

LED STREET LIGHTING IN MALAYSIA: PERFORMANCE EVALUATION AND BARRIERS TO IMPLEMENTATION

Received: 27th October 2025 | Accepted: 20th November 2025 | Available Online: 30th November 2025

DOI: 10.31436/japcm.v15i2.1032

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ABSTRACT

Street lighting plays a critical role in enhancing city aesthetics and minimising accidents and injuries by providing crucial illumination in public spaces, especially at dawn and dusk. However, Malaysia's street lighting system faces challenges related to energy efficiency, sustainability, and technology integration, as traditional lighting technologies are known for high energy consumption and light pollution. Thus, recognizing these issues, this paper is prepared with the objective to present the outcome of comparative study between the present conventional streetlights and the newly emerging technology of light-emitting diode (LED) with specific reference to energy and performance efficiency. The study employed a qualitative research strategy that in compasses of semi-structured interview with professionals that have established knowledge, skills, and experience actively engaged in streetlight projects in Malaysia. The study outcome revealed that the LED is deemed appropriate to enhance the visibility as compared to the present conventional streetlights. The adoption of LED street lighting in Malaysia presents a strategic move toward achieving national sustainability goals, offering enhanced energy and performance efficiency compared to conventional systems. Despite higher initial costs, LEDs contribute to reduced energy consumption, lower environmental impact, and improved urban infrastructure—aligning directly with Malaysia's green agenda and the global targets of SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 11 (Sustainable Cities and Communities).

Keywords: Economic planning, Energy-efficiency, Performance, Streetlights, Sustainable.

1.0 INTRODUCTION

The Twelfth Malaysian Plan 2021–2025 (12MP) emphasises sustainable economic growth, innovation, development, and environmental well-being as key pillars to enhance national prosperity. In line with this vision, the plan highlights the importance of sustainable infrastructure development, particularly for the advancement of smart cities. One of the critical components of this initiative is the implementation of cost-efficient and environmentally sustainable street lighting systems. Despite their vital function, the role of street lighting is frequently overlooked in urban planning discourse. Adequate street lighting is essential to urban infrastructure, as it has been shown to significantly reduce traffic accidents and crime rates while simultaneously enhancing the visual and aesthetic quality of urban environments. Empirical studies support the notion that well-lit public spaces contribute to improved safety and urban attractiveness (Ng et al., 2019; Agramelal et al., 2023; Khayam et al., 2023). Moreover, the integration of sustainable street lighting technologies is aligned with the United Nations Sustainable Development Goals (SDGs), specifically SDG 7: Affordable and Clean Energy, SDG 9: Industry, Innovation and Infrastructure, and SDG 11: Sustainable Cities and Communities.

Despite their widespread use, conventional street lighting systems are major contributors to high energy

consumption, which subsequently results in increased carbon emissions and elevated electricity costs (Allwyn et al., 2021; Valetti et al., 2023). In response to these challenges, numerous countries have initiated large-scale replacement programs aimed at transitioning to more energy-efficient and cost-effective lighting solutions. Globally, approximately 300 million conventional streetlights have been replaced with light-emitting diode (LED) alternatives, yielding estimated energy savings ranging from 50% to 70% (Crimina et al., 2015). In alignment with this global movement, Malaysia has implemented similar measures, notably replacing 33,101 high-pressure sodium (HPS) streetlights with LED luminaires in the state of Penang (Kingsun, n.d.; Ding et al., 2020). Other municipalities, including Mersing, Kajang, and Kuala Lumpur, have also begun adopting LED lighting systems, although a more comprehensive and nationwide implementation remains imperative. This transition represents a pivotal advancement in the development of sustainable smart cities, as it not only supports global energy efficiency goals but also reflects Malaysia's ongoing commitment to reducing its carbon footprint and improving urban liveability through environmentally responsible infrastructure (Davidovic & Kostic, 2022). Against this backdrop, there has been a demand to comparatively examine the energy and performance efficiency of conventional versus LED street lighting technologies within the Malaysian context. In essence, this paper is prepared with the objective to present the outcome of comparative study between the present conventional and the newly emerging technology of light-emitting diode (LED) streetlights with specific reference to energy and performance efficiency.

