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An Analysis of Road Light Intensity on Single Lane Road with Lamp Pole on Curbside Edge

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ABSTRACT – *This paper provides an in-depth analysis of light intensity on a single-lane road, where lamp poles are positioned at the curb's edge. The objective is to assess the distribution of light across the road. The study involves measuring light intensity at various heights and angles from the road surface, utilizing a lux meter. For this purpose, a portable streetlamp was specially designed to measure the light intensity on a single-lane road. Several factors were considered, including the road's length, width, the lamp's height, and the angle at which the light is projected. Based on these parameters, light intensity readings were obtained along a grid line on the road. The findings reveal that light intensity is higher at the beginning and end of the lamp's reach, with lower intensity levels observed in the middle of the road between lamp posts. This research provides a valuable foundation for city planners and engineers to improve road lighting systems, thereby enhancing safety and efficiency in transportation networks. Additionally, the study evaluates the potential effectiveness of Autonomous Emergency Braking Systems (AEB) in vehicles.*

KEYWORDS: Light intensity, road light, single-lane, Autonomous Emergency Braking (AEB), NCAP

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1. INTRODUCTION

The illumination of roadways is a critical component of rural infrastructure. It ensures safety and visibility for both pedestrians and motorists during nighttime hours. Among the various aspects of road lighting, the placement and intensity of lamp poles play a significant role in determining the overall quality of illumination and, by extension, road safety (Yusof et al., 2023).

The primary objective of road lighting is to ensure human safety by illuminating objects on the road and around cars, as well as to offer optimal visibility conditions and reduce potential hazards. Furthermore, good road lighting is required to estimate the automobile speed, monitor dangerous items beside the car, and maintain the spacing between the cars. As a result, the primary aim of road illumination is to assist road users in rapidly, accurately, and pleasantly recognizing objects around them (Setyaningsih et al., 2018).

The intensity of road illumination influences visibility and sensing distances as well. Road lighting intensity levels of 100% and 49% without glare give equivalent detection distances, whereas visibility is lowest at 71% of road lighting intensity (Chenani et al., 2016). However, a balance must be struck between delivering enough light intensity and limiting light pollution, which can have negative environmental and health consequences also ensuring optimal visibility for road users. Modern technology, such as energy-efficient LED streetlights, has made it possible to meet these objectives while lowering energy consumption and maintenance costs. In most situations, the intensity of road illumination is determined by specific road lighting classes, with different static road surface brightness levels applied to different types of roads. Furthermore, the brightness levels of road surfaces are often dynamic and greatly depend on the current weather conditions.

Environmental factors such as light levels and weather conditions play a critical role in influencing road light intensity (Chenani et al., 2016). Effective road lighting is crucial for enhancing the safety of road users by improving visibility, significantly lowering accident risks, and facilitating smoother traffic flow. Adequate lighting ensures that roads and their surroundings are well-lit, allowing drivers to clearly see the road ahead, potential obstacles, other vehicles, and pedestrians (Fotios et al., 2015; Uttley et al., 2020, Prasetijo et al., 2021). The quality of road lighting is determined not only by light intensity but also by factors like luminance and visibility conditions. Luminance measurements are essential for evaluating road lighting quality and visibility, helping to optimize lighting configurations (Vaaja et al., 2015). Research has examined how weather conditions, light conditions, and road lighting impact vehicle speed, revealing a complex interplay between these variables (Jägerbrand & Sjöbergh, 2016). Considering luminance, visibility, and speed collectively offers a comprehensive understanding of road light intensity.

The swift progress in autonomous driving technologies, especially Autonomous Emergency Braking (AEB) systems, has significantly contributed to a safer and more efficient road transportation network and enhanced the analysis of road light intensity (Fitri et al., 2021). LiDAR sensors have been employed for road classification by analyzing intensity data, allowing for identifying various road surfaces based on their physical characteristics (Liu et al., 2023). The integration of these advanced technologies boosts the accuracy and efficiency of evaluating lighting quality and improves the capability to detect and respond to potential hazards, such as obstacles or pedestrians, under different lighting conditions. Considering the influence of road lighting conditions on the efficacy of AEB systems is a crucial aspect of road safety. Although the references provided do not explicitly delve into this precise subject, certain sources touch upon related facets that can offer valuable insights into the broader implications of road conditions on the performance of AEB systems.

