“I hereby declare that I have read through this report entitled “Applying Green Building Strategies to a New Commercial Building (Restaurant)” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (industrial Power)”

Signature : ………………………………………….

Name : ………………………………………….

Date : ………………………………………….

# APPLYING GREEN BUILDING STRATEGIES TO A NEW COMMERCIAL BUILDING (RESTAURANT)

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**This report is submitted in Partial Fulfillment of Requirements for the Degree of Bachelor of Electrical Engineering (Industrial Power)**



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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2016**

I hereby declare that this report entitled "Applying Green Building Strategies to a New Commercial Building (Restaurant)" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………….

Name : ………………………………………….

Date : ………………………………………….

***Dedicated to my beloved parents, siblings***

***Lecturers and friends***

***For their love and sacrifices***

**ACKNOWKEDGEMENTS**

Praise to Allah, the most gracious and the most merciful, the lord of the universe and may the blessings and peace be upon his messenger Muhammad S.A.W, for granting me strength and ideas in order to complete this final project report. I will not be able to complete this project within the time given without any of it.

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Thank you.

# ABSTRACT

In this modern era, an enormous amount of energy is being devoured in Malaysia every single day. One of many reasons of the massive amount of energy consumed is due to the vast developing cities with growing number of building constructions. Most of the construction of buildings in Malaysia does not obey the green building strategies which in a long term, will contribute to pollution and hence the global warming. The main purpose of this report is to expose an overview of an installation of electrical equipment based on the Green Building Index (GBI) for a restaurant construction. Other than that, one of the main points is to compare the conventional and GBI building construction in terms of cost and efficiency. The cost of construction covers two major parts, they are the capital and savings. On the other hand, the efficiency of a building covers on the carbon dioxide emission, building energy index (BEI), and energy efficiency index (EEI). This report includes the development and design of a new green building construction (restaurant) by focusing on the green building strategies in term of energy efficiency. The design is lodged mainly to better the development of green building in order to improve the lifestyle of modern living. This project analyses the lighting system and the total electrical load by using DIALux software. Other than that, the HVAC system, SSO design, and even protective devices and cable selection will be done in this project in order to apply maximum effort towards the GBI standards. In brief, this is a project that further explains the basic study of indoor lighting performance in a restaurant.

# ABSTRAK

Dalam era serba moden ini, sangat banyak tenaga digunakan di Malaysia pada setiap hari. Salah satu daripada sebab jumlah besar tenaga yang digunakan adalah kerana bandar-bandar sedang pesat membangun dan juga projek pembinaan bangunan yang semakin banyak. Kebanyakan pembinaan bangunan di Malaysia tidak mematuhi strategi bangunan hijau yang akan menyumbang kepada pencemaran dan pemanasan global dalam jangka masa panjang. Tujuan utama laporan ini adalah untuk mendedahkan gambaran keseluruhan pemasangan peralatan elektrik berdasarkan Indeks Bangunan Hijau (GBI) untuk pembinaan restoran. Selain daripada itu, salah satu perkara utama adalah untuk membandingkan pembinaan konvensional dan bangunan GBI dari segi kos dan kecekapan. Kos pembinaan meliputi dua bahagian utama iaitu modal dan simpanan. Selain itu, kecekapan bangunan meliputi pelepasan karbon dioksida, indeks tenaga bangunan (BEI), dan indeks kecekapan tenaga (EEI). Laporan ini juga mengandungi pembangunan dan reka bentuk pembinaan bangunan hijau (restoran) baru dengan memberi tumpuan kepada strategi bangunan hijau dari segi kecekapan tenaga. Reka bentuk yang dibuat bertujuan memperbaiki pembangunan bangunan hijau dalam usaha untuk meningkatkan gaya hidup kehidupan moden. projek ini menganalisis sistem pencahayaan dan jumlah beban elektrik dengan menggunakan perisian DIALux. Selain daripada itu, sistem HVAC, reka bentuk SSO, peranti perlindungan, dan pemilihan kabel akan dilakukan dalam projek ini untuk berusaha sepenuhnya ke arah piawaian GBI. Pendek kata, ini adalah satu projek yang akan menjelaskan kajian asas prestasi pencahayaan dalaman di sebuah restoran.

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| | | |
|---|---|---|
| GBI | - | Green Building Index |
| MS | - | Malaysian Standard |
| LED | - | Light Emitting Diode |
| HVAC | - | Heating, Ventilating, and Air-Conditioning |
| SSO | - | Switch Socket Outlet |
| VRV | - | Variable Refrigerated Volume |
| JKR | - | Jabatan Kerja Raya |
| EE | - | Energy Efficiency |
| LLF | - | Light Loss Factor |
| BF | - | Ballast Factor |
| RSDD | - | Room Surface Dirt Depreciation |
| LLD | - | Lamp Lumen Depreciation |
| LDD | - | Lamp Dirt Depreciation |
| PAM | - | Pertubuhan Arkitek Malaysia |
| ACEM | - | Association of Consulting Engineers Malaysia |
| IES | - | Illuminating Engineering Society |

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

The global warming which is the raise in Earth's average temperature which caused by the thinning of the ozone layers has been increasing from time to time is a worldwide problem based on reference [1]. In order to resolve this crucial complication, solutions are required to at least decrease the global warming. One of the solutions available is to apply green building strategies in the construction field. On 2014, construction sector consumed 50% of the global energy which is the largest compared to transportation sector and industrial sector which consumed 20% respectively and 10% for the other sectors [2].

The construction industry is said to be one of the major industries that influence the economic growth of any country, based on reference [3]. The nature of construction movement makes a gigantic change to the natural landscape. Focusing on decreasing the environmental impacts, the Japanese has been extending the infrastructure service life by improving the sturdiness of the design and taking into account the life-cycle cost. There are researches that are still being handled in the construction industry although the significance of sustainable building was already widely acknowledged [4].

In order to achieve the Green Building Index (GBI) in Malaysia, there are several criteria to be considered including the Indoor Environment Quality, Material and Resources Energy Efficiency, Water Efficiency, Sustainable Site Planning and Management and Innovation. Pertubuhan Arkitek Malaysia (PAM) or also known as the Malaysian Institute of Architects and the Association of Consulting Engineers Malaysia (ACEM) are responsible in developing the Green Building Index (GBI).

Cited from reference [5], green building or also known as a sustainable building is defined as a structure that uses environmentally responsible and efficient resources throughout the whole building life-cycle. The life-cycle of a building includes the siting, design, construction, operation, maintenance, renovation and demolition. Green buildings are developed to maintain the balance between human and nature and also in order to improve the lifestyle of the human beings without harming the natural environment, or at least reducing the risk.

The Malaysian Standard [6], MS 1525:2007 which is The Code of Practice on Energy Efficiency and The Use of Renewable Energy for Residential Building has been introduced to promote the sustainable energy practices.

This project focuses on the green building movement in order to reduce pollution and minimize the world energy consumption. A single story restaurant will be designed by applying the green building strategies.

## 1.2 Problem Statement

At the moment, global warming has been an enormous threat to the human being due to the deforestation, pollution and vast urbanization. As time passes by, people tend to be more creative and intelligent in order to enhance the quality of living. However as the world modernize, people slowly starting to forget and ignore about the environment and the health of nature. Energy demands are peaking because of the rapid construction of buildings either for commercial or residential use. Rate of pollution increase as the rate of energy generation and production increase. Pollution causes the depletion in air quality and results in the increment of carbon dioxide emission. The green building movement is later founded focusing on saving energy in order to at least reduce the pollution by minimizing the usage of non-renewable resources and save construction cost. As a result, to overcome this crucial problem, a restaurant will be built based on the green building index by focusing on energy saving and energy efficiency. This project has an objective that should be achieved to complete the problem statement above.

## 1.3 Objectives

The major purpose is to design a new construction for a commercial building (restaurant) by focusing on the green building strategies. Yet, there are some other objectives that have to be covered in order to achieve this new construction for commercial building (restaurant) which are:

a) To develop the lighting system by using the DIALux software.
b) To analyze the electrical load before and after applying the GBI standards.
c) To design the layout of the plan such as lighting system, air-conditioning, switch-socket outlet (SSO), protection system and cable selection in the commercial building (restaurant) based on Malaysian's Green Building Index (GBI) using AutoCAD software.

The objective can be achieved by focusing on the scope of work that is needed in this project.

## 1.4 Scope of Work

This project focuses on the analysis and development according to the assessment of the Green Building Index (GBI) which includes Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning and Management, Water Efficiency, Innovation, Materials and Resources. Apart from that, AutoCAD software will be used to draw the plan for the restaurant while DIALux software will be used to show the brightness of lighting. The commercial building is composed of a single level which includes dining room, corridor, kitchen, chiller and freezer room, outdoor dining, customer switch room, EP room, male toilet, female toilet, male prayer room, female prayer room, hose reel pump room, and overall outdoor area.

All spaces included inside of the plan is designed completely using AutoCAD. After the design plan for this commercial building is completed, the electrical installation will be scheduled. This study focuses on the electrical installation which includes the installation of the lighting system, air-conditioning system, switch socket system (SSO), protection system, and cable selection to examine the energy saving performance.

Electrical installation in context of the sentences above means that every level, every area, and every room shall undergo the electrical installation in order to complete this building before it can be used commercially.

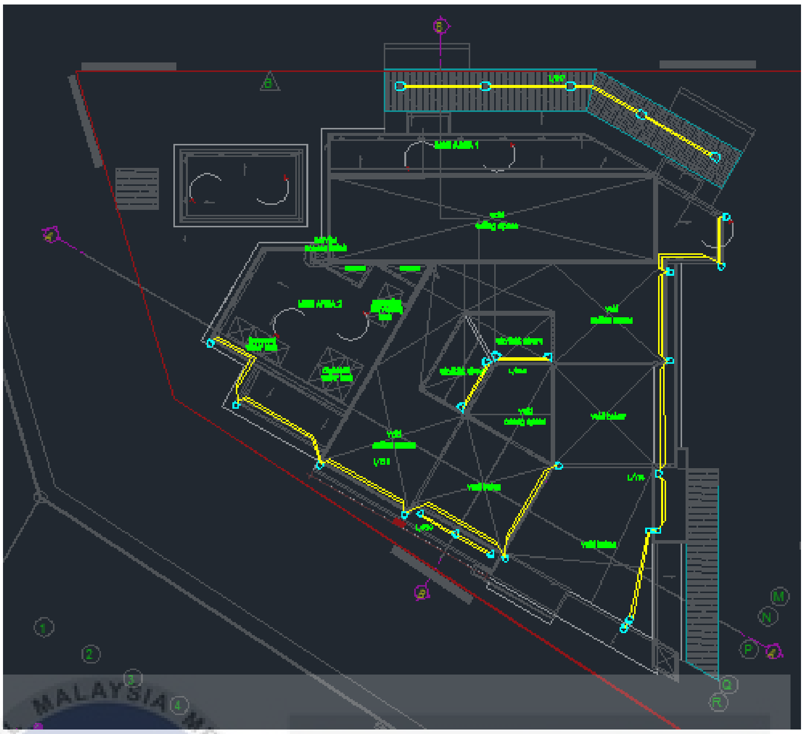


Figure 1.1: Restaurant Floor Layout

Figure 1.1 shows the layout of the first floor of the restaurant. It consists of dining room, corridor, kitchen, chiller and freezer room, outdoor dining, customer switch room, EP room, male toilet, female toilet, male prayer room, female prayer room, hose reel pump room, and overall outdoor area.

In order to build this restaurant, the rules of electrical installation must be followed as set by the IEEE regulation, JKR electrical standard and Electricity Supply Application Handbook of Tenaga Nasional Berhad (ESAH TNB). The electrical installation of a new construction building must follow the rule based on the regulation terms and conditions even though Green Building Index (GBI) is applied in the implementation of the new construction commercial building (restaurant). As for the constructability, the design of the restaurant was developed to be constructible. The design of this restaurant was developed by using AutoCAD, energy and cost data. The data is not limited to one particular state or town in order to provide a wide range of location for the restaurant to be built. The use of common and accessible construction materials, and a repetitive design makes the restaurant simple and easy to construct.

# CHAPTER 2

# LITERATURE REVIEW

In this chapter, the theory and basic principles in developing this system will be further discussed. Apart from that, there will be a case study where the review of previous works that is related and identical with this project and finally a summary and discussion of the review.

## 2.1 Theory and Basic Principles

### 2.1.1 Green Building Index (Commercial)

According to [7], a green building is an environmentally responsible structure and process that covers the building life cycle which includes the sitting, designing, constructing, maintaining, operating, modifying, and even deconstructing. Additionally, to discover the balance between the construction of the building and sustaining the environment is another requirement in designing a green building. In order to achieve that, a close collaboration is required among the design team, architects, engineers, and the clients in every stages of the project. In other name, green building is also well-known as a high performance and sustainable building.

Based on [8], the Green Building practices includes and applies the classic building design that takes into account on the economy, utility, durability and comfort. Table 2.1 differentiates the performance of green buildings and non-green buildings.

Table 2.1: Performance comparison between Green Buildings and Non-Green Buildings [8]

| **Building Type** | **Green Building** | **Non-Green Building** |
|---|---|---|
| Building Material | Environmental Friendly | Not Environmental Friendly |
| Indoor Environmental Quality | Excellent | Good |
| Project Practices | Sophisticated | Normal |
| Waste Management | Extremely Efficient | Efficient |
| Total Energy Consumption | Low | High |
| Emission | Low | High |
| Feasibility | >5% Than Threshold | Threshold |

According to [9], the type of building plays a crucial part in ensuring that the building achieve the green building standards. Table 2.2 and Table 2.3 display the assessment criteria and green building index (GBI) classification for a new green building construction.

Table 2.2: Overall Points for Assessment Criteria [9]

| Part | Item | Maximum Point |
|---|---|---|
| 1. | Energy Efficiency | 23 |
| 2. | Indoor Environment Quality | 11 |
| 3. | Sustainable Site Planning And Management | 39 |
| 4. | Material And Resources | 9 |
| 5. | Water Efficiency | 12 |
| 6. | Innovation | 6 |
| | **Total Score** | **100** |

From Table 2.2, it is clear that as the number of points increases, it means that the building is more environment-friendly and more likely to achieve the status of a green building. When a building achieve and apply environment- friendly features, it will be awarded with points under the GBI assessment framework. There are four level of awards that might be given to a building depending on the total GBI score achieved. Table 2.3 shows the required points in order to achieve the awards.

Table 2.3: Green Building Index Points Classification [9]

| Points | GBI Rating |
| --- | --- |
| 86 to 100 points | Platinum |
| 76 to 85 points | Gold |
| 66 to 75 points | Silver |
| 50 to 65 | Certified |

As referred to [10], there are some buildings in Malaysia that has been awarded as green buildings such as Suruhanjaya Tenaga Diamond Building and GEO Green Energy Office. The public awareness among Malaysians on the importance of high efficiency buildings started to rise in 2006. The energy efficient building trend started growing among premises in this starting from small and private scale properties to huge residential or commercial construction project. The green building rating should really be set as a benchmark in the construction sector in order for it to excel forward brilliantly.

According to [11], natural light or more widely-known as sunlight is an important factor in lighting up the interior and provide free light energy in buildings. There are certain factors that will vary the results of lighting and illumination level of a room. The factors are the depth of the room, the size and location of windows, the glazing system and any other external obstructions. Based on [30], in order to achieve the state of a high efficiency green building, a close integration of building of building systems with a detailed focus on energy, day-lighting, and material analysis during the design process.

In order to attain the GBI ratings, DIALux software has to be used so that the simulation of lighting design can be done. There are seven zones of lighting divided in the lighting strategies. A control circuit is placed in each zone so that the consumption of energy can be minimized.

### 2.1.2 DIALux


Figure 2.1: DIALux Logo

As a free software, DIALux is widely used by designers, architects and even engineers in order to plan the interior and outdoor lighting of a building to achieve different desires and designs that satisfy the client's expectations. The highlight of this software is the ability to visualize, estimate and calculate the amount of natural light (sunlight). Other than that, DIALux software is able to plan lighting vision, design the color and intensity of lights which are going to be applied. Not forgetting, it may also arrange the position of emergency lighting with the acceptable level of luminaires and many more potentials.



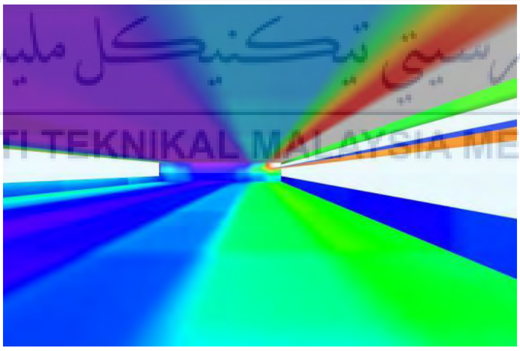


Figure 2.2: False Color Rendering of Building Interior by DIALux [12]

Figure 2.2 is an example of false color rendering. Based on [12], the image viewed from a 3D perspective of a building interior where different colors are assigned in order to differ the illuminance value measured in lux.

Based on [13], DIALux enables users to prepare a realistic visualization of the lighting plan. As an addition, the software uses different textures and even furniture. Not forgetting to mention that it applies an integrated ray-tracing module. While DIALux is able to save the file in .PDF format, it can also export the drawings made into .DWG and .DXF files. Other than that, it can even import files in those formats to apply the lighting plan with DIALux. DIALux regulates the intensity of light energy based on the support complying with the respective national and international regulations. Table 2.4 will show the visual evaluation of lighting system in work areas.

Table 2.4: Visual evaluation of lighting systems in workplace [13]

| **Concept** | **Description** | **Evaluation** |
|---|---|---|
| Light level | Whether it is dark or light in the room or at the workplace? | Dark - Light |
| Light Distribution | How is the light distributed in the room or at the workplace? | Varied - Equally |
| Light Color | Is the light color experienced as warm or cold? | Warm - Cold |
| Color | How are the colors and objects viewed? | Distorted - Natural |
| Glare | Does unpleasant glare occurs? | Troublesome - Not Noticeable |
| Shadow | Whether they are hard or soft? | Hard- Soft |
| Reflection | Whether they are instance or diffuse? | Intense - Diffuse |

The DIALux design and consulting philosophy states that it is their aim to improve man’s living and working environment, thus contributing to better architecture. To this end, DIALux focuses on the instrument of lighting and building automation. In order to create a lighting plan, AutoCAD software planning is very useful to facilitate the work.

### 2.1.3 AutoCAD


Figure 2.3: AutoCAD logo

According to [14], since 1982, AutoCAD is well-known as a private enterprise software application for 2D and 3D computer-aided design and drafting. In 2010, AutoCAD upgraded itself to a mobile web and even a cloud-based app which is marketed as AutoCAD 360. Around the globe, AutoCAD is being used in a wide-range of purposes. On 1994 only, there were already 750 training centers worldwide.

AutoCAD is the most famous and the most frequently used CAD application worldwide [15]. Developed by Mark Riddle, AutoCAD has survived for more than 29 years now. In 1979, it started as Interact for the Marinchip 9900 as one of the pioneers of computer aided design program available at that moment. Hence, Interact became the architectural basic for the very first version of AutoCAD.

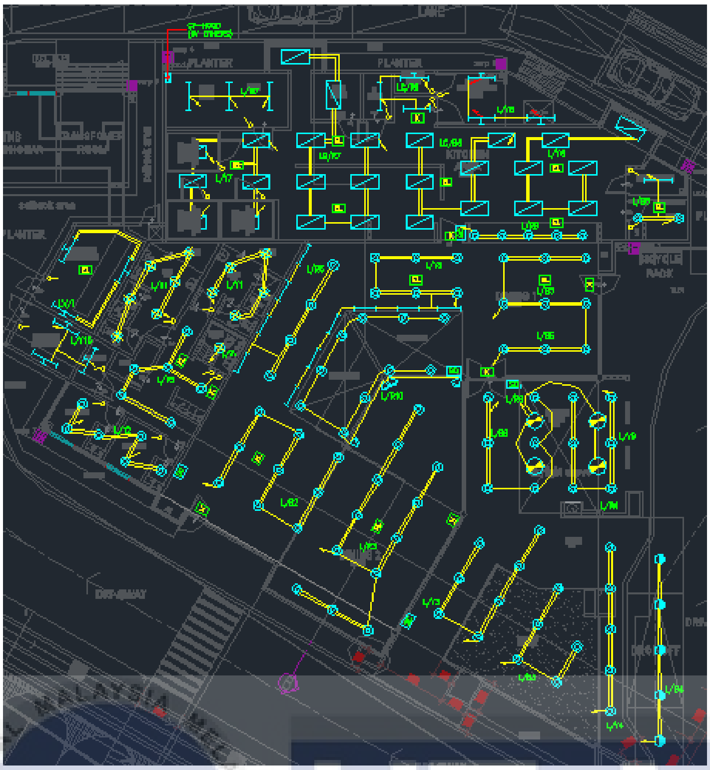


Figure 2.4: Design Layout with Electrical Installation

A basic design layout with complete electrical installation by applying the AutoCAD software is showed in Figure 2.4. This drawing file will later be exported into DIALux software where the lighting design can be completed. Each and every room and space will get the suitable lighting design in order to reduce electrical consumption and hence be more energy efficient. As the green building idea is getting more popular as days come by, the community will lean more towards energy efficiency and to design more environment-friendly buildings. The knowledge on green building strategies has to be adopted and spread so that the world could turn into a better place to live.

### 2.1.4 Lighting System

Lighting design is known to be the simplest design in order to achieve the GBI of a structure [16]. In order to achieve the design specifications, the energy efficiency and usage cost of an equipment has to be thoroughly considered. Lighting system is said to be an art in designing it. A good lighting design meets the satisfaction level of a person who will be using the specified space either to live or to work in it. Lighting design should not be taken easily if the GBI ratings need to be achieved. Managing lighting is the easiest way to save energy and hence, lead to energy efficiency.

