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The Use of LED Lighting on Malaysian Highways: Review on Key Benefits, Challenges, and Environmental Impacts

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ABSTRACT

One of the most important components of Malaysia's ambitions for sustainable infrastructure is the installation of Light Emitting Diode (LED) lighting on the nation's roadways. Modern lighting technology is a desirable option for road lighting since it provides several benefits. Significant benefits come with LED lighting on Malaysian roadways, including reduced power usage of up to 50%, improved safety and visibility, longer lifespan and cheaper maintenance costs, and environmental benefits (no mercury or greenhouse gas emissions). However, there are additional challenges such as Malaysia's tropical heat affecting maintenance and dependability, local conditions like monkey damage adaptation, and certification requirements. The usage of LED lighting on Malaysian highways can have both beneficial and bad effects on the environment. LED lights are recognized to reduce energy consumption and light pollution, but because some of them have a spectral composition that can cause skyglow, they may also have unexpected effects on animals. It is essential to use LED lighting with the right colour temperatures and optics to reduce these environmental issues. The widespread adoption of LED lighting on Malaysian highways has produced several benefits, including improved road safety, lower costs, and higher energy efficiency, making it an essential part of the nation's sustainable infrastructure development.

1. Introduction

On Malaysian highways, LED lighting is becoming more and more common. It offers several advantages, including increased energy efficiency, lower costs, and environmental sustainability. One of the main objectives of the nation's green agenda and infrastructure renovation initiatives has been the adoption of this cutting-edge lighting technology. LED highway lights have many benefits over conventional lighting sources like mercury vapor lamps and High-Pressure Sodium Vapor (HPSV) that make them a desirable option for road lighting [1], [2], [3], [4]. According to studies, installing LED lighting on Malaysian highways can cut power

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usage by up to 50%, which can result in significant electricity bill savings [5], [6], [7] . A detailed comparison of LED and High-Pressure Sodium Vapor (HPSV) street lighting, supported by references from current studies as shown in the Table 1.

Table 1
The advantages of LED technology over HPSV for street lighting

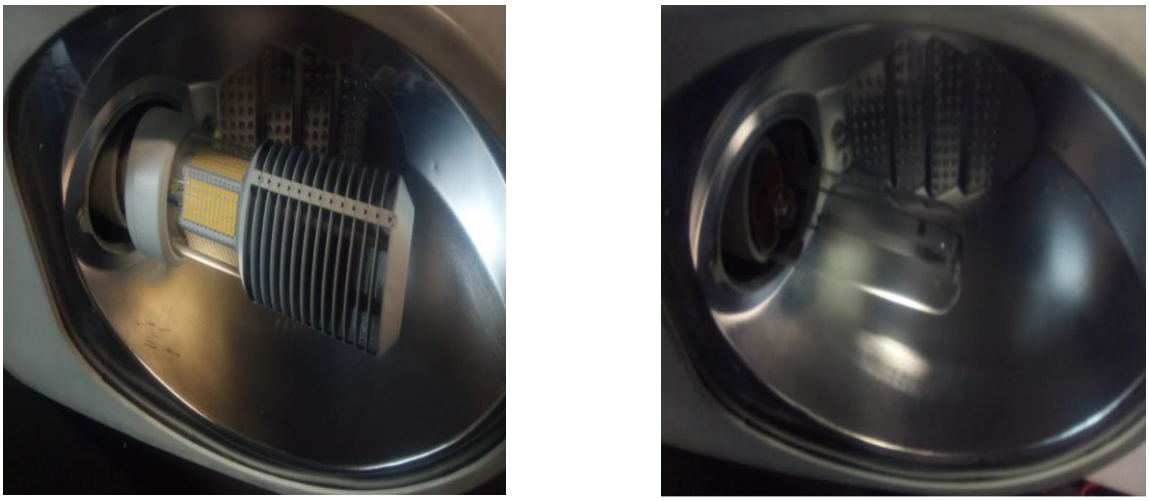
Aspect	LED Streetlights	HPSV Streetlights	References
Energy Efficiency	More energy-efficient, with efficacy ratings around 140 lm/W.	Less energy-efficient, with efficacy ratings around 83 lm/W.	[7], [8]
Lifespan	Typically lasts up to 100,000 hours.	Lasts around 24,000 to 28,000 hours.	[8]
Light Quality	Provides better colour rendering and uniform illumination.	Emits a yellow-orange light that can distort color perception.	[7], [9]
Instant On	Turns on instantly without warm-up time.	Takes 5 to 10 minutes to reach full brightness.	[7], [8]
Heat Emission	Emits very little heat, making them cooler to operate.	Produces significant heat, which can affect efficiency.	[9]
Maintenance Costs	Lower maintenance costs due to longer lifespan and fewer replacements.	Higher maintenance costs due to more frequent bulb replacements.	[7], [8]
Initial Installation Cost	Generally higher upfront costs but lower long-term costs.	Lower initial costs, making it more budget-friendly initially.	[7]
Light Distribution	Directional light, reducing light pollution and improving efficiency.	Omnidirectional light, which can lead to wasted light.	[9]
Environmental Impact	More eco-friendly due to lower energy consumption and longer lifespan.	Less eco-friendly due to higher energy consumption and shorter lifespan.	[8], [9]
Photometric Performance	Average luminance value is lower than HPSV, with a reduction of 52% in some studies, but with better overall uniformity.	Higher average luminance values, but less efficient in energy use.	[8], [9]

