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IMPROVING ROAD SAFETY AT ACCIDENT-PRONE AREAS: A COMPARISON BETWEEN GLOW-IN-THE-DARK AND CONVENTIONAL ROAD MARKING

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Abstract

Driving at night is challenging due to poor vision, poor road visual guidance, and the need to encounter bright light sources. Factors like lack of street lighting, fading, and lack of reflectivity by road studs and retro-reflective materials affect road users' vision at night. Commentators have pointed out there is a critical demand to improve road safety in preventing road accidents and hazards that caused by the poor visibility of road markings and inadequacy lighting. Although road safety management has been given an important focus by the Ministry of Transportation Malaysia to achieve 50% reduction of road accidents by 2030, there is a critical demand to improve the present road markings method to overcome the issues of poor visibility or unclear road markings and inadequacy lighting that may trigger potential hazards to road users at night, with a new innovative road marking technology. Therefore, this paper is prepared with the objective to present the outcome of comparative study between the present conventional road markings and the newly innovative technology of glow-in-the-dark method with specific reference to the road safety management in Malaysia. This study employed a questionnaire survey to interview fifty-one (51) respondents that have experience of driving at night, with the objectives to get their opinions on present condition of road markings in Malaysia, and how the newly innovative technology glow-in-the-dark can improve road safety in Malaysia. The study outcome revealed that the glow-in-the-dark is deemed appropriate to enhance the visibility during low-light conditions as compared to the present conventional road markings. Although the initial cost is higher, the economic advantages of glow-in-the-dark in reducing the streetlight usage, lower electrical costs, and substantially extended lifespan have made this newly innovative road marking outweighed the downsides and economically wise choice to revolutionize road safety management practice at the accident-prone areas in Malaysia for achieving the SDG 3: Good Health and Well-being.

Keywords: Road markings, Glow-in-the-dark, Road Safety, Condition, Cost

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INTRODUCTION

Around 1.3 million people die in road accidents (World Health Organisation, 2017, as cited in Babić et al., 2022), with Malaysia experiencing around 4600 deaths in 2020. These accidents cost the nation RM 56.15 million per day or RM 21 billion per year (MOT Malaysia, 2022). The lack of street lighting (Saleem & Hosoda, 2021), non-functional road studs (Anarkooli & Hosseinlou, 2016, as cited in Harun & Omar, 2022), and low luminance conditions at night (Stamatiadis et al., 2020) increase the risk of accidents and injuries. Although road safety management has been given an important focus by the Ministry of Transportation (MOT) Malaysia to achieve 50% reduction of road accidents by 2030, there is a critical demand to improve the present road markings to overcome the issues of poor visibility or unclear road markings and inadequacy lighting that have affected road users' vision and triggered potential hazards when driving at night (MOT, 2022; Harun & Omar, 2022). Driving at night has several challenges, as most the road users' vision is poor, and when this includes with poor road visual guidance, results in many deadly crashes at night (Ackaah et al., 2020). As advocated by the Malaysian Institute of Road Safety Research (MIROS) (as cited in MOT, 2022), the lack of vision by the road users is the third highest road accidents factors in Malaysia. Road marking is the application of lines, symbols, and other markings on the surface of a roadway to indicate traffic flow, lane direction, and additional information for road users. It is essential for defining roads, splitting opposing traffic strands, and separating the entire road into sub-areas for various road users (British Standard, 2022). In Malaysia, paint and thermoplastics are the most popular materials used for road line markings and glass beads as their retro-reflectivity material (PWD Malaysia, 2017a, 2017b). However, new innovative technology like glow-in-the-dark road line marking uses photo-luminescent technology has been invented to absorb energy from sunlight and artificial light, producing non-radioactive and non-toxic light that can make it visible for over 12 hours (Britannica, 2020, as cited in Saleem & Hosoda, 2021). There have been suggestions to explore and adopt a new innovative technology, i.e., Glow-in-the-dark method that has emerged as a promising solution to create safer and more sustainable transportation infrastructure in Malaysia towards achieving the United Nations' Sustainable Development Goals number 3, target 3.6, which is to halve global deaths and injuries from road traffic accidents by 2020 (United Nations, 2018). Therefore, this paper is prepared with the objective to present the outcome of comparative study between the present conventional road markings and the newly innovative technology method of glow-in-the-dark with specific reference to the road safety management in Malaysia.