Natural light (sunlight) intensity depends on the condition of weather and is not promised throughout the day. For instance, if the day is cloudy or raining, there will not be sufficient light to illuminate the rooms inside of a building. This calls for the existence of artificial light. Insufficient light and poor lighting system will affect the eyesight of human beings. Hence, adequate lighting is important in human's daily life.

A proper lighting system is essential in all of the industries. 2% to 10% of total power consumption in the industries are caused by lighting only. The rise of bigger energy saving in lighting system is mainly caused by the innovations and continuous improvements. By applying modern energy efficient light bulbs, luminaires and gears, and good practices will be a big contributor into achieving energy efficiency.

To design and simulate a lighting system is not an easy task as the natural light will have to be taken into account before applying artificial light in an area. This is because, the lux value for each area is not the same and depends on the surroundings. It is a very crucial element that is very important in architectural design, especially in the major of energy efficiency. The development of lighting design software has expended and improved in accuracy after 20 years. Those kind of software are very popular among interior designers, energy managers, architects, and even engineers.

Table 2.5: Details of Lumen Methods [16]

| Symbol | Terms | Units |
|---|---|---|
| N | Number of Luminaries Required | |
| A | Floor Area to Illuminate | $m^2$ |
| E | Required Lux | lux |
| F | Initial Lamp Lumen | lm |
| N | Lamp per Luminary | |
| MF | Maintenance Factory | |
| UF | Utilization Factory | |
| L | Room’s Length | m |
| W | Room’s Width | m |
| H | Room’s Height | m |



Lighting is considered as the major component there is in an electrical system design installation. There are many reasons for having good and proper lighting in an area. For instance the room would look brighter and more beautiful with a well plan lighting system. There are two types of lamp being used in this project and they are Light Emitting Diode (LED) lamp and fluorescent lamp. Both types of lamps are used in every single area of the restaurant. Generally, the average luminance level used, ranges from 100 to 500 lux. There are five basic types of lamps and they are fluorescent lamp, incandescent lamp, low pressure sodium lamp, LED lamp, and high intensity discharge (HID) lamp.

Table 2.6: Luminous Performance Characteristics of Commonly Used Luminaries [16]

| **Type of Lamp** | **Luminous Flux (Lumen)** | **Power (Watt)** | **Color Rendering Index** | **Typical Application** | **Typical Lifespan (Hours)** |
|---|---|---|---|---|---|
| | **Range** | **Average** | | | |
| Incandescent | 8 - 18 | 14 | Excellent | Houses, Restaurants, General Lighting, Emergency Lighting | 1000 |
| Fluorescent | 46-60 | 50 | Good | Offices, Shops, Hospital, Houses | 5000 |
| Compact Fluorescent (CFL) | 40 - 70 | 60 | Very Good | Restaurants, Shops, Houses, Offices | 8000 - 10000 |
| High Pressure Mercury (HPMV) | 44 - 57 | 50 | Fair | General Lighting in Factories, Garages, Car Parks, Flood Lighting | 5000 |
| Halogen | 18 - 24 | 20 | Excellent | Display, Flood Lighting, Stadium Exhibition Grounds, Construction Areas | 2000 - 4000 |
| High Pressure Sodium (HPSV) SON | 67-121 | 90 | Fair | General Lighting in Factories, Warehouses, Street Lighting | 6000 - 12000 |
| Low Pressure Sodium (LPSV) SOX | 101 - 175 | 150 | Poor | Roadways, Tunnels, Canals, Street Lighting | 6000 - 12000 |

## 2.2 Review of previous related works

### 2.2.1 An Overview of Green Building Control Strategies

This paper defines that a green building consumes less energy, water, and natural resources. Other than that this paper also suggests that a green building produces smaller amount of waste and is healthier for the people living inside it if to be compared to a standard building. Buildings consume more than 20% of annual total electricity in India. This paper discusses mainly on the control strategies to achieve the minimum thermal in order to conserve energy. The problem that is discussed in this paper is that the construction of a building takes a huge amount of time because there are frequent alterations and modifications. The construction of a building will also consume a lot of energy and money. These problems can be avoided by a proper planning and adopting suitable control strategies to conserve energy, save the environment and avoid pollution. This paper proposes two types of building control which are passive and active. Passive building control means that a building with appropriate orientation, shading devices and thermal mass. In the other hand, Active control means that a building is complete with earth pipe heat exchanger or even heat pump. As a conclusion, construction technology is responsible for at least 40% of world's energy. Infrastructure development in line with the green building concept is required in this present days [17]. This paper could have been done better if it takes into account the management of electrical services in a building.



### 2.2.2 Control, Estimation and Optimization of Energy Efficient Buildings

Based on this paper [18], there will be an enormous impact on energy cost and greenhouse gas emission after the optimization and control of energy efficient building is applied. In order to do that, the whole building is considered as a one whole integrated system. The integrated system is later installed with modern estimation and control techniques which will later result on a greater efficiency that is obtained by optimizing individual building components such as lighting and HVAC (heating, ventilation, air-conditioning). The problem stated is on designing and controlling high performance buildings. This paper suggested several potentials solutions that are simulation based design, holistic fully integrated design and hybrid design methods. In this paper, it shows that the distributed parameter control, combined with high performance computing will be able to provide practical insight into important issues such as actuator or sensor placement and state estimation for control. The method used in this paper is by designing, calculating, and allocating proper location for vents, sensors and electrical services. All in all, one can compute and use endless dimensional theory in order to convert insights into control problems that arise in the design and operation of high performance buildings. If this paper discusses more about lighting, the potential of energy savings and energy efficiency could be maximized.

### 2.2.3 Energy Performance: A Comparison of Four Different Multi-Residential Building Designs and Forms in the Equatorial Region

According to [19], the building sector has been identified as a major energy consumer with nearly half of the world's energy used is associated with providing environmental conditioning in buildings. The most important steps that may contribute to energy conservation are energy consumption evaluation and energy audits for buildings. This paper researches on four low-rise residential college buildings with each one with different specific layouts in discovering the connection between the green building strategies and the energy performance. The elements of bio-climatic design were implemented as matrices or criteria, particularly on ventilation and day-lighting. This research was done based on the Building Energy Performance (BEP) and Efficiency Index (EI) in a 5 years duration. As recorded in 2009, the commercial and residential construction sector account for about 13% of the total energy consumption in addition to 48% of electricity consumption in Malaysia. 60% to 70% of the total energy in non-industrial buildings are consumed by air-conditioning, lighting and mechanical ventilation. Green building strategies can somehow significantly eliminate or at least reduce negative environmental effects and enhances existing non-sustainable design, construction and practices. By using the methods of glazing, shading, insulating and natural ventilating can improve the rating of energy reduction to 43%. This paper states that there are two types of energy audit which are the walk-through audit and the detailed audit. There are three levels of analysis which are the walk-through analysis, the energy survey analysis and detailed analysis. This research focuses mainly on day-lighting and ventilation. The outcome of this research was the lamps in the residential building corridors need to be continuously switched on because of the passive design. However, the buildings are not oriented to the sun path which eliminates the thermal gain. It is concluded that the adoption of green building strategies, which is a combination of enclosed and facade design helps in reducing annual electricity consumption. This research could be improved by trying to apply delamping and relamping strategies.

### 2.2.4 Battery Management and Application for Energy-Efficient Buildings

Based on [20], hybrid energy supply is becoming more popular as the days come by, where multiple energy sources are scheduled together in order to improve energy efficiency. The examples of energy sources are grid electricity, on-site fuel cell generators, solar, wind and battery storage. In this paper, the researches focus on the application and management of battery storage for energy efficient buildings. The battery storage is co-scheduled with the control of HVAC (heating, ventilation, and air-conditioning) system in order to reduce the electricity consumption cost, as well as the peak demand charge and the battery cost. An Advanced RISC Machine (ARM) processor based programmable embedded battery management system (BMS), which monitors battery status, controls charging and discharging at the circuit level, and provides battery protection. The problem found by this paper is that the commercial and residential building stock consumes 40% of the U.S. Primary energy consumption, 40% of the gas emission, and 70% of the electricity use. Other than that, HVAC system accounts for 50% of the building energy consumption, and the control of it is crucial for building energy efficiency. To overcome the problem, a novel system-level alogrithm for the building management system to co-schedule the HVAC control with the usage of battery storage system and grid electricity to reduce the building energy cost, including both the electricity consumption charge and the peak demand charge. Over the past 18 months, researches installed additional measuring and control instruments for the HVAC system. To implement the model predictive control (MPC) based control alogrithm that controls and coordinates the roof units, a programmable controller is deployed, which can continuously monitor the real time energy demand, and send control commands. The conclusion is that by co-scheduling HVAC control with the battery usage results in the reduction of energy cost. The most suitable solution is by using battery storage for electron volt (EV) charging and other fixed building energy loads. In order to get a better result and widen the field of research, this project should also consider using the co-scheduling of the lighting system.

### 2.2.5 Intelligent Eco-Building Management System

This paper discusses mainly on the benefits of implementing sensors integration, wireless sensor network and empowerment Internet of Things (IoT) to overcome challenges [21]. This is in order to enable smarter energy management in building. The major concern at all segments of modern society activities is energy efficiency. Around 40% of all energy consumption is consumed in the residential and working space. In Clean Tech One Park Singapore, which is developed by JTC (Jurong Town Corporation), there is a new type of industrial building that emphasize on retaining natural environment and biodiversity in area. The building is integrated with some renewable energy technology such as Solar PV and Wind Turbine at the rooftop. Energy saving techniques can be applied in architecture engineering and civil engineering disciplines with passive solar heating, passive cooling, natural ventilation, natural day lighting, LED light bulbs, and certified appliances for energy. For a typical commercial building, 50% of energy consumed in air-conditioning mechanical ventilation (ACMV), combined with hot water needs, energy consumption in the heating and cooling energy zones may reach up to 60%. Lighting and office equipment take most of the rest of the energy consumption about 20% in a commercial building. The research was held in two places which are the rooftop of a building located at School of Electrical and Electronic Engineering in Nanyang Technological University and the other is a commercial office building at JTC Clean Tech One Park. The problem of this paper is that the integration work of Building Automation System with IoT is not fully realized. There are technical problems faced by Wireless Sensor nodes to work with various type of proprietary field bus protocols and equipment for purpose of exchanging real-time data. As a conclusion, the main goal of intelligent eco-building energy management system is to discover the balance between energy efficiency and user comfort level. A lot of network control system strategies can also be implemented in order to improve network performance of the system. Actually, the approaches stated in this paper can be adopted in a more complex system, such as using the hybrid generation to power up the HVAC system of a building.

## 2.3 Summary and Discussion of the Review

It is beneficial in terms of bringing together the community by integrating a green work culture. This will indirectly promote sustainable behaviors that will improve life quality. The green culture does not only bring a lot of advantages to the environment, but also to the community who gains more insight and in-depth knowledge of the change in climate and the following sustainable actions. The green work culture starts with a simple engagement tool that helps in fostering groundwork for people to be environmentally aware of their own actions and how they can change their life routines in sustainable living. The case studies proves that the increasing participatory action within the community and the workplace can stimulate a green mindset within the community. Institutions and organizations are working collaboratively together to develop green behavior programs to attract more people into the green community.

Sustainable designs can be integrated with communities to build upon the cultural assets and work with those communities to implement sustainable actions while preserving the community cultural values. Green building design is a brand new emerging movement that is working mutually with communities to not only benefit the building itself, but also the community that uses it.

Table 2.7: Comparison between Previous Related Works

| Paper | Contribution | Gaps for Improvement |
|---|---|---|
| **An Overview of Green Building Control Strategies** | 1. Proper planning and adopting suitable control strategies to conserve energy, save the environment and avoid pollution.<br><br>2. Proposes two types of building control, passive and active. | 1. Management of electrical services in buildings. |
| **Control, Estimation and Optimization of Energy Efficient Buildings** | 1. Greater efficiency that is obtained by optimizing individual building components such as lighting and HVAC.<br><br>2. Potential solutions that are simulated base design, holistic fully integrated design and hybrid design methods.<br><br>3. Designed, calculated, and allocated proper location for vents, sensors and electrical services. | 1. Lighting system can be improved so that the potential of energy savings and energy efficiency could be maximized. |
| **Energy Performance: A Comparison of Four Different Multi-Residential Building Designs and Forms in the Equatorial Region** | 1. Applied glazing, shading, insulating, and natural ventilating that improve the rating of energy reduction by 34%.<br><br>2. Focused on improving day-lighting and ventilation. | 1. Apply relamping and delamping strategies to improve the lighting efficiency. |
| **Battery Management and Application for Energy-Efficient Buildings** | 1. Battery storage is co-scheduled with the HVAC control.<br><br>2. Strategies to reduce the electricity consumption cost, peak demand charge, and battery cost. | 1. Consider to co-schedule with the lighting system. |
| **Intelligent Eco-Building Management System** | 1. Implementing sensor integration, wireless sensor network and empower Internet of Things (IoT) for smarter energy management in a building.<br><br>2. Designed a building with integrated renewable energy technology such as Solar PV and Wind Turbine on the rooftop. | 1. Apply the integrated renewable energy technology to power up HVAC or lighting system of a building. |

# CHAPTER 3

# RESEARCH METHODOLOGY

It is important that the suitable methodology is being used in this project in order that it can be successfully completed. In pursuance of achieving the objectives of this project, several phases of methods are utilized.

## 3.1 Introduction

There are three categories of electrical system installation and design. They are the design for low voltage system, the design for medium voltage system and the design for high voltage system. This project is classified as a low voltage system, 415V. The design of an electrical system in a building is dependent on the layout plan made by the architect. This is because the design of a room determines the design of the electrical system. For instance, an architect designed a room with a certain width and height. So, the electrical engineer has to plan a proper system that would satisfy the minimum requirements such as the lighting of the room. The number, type, and arrangement of lamps are very crucial in fulfilling the customer demand.

First and foremost, a distribution board (DB) is a vital element in an electrical system. It manages each and every types of load in a building such as switch socket outlet (SSO), lighting, and air-conditioning. The next important element is the sub-switchboard (SSB). The main purpose of a SSB is to gather all of the DB in a place. The size of cables, protective devices and voltage drops must be taken into account. Last but not least, the main switch board (MSB) is the third element of low voltage system. The MSB collects and connects all of the SSB available on a board and become the main switch that controls the entire load. Current transformers and capacitor banks often considered to be used in this stage to reduce the consumption of electricity and hence minimizing the electric bill.

## 3.2 Methods Used

The goal of this project is mainly to encourage the usage of environmental friendly and energy efficient products for the electrical installation in commercial buildings. There are seven methods used to complete this project. The flow chart of the methods used are as shown below:

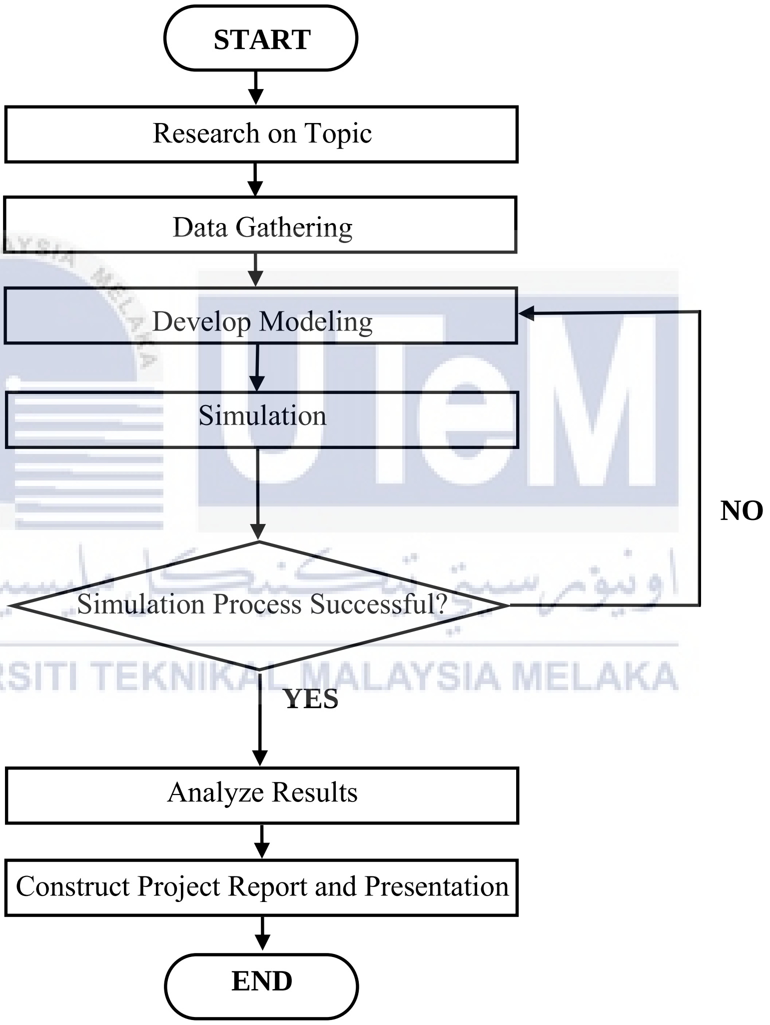



Figure 3.1: Flowchart of Overall Methodology

### 3.2.1 Research on Topic

In order to further understanding on this project, researches were conducted on the subject that has been done by previous researchers. Many readings were conducted so that information about the topic could be gathered. Journals, papers and previous projects were reviewed as guidelines and references. The main focus of this project is on designing the electrical services of a building which includes the lighting, switch socket outlets, air-conditioning, and protection devices. Researches were also done in a manner of interviewing lecturers, construction officers, electrical engineers, and even friends who are experts in the construction sector.

### 3.2.2 Data Gathering

Data gathering is a systematic approach to collecting information from a variety of sources to get complete and accurate picture of an area of interest. Obtaining relevant history for the variables to be forecast which includes the historical information on potential predictor variables is essential in this project. During this phase, it is also beneficial on beginning to plan on how the data collection and storage will be handled in the future so that the reliability and integrity of the data could be preserved.

### 3.2.3 Develop Modeling



There are some major steps in order to achieve the design strategies. DIALux software is being used in this project for software, calculation, and design.

#### 3.2.3.1 Lighting Design

In designing the lighting system, the required information are the area of the room which means that the width and length of the room must be considered. Not forgetting to be taken into account are the height of floor cavity, height of ceiling cavity, height of the room cavity, and surface reflectance. There are two methods in designing the lighting system, manual calculation and software calculation.

a) Illumination

To determine the quantity of lamps needed in a room, the illumination level must be highly considered. The base values can be referred to the Illuminating Engineering Society (IES) standard or Jabatan Kerja Raya (JKR) standard. However, this project will only be referring to the JKR standard since it is the Malaysian’s standard. Different tasks under different conditions require different levels of illumination. Areas such as office and laboratory need a high illumination level because important tasks are to be done there. However in an area or room that does not need high level of illumination, the potentials of energy saving is great.

b) Determining the Quantity of Lamps Needed

In order to calculate the number of lamps needed in a room, the illumination level or better known as average illuminance, lighting design lumen (LDL), coefficient of utilization (COU), maintenance factor (MF) and the area for the room. The quantity of the lamps is calculated based on equation 3.0:

$$\text{Number of Lamps} = \frac{\text{Average Illuminance (lux)} \times \text{Area (m2)}}{\text{LDL (lumen)} \times \text{COU} \times \text{MF}} \qquad (3.0)$$

c) Determining the Room Index

Coefficient of utilization (COU) is the ratio of the actual flux received on the working plain to the installed flux. To get this value, the room index, K must first be calculated. Then, the type of lamp to be installed is chosen. Later by using the room index value and reflection factor, the COU can be determined. The equation for room index is:

$$\text{Room Index} = \frac{\text{L (m)} \times \text{W (m)}}{\text{Hm (m)} \times [\text{L (m)} \times \text{W (m)}]} \qquad (3.1)$$

Where: L = Length

W = Width

Hm = Height mounting

The maintenance factor (MF) is made up of the lifespan of a lamp, dust deposited and reduction election factor of the interior room. The lighting design lumen (LDL) is the value of lumen for any type of lamp. The value of lumen is usually prepared by the supplier of the lamps on the packaging or brochure. Other than that, JKR standards can always be referred to.

A term called Light Lost Factor (LLF) occurs when a light fixture is activated, it produces light which must leave the lamp, then the fixture, then reach the work plane where it is needed. In this project, the Ballast Factor (BF) is set to 95% while the Room Surface Dirt Depreciation (RSDD) is set to 97%. Not forgetting that the Lamp Lumen Depreciation (LLD) is set to 85% and the Luminaire Dirt Depreciation (LDD) is set to 90%. In order to achieve the energy saving criteria, the parameters stated shall be evaluated on the lighting performance.

$$\text{Room Cavity Ratio (RCR)} = \frac{[(5 \times \text{Room Cavity} \times \text{Height}) \times (\text{Length} + \text{Width})]}{(\text{Length} \times \text{Width})} \tag{3.2}$$

$$\text{LLF} = \text{BF} \times \text{RSDD} \times \text{LLD} \times \text{LDD} \tag{3.3}$$

$$\text{No. Of Luminaires} = \frac{(\text{Designed Luminance}) \times (\text{Room Area})}{(\text{Lumen per Luminaires}) \times \text{CU} \times \text{LLF}} \tag{3.4}$$

**3.2.3.2 Exit Sign and Emergency Light**

The exit sign and emergency light is a compulsory in order to meet the client's demand and the safety standard. So, they have to be installed in this project. The main reason for their existence is no other than safety purposes. If there is no power supply in a building, the exit sign and emergency light will be the guide for escaping the building. This proves that they are some of the very important components in a building design.

#### 3.2.3.3 Heating, Ventilating, and Air Conditioning (HVAC)

According to [22], the health of occupants in a building can be improved by increasing the indoor air quality. For instance, by installing an energy recovery ventilation system, may reduce the rate of contamination that comes from the outside atmosphere while reducing the HVAC energy loads.

