A COMPARISON STUDY ON THE ECONOMIC PERFORMANCE OF CONVENTIONAL STREETLIGHT AND SOLAR STREETLIGHT IN BATU PAHAT

LIEW POK HUAI

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ABSTRACT

Streetlight is an essential public service that provides a safer environment to traffic users during night-time. However, improper streetlights cause some traffic and public security problems. A comparative study developed to compare the economic performance between conventional streetlight and solar streetlight in Batu Pahat. The first objective is to identify the economic performance issues of the streetlight. Fifty previous research articles were analyzed and fourteen different economic performance issues of streetlight were identified, the top two serious issues are the high electricity consumption and high bills consumption. The second objective is to compare the economic performance of solar streetlight and conventional streetlight by case study strategy, in terms of life cycle cost and payback period. Based on the calculation result, the life cycle cost of solar streetlight is 35.85% and 36.31% cheaper than conventional streetlight in both case studies. Solar streetlight has the cost and energy payback period of 50.15 years and 1.80 years in Case Study 1, meanwhile, 22.79 years and 1.75 years in Case Study 2. The third objective is to verify the most practical types of streetlight based on the economic performance by interview strategy. A total of five experts was involved in this study, while results from interview sessions show that solar streetlight is the most practical type of streetlight based on economic performance. The findings of this study lead to a better understanding and considerable optimization of energy usage and become more cost-effective for both commercial and governmental sectors such as planners, architects, and consultants.

ABSTRAK

Lampu jalan adalah perkhidmatan awam yang penting untuk menyediakan persekitaran yang selamat pada waktu malam kepada pengguna lalu lintas. Namun, lampu jalan yang tidak mengikut piawaian menyebabkan beberapa masalah lalu lintas keselamatan awam. Satu kajian perbandingan telah dibuat untuk membandingkan prestasi ekonomi antara lampu jalan konvensional dan lampu jalan solar di Batu Pahat. Objektif pertama adalah untuk mengenalpasti masalah prestasi ekonomi lampu jalan. Lima puluh artikel penyelidikan telah dianalisis dan empat belas masalah prestasi ekonomi lampu jalan telah dikenalpasti, dua masalah yang paling serius adalah penggunaan elektrik yang tinggi dan penggunaan bil yang tinggi. Objektif kedua adalah membandingkan prestasi ekonomi lampu jalan solar dan lampu jalan konvensional dengan kaedah kajian kes, dari segi pengiraan kos kitaran hidup, tempoh pembayaran balik. Berdasarkan hasil pengiraan, kos kitaran hidup lampu jalan solar adalah 35.85% dan 36.31% lebih murah daripada lampu jalan konvensional dalam kedua-dua kajian kes. Lampu jalan solar mempunyai tempoh pembayaran balik kos dan tenaga, 50.15 tahun dan 1.80 tahun dalam Kajian Kes 1, sementara itu, 22.79 tahun dan 1.75 tahun dalam Kajian Kes 2. Objektif ketiga adalah mengesahkan jenis lampu jalan yang paling praktikal berdasarkan prestasi dengan menggunakan kaedah temuduga. Terdapat lima pakar yang terlibat dalam kajian ini, sementara hasil dari sesi temuduga dengan para pakar menunjukkan bahawa lampu jalan solar adalah jenis lampu jalan yang paling praktikal berdasarkan prestasi ekonomi. Kejayaan penyelidikan ini membawa kepada pemahaman yang lebih baik dan pengoptimuman penggunaan tenaga yang besar dan menjadi lebih menjimatkan kos untuk sektor komersial dan kerajaan seperti perancang, arkitek, dan perunding.