REVIEW OF CURRENT ROAD MARKINGS IN MALAYSIA

Road markings are crucial for road safety in Malaysia that help to guide and regulate traffic movement. The choice of road marking materials depends on factors such as durability, visibility, and cost (PWD Malaysia, 2017a). Permanent markings should have a functional life as long as possible, while paint is less expensive (PWD Malaysia, 2017a, 2017b). The conventional road markings in Malaysia, specifically paint and thermoplastic, are based on PWD Malaysia (1988), which states that these materials are normally designed for 3 to 5 years' service life, and the performance is influenced by the road conditions.

Paint Road Marking

Paint road marking is a widely used technique for providing clear and visible guidance to road drivers. In Malaysia, the paint road marking is used as a temporary marking, and the colour is yellow (PWD Malaysia, 2017a, 2017b). It is cheaper compared to the thermoplastic road marking due to its simple application process that does not require heating or other unique technology (Babic´ et al., 2015). There are two types of paint road markings, i.e., solvent-borne paint and water-borne paint. Solvent-borne paint is cheaper and more environmentally friendly, as it has better drying control, better adhesion to asphaltic and oily surfaces, and is not affected by humidity (Babic´ et al., 2015). The average lifespan of solvent-borne paint road line marking is 12 months or 1 year, ranging from 6 months to 24 months, depending on various factors (Burghardt & Pashkevich, 2020). Water-borne paint is compatible with many surfaces, including bituminous and concrete materials, making it suitable for renewal road line marking. The average lifespan of solvent-borne paint road marking is 6 months, with a maximum of 12 months depending on various factors (Mohamed, 2019;). The total cost for paint road marking in Malaysia for both edges is RM 9.00 per m. This total cost will be only for materials, not including other costs such as labour and transportation (PWD Malaysia, 2021). The paint road marking is cost-effective and easy to apply, but it has limitations on durability and visibility. Its lifespan is short, with a maximum of 24 months. It has the lowest visibility and detection distance in wet conditions, causing difficulties for road users to detect potential hazards Gibbons & Hankey, 2007, as cited in Babic´ et al., 2020).

Thermoplastic Road Marking

Thermoplastic road marking is a popular material in many countries, including Malaysia, due to its effectiveness in providing clear guidance to road users and preventing collisions. The material is made from a combination of resins, pigments, and fillers, which are melted and mixed to create a hot molten plastic

material. The average lifespan of thermoplastic road line marking is around 3.6 years or 42 months (Dormidontovaa & Filatova, 2016; Babic´ et al., 2019;), ranging from 2 years to 7 years depending on factors like thickness, traffic volume, and frequency. Thicker markings are more durable, while heavy traffic and frequent heavy vehicles can cause faster deterioration. The total cost for thermoplastic road line marking in Malaysia for both edges is RM 36.30 per m^2. This total cost will be only for materials, not including other costs such as labour and transportation (PWD Malaysia, 2021). It is a popular material for creating durable and visible lines on roads, but it has some limitations. Its cost is higher as compared to other paint road marking methods. It is made from plastic resin, glass beads, and pigments, which requires specialized equipment and time for application (Dormidontovaa & Filatova, 2016). Additionally, the thermoplastic road marking has environmental concerns such as high-temperature emissions, toxic smoke, and hothouse gas, which can affect the environment (Dormidontovaa & Filatova, 2016). The process also leaves a carbon footprint due to the need to heat the thermoplastic up to 200°C (Burghardt et al., 2021a). Glass beads containing thermoplastic road line marking are also concerned about retro-reflectivity during rain or wet conditions, which can reduce visibility and increase potential hazards to road accidents (Harun et al., 2019).

