LIGHTING SIMULATION OF ENERGY SAVING FOR REST AND SERVICE AREA IN MALAYSIA

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DEDICATION

Special dedication to my mom, lover and best friends

For their endless love, support and encouragement

You know who you are. Thank you so much

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ABSTRACT

Rest and Service Areas (RSA) is to provide a refreshing feeling for traveller to relax and rest. However, it is reported that a large amount of electrical energy was consumed every day at RSAs which reported almost 250 kW/h in a day. Reducing the amount of end-use energy and enhancing energy efficiency in buildings are essential strategies to reduce the carbon emission. Most energy efficiency can be applied for retrofitting purposes such as advancing the electrical appliances, yet less effort of energy saving has been introduced to improve the energy performance at RSA which also known as semi-open space building. Semi-structure interview was conducted among the concessionaire for Malaysia Highway Authority (MHA), and as a result RSA Ayer Keroh located at the North bound highway consumes the highest energy. Hence, this study aims to improve building energy performance at RSA Ayer Keroh Northbound by using quantitative study and energy-saving simulation as retrofitting measures. To achieve this aim four objectives have been lined up; the first objective is to identify the significant factors affecting energy consumption in building for retrofitting initiative, second is determination of existing building energy index and lighting performance at RSA. The third is an investigation of existing lighting characteristic for proposing lighting retrofitting scenarios in reducing energy consumption at RSA. Finally, the evaluation on the optimum lighting energy saving based on the proposed lighting scenarios were identified using DesignBuilder. The process begins with a comprehensive literature review in identifying the most appropriate variables for factor affecting energy consumption for RSA followed by a survey questionnaires method to identify the level of significance of each variable. Factor analysis was performed to reduce the numbers of variables on energy consumption and to prioritize the level of its importance. The results from the factor analysis optimized retrofitting measures, where the end-use factor is the most dominant factor with weightage 49% and indicated that the artificial lighting combined with daylight harvesting was selected as most significant in proposing the energy-saving method. Based on the results, three lighting simulation scenarios were proposed. Scenario 1 is the baseline of the case study in which the light is assumed to be ON for 24 hours, scenario 2 is to reduce the amount of luminaire in the existing layout of Ayer Keroh RSA and scenario 3 is reducing the time operation by using the timer devices. The step in predicting the energy-saving from the lighting control scenarios begins with the use of Autodesk Revit software to model the architectural template and MEP template for the building. Timer effect was modelled in DesignBuilder software by creating a new schedule template. The simulation individually was performed on each scenario of lighting to predict the energy consumption. The results showed a high opportunity of energy-saving with 24% and 42 % total annual lighting load reduction respectively for scenario 2 and 3. Besides that, the results were estimated about RM 84,000 annually can be saved from electricity cost and reduced about 10 metric tonnes of carbon emission.