2.0 LITERATURE REVIEW

2.1 Overview of Malaysia's Street Lighting Systems

Literature Street lighting is a critical public infrastructure system in modern nations like Malaysia, playing essential role in the daily lives of its citizens. It enhances safety by deterring criminal activities and providing a psychological sense of security (Ciriminna et al., 2015; Ibrahim et al., 2020; Sutopo et al., 2020; Gordic et al., 2021; Pardo-Bosch et al., 2021; Khayam et al., 2023). As an integral component of urban infrastructure, street lighting evolves in tandem with urbanization, reflecting the nation's progress and commitment to improve the quality of life of an individual and society (Allwyn et al., 2010; Khayam et al., 2023).

The history of street lighting in Malaysia dates back to the late 19th century, during the period of British influence on infrastructure development. The initial transition from gas lamps to incandescent bulbs marked a significant milestone in the evolution of street lighting. This was followed by the adoption of fluorescent lights, which offered improved energy efficiency and durability. The introduction of electric street lighting fundamentally transformed the urban landscape, enabling widespread installation of electric streetlights (Wenli, 2021).

The evolution of street lighting technologies has witnessed remarkable advancements, transitioning from traditional options like incandescent and high-pressure sodium lamps to more efficient and sustainable solutions such as LED technology. This shift signifies not only technological progress but also a commitment to sustainability and environmental stewardship. In the early 2000s, LED technology gained popularity for street lighting due to its sustainability and environmental benefits. Malaysia has been gradually implementing LED streetlights to reduce energy consumption and maintenance costs, resulting in significant cost savings, enhanced visibility, and a reduced carbon footprint (Abdullah et al., 2019; Omar et al., 2022; Ramli et al., 2015). This gradual but steady adoption of LED streetlights underscores Malaysia's commitment to modernizing its urban infrastructure and enhancing the quality of urban life through greener, more efficient lighting solutions.

2.2 Types of Existing Street Lighting Systems in Malaysia

2.2.1 Incandescent Light

Historically, incandescent streetlights—initially powered by gas or oil, became the standard lighting solution in Malaysia due to their affordability and widespread availability. While these systems offered a cost-effective approach during earlier phases of urban development, their long-term viability diminished with the growing demand for more reliable and sustainable lighting solutions. As urbanization accelerated, the limitations of incandescent technology, particularly in terms of energy inefficiency and short operational lifespan became increasingly evident (Green Frog Systems, n.d.; Cloud, 2023).

Beyond excessive energy consumption, incandescent streetlighting systems are fundamentally incompatible with the evolving requirements of modern urban infrastructure. They lack essential features such as adaptive

brightness control, automated operation, and integration with energy management systems—all of which are critical for smart city initiatives and sustainable development. Additionally, their inherently limited-service life leads to frequent replacements, resulting in higher maintenance costs and a larger environmental footprint due to repeated manufacturing, transport, and disposal cycles. These shortcomings collectively render incandescent lighting an unsustainable and outdated option for contemporary urban planning (Valetti et al., 2023).

In recognition of these deficiencies, Malaysia has gradually phased out incandescent streetlighting in favour of more energy-efficient alternatives, such as fluorescent and high-pressure sodium (HPS) lamps (The Edge, 2020). While these technologies represent incremental improvements in terms of energy savings, they continue to fall short in delivering optimal efficiency, lighting quality, and environmental sustainability when compared to modern LED lighting systems (Shahedah, 2015).