The construction sector consumes one-third of the world's energy and this trend is expected to continuously increase until the year 2025. Office building are known to be the major consumer of energy compared to residents and restaurants, where most of it is caused by the air-conditioning system. In order to save money and energy usage, the owner of the building should take several energy saving actions. This is also to avoid any kind of energy wastage. Generally, the air-conditioning system of a building can be categorized in to several categories [23]:

a) Split/Window Units

b) Package Units

c) Centralized Air-Conditioning System

The split unit has two different units which is the indoor unit and the outdoor unit. The indoor unit is the unit that is placed inside of a room or an area that needs to be cooled, while the outdoor unit is the unit that is placed outside of the building. The indoor unit is made up of an evaporator and a blower. The outdoor unit is made up of a condenser, compressor, and a blower. In the other hand, the package unit are applied only for a higher capacity air conditioning loads that ranges from 3 to 15 tons. The package unit is made up of cooling, filtrating, air-handling, and drying components either with water-cooled or air-cooled condensers. The system can be based on either one of two systems, which are the indirect chilled water system or the direct expansion system. In choosing the size of horsepower of an air conditioning unit that needs to be used in a room, the following equation might satisfy the requirements:

$$[(\text{Area Length} \times \text{Weight}) \times 25] + [\text{Windows} \times 1000] + [\text{Human Bodies} \times 400] \qquad (3.5)$$

### 3.2.3.4 Switch Socket Outlet Design

First and foremost, in designing the switch socket outlet, the location for the power point is the main aspect that needs to be taken care of. Other than that, it is also important to know how many rooms or area needed for the services. Depending on the type and activity to be done in the room, the number of switch socket outlets may vary. As an example, an office room will require a larger amount of power points compared to the toilet because there are lots of activities or work to be done in the office.

The location for power points are determined by referring to the furniture layout in the project drawing. Different types of power points are used at different locations such as under floor trunking, at or on the ceiling, and on the walls at different heights. For instance, the under floor trunking system that uses a service box or a junction box is usually used in a largo office, or even a laboratory. The power point placed on the ceiling is used to supply power to the overhead projector. Not forgetting that the demand from the consumer must be taken into the design of the power points because sometimes, the consumers has a design on their own. Then only comes the connection of the switch socket outlets either to be installed in a radial or ring connection, based on the suitable design.



For the radial circuit design, each socket outlet is fed from the previous one. The important thing is that each radial circuit must not exceed the floor area stated and the calculated estimated load. A radial circuit uses an over current protective device of 20A with 2.5 copper conductive PVC insulated cable. This will allow to supply to a maximum of only two socket outlets.

As for the ring circuit design, it is actually similar to the radial circuit design except that it the latter will be wired return to the supply source. On each of the ring final circuit conductors, it must be looped to any socket or box with a ring form and shall be electrically continuous throughout its length. For this circuit, it is standard that 32A or more current protection devices are used with the wire size of 2.5mm$^2$ with copper PVC insulation.

Table 3.1: 13A Switch Socket Outlet (BS1363)

| **Type of 13A Socket Outlets** | **Area** | **Cable Sizing** | **Circuit Breaker** |
|---|---|---|---|
| Single Socket Outlet | $20mm^2$ | $2.5mm^2$ PVC Cable | 16A |
| Double Socket Outlet | $20mm^2$ | $2.5mm^2$ PVC Cable | 20A |
| Ring (10Nos 13A socket outlet provided all area within an area not more than 1000 sq feet) | $100mm^2$ | $2.5mm^2$ PVC Cable | 32A |
| Radial (Max 6 socket outlets) | $50mm^2$ | $4mm^2$ PVC Cable | 32A |

There are two types of heavy industrial sockets which are made suitable for three phase (TPN) and single phase (SPN). The current rating for these sockets range from 16A to 125A. They are as shown in Figure 3.2 and Figure 3.3 below.



Figure 3.2: Industrial Socket (Single Phase)

Figure 3.3: Industrial Socket (Three Phase)

### 3.2.4 Simulation Process (Load Calculation)

Table 3.2: Load Demand for Preliminary Analysis

| TYPE OF LOAD | AVERAGE DEMAND |
|---|---|
| Lighting in Building | 10 to 35 W/m$^2$ |
| General Purpose Socket Outlets | 6 to 12 W/m$^2$ |
| Air Conditioning in Commercial Building | 30 to 80 W/m$^2$ |
| Typical Textile Factory | 120 W/m$^2$ |
| Small Device Manufacturing | 35 to 75 W/m$^2$ |
| Typical Electronics Manufacturing | 100 W/m$^2$ |
| Industrial Lighting | 10 to 80 W/m$^2$ |
| Water Pump | 10 to45 kW |
| Fire Pump | 65 to 100kW |

The very first stage in designing an electrical system is load calculation. This stage is very critical for the submission to the TNB on the load demand proposal. In this project, the total load connection came from the lighting system, switch socket outlets, fan, mechanical devices and many others.



There are several individual power components that will sum up into the total power consumed by load. They are the apparent power (kVA), reactive power (kVAR), and real power (kW). The value of real power is actually the portion of load that performs the real working operation. In other words, it is also the sum of the nominal power of all of the power consuming devices in the system. On the other hand, the reactive power of a load is used to supply energy that is stored in either a magnetic field, or an electric field.

Power factor (PF) is an index used to compute the efficiency level of electricity usage. The index is measured from 0 to 1. A higher index shows efficient usage of electricity and the same goes the other way around. Low power factor shortens the lifespan of electrical appliances and causes power system losses to TNB [24]. The PF equation:

$$\text{PF} = \frac{P(kW)}{S(kVA)} = \cos \Theta \tag{3.6}$$

Demands factors or diversity factors (DF) is applied to the load due to the diversity of use that occasionally occurs in a load. The actual demand load for any type of load in a building is lower than the sum of all connected load due to DF of equipment use. The equation is:

$$D.F = \frac{Maximum\, Demand\,(DB)}{Total\, Connected\, Board\,(Switchboard)} \tag{3.7}$$

According to [25], maximum demand is the capacity of electrical usage. It is used to access the level of capacity (load) of electricity used by customers. Maximum demand is measured in kilowatts, and it is calculated as double the highest amount of electricity consumed (in kilowatt-hours) within any consecutive period of thirty minutes, every single month. The calculation of maximum demand varies depending on the customer tariff categories. However, it is only applicable to customers using a supply of 6.6kV and above. Maximum demand current, $I_b$ is divided to two different levels which are the single phase (1Ø) and the three phase (3Ø) each of them have their own formula.

$$\text{Single Phase } (I_b) = \frac{Maximum\, Demand}{240 \times \cos\theta} \tag{3.8}$$

$$\text{Three Phase } (I_b) = \frac{Maximun\, Demand\,(MD)}{\sqrt{3} \times 415 \times \cos\theta} \tag{3.9}$$

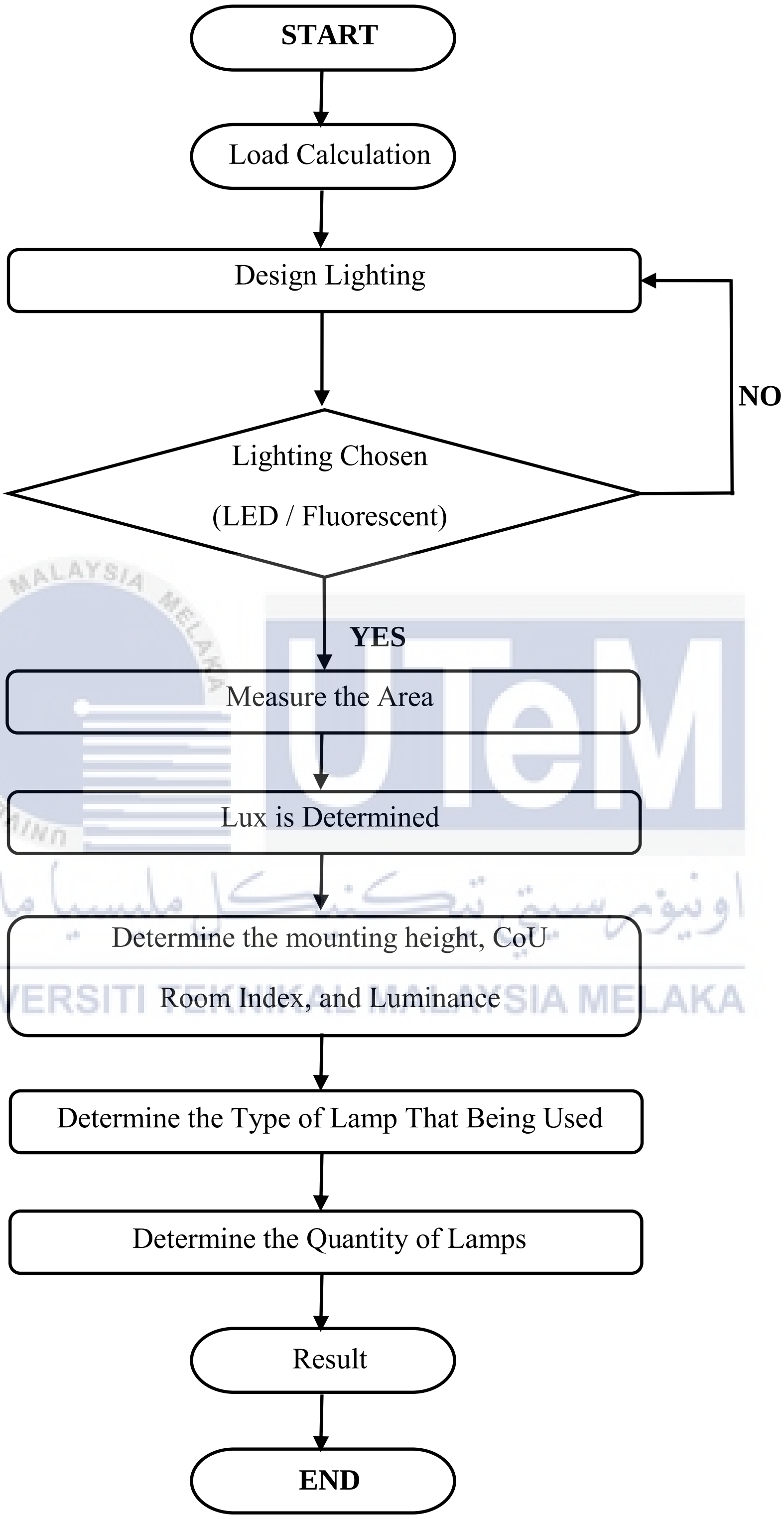





Figure 3.4: Flow Chart to determine the value of Luminaire

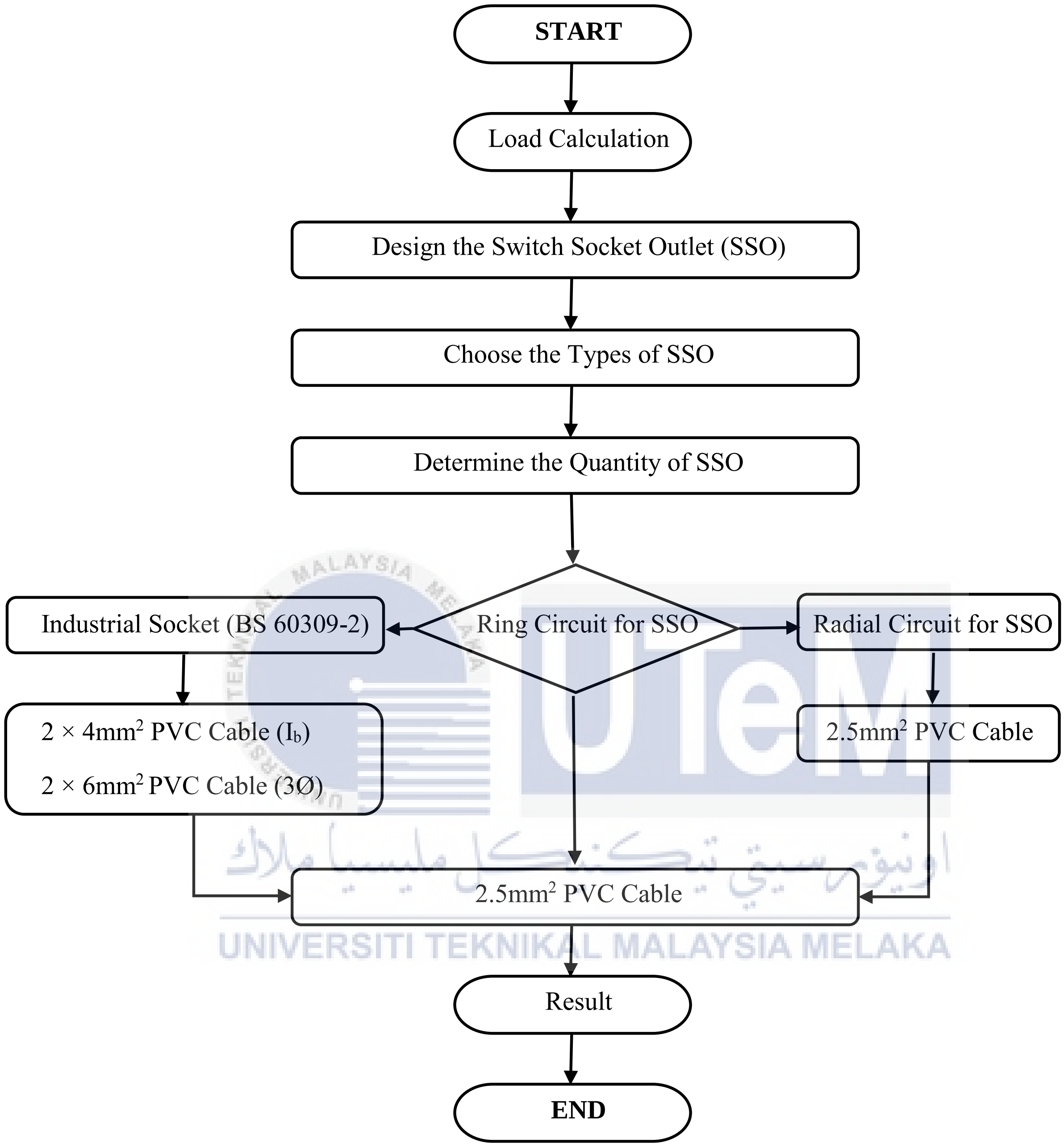





Figure 3.5: Flow Chart for SSO Load Calculation

### 3.2.5 Result Analysis

#### 3.2.5.1 Cable Sizing and Protective Device

Cable is defined as a length of an insulated single conductor, or two or more such conductors that each provided with its own insulation placed together. To ensure the cable is protected against overload and short circuit, protective devices are used [26]. Cable selection indicates two major principles. The first principle is that the cable should be able to conduct the current load attached to it without overheating. The second principle is that the cable should offer adequate earthing protection in order to limit the voltage that human being are vulnerable to a safe level and allow the fault current to trip the fuse or MCB in a short period of time.

Based on [27], the consideration for the protection of the circuit load current, the ambient temperature, cable length and thickness, and over-current protection device are the best way to meet these requirements. Cable installations such as trunking, cable ladder, cable tray and cable in underground are most commonly used in the wiring system.

Cable trunking is an approach by the manufacturers in order to help protecting the cables, normally with a rectangular cross-section with one side removable and the other is hinged. This approach is used mostly where loads are low and the side tee are only a few. The function of the cable ladder is to maintain a series of supporting elements. On the other hand, the cable tray is a cable made up of an incessant base with generated boundaries and do not have any wrapper. It is used for heavy load submains.

Relevant symbols and rules used in this regulation:

$I_z$ = Current-carrying capacity of a cable under exacting installation condition

$I_b$ = Design current of the circuit

$I_n$ = Nominal current of the protecting device against overcurrent

$I_2$ = Operating current of the device against overload

Rule 1: $I_n \geq I_b$

Rule 2: $I_z \geq I_n$

Rule 3: $3I_2 \geq 1.45I_z$

#### 3.2.5.2 Procedure of Cable Sizing and Protective Device

The current rating for the protective device must not be larger than the cable protected, so that it can protect it from overloading. In that case, $I_2$ must not exceed 1.45 times of $I_z$ and $I_z$ must be greater than $I_n$. The requirements are satisfied by choosing $I_z$ that is greater than $I_n$. The current rating for the cable is determined by some correction factors [28]. The correction factors are ambient current correction factor, $C_a$, grouping correction factor, $C_g$, and the thermal insulation correction factor, $C_i$, which will be used in order to equate the minimum current rating of a cable.

$$I_{x,\,min} = \frac{In}{Ca \times Cg \times Ci} \quad (3.10)$$

The design current, $I_b$ is determined by the maximum demand and power factor:

$$\text{Design Current, } I_b = \frac{Maximum\,Demand}{\sqrt{3} \times 415 \times \cos\theta} \quad (3.11)$$

In this project, the protection devices that being used are molded case circuit breaker (MCCB), air circuit breaker (ACB), and residual current circuit breaker (RCCB). The rating of MCCB that being used in this project ranges from 30A to 600A. Meanwhile, the rating of ACB that being used is 1000A. For the rating of RCCB, air-condition and switch socket outlet uses 100mA while lighting uses 30mA. As for the industrial three phase socket, the rating of RCCB is 300mA.

The type of cable must be properly selected based on the situation. The cable selection for this project is as shown in the table below.

Table 3.3: Types of Loads and Cables

| Type of Load | Type of Cable |
|---|---|
| Lighting and Small Power (Indoor) | Single Core PVC |
| MSB to DB, Feeder Pillar, Street, Compound Lighting Panel | Multi Core PVC/SWA/PVC |
| MSB to SSB | 4-Core XLPE/SWA/PVC |

Steps in choosing the right cable size is as shown below:

Step 1: Calculate the expected design in the circuit.

Step 2: Choose the type and rating of protective device to be used.

Step 3: Apply the ambient temperature correction factor, $C_a$, grouping correction factor, $C_g$, and thermal insulation correction factor, $C_i$.

Step 4: Choose the appropriate cable size.

**CHAPTER 4**

**RESULTS AND DISCUSSION**

## 4.1 Design Building and Layout Plan

By using AutoCAD software, the layout of the restaurant complete with the lighting system were drawn. The layout of the restaurant was designed by AutoCAD because it looks tidy, clean, and well-organized. The electrical installations which includes the lighting system, HVAC system, SSO system, and other electrical services were are drawn in the layout. This project focuses on all of the electrical services in order to evaluate the energy performance. Figure 4.1 and Figure 4.2 show the complete layout with lighting system and the legends of electrical services respectively.



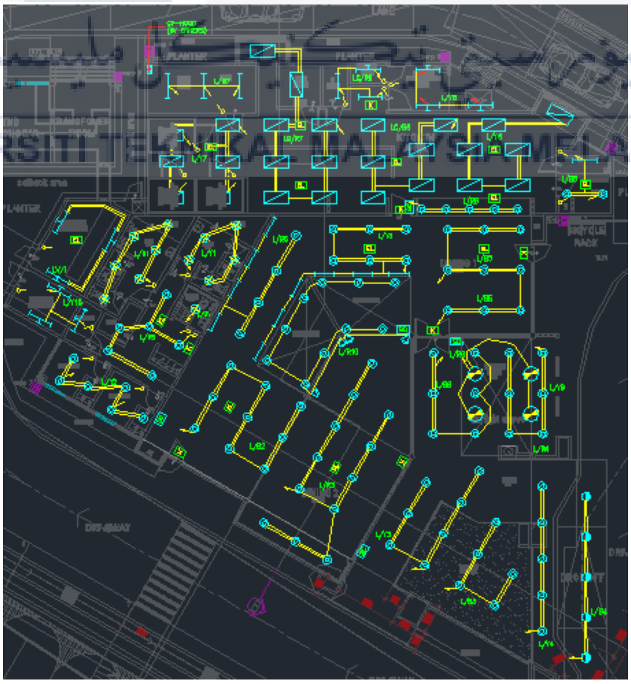


Figure 4.1: Floor Layout with Lighting System

LEGEND

| SYMBOL | DESCRIPTION | NOS |
|---|---|---|
| | 2 x 19W LED LIGHT FITTING C/W DIFFUSER (1200mm X 600mm) | 26 |
| | 1 X 21W LED TUBE LIGHT FITTING | 16 |
| | 1 X 21W LED TUBE WALL MOUNTED LIGHT FITTING | 10 |
| | 2 x 11W LED SURFACE MOUNTED DOWN LIGHT (6" DIA) | 5 |
| | 2 x 11W LED DOWN LIGHT (6" DIA) | 90 |
| | LED KELUAR SIGN (RECESSED) | 7 |
| | 1 x 13W RECESSED SELF CONTAINED EMERGENCY LIGHT FITTING | 13 |
| | 1 WAY 10A SWITCH (NO OF GANG AS INDICATED) | 19 |
| | CEILING FAN POINT C/W REMOTE CONTROL | 4 |
| | 1 x 50W LED SPOTLIGHT | 6 |
| | SWITCH CENTER | 5 |
| | DISTRIBUTION BOARD | |

Figure 4.2: Legend of Electrical Equipment

## 4.2 Lighting Design Strategy

This is the stage where the proper planning of the electrical plan begins. The room space and concept of the building will determine the suitable lighting that will be used. Before the lamps are chosen, there are several crucial qualities that need to be considered to meet the needs of this project. The qualities are lux, cou, lumen, room index, and mounting height. Each and every type of lamps have different qualities and characters.

The most basic design of the designing a lighting system is the lumen method. It is important to figure out the requirements for general lighting such as room area, foot-candles (lumen per square foot), light loss due to room proportions, color of wall, and the coefficient of utilization and maintenance factor.

