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Visual Performance and Motorcycle Safety-Related Impacts of Various High Beam Headlight Intensities

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Abstract – *In Malaysia, the three main types of motorcycle accidents include collision with passenger cars, collision with other motorcycles and single-motorcycle accidents. An accident may occur due to the lack of road design consistency and visibility where most drivers make more errors in the absence of geometric features. One of the most important barriers to the more frequent use of high beam headlight is the length of visibility of the headlight beam in relation to the stopping distance of a vehicle. Furthermore, it is crucial to evaluate the current limits on the luminous intensity of high beam headlights that is considered visible for a driver to come to a stop. Therefore, this first stage study summarizes and investigates the stopping sight distances, braking distances that allow for the evaluation of the vehicle's performance to increase the capability of both the driver and vehicle with regard to safety. A total of ten experiments were carried out with a passenger car, the Perodua Myvi, on a road within a local university. The results found that Stopping Sight Distance (SSD) could be used to determine the SSD graph by considering the velocity (v_0), driver's perception reaction time (t_R), coefficient of breaking friction (f_T), gravitational constant (g), deceleration rate (a) and roadway grade (G). The study also concludes that SSD could be used to determine the SSD graph by considering the velocity (v_0), driver's perception reaction time (t_R), coefficient of breaking friction (f_T), gravitational constant (g), deceleration rate (a) and roadway grade (G). Ultimately, the study also indicates that the time to switch to hi-beam (Automatic High Beam – AHB) is at SSD distance (meter or second).*

Keywords: Braking distance, Stopping Sight Distance (SSD), headlight beam, Automatic High Beam (AHB), visual of motorcycle

1.0 INTRODUCTION

High beam headlights produce a certain amount of visible light, with different sight distance to the human eye. The light is measured as lumens per square meter (lux). Various studies have demonstrated the visual effects of high beam headlights to oncoming and leading vehicles (Bullough et al., 2013; Bullough, 2014). Such studies have also underlined the need for a limit on the level of luminous intensity of high beam headlights. However, an in-depth investigation led by Zainal Abidin et al. (2012) from the Crash Reconstruction Unit (CRU) of MIROS found that risky driving, speeding, and fatigue were the main causes of road accidents out of ten factors. It did not indicate the causes related to the vehicle headlights effects – during day time or night time driving. Nevertheless, the study showed that environment factor caused 8.5 percent of accidents (from 445 cases) (Zainal Abidin et al., 2012). Although such a factor has contributed to a number of road crashes, poor visibility may have also played a role (IIHS, 2016). Since 1969, the Federal Motor Vehicle Safety Standard (FMVSS) 108 specified that all motor vehicles sold in the United States must have separate switches for manually selecting low beam and high beam headlamps, with the low beam needed to limit glare to oncoming or leading vehicles and the high beam to maximize forward luminance in the absence of other vehicles. The most important issue regarding the more frequent use of high beam headlight is that it creates glare to the drivers of oncoming and preceding vehicles (Prasetijo et al., 2018a).

However, aside from headlight glare, one should also consider the high beam range for safety driving (Bullough et al., 2016). The range is important so that a vehicle can have enough distance to stop before hitting the object in front. With regard to the range, there are various factors to consider, namely velocity, brake reaction time, braking distance and stopping distance. The stopping distance is the distance a car travels before it comes to a rest. This depends on the speed of the car and the coefficient of friction (μ) between the wheels and the road. The stopping distance formula does not include the effect of anti-lock brakes or brake pumping. The SI unit for stopping distance is meter,

$$stopping\ distance = \frac{v^2}{2\ \mu g}$$

where v is the velocity of cars (m/s), μ as the coefficient of friction and g is the acceleration due to gravity (9.80 m/s^2).

