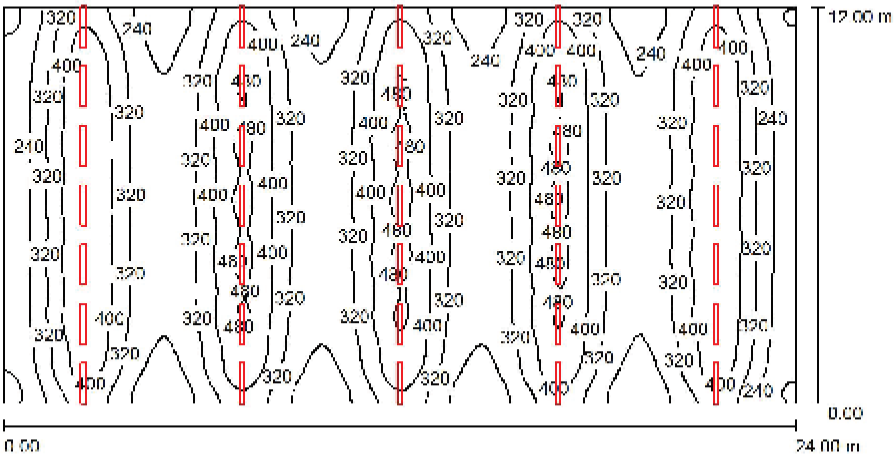
APPENDIX I

SIMULATION RESULT OF PRELIMINARY DESIGN OF 2 X 36W T8 FLUORESCENT LAMP LIGHTING SYSTEM

DIALux
25.03.2016

Operator
Telephone
Fax
e-Mail

Prelim 2 x 36W T8 / **Summary**



Height of Room: 3.000 m, Mounting Height: 3.048 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	335	137	502	0.409
Floor	20	318	153	418	0.480
Ceiling	80	70	44	186	0.633
Walls (4)	50	167	59	882	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.499, Ceiling / Working Plane: 0.208.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)		Φ (Luminaire) [lm]		Φ (Lamps) [lm]	P [W]
1	35	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (1.000)		3439		6700	72.0
			Total:	120355	Total:	234500	2520.0

Specific connected load: 8.75 W/m² = 2.61 W/m²/100 lx (Ground area: 288.00 m²)

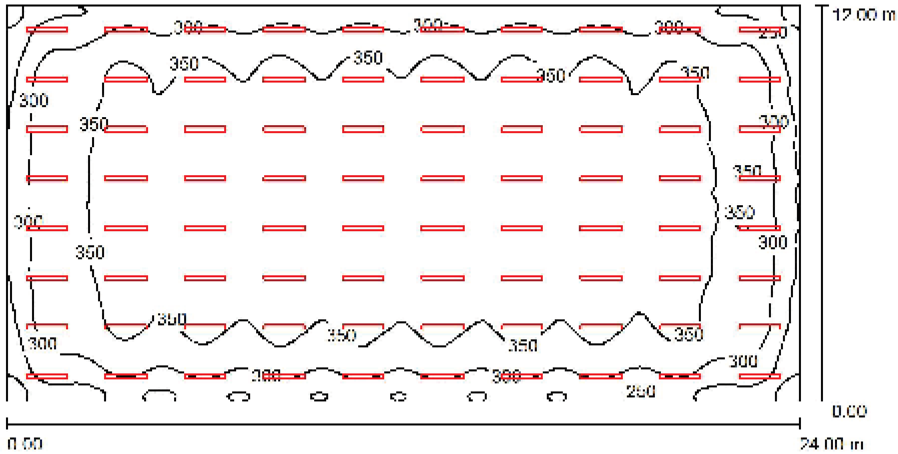
APPENDIX II

SIMULATION RESULT OF PRELIMINARY DESIGN OF 2 X 20W LED LIGHTING SYSTEM

DIALux
25.03.2016

Operator
Telephone
Fax
e-Mail

Prelim LED / **Summary**



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	338	165	398	0.487
Floor	20	321	170	376	0.529
Ceiling	80	64	49	115	0.764
Walls (4)	50	164	68	288	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.482, Ceiling / Working Plane: 0.190.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	80	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (Type 1)* (1.000)	1540	3000	40.0
*Modified Technical Specifications			Total: 123178	Total: 240000	3200.0

Specific connected load: 11.11 W/m² = 3.28 W/m²/100 lx (Ground area: 288.00 m²)