LED lights not only save energy but also improve colour rendering, brightness, and uniformity of illumination, which increases driver visibility and safety. The extended lifespan and lower maintenance needs of LED technology add even more to this lighting solution's financial advantages. The Malaysian government has acknowledged the benefits of LED highway lighting and is promoting its wider implementation throughout the nation's road network. The Green Technology Master Plan (GTMP) is one initiative that aims to accelerate the shift to more sustainable energy use, and LED lighting is essential to reaching these objectives [10], [11].Using information from the available search results, this paper will examine in greater detail the main advantages, difficulties, and environmental effects related to the use of LED lighting on Malaysian highways.

2. The benefits of using LED lighting

In Malaysia, LED lighting has a significant energy efficiency advantage over conventional highway lighting solutions. Compared to high-pressure sodium or mercury vapor lamps, studies have indicated that installing LED lighting on Malaysian highways can reduce electricity consumption by up to 50%

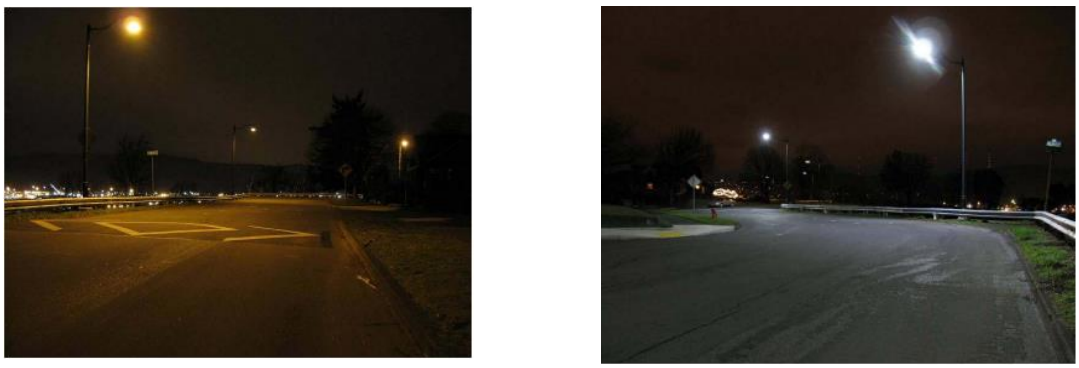
[5], [6], [7]. This is a result of LEDs' increased luminous effectiveness, which generates more light output for each unit of power supplied. To further improve energy efficiency, LED lights can also be fitted with adaptive controls that change brightness in response to variables like traffic density. According to one project in Malaysia, switching to LED street lighting could result in 50% energy savings and 20% less maintenance expenses [12], [13]. Compared to traditional lamps, the considerable energy savings from LED roadway lighting result in a 60% decrease in yearly greenhouse gas emissions [1], [5]. Furthermore, the test sample fitted in the HPSV road light fitting was done by [9], as shown in Fig. 1. The test shows that LED lighting has enhanced brightness and energy efficiency, demonstrating its practical advantages over conventional bulbs.