2.2.2 Fluorescent Light

Fluorescent streetlights have been a common feature in Malaysia since the mid-20th century, prized for their energy efficiency and extended lifespan compared to incandescent lights. These lights operate by passing electricity through a gas, which then excites a phosphor coating to emit light. Despite their energy-saving advantages, fluorescent lights still consume a substantial amount of electricity, leading to high energy bills and increased strain on the power grid. Additionally, the light quality from fluorescent lamps can be harsh and uncomfortable, causing visual fatigue and potential health issues for both pedestrians and motorists. This discomfort can make it challenging to focus on the road, thereby compromising safety (Green Frog Systems, n.d.; Abdullah et al., 2019; Wenli, 2021; Viana et al., 2022; Omar et al., 2022).

2.2.3 High-pressure Sodium (HPS) Light

High-pressure sodium (HPS) streetlights have been a popular choice for outdoor lighting due to their high luminous efficacy, warm colour rendition, and relatively long lifespan. These lights produce a bright orange or yellow glow by passing electricity through a gas mixture, making them both cost-effective and environmentally friendly compared to older technologies. HPS lamps typically last between 14,000 to 24,000 hours, offering a balance between efficiency and longevity (Green Frog Systems, n.d.; Abdullah et al., 2019; Taufik et al., 2020; Wenli, 2021; Allwyn et al., 2021; Viana et al., 2022; Omar et al., 2022; Khayam et al., 2023). However, with the advent of more energy-efficient lighting technologies, particularly LEDs, the use of HPS lights has been declining. While HPS streetlights are more efficient than incandescent lights, they still require frequent replacements and maintenance, leading to higher long-term in-use costs. Their high-power consumption also results in increased recurring expenses and a lower luminous output compared to modern LED solutions. Thus, while HPS lights have served well historically, their drawbacks are becoming more apparent in the face of superior alternatives (Viana et al., 2022; Omar et al., 2022; Khayam et al., 2023).

2.2.4 Light-emitting Diode (LED)

The adoption of emerging LED street lighting technology is increasingly recognised as a strategic initiative aligned with environmental stewardship, sustainable urban development, and national policy objectives. As highlighted by Ding et al. (2020), LED streetlights provide significant long-term cost savings due to their lower energy consumption and reduced maintenance requirements. These operational efficiencies contribute not only to fiscal prudence but also to the broader national agenda on Environmental, Social, and Governance (ESG) performance by reducing greenhouse gas emissions and environmental impact. Moreover, the implementation of LED technology supports Malaysia's commitment to several United Nations Sustainable Development Goals—namely, SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), and SDG 11 (Sustainable Cities and Communities). In addition to environmental and economic benefits, enhanced visibility from LED lighting plays a critical role in advancing road safety, contributing to national efforts aimed at reducing traffic-related accidents and fatalities through improved nighttime illumination (Research and Markets, 2025). Comprising a semiconductor chip, heat sink, and electrical connections, LED streetlights have quickly gained popularity for their remarkable energy efficiency and longevity. These lights can last up to 50,000 hours before needing replacement, significantly lowering maintenance costs and operational disruptions. Since their introduction in Malaysia in the early 2000s, LED streetlights have revolutionized urban development by providing superior brightness, colour rendering, and directional lighting, which greatly improves visibility and safety on the roads. Despite the higher initial costs and the need for updates to existing infrastructure, the long-term benefits of LED streetlights—including lower energy consumption, reduced carbon footprint, and

enhanced public safety—make them an ideal choice for modern urban environments (Green Frog Systems, n.d.; Zin & Abdullah, 2015; Mohring, 2018; Taufik et al., 2020; Gordic et al., 2021; Allwyn et al., 2021; Omar et al., 2022; Agramelal et al., 2023; Khayam et al., 2023).

2.3 Strategies to Enhance the Implementation of LED Streetlights Application in Malaysia

The study proposes several strategic recommendations to facilitate the broader adoption of LED street lighting systems in Malaysia. Primarily, increased investment in research and development (R&D) is essential to drive innovation and reduce the manufacturing and installation costs of LED technology. Lowering these initial capital expenditures would enhance affordability and promote widespread implementation across urban and rural municipalities. In parallel, the introduction of financial incentives—such as government-backed subsidies, tax rebates, and targeted grants—can significantly offset the high upfront investment, thereby accelerating the transition to energy-efficient lighting solutions. Such fiscal support mechanisms have been recognised as critical enablers of LED adoption in global markets (Research and Markets, 2025).