APPENDIX III

TECHNICAL DATA OF 2 X 36W T8 OSRAM LUMILUX DUO T8 LOUVER

Product datasheet

LUMILUX DUO EL-F/R 2X36 W HF

LUMILUX DUO T8 louver | Ceiling luminaires

–

Product benefits

– Extremely low-profile luminaire for fixed connection

Product features

– High-quality luminaire casing made from anodized aluminum

Product datasheet

Technical data

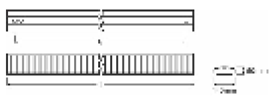
Electrical data

Operating mode	ECG
Lamp wattage	36 W
Nominal voltage	230…240 V
Mains frequency	50…60 Hz

Photometrical data

Color temperature	3000 K
Luminous flux	6700 lm
Light color (designation)	Warm white
Color rendering index Ra	80…89

Dimensions & weight

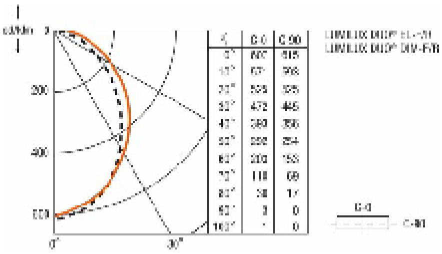


Length	1235 mm
Width	140.0 mm
Height	50.0 mm
Cable penetration	83.0 mm

Colors & materials

Body material	Aluminum
Product color	Silver
Cover material	Aluminum

Additional product data



Luminous intensity distribution

Number of lighting outlets	2
Equipped with lamp	Yes

Capabilities

Type of installation	Surface-mounted
Type of connection	Fixed (cutting terminal)
Holder designation	G13
Accessories	Pendant kit (4050300792200)

Certificates & standards

Luminous efficacy of lamp in luminaire	93 lm/W
EEI of control gear in luminaire	A2
Protection class	I
Type of protection	IP20
Protection against ignition and fire	F/MM
Protection class IK (shock resistance)	IK05

Country specific categorizations

Order reference	1305023620

Product datasheet

Country specific information

Product code	METEL code	SEG-No.	STK number	UK Org
4050300774329	OSRLUMDUOELFR236	-	4110731	-

–

Product datasheet

Equipment / Accessories

- With aluminum louvre and highly polished reflector for glare-free light
- Combined with the pendant kit accessory ideal for workplace lighting / home offices
- Equipped with two LUMILUX T8 830 fluorescent lamps
- With QUICKTRONIC electronic control gear

Logistical Data

Product code	Product description	Packaging unit (Pieces/Unit)	Dimensions (length x width x height)	Volume	Gross weight
4050300774329	LUMILUX DUO EL-F/R 2X36 W HF	Folding carton box 1	1286 mm x 62 mm x 146 mm	11.64 dm^3	2505.00 g
4050300774343	LUMILUX DUO EL-F/R 2X36 W HF	Shipping carton box 4	1295 mm x 161 mm x 233 mm	48.58 dm^3	10507.00 g

The mentioned product code describes the smallest quantity unit which can be ordered. One shipping unit can contain one or more single products. When placing an order, for the quantity please enter single or multiples of a shipping unit.

Disclaimer

Subject to change without notice. Errors and omission excepted. Always make sure to use the most recent release.

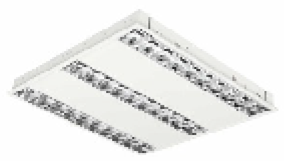
APPENDIX IV

TECHNICAL DATA OF 3 X 14W OSRAM DEDRA PLUS T5 DOUBLE PARABOLIC

Product datasheet

DED T5 DPB KIT 3X14 W/840

OSRAM DEDRA plus T5 double parabolic | Recessed luminaires



Areas of application

- For installation in suspended ceilings

Product benefits

- Peel-off film to protect the surfaces during installation

Product features

- Casing of powder-coated steel in white (RAL 9016) with safety cable
- Connection with 5-pin double plug terminal
- Double parabolic optics
- Symmetrical longitudinal reflector and louver with a polished finish
- Very low luminance (2 for 65°)

Product datasheet

Technical data

Electrical data

Operating mode	ECG
Lamp wattage	14 W
Nominal voltage	230...240 V
Mains frequency	50...60 Hz

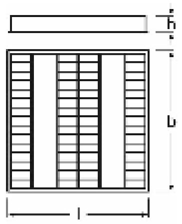
Photometrical data

Color temperature	4000 K
Luminous flux	3600 lm
Light color (designation)	Cool white
Color rendering index Ra	80...89
Color rendering group	1B
Luminaire efficiency	0.82