ABSTRAK

Kawasan Rehat dan Rawat (RSA) adalah bertujuan memberikan kesegaran kepada pengunjung untuk beristirehat. Namun, tenaga elektrik yang digunakan di Kawasan Rehat dan Rawat adalah sebanyak 250kW/h sehari kerana perkhidmatan secara 24 jam oleh penguna lebuhraya. Pengurangan jumlah tenaga melalui pengurangan jumlah penggunaan akhir dan pengunaan kecekapan tenaga di bangunan adalah strategi penting untuk mengurangkan pelepasan karbon. Sebilangan besar kecekapan tenaga telah diterapkan melalui cara pemasangan, namun indikator pengurangan tenaga kurang diperkenalkan bagi meningkatkan prestasi pengunaan tenaga di RSA *Semi-structure interview* telah dijalankan dikalangan syarikat konsesi Lembaga Lebuhraya Malaysia (MHA). Kawasan RSA Ayer Keroh yang terletak di bahagian lebuhraya sempadan utara didapati antara yang menggunakan tenaga elektrik yang tertinggi. Oleh itu, kajian ini bertujuan untuk mengenal pasti amalan kecekapan tenaga terbaik untuk kawasan RSA Ayer Keroh Arah Utara dengan menggunakan kajian kuantitatif dan simulasi penjimatan tenaga sebagai langkah baik pulih. Untuk mencapai tujuan ini, empat objektif telah disenarai; objektif pertama adalah untuk menentukan tahap signifikan pada faktor yang mempengaruhi penggunaan tenaga, kedua adalah menentukan indeks tenaga bangunan dan prestasi dalaman yang ada di Kawasan RSA. Ketiga, ciri pencahayaan penyelidikan bagi mencadangkan senario pemasangan lampu yang terbaik bagi mengurangkan penggunaan tenaga di Kawasan Rehat dan Rawat. Akhirnya, Simulasi berdasarkan tiga senario kecekapan tenaga pencahayaan dijalankan dengan menggunakan 'DesignBuilder' bagi mengenal pasti penjimatan tenaga yang terbaik. Prosesnya tinjauan literatur yang komprehensif telah dijalankan bagi mengenal pasti pemboleh ubah yang sesuai untuk faktor yang mempengaruhi penggunaan tenaga di Kawasan RSA diikuti dengan kaedah soal selidik tinjauan untuk mengenal pasti tahap signifikan setiap pemboleh ubah. Analisis faktor telah dikenalpasti bagi mengurangkan bilangan pemboleh ubah mengikut kepada penggunaan tenaga dan tahap kepentingannya.. Hasil dari analisis faktor langkah-langkah pemasangan merupakan faktor dominan, dengan bacaan 49% dan cadangan melalui cara pencahayaan buatan yang digabungkan dengan penuaian pengcahayaan disiang hari adalah paling signifikan didalam bagi kaedah penjimatan tenaga. Selain daripada itu,tigasenario simulasi pencahayaan telah dicadangan. Senario 1 adalah garis dasar kajian kes yang lampu dianggap menyala selama 24 jam, senario 2 adalah mengurangkan jumlah lampu dalam susun atur yang ada pada RSA Ayer Keroh dan senario 3 adalah mengurangkan operasi waktu dengan menggunakan alat permasa. Bagi meramal penjimatan tenaga ini,Perisian AutoDesk Revit dengan memodelkan bangunan RSA menggunakan templat MEP telah direka. Kesan pemasangan dimodelkan dalam perisian 'DesignBuilder' dengan meletakkan ramalan templat masa. Kemudian 'DesignBuilder' akan menjalankan simulasi secara berasingan pada setiap senario pencahayaan bagi meramalkan penggunaan tenaga. Hasil dari tiga simulasi kawalan pencahayaan dari perisian 'DesignBuilder' menunjukkan peluang penjimatan tenaga yang tinggi dengan pengurangan beban pencahayaan tahunan sebanyak 24% dan 42%, masing-masing bagi senario 2 dan 3. Selain itu, keputusan menunjukkan sebanyak RM 84,000 berjaya dijimatkan setiap tahun dari kos elektrik dan ini dapat menjimatkan 10 metrik tan pelepasan karbon.

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LIST OF ABBREVIATIONS

AM	-	Analytical Model
BEI	-	Building Energy Index
BIM	-	Building Information Modelling
BEM	-	Building Energy Model
BEPS	-	Building Energy Performance Simulation
EPBD	-	Energy Performance Building Directives
EAM	-	Energy Analytical Model
FA	-	Factor Analysis
FS	-	Factor Score
GBCA	-	Green Building Council Australia
GHG	-	Green House Gas
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
LED	-	Light Emitting Diode
LEED	-	Leadership in Energy and Environment Design
NZEB	-	Net Zero Energy Building
NZEH	-	Net Zero Energy Home
SDGs	-	Sustainable Development Goals
SPSS	-	Statical Packages for Social Study
UTM	-	Universiti Teknologi Malaysia
XML	-	Extensible Markup Language