(a) 150W HPSV light fixture with an LED lamp (b) 150W HPSV light fixture with a 150W HPSV lamp inside

Fig. 1. Test sample (a) and (b) installed in the HPSV road light fitting [9]

High colour rendering and increased brightness from LED lights greatly improve visibility for both cars and pedestrians on Malaysian roadway [14]. Due to its improved illumination, drivers can see farther ahead and respond to changing road conditions more rapidly, which lowers the risk of accidents and increases road safety, particularly at night as shown in Fig. 2. The uniform lighting and decreased glare of LED lights guarantee that the entire road is well-lit and enhance visibility. To further improve visibility and safety, adaptive lighting controls can also modify brightness based on ambient light levels and traffic congestion.



(a) (b)

Fig. 2. Use of (a) HPSV streetlamp and (b) LED street light [15]

Compared to more conventional lighting technologies like incandescent and fluorescent bulbs, LED lights are said to have a substantially longer lifespan and require less maintenance. According to studies, the rated lifespan of LED roadway lights can reach 90,000 hours, while that of traditional bulbs is just 20,000–30,000 hours [16]. Because of its longer lifespan, bulbs are not required to be changed as frequently, which decreases the lighting system's overall operating and maintenance costs over time. According to one project in Malaysia, switching to LED street lighting might result in 20% lower maintenance costs and a 50% reduction in energy use [6]. Over the duration of the installation, LED lighting proves to be a more economical alternative due to its high dependability and low maintenance requirements, resulting in significant cost savings for owners of infrastructure and highway operators [17].

Sensors enable LED lights to adjust to variations in traffic volume and sunlight intensity, guaranteeing that the lighting system is optimum for all scenarios. This adaptive lighting system makes driving safer and more efficient by adjusting brightness and colour temperature based on real-time data. For example, LED lights can be set to turn down when there is a lot of sunshine during the day to save energy and glare, and to turn up the brightness at night to increase safety and visibility. Because it guarantees that the lighting system always provides the ideal amount of illumination, regardless of the time of day or traffic circumstances, this adaptability is essential for improving road safety.

Several sources claim that LED lighting may be created to create a visually beautiful and safe atmosphere that improves the overall look of roadways and the areas around them [18], [19], [20]. By precisely adjusting their optics and colour temperatures, LED lights may minimize light pollution and glare by directing light just where it is required [21]. This contributes to more consistent and aesthetically pleasing lighting along the route. Furthermore, LED technology's extended lifespan and minimal maintenance needs enable constant, dependable lighting that keeps its appealing appearance over time. According to studies, installing well-thought-out LED highway lighting can enhance the road infrastructure's aesthetics and make driving more enjoyable as well as create a more aesthetically pleasing metropolitan environment [22]. This is in line with Malaysia's objectives to develop aesthetically pleasing and sustainable transportation systems that serve local residents as well as drivers.

LED lights are a more environmentally friendly choice than previous lighting technologies, according to several kinds of sources. LED lights don't contain any hazardous elements like mercury, in contrast to fluorescent and mercury vapor lamps [23], [24], [25]. As a result, recycling and disposing of LED lights is safer, supporting Malaysia's sustainability objectives. Furthermore, ultraviolet (UV) radiation can be hazardous to both people and the environment [26], [27]; this is not an issue with LED lights. LED lighting's lack of UV radiation [28] lessens the possibility of harming delicate materials and has a negligible effect on local wildlife and ecosystems. The benefits of LED technology for the environment help Malaysia's larger efforts to promote green growth and lower its carbon footprint. As Malaysia continues to emphasize sustainable practices, LED lighting is a more environmentally beneficial option for lighting the country's streets, highways, and other infrastructure because it is non-toxic and UV-free.

3. The Environmental Impacts

LED roadway lights drastically lower greenhouse gas emissions by up to 80% when compared to conventional illumination [15]. There are significant environmental advantages associated with this energy efficiency. As demonstrated by initiatives like the GTMP, Malaysia's green agenda and efforts towards sustainable development are in line with this emission reduction. Malaysia is working

towards a safer, more effective transportation network and lowering its carbon footprint with the installation of LED lighting on its highways. The overall demand for electricity generation in Malaysia is considerably reduced by the enormous energy savings from LED adoption on the nation's roadways. Research indicates that LED lighting can save electricity usage by as much as 50–80% when compared to conventional high-pressure sodium or mercury vapor lamps [29]. By lowering the overall load on the country's power system, this decrease in energy consumption enables power plants to run more effectively and lessens the demand for new fossil fuel-based producing capacity.

According to one study, switching to LED street lighting might result in a 50% energy savings [5]. Malaysia can fulfil its increasing electricity demand in a more sustainable way due in large part to the significant energy savings from the widespread deployment of LEDs on highways and roads, which supports the nation's green strategy and efforts to reduce greenhouse gas emissions.