Light technical data

Light distribution	Symmetric
Unified glare rating axial	14

Dimensions & weight



Length	596.0 mm
Width	596.0 mm
Height	58.0 mm

Colors & materials

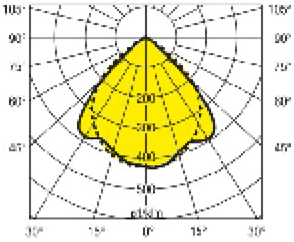
Body material	Sheet steel
Product color	White
RAL number	9016

Louver material	Anodized aluminum
Cover material	Aluminum

Temperatures & operating conditions

Ambient temperature range	-20...+50 °C

Additional product data



Luminous intensity distribution

Number of lighting outlets	3
Equipment	FH 14 W/840 HE
Equipped with lamp	Yes
Reflector type	Double parabolic grid
Water-tight	No
Type of cover	Cover

Capabilities

Type of installation	Recessed
Application	Offices / Floor lighting / Workplaces
Adjustable	No
Dimmable	No
Color management (RGB)	No
Type of fixing	Recessed mounting (lay-in)

Product datasheet

Type of connection	Terminal, 3-pole, max. 2,5 mm²
Ball shot safe	No
Holder designation	G5

Certificates & standards

Glow Wire Test according to IEC 695-2-1	960 °C
Type of lamp compatible w. luminaires	FDH-14/40/1B-L/P-G5-16/549
Luminous efficacy of lamp in luminaire	86 lm/W
Type of ballast compatible w. luminaires	QTP5 3X14,4X14
EEI of control gear in luminaire	A2 BAT
Protection class	I
Type of protection	IP20
Protection against ignition and fire	F
Protection class IK (shock resistance)	IK07

Country specific categorizations

Order reference	DED T5 DPB KIT

Country specific information

Product code	METEL code	SEG number	STK number	UK Org
4008321366672	OSRDET5DPB314840	7095000	4283408	-

Product datasheet

Equipment / Accessories

– Equipped with QUICKTRONIC dimmable electronic control gear

Logistical Data

Product code	Product description	Packaging unit (Pieces/Unit)	Dimensions (length x width x height)	Volume	Gross weight
4008321366672	DED T5 DPB KIT 3X14 W/840	Shipping carton box 1	634 mm x 73 mm x 628 mm	29.07 dm³	4100.00 g

The mentioned product code describes the smallest quantity unit which can be ordered. One shipping unit can contain one or more single products. When placing an order, for the quantity please enter single or multiples of a shipping unit.

Disclaimer

Subject to change without notice. Errors and omission excepted. Always make sure to use the most recent release.

–

APPENDIX V

TECHNICAL DATA OF 20 W / 19 W LED TUBES

Product datasheet

ST8V-EM 19 W/830 1200 mm EM

SubstiTUBE Value | Economic LED tubes for electromagnetic control gears

Areas of application

- General illumination within ambient temperatures from −20...+45 °C
- Corridors, stairways, parking garages
- Cooling and storage rooms
- Domestic applications
- Industry
- Warehouses
- Supermarkets and department stores

Product benefits

- Quick, simple and safe replacement without rewiring
- Energy savings of up to 65 % (compared to T8 fluorescent lamp on CCG)
- Instant-on light, therefore ideally suitable in combination with sensor technology
- Very high resistance to switching loads
- Also suitable for operation at low temperatures
- Extremely break resistant thanks to aluminum heat sink and polycarbonate cover

Product features

- LED alternative to classic T8 fluorescent lamps in CCG luminaires
- Bright, robust and durable
- Uniform illumination
- Lifetime: up to 30,000 h
- Wide beam angle: 160° (0.6 m), 150° (1.2 m, 1.5 m)
- Mercury-free and RoHS compliant
- Type of protection: IP20
- Integrated ECG with high power factor

Product datasheet

Technical data

Electrical data

Rated luminous flux	1500 lm
Nominal wattage	19.00 W
Rated wattage	19.00 W
Nominal voltage	220...240 V
Operating frequency	50...60 Hz
Type of current	AC
Max. tube no. on circuit break. 10 A (B)	80 / 14 / 80 [1)]
Max. tube no. on circuit break. 16 A (B)	125 / 22 / 125 [1)]
Number of switching cycles	200000
Power factor λ	> 0.90