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide
kW	-	Kilowatt
kWh	-	Kilowatt hour
kBtu	-	Kilowatt British Thermal Unit
$kWh/m^2/year$	-	Kilowatt hour per meter square per year
m^2	-	Meter square
P	-	Baelett's Test of Sphericity
W	-	Watt
^0C	-	Degree Celcius
RM	-	Ringgit Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

As the world energy consumption is becoming inadequate, building energy efficiency and energy conservation is a rising topic for all researchers around the globe (T. Zhu et al., 2017). Reducing the amount of energy consumption in a building is a compulsory job to mitigate the relevant amount of Greenhouse Gases (GHG). The small building is relatively low in energy consumption when compared to a huge or high-rise building due to a large amount of electrical appliance. However, some small building provides service in 24 hours, which results in high energy consumption due to the huge amounts of electrical appliances in the building (Krem, 2012). Rest and Service Areas, also are known as RSAs or R&R are provided for passenger's stop points during a long journey of travelling (Farinee & Rozana, 2012). RSAs can be found in every 80 kilometres or 100 kilometres distance of travelling and provided multiple facilities such as restaurant, toilet, pray room, petrol station, children's playground, ATMs, and public telephone. There is a total of 24 RSAs can be found in PLUS highway in both Northbound and Southbound Malaysia (Chester, 2014). All the activities use to service in these areas are categorized into operation energy for highway energy consumption (Farinee & Rozana, 2012). This end-use energy consumption is enormous and emitted a related amount of carbon emission. The reduction of energy use in building RSAs can be made by energy efficiency practices such as refurbishment and the use of renewable sources is the root to achieve the reduction in fossil fuel consumption and Greenhouse Gas emission (Ferrari & Beccali, 2017). Energy-efficient measure for the refurbishment of one existing building varies from one another due to the different characteristic of each building such as its function, service provided, and the operation hours itself.

According to (N. Abidin, 2019) refurbishment or retrofitting decision making criteria of the existing building comprise of lean energy, green technology, and clean energy. The lean energy retrofitting potential includes daylighting (side lighting), daylighting (roof lights), building orientation, building massing, building shading devices, plant shading, green roof, green wall, glazing, thermal mass, wind-ventilation (cross ventilation), and wind ventilation (stack ventilation). While green technology retrofitting is the adoption of current technology to the existing equipment, machinery and appliances. And clean energy is the consideration of renewable energy such as solar photovoltaic, wind turbine, and electric hydropower. Numerous studies have been carried out to improve energy efficiency and energy conservation through the retrofitting decision. In recent years, the magnitude of energy consumption in buildings seems to crest from the normal demand and that has to be carefully addressed through implementing energy conservative and energy management techniques (Parameshwaran et al., 2012). Parameshwaran et al., (2012) emphasized that the awareness of energy end-user is important as other categories of global total energy consumption which consists of economic growth, pricing nature, and type of region. Thus, the end-user awareness for energy conservation is one of the most crucial parts of to improve energy performance.

Energy efficiency refers to the amount of energy required to generate or produce the desire to end products (Parameshwaran et al., 2012). In other words, energy efficiency is a parameter that indicates the minimum level of energy usage for performing an associate task and that largely depends on the state-of-the-art technology and production processes. The state of the art of technology can be referred to as retrofitting technology, which retrofitting technology scenarios have cover three important aspects such as economics, environmental, and social (Najihah et al., 2015). However, the retrofitting project has some challenges in terms of the expensive cost of instalment and the long-term payback period (Tahir et al., 2016). To make a decision for retrofitting, there are some important steps to be conducted such as identifying the characteristics of buildings and energy auditing. While energy conservative is more to identifying the energy management techniques that would reduce the demand for energy (Parameshwaran et al., 2012). Energy auditing is part of the energy conservative techniques, the investigation of the energy usage in a certain place or area, in which it shows a clear image of energy consumption in building and cost. It

also plays a crucial part in the early stage of the refurbishment program to determine the potential's spot of energy-saving and building energy performance (Ma et al., 2012).