Table 4.1: General Lighting Requirements

| Zones | Ground Area ($m^2$) | Room Cavity Ratio (RCR) | Room Index | Light Loss Factor | Number of Luminaries |
|---|---|---|---|---|---|
| Indoor Dining Area | 171.74 | 13.715 | 0.36 | 0.8 | 33 |
| Corridor | 19.91 | | | | 8 |
| Kitchen | 122.76 | | | | 26 |
| Chiller and Freezer Room | 16.12 | | | | 4 |
| Outdoor Dining Area | 141.94 | | | | 33 |
| Consumer Switch Room | 14,74 | | | | 3 |
| EP Room | 2.24 | | | | 1 |
| Male Toilet | 8.89 | | | | 4 |
| Female Toilet | 8.95 | | | | 4 |
| Male Prayer Room | 6.05 | | | | 3 |
| Female Prayer Room | 6.69 | | | | 3 |
| Hose Reel Pump Room | 6.24 | | | | 2 |
| Outdoor Lighting (Façade) | 738.53 | | | | 32 |
| Street Lighting | 2539.21 | | | | 22 |

Table 4.1 describes the lighting requirements in order to examine and analyze the lighting performance in the restaurant. The value of the room cavity ratio of the restaurant is 13.71 while the room index and light loss factor are 0.36 and 0.8 respectively. Those stated parameters will be used to estimate the lighting performance to meet the energy saving criteria. A larger area will consume a larger number of lighting system compared a smaller area. This is vital to guarantee a good and satisfying lighting condition in a specific area.

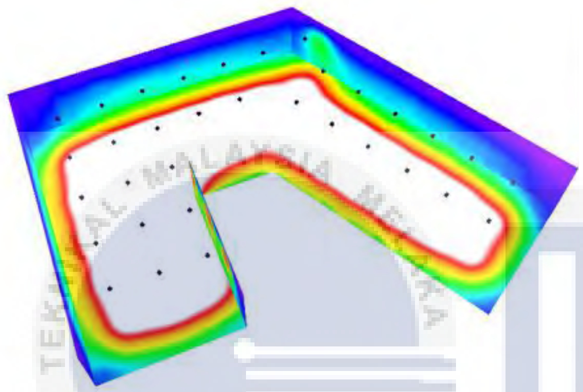
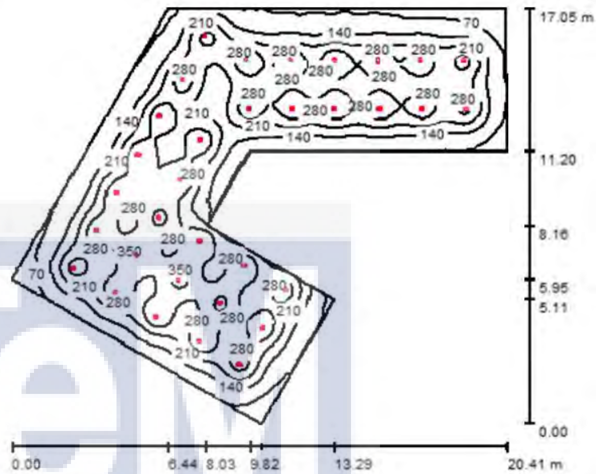
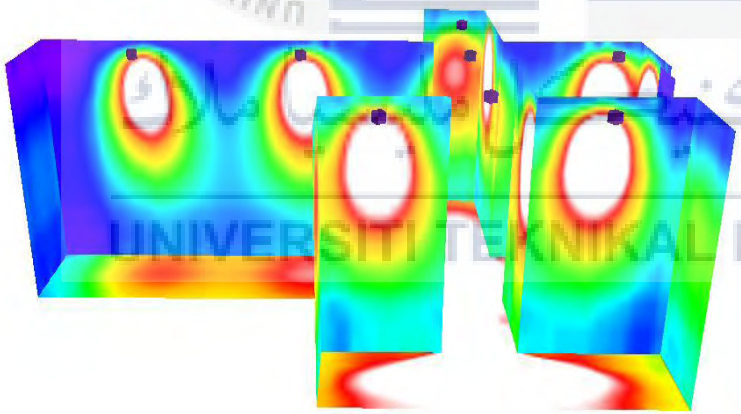
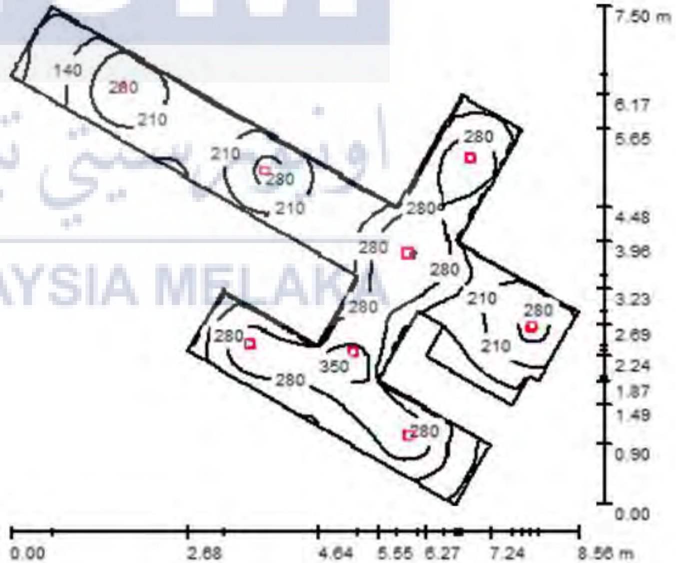


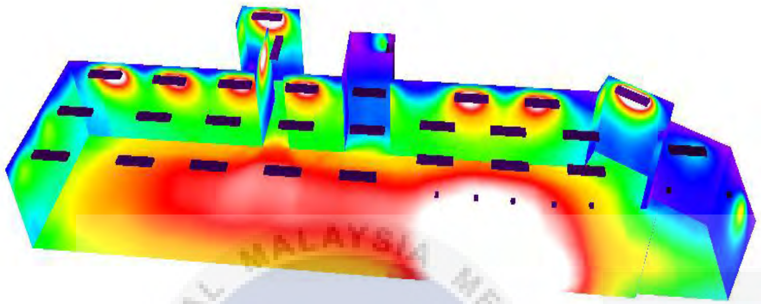
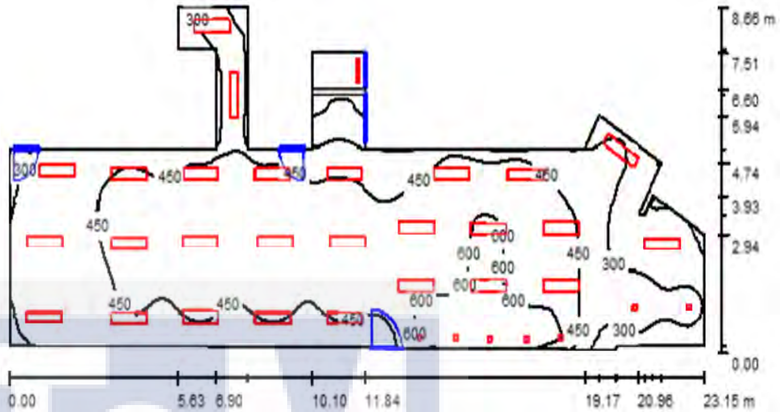
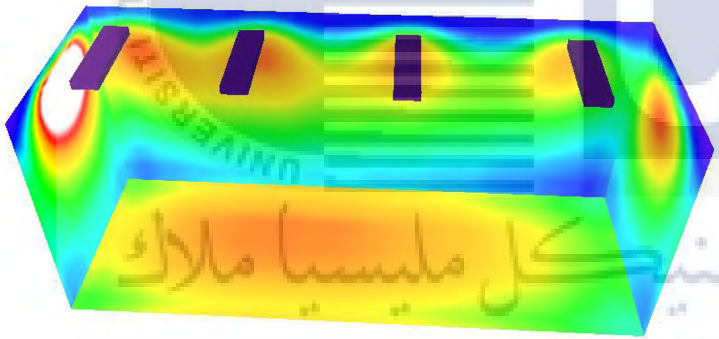
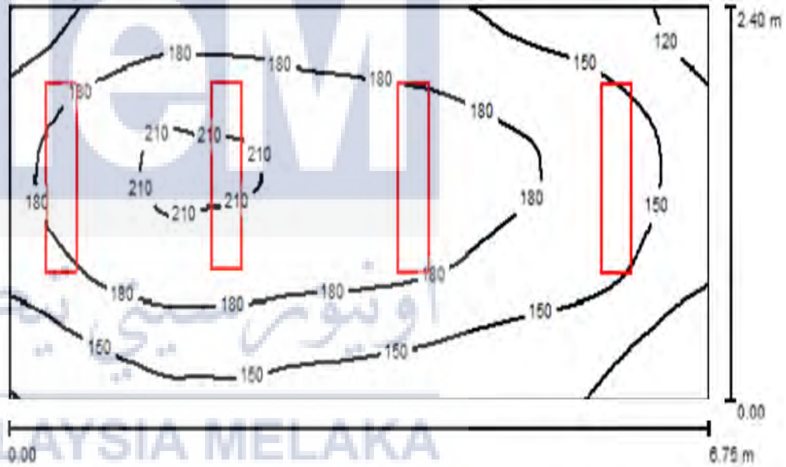

Figure 4.3: Color Rendering Index (CRI)

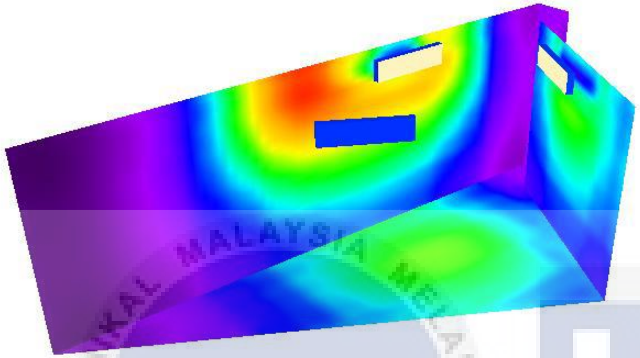
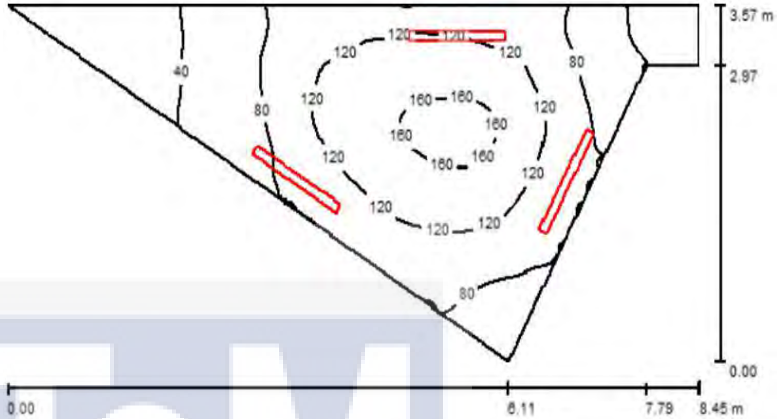
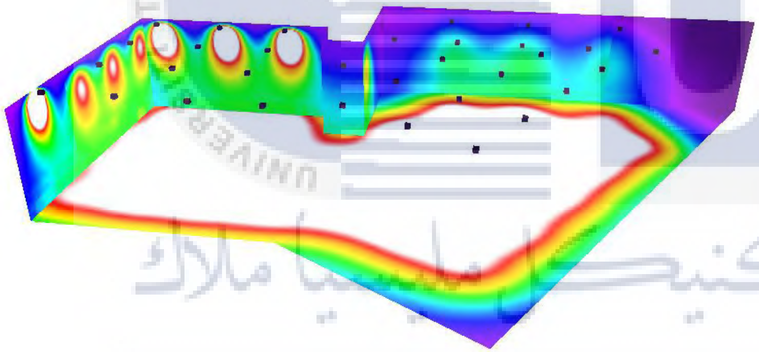
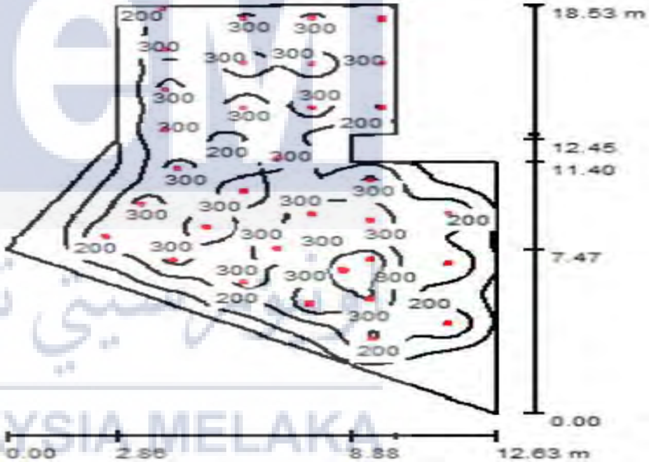
Figure 4.3 describes the color rendering index (CRI) that will measure and indicate the brightness of an artificial light source. The CRI is determined by differentiating the appearance of a colored object under an artificial light source. The best possible color rendition is a thousand while the poorest is zero.

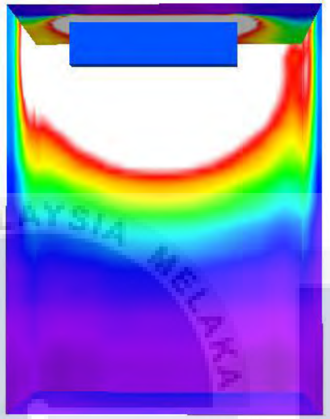
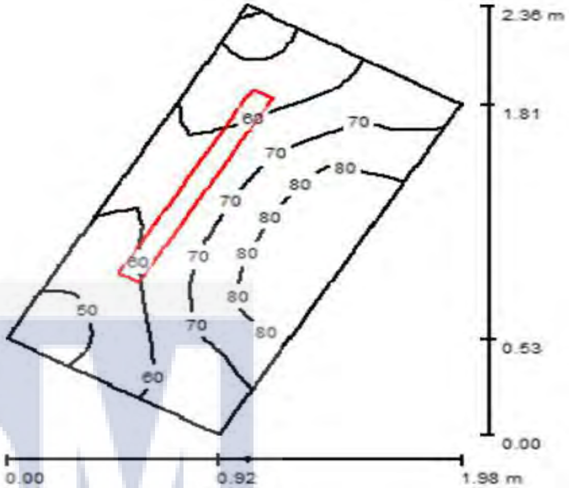
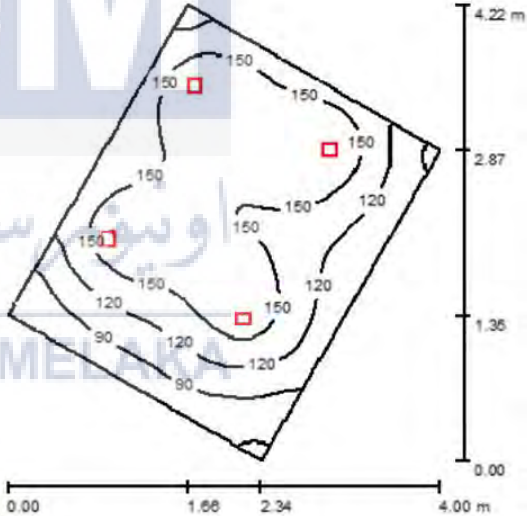
Areas of land are divided into zones within which lots of uses are permitted. Zoning is a technique of land-use planning as a tool of urban planning that normally being used by local governments in most developed countries.

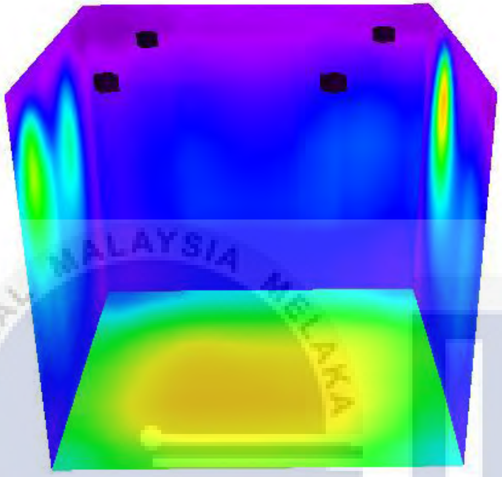
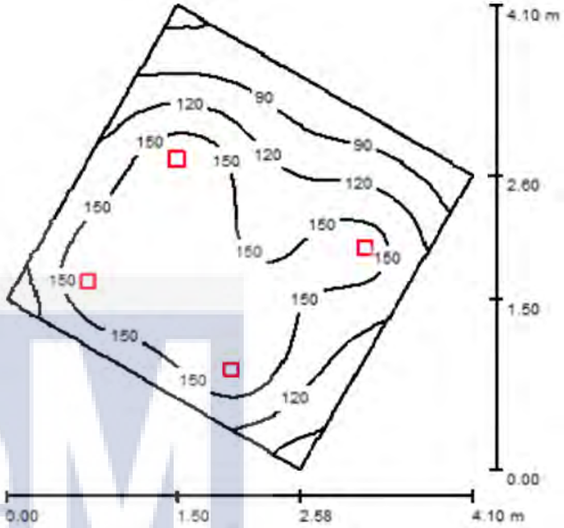
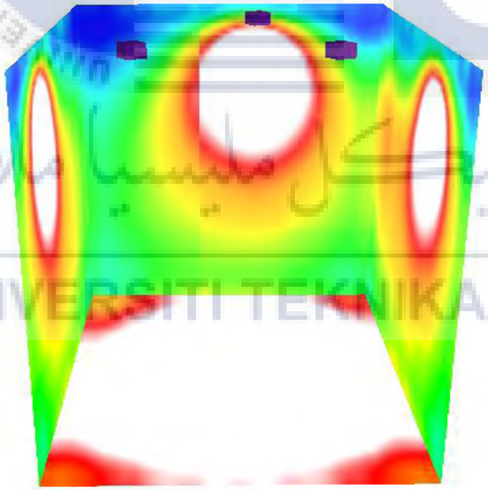
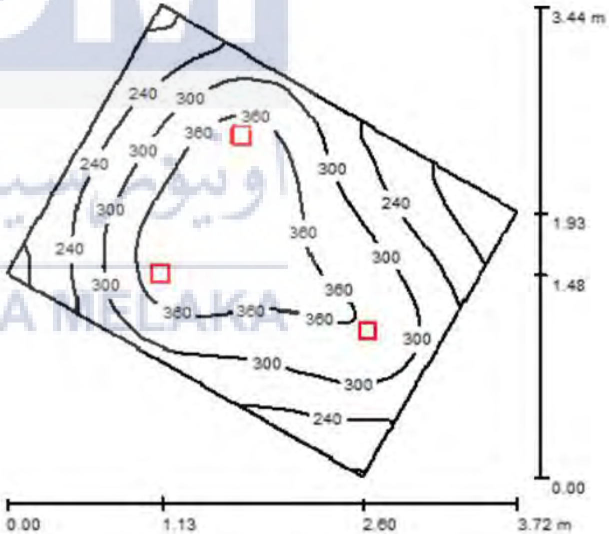
Table 4.2: Colour Rendering and Light Distribution Analysis

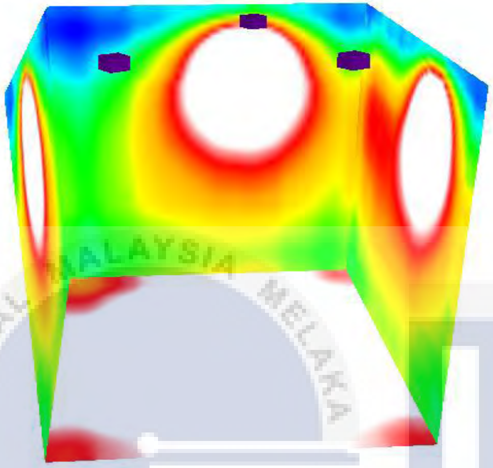
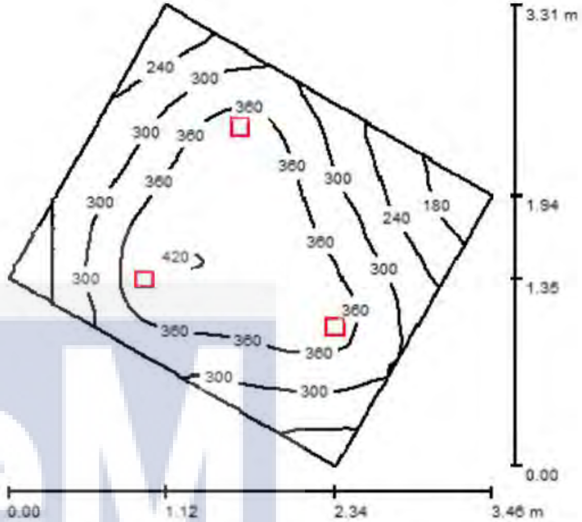
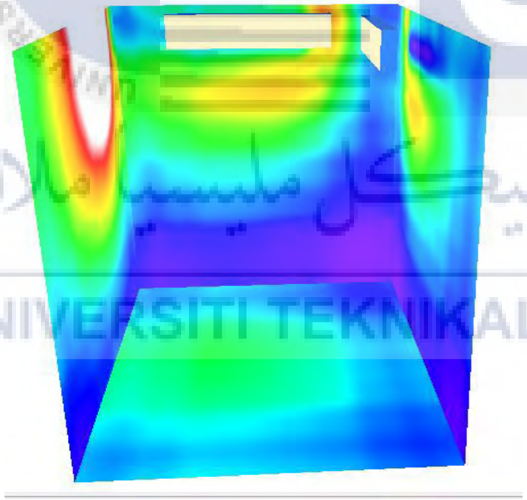
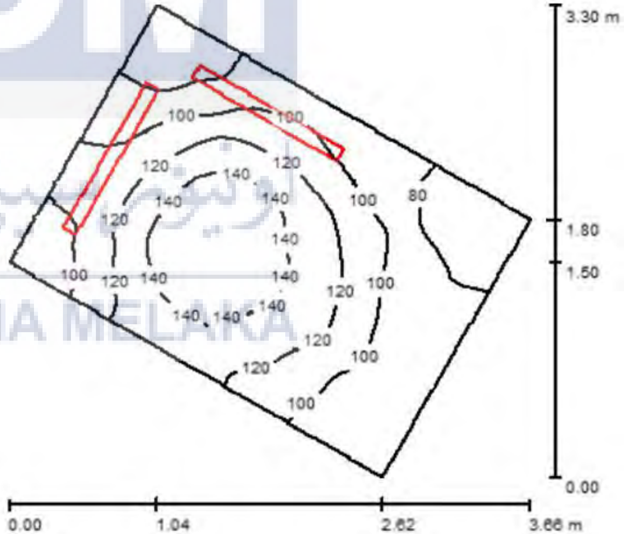
| Area | Colour Rendering | Light Distribution |
|---|---|---|
| **Indoor Dining Room** |  |  |
| **Corridor** |  |  |

| Area | Colour Rendering | Light Distribution |
|---|---|---|
| Kitchen |  |   |
| Chiller and Freezer Room |  |   |

| Area | Colour Rendering | Light Distribution |
|---|---|---|
| **Customer Switch Room** |  |  |
| **Outdoor Dining Area** |  |  |

| Area | Colour Rendering | Light Distribution |
|---|---|---|
| **EP Room** |  |  |
| **Male Toilet** |  |  |

| Area | Colour Rendering | Light Distribution |
|---|---|---|
| **Female Toilet** |  |  |
| **Male Prayer Room** |  |  |

| Area | Colour rendering | Light Distribution |
|---|---|---|
| **Female Prayer Room** |  |   |
| **Hose Reel Pump Room** |  |   |