The study by Yang et al. (2020) focuses on the influence of pavement conditions on the performance of AEB systems. Although the discussion doesn't explicitly touch upon road lighting conditions, it implies that variations in road surface conditions may impact the effectiveness of AEB systems (Yang et al., 2020). This suggests that factors like wet or slippery road surfaces, which lighting conditions can influence, have the potential to affect how well AEB systems operate. Consequently, it implies that road lighting conditions, being an integral component of the overall road infrastructure, could potentially play a role in influencing the performance of AEB systems.

In this study, exploration was done on the early study of light intensity on single-lane roads with lamp poles positioned on curbside edges. The aim is to correlate the effects of height and angle from lamp pole toward road light intensity.

2. METHODOLOGY

This study's methodology employs a systematic approach to gathering and analyzing data on road light intensity, following the Public Works Department (JKR) federal road specifications for single-lane roads. Initially, data collection will be carried out through on-site visits, where light-intensity measurements will be taken at various points along the road. A lux meter will be utilized to measure light intensity at different heights and angles. The methodology includes defining measurement parameters and establishing a gridline layout on the road to facilitate systematic data collection. The height and angle of the lux meter will be adjusted to examine the distribution of light intensity. Measurements will be taken at heights of 0 meters, 1.1 meters, 1.4 meters, 1.7 meters, and 2.0 meters, and at angles of 0 degrees and 45 degrees. All scenarios will be recorded and presented comprehensively.

2.1 Experimental Setup

This project aims to evaluate the illumination levels of individual road lights, considering the type of road and the placement of lamp poles. The primary variables considered for measuring light intensity on a single-lane road with lamps positioned alongside the lane include the height and angle of the lamp poles, road width, and the distance between each lamp pole. Figure 1 shows the conditions of a single-lane road with a lamp pole on the curbside edge.

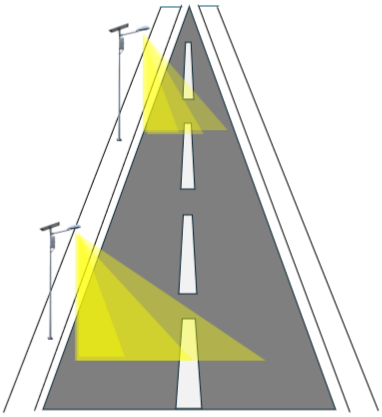


FIGURE 1: Single-lane road with lamp pole on the curbside edge

2.2 Instrument and Equipment

For analyzing road light intensity in this project, a high-quality lux meter is employed. Figure 2 shows the type of Digital Lux Meter, Kyoritsu Model 5202 used in this project. The selection process involves careful consideration of features such as a broad measurement range, precise illuminance sensors, and suitability for various environmental conditions. Before data collection, meticulous calibration procedures are conducted to ensure the lux meter's accuracy and dependability. The chosen device includes data logging capabilities, allowing for automatic recording of illuminance measurements at specified intervals. Portability is essential, necessitating a design that facilitates easy movement along the single-lane road. Furthermore, integration with data analysis tools is taken into account, enabling smooth interpretation and visualization of the gathered data. Opting for a highly accurate lux meter ensures continuous and reliable data collection throughout extensive fieldwork. This comprehensive approach to lux meter selection and application aims to deliver precise and detailed insights into road light intensity.

FIGURE 2: Digital Lux Meter, Kyoritsu Model 5202

Figure 3 shows the modified portable road lamp with a developed new brightness controller. The portable lamp pole designed for measuring road light intensity offers a versatile system optimized for accurate fieldwork. It is equipped with a portable, adjustable telescopic structure that allows for flexible height adjustments. The lamp pole also features an adjustable angle mechanism, enabling users to precisely control the direction of the light source for targeted illumination. Enhancing its versatility, the lamp pole includes a brightness control mechanism, which allows for adjusting the light intensity to accommodate different environmental conditions and measurement scenarios. A robust power supply system ensures operational efficiency during extended fieldwork, facilitating prolonged monitoring of measurement outcomes.