Energy conservation and energy efficiency practice by critical considered on the selection of retrofitting methods in RSAs building is a key strategy to reduce the amount of energy-consuming. Thus, this study focuses on the refurbishment strategy on one selected RSA building along the Malaysian's Highway by critically analysing the feasibility of potential energy saving for energy efficiency purpose.

1.2 Problem Statement

RSAs service is to provide a refreshing feeling for the traveller to relax and rest (Binti & Zakaria, 2012) and in term of operation, the services provided in 24 hours to traveller along the highway. RSA which consumed lots of energy inefficiency has the opportunity to implement energy efficiency to encourage energy conservation of users. Huge energy was consumed every day at Rest and Service Areas such as artificial lighting, water consumption and HVAC (Heating, ventilation, and air conditioning) system. However, user awareness of energy-saving is arguable and there are opportunities for appropriate behaviours toward energy using at RSAs, which can be improved. For example, the fan and lighting in the common dining area are operating almost 24 hours a day even there is no traveller in the areas without proper energy conservative manner or advance lighting and fan sensor system to reduce the energy demand (Farinee & Rozana, 2012). Thus, this end-user behaviour causes a huge amount of energy wastage daily at RSA which demand a proper retrofitting measure.

Previous research conducted by (Farinee & Rozana, 2012) determined the potential of retrofitting of RSAs at highway Malaysia by analysing the energy consumption and seeking the cause of energy wastage. The study found out that there are some activities regarding to energy wastage at RSAs Pagoh (North and South), Machap (South) and Gelang Patah (North and South). The three main causes that leads to energy wastage are first is spotlight was not efficient at the parking area and

secondly fan is operating even there are no occupants in the areas. Thirdly, artificial lighting is operation hours. The results of the study show energy can be significant save by reducing the number of air-conditioners at Machap Northbound and retrofitting on a variable refrigerate flow system on the HVAC system. Equipment retrofitting such as LED lighting and dimming system also helps in reducing the amount of energy use and improving energy performance.

A preliminary study on the problem has been conducted by a semi-interview with high way authority who responsible for managing Rest and Service Areas for energy auditing purposes. The interview is to figure out the current status of energy consumption and energy behaviour at RSAs Ayer Keroh Northbound. The results from the preliminary study showed that the Building Energy Index (BEI) at RSAs such as Ayer Keroh is a range between 290 kWh/m2/year to 320 kWh/m2/year from 2015 to 2017 which lighting consumption is the dominant contribution to the overall energy consumption. In Malaysia Standard for energy efficiency and use of renewable energy for non-residential building (Malaysia & Standard, 2012), BEI of office building range of 200 to 250 kWh/m^2/year and BEI is commonly used for comparing energy used in building. As a result of fact, the higher number of BEI simply means that the building is consumed a high amount of energy and there is room to improve energy performance to eliminate the energy wastage.

Hence, there is still a lack of studies that are associated with energy efficiency focusing on energy simulation at highway RSA for reducing energy load. A few studies conducted on RSA retrofitting strategies; the outcome of the studies only show the potential retrofitting process. This study will focus specifically on energy consumption and analysis at RSA Ayer Keroh Northbound by seeking building energy efficiency measure, which is suitable for refurbishment toward a better energy performance.

1.3 Research gap

As the world population keeps rising, the energy demand is becoming the world most challenging issue, which consequently creates a rising topic for all researchers around the globe (T. Zhu et al., 2017). RSA service is provided 24/7 resulting in a large amount of energy consumption consumed daily. RSA Ayer Keroh is situated at KM 205.1 along PLUS Expressways, Alor Gajah, Melaka. This food court's building of RSA can be categorized as a semi-open space building due to its building envelop characteristic.