With programs like the GTMP, which intends to reduce greenhouse gas emission intensity by 45% across the economy by 2030 [30], [31], Malaysia has shown a significant commitment to sustainability and renewable energy. By consuming substantially less electricity than conventional lighting technologies, the switch to energy-efficient LED roadway lighting directly contributes to these national environmental goals. According to studies, LED lighting can reduce energy use by up to 80%, which results in a decrease in greenhouse gas emissions [5], [32]. For example, a study discovered that switching to LED street lighting might result in a 50% reduction in energy use [6]. The extensive use of LEDs on highways has resulted in significant energy savings, which have eased Malaysia's overall need for electricity generation. This has reduced the need for additional fossil fuel-based capacity and allowed power plants to function more efficiently. This is in line with Malaysia's National Energy Transition Roadmap objective to raise the proportion of renewable energy to 70% of total generation capacity by 2050 [32].

By using accurate optics in their design, LED lights can minimize light trespass and sky glow by directing light only where it is needed on the road surface [15]. This lessens the effect on astronomy and nocturnal wildlife [33]. Research indicates that LED traffic lights featuring precisely engineered optics can restrict the quantity of light released above the horizontal plane, so obstructing its dispersion into the environment and mitigating the formation of sky glow [32]. LED lights also minimize the impact on neighbouring environments by reducing light pollution and disturbance, which is especially beneficial for species that depends on natural darkness for survival [32]. For instance, compared to conventional lighting, it has been discovered that LED streetlights with full-cut off optics can minimize sky glow by as much as 50% [34]. LED road light manufacturers are able to balance the need to mitigate the negative environmental effects of artificial lighting at night with the need to provide safe illumination for vehicles and pedestrians through the integration of advanced optical systems.

When compared to more conventional lighting technologies like fluorescent and mercury vapor lamps, LED lights are a more environmentally responsible choice [32]. In contrast to CFLs, mercury, a very hazardous material that, if released into the environment, might harm both people and the environment, is not present in LED lights. In addition, compared to traditional lamps, the parts of LED lights are easier to recycle after their useful lives are over. Because of this, LED lighting is a more environmentally friendly option overall. Lead, arsenic, and other potentially harmful elements are present in LED lights, although in smaller amounts than in some conventional lamps, according to studies [32]. By redesigning their goods with safer materials, LED manufacturers might further minimize the presence of heavy metals. All things considered, LED lights are a greener choice because they don't contain mercury and can be recycled better than compact fluorescent and high-intensity discharge lamps.

4. LED Lighting Challenges on Malaysian Highways

Lightning strikes can cause serious problems for LED drivers because of Malaysia's tropical climate and frequent thunderstorms. This is due to the possibility of high-voltage pulses caused by lightning striking the power grid, which could harm other electronic parts including LED drivers. To ensure the dependable operation of LED lighting systems in such conditions, stronger fixtures and adequate surge protection are essential. Done Power, for example, stresses the significance of carefully thought-out surge protection to enable LED lighting solutions to function securely and dependably, even in challenging operating conditions like those seen in Malaysia. Furthermore, research has demonstrated that inadequate shielding can result in LED driver failure, emphasizing the necessity of strong surge protection and strengthened fixtures to lessen the impact of lightning strikes [15], [32]. This is consistent with Malaysia's attempts to implement energy-efficient and sustainable lighting solutions, as demonstrated by the Green Switch program, which encourages the use of LED lighting that is low in energy consumption to lower greenhouse gas emissions and further the nation's environmental goals.

Proactive outreach and focused improvements are needed to address the persistent difficulty of ensuring equal road illumination in underprivileged neighbourhoods. Research has indicated that inadequate lighting is a common problem in lower-class neighbourhoods because of old infrastructure and little financing for improvements [35]. The difference in illumination levels may be a factor in decreased sense of community and safety concerns. In response to this, a number of cities have put in place efforts to evaluate the lighting requirements in marginalized communities and provide funding for both new installations and LED retrofits [13]. Town hall meetings and surveys with the community at large aid in the identification of priority locations and guarantee that the light exposure satisfies their needs. Ensuring that every neighbourhood has equal lighting, irrespective of financial standing, is essential to fostering a sense of security, safety, and community for all residents. Cities can attempt to make sure that no one is left in the dark by enlisting the community's help and making appropriate investments.