[1)] Operated with conventional control gear / Operated with conventional control gear incl. compensation capacitor / Operated with direct mains connection (220...240 V)

Photometrical data

Light color (designation)	Warm White
Color temperature	3000 K
Nominal luminous flux	1500 lm
Color rendering index Ra	>80
Standard deviation of color matching	≤6 sdcm

Light technical data

Starting time	< 0.5 s
Warm-up time (60 %)	< 2.00 s
Rated beam angle (half peak value)	160.00 °

Dimensions & weight

Product datasheet

Overall length	1200 mm
Tube diameter	27.5 mm
Base diameter	27.5 mm
Product weight	165.00 g

Temperatures & operating conditions

Ambient temperature range	-20...+45 °C
Temperature range in operation	-20...65 °C

Lifespan

Nominal lamp life time	30000 h
Rated lamp life time	30000 h
Lumen main.fact.at end of nom.life time	0.70

Additional product data

Base (standard designation)	G13
Mercury-free	Yes
Product remark	When used to replace a T8 fluorescent lamp the total energy efficiency and light distribution depends on the design of the lighting system/Not usable in luminaires with serial lamp connection, i.e. more than one tube at one magnetic ballast (tandem circuitry)

Capabilities

Dimmable	No

Certificates & standards

Standards	CE
Energy efficiency class	A
Energy consumption	24 kWh/1000h

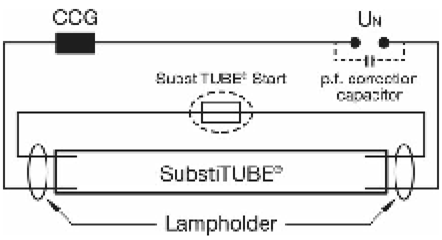
Country specific categorizations

ILCOS	DR-24/840-G13-27.5/1500
Order reference	ST8V-1.2M 19W/8

Logistical data

Temperature range at storage	-20...80 °C

Wiring Diagram



Wiring diagram

–

Equipment / Accessories

– Suitable for operation with low-loss and conventional control gears

Safety advice

Not suitable for operation with electronic control gear.
Operation in outdoor applications in suitable damp-proof luminaires possible according to data sheet and installation instruction.

Logistical Data

Product code	Product description	Packaging unit (Pieces/Unit)	Dimensions (length x width x height)	Volume	Gross weight
4052899937147	ST8V-EM 19 W/830 1200 mm EM	Shipping carton box 8	1330 mm x 139 mm x 73 mm	13.50 dm^3	2420.00 g

The mentioned product code describes the smallest quantity unit which can be ordered. One shipping unit can contain one or more single products. When placing an order, for the quantity please enter single or multiples of a shipping unit.

References / Links

Product datasheet

For current information see
- www.osram.com/substitube

Legal advice

When used to replace a T8 fluorescent lamp the total energy efficiency and light distribution depends on the design of the lighting system.

Disclaimer

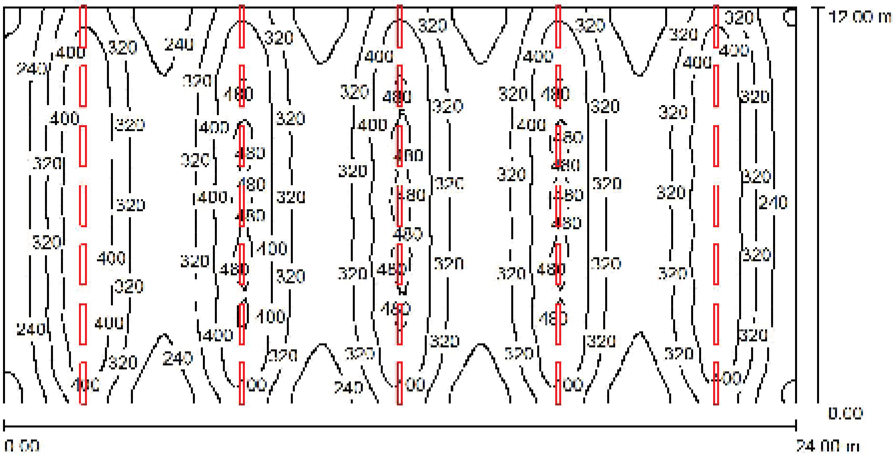
Subject to change without notice. Errors and omission excepted. Always make sure to use the most recent release.