Glass Beads

Standard glass beads are the most common type of glass beads in road marking due to the affordability and ease of manufacturing (Wenzel et al., 2022). The standard glass beads are typically made from recycled float glass and window glass, which are ground to the desired dimensions (Burghardt & Pashkevich, 2020; Burghardt et al., 2022; Wenzel et al., 2022). The lifespan of glass beads can be measured through the minimum requirement of retro-reflectivity for the road marking. Standard glass beads have a shorter lifespan due to lower durability and abrasion resistance (Burghardt et al., 2021b). The minimum retro-reflectivity requirement for road line marking that needs to be maintained is 300 mcd/m^2/lx in dry conditions and 75 mcd/m^2/lx in wet and rainy conditions (PWD Malaysia, 2019). The average lifespan of general paint road marking is 7 months, while thermoplastic road marking is 42 months. Glass beads' lifespan depends on the type of road marking applied, with the lifespan ending when the marking ends. The total cost for both edges of road marking using the standard glass beads in Malaysia are RM 11.50 per m^2 while the premium glass beads are RM 13.12 per m^2 (Made-in-China, n.d.a, n.d.b, n.d.c; Janio, 2020). This total cost includes the cost of material, shipping, and tax. The glass beads are used in road line marking to improve visibility, but the retro-reflectivity performance can be reduced during rain due to water film on the road surface. The service life span can be shorter due to high refractive index (Harun et al., 2019; Burghardt et al., 2021a).

REVIEW OF GLOW-IN-THE-DARK ROAD MARKING

Glow-in-the-dark road marking is a new promising solution to enhance road visibility, improve traffic safety, and reduce environmental impacts. This innovative technology, based on photoluminescence materials with longer afterglow, provides visible light for lane separation and edge detection, that addressing the challenges of poor nighttime visibility or low-light conditions (Li, Wang, and Wang, 2014, as cited in Sha et al., 2021; Saleem & Hosoda, 2021). Unlike the conventional road markings, it does not rely on external light sources, offering a self-sustaining, energy-efficient solution (Jiang et al., 2019, as cited in Sha et al., 2021). The roots of glow-in-the-dark road marking can be traced back to Studio Roosegaarde, a renowned Dutch design firm, and the ingenious expertise of the Heijmans infrastructure management group the invented the concept of a luminous highway as part of the Smart Highway Project (Sha et al., 2021). The technology involves a special "photoluminescent" powder integrated into road paint, which absorbs and stores solar energy during daylight hours, charging itself for a captivating nighttime glow. This innovative technology has been successfully implemented on a 500-meter stretch of highway in the Netherlands, reducing the need for streetlights (Bhujbal et al., 2022).

The glow-in-the-dark road markings absorb and store ambient light energy during the day, allowing them to emit a captivating glow when darkness descends (Saleem & Hosoda, 2021). The main material used is strontium aluminate (SrAl2O4), which is activated by europium, dysprosium, and yttrium (Sakhapov et al., 2020). The effective thickness of the luminous or glow-in-the-dark surface layer is between 3 to 5mm, which ensures both mechanical strength and luminous effect (Sha et al., 2021). The "glow time" or "luminous time" is a critical factor determining the efficacy of these markings, as it directly impacts road safety and driver awareness during night travel. The outcome of review presented in Table 1 below shows that the glow-in-the-dark road markings have an average glow time of around 9 hours, varying between 6 and 12 hours depending on internal and external factors. The retroreflected luminance (R_L) is crucial for visibility and guiding road users through darkness. In dry conditions, the minimum $R_L$is 300 mcd/m^2/lx, while in wet and rainy conditions, it should be 75 mcd/m^2/lx (PWD Malaysia, 2019).