Subsequently, Research and Markets (2025) in their articles stated, to support the widespread adoption of LED street lighting, strategic collaboration between government agencies and private sector entities is essential. Public-Private Partnerships (PPPs) offer a robust mechanism to harness the strengths of both sectors, enabling access to financing, shared resources, and the transfer of technical knowledge and best practices. This integrated approach can enhance implementation efficiency, promote innovation, and ensure the optimal utilisation of available infrastructure and funding. Moreover, capacity building through targeted training and workshops is crucial for the sustainable deployment of LED lighting systems. Developing comprehensive training programmes for technicians, engineers, and maintenance personnel will ensure the correct installation, operation, and upkeep of LED streetlights, thereby maximising their operational lifespan and performance efficiency.

In parallel, the reinforcement of regulatory frameworks is vital to support the transition to advanced lighting technologies. Establishing clear, standardised specifications and technical guidelines can mitigate implementation risks, reduce ambiguity during procurement and planning phases, and foster greater stakeholder confidence. Robust policy development can also address common challenges—such as interoperability, quality assurance, and long-term maintenance strategies—thus empowering municipalities, contractors, and policymakers to make informed, risk-aware decisions in the pursuit of sustainable urban infrastructure.

3.0 METHODOLOGY

This study adopted a qualitative research strategy, underpinned by a semi-structured interview approach, to comprehensively examine the implementation status and challenges associated with street lighting systems in Malaysia. The qualitative research strategy was chosen to enable a deeper exploration of expert perspectives, allowing for rich, context-specific insights that are essential when investigating complex, multi-dimensional issues such as urban infrastructure, technological transition, and policy integration.

Primary data was collected through semi-structured interviews with selected professionals that have established knowledge, skills, and experience actively engaged in streetlight projects actively involved in streetlight projects across Malaysia. Respondents were purposively sampled based on their technical expertise, professional experience, and willingness to participate, ensuring that insights were drawn from individuals with relevant and substantive knowledge. Secondary data was obtained through an extensive literature review to establish the foundational understanding of global and local practices, energy policies, and sustainable lighting technologies. The interview protocol was developed through iterative refinement, guided by themes identified in the literature. The questionnaire comprised both Likert-scale and open-ended questions. The Likert-scale items were designed to measure respondents' evaluations of streetlight system effectiveness, comparing conventional and LED technologies, as well as their perceptions of implementation feasibility and sustainability. The open-ended questions, on the other hand, facilitated the exploration of perceived implementation barriers and solicited recommendations for improving LED streetlight deployment (Ayob & Abdul Rashid, 2020; Abdul Rahman & Ayob, 2024).

Qualitative data from the open-ended responses were analysed using thematic coding. Codes were generated inductively, allowing recurring themes, patterns, and categories to emerge organically from the data. This

process supported a nuanced understanding of implementation challenges and stakeholder expectations.

For the Likert-scale data, descriptive statistical analysis was conducted. The mean (M) was used to determine the central tendency of responses, providing an average assessment across participants. Standard deviation (SD) was used to measure the degree of response dispersion, indicating the extent of consensus among stakeholders. A standard deviation classification table was employed to categorise the level of agreement or divergence: $SD \leq 0.99$ was interpreted as high consensus, SD between 1.00–1.99 as moderate consensus, and $SD \geq 2.00$ as low consensus. This combined analytical approach ensured a robust interpretation of both quantitative and qualitative findings, supporting data triangulation and enhancing the study's validity (Ayob & Abdul Rashid, 2020; Abdul Rahman & Ayob, 2024).