FIGURE 3: Portable lamp (left); Brightness controller (right)

2.3 Measurement Parameters

This project will employ a grid measurement layout approach to analyze light intensity based on different heights from the road surface and various angles of lamp poles. It will consider factors such as the spacing between lamp poles, road width, lamp pole height, and specific measurements of light intensity at various heights and angles. Initially, a standardized distance of 15 meters between lamp poles will be maintained to ensure uniformity throughout the experimental process (see Figure 4). This distance is selected to mirror typical urban road lighting setups.

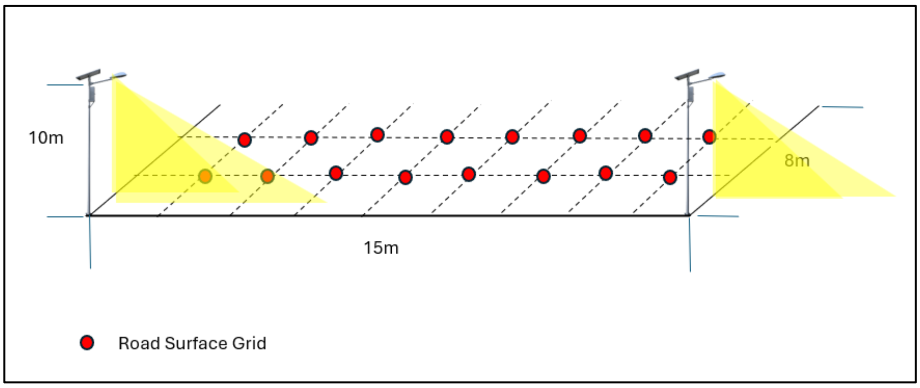
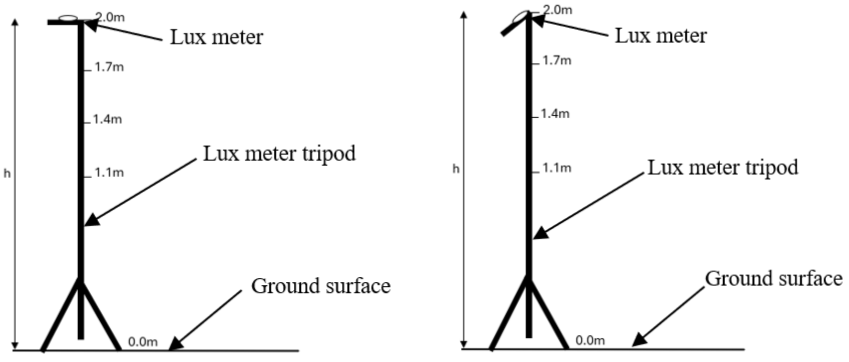


FIGURE 4: Grid measurement layout

For the road width, a 4-meter width will be considered to simulate a single-lane scenario. The height of the lamp poles will be fixed at 10 meters to match typical road lighting installations. Each test will be repeated at least three times to ensure statistical validity and minimize the impact of random fluctuations. The measured data will primarily focus on light intensity, quantified in lux, at different heights from the road surface (0, 1.1, 1.4, 1.7, and 2.0 meters) to account for varying vehicle heights. Additionally, light intensity will be measured at different angles (0 and 45 degrees) to consider the minimum and maximum angles of vehicle windshields, which can influence visibility and perception of light.

2.4 Grid Construction

To ensure accurate measurement of light intensity, a grid was laid out on the road surface (see Figure 6). This grid comprised evenly spaced lines that intersected to form measurement points at regular intervals. This systematic arrangement facilitated consistent data collection across the entire research area. The gridlines created a network of squares or rectangles, spaced uniformly both horizontally and vertically. At each intersection point, a lux meter was positioned to measure light intensity (see Figure 7). This method minimized potential biases and data gaps, enabling a thorough mapping of light distribution and yielding a precise and detailed representation of the lighting pattern.