This public facility is built as part of the development of the Interstate Highway system and as a result, many are reaching the end of their useful life or require renovations. This ageing facility contributes to poor energy performance and rising operational costs of the highway sector (Hirsch, 2014). Even though there are few studies that focus on the retrofitting measure for RSA, but there is still a lack of study that emphasizes building energy simulation. Modernizing the retrofitting measure by using computerized simulation to predict energy saving is a compulsory task for maintaining the facility performance and to find the optimum measure for energy saving (Ascione *et al.*, 2017).

Thus, building energy simulation (BES) is needed to performed building energy calibration for RSA and seeking the best retrofitting measure. Building Information Modelling (BIM) has a direct connection with energy modelling which allow the potential solution for energy efficiency and also enables the process of preparing building energy performance simulation (BEPS). This study will be introducing the building energy performance simulations (BEPS) in RSA Ayer Keroh for the first time to find the optimum energy saving.

1.4 Research Aim and objectives

This study aims to improve building energy performance at Rest and Service Area Ayer Keroh Northbound by analysing the building retrofitting scenarios. The objectives of the research are:

1. To identify significant factors affecting energy consumption in building to retrofitting initiative in RSA Ayer Keroh.

2. To determine the existing building energy index and lighting performance at RSA.

3. To investigate the existing lighting characteristic for proposing lighting retrofitting scenario.

4. To evaluate the optimum lighting energy saving based on the proposed lighting scenarios by using DesignBuilder.

1.5 Scope of Study

The scope of this study is to focus on the method to save lighting consumption for open space building specifically RSA in Malaysia. The objectives of this study are achieved by taking into consideration the scope of data collection as listed below. Rest and Service Area Ayer Keroh northbound was selected as the case study due to the lack of energy management practice in the area. The preliminary study revealed that the energy conservation practice in the building is relatively low which leads to energy wastage. The energy efficiency strategy is proposed during the operation period of RSA for reducing the operation cost of the Highway sector and also increase building performance for this public service facility.

The limitation of the questionnaire survey conducted is with the sample size as

it is limited based on the registration of professional engineers. The questionnaire was distributed only to engineers and experts who working under highway contractor companies. The experience involved with green development is the crucial key to the answer to the questionnaire. The respondent's selection is also based on their knowledge and involvement in green building and energy efficiency technology. This research aim is to find an appropriate energy-efficient strategy based on the result achieved from the questionnaire analysis combined with the computerized-simulation to define the building energy performance.

The data set was therefore analysed by using SPSS software for statistical study and factor analysis is the main method to define the significant factor affecting energy consumption in RSA building. The factor analysis conducted on the variables that affecting energy consumption which covers design factor, non-design factor, end-use and renewable technology which gather from the literature review. Therefore, the result from factor analysis will eliminate the less significant variables and prioritize the variable, which is significant for energy consumption and energy-efficient strategies.

The energy-efficient strategy in this study is lighting control technology which natural daylighting harvesting is selected as the main energy-saving measure due to the result from factor analysis and the lighting performance of the existing condition of the building. The energy simulation is only focused on lighting simulation to see energy saving. Besides, the simulation is performed only in the dinning zones of RSA Ayer Keroh Northbound due to the potential of natural daylight harvesting in the area. Last but not least, the simulation period is run for one whole year to see total energy consumption and the energy-saving from the energy-efficient strategy.

1.6 Significant of Study

The study is beneficial for promoting green building technologies such as lighting control technology into existing buildings in RSAs by implement energy efficiency to improve energy performance. RSA building can be categorized as an

open space building due to its building envelope characteristic thus lighting control technology by harvesting the daylighting is an optimum energy efficient strategy for this facility. The enormous amount of energy will be saved from energy wastage and result in carbon emission reduction if the study is introduced into application in this Rest and Service Areas building. In addition, this study also attempts to practice sustainable living by reducing the energy use from fossil fuel and upgrade the highway facilities toward a green practice.