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LIST OF SYMBOLS AND ABBREVIATIONS

Ai	Material's area (m^2)
ASEAN	Association of Southeast Asian Nations
C	Initial cost capital
CO_2	Carbon dioxide
Ccc	Capital cost of conventional components
Cce	Capital cost of energy components
CE	Cost of electricity (£ / kWh)
CH	Cost of heating energy (£ / kWh)
Ci	Material's cost (£ / m^2)
Di	Material's density (kg/m^3)
E_m	Primary energy require to produce materials
E_{mf}	Primary energy require to manufacture PV system
E_t	Primary energy require to transport materials
E_i	Primary energy require to install the system
E_{mg}	Primary energy require for end-of-life management
E_g	Annual electricity generation
E	Electricity energy (kWh)
EE	CO_2emission due to electricity fuel (kgCO_2/kWh)
EH	CO_2 emission due to heating fuel (kgCO_2/kWh)
GST	Government Service Tax
i	Number of material
IC	Total initial cost capital
IEA-PVPS	International Energy Agency Photovoltaic Power System Programme

j	Number of surface of the i'th material
Ki	Material's embodied CO_2
KWTBB	Kumpulan Wang Tenaga Boleh Baharu
LCC	Life cycle cost
LED	Light-emitting diode
Li	Material's waste and transport and maintenance cost coefficient
lm	Lumens
Mi	Material's waste, transport, construction, maintenance and demolition CO_2 coefficient
n	Lifespan of equipment (years)
N	Population size
OC_t	Operation cost in year t
PV	Photovoltaic
$PV_{RECURRING}$	Present value of all recurring costs
$PV_{RESIDUAL-VALUE}$	Present value of the residual value at the end of life cycle period
r	Discount rate
Rc	Repair cost
Rece	Replacement cost
S	Sample size
S	Space heating energy (kWh)
Sdn. Bhd.	Sendirian Berhad
t	Year for operating cost
Ti	Material's thickness (m)
UNFCCC	United Nations Framework Convention on Climate Change
UTHM	Universiti Tun Hussein Onn Malaysia
W	Water heating energy (kWh)
Y	Number of years
$\|Ic\|$	Absolute installation cost
$\|O\&Mc\|$	Absolute operation and maintenance cost

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CHAPTER 1

INTRODUCTION

1.1 Background

The world's energy demand is continuing to rise substantially as a result of population expansion and industrialization. It was stated that the population of developing countries has expanded by 2 billion people in just one generation (Kannan & Vakeesan, 2016). According to Li & Makumbe (2017), global lighting demand would increase by 80% in 2030 compared to 2005 (Li & Makumbe, 2017). Malaysia's energy consumption is also expected to rise by 4.8% by 2030 (Yunus, 2017). Increased energy demand poses significant hurdles for enterprises in terms of energy generation, especially in light of pollution concerns and a desire for renewable technology.

Because of the expanding population in cities, lighting demand will be 80% more in 2030 than it was in 2005 (Li & Makumbe, 2017). As a result, the energy consumption of streetlight will increase dramatically in the future. Furthermore, Li & Makumbe (2017) claimed that increasing the use of streetlights will result in economic growth, a 20% reduction in crime, and a 35% reduction in traffic accidents (Li & Makumbe, 2017). In addition, a randomised controlled trial involving about 40 public housing developments designed by the Mayor's Office of Criminal Justice, the New York City Police Department, and the New York City Housing Authority, Crime Lab, found that when lighting levels were increased, crime decreased by about 36% (Chalfin *et al.*, 2019).

During the night and darkness, streetlights are crucial amenities that brighten roadways and offer required visibility for motorists and pedestrians. Additionally, streetlight can serve to enhance traffic conditions, reduce driver fatigue, increase road capacity, and ensure traffic safety (Endd, 2017). Because of the importance and extended operating periods of streetlights, their economic performance is increasingly being studied in order to improve their efficiency.

This research aimed to create a comparison of the economic performance of conventional and solar streetlights. According to the research by Backhouse & Medema (2009), “economic” refers to the social sciences that deal with trade, industry, and money, as well as the concept of profit (Backhouse & Medema, 2009). And the definition of the term "performance" is how well or badly for something or how well or badly something works, it is also defined as the act or process of performing a task (Ghalem *et al.*, 2016). The economic performance of a streetlight is characterised in this study as to how profitable the streetlight is in terms of energy efficiency and cost consumption, as determined by calculating the streetlight's life cycle cost, cost payback time, and energy payback period.

