AN ANALYSIS OF ROAD LIGHT INTENSITY ON DOUBLE LANE ROAD WITH LAMP POLE ON KERB SIDE EDGE

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DECLARATION

I declare that this project report entitled "An Analysis Of Road Light Intensity On Double Lane Road With Lamp Pole On Kerb Side Edge" is the result of my own work except as cited in the references

Signature : ....

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Date : 5/7/2024

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ....

Name of Supervisor : IR. TS. DR MOHD ZAID BIN AKOP

Date : 5/7/2024

DEDICATION

To my beloved mother and father

ABSTRACT

This thesis presents a comprehensive analysis of light intensity on a double lane road with lamp poles positioned at the kerb side edge. The study aims to evaluate light distribution on double lane road. The investigation involves measuring light intensity at various heights and angles from the road surface, using advanced photometric equipment to gather precise data. A portable streetlamp has been specifically created for this study to measure the light intensity of the road on double lanes. Various aspects have been considered, such as the road's length, the lamp's height, the road's width, and the angle at which the lamp shines. Based on the calculated factors, the light intensity readings will be obtained along the grid line of the road. The results indicate higher light intensity levels at the beginning and end of the lamp, with lower light intensity distributed in the middle of the road between the lamp posts. This study offers a valuable foundation for city planners and engineers to enhance road lighting systems for safer and more effective transportation networks. Moreover, this study potentially evaluates the effectiveness of car Autonomous Emergency Braking Systems (AEB).

ABSTRAK

Kajian ini mempersembahkan analisis komprehensif terhadap intensiti cahaya di jalan dua lorong dengan tiang lampu yang diposisikan di tepi bahu jalan. Kajian ini bertujuan untuk menilai pengagihan cahaya di jalan dua lorong. Penyelidikan ini melibatkan pengukuran intensiti cahaya pada pelbagai ketinggian dan sudut dari permukaan jalan, menggunakan peralatan fotometrik canggih untuk mengumpulkan data yang tepat. Sebuah lampu jalan mudah alih telah direka khas untuk kajian ini bagi mengukur intensiti cahaya di jalan dua lorong. Pelbagai aspek telah dipertimbangkan, seperti panjang jalan, ketinggian lampu, lebar jalan, dan sudut cahaya lampu. Berdasarkan faktor yang dikira, bacaan intensiti cahaya akan diperoleh sepanjang garis grid jalan. Hasil kajian menunjukkan tahap intensiti cahaya yang lebih tinggi pada permulaan dan akhir lampu, dengan intensiti cahaya yang lebih rendah di bahagian tengah jalan antara tiang lampu. Kajian ini menawarkan asas yang bernilai untuk perancang bandar dan jurutera dalam meningkatkan sistem pencahayaan jalan untuk rangkaian pengangkutan yang lebih selamat dan berkesan. Selain itu, kajian ini berpotensi menilai keberkesanan Sistem Pembrekan Kecemasan Autonomi (AEB) kereta.

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Last but not least, I wanna thank me, I wanna thank me for believing in me. I wanna thank me for doing all this hard work. I wanna thank me for having no days off. I wanna thank me for never quitting. I wana thank me for always being a giver and trying to give more than I receive. I wanna thank me for trying to do more rights than wrong. I wanna thank me for just being me at all times.

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LIST OF ABBEREVATIONS

AEB	Autonomous Emergency Braking
ADAS	Advance Driver Assistant System
ASEAN	Association of Southeast Asian Nation
HID	High Impact Density
HSPV	High Pressure Sodium Vapor
LED	Light Emitted Diode
LiDAR	Light Distance and Ranging
NCAP	National Car Assessment Program
SAE	The Society of Automotive Engineers
UTeM	University Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Background

The intensity of road lights is critical in assuring safety and visibility on roadways, especially on double-lane roads with curb-side lighting poles. Adequate lighting is required for vehicles to navigate safely, notice possible risks, and respond quickly. Analyzing road light intensity in this context is critical for identifying flaws and proposing modifications that increase safety for all road users. While earlier research has investigated the impact of road lighting on safety, there is a significant gap in the literature when it comes to analyzing road light intensity on double-lane roads with curb-side lamp poles. Existing research frequently focuses on general road illumination or specialized lighting systems, ignoring the unique issues and considerations associated with this specific road structure. This thesis aims to bridge this gap by providing a comprehensive analysis of road light intensity in this specific context.

To achieve this objective, a multi-faceted approach will be employed. The research will involve on-site inspections and measurements to assess the positioning, height, and angle of the lamp poles. Light intensity measurements will be conducted at various points on the road to evaluate the overall illumination and its distribution across both lanes. Additionally, weather conditions and their impact on visibility will be considered to ensure a comprehensive analysis.

1.2 Problem Statement

The modernization of transportation infrastructure has brought about significant advancements, yet there exists a critical concern pertaining to road safety, particularly on double-lane roads with lamp poles situated on the curb side edge. The focus of this thesis is to conduct a comprehensive analysis of road light intensity in such configurations, aiming to understand its implications on overall road safety. The placement of lamp poles on the curb side edge introduces unique lighting conditions that may impact visibility and reaction times for drivers, particularly during low-light conditions. This issue gains added significance in the context of autonomous emergency brake (AEB) systems, as the efficacy of these systems relies heavily on accurate environmental perception. The potential interplay between road light intensity variations and the performance of AEB systems raises questions about the reliability and effectiveness of these safety features in the specific context of double-lane roads with curb side edge lamp poles. Consequently, addressing this problem is crucial for advancing our understanding of the factors influencing road safety and enhancing the performance of autonomous emergency brake systems in real-world scenarios.

1.3 Objective

The objectives of this project are as follows:

1. To analyse light intensity based on various height from road surface.
2. To analyse light intensity based on various angle from lamp pole.
3. To correlate height and angle from lamp pole on light intensity.

1.4 Scope of Project

The scopes of this project are:

1. To select street lighting based on double lane road.
2. To perform measurement on road light intensity at night condition based on double lane road on curb side edge.
3. Validation of the light intensity produce by the customize road light intensity simulation test rig.
4. Data gathering and analysis using on board data measurement and acquisition system.
5. Report writing, journal publication and project presentation

CHAPTER 2

LITERATURE REVIEW

2.1 Road Light Intensity

Road light intensity refers to the brightness level produced by the lighting infrastructure on roads. Research has indicated that road lighting plays a vital role in decreasing the frequency and severity of road accidents (Yannis et al., 2013). The visibility and detection distances on the road are directly affected by the intensity of road lighting, and different lighting intensities impact the ability to detect objects on the road (Chenani et al., 2017). Moreover, the design of road lighting, particularly the distribution of the luminaire photometric intensity curve, is crucial in ensuring optimal lighting parameters for road safety (Czyżewski & Fryc, 2020). It is clear that road lighting significantly influences driver behavior and environmental conditions, resulting in improved safety and reduced nighttime accident rates (Bassani & Mutani, 2012). Additionally, the presence of road lighting enhances the clarity and perception of traffic signs and road markings, contributing to overall road safety (Setyaningsih et al., 2018). However, it is worth noting that further investigation is needed to understand the relationship between safety and the amount of light provided by road lighting (Niaki et al., 2016).

2.2 Consideration of Lamp for Road Lighting Specification

To ensure road lighting that prioritizes safety and energy efficiency, it is essential to consider areas where pedestrians are commonly found rather than areas with high speeds (Boyce et al., 2009). Moreover, the design of the lighting should allow pedestrians to identify obstacles, be aware of other pedestrians, and detect potential dangers from vehicles to guarantee their safety. Additionally, the lighting should be adaptable, adjusting the level of brightness based on the presence of pedestrians and tracking their movements (Fotios et al., 2014). This approach not only enhances the safety of pedestrians but also contributes to reducing energy consumption by optimizing the use of light.

In the context of energy efficiency, the utilization of LED road lighting fixtures has been proposed as an effective and efficient solution (Ge et al., 2016). Moreover, enhancing the performance and energy efficiency can be achieved by optimizing the combination of road surface and lighting (Muzet et al., 2018). In addition, recent studies indicate the possibility of reducing the intensity of road lighting when car headlights are present, which implies potential energy savings without compromising driver safety (Pihlajaniemi et al., 2022).

In addition, it is crucial to consider the pollutants released by cars, specifically reactive nitrogen compounds, as they have the potential to affect the quality of air and the environment. Research has indicated that the on-road emissions of reactive nitrogen compounds from light-duty vehicles exhibit long-term patterns, highlighting the necessity of effective road lighting to minimize the impact of vehicle emissions on the air quality (Bishop & Stedman, 2015). Moreover, the significance of road lighting in ensuring visibility and safety, particularly in areas with heavy traffic, is emphasized by the impact of vehicle emissions on air quality (Chen et al., 2020).

2.2.1 Fluorescent Lamps

Fluorescent lamps are commonly used for street lighting because of their energy efficiency and long lifespan. The operation of fluorescent lamps involves the utilization of a low-pressure mercury-argon discharge in a cylindrical tube coated with phosphor. This coating converts the ultraviolet radiation produced into visible light (Loo et al., 2005). Moreover, the incorporation of electronic ballasts in fluorescent lamps ensures a more stable voltage and current, even under flicker conditions, resulting in a reliable and consistent operation (Cai et al., 2009).

In addition, the design and implementation of electronic ballasts for fluorescent lamps play a vital role in achieving efficient and intelligent street lighting. These ballasts allow for more effective management of streetlamp systems through advanced interface and control architecture (Leccese, 2013). Furthermore, the use of dimmable electronic ballasts for fluorescent lamps is rapidly increasing due to the recognition of their high efficiency and ability to provide comfortable lighting systems, which have a positive impact on people's health and working performance while also saving energy (Wang et al., 2013).

Moreover, the development of new types of fluorescent lamps, such as T5 fluorescent lamps with electronic ballasts, has been proven to reduce the overall cost of lighting systems for various end users, including residential and general service customers (Sriamonkitkul et al., 2010). This reduction in cost is attributed to the energy-saving capabilities and efficiency of these fluorescent lamps.

Regarding road lighting, the use of fluorescent lamps with well-designed filters has been suggested to increase illuminance and provide an air cleaning function without consuming additional electricity (Teng, 2013). Furthermore, the implementation of an intelligent control system called "Illumination Moving with the Vehicle" for road tunnel lighting, which adjusts the luminance of LED lamps based on vehicle detection, demonstrates the potential for energy-saving strategies in road lighting (Wang et al., 2020).

2.2.2 High Pressure Sodium-Vapour (HPSV) Lamps

High-pressure sodium vapor (HPSV) lamps have been extensively utilized in public lighting because of their effectiveness and stability in luminous flux (Bruening & He, 1988). However, there is an ongoing shift from HPSV lamps to LED streetlamps, which provide higher efficiency, cost savings, and improved photometric performance (Sakar et al., 2020). This shift is motivated by the potential for greater effectiveness and improved visibility offered by LED lamps compared to HPSV lamps (Saraiji et al., 2016). Additionally, the use of LED lamps has been found to be statistically like metal halide lamps in terms of pedestrian visibility at night, with both being superior to HPSV lighting (Saraiji et al., 2016).

The effectiveness of HPSV lamps has been a topic of research, with studies examining the relationship between effectiveness, arc tube temperature, and power dissipation (Denbigh et al., 1983). It has been observed that metal halide lamps were more effective than HPSV lamps in eliciting an equivalent reaction time to off-axis stimuli, despite HPSV lamps being rated as more effective using a photopic luminous efficacy function (Bullough & Rea, 2000). Furthermore, the stability of commercial

HPSV lamps has been investigated to ensure the selection of lamps that produce a consistent luminous flux upon relighting (Bruening & He, 1988).

The use of obstacle detection to determine suitable illuminances for lighting in residential roads has been examined, with the obstacle detection ability of older and younger observers under different illuminances for HPSV lamps being compared to other lamp types (Fotios & Cheal, 2012). This highlights the significance of illuminance levels in ensuring visibility and performance, particularly in outdoor lighting applications.

2.2.3 Light Emitted Diode (LED) Lamp

The main changes behind the transition from traditional road lighting technologies to Light-Emitting Diode (LED) lighting is the need for energy efficiency, cost savings, and environmental considerations (Rofaie et al., 2022). LED road lighting has been widely implemented because it offers potential advantages such as increased energy efficiency, longer operating life, and better light distribution compared to traditional street lighting technologies (Ge et al., 2016). Research has shown that LED luminaires can achieve the desired luminous characteristics in road lighting, and advancements in LED technology have improved luminous flux and efficiency, making them suitable for road lighting applications (Wang et al., 2010; Wang et al., 2009). Moreover, the use of LED lighting in road tunnels has been investigated, and smart control systems have been developed to automatically operate and adjust the luminous flux emitted by the lighting system (Wang et al., 2020; Lai et al., 2014).