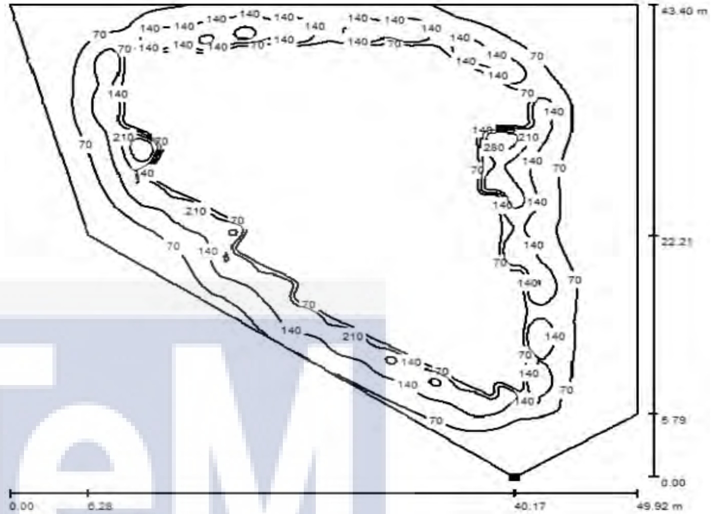
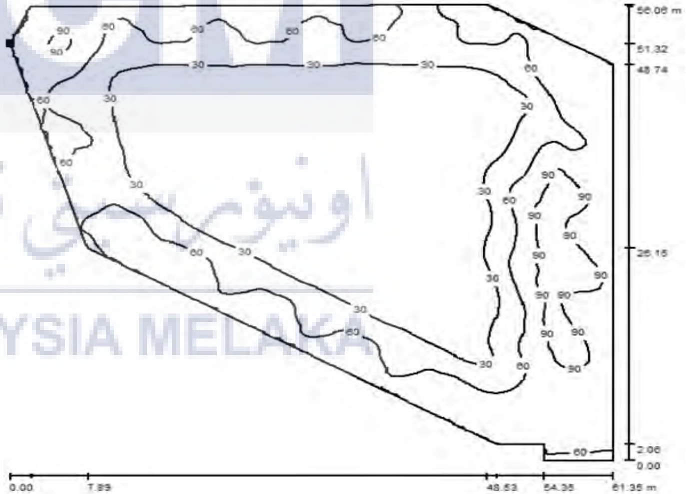
| Area | Colour Rendering | Light Distribution |
|---|---|---|
| **Outdoor Lighting (Façade)** |  |  |
| **Street Lighting** |  |  |

Table 4.3: Load Details – Energy Saving for Lighting

| ID | Luminaire Description<br>Lamps/Fixture | Number of Luminaires | Watts/Luminaire | Total Watts | Ground Area ($m^2$) | Lighting Power Density ($W/m^2$) |
|---|---|---|---|---|---|---|
| **Indoor Dining Area** | ExtraLED P-LMH 2000-25W | 33 | 25 | 825 | 171.74 | 4.80 |
| **Corridor** | ExtraLED P-LMH 2000-25W | 8 | 25 | 200 | 19.91 | 10.05 |
| **Kitchen** | ExtraLED P-LMH 2000-25W | 7 | 25 | 1138 | 122.76 | 9.27 |
| | ExtraLED S-B Series 1x9W | 1 | 9 | | | |
| | ExtraLED S-B Series 2x18W | 1 | 18 | | | |
| | ExtraLED S-R Series 2x18W | 26 | 36 | | | |
| **Chiller and Freezer Room** | ExtraLED S-B Series 2x18W | 4 | 36 | 144 | 16.12 | 8.93 |
| **Outdoor Dining Area** | ExtraLED P-LMH 2000-25W | 33 | 25 | 825 | 141.94 | 5.81 |
| **Consumer Switch Room** | ExtraLED S-B Series 2x18W | 3 | 36 | 108 | 14.74 | 7.33 |
| **EP Room** | ExtraLED S-B Series 2x18W | 1 | 36 | 36 | 2.24 | 16.07 |
| **Male Toilet** | ExtraLED P-LMH 850-11W | 4 | 11 | 44 | 8.89 | 4.95 |
| **Female Toilet** | ExtraLED P-LMH 850-11W | 4 | 11 | 44 | 8.95 | 4.92 |
| **Male Prayer Room** | ExtraLED P-LMH 2000-25W | 3 | 25 | 75 | 6.69 | 11.21 |
| **Female Prayer Room** | ExtraLED P-LMH 2000-25W | 3 | 25 | 75 | 6.05 | 12/39 |
| **Hose Reel Pump Room** | ExtraLED S-B Series 2x18W | 2 | 36 | 72 | 6.24 | 11.54 |
| **Outdoor Lighting (Façade)** | ExtraLED M-Series 80W | 32 | 80 | 2560 | 738.53 | 3.47 |
| **Street Lighting** | ExtraLED J-Series 80W | 22 | 80 | 1760 | 2539.21 | 0.69 |

### 4.2.1 Lighting Analysis

As referred to MS 1525:2007, standard point 6.3, the maximum level of light power density allowed for a restaurant is 15W/m$^2$. Both Table 4.2 and Table 4.3 exhibit the lighting strategies for 14 different zones of the restaurant divided equally and they all are well-lighted. Among all of the zones, the kitchen gave the highest value of power consumed by lighting load for the indoor area which is 1138W with 9.27W/m$^2$ light power density. Next in line is the indoor dining area which consumed 825W with 4.80W/m$^2$ light power density. The outdoor dining area consumed the equal amount of lighting load however, it differs in the light power density and that is 5.81W/m$^2$ due to the different size of ground area. The façade lighting consumed 1290W of lighting load and the light power density of 2.59W/m$^2$. Not forgetting that the street lighting consumed 1760W of power load with 0.69W/m$^2$ light power density. The other remaining zones only consumed a small amount of lighting load and the power densities of these zones are still in the range of 0 to 15W/m$^2$.

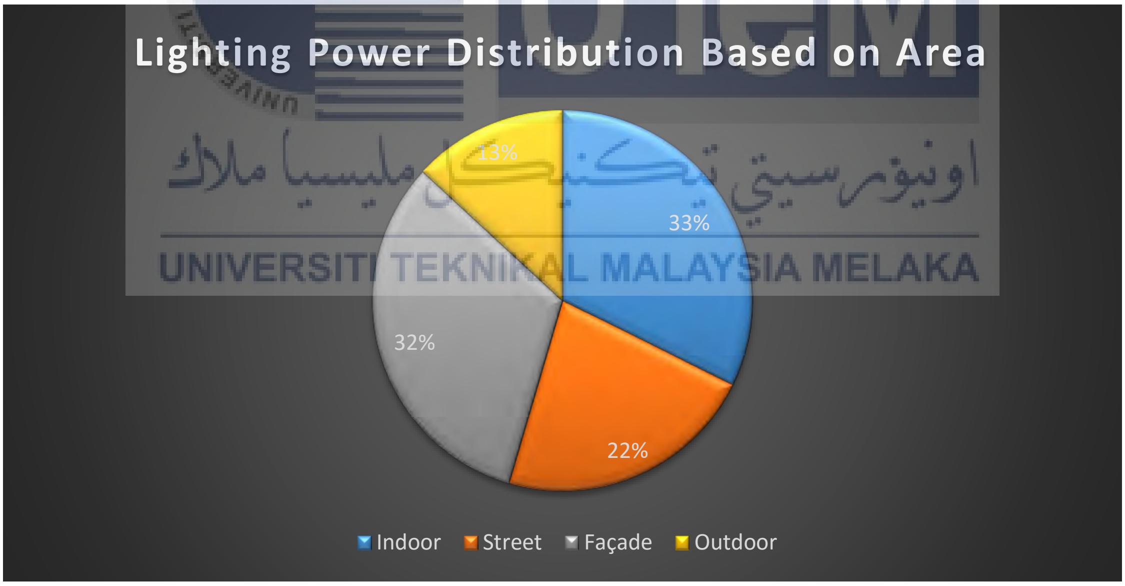





Figure 4.4: Lighting Power Distribution Based on Area

Figure 4.4 proves that the highest power consumed is by the indoor area of the restaurant, compared to the other three areas which are the façade lighting, street lighting, and outdoor lighting. The results are caused by the number of rooms inside of the indoor area. The result makes sense because the indoor area consists of 10 zones while there are only two areas for outdoor lighting and a single area for façade lighting and street lighting respectively.

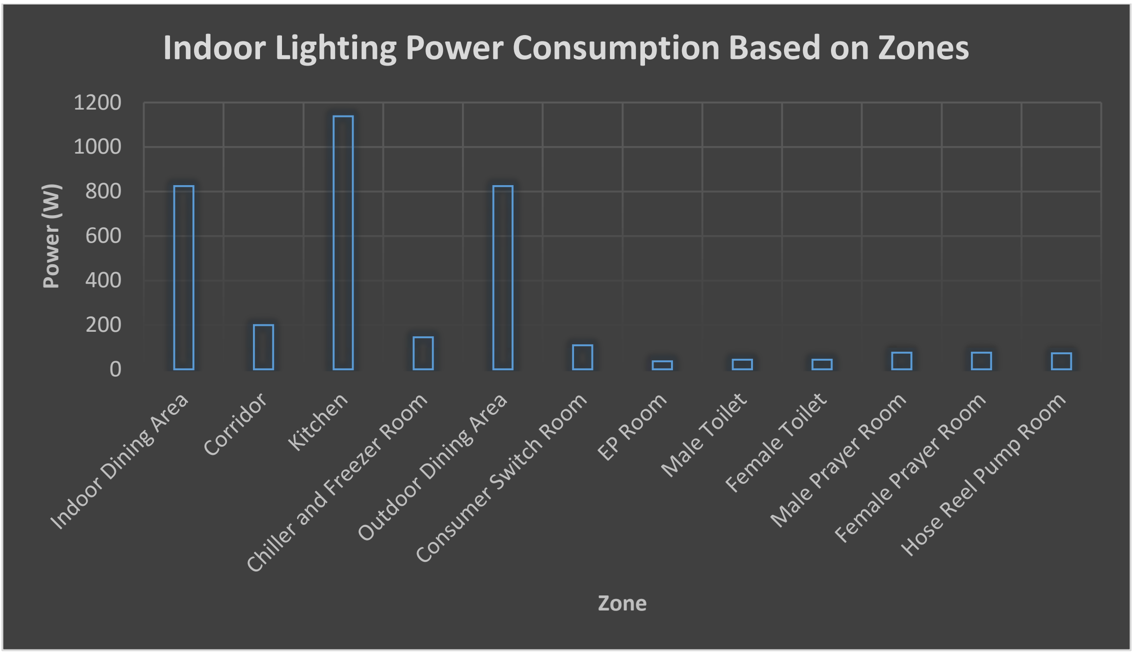



Figure 4.5: Indoor Lighting Power Consumption Based on Zones

Based on Figure 4.5, the kitchen consumes the largest power for indoor lighting with a total of 1138W. The kitchen zone is the most crucial area within a restaurant. This is because the kitchen is where all of the food is being prepared. Good and sufficient lighting is required in order for the staffs to work and handle food for the customers within a safe working and clean environment. According to Malaysian Standard, MS 1525:2007 "Code of Practice on Energy Efficiency and use of Renewable Energy for Non-Residential Building", indoor light requirements may vary depending on the task to be carried out in the different areas. It is actually normal that the kitchen consumes most of the lighting power because the kitchen is where all the important work is held.

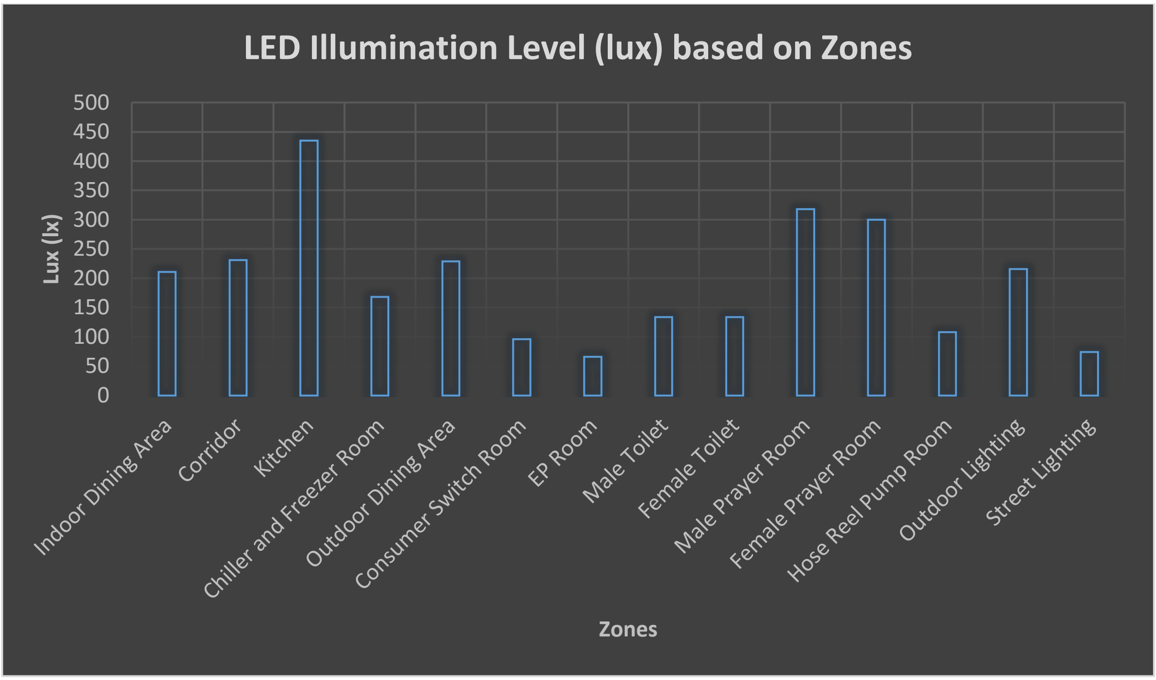



Figure 4.6: LED Illumination Level (lux) based on Zones

LED-based lighting is low in voltage and current requirements. It has high switching speed, high reliability, robust, absence of mercury, compact size, low-maintenance cost, and high in efficiency. The figure 4.6 proves that all 14 zones of the restaurant successfully fulfilled the standard of Jabatan Kerja Raya (JKR). The kitchen area displays the highest lux level which is 435lx. This is because all of the important and hard work inside of a restaurant such as cooking is held in the kitchen. The other zones have a good and matching lux level in each area respectively as the lux level is well-fitted with the standard. According to the JKR standard, the distribution of luminance in the field of view controls the adaptation level of the eyes, which will then affect the task visibility. Hence, the illumination level for each area must be good and adequate.

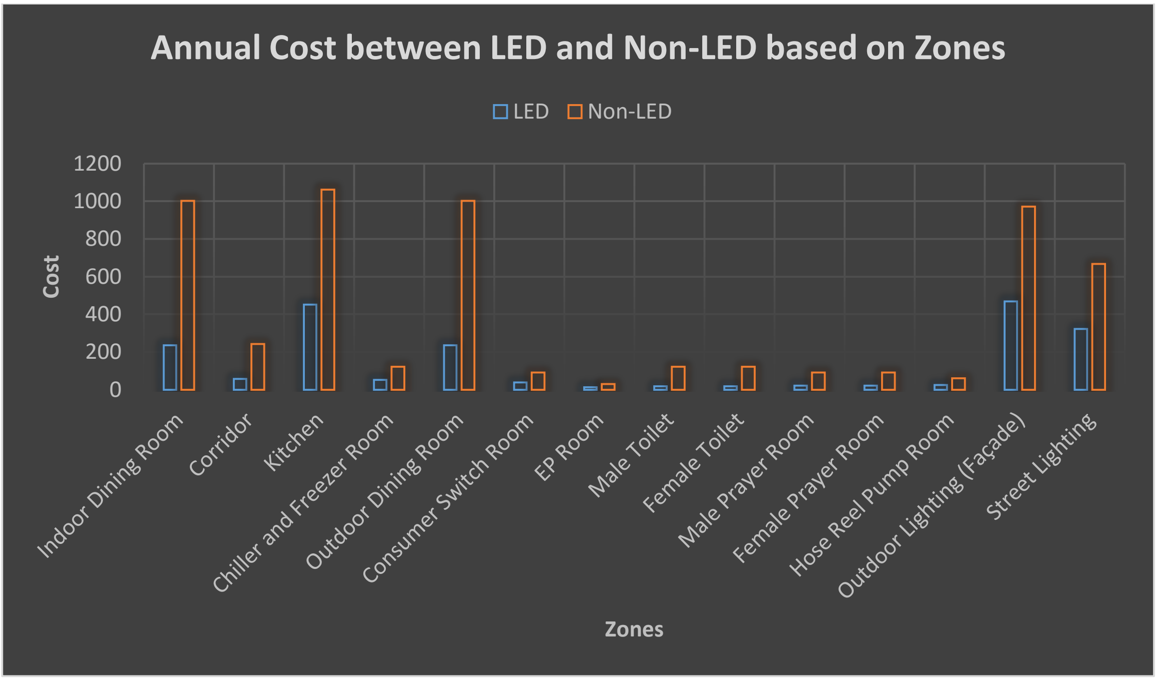



Figure 4.7: Annual Cost between LED and Non-LED based on Zones

Figure 4.7 proves that the Light Emitting Diode (LED) lamps gives a much lower annual cost compared to the non-LED lamps. The initial cost of LED lamps may be higher than the non-LED lamps, but in a long run, the LED lamps will bring much better benefits. The average cost for an LED lamp is between RM20 to RM100 while the average cost for a non-LED lamp is RM5 to RM20 only. This shows the difference in the initial cost of lighting design can be a burden. However, the LED lamps have a longer life rating compared to other types of lamps and they are between 10000 to 15000 hours which means that they could be used to a maximum of 13.7 years. The implementation of LED lamps will not reduce the initial cost of a system. However, it will later give a netter result in term of return of investment.

### 4.2.2 Exit Sign and Emergency Light

Table 4.4: Exit Sign and Emergency Light Load Details

| Type | Quantity | Current (A) | Load (W) | Power (W) |
|---|---|---|---|---|
| 2 × 13W EXIT Sign C/W Integral Gear | 14 | 13 | 0.04 | 0.56 |
| 1 × 13 Recessed Self Contained Emergency Light Fitting | 13 | 13 | 0.04 | 0.52 |

Table 4.4 displays the consumption of energy of the additional lightings that are the Exit sign and the emergency light. Even though it is not much, the additional lightings still contribute in additional power consumption because they are switched on 24 hours a day as a safety and precaution measure. The application of LED light bulbs helped in reducing power consumption for emergency lightings.

## 4.3 Heating, Ventilating, and Air-Conditioning (HVAC) Design Strategy

According to [29], the HVAC system consumes 54% of overall energy consumption in a building. This calls for a new and improved way to reduce the consumption of energy. Three main purposes of heating, ventilating, and air-conditioning are interrelated especially with the need to provide thermal comfort and satisfying indoor air quality with reasonable installation, operation, and maintenance cost. Generally, an air-conditioner is a device that cools a room or area by lowering the temperature.