1.2 Problem statement

Despite urban occupying only 2% of the planet's area, urban development is responsible for 80% of global gas emissions and 75% of worldwide energy usage (Cacciatore *et al.,* 2017). Lighting facilities accounted for over 19% of world energy use, with 8% of that going to outdoor lighting, particularly streetlight (Perandones *et al.*, 2014). A streetlight is an important community utility that provides safety and protection to the public at night. However, streetlight has some significant drawbacks, including low economic performance, electrocution, as well as health and environmental impact. Only the topic of the low economic performance of streetlights has been addressed in this study. Low energy efficiency and high cost consumption of streetlights explain the poor economic performance of streetlights. The lower the energy efficiency of streetlight, it required more electricity to turn on the light bulb. The more the electricity being use, the greater the bills or costs associated with it.

According to Gan (2020), there are currently 300 million streetlights in use around the world. In Taiwan, streetlight facilities consume 40% of the city's energy consumption, and the Taiwan government has begun replacing conventional streetlights with Light-Emitting-Diodes (LED) to reduce electricity costs (Gan, 2020). Streetlight accounts for around 40% of overall energy usage in cities, according to reports from the European Commission (2013) & Mohamed (2013). For example, 24,000 streetlights in Graz consume around 8.5 million kWh of electricity on a yearly basis, equating to 4.95 million ringgit Malaysia in electricity consumption and 7.65 million ringgit Malaysia in maintenance costs. According to Li & Makumbe (2017), streetlight in Quezon City, Philippines, accounts for 65% of the city's electricity costs (Li & Makumbe, 2017). Lighting facilities accounted for 18% of total electricity usage in the United States (Dzombak, Kasikaralar & Dillon, 2020). This completely demonstrates the need of streetlight; streetlight causes significant energy consumption and overhead; this also demonstrates that today's streetlight still has low economic performance issues.

The Former Minister of Housing and Local Government Malaysia, Zuraida Kamaruddin, announced on April 14th, 2019 that the Ampang region had been chosen as a programme pioneer for installing CCTV and streetlights to lower the crime rates, which would begin in May (Idris, 2019). On October 17th, 2017, the Sarawak government was also allocated an amount of RM14.64 million to carry out the Village Streetlight project under the eleventh Malaysia Plan (Desk *et al.*, 2017). In the same year, the state government of Negeri Sembilan set aside RM16 million for streetlight installation (Hamdan, 2017). In a news conference at Lebuh McNair in George Town in July 2019, State Housing, Town, Country Planning, and Local Government Committee Chairman Jagdeep Singh Deo stated that Penang state intends to push forward its Green Agenda to attain 100% LED for streetlight (The Star Online, 2019). The Head of the Kepong Community Centre, Yee Poh Ping, has reported the issue of defective streetlights along the Middle Ring Road 2 (MRR2) to the Public Works Department, according to the news posted by Lim (2020). Motorists travelling at night were put at risk by the defective lights (Lim, 2020). As stated, streetlight is extremely important for both public and private sectors. The Malaysian government has dedicated several times to the building and development of high economic performance kind of streetlight, and public complaints have once again completely justified the fact that today's streetlight is still suffering from low economic performance. Mostly streetlights in Malaysia nowadays consume a lot of electricity, which is not only bad for the environment but also expensive.

1.3 Research questions

The research questions of this study are:

1. What are the economic performance issues of streetlight?
2. What are the differences in economic performance in both conventional and solar streetlight?
3. Which types of streetlight are the most practical based on the economic performance?

1.4 Objectives

This study aims to highlight the economic performance of streetlight in terms of cost consumption and energy efficiency. Therefore the objectives that will satisfy the study are:

1. To identify the economic performance issues of a streetlight.
2. To compare the economic performance of solar streetlight and conventional streetlight.
3. To verify the most practical type of streetlight based on the economic performance.

1.5 Scope of Study

To achieve the objectives mentioned above, this study was conducted within the following scopes:

a) The economic performance of streetlight is defined as how profitable the streetlight is in term of energy efficiency and cost consumption by calculating life cycle cost, cost payback period and energy payback period of a streetlight.
b) The area of research is limited only to Batu Pahat, Johor.
c) The qualitative method is selected as a research approach; it involves research strategies of case study and interview.
d) The typology of streetlights in this study are being focused on conventional streetlight and solar streetlight for accommodation and district area.
e) Due to the collected data are confidential, the case study organizations are name as Case study organization 1 and 2; locations of each organization are name as Location 1 and 2. Solar streetlight company is name a Solar Streetlight Company 1.