Optical design plays a vital role in the effectiveness of LED road lighting. Researchers are focusing on designing compact freeform lenses and chip-on-board LED arrays to optimize light distribution and luminous intensity for road illumination (Hao et al., 2018; Zalewski, 2015; Ge et al., 2014). Additionally, there is a proposal to use wireless intelligent control systems for combined illumination in road tunnels using HPS lamps and LEDs as an energy-saving solution (Lai et al., 2014). The potential of LED street lighting using micro lens arrays has been proven through optical analysis, demonstrating its suitability for various road lighting arrangements (Lee et al., 2013).

While LED road lighting has potential benefits, there is a need to further evaluate its performance after installation. It is also important to understand how users perceive and respond to this lighting technology (Jägerbrand, 2016; Kuhn et al., 2012). In addition, the development of smart LED luminaires for pedestrian road lighting and the rapid advancements in smart LED systems show the ongoing progress in LED lighting solutions for road applications (Juntunen et al., 2013; Park & Jun, 2017).

2.2.4 Metal Halide Lamps

Metal halide lamps, which are commonly used for outdoor lighting applications such as street lighting, are a type of high-intensity discharge (HID) lamp (Jurney et al., 2017). These lamps work by creating an electric arc through a gaseous mixture of vaporized mercury and metal halides (Jurney et al., 2017). Typically, metal halide lamps contain a rare gas and vapor from the dosing of a metal halide solid and mercury (Lay et al., 2002). The rare gas fill and the vapor produced by the metal donor are responsible for the electrical breakdown of these lamps (Moss et al., 2004). To achieve the desired colour temperature, colour rendering, and luminous efficacy, metal halide salts are used to provide the spectral power distribution (Lierop et al., 2000). These lamps are known for their high luminous efficacy, excellent color-rendering properties, and the ability to combine good colour appearance with compact size, which makes them highly efficient white light sources (Mucklejohn et al., 1987).

Metal halide lamps with ceramic envelopes have been seen as a significant advancement in colour control, making them even more suitable for various applications, including street lighting (Carleton et al., 1997). Studies have also been conducted on the use of metal halide lamps for inducing photohemolysis in porphyria, suggesting their potential for specific medical applications (Honda et al., 1984). Furthermore, metal halide lamps have been found to have higher intensity, greater luminous efficacy, and longer lifespan compared to incandescent lamps, further supporting their suitability for street lighting applications (Inouye & Honda, 1986).

2.2.5 Yellowish and White Road Lighting

The topic of choosing between yellowish and white road lighting has been a subject of interest in transportation engineering and visual safety perception research. Setyaningsih et al. (2018) conducted a study on how road lighting affects visual safety perception and the visibility of traffic signs and road markings. Their findings differ from other research, such as Fotios' claim that white road lighting creates a safer feeling compared to yellowish lighting, Knight's statement that people perceive white light as more comfortable and safer than yellowish light, and Morante's report that white road lighting is perceived as safer than yellowish light. This suggests that there is a difference in how people perceive safety between yellowish and white road lighting, and individual preferences and perceptions may influence this.

Moreover, Brons et al. (2021) discussed the logical basis for selecting light-emitting diode (LED) street lighting retrofits. They emphasized that LED lighting systems with white illumination appear brighter on the road compared to high pressure sodium vapour (HPSV) lights with yellowish illumination. This indicates that from a technical perspective, white LED lighting may offer better brightness and visibility than yellowish HPS lighting, potentially contributing to improved road safety and visibility.

Additionally, Zhu et al. (2012) explored the research on LED lights for road lighting in mesopic vision. Their simulation analysis of image clarity in mesopic vision showed that choosing white and green LED light sources for road lighting resulted in better clarity and sensitivity compared to yellow high-pressure sodium light and white LED light. This suggests that in specific visual conditions like mesopic vision, white LED lighting may provide advantages in terms of clarity and sensitivity, which are crucial factors for road visibility and safety.

2.3 Autonomous Emergency Braking (AEB)

Autonomous Emergency Braking (AEB) is a sophisticated safety technology designed to prevent or reduce collisions by automatically applying the brakes of the vehicle. AEB systems utilize sensors like radar, cameras, and LiDAR to detect potential collision partners ahead of the vehicle. When the system identifies a risk of collision, it can either alert the driver or engage the brakes on its own to avoid or minimize a crash (Wu, 2017). Studies have been conducted to examine the effectiveness of AEB systems in reducing front-to-rear crash rates, and it has been determined that forward collision warning and AEB systems are indeed successful in reducing such crash rates (Cicchino, 2017). Additionally, AEB systems designed for lower speeds have proven effective in real-world rear-end crashes, further emphasizing the potential of AEB technology in enhancing vehicle safety (Fildes et al., 2015).

AEB systems are not limited to scenarios involving vehicle-to-vehicle collisions but also extend to pedestrian collision avoidance. Research has been carried out on the development of Longitudinal Active Collision Avoidance of Autonomous Emergency Braking Pedestrian Systems (AEB-P), with a focus on the functional requirements for avoiding pedestrian collisions and ensuring pedestrian safety (Wei et al., 2019). Furthermore, an enhanced AEB algorithm has been proposed, which includes the estimation of the road's adhesion coefficient and considers the performance of the Electro-Hydraulic Brake (EHB) system, demonstrating the ongoing advancements in AEB technology (Zeng et al., 2021).

The application of AEB systems is not limited to standard driving scenarios but also extends to unexpected collision avoidance strategies. For example, an unexpected collision avoidance driving strategy has been developed using deep reinforcement learning, utilizing cameras and laser scanners to automatically brake the vehicle when detecting another vehicle within the risk range (Kim et al., 2020). Additionally, the coordinated control of steer-by-wire and brake-by-wire for AEB on split-μ roads has been explored, highlighting the aim of active safety technology to prevent collisions by implementing strong braking (Xue et al., 2020).

The importance of the AEB control strategy in enhancing passenger safety in vehicles has been emphasized, as AEB has the potential to significantly reduce the speed and severity of collisions (Jiang et al., 2020). Furthermore, studies have examined the willingness of drivers to use AEB systems, indicating the significance of user acceptance and adoption of this advanced safety technology (Nawi et al., 2022). Additionally, the consideration of AEB systems in safety rating assessments and their role in reducing accident risks by automatically applying brakes before an accident has been emphasized, underscoring the importance of AEB in enhancing overall vehicle safety (Baharuddin et al., 2021).

2.3.1 Functionality of Censors Technology in AEB System

The functionality of Automatic Emergency Braking (AEB) systems is heavily reliant on sensor technology, which serves to detect potential collisions and trigger braking to prevent or mitigate crashes.A commonly employed sensor in AEB systems is the camera sensor, utilized for pedestrian detection and capable of modeling various attributes in crash scenarios (Hamdane et al., 2015). Another widely used sensor is radar, often combined with cameras to detect pedestrians and other vehicles in the vehicle's path (Haus et al., 2019). Additionally, LiDAR is integrated into AEB systems, such as the Volvo City Safety AEB system, to monitor the vehicle ahead and activate braking upon collision detection (Hu et al., 2020).

Beyond these sensors, technologies like DSRC (Dedicated Short-Range Communication) can be applied to furnish drivers with information about other vehicles beyond their line of sight, facilitating the development of driving support systems like rear-end collision warning systems (Zhao et al., 2019). Sensor data fusion is also deployed in AEB systems to amalgamate information from multiple sensors, enhancing the accuracy of collision detection (Sangorrin et al., 2010).

Numerous studies have attested to the effectiveness of AEB systems in preventing crashes and reducing injury severity. AEB systems with pedestrian detection, utilizing a combination of camera and radar sensors, have demonstrated a potential reduction of rear-end crash rates by up to 43% (Graci et al., 2019). Furthermore, estimates of the potential benefits of installing AEB systems in cars for pedestrian protection underscore the cost-effectiveness of these systems (Edwards et al., 2014).

2.3.2 Performance of RADAR in AEB System

The RADAR technology is extensively utilized in AEB systems to detect potential collision partners ahead of the vehicle, allowing the system to automatically engage the brakes to prevent or reduce the impact of a crash (Wu, 2017). Studies indicate that AEB systems equipped with RADAR sensors have specific requirements aimed at avoiding pedestrian accidents and ensuring pedestrian safety (Wei et al., 2019). Moreover, tests conducted on RADAR-based AEB systems have demonstrated their effectiveness in preventing collisions (Kim et al., 2016).

Furthermore, the advancement of affordable AEB systems has demonstrated that RADAR can effectively function with varying braking distances, ranging from 3.3 m to 31.7 m. This highlights the versatility and dependability of RADAR technology in AEB applications (Ariyanto et al., 2018). Additionally, the integration of RADAR with other technologies such as steer-by-wire and brake-by-wire has been thoroughly explored, underscoring the significance of coordinated control for efficient AEB in challenging road conditions (Xue et al., 2020).

2.3.3 Performance of LiDAR in AEB system

The performance of LiDAR sensors in AEB systems is a crucial aspect in ensuring the safety and effectiveness of these systems. LiDAR, along with radar and camera technologies, plays a vital role in identifying potential collision partners and enabling AEB systems to automatically apply brakes to avoid or reduce crashes (Wu, 2017).

Moreover, various studies have been conducted to improve collision avoidance systems, including AEB, for different scenarios like curves and intersections. These studies highlight the significance of considering road surface conditions and V2V communication to enhance the braking performance of AEB systems. Furthermore, the integration of V2V communication and the consideration of road friction on slopes have been identified as factors that can greatly impact the performance of AEB systems (Jeon et al., 2016).

It is important to note that the performance of AEB systems, including those that use LiDAR sensors, aims to reduce accident risks by automatically applying brakes before an accident occurs, thus preventing collisions and ensuring the safety of pedestrians and other road users (Wei et al., 2019; Baharuddin et al., 2021). Additionally, the development of AEB algorithms that take into account the adhesion coefficient of the road ahead and the performance of the Electronic Hydraulic Brake

(EHB) further emphasizes the ongoing efforts to enhance the capabilities of AEB systems, including those that incorporate LiDAR technology (Zeng et al., 2021).

2.4 Impact Factors of AEB System

The performance of the AEB system is impacted by both the inherent and external factors of the equipped vehicle while driving. The inherent factors include on-board sensing, decision-making, and actuation, while the external factors refer to everything other than the vehicle itself. This research further categorizes these factors into three groups based on their level of influence: vehicle, driver, and environmental factors. These factors may simultaneously exist during the AEB working process and affect safety, comfort, and energy consumption, as demonstrated in Figure 2.1.

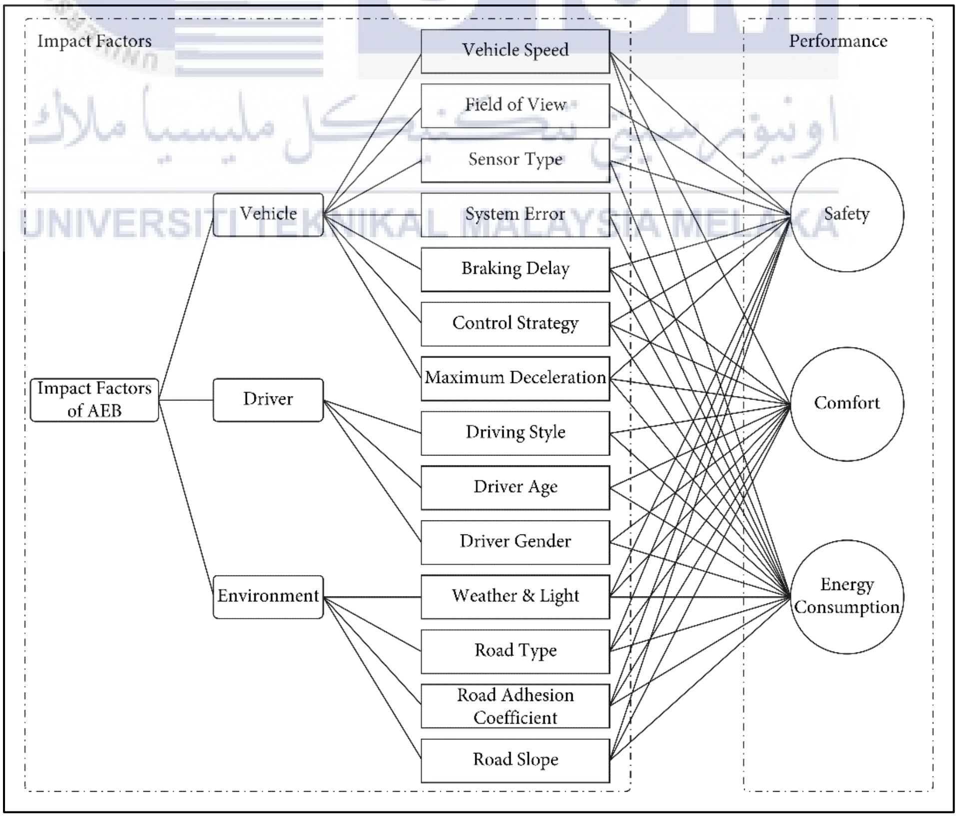

Figure 2.1 Impact Factor of AEB (Lan Yang et, 2022)

2.4.1 Vehicle Impact

While driving, vehicles may encounter complex road environment and traffic conditions, such as curves (horizontal and vertical), intersections, overtaking, and lane changes. Currently, the AEB system is usually applied to low- and medium-speed traffic scenes, rarely applied to high-speed traffic scenes. In international testing standards, the maximum speed of the test vehicle is 80 km/h. At the same time, it is important to identify the most dangerous targets as quickly as possible in complex road conditions. The basic function of AEB is that the camera and radar can recognize objects ahead. However, as the vehicle's primary detection equipment, cameras and radar are less effective in bad weather and low light conditions, such as sandstorms, fog, snow, and darkness. The field-of-view (FOV) of the sensor has a significant effect in avoiding collisions, especially collisions between vehicles and pedestrians (or cyclists). Studies have shown that when the detection angle of an AEB system is set between 30° and 50°, more than 95.3% of serious and fatal injury accidents can be detected and 78. 5% to 92.2% of accidents cause minor injuries (Liu et al, 2018). With increasing the detection angle, more targets (especially pedestrians and cyclists) can be detected (Jenald et al, 2018), thus avoiding more accidents.