(a) (b)

FIGURE 5: Lux meter positioning at (a) 0-degree and (b) 45-degree angle

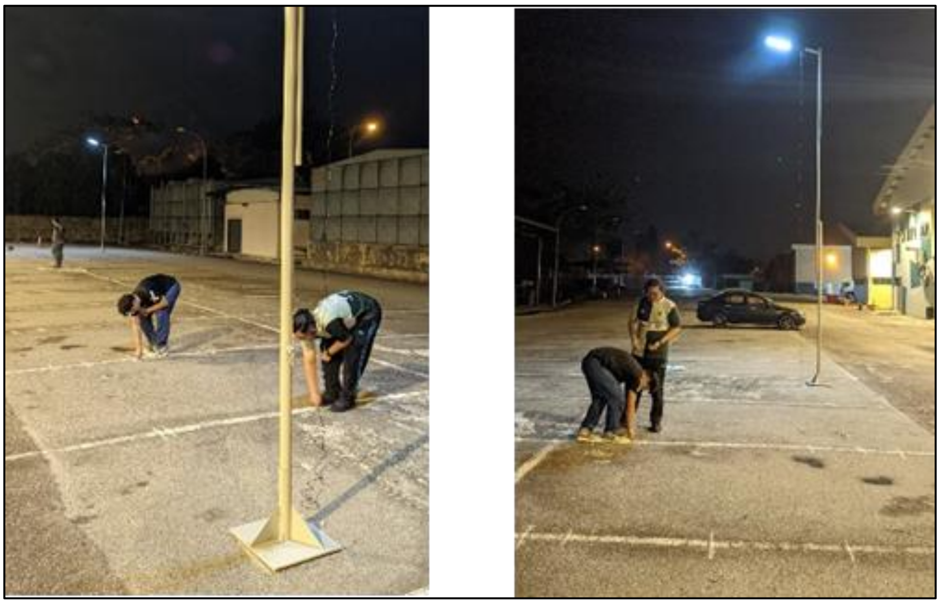


FIGURE 6: Gridline construction

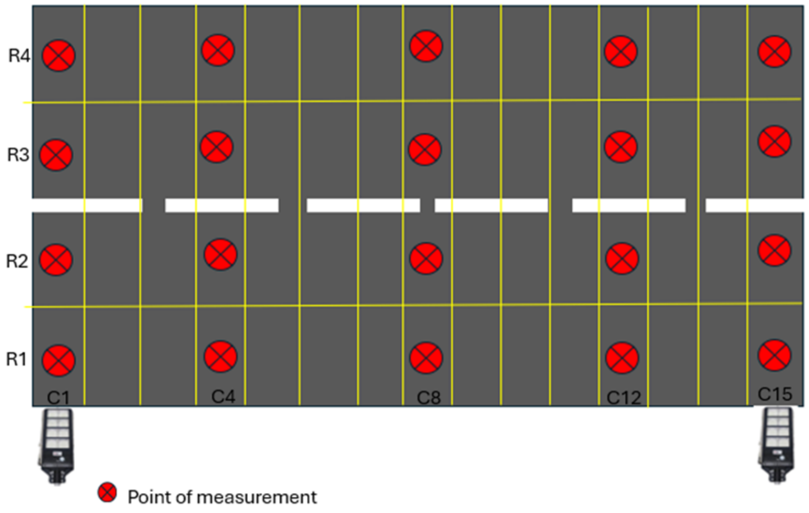


FIGURE 7: Gridline layout

.3. RESULTS AND DISCUSSION

Figure 8 illustrates the average light intensity measurements for a single-lane road equipped with lamp poles situated at the curbside edge. This average light intensity is plotted concerning the road's length, ranging from 1 meter to 15 meters, and the height at which the light intensity is measured from the ground, spanning from 0 meters to 2 meters. The primary variable examined in this graph is the 0° angle of lamp distribution. Notably, the highest recorded average light intensity occurs at a road length of 1 meter and a measurement height of 2 meters, registering a value of 20.275 lux. Conversely, the lowest recorded average light intensity is observed at a road length of 8 meters and a measurement height of 2 meters, with a value of 1.35 lux. This data highlights significant variations in light intensity based on the specified parameters of road length and measurement height.