APPENDIX VI

SIMULATION RESULT OF 2 X 36W T8 FLUORESCENT LAMP LIGHTING SYSTEM

Operator
Telephone
Fax
e-Mail

2 x 36W T8 / Summary



Height of Room: 3.000 m, Mounting Height: 3.048 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	335	136	502	0.407
Floor	20	318	150	418	0.472
Ceiling	80	69	44	184	0.628
Walls (4)	50	166	58	880	/

Workplane:
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.496, Ceiling / Working Plane: 0.207.

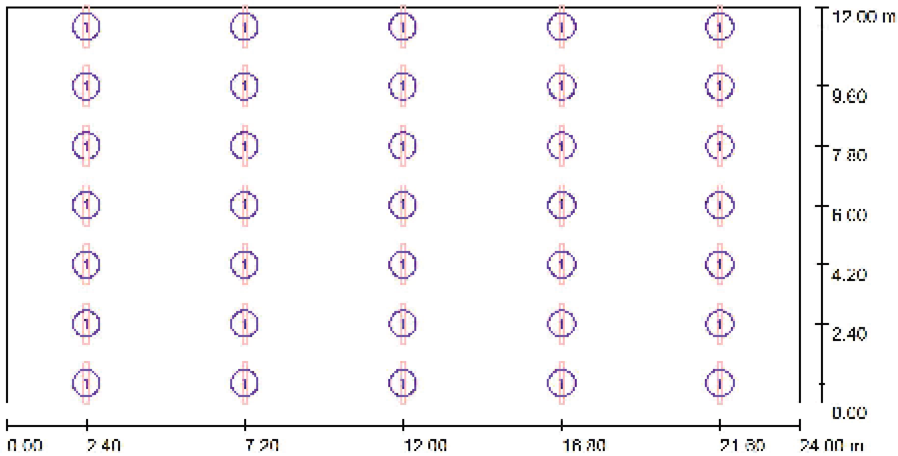
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	35	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (1.000)	3439	6700	72.0
			Total: 120355	Total: 234500	2520.0

Specific connected load: 8.75 W/m² = 2.61 W/m²/100 lx (Ground area: 288.00 m²)

Operator
Telephone
Fax
e-Mail

2 x 36W T8 / Luminaires (layout plan)



Scale 1 : 172

Luminaire Parts List

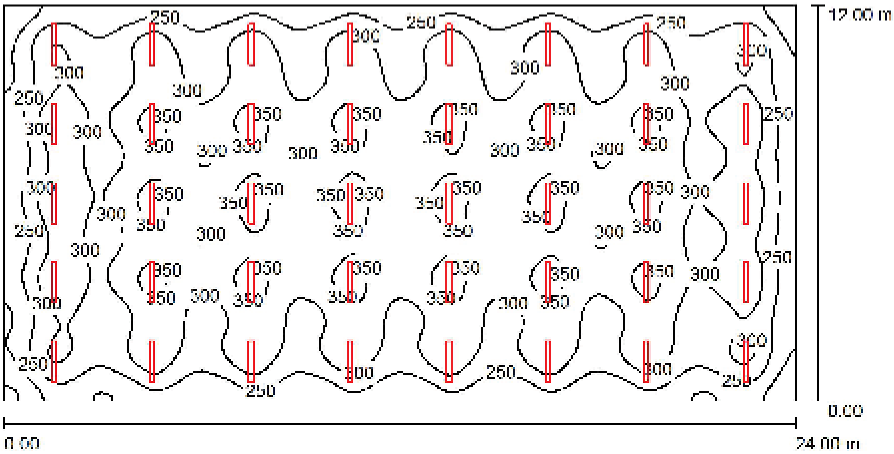
No.	Pieces	Designation
1	35	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W

APPENDIX VII

SIMULATION RESULT OF 2 X 28W T5 FLUORESCENT LAMP LIGHTING SYSTEM

Operator
Telephone
Fax
e-Mail

2 x 28W T5 840 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	298	139	379	0.466
Floor	20	282	143	338	0.507
Ceiling	80	56	40	85	0.714
Walls (4)	50	137	58	211	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.449, Ceiling / Working Plane: 0.190.