The impact of system factors on collision avoidance performance is demonstrated by system errors, braking delays, deceleration strategies and maximum control (Hu et al, 2017). System errors occur due to measurement errors and inadequate perception of the environment, leading to uncertainty in the system's decision making. Brake lag is the time from when the driver presses the brake pedal until the brake system begins to build up pressure, which depends on the system's ability to perform braking. When the vehicle applies full braking behavior, slowing down the vehicle more will reduce braking time and ensure vehicle safety, but slowing down too much will affect the driver's driving experience. With advances in sensor and braking technology, the AEB system's target recognition capabilities, the quantity and accuracy of data acquired, and the system's latency are continuously improving. The choice of control strategy directly affects the overall performance of the AEB system, which forms the central part of the system. Comparing current popular collision avoidance algorithms based on safe distance or time to collision (TTC), when the vehicle speed is less than 60 km/h, the collision avoidance algorithm based on TTC has good stability, better stability, and smaller braking force, helping the driver feel safer. Driving feels more comfortable. When the vehicle speed exceeds 60 km/h, the collision avoidance algorithm based on safe distance can ensure the reliability of vehicle emergency braking (Gu et al, 2018).

2.4.2 Driver Factor

The “autonomous” of the AEB system primarily means that the driver’s intervention is not required. However, each driver’s driving style varies owing to his or her characteristics, such as driver’s age, gender, experience, responsiveness, and psychological endurance. Therefore, unified collision avoidance logic and evaluation criteria may not be applicable to different drivers. Therefore, in addition to ensuring safety, the driver’s driving comfort should be guaranteed to a certain extent.

To analyse the driving styles of different types of drivers and avoid the dissatisfaction and doubt caused by the control strategies that do not conform to their driving styles, drivers are classified according to the true test data of driving characteristics. This data can be obtained by a driving characteristic identification model based on a hidden Markov chain or a Bayesian filter and support vector machine model. Drivers can be divided into three types: radical, standard, and conservative. After determining the driver style, different control strategies and parameters can be set for different types of drivers to enhance the control accuracy and driving comfort of the system.

2.4.3 Environmental Factor

The primary meaning of the "autonomous" of the AEB system is that the driver's intervention is not needed. However, the driving style of each driver differs based on their individual characteristics such as age, gender, experience, responsiveness, and psychological endurance. Therefore, in addition to ensuring safety, it is crucial to guarantee a certain level of driving comfort for the driver. Drivers can easily distinguish weather and light conditions, but AEB systems rely mainly on sensors and are susceptible to weather and light. Under special conditions like rain, snow, and fog, the system's ability to perceive surrounding objects and the vehicle's deceleration effect after braking can be affected. Weather can be classified as sunny, cloudy, rainy, or severe, while light can be classified as daytime or night-time with or without streetlights. The percentages of good light conditions among fatalities and injuries were calculated to be 75.58% and 85.51%, respectively, except for collisions that occur on roads without streetlights. It is assumed that the AEB system only works effectively in collisions that happen in good weather conditions, including sunny and cloudy days. The percentages of good weather conditions among fatalities and injuries were calculated to be 88.36% and 88.82%, respectively (Yang et al., 2022).

The road adhesion coefficient is influenced by various factors such as the type of road, the level of wetness, the properties of the tire, and the air pressure. This coefficient represents the static friction between the tire and the pavement. If the AEB system fails to consider the impact of pavement adhesion on braking distance while a vehicle is traveling on a road with a low adhesion factor, the collision avoidance efficiency of the system will be compromised, and the braking distance will exceed expectations. Therefore, to improve the performance of the AEB system for different pavement adhesion coefficients, Rajamani et al. (2010) estimated the peak pavement friction based on the longitudinal, transverse, and normal direction tire forces. Hwang and Choi (2014) and Sevil et al. (2019) implemented an adaptive AEB system for different pavement adhesion coefficients. Han et al. (2016) and Koglbauer et al. (2018) conducted experiments which provided evidence of the adaptive AEB system's ability to mitigate collisions and enhance drivers' subjective safety and trust based on their real-life driving experiences.

2.5 Advanced Driver Assistant System (ADAS)

ADAS, or Advanced Driver Assistance Systems, have the potential to greatly enhance road safety and decrease the severity of accidents. These systems are designed to detect the surrounding environment and enable safe driving by utilizing sensors, cameras, and radar. However, it is important to acknowledge that they may not function properly during adverse weather conditions (Victorova, 2018). Research shows a growing trend towards incorporating ADAS technologies into vehicles (Oviedo-Trespalacios et al., 2021). Nevertheless, there has been limited study on the acceptance of these technologies among law enforcement officers, highlighting the need for further research in this area (Shahini et al., 2022). Additionally, it is crucial for automobile manufacturers to understand driver perceptions of ADAS in order to assess consumer reactions to this technology (Razak et al., 2021).

The significance of ADAS in active safety systems for vehicles cannot be overstated, as these systems play a critical role in preventing collisions and improving overall road safety (Kilic et al., 2015). Moreover, the implementation of ADAS requires adaptable planning to address uncertainty, underscoring the importance of robust strategies for effectively integrating these systems (Marchau & Walker, 2004).

The Society of Automotive Engineers (SAE) has defined six levels of driving automation, ranging from Level 0 (no automation) to Level 5 (full automation) (Enayati et al., 2022). The integration of ADAS technologies has led to an increasing number of perception sensors on automated vehicles, reflecting the growing complexity of ADAS functions and the need for advanced automation (Elfring et al., 2016). Furthermore, the effectiveness of ADAS in reducing crashes and the number of injured persons has been studied, highlighting the impact of automation on safety outcomes (Bareiss et al., 2019).

Table 2.1 ADAS Level of Automation (The Society of Automotive Engineers, 2021)

Level	Type of Automation	Description
Level 0	No Automation	The human driver is fully responsible for controlling the vehicle.
Level 1	Driver Assistance	Automation at this level involves either steering or acceleration/deceleration assistance.

		Examples include adaptive cruise control or lane-keeping assistance, but not both simultaneously.
Level 2	Partial Automation	The vehicle can control both steering and acceleration/deceleration simultaneously under certain conditions. However, the driver must remain engaged and monitor the environment. Examples include advanced adaptive cruise control and lane-keeping assist working together.
Level 3	Conditional Automation	The vehicle can manage some driving tasks independently under specific conditions, allowing the driver to disengage momentarily. The driver must be ready to take control when requested by the system.
Level 4	High Automation	The vehicle can handle most driving tasks under defined conditions without driver intervention. The driver may not need to be actively engaged in certain scenarios, such as highway driving. However, the system may request driver intervention in specific situations.
Level 5	Full Automation	The vehicle is fully autonomous, requiring no human intervention. There is no need for a steering wheel or pedals as the vehicle can handle all driving tasks under all conditions.

2.5.1 ADAS Longitudinal

The extensive research and technological advancements have focused on the development and integration of Advanced Driver Assistance Systems (ADAS). ADAS includes various components and functionalities that aim to enhance vehicle safety and assist drivers. One important aspect of ADAS is longitudinal control, which involves systems like Adaptive Cruise Control (ACC) (Yu & Wang, 2021). ACC plays a crucial role in ADAS by taking control of the vehicle's longitudinal movement in necessary driving scenarios, leading to improved safety, and driving comfort (Hidayatullah & Juang, 2021). Estimating longitudinal jerk is also essential in ADAS as it helps understand driver intentions and ensures preventive safety (Bisoffi et al., 2017). Additionally, comparing autonomous and manual driving in terms of traffic flow and adaptive cruise control emphasizes the significance of longitudinal control in ADAS (Acerra et al., 2023).

Vision-based ADAS is another important component that utilizes computer vision and artificial intelligence to create advanced driver assistance systems (Nieto et al., 2015). The integration of fault tolerance mechanisms is crucial for ensuring the reliability and safety of ADAS, especially in cases of system failures or malfunctions (Lee et al., 2017). Furthermore, the integration of cutting-edge technologies like advanced temporal dilated convolutional neural networks enhances driver assistance and safety in ADAS, as demonstrated by robust car driver identification (Rundo et al., 2021).

2.6 The Effect of Weather Condition on Road Light Intensity

The impact of weather conditions on road light intensity is a crucial aspect of road safety and traffic management, with various studies examining the effects of weather conditions, visibility, and road lighting on driving behaviour and traffic safety. These studies have explored the combined influences of light conditions, posted speed limit, and weather conditions on driving speed, highlighting the significance of daylight, road lighting, and darkness on vehicle speed (Jägerbrand & Sjöbergh, 2016; Shi et al., 2023). They have also emphasized the reduction in road visibility and illumination during unfavourable weather, resulting in longer driver reaction times and potential traffic accidents (Shi et al., 2023; Lu et al., 2023). Furthermore, the significant impact of weather, such as rain and fog, on road lighting effectiveness, particularly in the context of intelligent streetlamp control systems, has been highlighted (Lu et al., 2023).

Additionally, Maze et al. (2006) conducted a literature review on the influence of weather on traffic demand, traffic safety, and traffic flow relationships, emphasizing the multidimensional effects of weather conditions on traffic operations and flow (Maze et al., 2006; Owens & Tyrrell, 1999). They provided insights into the deterioration of headlights under different weather conditions, indicating substantial losses of intensity, especially in winter weather (Owens & Tyrrell, 1999). These findings underscore the importance of considering weather conditions in road lighting design and maintenance to ensure adequate light intensity for drivers.

Moreover, Kwon et al. (2013) investigated the impacts of winter weather and road surface conditions on macroscopic traffic parameters, including visibility, snow intensity, and road surface condition, highlighting the intricate relationship between weather conditions and traffic dynamics (Kwon et al., 2013; Kim et al., 2015). They emphasized the significant effects of adverse weather, such as snow, rain, and fog, on traffic conditions due to reduced visibility, modified driving behaviour, and poor road surface friction (Kim et al., 2015). These studies underscore the necessity of considering weather-related factors in road light intensity management to mitigate the influence of adverse weather on traffic safety and mobility. Additionally, Samo et al. (2023) demonstrated the utilization of deep learning with attention mechanisms for road weather detection, highlighting the potential of advanced technologies to enhance weather-aware road light intensity management and improve road safety (Samo et al., 2023).

Furthermore, Linton & Fu (2016) proposed a solution for monitoring winter road surface conditions using connected vehicles, integrating vehicle-based image data with road weather information systems, and emphasizing the role of advanced monitoring systems in addressing weather-related challenges (Linton & Fu, 2016).

2.7 Night-time Visibility for Driver Safety

Reduced visibility during night-time driving poses significant challenges and safety concerns for road users. The visibility problems associated with night-time driving, including darkness, contrast sensitivity, and glare, are crucial considerations for road safety Wood (2019). Studies have shown that the lack of clear visibility at night can increase the perception time of both drivers and other road users, affecting their ability to take evasive action and navigate safely (Yan et al., 2011). Road lighting is considered a countermeasure to address the reduced visibility at night, providing road users with essential visual information to move safely during night-time hours (Niaki et al., 2016).

The impact of visibility on driver behaviour and safety is further emphasized by the association between traffic accidents and reduced visibility in dark conditions. Drivers often fail to adjust their speed to the reduced visibility during night-time driving, leading to safety implications (Jägerbrand & Sjöbergh, 2016). Additionally, the difficulty in detecting traffic signs and pedestrians due to poor visibility at night contributes to safety concerns for drivers and other road users (Yamamoto et al., 2022). Furthermore, the effects of non-driving-related task engagement on automated driving takeover performance are exacerbated during night-time driving, making vehicle-to-driver takeover tasks considerably difficult under low visibility conditions (Liang et al., 2022).