Besides, to come up with building retrofitting solutions, some retrofitting activities are conducted in this study such as energy auditing, optimize the retrofitting selection, and measurement of energy-saving by simulation. Critical analysis such as factor analysis and energy optimization in Revit software is conducted for retrofitting strategies to ensure an efficient and proper refurbishment is made on the RSA. The output from the factor loading from SPSS in this study provides prioritize-option for the retrofitting selection technologies such as integrate with daylight harvesting and operation hours of electrical appliances.

Furthermore, the study will estimate the lighting energy consumption from the proposed technology to optimize the energy-saving from lighting. The energy that can be reduced from the proposed lighting technology also can save some amount of electric bill costs. The study will also contribute to Malaysia Highway Government (MHA) to achieve the goal of carbon emission reduction by 45% by the year 2030 (Susskind et al., 2020).

1.7 Organization of the Thesis

This thesis consists of five chapters and the arrangement of the chapters is presented as follows:

Chapter 1: Introduction – discuss the background of the study, aim, and knowledge gaps relevant to this research. Research problem, research objectives,

research scopes, and the significance of the research also includes in this chapter. The chapter is discussing the necessity of conducting this research.

Chapter 2: Literature review – Presents a comprehensive literature review of published paper or thesis by other researchers and scholars related to the field of energy efficiency in building. The supporting knowledge on building toward sustainable energy, building retrofitting technologies, energy auditing in retrofitting technology, factors affecting energy consumption in non-residential buildings, and simulation on building energy consumption is consistent in this chapter. The literature review of this thesis is used as supporting knowledge to achieve the aim and objectives.

Chapter 3: Research Methodology – illustrates the detail of the methodology used in this study by presents the research design and procedures, research operation framework, research boundary, sampling procedures, preparation of the questionnaire, the method used for analysis on the variable affecting energy and lighting energy consumption simulation procedures in Autodesk Revit and Design Builder software incorporates with Energy PLUS calculation engine. The proposed retrofitting scenarios and the simulation framework also presented in the chapter. Design-Builder is selected for simulation in this study as it has control procedures that ensure the results are more accurate comparing to Energy PLUS stand-alone engine (El-Darwish & Gomaa, 2017).

Chapter 4: Result and Discussion – Presents the process of analysis of quantitative and qualitative data through the data collection procedure. The data collection procedures from the RSA officer to analyze the building energy performance and data collection from highway engineers under PLUS Highway are presented in this chapter. The data obtained from the survey were analyzed to fulfill the objective of this study. The analysis tool for this stage includes Statistics Packages for Social and Science (SPSS) and Microsoft Excel Software. Next, the energy analysis tools in this study include Autodesk Revit to build up the 3D architecture model and lighting model. Design-Builder was used to simulate lighting energy consumption for the proposed retrofitting scenarios. The data are illustrated in the form of a graph, pie chart, and table to facilitate the understanding of the study results.

Chapter 5: Conclusion and Recommendation - Concludes the thesis by providing a summary of the results in this research that involving the review of the achievements in the research objectives, theoretical and practical contributions, limitations, and future research suggestions.

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LIST OF PUBLICATIONS

Factor Analysis on Variables Affecting Energy Consumption for Retrofitting Initiative at Rest and Service Area Malaysia.

Simulation on Lighting Energy Consumption based on Building Information Building for Energy Efficiency at Highway Rest and Service Area Malaysia.

Carbon Footprint Calculator of Highway Pavement Rehabilitation: The Quantification of Carbon Emissions per unit Activity.

Review on the Method for Carbon Footprint Calculation of Highway Development.

Carbon Footprint Calculator for Malaysia Green Highway Index.

Energy and Economic Benefits of LED Adoption in Malaysia Highway Lighting System.

Adoption of Building Information Modelling in Malaysia Road Construction.