1.6 Significance of Study

Streetlight has undergone extensive research in order to attain its excellent economic performance, which includes excellent energy efficiency and cost savings. Ergüzel (2019), Marino *et al.* (2017), and Lau *et al.* (2015), for example, used traffic density to boost the energy efficiency of streetlights (Ergüzel, 2019; Marino *et al.*, 2017; Lau *et al.*, 2015). Researchers, on the other hand, have paid very little attention to a comparison study on the economic performance for conventional and solar streetlights. Two case study organisations represent two distinct numbers of streetlight units in this study, intended to make the comparison between conventional and solar streetlights more apparent. By giving precise information and calculating power usage and total cost investment, this study provided a clear picture of energy efficiency and cost consumption.

The success of this research could lead to a better understanding and considerable optimization of energy usage, as well as become more cost-effective for both the commercial and governmental sectors. This study's project also intends to provide added value information services for both sectors For instance, the Malaysia Public Works Department (JKR) may utilize this study as a source of perspective to plan better answers for city streetlights. Additionally, Tenaga Nasional Berhad (TNB) Batu Pahat likewise can work together with JKR to create and further develop the streetlight facilities in Batu Pahat District. This study gives a piece of knowledge for a better approach for business and activity of streetlights while keeping up with the streetlight facilities could likewise be arranged among sellers and clients. This concentrate likewise is exceptionally significant and can possibly permit researchers and general society to comprehend the strength and shortcoming of utilizing solar streetlights and conventional streetlights. Notwithstanding the limits of this review, it could prompt greater improvement and progress for future examination.

1.7 Thesis layout

The brief introduction of the chapter layout is explained in this section. A total of 5 chapters in this study, introduced the comparison study on the economic performance of conventional streetlight and solar streetlight in Batu Pahat.

Starting with Chapter 1 which gave an introduction for a whole research study about the research background, problem statement, research questions, objectives of this study, the scope of the study, and the significance of the study.

The in-depth literature reviews in Chapter 2 purposely provided the foundation of knowledge on this study. This chapter briefly introduced the conventional streetlight and solar streetlight and analyses the related previous research study. From the analysis, chose useful key information as technical support for this study. Also, objective 1 of this study achieved in this chapter.

Chapter 3 provided the methodology of the whole study focuses on the steps and process to achieve the three objectives of this study. This chapter consists of three phases. Phase 1 is the identification of current issues; it is the schematic analysis strategy in Chapter 2. Phase 2 involved developing the comparison study between conventional streetlight and solar streetlight using document analysis and calculation methods. Finally, Phase 3 involved the verification process of economic performance for streetlight by using the interview method.

Chapter 4 is the results of the study. In this chapter, the background of two case studies are introduced at the beginning, and then the collected research data from both case study organisations were analysed. The previous analysis results then used to calculate both case studies' life cycle cost and payback period. Finally, five experts evaluated the results for advice and recommendation.

In the end, Chapter 5 concluded this study. This chapter also discussed the research achievements, limitations, and recommendations for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is crucially important in this study. A literature review is an in-depth analysis and evaluation of previous research. It also summarises a particular area of research that allows the readers to establish general knowledge and current literature on related topics.

The first section of this study is the introduction of conventional streetlight and solar streetlight. It is significant due to the difference of components and operation in both types of streetlights. Besides, the streetlight issues were further explained and distributed into three issues: economic performance issues, electrocuted issues, and health & environmental impact issues. It is vital to clarify each of the issues to justify the importance of this study to be conducted. Further, a section was allocated to explain the life cycle cost and payback period analysis for conventional and solar streetlights. The analysis of previous research of case studies and interviews also summarized and explained in the next section.

2.2 Conceptual framework

A conceptual framework addresses the researcher's synthesis of the literature on how to explain a phenomenon. It outlines the activities needed throughout the study, given previous knowledge on other researchers' perspective and perceptions regarding the matter of study (Swaen, 2015).