For instance, a study on the application of LED lighting on Malaysian highways observes that in certain regions, the monkey population has led to the monkeys damaging the street lights [36]. Lighting suppliers have been forced to employ anti-fall precautions and strengthened fixtures in order to lessen this problem and guarantee the longevity of the lighting system. In order to prevent damage from the monkeys to the LED lights and related components, the lighting infrastructure is strengthened and equipped with anti-fall measures. This ensures that the lights perform as intended and provide the required illumination for road safety. This emphasizes how crucial it is to modify lighting solutions to suit regional environmental conditions as well as animal considerations when implementing effective and sustainable lighting systems throughout Malaysia's road networks.

For their goods to be permitted for usage, lighting manufacturers must first clear a significant obstacle: obtaining the necessary SIRIM and JKR certifications for road lighting in Malaysia as shown in Table 2. SIRIM certification guarantees that items fulfil safety and performance criteria and is a mandatory requirement for numerous electrical devices, including lights. To ensure the products' dependability and safety, extensive testing and assessment are required during the certification procedure. As an example, the SIRIM certification of the EYE IWASAKI LED Street Light WD & MD Series 100W attests to its conformity with Malaysian standards. Road lighting items must also have the JKR certification in order to guarantee that they fulfil the particular standards for highway illumination. By going through this dual certification procedure, lighting items are guaranteed to be both safe and compliant with the technical requirements needed for road lighting installations.

Table 2
An overview of the certifications required for road lighting products in Malaysia, along with examples of certified products.

Certification	Description	Requirements	Example Product
SIRIM Certification	A certification by SIRIM QAS International, ensuring products meet Malaysian Standards (MS) and other relevant standards.	- Compliance with Malaysian Standards, British Standards, or International Standards. -Assessment and supervision of product quality. -Valid for one year, with annual inspections required for renewal	EYE IWASAKI LED Street Light WD & MD Series 100W SIRIM Product Certificate: PC004404
JKR Certification	Certification by the Public Certification Works Department (Jabatan Kerja Raya, JKR) ensuring compliance with specific road lighting standards.	-Adherence to JKR specifications for road lighting. - Products must undergo testing and evaluation to ensure safety and reliability -Compliance with relevant Malaysian Standards.	LEDioc/SL-EY686 LED Street Light Certified for compliance with JKR standards reliability.

5. Conclusion

To sum up, the use of LED lighting on Malaysian highways has provided significant advantages, rendering it a compelling option for road lighting. LED technology's environmental benefits, lower maintenance needs, increased safety and visibility, and energy efficiency all perfectly complement Malaysia's objectives for developing a sustainable infrastructure. Even if there are obstacles to overcome, such maintaining in tropical climates, adjusting to native wildlife, and obtaining certification, they can be avoided with careful design, strengthened fixtures, and cooperation between government agencies and lighting manufacturers. With Malaysia striving to upgrade its highway infrastructure and lower its carbon impact, LED lighting will surely become more crucial to accomplishing these goals. The advantages of LED highway lighting may be fully realized to build safer, more effective, and environmentally friendly roadways for all Malaysians with the appropriate plans and solutions in place.

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References

[1] S. Yoomak, C. Jettanasen, A. Ngaopitakkul, S. Bunjongjit, and M. Leelajindakrairerk, "Comparative study of lighting quality and power quality for LED and HPS luminaires in a roadway lighting system," *Energy Build*, vol. 159, pp. 542–557, Jan. 2018, doi: 10.1016/j.enbuild.2017.11.060.

[2] J. Bullough and L. Radetsky, *Analysis of New Highway Lighting Technologies*. 2013.

[3] Y. Jiang *et al.*, "Field evaluation of selected light sources for roadway lighting," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 5, no. 5, pp. 372–385, Oct. 2018, doi: 10.1016/j.jtte.2018.05.002.

[4] A. Tiago Queiroz *et al.*, "Efficiency Evaluation in Public Lighting by Using LED and HPS Technologies," vol. 5, pp. 12–21, Mar. 2019.

[5] S. Gorgulu and S. Kocabey, "An energy saving potential analysis of lighting retrofit scenarios in outdoor lighting systems: A case study for a university campus," *J Clean Prod*, vol. 260, p. 121060, Jul. 2020, doi: 10.1016/j.jclepro.2020.121060.