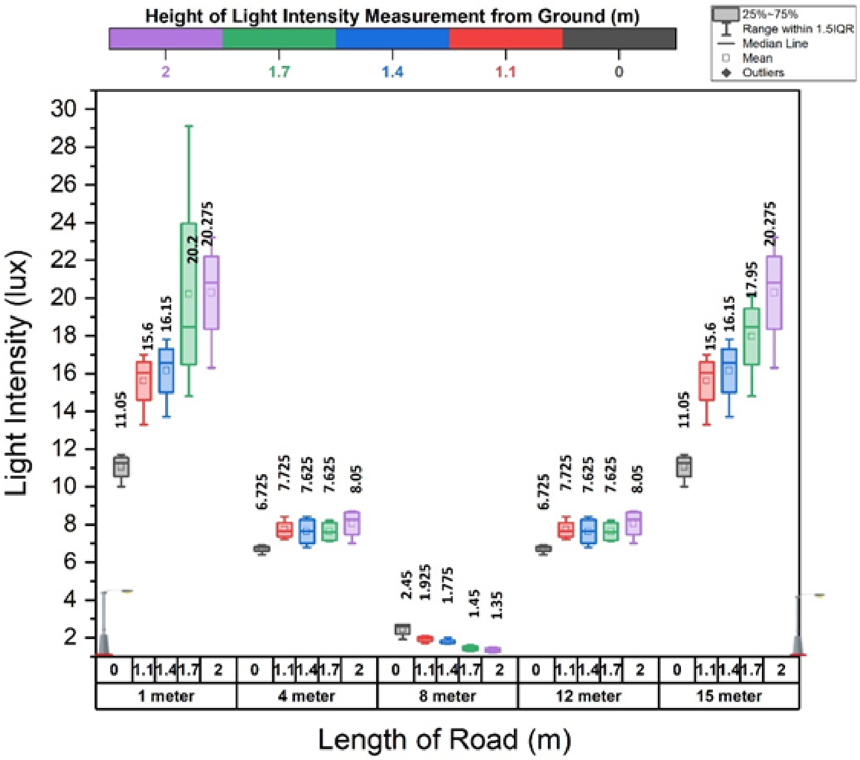


FIGURE 8: Average light intensity of 0° angle

Figure 9 presents the results of the average light intensity for a single-lane road illuminated by a lamp pole positioned at the curbside, with the lamp distribution set at a 45° angle. In this figure, the x-axis represents the road's length and height at which the light intensity is measured. The highest average light intensity recorded in this configuration is 16.7 lux, occurring at a road length of 15 meters and a measurement height of 2 meters. On the other hand, the lowest average light intensity observed is 1.2 lux, found at a road length of 8 meters and a measurement height of 2 meters. This figure underscores the variation in light intensity distribution along the length of the road and at different heights, influenced by the 45° angle of lamp distribution.

Upon analyzing Figures 8 and 9, it is apparent that the average recorded values of both the highest and lowest light intensities occur at consistent positions relative to the road. The highest average light intensities are observed near the light source and at the end of the illuminated area, specifically at road lengths of 1 meter and 15 meters, and a height of 2 meters. Conversely, the lowest average light intensity consistently appears at the midpoint between two light sources, precisely at a road length of 8 meters and a measurement height of 2 meters. This pattern underscores how the arrangement of lamp positions and the angles of light distribution significantly influence variations in light intensity along the road.