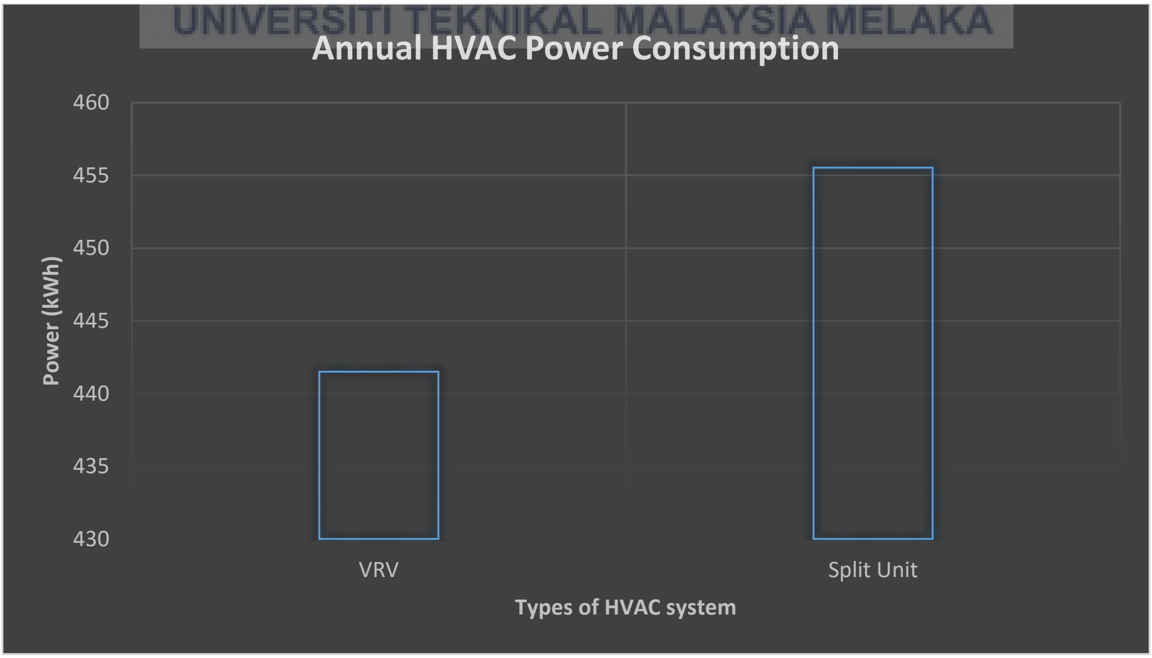



Figure 4.8: Annual HVAC Power Consumption between VRV and Split Unit Air-Conditioners

The type of air-conditioning system chosen to be applied in this restaurant is the Variable Refrigerated Volume (VRV). This is because VRV offers a greater energy savings compared to conventional air-conditioners. Figure 4.8 displays the difference between the annual power consumption between VRV air-conditioning system and split unit air-conditioning system. The VRV system gives a total of 441.50kWh which is comparably lower than the split unit system which is 455.52kWh. The cost of VRV air-conditioning system is RM64862 which is a little bit more expensive than the split unit air-conditioning system which is RM 53430. However, VRV air conditioner has a higher energy efficiency compared to the split unit. The VRV air-conditioner includes both one unit of compressor with 22.4kW rated capacity with 12 indoor units while the split unit air-conditioner includes a single unit of compressor of 2kW and one indoor unit. The rated capacity of VRV air-conditioner with 12 indoor units is much lower compared to the rated capacity of split unit air-conditioner with only a single indoor unit. Other than that, split unit requires a larger space compared to VRV.

## 4.4 Switch Socket Outlet (SSO) Design Strategy

One of the most vital element in the electrical installation design is the switch socket outlet. The plug acts as a moveable connector attached to an electrical operated device's cable while the socket is fixed on an equipment or a structure. In order to minimize the risk of electrical leakage or electrical shock, plugs and sockets are added up with some safety features. Sockets are mainly designed to prevent any exposures of bare live contacts. The only exposed contacts available in certain sockets should be exclusively and only for earthing or in other word, grounding.

Ring and radial configurations of socket are used in the restaurant design. The configurations were selected based on the number of socket inside of a circuit. For a circuit that consists of less than 6 sockets, radial configuration will be used whereas for a circuit with more than six sockets, ring configuration is more suitable because it saves cost and if a socket in the circuit breaks, the other sockets can still be used.

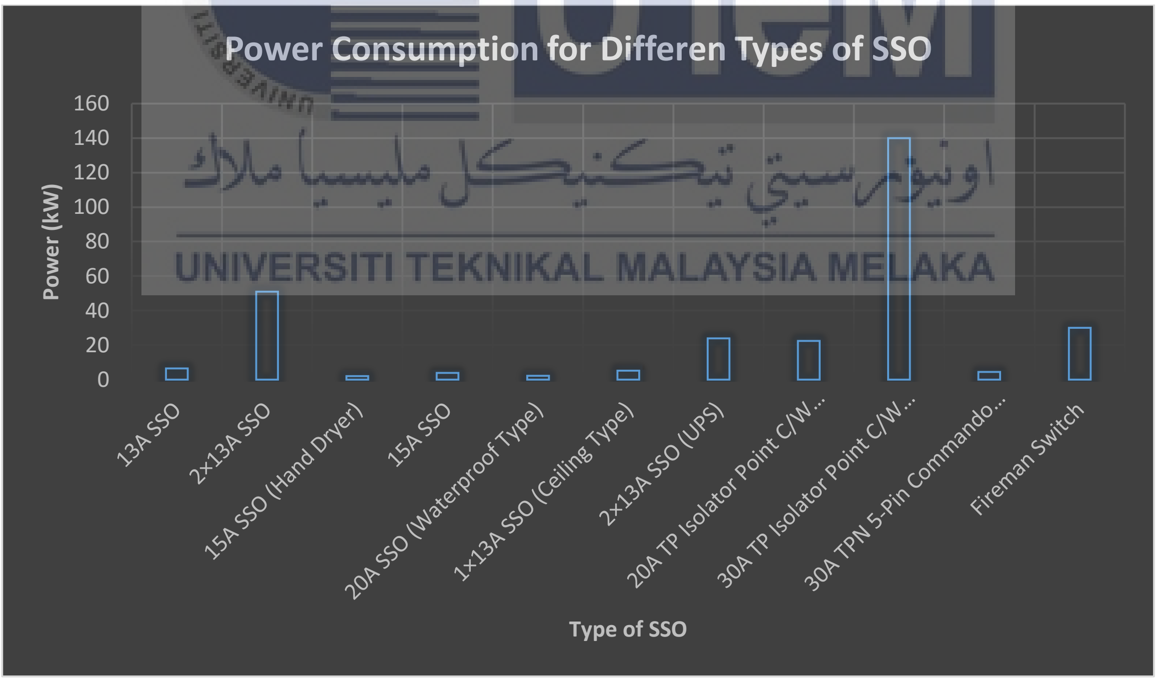





Figure 4.9: Power Consumption of Different Types of SSO

The area with the most energy consumption in a restaurant is the kitchen. This occurs because all of the food service facilities were located there and they are one of the biggest energy consumers per square foot among commercial buildings. Basically, in a typical food service facility, food preparation, water heating, and refrigeration combined will represent almost 60% of the total energy usage, making those system excellent targets for energy savings. According to Figure 4.9, 30A TP Isolators gives the highest reading of power consumed of 140kW because they are applied in the kitchen area. Almost all of the equipment in the kitchen uses high power rating such as steam cookers, ovens, fryers, and air-conditioners. Not forgetting that the installation of SSO is based on the need of statement as they are only being used in a certain demand and a period of time.

### 4.5 Protective Device and Cable Selection

Table 4.5: Protective Devices and Cable Selection

| Distribution Board | Type of Protective Device | Cable Type and Size |
|---|---|---|
| **DB1 (Lighting)** | 100A MCCB | 4×1C, 50mm$^2$ PVC Cu, Trunking |
| **DB2 (HVAC)** | 100A MCCB | 4×1C, 50mm$^2$ PVC Cu, Trunking |
| **DB3 (HVAC)** | 100A MCCB | 4×1C, 50mm$^2$ PVC Cu, Trunking |
| **DB4 (HVAC)** | 100A MCCB | 4×1C, 50mm$^2$ PVC Cu, Trunking |
| **DB5 (ISO)** | 200A MCCB | 4×1C, 120mm$^2$ PVC/PVC Cu, Trunking |
| **DB6 (SSO)** | 100A MCCB | 4×1C, 50mm$^2$ PVC Cu, Conduit/Trunking |



Table 4.5 describes the types of protective device and cable used for each and every load there is. Air-conditioning system requires three distribution boards, unlike the other systems that only requires one. This scenario happens because the VRV air-conditioner is connected to a maximum number of 12 indoor units. The overall results of protective devices and cables are shown in appendix F1, F2, F3, and F4. Poly-Vinyl Chloride (PVC) copper type cables are used mostly because copper is a great conductor and PVC is a good insulator and acts as a very effective sheath as it can withstand high temperatures up to 80°C. The cables are placed in trunking or conduit because it helps in minimizing the space used and to arrange the cables in a tidy arrangement.

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATION

This chapter will discuss the summary and conclusion for this project. The conclusion made is based on the whole analysis which focused on the Green Building Strategies. Recommendation will be suggested based on this project analysis for future research and development.

## 5.1 Conclusion

As a conclusion, this project describes the basic study of indoor lighting performance for a restaurant for the commercial building development. The fundamental study of illumination is conducted by using the formula of illumination. The quantity of luminaires is obtained by installing energy saving lamps in different areas inside of the restaurant. It has been proven that by using LED lamps with smaller wattage may also brighten up an area or room with the illuminance standard by Illuminating Engineering Society (IES) standard illumination level. This project uses the DIALux software in order to analyze the lighting effects for each area or room by using a false color rendering method in a building which in this project, a restaurant. Other than that, the energy saving strategies that has been applied will enhance the appearance and environmental quality while boosting the sense of comfort for customers and workers inside of the restaurant. All of the systems inside of the restaurant which includes the lighting system, HVAC system, SSO system, protection system, and cable system needs a good energy performance. By enhancing the energy performance, rapid benefits can be obtained by maximizing the use of the usage of its energy sources and energy-related assets, hence minimizing both energy consumption and energy cost. This scenario may also help in healing world energy resources and minimize worldwide effects of energy usage such as global warming. Nowadays, commercial buildings such as restaurants are gradually being upgraded into Green Buildings. Going towards a Green Building level does not limit only by planting trees and implementing water-saving equipment, but also by using energy efficient electrical equipment that does not bring any negative impact to the environment. By implementing green building strategies, not only the environment gets healthier, but also a better atmosphere for customers and workers inside of a restaurant. All in all, green buildings offers a whole lot of advantages towards people and environment.

## 5.2 Recommendations

This project exhibits not only the growth in number of commercial buildings and the vast development of residential buildings gives a major impact on the development section, but also the growth in energy demand. It is important that a study on Overall Thermal Transfer Value (OTTV) as another approach towards Green Building so that more energy can be saved. Other than that, solar system and water harvesting system could be added to the restaurant in the future research and development for a greater power saving as well as water saving. Another recommendation would be installing a control system to the variation in the heat load because it could save more energy. Most of it all, installing Fault Detection Diagnosis (FDD) system in order to diagnose failures as it may be beneficial towards the air-conditioning system. According to [30], up to 40% of heating, ventilating, and air-conditioning (HVAC) energy consumption can be saved by using a successful FDD. Finally, I suggest that luminance and illumination measurement should be included in future research.

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# APPENDIX A: LIST OF LUMINAIRES

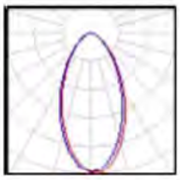
**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**INDOOR LIGHTING / Luminaire parts list**

8 Pieces | Extra Built (M) Sdn. Bhd. PLUTO LMH-0850lm-3000K-11W
Article No.:
Luminous flux (Luminaire): 535 lm
Luminous flux (Lamps): 538 lm
Luminaire Wattage: 0.0 W
Luminaire classification according to CIE: 100
CIE flux code: 77 96 100 99 100
Fitting: 1 x LED (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

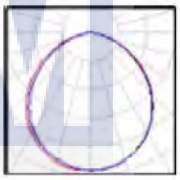


87 Pieces | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W
Article No.:
Luminous flux (Luminaire): 1311 lm
Luminous flux (Lamps): 1317 lm
Luminaire Wattage: 25.2 W
Luminaire classification according to CIE: 100
CIE flux code: 72 93 99 100 100
Fitting: 1 x LED (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

1 Pieces | Extra Built (M) Sdn. Bhd. SATURN ST-27W-3x9W (Type 1)
Article No.:
Luminous flux (Luminaire): 548 lm
Luminous flux (Lamps): 549 lm
Luminaire Wattage: 10.0 W
Luminaire classification according to CIE: 100
CIE flux code: 52 84 98 100 100
Fitting: 1 x User defined (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.





10 Pieces | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (Type 1)
Article No.:
Luminous flux (Luminaire): 1373 lm
Luminous flux (Lamps): 1375 lm
Luminaire Wattage: 22.0 W
Luminaire classification according to CIE: 100
CIE flux code: 50 82 97 100 100
Fitting: 1 x User defined (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

26 Pieces | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W
Article No.:
Luminous flux (Luminaire): 2746 lm
Luminous flux (Lamps): 2749 lm
Luminaire Wattage: 44.1 W
Luminaire classification according to CIE: 100
CIE flux code: 50 82 97 100 100
Fitting: 1 x LED (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

Figure A1: Luminaire Part Lists for Indoor and Outdoor Lightings

**FAÇADE EXTERIOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**EXTERIOR LIGHTING / Luminaire parts list**

32 Pieces EXTRA-BUILT (M) SDN BHD Non-LENS with XPG2 8800 lm (Type 1)
Article No.: Non-LENS with XPG2
Luminous flux (Luminaire): 6598 lm
Luminous flux (Lamps): 6600 lm
Luminaire Wattage: 60.0 W
Luminaire classification according to CIE: 100
CIE flux code: 45 78 97 100 100
Fitting: 1 x User defined (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

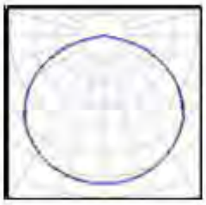


Figure A2: Luminaire for Façade Lighting

**STREET LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**Street Lighting / Luminaire parts list**

22 Pieces EXTRA-BUILT (M) SDN BHD L712(P-Glass) with XPG2 8500 lm
Article No.: L712(P-Glass) with XPG2
Luminous flux (Luminaire): 8499 lm
Luminous flux (Lamps): 8500 lm
Luminaire Wattage: 80.0 W
Luminaire classification according to CIE: 100
CIE flux code: 37 74 97 100 100
Fitting: 1 x CREE XPG2 with L712(P-Glass) (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

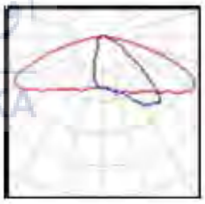




Figure A3: Luminaire for Street Lighting

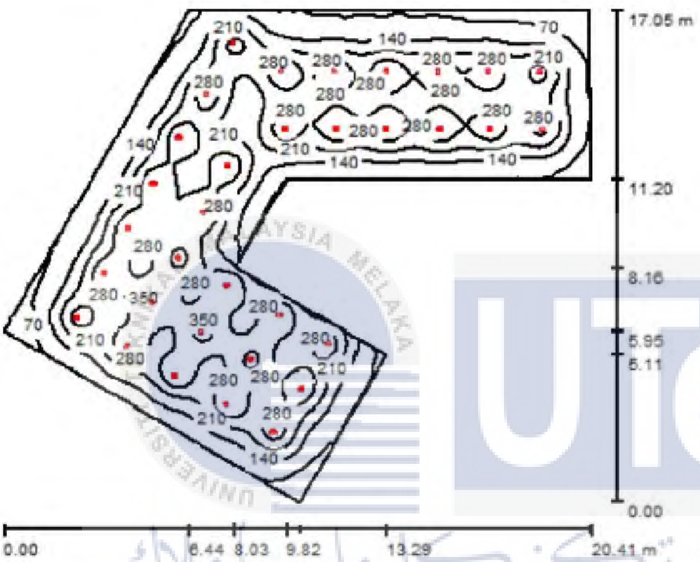
# APPENDIX B: DIALUX SIMULATION SUMMARY

DIALux

**INDOOR LIGHTING**

Extra-Built (M) Sdn Bhd

## Dining / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80

Values in Lux, Scale 1:219

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 211 | 28 | 375 | 0.132 |
| Floor | 20 | 199 | 46 | 311 | 0.230 |
| Ceiling | 80 | 36 | 21 | 56 | 0.589 |
| Walls (9) | 50 | 61 | 22 | 201 | / |

**Workplane:**

Height: 0.750 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.269, Ceiling / Working Plane: 0.173.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 33 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1311 | 1317 | 25.2 |
| | | | Total: 43263 | Total: 43445 | 831.6 |

Specific connected load: 4.82 W/m² = 2.29 W/m²/100 lx (Ground area: 172.64 m²)

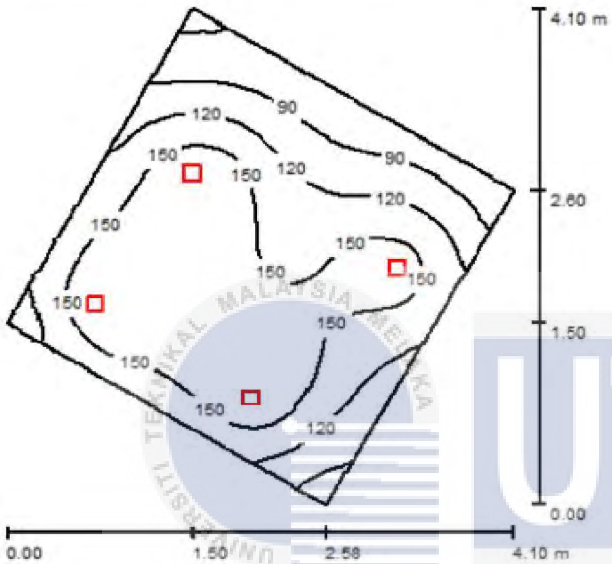


Figure B1: DIALux Simulation Summary in Dining Room (Indoor)

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**Female toilet / Summary**






Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80 Values in Lux, Scale 1:53

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 134 | 55 | 181 | 0.411 |
| Floor | 20 | 109 | 58 | 139 | 0.530 |
| Ceiling | 80 | 25 | 16 | 30 | 0.655 |
| Walls (6) | 50 | 53 | 18 | 144 | / |

**Workplane:**
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.414, Ceiling / Working Plane: 0.183.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 4 | Extra Built (M) Sdn. Bhd. PLUTO LMH-0850lm-3000K-11W (1.000) | 535 | 538 | 0.0 |
| | | | Total: 2141 | Total: 2152 | 0.0 |

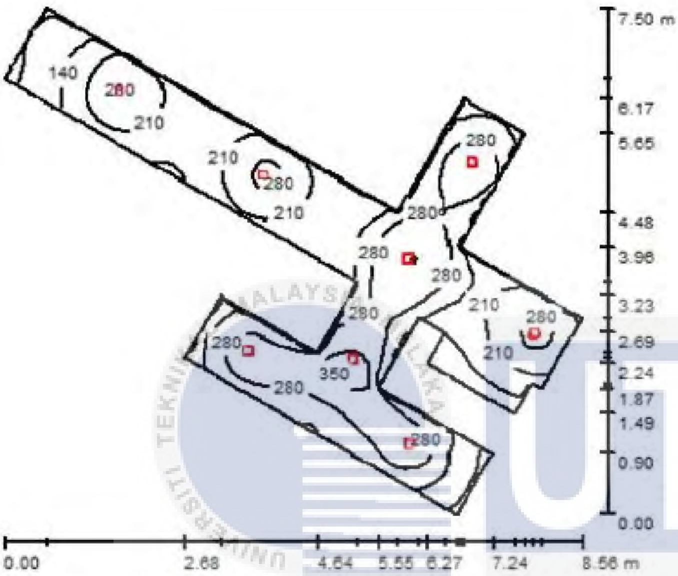
Specific connected load: 0.00 W/m² = 0.00 W/m²/ lx (Ground area: 9.00 m²)

Figure B2: DIALux Simulation Summary in Female Toilet

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Corridor / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80 — Values in Lux, Scale 1:97

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 231 | 63 | 395 | 0.271 |
| Floor | 20 | 178 | 66 | 290 | 0.372 |
| Ceiling | 80 | 49 | 24 | 95 | 0.495 |
| Walls (20) | 50 | 104 | 30 | 386 | / |

**Workplane:**
Height: 0.760 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.492, Ceiling / Working Plane: 0.209.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 8 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1311 | 1317 | 25.2 |
| | | | Total: 10488 | Total: 10532 | 201.6 |

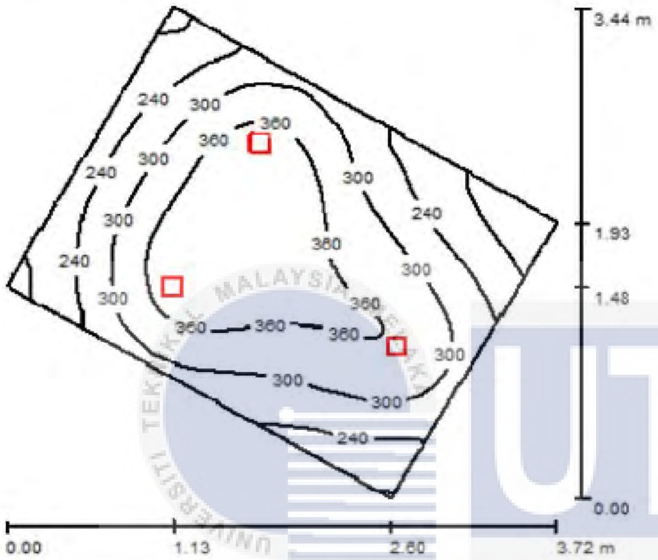
Specific connected load: 10.07 W/m² = 4.35 W/m²/100 lx (Ground area: 20.01 m²)

Figure B3: DIALux Simulation Summary in Corridor

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Female Prayer Room / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80

Values in Lux, Scale 1:45

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 300 | 133 | 418 | 0.442 |
| Floor | 20 | 234 | 143 | 298 | 0.611 |
| Ceiling | 80 | 59 | 38 | 69 | 0.648 |
| Walls (6) | 50 | 128 | 46 | 357 | / |

**Workplane:**
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.446, Ceiling / Working Plane: 0.195.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 3 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1311 | 1317 | 25.2 |
| | | | Total: 3933 | Total: 3950 | 75.6 |