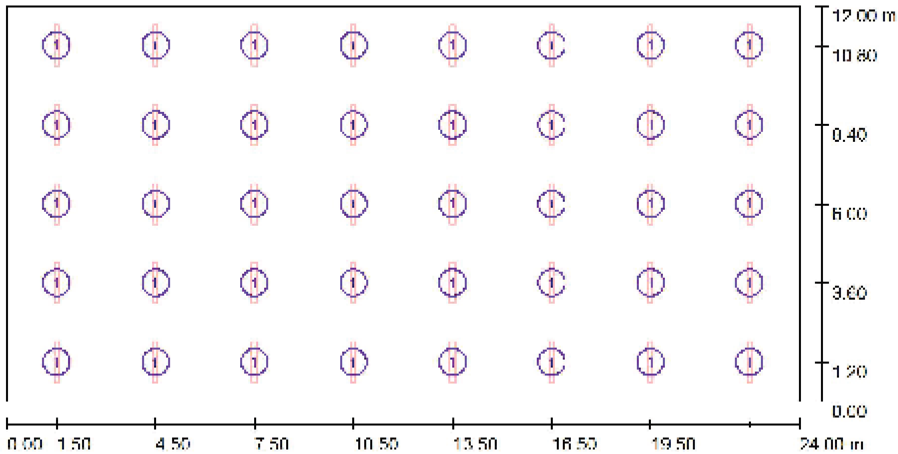
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	40	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (Type 1)* (1.000)	2669	5200	56.0
		*Modified Technical Specifications	Total: 106754	Total: 208000	2240.0

Specific connected load: 7.78 W/m² = 2.61 W/m²/100 lx (Ground area: 288.00 m²)

Operator
Telephone
Fax
e-Mail

2 x 28W T5 840 / Luminaires (layout plan)



Scale 1 : 172

Luminaire Parts List

No.	Pieces	Designation
1	40	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (Type 1)*

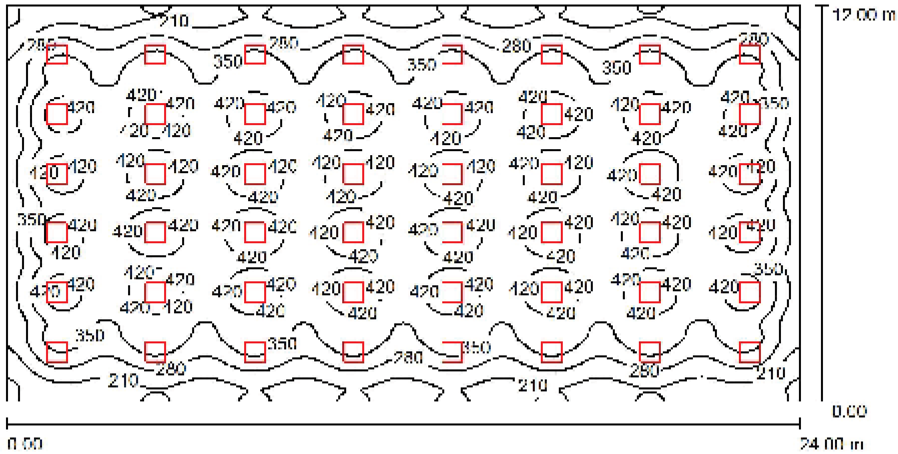
*Modified Technical Specifications

APPENDIX VIII

SIMULATION RESULT OF 3 X 14W T5 FLUORESCENT LAMP LIGHTING SYSTEM

Operator
Telephone
Fax
e-Mail

3 x14W T5 840 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	353	128	475	0.363
Floor	20	339	124	429	0.366
Ceiling	80	57	34	73	0.597
Walls (4)	50	102	36	182	/

Workplane:

Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.255, Ceiling / Working Plane: 0.163.

Luminaire Parts List

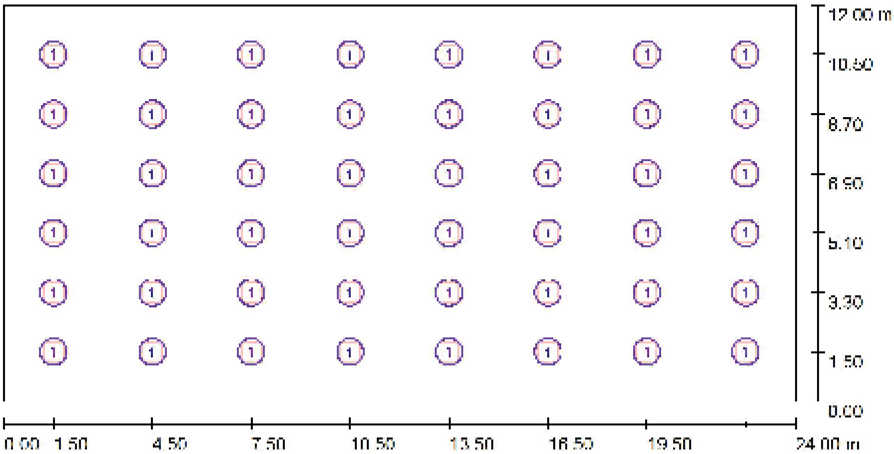
No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	48	OSRAM 4008321380890 DED T5 DPB KIT 3X14 W/840 WIELAN (Type 1)* (1.000)	2468	3600	42.0
			Total: 118476	Total: 172800	2016.0