The presence or absence of street lighting also significantly affects night-time visibility and driver safety. While the presence of sunlight enhances driver vision during the daytime, visibility often degrades during night-time, especially on rural roads without street lighting, where drivers rely solely on their vehicle headlights (Abdel-Wahed & Esawey, 2022). Moreover, the impact of road lighting on road safety has been quantified in studies, emphasizing the importance of road lighting in improving visibility and enhancing road safety during night-time driving (Jackett & Frith, 2013).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project to obtain data input for light intensity. This project starts by studying and reviewing literature review for comprehensive understanding. The experiment begins with selection of portable lamp road and then the lamp pole will be setup according to parameters that need to be evaluate. The light intensity will be measure by using light intensity meter with temperature sensor. After that, the data recorded is validated to determine its validity. Then, the valid data began to be analysed; otherwise, the invalid data had to repeat the experiment again. The objectives of this experiment will be further discussed and compared with previous studies. Thus, this project will end by report writing.

3.2 General Experimental Setup

Figure 3.1 show the general experiment setup for analysis road light intensity on double lane road with lamp pole on curb side edge. The experiment conducted to measure the actual light intensity. Some variables have been used to observe the light intensity such as the height of the lamp, the length of road (distance between pole), the length of road width and the angle of lamp distribution.

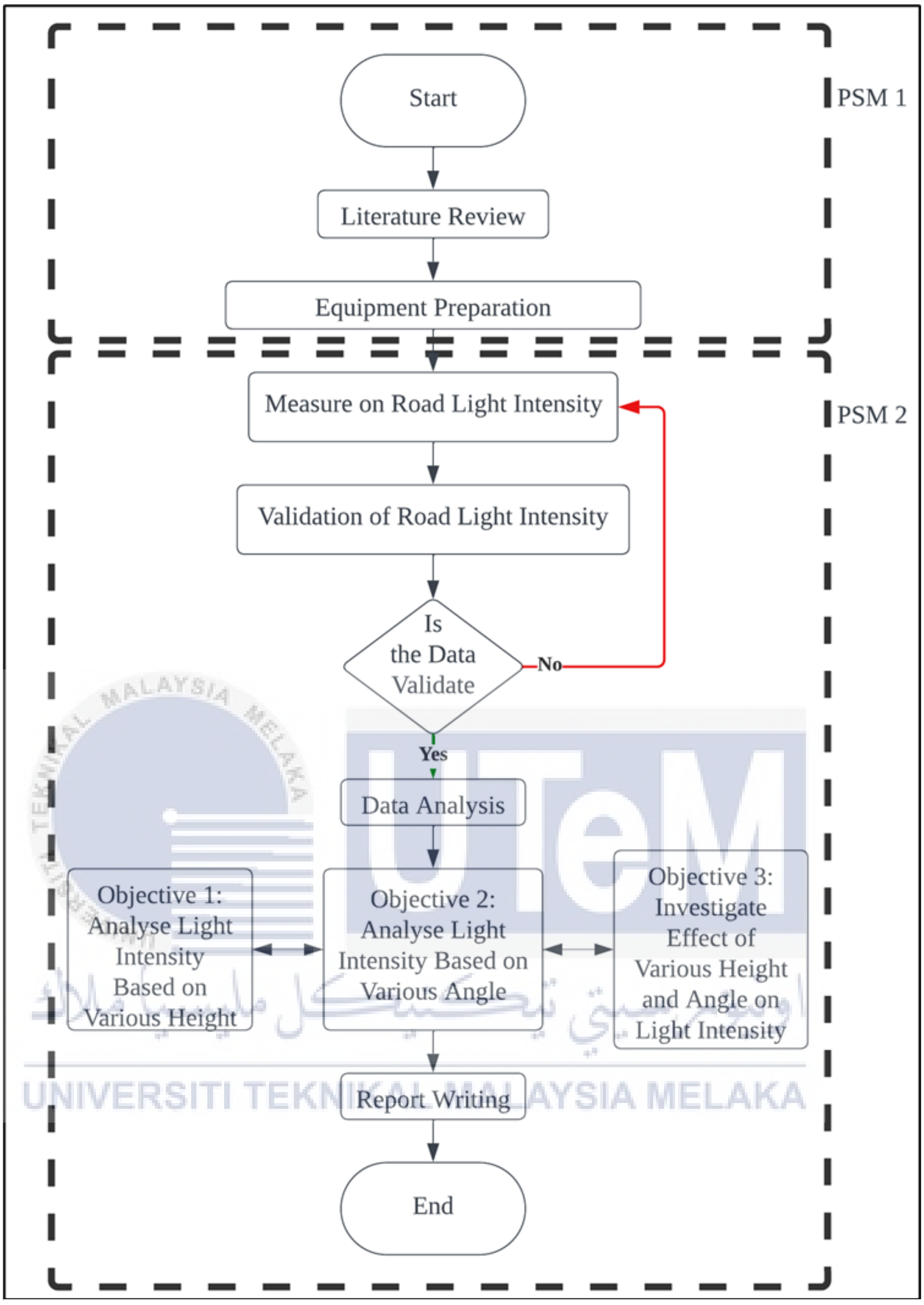

Figure 3.1 Flow Chart of The Methodology

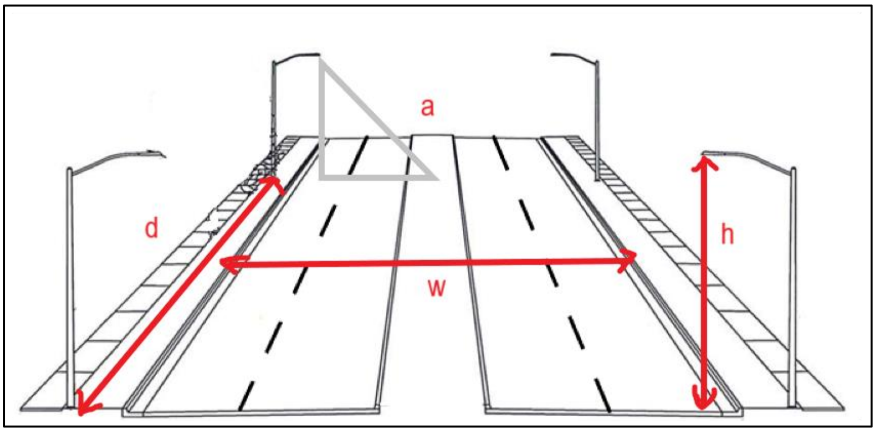

Figure 3.2 Double Lane Road with Lamp Pole on Curb Side Edge

3.3 Instrument and Equipment

The In the context of analysing light intensity on a double-lane road for this project, the equipment shown in Figure 3.3 plays crucial roles in data collection and measurement. The top-left device, a digital light meter (Lux meter), is essential for measuring the illuminance levels along the road. It accurately records the intensity of light in lux, ensuring that the lighting on the road meets the required standards for visibility and safety.

The top-right device appears to be a custom-built data logger with a light sensor, which can be used to continuously monitor light levels over an extended period. This device helps in gathering time-series data on light intensity, which is vital for assessing the consistency and adequacy of road illumination throughout different times of the day and night.

The bottom-left image shows a remote control, likely for controlling street lighting fixtures or the operation of light measurement devices from a distance. This tool is practical for conducting light intensity tests without manually adjusting each device, thereby saving time, and ensuring more consistent data collection.

Finally, the bottom-right image depicts an LED street light fixture, which is a critical component of modern road lighting systems. This fixture represents the type of lighting installed on the double-lane road. By analysing the light intensity from these fixtures, their efficiency, coverage, and effectiveness in providing adequate illumination for road safety can be evaluate.

a) b) c) d)

Figure 3.3 a) Lux Meter b) Brightness Controller c) Lamp Pole Remote Control d) Portable Lamp Pole

3.3.1 Illuminance in Light Intensity

Illuminance is a measure of the total luminous flux incident on a surface per unit area. It is often used to quantify the light intensity falling onto a given area and is expressed in lux (lx). Lux is the International System of Units (SI) derived unit of illuminance, and it is defined as one lumen per square meter. The study on the analysis of road light intensity, illuminance becomes a crucial parameter. It provides a quantitative measure of the brightness or light level experienced on the road surface.

3.3.2 Portable Lamp Pole

A portable lamp pole such as in the Figure 3.4 that is designed for measuring road light intensity provides a versatile and advanced system that is customized for precise fieldwork. The lamp pole is made with a portable and adjustable telescopic structure, allowing for different height adjustments. This lamp pole also has a mechanism that allows users to control the angle of the light source, directing the illumination exactly where it is needed. In addition, the lamp pole includes a brightness control mechanism that allows the adjustment of the light intensity to match different environmental conditions and measurement scenarios. The lamp pole also includes a reliable power supply system, ensuring efficient operation during fieldwork and enabling long-term monitoring of measurement results.

3.4 Light Intensity Parameters

The data collection process for measuring light intensity in this project involves carefully selecting a representative double lane road with a lamp pole on curb side edge. A lux meter is set up following manufacturer guidelines and project specifications to ensure accuracy. Strategic measurement points along the road are identified to capture diverse scenarios, covering varying distances from the lamp pole. Data collection sessions are planned for different conditions, with regular intervals for measurements to account for temporal variations. Multiple trials are conducted to enhance data reliability, and detailed documentation of each session contributes to transparency. Upon completion, the collected data is organized and stored systematically for subsequent analysis, aiming to give precise information on light intensity for robust analysis of road lighting conditions. Table 3.1 road lighting matrix parameters for this project.

Table 3.1 Road Lighting Matrix Parameters

<table>
<tr><td colspan="7">Road Lighting Matrix (Evaluation Parameters)</td></tr>
<tr><td>Type of Road</td><td colspan="6">Road Light Intensity</td></tr>
<tr><td rowspan="6">Double Lane Road with Lamp Pole on Curb Side Edge</td><td>Without Lighting</td><td>Low</td><td>Low to Medium</td><td>Medium</td><td>Medium to High</td><td>High</td></tr>
<tr><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td colspan="6">Lamp Pole Configuration</td></tr>
<tr><td colspan="2">Height of Lamp Pole</td><td>Angle of Lamp Pole</td><td>Length of Road</td><td colspan="2">Length of Road Width</td></tr>
<tr><td colspan="2">√</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="7">Note: “√” = Parameter evaluated</td></tr>
</table>

3.5 Proposed Standard Setup

To achieve objectives of this experiment which is evaluation of light intensity on double lane road with lamp pole on kerb side edge, a standard setup was being proposed. It aims to evaluate the light conditions through experimental method.

Background of illuminance, illuminance at VUT path and illuminance at EPT path are some of lighting condition that will be observed before the setup was made.

3.5.1 Background of Illuminance

The location where the background illumination is measured is at the collision point. While conducting the measurement of background illumination, it is required that all lamps are turned off. A visual representation of the situation can be seen in Figure 3.7. The maximum allowable background illumination in a test area at night should not exceed: IEB < 1lux due to deficiencies in the concept.

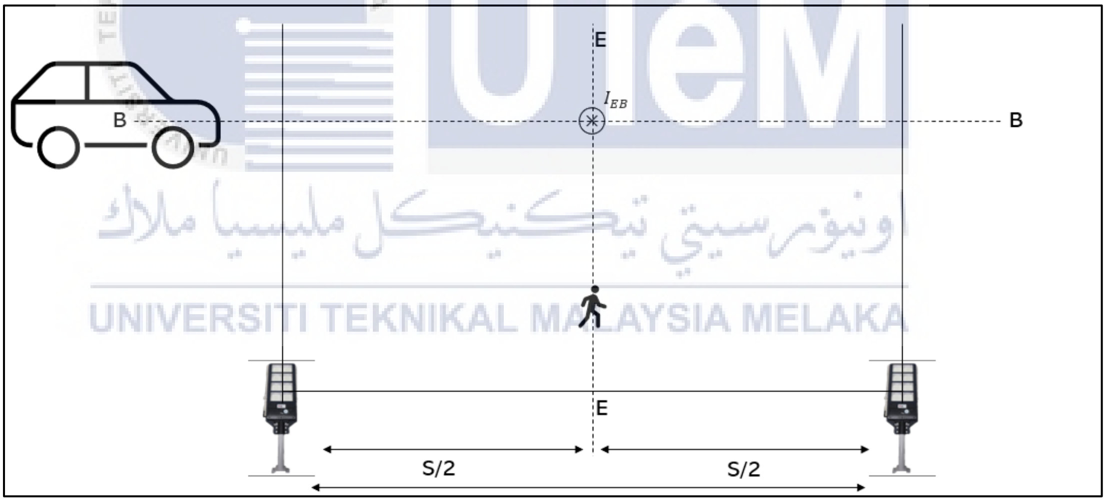

Figure 3.4 Background of Illuminance

EE: Axis of centreline of pedestrian dummy
BB: Axis of centreline of vehicle under Test
S: Distance between Lamp Poles

3.5.2 Illuminance at VUT Path

The average illuminance of VUT path ($\overline{I\,VUT}$) is determined by averaging illuminance measurement points along the VUT path, trajectory BB, as shown in Figure 3.8. It is required that the average illuminance falls within a specific range.