4.0 RESULTS

4.1 Background of Interviewees

Based on a comprehensive search of suitable respondents, it was found there is a limited number of potential people with established knowledge, skills, and experience actively engaged in streetlight projects in streetlight projects across Malaysia that can be invited as respondents in the interview approach. Therefore, a total of five people with diverse backgrounds and expertise were only identified that met the respondent's selection criteria used and willingness to participate as respondents in the interview approach. These include Risk Managers, Mechanical and Electrical Engineers, and a Corporate Transformation specialist. The combination of emerging talents and seasoned professionals broadens the scope of the research and strengthens the credibility of its findings. To uphold privacy and confidentiality, the anonymity of the interviewees was rigorously maintained throughout the study. Table 1 below summarises the demographic profile of the interviewees, illustrating the diversity and expertise contributing to the study's comprehensive analysis.

Table 1: Summary of the interviewees' profile data

No.	Interviewee's Name	Position	Years of Experience in Street Lighting Projects
1.	Interviewee A	Risk Manager	1 - 5 years
2.	Interviewee B	Mechanical Engineer	1 - 5 years
3.	Interviewee C	Electrical Engineer	6 - 10 years
4.	Interviewee D	Corporate Transformation	1 - 5 years
5.	Interviewee E	Electrical Engineer	1 - 5 years

4.2 The Current State of Street Lighting Application in Malaysia

The following part of interview asked interviewees to provide score to each question statement, indicating their preferences and perceptions on the cost-effectiveness of four different competing street lighting solution types, i.e. Light-Emitting Diode (LED) Street Light, High-Pressure Sodium (HPS), Fluorescent Street Light, and Incandescent Street Light. The study found that incandescent lights were the lowest-ranked choice among street lighting options, with a mean rating of 1.60, while the LED streetlights scored the highest mean score (4.40), with lowest standard deviation score (0.55), respectively. The results for each question statement are illustrated in Table 2 below:

Table 2: Efficiency of Current Street Lighting in Malaysia

Rank	Questions	Mean	SD
1	Based on your experience, could you please rate the degree of cost efficiency for the Light-Emitting Diode (LED) Street Light solution in Malaysia?	4.40	0.55
2	Based on your experience, could you please rate the degree of cost efficiency for the High-Pressure Sodium (HPS) Street Light solution in Malaysia?	3.20	0.84
3	Based on your experience, could you please rate the degree of cost efficiency for the Fluorescent Street Light solution in Malaysia?	2.40	0.55
4	Based on your experience, could you please rate the degree of cost efficiency for the Incandescent Street Light solution in Malaysia?	1.60	0.89

Evidently, the study underscores that the LED streetlights emerge as the most cost-effective option for street lighting in Malaysia, despite their higher initial costs relative to traditional incandescent, fluorescent, and high-pressure sodium lights (Abdullah et al., 2019; Lindawati et al., 2019; Gordic et al.2021; Viana et al., 2022). On this account, LED lights boast longer operational lifespans, reduced maintenance requirements, and superior environmental friendliness. Beyond financial considerations, the research delves into the psychological, quality-of-life, and environmental benefits associated with improved street lighting infrastructure. The findings also highlight a clear need for enhancing maintenance practices in Malaysia's street lighting systems. Interviewees expressed cautious optimism regarding future advancements in street lighting, particularly the ongoing shift towards LED technology. This optimism stems from the environmental advantages of LED lights and their potential to enhance urban aesthetics and safety. Overall, the study's results align closely with existing literature, affirming that LED streetlights are viewed as the most cost-effective and efficient option compared to incandescent, fluorescent, and high-pressure sodium alternatives. While interviewees generally expressed moderate satisfaction with current street lighting, they emphasised the imperative for better maintenance practices to maximise efficiency and longevity. Their positive outlook on the transition to LED streetlights reflects broader recognition of the environmental benefits driving this shift in urban infrastructure.