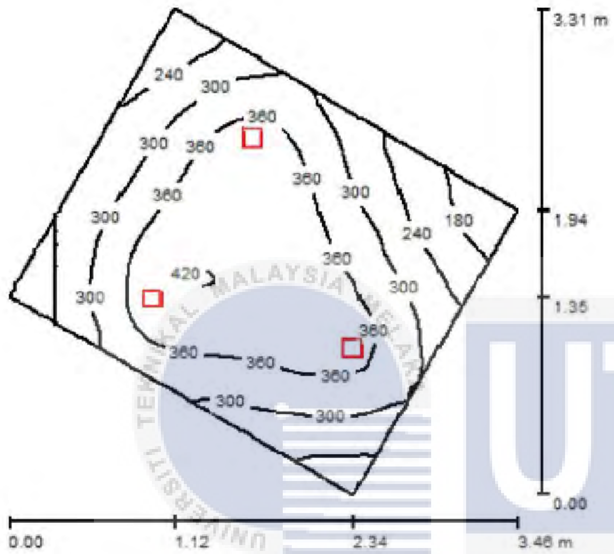
Specific connected load: 11.25 W/m² = 3.74 W/m²/100 lx (Ground area: 6.72 m²)

Figure B4: DIALux Simulation Summary in Female Prayer Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**Male Prayer Room / Summary**




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80

Values in Lux, Scale 1:43

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 318 | 144 | 422 | 0.451 |
| Floor | 20 | 245 | 150 | 307 | 0.612 |
| Ceiling | 80 | 65 | 41 | 80 | 0.634 |
| Walls (4) | 50 | 139 | 47 | 386 | / |

**Workplane:**
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.463, Ceiling / Working Plane: 0.203.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 3 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1311 | 1317 | 25.2 |
| | | | Total: 3933 | Total: 3950 | 75.6 |

Specific connected load: 12.42 W/m² = 3.91 W/m²/100 lx (Ground area: 6.09 m²)

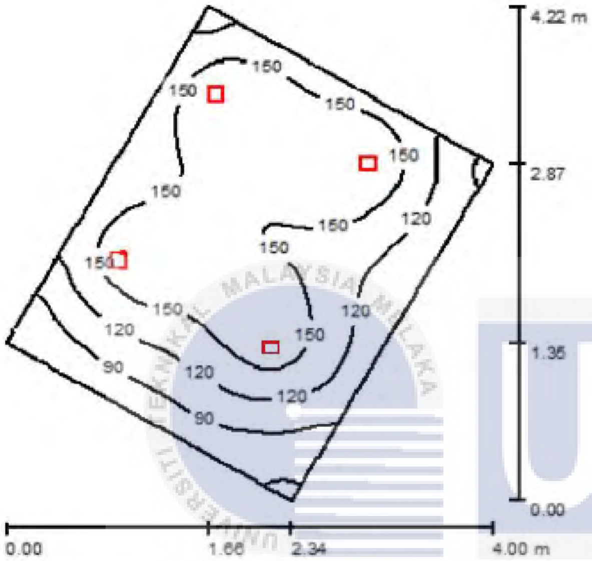


Figure B5: DIALux Simulation Summary in Male Prayer Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Male toilet / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80

Values in Lux, Scale 1:55

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 134 | 57 | 176 | 0.423 |
| Floor | 20 | 109 | 57 | 136 | 0.526 |
| Ceiling | 80 | 25 | 17 | 31 | 0.668 |
| Walls (4) | 50 | 54 | 18 | 158 | / |

**Workplane:**
Height: 0.760 m
Grid: 64 x 64 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.420, Ceiling / Working Plane: 0.185.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 4 | Extra Built (M) Sdn. Bhd. PLUTO LMH-0850lm-3000K-11W (1.000) | 535 | 538 | 0.0 |
| | | | Total: 2141 | Total: 2152 | 0.0 |

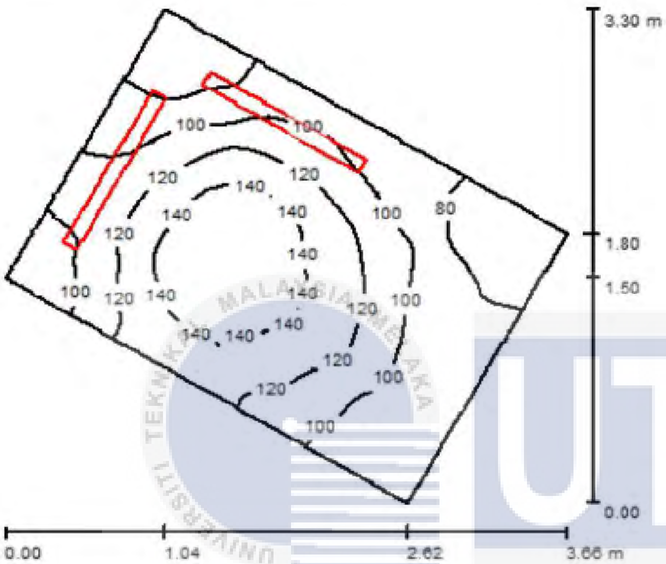
Specific connected load: 0.00 W/m² = 0.00 W/m²/ lx (Ground area: 8.95 m²)

Figure B6: DIALux Simulation Summary in Male Toilet

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**Hose Reel Pump Room / Summary**




Height of Room: 2.743 m, Light loss factor: 0.80 Values in Lux, Scale 1:43

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 108 | 60 | 158 | 0.553 |
| Floor | 20 | 73 | 47 | 95 | 0.641 |
| Ceiling | 80 | 190 | 31 | 989 | 0.165 |
| Walls (4) | 50 | 88 | 28 | 345 | / |

**Workplane:**
Height: 0.760 m
Grid: 32 x 32 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.948, Ceiling / Working Plane: 1.763.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 2 | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (Type 1)* (1.000) | 1373 | 1375 | 22.0 |
| | | | Total: 2747 | Total: 2750 | 44.0 |

*Modified Technical Specifications

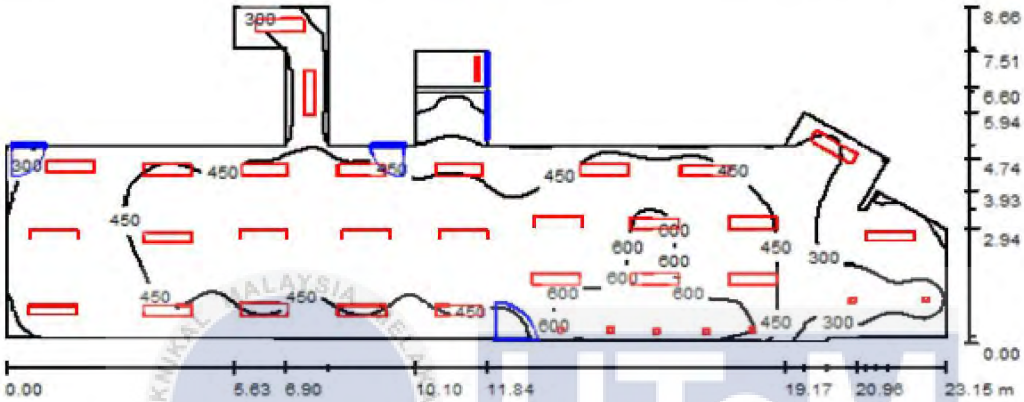
Specific connected load: 7.02 W/m² = 6.49 W/m²/100 lx (Ground area: 6.27 m²)

Figure B7: DIALux Simulation Summary in Hose Reel Pump Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Kitchen Dining / Summary




Height of Room: 2.743 m, Light loss factor: 0.80 Values in Lux, Scale 1:166

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 435 | 11 | 716 | 0.025 |
| Floors (2) | 20 | 388 | 16 | 596 | / |
| Ceilings (2) | 70 | 86 | 26 | 268 | / |
| Walls (25) | 50 | 223 | 6.60 | 919 | / |

**Workplane:**
Height: 0.800 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: - , Ceiling / Working Plane: - .

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 7 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1511 | 1517 | 25.2 |
| 2 | 1 | Extra Built (M) Sdn. Bhd. SATURN ST-27W-3x9W (Type 1)* (1.000) | 548 | 549 | 10.0 |
| 3 | 26 | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (1.000) | 2740 | 2745 | 44.1 |
| 4 | 1 | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (Type 1)* (1.000) | 1303 | 1305 | 21.0 |
| | | | Total: 82422 | Total: 82552 | 1354.0 |

*Modified Technical Specifications

Specific connected load: 10.97 W/m² = 2.52 W/m²/100 lx (Ground area: 123.41 m²)

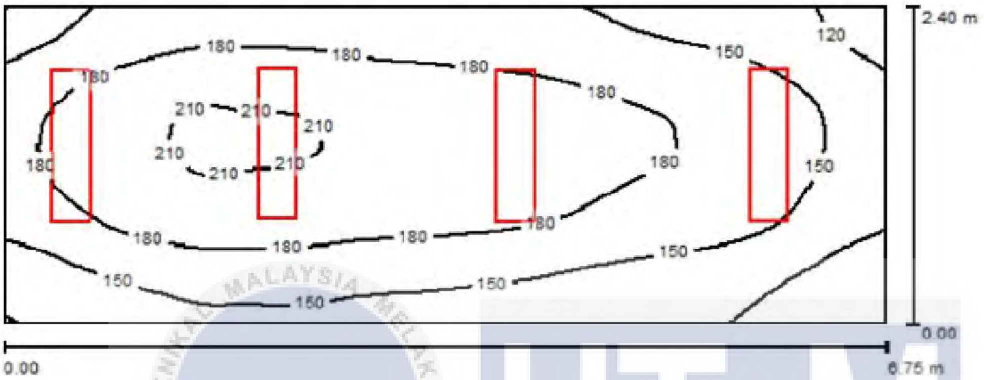


Figure B8: DIALux Simulation Summary in Kitchen

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## chiller & freezer room / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80

Values in Lux, Scale 1:49

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 168 | 95 | 216 | 0.564 |
| Floor | 20 | 132 | 81 | 160 | 0.617 |
| Ceiling | 80 | 37 | 19 | 65 | 0.508 |
| Walls (4) | 50 | 97 | 34 | 345 | / |



**Workplane:**
Height: 0.760 m
Grid: 32 x 64 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.624, Ceiling / Working Plane: 0.222.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 4 | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (Type 1)* (1.000) | 1373 | 1375 | 22.0 |
| | | | Total: 5493 | Total: 5500 | 88.0 |

*Modified Technical Specifications

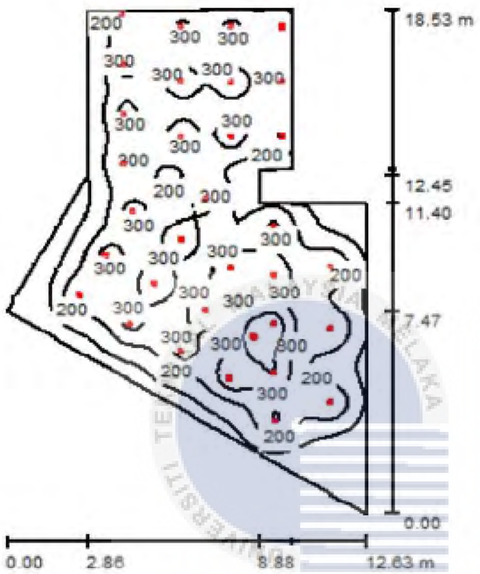
Specific connected load: 5.43 W/m² = 3.23 W/m²/100 lx (Ground area: 16.20 m²)

Figure B9: DIALux Simulation Summary in Chiller and Freezer Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Dining outdoor / Summary




Height of Room: 2.743 m, Mounting Height: 2.743 m, Light loss factor: 0.80 Values in Lux, Scale 1:238

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 229 | 9.21 | 497 | 0.040 |
| Floor | 20 | 213 | 13 | 381 | 0.062 |
| Ceiling | 80 | 31 | 11 | 44 | 0.345 |
| Walls (11) | 6 | 68 | 9.68 | 1960 | / |

**Workplane:**
- Height: 0.760 m
- Grid: 128 x 128 Points
- Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.291, Ceiling / Working Plane: 0.137.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 33 | Extra Built (M) Sdn. Bhd. PLUTO LMH-2000lm-4000K-25W (1.000) | 1311 | 1317 | 25.2 |
| | | | Total: 43263 | Total: 43445 | 831.6 |

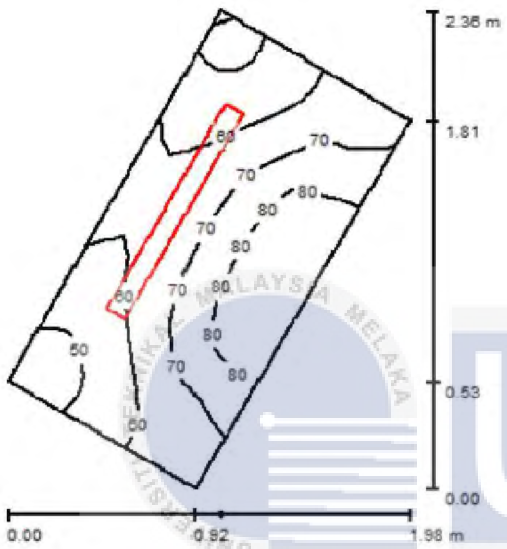
Specific connected load: 5.82 W/m² = 2.54 W/m²/100 lx (Ground area: 142.78 m²)

Figure B10: DIALux Simulation Summary in Dining Room (Outdoor)

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## EP Room / Summary




Height of Room: 2.743 m, Mounting Height: 2.543 m, Light loss factor: 0.80

Values in Lux, Scale 1:31

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 66 | 43 | 88 | 0.656 |
| Floor | 20 | 38 | 31 | 47 | 0.814 |
| Ceiling | 80 | 243 | 21 | 947 | 0.085 |
| Walls (4) | 50 | 91 | 18 | 621 | / |

**Workplane:**

Height: 0.760 m
Grid: 32 x 16 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.766, Ceiling / Working Plane: 3.691.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 1 | Extra Built (M) Sdn. Bhd. SATURN ST-36W-2x18W (Type 1)* (1.000) | 1373 | 1375 | 22.0 |
| | | | Total: 1373 | Total: 1375 | 22.0 |

*Modified Technical Specifications

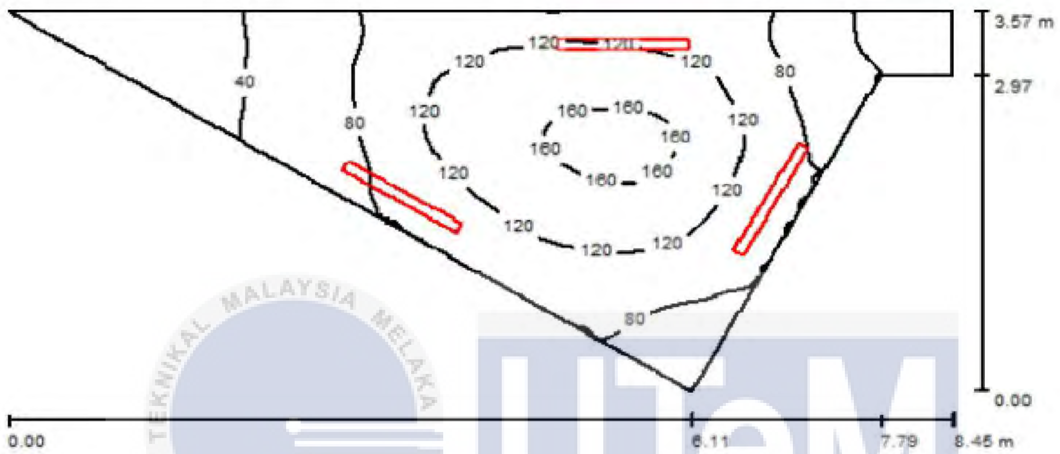
Specific connected load: 9.77 W/m² = 14.79 W/m²/100 lx (Ground area: 2.25 m²)

Figure B11: DIALux Simulation Summary in EP Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## customer switchroom / Summary




Height of Room: 2.743 m, Mounting Height: 2.543 m, Light loss factor: 0.80

Values in Lux, Scale 1:61

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 96 | 13 | 170 | 0.139 |
| Floor | 20 | 72 | 17 | 110 | 0.243 |
| Ceiling | 80 | 128 | 8.46 | 924 | 0.066 |
| Walls (5) | 50 | 60 | 8.39 | 170 | / |

**Workplane:**
Height: 0.760 m
Grid: 128 x 64 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.687, Ceiling / Working Plane: 1.334.

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 3 | Extra Built (M) Sdn Bhd SATURN ST-36W-2x18W (Type 1)* (1.000) | 1373 | 1375 | 22.0 |
| | | | Total: 4120 | Total: 4125 | 66.0 |

*Modified Technical Specifications

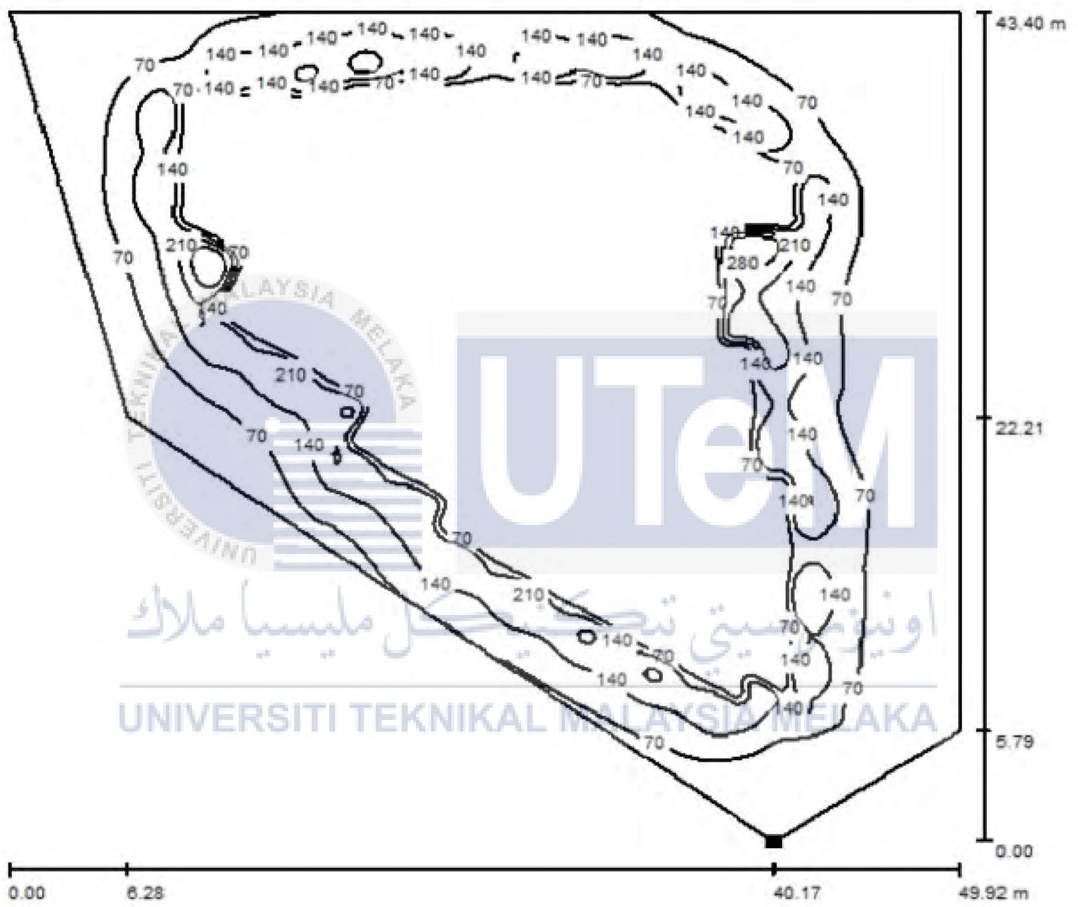
Specific connected load: 4.45 W/m² = 4.63 W/m²/100 lx (Ground area: 14.82 m²)

Figure B12: DIALux Simulation Summary in Consumer Switch Room

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

## Façade Lighting/ Summary






Light loss factor: 0.80, ULR (Upward Light Ratio): 24.5% Scale 1:403

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 32 | EXTRA-BUILT (M) SDN BHD Non-LENS with XPG2 8800 lm (Type 1)* (1.000) | [illegible] | [illegible] | [illegible] |
| | | | Total: 211151 | Total: 211200 | 1920.0 |