[6] O. Sadeghian *et al.*, "A comprehensive review on energy saving options and saving potential in low voltage electricity distribution networks: Building and public lighting," *Sustain Cities Soc*, vol. 72, p. 103064, Sep. 2021, doi: 10.1016/j.scs.2021.103064.

[7] N. S. A. Rofaie, S. W. Phoong, and M. A. T. Abdul Mutalib, "Light-Emitting Diode (LED) versus High-Pressure Sodium Vapour (HPSV) Efficiency: A Data Envelopment Analysis Approach with Undesirable Output," *Energies (Basel)*, vol. 15, no. 13, Jul. 2022, doi: 10.3390/en15134589.

[8] M. H. Jamaludin, W. Z. Wan Ismail, E. Mohd Husini, and N. A. Mohd Bahror, "Study of LED Retrofit Lamps in HSPV Luminaires Based on Photometric Method for Road Lighting," *Pertanika J Sci Technol*, vol. 32, no. 3, pp. 1187–1201, Apr. 2024, doi: 10.47836/pjst.32.3.11.

[9] M. H. Jamaludin, W. Z. Wan Ismail, E. M. Husini, and N. A. M. Bahror, "Investigation of photometric distribution of LED and HSPV for road lighting," *Journal of Engineering and Applied Science*, vol. 70, no. 1, p. 112, Dec. 2023, doi: 10.1186/s44147-023-00286-6.

[10] S. C. Chua and T. H. Oh, "Green progress and prospect in Malaysia," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 6, pp. 2850–2861, Aug. 2011, doi: 10.1016/j.rser.2011.03.008.

[11] J. O. Petinrin and M. Shaaban, "Renewable energy for continuous energy sustainability in Malaysia," *Renewable and Sustainable Energy Reviews*, vol. 50, pp. 967–981, Oct. 2015, doi: 10.1016/j.rser.2015.04.146.

[12] B. A. Jones, "Measuring externalities of energy efficiency investments using subjective well-being data: The case of LED streetlights," *Resour Energy Econ*, vol. 52, pp. 18–32, May 2018, doi: 10.1016/j.reseneeco.2017.12.002.

[13] F. Pardo-Bosch, A. Blanco, E. Sesé, F. Ezcurra, and P. Pujadas, "Sustainable strategy for the implementation of energy efficient smart public lighting in urban areas: case study in San Sebastian," *Sustain Cities Soc*, vol. 76, p. 103454, Jan. 2022, doi: 10.1016/j.scs.2021.103454.

[14] W. van Bommel, *Road Lighting*. Cham: Springer International Publishing, 2015. doi: 10.1007/978-3-319-11466-8.

[15] K. A. A. Rahim, " Ray, " Benekohal, and J. Medina, "LED Roadway Lighting Volume 1: Background Information," 2012.

[16] R. M. Ramli, Y. Z. Arief, and P. Dewi Abd Aziz, "Application of LED technology into public road lighting in Malaysia for replacing the high pressure sodium vapour lighting," in *2015 International Conference on Sustainable Energy Engineering and Application (ICSEEA)*, IEEE, Oct. 2015, pp. 76–81. doi: 10.1109/ICSEEA.2015.7380749.

[17] K. F. Tee and E. Ekpiwhre, "Reliability-based preventive maintenance strategies of road junction systems," *International Journal of Quality & Reliability Management*, vol. 36, no. 5, pp. 752–781, May 2019, doi: 10.1108/IJQRM-01-2018-0018.

[18] C. Blumentrath and M. S. Tveit, "Visual characteristics of roads: A literature review of people's perception and Norwegian design practice," *Transp Res Part A Policy Pract*, vol. 59, pp. 58–71, Jan. 2014, doi: 10.1016/j.tra.2013.10.024.

[19] S. Fotios, J. Unwin, and S. Farrall, "Road lighting and pedestrian reassurance after dark: A review," *Lighting Research & Technology*, vol. 47, no. 4, pp. 449–469, Jun. 2015, doi: 10.1177/1477153514524587.

[20] P. R. Boyce, "The benefits of light at night," *Build Environ*, vol. 151, pp. 356–367, Mar. 2019, doi: 10.1016/j.buildenv.2019.01.020.

[21] C. H. Lim, M. Dalman, M. E. Salim, B. Bakhtyar, A. M. Ghafarij, and O. Saadatian, "LED Technology for Built and Environment of Malaysia," *Am J Appl Sci*, vol. 11, no. 9, pp. 1722–1726, Sep. 2014, doi: 10.3844/ajassp.2014.1722.1726.