*Modified Technical Specifications

Specific connected load: 7.00 W/m² = 1.98 W/m²/100 lx (Ground area: 288.00 m²)

Operator
Telephone
Fax
e-Mail

3 x14W T5 840 / Luminaires (layout plan)



Scale 1 : 172

Luminaire Parts List

No.	Pieces	Designation
1	48	OSRAM 4008321380890 DED T5 DPB KIT 3X14 W/840 WIELAN (Type 1)*

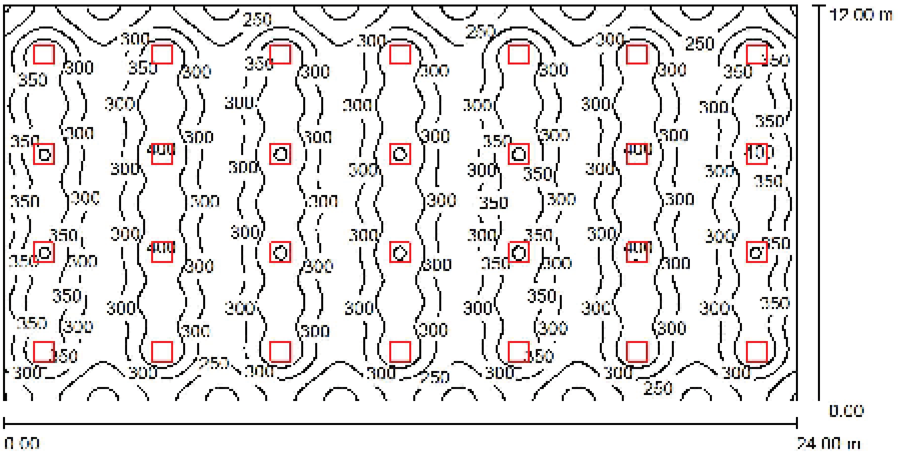
*Modified Technical Specifications

APPENDIX IX

SIMULATION RESULT OF 4 X 14W T5 FLUORESCENT LAMP LIGHTING SYSTEM

Operator
Telephone
Fax
e-Mail

4 x14W T5 840 / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	312	182	409	0.582
Floor	20	297	164	349	0.553
Ceiling	80	56	35	96	0.627
Walls (4)	50	112	41	259	/

Workplane:

Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.327, Ceiling / Working Plane: 0.178.

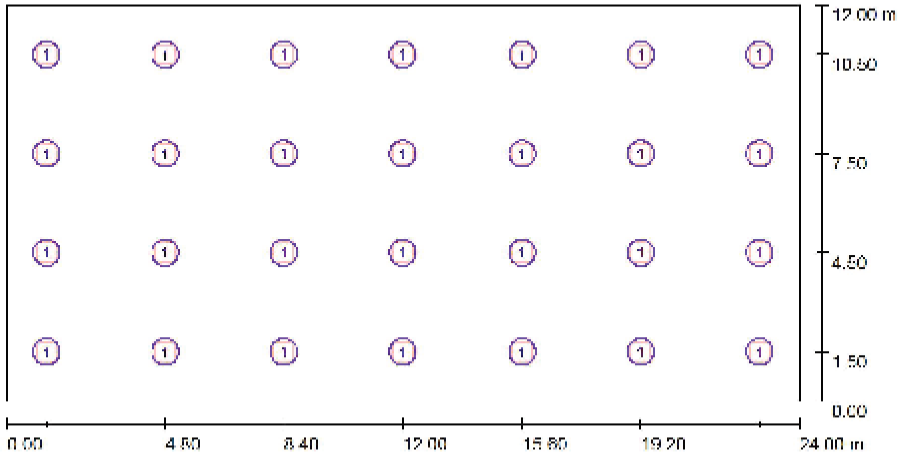
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	28	OSRAM GmbH DEDRA plus T5 DPB Kit 4x14W (Type 1)* (1.000)	3804	4800	56.0
*Modified Technical Specifications			Total: 106499	Total: 134400	1568.0