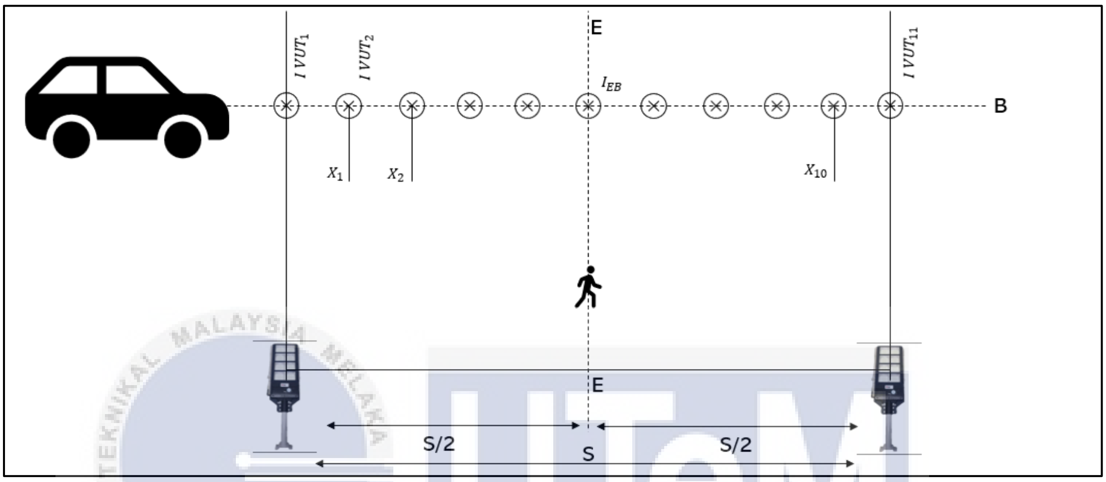

Figure 3.5: Illuminance of VUT Path

EE: Axis of centreline of pedestrian dummy
BB: Axis of centreline of vehicle under Test
S: Distance between Lamp Poles
X_i: Distance between measurement points
X_1, X_2…X_{10}=S/10

3.5.3 Illuminance at EPT Path

The figure 3.9 below show the illuminance at EPT path. The illuminance at EPT path, trajectory EE shall be at least I EPT_i > 4.4lux.

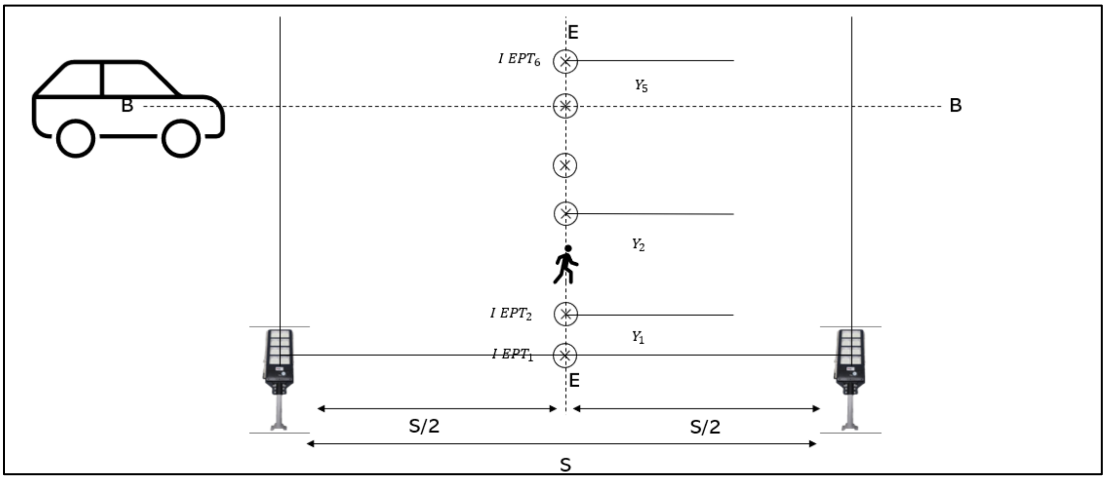

Figure 3.6 Illuminance at EPT Path

EE: Axis of centreline of pedestrian dummy
BB: Axis of centreline of vehicle under Test
S: Distance between Lamp Poles
Y_i: Distance between measurement points
Y_1, Y_2…Y_5= 1m

3.5.4 Measurement Parameters

In the lighting setup, the distance between lamp poles ranges from 4 meters to 15 meters, with a lane road width of 8 meters. Each lamp pole stands at a height of 5 meters. The ambient temperature during testing remains between 24 and 26 degrees Celsius. To ensure robust data collection, a minimum of three repetitions are conducted per test. Measured data encompasses light intensity (lux) readings taken at different heights from the road surface (0, 1.1, 1.4, 1.7, and 2.0 meters), corresponding to various vehicle heights, and at different angles (0 and 45 degrees) to account for the minimum and maximum angles of vehicle windscreens.

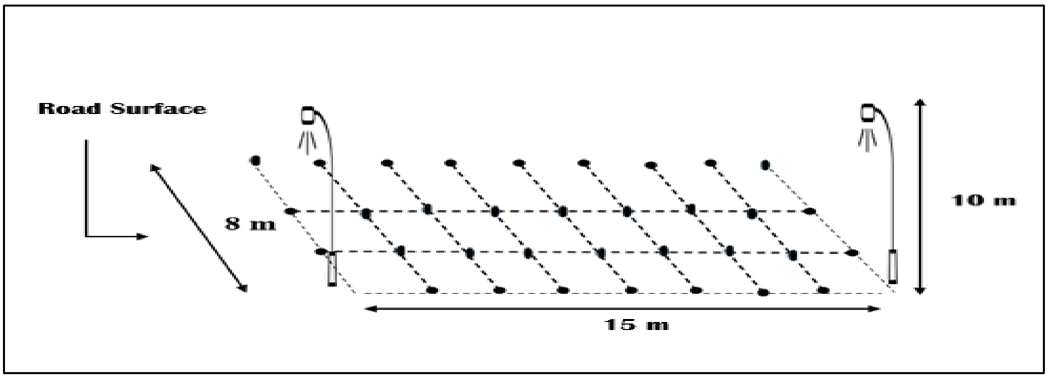

Figure 3.7 Grid Measurement of Double Lane Road

3.5.5 Illuminance Measurement

To measure the illumination, a calibrated luxmeter must be set on ground in a right angle to the street.

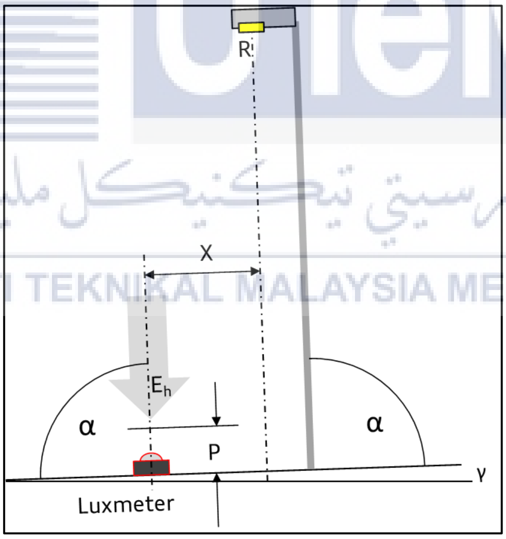

Figure 3.8 Illuminance Measurement

E_h: Horizonal Illumination
R: Reference point geometric centre of the light field
P: maximal height over ground
X: Position X
α: Angle against ground

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter was included in the result and discussion from the experiment that was done. The result was analysed and discussed properly in this chapter. The experiment was done and all data of light intensity on double lane road with lamp pole on kerb side edge was recorded. The result for this experiment is to show the comparison that was recorded. The result was presented in the graph and contour colour. The graph is consisting of many variables such as height of reading lamp intensity, length of road width and the angle of distribution that will affect the light of intensity.

4.2 Effect of Light Intensity at 0° Angle

The result for this experiment is to show the comparison that was recorded. It was clearly shown that all the light intensity across various height having the same pattern for all width of the road (R1 to R8). Additionally, the overall trend remains consistent, showing higher intensities at both ends and a significant decrease in the middle.

4.2.1 Light Intensity at 0 m Height

Figures 4.1 illustrate the light intensity along the road at a height of 0 meters from the ground. The graphs of light intensity ranges from approximately 0 to 40 lux. At the starting point (0 meters) and the end point (15 meters), the light intensity is relatively higher, around 11.7 lux, while there is a noticeable dip in the middle section of the road, with values dropping as low as 1.8 lux. Despite that, the overall trend remains consistent, showing higher intensity at both ends and a significant decrease in the middle.

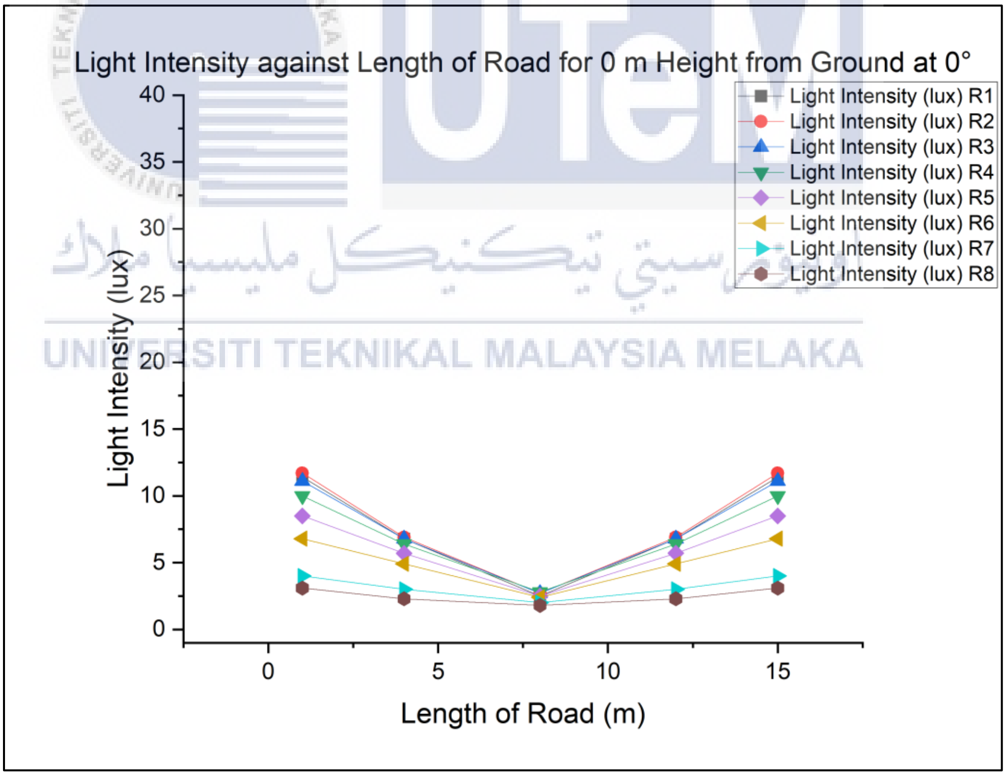

Figure 4.1 Light Intensity at 0 m Height from Ground (0°)

4.2.2 Light Intensity at 1.1 m Height

Figures 4.2 illustrate the light intensity along the road at a height of 0 meters from the ground. It is noticeable that the graph trend remains unchanged showing higher intensities at both ends and a significant decrease in the middle. However, the Figure 4.2 exhibit larger distribution of light intensity across the width of the road (R1 to R8) with the peak value of 17 lux compared to light intensity exhibit in the Figure 4.1 with the peak value of 11.7 lux.