4.3 Recommendations to Enhance the Implementation of LED streetlights in Malaysia

In this interview part, the interviewees were asked to provide score to each recommendation statement, indicating their level of agreement on the enhancement of LED streetlights implementation from the impact of investing in research and development, providing financial incentives, collaborations between government agencies and private sectors, the importance of workshops and training, and strengthening regulations and guidelines. The results for each recommendation statement are presented in Table 3 below:

Table 3: Recommendations to Enhance the Implementation of LED Streetlights in Malaysia

Rank	Questions	Mean	SD
1	Based on your expertise, could you kindly rate the level of agreement that fostering collaborations between government agencies and private sectors to leverage expertise, resources, and funding can improve the integration of LED Street Lights in Malaysia?	4.80	0.45
2	Based on your expertise, could you kindly rate the level of agreement that strengthens the government's current regulations and guidelines can improve the integration of LED Street Lights in Malaysia?	4.60	0.55

Rank	Questions	Mean	SD
3	Based on your expertise, could you kindly rate the level of agreement that providing financial incentives can improve the integration of LED Street Lights in Malaysia?	4.40	0.89
4	Based on your expertise, could you kindly rate the level of agreement that providing workshops and training to enhance the skills of stakeholders in street lighting projects can improve the integration of LED Street Lights in Malaysia?	4.20	1.30
5	Based on your expertise, could you kindly rate the level of agreement that investing in research and development to reduce the initial expenses of LED Street Lights can improve the integration of LED Street Lights in Malaysia?	4.00	1.23

The study emphasizes the pivotal role of fostering collaborations between government agencies and the private sector in Malaysia to enhance the integration of LED streetlights (Hashim et al., 2017). This strategy received the highest mean score of 4.80 and low standard deviation score of 0.45, indicating a strong consensus established among the interviewees. Collaborations facilitate more efficient resource utilization, streamline implementation processes, and promote the exchange of best practices, thereby bolstering overall project effectiveness. Second rank mean score (4.60) is the strengthening of government regulations and guidelines, aligning with findings from Ding et al. (2020). Enhanced guidelines contribute to better planning, reduce uncertainties, and instil confidence among stakeholders in adopting new technologies. This regulatory framework is crucial for addressing common challenges and mitigating risks associated with LED street lighting projects, supporting municipalities, contractors, and other stakeholders in making well-informed decisions. Financial incentives, such as subsidies, tax rebates, and grants, were also discussed as viable strategies to accelerate the adoption of LED streetlights, although opinions varied among interviewees. These incentives aim to alleviate the high initial costs associated with LED installations, thereby fostering faster adoption rates across Malaysia. Conversely, investing in research and development to reduce the costs of LED streetlights received the lowest consensus among the proposed strategies. This highlights the need for further exploration and alignment of stakeholder priorities in advancing cost-effective LED solutions for street lighting, ensuring sustainable and efficient urban infrastructure development.

5.0 CONCLUSION

This paper has presented the outcome of comparative analysis of conventional and light-emitting diode (LED) street lighting systems in Malaysia, evaluating their performance, energy efficiency, and alignment with national sustainability goals. The study findings have established that the LED streetlights outperform traditional lighting in terms of energy savings, environmental impact, lifespan, and maintenance costs. The study underscores the importance of adopting LED technologies in achieving the three key Sustainable Development Goals, i.e. SDG 7, SDG 9, and SDG 11, and recommends policy enhancements, public-private partnerships, and workforce training as critical enablers of nationwide implementation. The outcome of the study could serve as a basis to facilitate and guide the policymakers and urban planners in developing sustainable and efficient road lighting infrastructure aligned with Malaysia's green agenda.

ACKNOWLEDGMENTS

This paper follows the other paper below that has been presented elsewhere by the first author from nearly 9 months of research under the second author supervision:

Ishak, S. N. A. N. M. (2024). Advancing Sustainable Street Lighting in Malaysia: Assessing Performance and Implementation Barriers of LED Solutions. [Unpublished Degree's Dissertation], International Islamic University Malaysia.

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