Table 1: Glow time duration of glow-in-the-dark road line marking

No.	Paper Title	Author / Year	Glow Time Duration
1	Development and testing of glow-in-the-dark concrete based raised pavement marker for improved traffic safety	Saleem and Hosoda (2021)	12 hours
2	Invention of fluorescent pavement	Pavalarathinam et al. (2012)	12 hours
3	Towards the new concept of smart roads: Regulatory framework and emerging projects overview	Franzò, Latilla and Longo (2018)	10 hours
4	Study smart road with glowing lines	Bhujbal et al. (2022)	8 hours
5	Ways to avoid traffic congestion in India and make India smarter – A prelude	Deepashree and Radhika (2020)	8 hours
6	Strontium aluminate compound as road line materials application	Munikanan, Peng, Yahya and Yusof (2021)	6 hours

The glow-in-the-dark road markings also can be a promising solution for safer and more sustainable transportation systems. An optimum design lifespan is crucial for the effectiveness and long-term viability of the glow-in-the-dark. The markings emit a captivating glow at night, providing continuous visibility and reducing accident risks. The precise lifespan of glow-in-the-dark depends on several factors like strontium materials, environmental conditions, and maintenance practices. Despite the lack of long-term studies, several authors suggest that the service life of glow-in-the-dark material can last up to 5.5 years or 66 months (Deepashree & Radhika, 2020). Besides, the total cost of glow-in-the-dark markings, including materials and transportation, is crucial for evaluating their economic viability and long-term benefits. The application of glow-in-the-dark markings can help to eliminate the need for traditional streetlights, offering a cost-effective and eco-friendly alternative. For instance, the total cost of installing a new LED-type streetlight is RM 1,685.00, and the electricity cost for 1 month operation is RM 10.20 (PWD Malaysia, 2023). On the other hand, the total cost for strontium aluminate including the cost of shipping and tax for both edges of road is RM 16.28 per m^2 (Munikanan et al., 2021). Although the glow-in-the-dark is designed to enhance visibility during low-light conditions, using luminous materials to emit a radiant glow; however, their effectiveness depends on the surrounding lighting conditions, as the emitted light may be negligible in areas with ample external lighting (Bacero et al., 2015). Additionally, the high cost of materials used to create the luminous afterglow has become a limitation to glow-in-the-dark application in the road safety management (Steyn, 2008, as cited in Sha et al., 2021).

Current State of Glow-In-The-Dark Application in Malaysia

The Malaysia's first glow-in-the-dark road marking project was implemented by the Public Works Department (PWD) on 28th October 2023 at the intersection of Jalan Sg Lalang Batu 19 and Jalan Sg Tekali Batu 16 in Hulu Langat, Selangor. The project was carried out by the District PWD for the purpose piloting to investigate the overall performance effectiveness and implementation cost of glow-in-the-dark at a length of 245 metres with 490 metres of road marking (NST, 2023a; TST, 2023; Alexander Nanta Linggi, 2023). Subsequently, the application of glow-in-the-dark road marking received critical demand to be extended nationwide in other states like Kedah and Johor to improve road safety road safety in areas prone to road accidents that caused by poor visibility of road markings and inadequacy lighting. Kedah's first glow-in-the-dark road marking was applied at three kilometres road length in Padang Sanai of Padang Terap that was recognized as the longest glow-in-the-dark road marking application in Malaysia in the year of 2023 (Latest Malaysia, 2023; NST, 2023b). Whilst Johor's first glow-in-the-dark road marking was implemented at Masai River Bridge in Masai (Media Digital Johor, 2023; World of Buzz, 2023). The Johor's State Minister, Onn Hafiz Ghazi announced in January 2024 there are 31 roads in Johor that have been identified for road safety upgrading with the installation of newly innovative technology, i.e., glow-in-the-dark road marking (Media Digital Johor, 2024; World of Buzz, 2024).

Although the glow glow-in-the-dark road marking in these three states has received good impression and positive feedback from road users, the Malaysia Works Minister, Alexander Nanta Linggi suggested a comprehensive feasibility study should be carried to investigate the cost-effectiveness of glow-in-the-dark over the road service life rather before deciding to extend its application nationwide. The Minister observed the initial cost of applying photoluminescent paint for glow-in-the-dark is high at RM749 per sq. metre, that costed approximately nineteen times higher than the conventional road marking paint of RM40 per sq. metre (Berita Harian, 2024, The Star, 2024). Due to high initial cost and maintenance cost concern, suggestion given that the glow-in-the-dark appropriate for road marking application at short road stretch (PTAN, 2024; The Star, 2024). Besides, the substitute material, i.e., glass beads, has been suggested to be assessed to identify the performance and cost comparison with the photoluminescent paint for enhancing the performance and cost-efficiency of glow-in-the-dark road marking application (The Star, 2024).