Specific connected load: 5.44 W/m² = 1.75 W/m²/100 lx (Ground area: 288.00 m²)

Operator
Telephone
Fax
e-Mail

4 x14W T5 840 / Luminaires (layout plan)



Scale 1 : 172

Luminaire Parts List

No.	Pieces	Designation
1	28	OSRAM GmbH DEDRA plus T5 DPB Kit 4x14W (Type 1)*

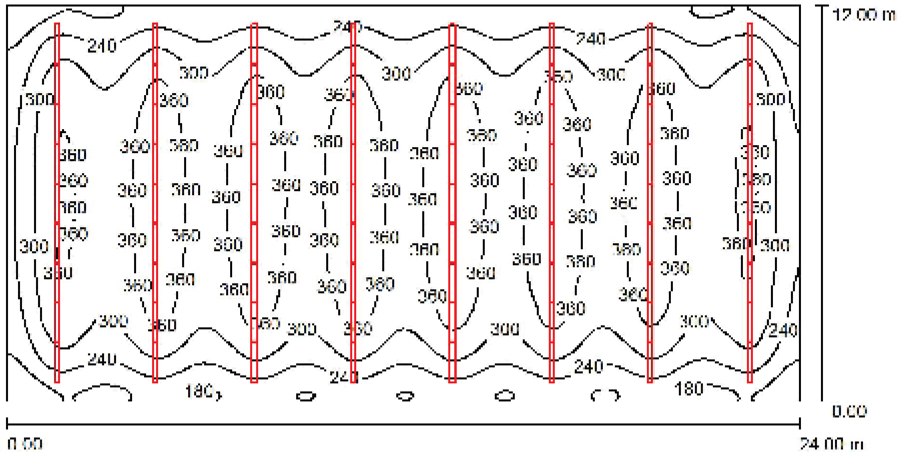
*Modified Technical Specifications

APPENDIX X

SIMULATION RESULT OF 2 X 20W LED LIGHTING SYSTEM

Operator
Telephone
Fax
e-Mail

LED Revised / **Summary**



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80

Values in Lux, Scale 1:172

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	311	118	411	0.378
Floor	20	295	130	375	0.440
Ceiling	80	54	38	70	0.696
Walls (4)	50	129	51	195	/

Workplane:
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.397, Ceiling / Working Plane: 0.174.

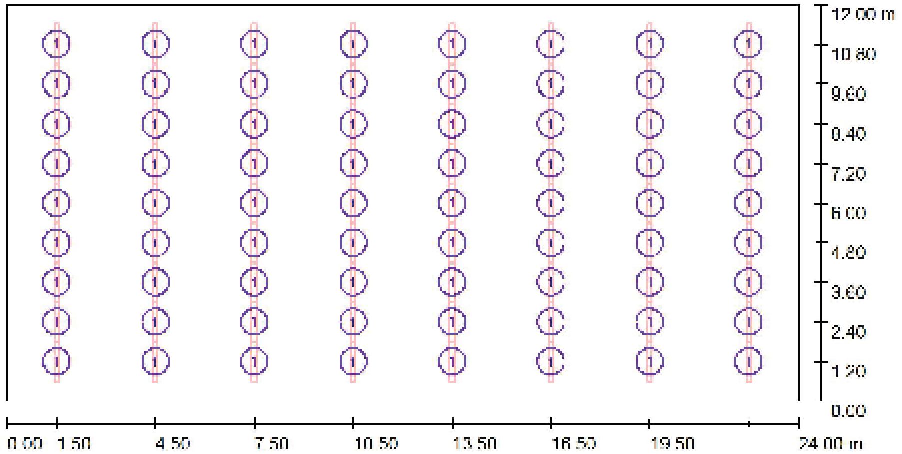
Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	72	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (Type 1)* (1.000)	1540	3000	40.0
*Modified Technical Specifications			Total: 110880	Total: 216000	2880.0

Specific connected load: 10.00 W/m² = 3.21 W/m²/100 lx (Ground area: 288.00 m²)

Operator
Telephone
Fax
e-Mail

LED Revised / Luminaires (layout plan)



Scale 1 : 172

Luminaire Parts List

No.	Pieces	Designation
1	72	OSRAM GmbH 4050300774329 LUMILUX DUO® EL-F/R 2 x 36W (Type 1)*

*Modified Technical Specifications