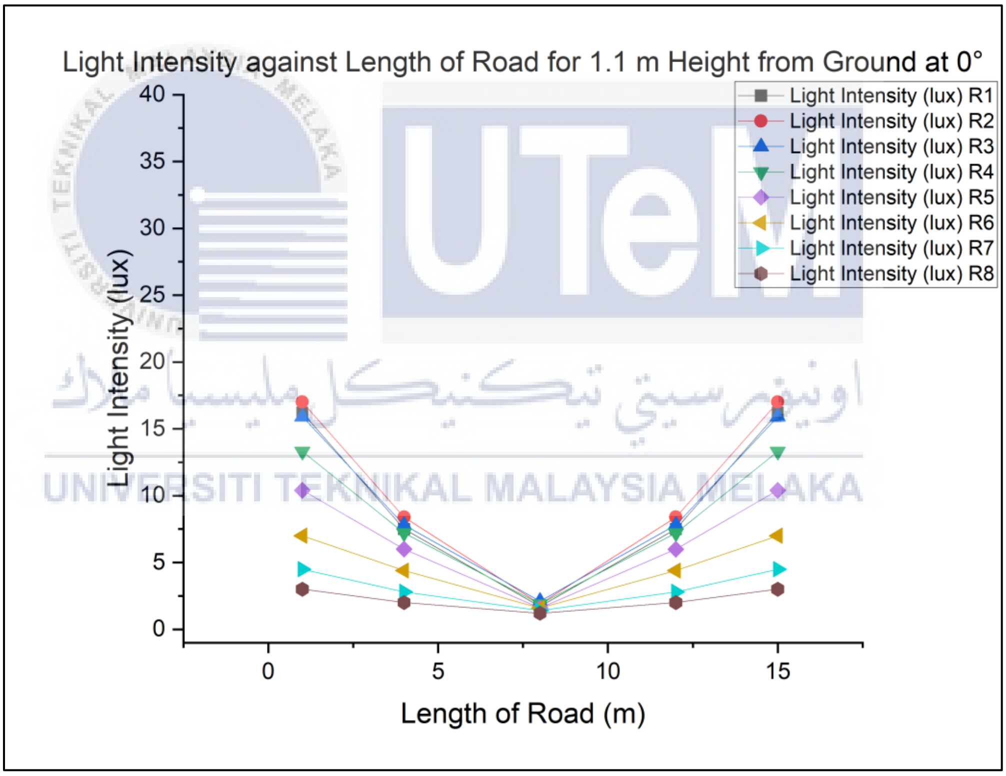

Figure 4.2 Light Intensity at 1.1 m Height from Ground (0°)

4.2.3 Light Intensity at 1.4 m Height

Base on Figure 4.3 illustrate the light intensity along the road at a height of 1.4 meters from the ground, In the graphs below, the starting point (0 meters) and the end point (15 meters), the light intensity is relatively higher, around 17.8 lux, while there is a noticeable dip in the middle section of the road, with values dropping as low as 1.1 lux Despite the angle change, the overall trend remains consistent, showing higher intensities at both ends and a significant decrease in the middle.

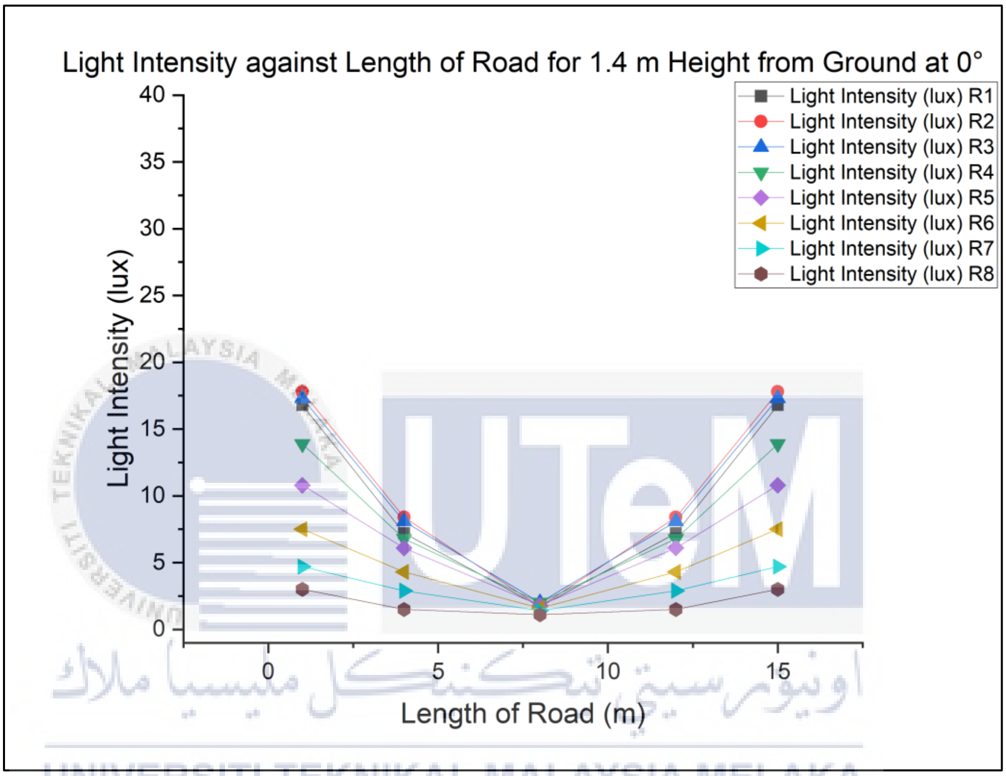

Figure 4.3 Light Intensity Measure at 1.4 m Height from Ground (0°)

4.2.4 Light Intensity at 1.7 m Height

Figure 4.4 graph illustrates the light intensity along a road measured at 1.7 meters height, showing data for eight different road segments (R1 to R8). The light intensity is highest at both ends of the road (0 and 15 meters) for all segments, gradually decreasing towards the middle, where it reaches its minimum around 1.0 meter. This consistent pattern across all segments indicates that the lighting setup creates a U-shaped distribution of light intensity along the road's length.

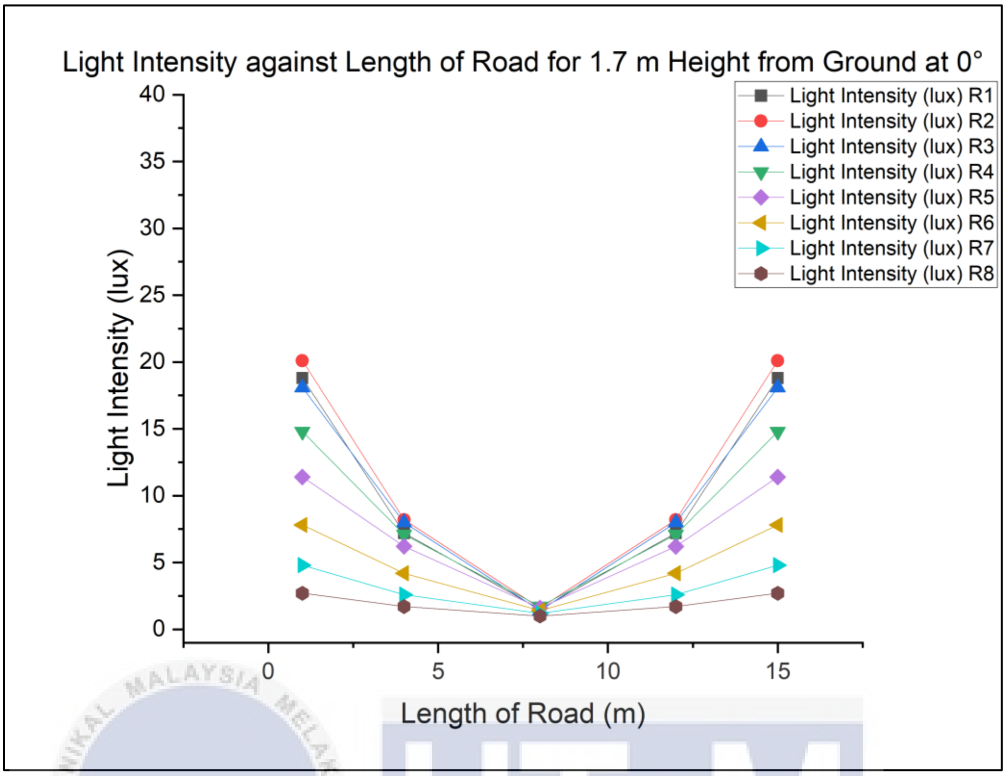

Figure 4.4 Light Intensity Measure at 1.7 m Height from Ground (0°)

4.2.5 Light Intensity at 2.0 m Height

Based on Figure 4.5, the graph shows the light intensity along the road measured at a height of 2 meters from the ground, with data for the same eight road segments (R1 to R8). Similar with the graph in Figure 4.2, 4.3, and 4.4, the light intensity is highest at both ends of the road (0 and 15 meters) and decreases towards the centre, reaching the lowest point around 0.8 meters. This pattern indicates that at a slightly higher measurement height, the distribution of light intensity along the road maintains the same U-shaped profile, with intensity peaks at the edges and a dip in the middle for all segments.

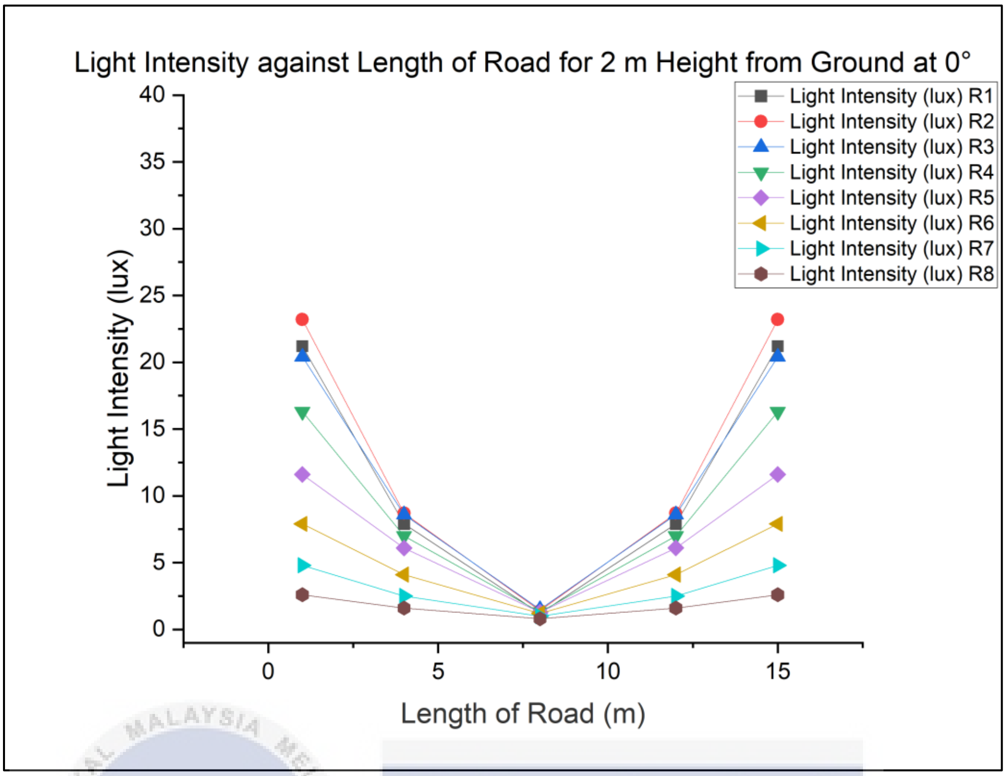

Figure 4.5 Light Intensity Measure at 2.0 m Height from Ground (0°)

4.3 Effect of Height at 45° Angle

The lux intensity varies across height for angle 45° has recorder and plot in the graph for all width of the road (R1 to R8). The pattern of intensity distribution is similar in all cases, with a noticeable dip in the middle of the road. This indicates that the angle of light source impacts the overall intensity levels, but the distribution pattern remains consistent. However, it is clear that the lower height from the lamp pole the lower light intensity distributed and the higher height toward lamp pole the lux intensity the higher light intensity were distributed.

4.3.1 Light Intensity at 0 m Height

The graph shows the light intensity measured along the length of a road at 0 meters height from the ground and a 45° angle. Multiple datasets measured for the road width (R1 to R8) are plotted, each represented by different markers and colours. The light intensity is highest at the ends of the road which is 8.2 lux and lowest in the middle which is 1 lux. However, the overall trend remains consistent, showing higher intensities at both ends and a significant decrease in the middle, thus indicating a U-shaped profile.