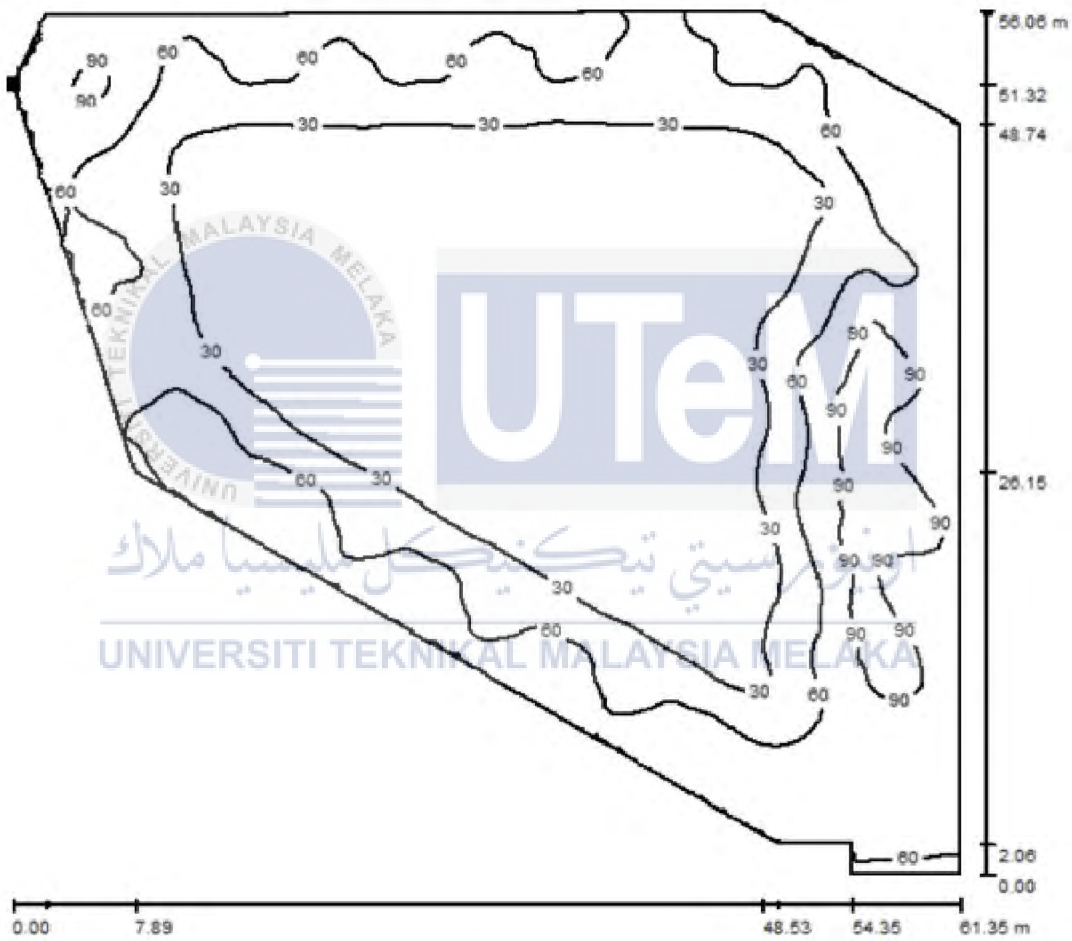
*Modified Technical Specifications

Figure B13: DIALux Simulation Summary in Façade Lighting

**INDOOR LIGHTING** DIALux

Extra-Built (M) Sdn Bhd

**Street Lighting/ Summary**






Light loss factor: 0.80, ULR (Upward Light Ratio): 0.0% Scale 1:520

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 22 | EXTRA-BUILT (M) SDN BHD L712(P-Glass) with XPG2 8500 lm (1.000) | 8499 | 8500 | 80.0 |
| | | | Total: 186977 | Total: 187000 | 1760.0 |

Figure B14 DIALux Simulation Summary in Street Lighting

# APPENDIX C: LIGHTING ANALYSIS AND CALCULATION DATA

| ID | Number of Luminaires | LED Illumination Level (lux) | Non-LED Illumination Level (lux) | LED Electricity Cost (RM) | Non-LED Electricity Cost (RM) | LED Tube Cost (RM) | Non-LED Tube Cost (RM) | LED Labour Cost (RM) | Non-LED Labour Cost (RM) | LED Total Cost (RM) | Non-LED Total Cost (RM) | Total Saving Cost (RM) | Ground area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dining Room (Indoor) | 33 | 211 | 315 | 10.84 | 43.36 | 138.76 | 476.66 | 86.72 | 481.8 | 236.32 | 1001.8 | 765.5 | 171.74 |
| Corridor | 8 | 231 | 363 | 2.63 | 10.51 | 33.64 | 115.55 | 21.02 | 116.8 | 57.29 | 242.86 | 185.57 | 19.91 |
| Kitchen | 35 | 435 | 550 | 16.56 | 45.99 | 343.39 | 505.55 | 91.98 | 511 | 451.93 | 1062.5 | 610.61 | 122.76 |
| Chiller and Freezer Room | 4 | 168 | 212 | 1.89 | 5.26 | 39.24 | 57.78 | 10.51 | 58.4 | 51.64 | 121.44 | 69.8 | 16.12 |
| Dining Room (Outdoor) | 33 | 229 | 235 | 10.84 | 43.36 | 138.76 | 476.66 | 86.72 | 481.8 | 236.32 | 1001.82 | 765.5 | 141.94 |
| Consumer Switch Room | 3 | 96 | 112 | 1.42 | 3.94 | 29.43 | 43.33 | 7.88 | 43.8 | 38.73 | 91.07 | 52.34 | 14.74 |
| EP Room | 1 | 66 | 97 | 0.47 | 1.31 | 9.81 | 14.44 | 2.63 | 14.6 | 12.91 | 30.35 | 17.44 | 2.24 |
| Male Toilet | 4 | 134 | 161 | 0.57 | 5.26 | 7.36 | 57.78 | 10.51 | 58.4 | 18.44 | 121.44 | 103 | 8.89 |
| Female Toilet | 4 | 134 | 161 | 0.57 | 5.26 | 7.36 | 57.78 | 10.51 | 58.4 | 18.44 | 121.44 | 103 | 8.95 |
| Female Prayer Room | 3 | 318 | 330 | 0.99 | 3.94 | 12.61 | 43.33 | 7.88 | 43.8 | 21.48 | 91.07 | 69.59 | 6.69 |
| Male Prayer Room | 3 | 300 | 332 | 0.99 | 3.94 | 12.61 | 43.33 | 7.88 | 43.8 | 21.48 | 91.07 | 69.59 | 6.05 |
| Hose Reel Pump Room | 2 | 108 | 115 | 0.95 | 2.63 | 19.62 | 28.89 | 5.26 | 29.2 | 25.83 | 60.72 | 34.89 | 6.24 |
| Outdoor Lighting (Façade) | 32 | 216 | 250 | 33.64 | 42.05 | 350.4 | 462.22 | 84.1 | 467.2 | 468.14 | 971.47 | 503.33 | 738.53 |
| Street Lighting | 22 | 74 | 77.98 | 23.13 | 28.91 | 240.9 | 317.77 | 57.82 | 321.2 | 321.85 | 667.88 | 346.03 | 2539.21 |

## APPENDIX D- HVAC ANALYSIS AND CALCULATION DATA

| Zone | Area | Ground Area ($m^2$) | Ground Area ($ft^2$) | Power Consumption (Btu/h) | Power Consumption (RT) | Power Consumption (kW) |
|---|---|---|---|---|---|---|
| 1 | Dining Room (Indoor) | 171.74 | 1858.29 | 70000 | 5.83 | 20.51 |
| 2 | Kitchen | 122.76 | 1328.32 | 50000 | 4.17 | 14.65 |
| | Chiller and Freezer Room | 16.12 | 174.38 | 9000 | 0.75 | 2.64 |
| 3 | Consumer Switch Room | 14.74 | 159.53 | 9000 | 0.75 | 2.64 |
| | EP Room | 2.24 | 24.24 | 600 | 0.05 | 0.18 |
| | Male Toilet | 8.89 | 96.28 | 600 | 0.05 | 0.18 |
| | Female Toilet | 8.95 | 96.86 | 600 | 0.05 | 0.18 |
| | Female Prayer Room | 6.69 | 72.35 | 600 | 0.05 | 0.18 |
| | Male Prayer Room | 6.05 | 65.5 | 600 | 0.05 | 0.18 |
| | Hose Reel Pump Room | 6.24 | 67.51 | 600 | 0.05 | 0.18 |

# APPENDIX E- LOAD DEMAND PROFILE

| Item. | Load Category<br>Lighting | Qty. | Load/Unit<br>(kW) | Total Connected<br>Load (TCL)(kW) | D.F. | Maximum<br>Demand (MD)(kW) | Monthly Peak MD<br>(kW) | Monthly Consumption<br>Hours/Month (kW) | Load Factor | Estimated Monthly Consumption<br>(kWh) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | ExtraLED P-LMH 2000-25W | 33 | 0.025 | 0.825 | 1.0 | 0.825 | 0.825 | 594 | 0.80 | 475.2 |
| 1.2 | ExtraLED P-LMH 2000-25W | 8 | 0.025 | 0.200 | 0.8 | 0.160 | 0.160 | 115.2 | 0.80 | 92.16 |
| 1.3 | ExtraLED P-LMH 2000-25W | 7 | 0.025 | 1.138 | 1.0 | 1.138 | 1.138 | 819.36 | 0.80 | 655.488 |
| 1.4 | ExtraLED S-B Series 1x9W | 1 | 0.009 | | | | | | | |
| 1.5 | ExtraLED S-B Series 2x18W | 1 | 0.018 | | | | | | | |
| 1.6 | ExtraLED S-R Series 2x18W | 26 | 0.036 | | | | | | | |
| 1.7 | ExtraLED S-B Series 2x18W | 4 | 0.036 | 0.144 | 0.8 | 0.115 | 0.115 | 82.8 | 0.80 | 66.24 |
| 1.8 | ExtraLED P-LMH 2000-25W | 33 | 0.025 | 0.825 | 0.8 | 0.660 | 0.660 | 475.2 | 0.80 | 380.16 |
| 1.9 | ExtraLED S-B Series 2x18W | 3 | 0.036 | 0.108 | 0.8 | 0.087 | 0.087 | 62.64 | 0.80 | 50.112 |
| 1.10 | ExtraLED S-B Series 2x18W | 1 | 0.036 | 0.036 | 0.8 | 0.029 | 0.029 | 20.736 | 0.80 | 16.5888 |
| 1.11 | ExtraLED P-LMH 850-11W | 4 | 0.011 | 0.044 | 1.0 | 0.044 | 0.044 | 31.68 | 0.80 | 25.344 |
| 1.12 | ExtraLED P-LMH 850-11W | 4 | 0.011 | 0.044 | 1.0 | 0.044 | 0.044 | 31.68 | 0.80 | 25.344 |
| 1.13 | ExtraLED P-LMH 2000-25W | 3 | 0.025 | 0.075 | 0.8 | 0.060 | 0.060 | 43.2 | 0.80 | 34.56 |
| 1.14 | ExtraLED P-LMH 2000-25W | 3 | 0.025 | 0.075 | 0.8 | 0.060 | 0.060 | 43.2 | 0.80 | 34.56 |
| 1.15 | ExtraLED S-B Series 2x18W | 2 | 0.036 | 0.072 | 0.8 | 0.058 | 0.058 | 41.76 | 0.80 | 33.408 |
| 1.16 | ExtraLED M-Series 80W | 32 | 0.08 | 2.560 | 0.8 | 2.048 | 2.048 | 1474.56 | 0.80 | 1179.648 |
| 1.17 | ExtraLED J-Series 80W | 22 | 0.08 | 1.760 | 0.8 | 1.408 | 1.408 | 1013.76 | 0.80 | 811.008 |
| | Total Load (kW) | | | 7.91 | | 6.74 | | 4849.78 | | 3880 |

| Item. | Load Category<br>HVAC | Qty. | Load/Unit<br>(kW) | Total Connected<br>Load (TCL)(kW) | D.F. | Maximum<br>Demand (MD)(kW) | Monthly Peak MD<br>(kW) | Monthly Consumption<br>Hours/Month (kW) | Load Factor | Estimated Monthly Consumption<br>(kWh) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | AIRCOND POINT ( VRV ) | 3 | 22.4 | 67.200 | 1.0 | 67.200 | 67.200 | 48384 | 0.85 | 41126.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Load (kW) | | | 67.200 | | 67.200 | | 48384 | | 41126.4 |
| Item. | Load Category<br>SSO | Qty. | Load/Unit<br>(kW) | Total Connected<br>Load (TCL)(kW) | D.F. | Maximum<br>Demand (MD)(kW) | Monthly Peak MD<br>(kW) | Monthly Consumption<br>Hours/Month (kW) | Load Factor | Estimated Monthly Consumption<br>(kWh) |
| 1.1 | 13A Switch Socket Outlet | 26 | 0.25 | 6.50 | 0.4 | 2.60 | 2.60 | 1872.00 | 0.6 | 1123.2 |
| 1.2 | 2x13A Switch Socket Outlet | 102 | 0.5 | 51.00 | 0.4 | 20.40 | 20.40 | 14688.00 | 0.6 | 8812.8 |
| 1.3 | 15A Switch Socket Outlet (For Hand Dryer) | 4 | 0.5 | 2.00 | 1.0 | 2.00 | 2.00 | 1440.00 | 0.6 | 864.0 |
| 1.4 | 15A Switch Socket Outlet | 8 | 0.5 | 4.00 | 1.0 | 4.00 | 4.00 | 2880.00 | 0.6 | 1728.0 |
| 1.5 | 20A Switch Socket Outlet (Weatherproof Type) | 9 | 0.25 | 2.25 | 1.0 | 2.25 | 2.25 | 1620.00 | 0.6 | 972.0 |
| 1.6 | 1x13A Switch Socket Outlet (Ceiling Type) | 21 | 0.25 | 5.25 | 0.4 | 2.10 | 2.10 | 1512.00 | 0.6 | 907.2 |
| 1.7 | 2x13A Switch Socket Outlet (UPS) | 48 | 0.5 | 24.00 | 0.4 | 9.60 | 9.60 | 6912.00 | 0.6 | 4147.2 |
| 1.8 | 20A TP Isolator Point C/W Isolator | 3 | 7.5 | 22.50 | 1.0 | 22.50 | 22.50 | 16200.00 | 0.6 | 9720.0 |
| 1.9 | 30A TP Isolator Point C/W Isolator | 14 | 10 | 140.00 | 1.0 | 140.00 | 140.00 | 100800.00 | 0.6 | 60480.0 |
| 1.10 | 30A TPN 5-Pin Commando Socket C/W Plug TDP Mounted to 1/4"THK Fibre Base & Isolater Switch to Be Installed at Switch Panel | 9 | 0.5 | 4.50 | 1.0 | 4.50 | 4.50 | 3240.00 | 0.6 | 1944.0 |
| 1.11 | Fireman Switch | 1 | 30 | 30.00 | 1.0 | 30.00 | 30.00 | 21600.00 | 0.6 | 12960.0 |
| | Total Load (kW) | | 50.75 | 292.00 | | 239.95 | | 172764.00 | | 103658 |
| Item. | Load Category<br>Other Electrical Equipment | Qty. | Load/Unit<br>(kW) | Total Connected<br>Load (TCL)(kW) | D.F. | Maximum<br>Demand (MD)(kW) | Monthly Peak MD<br>(kW) | Monthly Consumption<br>Hours/Month (kW) | Load Factor | Estimated Monthly Consumption<br>(kWh) |
| 1.1 | 2 x 13W KELUAR SIGN C/W | 14 | 0.4 | 5.60 | 0.6 | 3.36 | 3.36 | 2419.20 | 0.8 | 1935.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | INTEGRAL GEAR | | | | | | | | | |
| 1.2 | 1 x 13W RECESSED SELF CONTAINED EMERGENCY LIGHT FITTING | 13 | 0.4 | 5.20 | 0.6 | 3.12 | 3.12 | 2246.40 | 0.8 | 1797.1 |
| 1.3 | CEILING FAN POINT C/W REMOTE CONTROL | 3 | 0.4 | 1.20 | 0.6 | 0.72 | 0.72 | 518.40 | 0.8 | 414.7 |
| 1.4 | EXHAUST FAN PANEL | 100 | 0.08 | 8.00 | 1.0 | 8.00 | 8.00 | 5760.00 | 0.8 | 4608.0 |
| | Total Load (kW) | | 1.28 | 20.00 | | 15.20 | | 10944.00 | | 8755 |

# APPENDIX F: CABLE SIZING AND PROTECTIVE DEVICE

| INDOOR LIGHTING | | QTY | Load/unit (kW) | TCL (kW) | DF | MD (kW) | Ib (A) | In (A) | PD | It (A) | Cable Size (mm2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dining Room (Indoor) | ExtraLED P-LMH 2000-25W | 33 | 0.025 | 0.825 | 1.0 | 0.825 | 3.59 | 6 | MCB | 6 | 1.5 |
| Kitchen | ExtraLED P-LMH 2000-25W | 7 | 0.025 | 1.138 | 1.0 | 1.138 | 4.95 | 6 | MCB | 6 | 1.5 |
| | ExtraLED S-B Series 1x9W | 1 | 0.009 | | | | | | MCB | | 1.5 |
| | ExtraLED S-B Series 2x18W | 1 | 0.018 | | | | | | MCB | | 1.5 |
| | ExtraLED S-R Series 2x18W | 26 | 0.036 | | | | | | MCB | | 1.5 |
| Chiller and Freezer Room | ExtraLED S-B Series 2x18W | 4 | 0.036 | 0.144 | 0.8 | 0.115 | 0.50 | 6 | MCB | 6 | 1.5 |
| Consumer Switch Room | ExtraLED S-B Series 2x18W | 3 | 0.036 | 0.108 | 0.8 | 0.086 | 0.38 | 6 | MCB | 6 | 1.5 |
| EP Room | ExtraLED S-B Series 2x18W | 1 | 0.036 | 0.036 | 0.8 | 0.029 | 0.13 | 6 | MCB | 6 | 1.5 |
| Male Toilet | ExtraLED P-LMH 850-11W | 4 | 0.011 | 0.044 | 1.0 | 0.044 | 0.19 | 6 | MCB | 6 | 1.5 |
| Female Toilet | ExtraLED P-LMH 850-11W | 4 | 0.011 | 0.044 | 1.0 | 0.044 | 0.19 | 6 | MCB | 6 | 1.5 |
| Female Prayer Room | ExtraLED P-LMH 2000-25W | 3 | 0.025 | 0.075 | 0.8 | 0.060 | 0.26 | 6 | MCB | 6 | 1.5 |
| Male Prayer Room | ExtraLED P-LMH 2000-25W | 3 | 0.025 | 0.075 | 0.8 | 0.060 | 0.26 | 6 | MCB | 6 | 1.5 |
| Hose Reel Pump Room | ExtraLED S-B Series 2x18W | 2 | 0.036 | 0.072 | 0.8 | 0.058 | 0.25 | 6 | MCB | 6 | 1.5 |
| | 2 X 13w EXIT Sign C/W Integral Gear | 14 | 0.4 | 5.6 | 0.6 | 3.36 | 14.61 | 16 | MCB | 16 | 2.5 |
| | 1 X 13w Recessed Self Contained EMERGENCY Light Fitting | 13 | 0.4 | 5.2 | 0.6 | 3.12 | 13.57 | 16 | MCB | 16 | 2.5 |
| TOTAL | | | | 13.361 | | 8.939 | 38.87 | 40 | MCCB | 40 | |

Figure F1: Cable Sizing and Protective Device (Lighting)

| HVAC | | QTY | Load/unit (kW) | TCL (kW) | DF | MD (kW) | Ib (A) | In (A) | PD | It (A) | Cable Size (mm2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DB 2 | AIRCOND POINT ( VRV ) | 1 | 22.4 | 22.4 | 1.0 | 22.4 | 97.39 | 100 | MCCB | 100 | 4x1C, 50 mm2 PVC Cu, TRUNKING |
| DB 3 | AIRCOND POINT ( VRV ) | 1 | 22.4 | 22.4 | 1.0 | 22.4 | 97.39 | 100 | MCCB | 100 | 4x1C, 50 mm2 PVC Cu, TRUNKING |
| DB 4 | AIRCOND POINT ( VRV ) | 1 | 22.4 | 22.4 | 1.0 | 22.4 | 97.39 | 100 | MCCB | 100 | 4x1C, 50 mm2 PVC Cu, TRUNKING |

Figure F2: Cable Sizing and Protective Device (HVAC)

| KITCHEN ISOLATORS | QTY | Load/unit (kW) | TCL (kW) | DF | MD (kW) | Ib (A) | In (A) | PD | It (A) | Cable Size (mm2) |
|---|---|---|---|---|---|---|---|---|---|---|
| 20A TP Isolator Point C/W Isolator | 1 | 7.5 | 7.50 | 1.0 | 7.50 | 20.00 | 20 | MCCB | 20 | 6 |
| 20A TP Isolator Point C/W Isolator | 1 | 7.5 | 7.50 | 1.0 | 7.50 | 20.00 | 20 | MCCB | 20 | 6 |
| 20A TP Isolator Point C/W Isolator | 1 | 7.5 | 7.50 | 1.0 | 7.50 | 20.00 | 20 | MCCB | 20 | 6 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |
| 30A TP Isolator Point C/W Isolator | 1 | 10 | 10.00 | 1.0 | 10.00 | 30.00 | 30 | MCCB | 30 | 10 |

Figure F3: Cable Sizing and Protective Device (Isolators)

| SSO | QTY | Load/unit (kW) | TCL (kW) | DF | MD (kW) | Ib (A)/unit | In (A) | PD | It (A) | Cable Size (mm2) |
|---|---|---|---|---|---|---|---|---|---|---|
| 13A Switch Socket Outlet | 26 | 0.25 | 6.50 | 0.4 | 2.60 | 20 | 20 | MCB | 20 | 2.5 |
| 2x13A Switch Socket Outlet | 102 | 0.5 | 51.00 | 0.4 | 20.40 | 30 | 30 | MCB | 30 | 4.0 |
| 15A Switch Socket Outlet (For Hand Dryer) | 4 | 0.5 | 2.00 | 1.0 | 2.00 | 20 | 20 | MCB | 20 | 2.5 |
| 15A Switch Socket Outlet | 8 | 0.5 | 4.00 | 1.0 | 4.00 | 20 | 20 | MCB | 20 | 2.5 |
| 20A Switch Socket Outlet (Weatherproof Type) | 9 | 0.25 | 2.25 | 1.0 | 2.25 | 20 | 20 | MCB | 20 | 2.5 |
| 1x13A Switch Socket Outlet (Ceiling Type) | 21 | 0.25 | 5.25 | 0.4 | 2.10 | 20 | 20 | MCB | 20 | 2.5 |
| 2x13A Switch Socket Outlet (UPS) | 48 | 0.5 | 24.00 | 0.4 | 9.60 | 20 | 20 | MCB | 20 | 2.5 |

Figure F4: Cable Sizing and Protective Device (SSO)