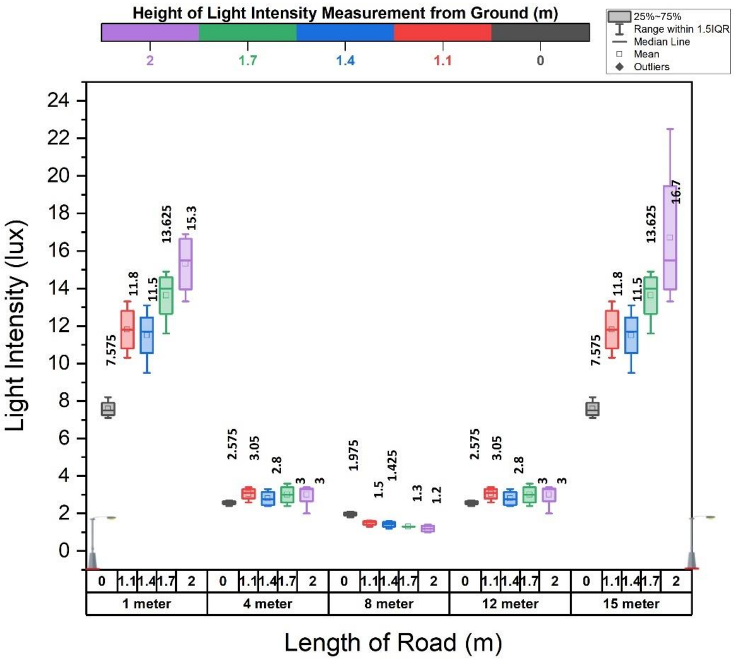


FIGURE 9: Average light intensity of 45° angle

Figure 10 depicts scatter plots that demonstrate variations in light intensity across different road lengths, emphasizing the significant influence of road length on light intensity levels. The findings reveal that road lengths of 1 meter and 15 meters consistently exhibit the highest average light intensity compared to other lengths. This is primarily attributed to the proximity of measurement points to the road lamp, resulting in higher intensity readings. Another influential factor affecting light intensity is the angle of lamp distribution. The scatter plots illustrate that a lamp distribution angle of 0° contributes more to light intensity than a 45° angle. This is because a 0° angle allows for more efficient light deployment.

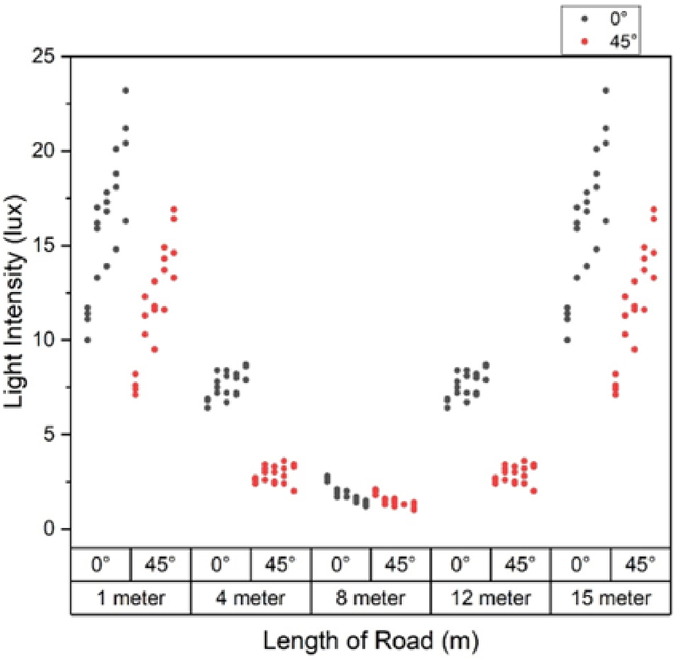


FIGURE 10: Scatter graph of light intensity for single lane road with lamp pole on the curbside edge

4. CONCLUSION

The study identified significant areas for improvement in road lighting. The uneven distribution of light intensity indicated that the current positioning and alignment of lamp posts did not effectively ensure uniform illumination across the road surface. This inconsistency could potentially pose safety hazards for drivers, especially in areas where light intensity is low, thereby increasing the risk of accidents.

Furthermore, the findings suggested that optimizing the height and angle of lamp posts could enhance the evenness of light distribution. For example, lowering lamp post heights to approximately 1.1 meters to 1.4 meters could improve road surface illumination, thereby enhancing visibility for drivers. Similarly, adjusting the angle to achieve a broader light spread might mitigate intensity variations across the road. The study also underscored the importance of minimizing glare and shadows, which can affect the performance of AEB sensors. Properly aligning and positioning lamp posts could mitigate these issues, thereby improving the detection capabilities of AEB systems. These insights are particularly relevant for urban planners and engineers involved in designing and maintaining road lighting systems.

The study offered important insights into how light intensity, height, and angle impact road illumination quality and the effectiveness of AEB systems. Well-adjusted road lighting systems play a crucial role in enhancing safety through improved visibility and lowered accident risks. The findings provide recommendations for optimizing road lighting setups to better support advanced driver assistance technologies and enhance overall road safety.

A major limitation of the study was the variability in light intensity caused by weather conditions like rain, fog, and other environmental factors. These conditions could substantially influence the consistency and precision of light-intensity measurements. Future research should aim to address this limitation by conducting experiments in diverse weather conditions to gain a deeper understanding of their effects on road lighting and safety. Additionally, it would be beneficial for future studies to incorporate real-world field investigations alongside controlled experimental setups to validate findings in more varied and realistic environments.

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