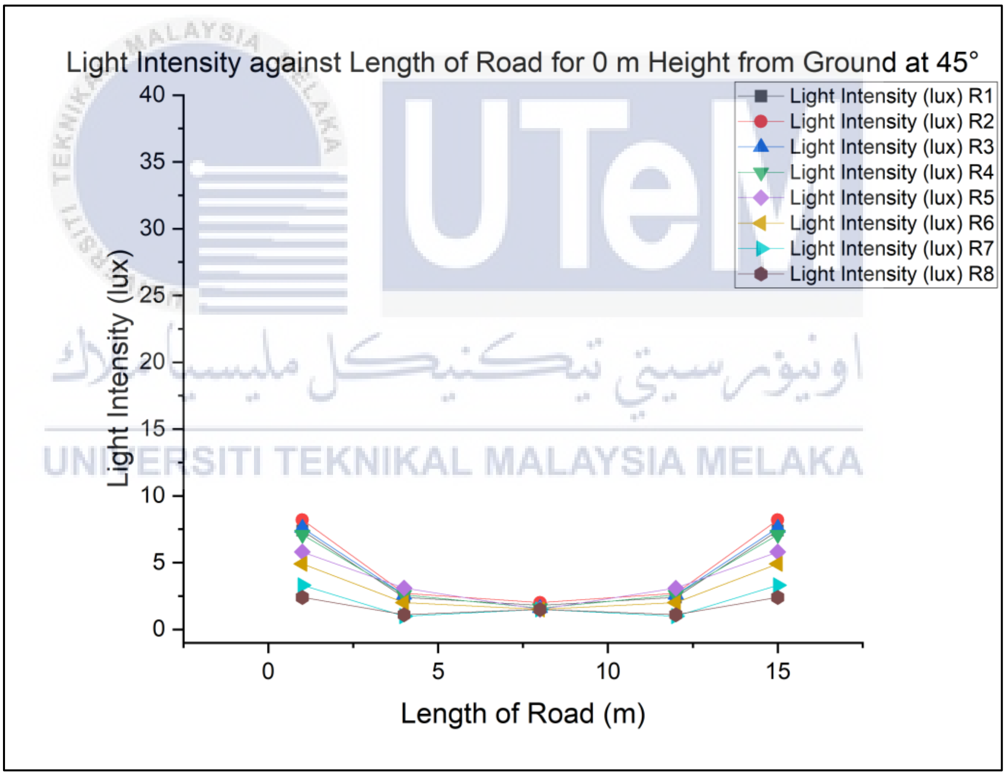

Figure 4.6 Light Intensity Measure at 0 m Height from Ground (45°)

4.3.2 Light Intensity at 1.1 m Height

The graph in the Figure 4.7 displays the light intensity along the road, measured at 1.1 meters above the ground. It shows light intensity from different readings of road width (R1 to R8) over a 15-meter length. The data reveals that light intensity peaks at both ends of the road, around 11-14 lux, and drops significantly in the middle, to about 2-5 lux, creating a symmetrical pattern. This suggests that the lighting is strongest at the ends and diminishes towards the middle, likely due to lights being positioned at the road's ends, resulting in uneven distribution of illumination along the road's length.

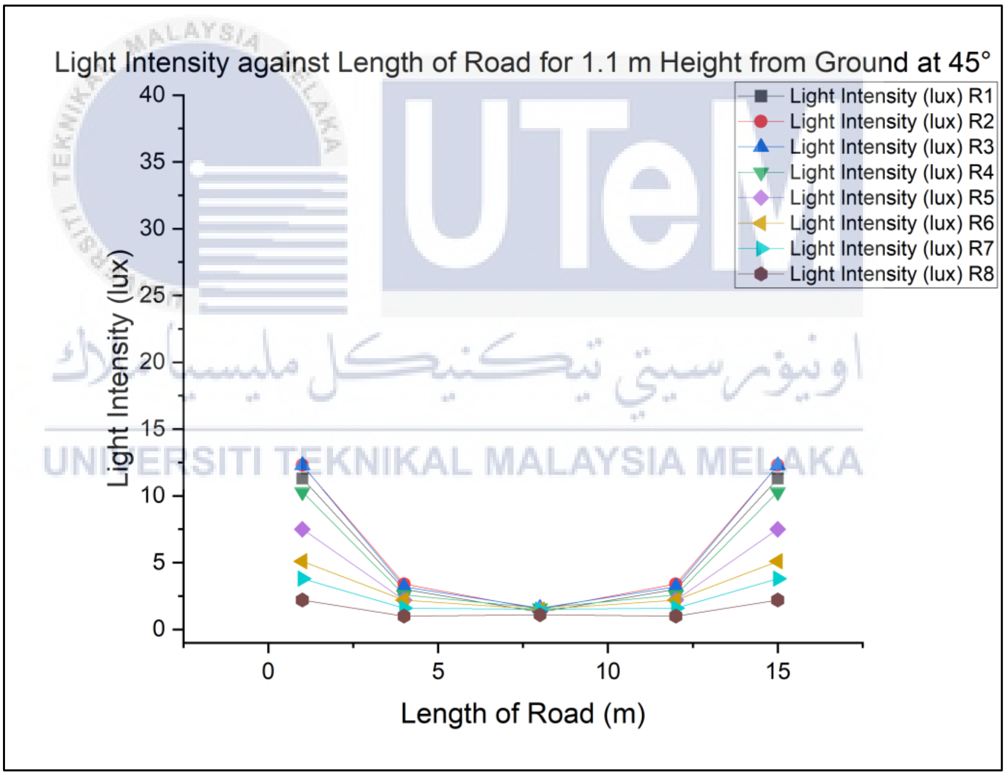

Figure 4.7 Light Intensity Measure at 1.1 m Height from Ground (45°)

4.3.3 Light Intensity at 1.4 m Height

The Figure 4.8 illustrates the light intensity along a road, measured at a height of 1.4 meters from the ground and at a 45-degree angle. It depicts light intensity (in lux) from different readings (R1 to R8) over a 16-meter length. The data shows that light intensity peaks at both ends of the road, reaching around 12-15 lux, and decreases significantly in the middle to about 2-5 lux, creating a symmetrical pattern. This suggests that the lights are positioned at the road's ends, resulting in stronger illumination at these points and a drop in intensity towards the middle, indicating an uneven distribution of light along the road's length.

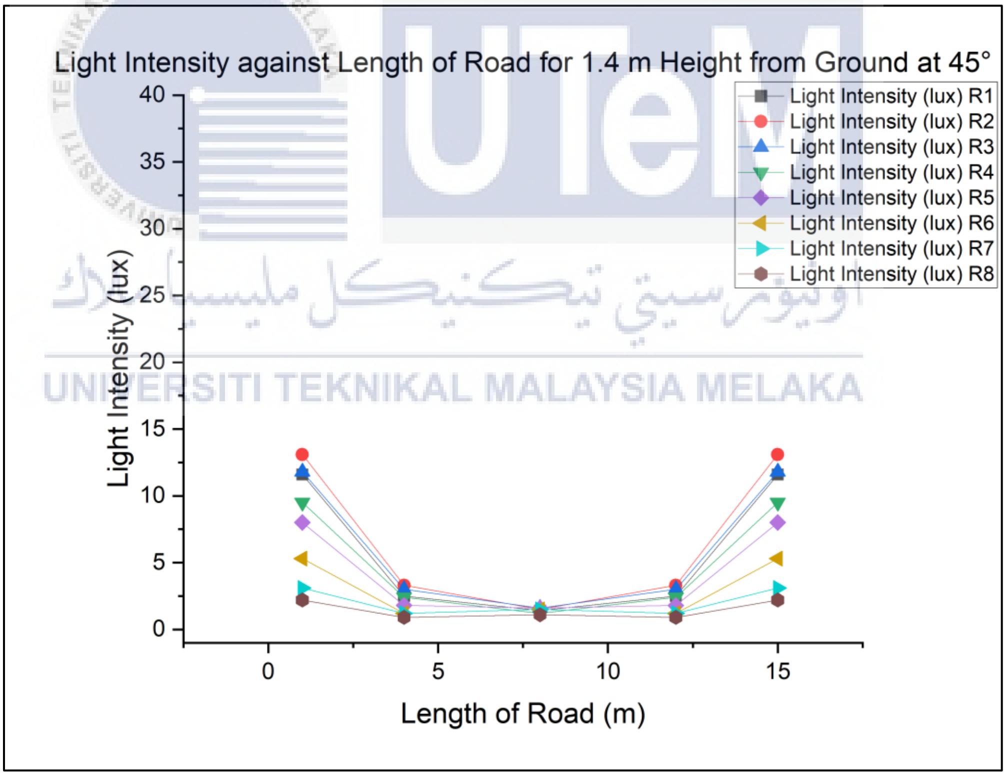

Figure 4.8 Light Intensity Measure at 1.4 m Height from Ground (45°)

4.3.4 Light Intensity at 1.7 m Height

Figures 4.9 shows the light intensity along a road, measured at a height of 1.7 meters from the ground. It presents light from different readings of road width (R1 to R8) over a 15-meter length. The data indicates that light intensity peaks at both ends of the road, around 14.9 lux, and diminishes significantly in the middle to about 0.9 lux, creating a symmetrical pattern. This pattern suggests that lights are positioned at the ends of the road, resulting in higher illumination at these points and lower intensity towards the centre, indicating an uneven distribution of light along the road's length.

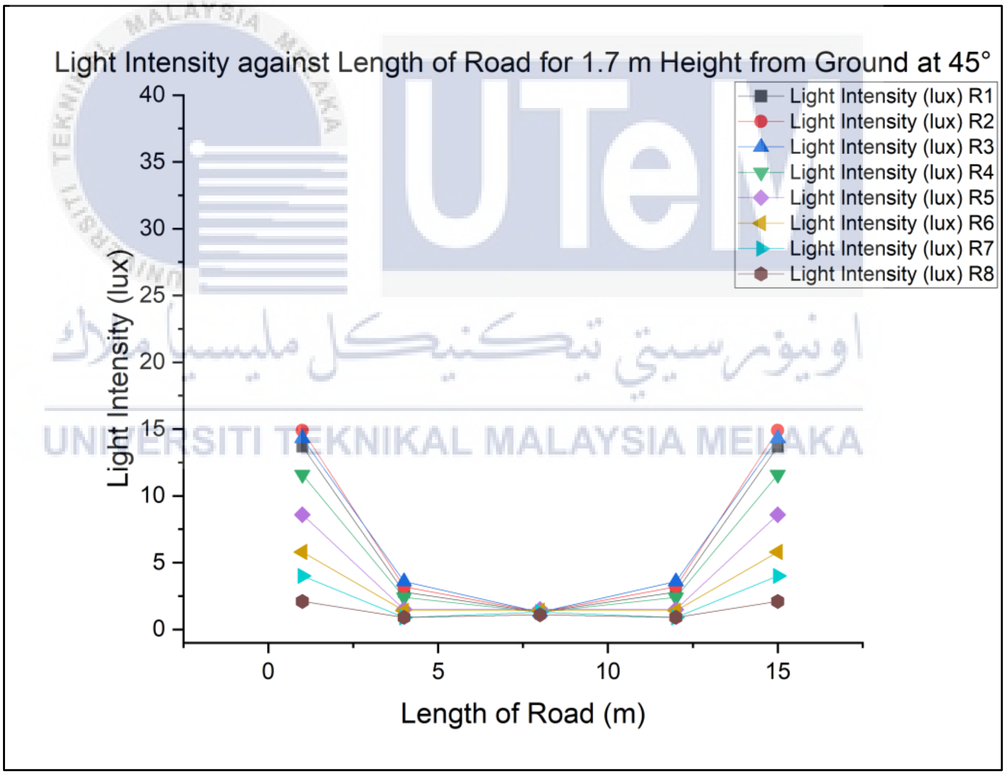

Figure 4.9 Light Intensity Measure at 1.7 m Height from Ground (45°)

4.3.5 Light Intensity at 2 m Height

Based on Figure 4.5, the graph shows the light intensity along the road measured at a height of 2 meters from the ground, with data for the same eight road segments (R1 to R8). Similar with the graph in Figure 4.2, 4.3, and 4.4, the light intensity is highest at both ends of the road (0 and 15 meters) and decreases towards the centre, reaching the lowest point around 0.8 meters. This pattern indicates that at a slightly higher measurement height, the distribution of light intensity along the road maintains the same U-shaped profile, with intensity peaks at the edges and a dip in the middle for all segments.