METHODOLOGY

A quantitative research strategy was chosen rather than qualitative and mixed method research strategies because it is more suitable for obtaining measurable, generalizable, and objective data to compare the effectiveness of glow-in-the-

dark and conventional road line markings in enhancing road safety in Malaysia. The questionnaire survey approach was carried out to interview respondents that have driving experience at night, with the objectives to get their opinions on the present condition of road markings in Malaysia, and how the newly innovative technology, i.e., glow-in-the-dark can improve road safety in Malaysia. The questionnaire survey was chosen because it can be dispersed through various modes, such as online platforms, email, or in-person distribution (Young, 2016). This flexibility allows respondents to choose the mode that best suits their convenience, increasing the likelihood of participation. In addition, the data collection period can be significantly shortened compared to other data collection methods because the survey can be easily implemented using modern tools, such as Google Forms (Pozzo et al., 2019). The questionnaire survey for the study was designed with close-ended questions using Google Forms, which have two types of answers, where the respondents need to state the degree of agreement for the research question statement and choose either one of the answers given for the research question. The designed Google Forms of questionnaire survey was distributed to respondents through WhatsApp and Telegram.

The data collected was analysed using descriptive analysis, consists of mean, mode, and standard deviation. The questionnaire design uses close-ended questions with various answers from the respondents who need to use mean to find an average range of agreement, from strongly disagree to strongly agree (i.e., 5-point Likert scale). The standard deviation was calculated to find the amount of disagreement among the respondents and to indicate the measurement level of consensus achieved. According to Table 2 the standard deviation and consensus achieved are inversely related. The reason is that when the standard deviation has lower values, the level of consensus achieved will be higher. On the other hand, when the standard deviation has higher values, the level of consensus achieved will be lower (Grobbelaar, 2007 as cited in Ayob, 2014). For close-ended questions that are designed with only two or three answers, mode was calculated to determine the greatest frequency in a set of numbers or distribution (Fellows and Liu, 2008 as cited in Ayob, 2014).

Table 2: Standard deviation and consensuses (Grobbelaar, 2007 as cited in Ayob, 2014)

Standard deviation (SD)	Level of consensus achieved.
$0 \leq X < 1$	High level of consensus
$1 \leq X < 1.5$	Reasonable/ fair level of consensus
$1.5 \leq X < 2$	Low level of consensus
$2 \leq X$	No consensus

RESULTS

The questionnaire survey comprises of three sections, which are Section A – Demographic information, Section B – Malaysia's road line marking, and Section C – Retro-reflectivity of road line marking. Fifty-three responses (53) were collected, but only fifty-one (51) responses were valid, as the other two (2) responses were not valid due to no driving experience at night.

Section A – Demographic Information

Table 3 below shows a full review of the demographic of respondents that participated in the questionnaire survey. Based on the respondents' demographic, it is not misconception to conclude that all 51 out of 53 participants meet the specified criteria and are qualified to be respondents to provide their opinion and judgement to the questions in the questionnaire survey.

Table 3: Demographic of respondents in the questionnaire survey

Characteristics		Results	
		Frequency	**Percentage (%)**
Gender			
i.	Male	18	34
ii.	Female	35	66
Age (in years)			
i.	18-34	41	77.4
ii.	35-49	9	16.9
iii.	50 and above	3	5.7
Have you ever driven a vehicle on the road in Malaysia, especially at night?			
i.	Yes	51	96.2
ii.	No	2	3.8
If Yes, how frequently do you drive a vehicle on the road at night within a week?			
i.	Less than 2 times	16	31.37
ii.	3 times to 5 times	16	31.37
iii.	More than 6 times	19	37.26

Section B – Malaysia's Road Line Marking

In this section, the respondents were asked on their range of agreement on the present conventional road marking in Malaysia. They need to rate on scale from 'Strongly Disagree (1)' to 'Strongly Agree (5)' based on their perspective and opinion on the statements given. The range of agreement being categorized from 1 to 5 to simplify calculations. Table 4 presents the calculated mean and standard deviation values based on the respondents' feedback on Malaysia's road line marking condition statements.