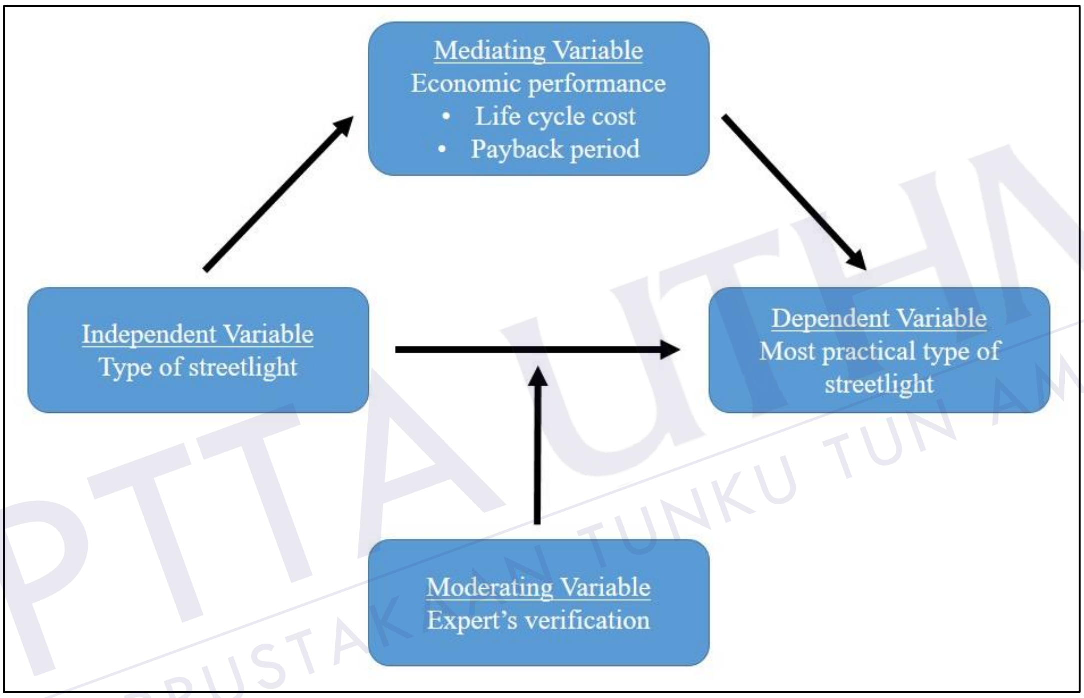

Figure 2.1: Conceptual framework

In this study, independent variable is the type of streetlight and the dependent variable is the most practical type of streetlight. The relationship between independent and dependent variables is the comparison between different types of streetlight will justify out the most practical type of streetlight. Economic performance of streetlight which including the calculation of life cycle cost and payback period set as mediating variable in this study. In order to justify the most practical type of streetlight, the different types of streetlight are being compared based on their economic performance. Besides, expert's verification on the most practical type of streetlight is act as a moderator, it interact with the independent variable to enhance the relationship between the independent and dependent variables. Expert's verification help to verify the most practical type of streetlight in this study.

2.3 Type of streetlight

The typology of streetlights in this study are being focused on conventional streetlight and solar streetlight for accommodation and district area.

2.3.1 Conventional streetlight

Conventional streetlight is an essential public infrastructure that provides a safer environment at night-time to commuters and pedestrians and increases the quality of life by extending the hours of lighting artificially for outdoor activities able to take place at night-time.

Conventional streetlight can be define as a combination of lamp set, wiring cable, pole, lamp holder, concrete foundation, steel bar foundation and controller device. It usually operates during the night-time and also functions during low light intensity. The conventional streetlight is defined as a conventional grid-tied streetlight. So the energy is provided by a grid wire connection from the electric utility company, they are Tenaga Nasional Berhad in Peninsular Malaysia, Sarawak Energy Berhad in Sarawak state, and Sabah Electricity Sdn. Bhd. in Sabah state.

The conventional streetlight applied in Malaysia is a High-Pressure Sodium Vapour lamp (Nor *et al.*, 2013). A high-Pressure Sodium Vapour lamp is a specific type of gas-discharge light. A high-Pressure Sodium Vapour lamp is operated under high internal pressure. A high-Pressure Sodium Vapour lamp requires a warm-up period to evaporate the internal gas into plasma. As the lamp becomes less efficient, it will require more and more energy to produce the same output. Plus, the High-Pressure Sodium Vapour lamp also contains little which is, Figure 2.2 shows the example of streetlight facilities in Malaysia.

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