[22] O. Pidlisna, A. Simonova, N. Ivanova, V. Bondarenko, and A. Yesipov, "Harmonisation of the urban environment by means of visual art, lighting design, and architecture," *Acta Scientiarum Polonorum Administratio Locorum*, vol. 22, no. 1, pp. 59–72, Mar. 2023, doi: 10.31648/aspal.8214.

[23] A. R. Kadam, G. B. Nair, and S. J. Dhoble, "Insights into the extraction of mercury from fluorescent lamps: A review," *J Environ Chem Eng*, vol. 7, no. 4, p. 103279, Aug. 2019, doi: 10.1016/j.jece.2019.103279.

[24] L. P. Singh and G. Katal, "A Comparative Study on Design and Operation of Fluorescent Lamps, Cfls and Leds," 2013. [Online]. Available: www.ijera.com

[25] J. Alvarez-Caicoya, A. Cosme-Torres, and E. Ortiz-Rivera, "Compact Fluorescent Lamps, an Anticipatory Mind to Mercury," *IEEE Potentials*, vol. 30, no. 1, pp. 35–38, Jan. 2011, doi: 10.1109/MPOT.2010.939762.

[26] A. Khan *et al.*, "A review of UV radiation protection on humans by textiles and clothing," *International Journal of Clothing Science and Technology*, vol. 32, no. 6, pp. 869–890, May 2020, doi: 10.1108/IJCST-10-2019-0153.

[27] S. J. Balk, "Ultraviolet Radiation: A Hazard to Children and Adolescents," *Pediatrics*, vol. 127, no. 3, pp. e791–e817, Mar. 2011, doi: 10.1542/peds.2010-3502.

[28] M. Bessho and K. Shimizu, "Latest trends in LED lighting," *Electronics and Communications in Japan*, vol. 95, no. 1, pp. 1–7, Jan. 2012, doi: 10.1002/ecj.10394.

[29] H. Khorasanizadeh, J. Parkkinen, R. Parthiban, and J. David Moore, "Energy and economic benefits of LED adoption in Malaysia," *Renewable and Sustainable Energy Reviews*, vol. 49, pp. 629–637, Sep. 2015, doi: 10.1016/j.rser.2015.04.112.

[30] Sazalina Zakaria, Radin Diana R. Ahmad, Ahmad Rosly Abbas, and Mohd Faizal Mohideen Batcha, "Greenhouse Gas Emission Intensity Assessment for Power Plants in Peninsular Malaysia," *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 88, no. 2, pp. 14–26, Nov. 2021, doi: 10.37934/arfmts.88.2.1426.

[31] M. A. Zubir, C. P. C. Bong, S. A. Ishak, W. S. Ho, and H. Hashim, "The trends and projections of greenhouse gas emission by the livestock sector in Malaysia," *Clean Technol Environ Policy*, vol. 24, no. 1, pp. 363–377, Jan. 2022, doi: 10.1007/s10098-021-02156-2.

[32] M. Franz and F. P. Wenzl, "Critical review on life cycle inventories and environmental assessments of LED-lamps," *Crit Rev Environ Sci Technol*, vol. 47, no. 21, pp. 2017–2078, Nov. 2017, doi: 10.1080/10643389.2017.1370989.

[33] J. Falcón *et al.*, "Exposure to Artificial Light at Night and the Consequences for Flora, Fauna, and Ecosystems," *Front Neurosci*, vol. 14, Nov. 2020, doi: 10.3389/fnins.2020.602796.

[34] A. Jägerbrand, "New Framework of Sustainable Indicators for Outdoor LED (Light Emitting Diodes) Lighting and SSL (Solid State Lighting)," *Sustainability*, vol. 7, no. 1, pp. 1028–1063, Jan. 2015, doi: 10.3390/su7011028.

[35] L. Cellucci *et al.*, "Urban Lighting Project for a Small Town: Comparing Citizens and Authority Benefits," *Sustainability*, vol. 7, no. 10, pp. 14230–14244, Oct. 2015, doi: 10.3390/su71014230.

[36] C. H. Southwick, M. A. Beg, and M. R. Siddiqi, "A Population Survey of Rhesus Monkeys in Northern India: II. Transportation Routes and Forest Areas," *Ecology*, vol. 42, no. 4, pp. 698–710, Oct. 1961, doi: https://doi.org/10.2307/1933499.