Table 4: Respondents' feedback on Malaysia's road line marking

No	Condition Statement	Mean	SD
1	The condition of conventional road line markings usually found is faded or worn out.	4.02	0.79
2	The poor condition of conventional road line markings is caused by lack of retro-reflectivity	3.80	0.98
3	The conventional road line marking in Malaysia is quality.	3.12	0.91
4	The conventional road line marking in Malaysia is clear and visible at night.	3.00	0.92
5	The maintenance carried out on the conventional road line marking in Malaysia is good and on time.	2.43	0.90

Section C – Retro-Reflectivity of Road Line Marking

For Section C, the respondents were asked on their preference for the type of road line marking with better retro-reflectivity, either conventional or glow-in-the-dark road markings. Overall, the mode values in Table 5 show that the glow-in the dark obtained greater preference by the respondents on retro-reflectivity performance at night rather than conventional road line marking method.

Table 5: Respondents' feedback on retro-reflective performance at night

No.	Research Question	Convent. (Mode)	GITD (Mode)
1	Which road line marking can easily be seen better at night?	1	50
2	Which road line marking has better retro-reflectivity at night?	0	51
3	Which road line marking is better in helping to determine the corner of the road better at night?	1	50
4	Which road line marking is better in helping to maintain the lane better at night?	0	51
5	Which road line marking is better in improving lane changes at night?	2	49
6	Which road line marking is better in determining the potential hazards or objects at night?	4	47

DISCUSSIONS

Present Condition of Road Markings in Malaysia

The results in Table 4 have established that the majority of respondents believed the current conventional road markings are in poor condition, with faded or worn-out signs, with the scores of mean 4.02 and standard deviation 0.79. This is attributed to poor maintenance and lack of retro-reflectivity (mean score 3.80 and standard deviation 0.98). The invisibility of road markings is a common cause of accidents, as highlighted by Nikolaev (2016, as cited in Sakhapov et al., 2020). The current road markings in Malaysia can lead to accidents, and therefore there is a critical demand to address these limitations in prevent road accidents. The

findings suggest that immediate actions are needed to improve the condition of road markings for enhancing the safety management practice in Malaysia.

Glow-in the Dark: Improving Road Safety Performance

The results in Table 5 show that the glow-in-the-dark has a better retro-reflectivity to improve road management safety in Malaysia as compared to conventional road markings. It improves visibility and reduces fatal crashes at night due to poor vision and road visual guidance. According to Ackaah et al. (2020), the challenges of nighttime driving are poor vision and inadequate road visual guidance. To overcome this, the glow-in-the-dark road marking is recommended for application in road safety management to facilitate the nighttime drivers to determine road corners, maintain lane, improve lane changes, and identify potential road hazards at night.

Glow-in the Dark: Economical Standpoint Over the Long Term

The results in Table 6 show that the road markings in Malaysia are costed in average RM 36.60 per m^2 in 2021 (PWD 2021), and gradually increases to RM40 per m^2 in 2024 (Berita Harian, 2024; The Star, 2024) for both edges, including installation of retro-reflective glass beads (PWD 2021, Berita Harian, 2024). The average total installation cost of conventional (glass beads) thermoplastic road marking is RM 12.31 per m^2slightly lower compared to strontium aluminate at RM 16.28 per m^2 (Bacero et al., 2015; Munikanan et al., 2021). The total cost for glow-in-the-dark road marking is RM 40.57 per m^2, (RM749-Berita Harian, 2024) which is more expensive compared to current cost of conventional road marking at RM40 per m^2 (Berita Harian, 2024) Even though the cost of glow-in-the-dark materials is higher than the conventional road marking, it provides significant saving through reduced streetlight installation and operation costs, making it more cost-effective over the long term. The installation cost of LED-type streetlighting alone is RM 1,685.00, with the combination of electrical cost at RM10.20 per month can make a huge difference in cost savings when the glow-in-the-dark is economically applied for road safety over the long term (PWD Malaysia, 2023).