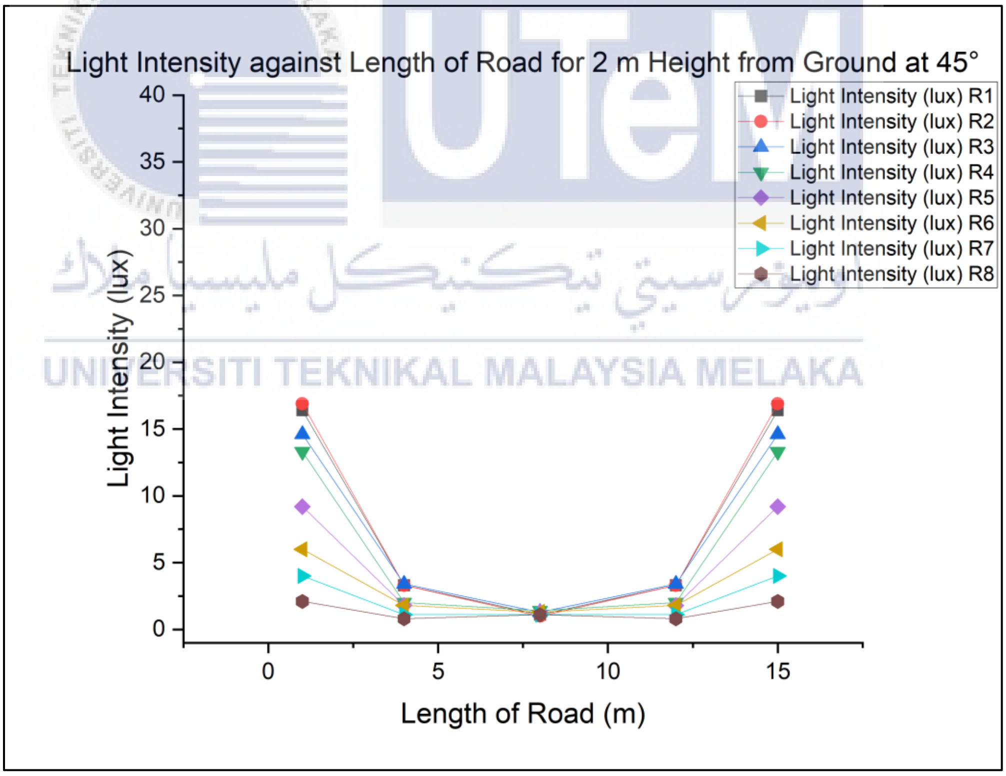

Figure 4.10 Light Intensity Measure at 2.0 m Height from Ground (45°)

4.4 Average Light Intensity at 0°

Figure 4.11 shows the average light intensity result for a double-lane road with a lamp pole on kerb side edge. This figure is based on the 0° angles of lamp distribution. All the recorded average values have the same trend and do not exceed the limit of lux and above. The highest average value of light intensity obtained is only 12.3125 lux at the length of the road, 1 and 15 meters, and the height of light intensity measurement, 1.7 meters. In comparison, the lowest average light intensity values plotted at the length of the road, 8 meters and the height of light intensity measurement, 2 meters which are 1.2125 lux.

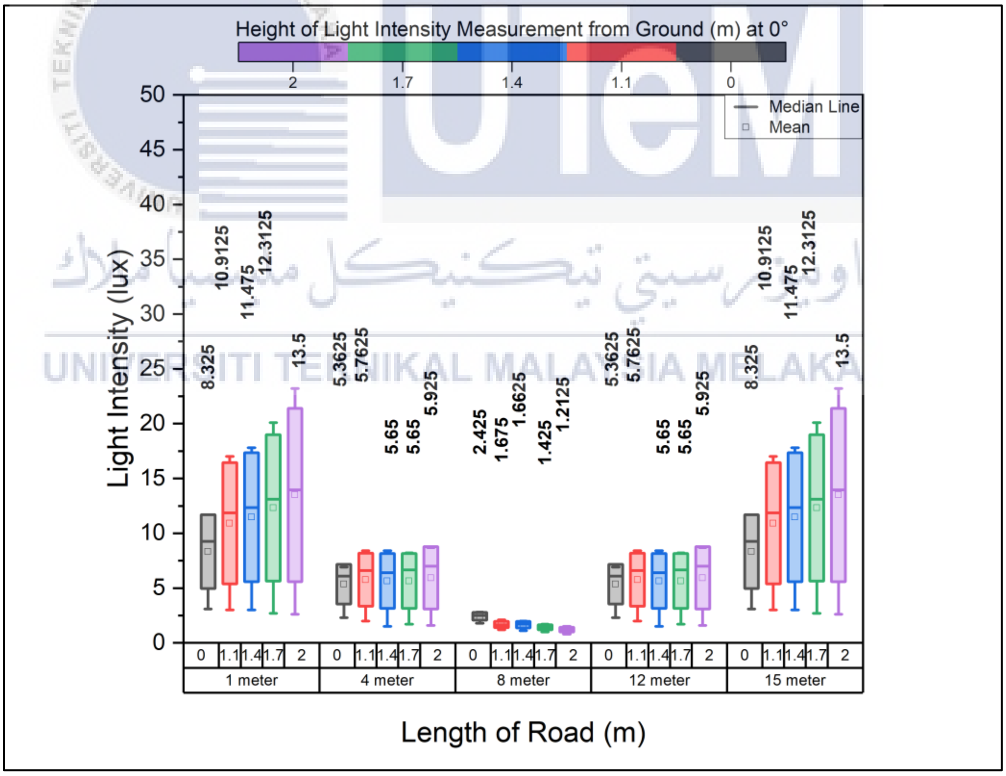

Figure 4.11 Average Light Intensity for Double Lane Road with lamp pole on kerb side edge (one side 0°)

4.5 Average Light Intensity at 45°

Figure 4.12 shows the light intensity result for a double-lane road with a lamp pole on the kerb side edge. This figure is based on 45° angles of lamp distribution. All the recorded average values have the same trend and do not exceed the limit of 15 lux and above, as in figure 4.12. The highest average value of light intensity obtained is only 10.3125 lux at the length of the road, 1 meter, and the height of light intensity measurement, 2 meters. In comparison, the lowest average light intensity value is plotted at the length of the road, 8 meters and the height of light intensity measurement, 2 meters which the value is 1.2 lux.

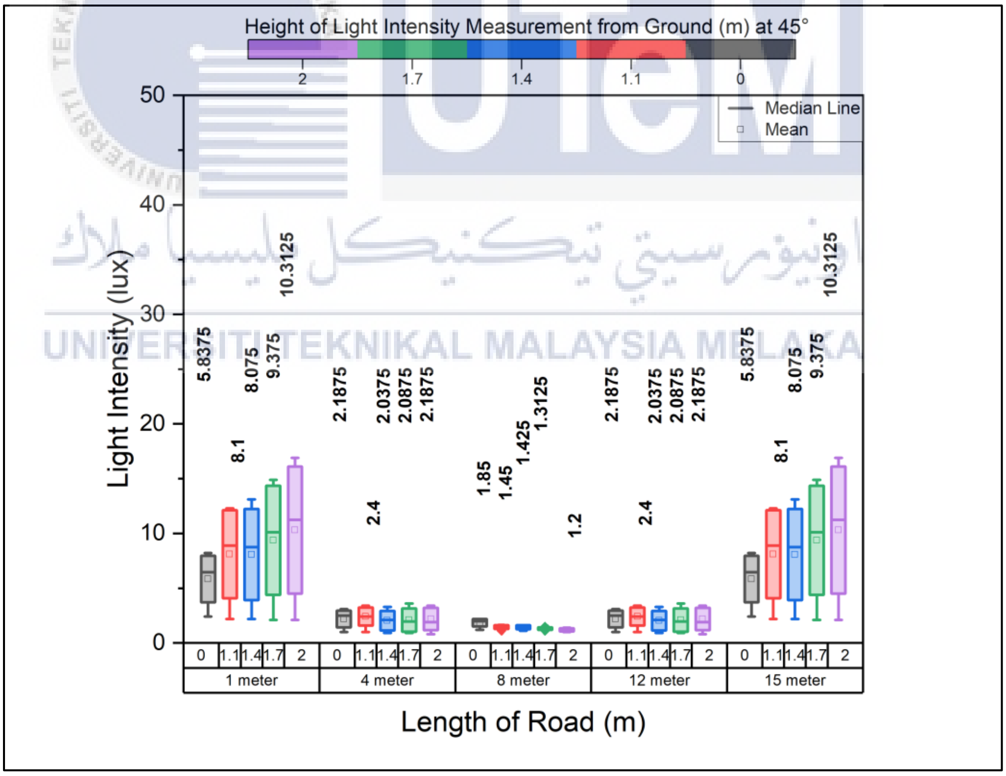

Figure 4.12 Average Light Intensity for Double Lane Road with lamp pole on kerb side edge (one side 45°)

4.6 Correlation Effect of Height and Angle on Light Intensity

Figure 4.13 represent scatter graphs illustrating the variations in light intensity across different road lengths. This figure reveals several similarities and differences that influence the amount of light intensity. The primary factor impacting the highest light intensity is the length or road. Notable, road lengths of 1 meter and 15 meter exhibit the highest average light intensity compared to other road lengths. This is attributed to the proximity of the lamp pole to the measurement point, resulting in higher intensity readings. The second factor affecting light intensity is the angle of lamp distribution. From figure indicate that a lamp distribution angle of 0° contributes more to light intensity compared to a 45° angle. The reason behind this is that a 0° angle facilitates a more effective deployment of lamp distribution.

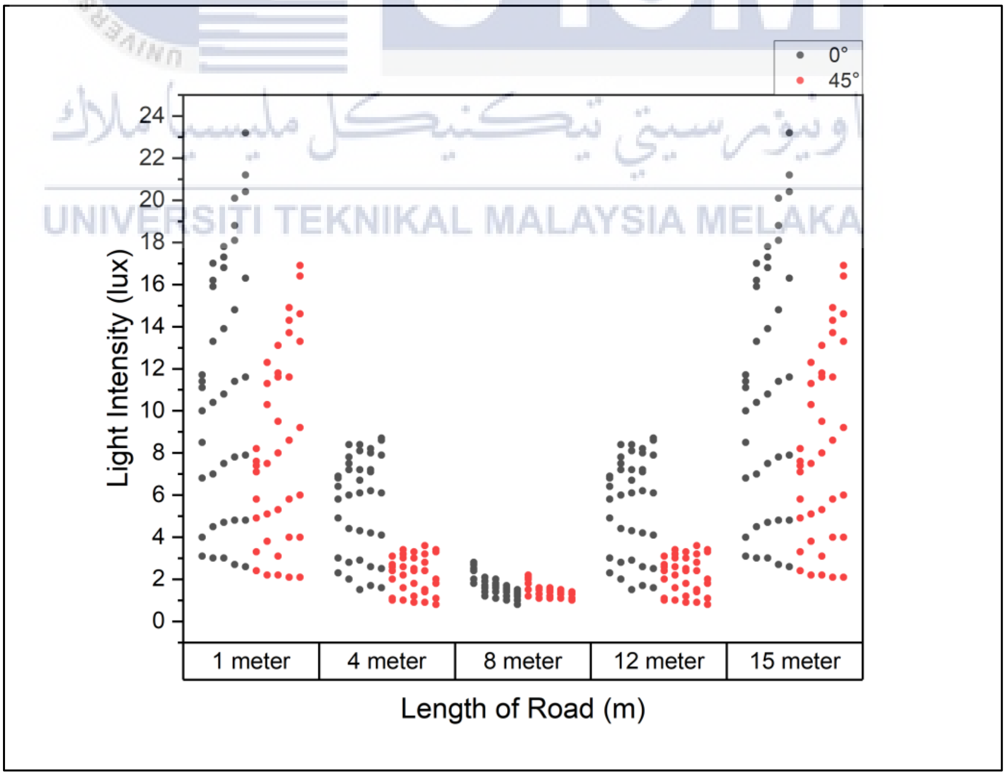

Figure 4.13 Scatter Graph of Validation for 15-meter length Road

CHAPTER 5

CONCLUSION AND RECOMENDATIONS

5.1 Conclusions

The final section of this project outlines the overall conclusions derived from the study, focusing on two main aspects: the varying height and angle of light intensity from lamp poles on a double lane road with a lamp pole on the kerb side edge (one side pole). The primary goal was to examine light intensity based on different heights from the road surface, revealing that the highest average light intensity measured was 13.5 lux at 2 m height measurement from the ground. Higher lamp poles tend to distribute light more evenly, reducing dark spots and enhancing visibility. The secondary objective concentrated on analysing light intensity according to different angles from the lamp pole, indicating that a lamp distribution angle of 0° contributes more to light intensity than a 45° angle where the highest value measure were 23.2 lux and 16.9 lux respectively. This is because a 0° angle allows for a more efficient distribution of lamp light. Ultimately, investigation the effect of height and angle must be carefully optimized to ensure uniform and sufficient lighting across the road surface. These insights are crucial for designing effective street lighting systems that enhance visibility and safety for road users, emphasizing the importance of considering both height and angle in the placement of lamp poles.

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5.2 Recommendations for Future Study

To optimize roadway illumination, future studies should focus on advanced lighting design and the impact of environmental factors. This includes investigating the optimal placement, height, and angle of lamp poles to achieve uniform light distribution. Different lighting technologies, such as LEDs and HPS, should be evaluated for their performance and sustainability. Additionally, the effects of weather conditions like rain, and fog, as well as seasonal variations in ambient light, need to be analysed to ensure consistent visibility and safety. By addressing these factors, the studies can enhance road safety and optimize energy usage.

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APPENDIX A

SITE AREA – CAR PARK UTEM LABORATORY

APPENDIX B

DURING DATA MEASUREMENT