Table 6: Literature data compilation on the cost comparison between conventional and glow-in-the-dark road markings.

Items	**Thermoplastic Road Line Marking**	
Total Cost including glass beads (per m^2 for both edges)	i. **RM 36.60** (PWD, 2021) ii. **RM40** (Berita Harian, 2024)	
Two (2) competing road line marking	**Conventional Road Markings (Glass Beads)** per m^2	**Glow-In-The-Dark (Strontium Aluminate)** per m^2
Total Cost (per m^2 $for\ both\ edges$)	RM 11.50 (standard)	**RM 16.28**

Items	Thermoplastic Road Line Marking	
(Material + Shipping + Tax)	RM 13.12 (premium) (Made-in-China, n.d.a, n.d.b, n.d.c; Janio, 2020). Or **RM 12.31** (Average cost between standard and premium Glass Beads)	(Bacero et al., 2015; Munikanan et al., 2021).
Total Cost of Thermoplastic Road Line Marking including Retro-reflective Material	**RM 36.60**	**RM 40.57**
Streetlighting cost	i. Installation cost of LED-Streetlight type: RM 1,685.00 ii. Electricity cost: RM 10.20 per month (Source PWD Malaysia, 2023).	
Design lifespan (Babic´ et al., 2019; PWD Malaysia, 2019; Deepashree & Radhika, 2020)	**42 months**	**66 months**

Furthermore, the literature data reveals that the design lifespan of glow-in-the-dark (66 months) is longer than the conventional road markings (42 months). Hence, it is not misconception to state that although the upfront cost required for the glow-in-the-dark (RM 40.57 per m^2) is slightly higher than the conventional road marking (RM36.60 per m^2), it offers a lasting period of effectiveness before requiring replacement. Therefore, despite slightly higher on initial costs, the economic advantages of reduced streetlight usage, lower electrical costs, and extended lifespan make the glow-in-the-dark road line marking an economically wise choice over the long term.

United Nations (2018) has established the Sustainable Development Goals (SDGs), which include a specific goal SDG 3: Good Health and Well-being. One of the targets under this SDG3 goals, is target 3.6 that focuses on halving the number of global deaths and injuries from road traffic accidents by 2020. Although the deadline target date of 2020 for addressing SDG 3: Target 3.6 has passed, continuing efforts are needed to find ways to reduce road traffic accidents in order to ensure safe mobility for all. This innovative technology, glow-in-the-dark road marking, can be potentially revolutionized road safety management in Malaysia. With its ability to provide clear and consistent road markings during low-light conditions, glow-in-the-dark road line marking can significantly reduce the number of accidents and fatalities on the road to help achieving the target 3.6 under the SDG 3.

CONCLUSION

This paper has presented the outcome of comparative study between the present conventional road markings and the newly innovative technology of glow-in-the-

dark with specific reference to the road safety management in Malaysia. The results of the study have established that the glow-in-the-dark is more superior than the present conventional road markings for improving the road safety management practice at the accident-prone areas in Malaysia. Although the cost of glow-in-the-dark materials is higher than the conventional road marking, it is to misconception to state the economic and performance advantages of glow-in-the-dark for improving road safety at the accident-prone areas outweigh the downsides. Therefore, it could be deemed appropriate for consideration to extend the application of glow-in-the-dark road marking to revolutionize the road safety management practice at the accident-prone areas in Malaysia. The outcome of the study contributes to the understanding of road safety enhancement in Malaysia, that can be useful inputs for guiding towards promoting road safety standards that align with road accident cost reduction consideration for achieving the Sustainable Development Goals, i.e., Target 3.6 under SDG 3: Good Health and Well-being.

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> Hadi Farhan Semadi (2023). Enhancing Road Safety in Malaysia: A Comparative Analysis of Retro-Reflectivity in Glow-In-The-Dark and Conventional Road Line Marking. [Unpublished Degree's Dissertation], International Islamic University Malaysia.

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