Braking distance is the distance that a vehicle travels before coming to a complete stop. The braking distance is dependent on several variables. First, the slope (grade) of the roadway will affect the braking distance. If a vehicle is going uphill, gravity assists in the vehicle's attempt to stop and reduces the braking distance. Similarly, gravity works against a vehicle as it descends and will increase the vehicle braking distance. The formula for the braking distance is given below:

$$d = \frac{v^2}{254\ f_T}$$

where f_T is the coefficient of breaking friction between the tires and the pavement surface.

Brake reaction time is the amount of time that elapses between the recognition of an object or hazard in the roadway and the application of the brakes. The length of the brake reaction time varies between individual drivers. An alert driver may react in less than 1 second, whereas other drivers may require up to 3.5 seconds. The brake reaction time depends on an extensive list of variables, including:

i. driver characteristics such as attitude, level of fatigue, and experience;
ii. environmental conditions such as clarity of the surroundings and the time of day; and
iii. the properties of the hazard or object itself, such as size, colour and movement.

Relatedly, an on-road measurement of braking reaction time reveals that for average drivers, the braking reaction time can range from 1.0 to 2.0 seconds (Sohn & Stepleman, 1998). This brake reaction time entails the time for drivers to perceive a threat, release the accelerator pedal, and shift the foot to the brake pedal. A total of 89 motorcycle riders were recruited (i.e. 56 males and 33 females), where 60 riders were between 16 to 30 years old (i.e. 38 males and 22 females), with a mean age of 25.4. In addition, 29 riders were 50 – 60 years old with a mean age of 54.7 years old (i.e. 18 males and 11 female). The reaction time ranged between 0.55s and 2.55s with a mean of 1.29 s (Davoodi et al., 2012).

The Japan New Car Assessment Program (JNCAP) and Toyota Central Driving School have produced a graph of the relationship between car velocity, stop distance and high beam range. The graph acts as the main reference for this research study. The graph does not show the parameters involved (driver's performance, vehicle's performance) and the values for suitable braking reaction time (Figure 1).

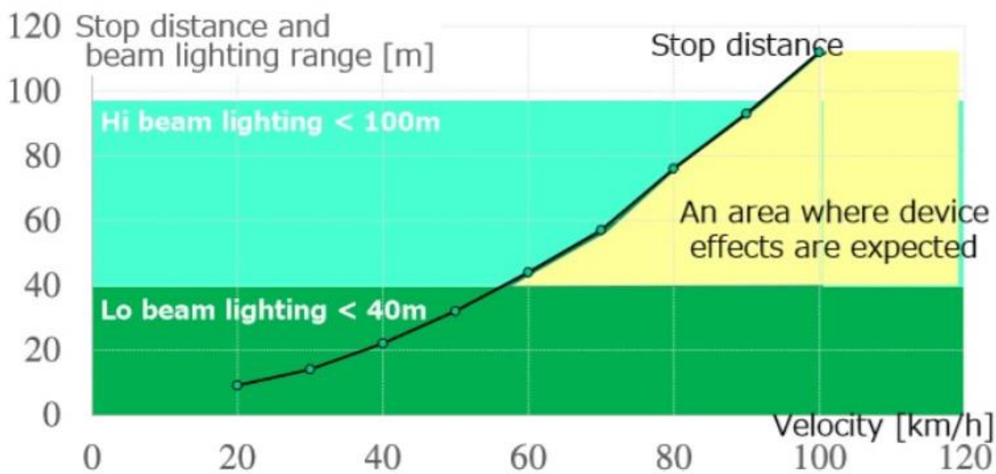

Figure 1: JNCAP – Toyota SSD

Therefore, the objectives of the current research are: (i) to identify the formula used by Toyota Central Driving School for producing the graph of stop distance; (ii) to identify the formula for producing the graph of stop distance; and (iii) to identify the difference (in distance) between Stopping Sight Distance (SSD) for level surface and flat surface. It is expected that the results of this research will allow for the evaluation of the potential benefits of luminous intensity to forward visibility and potential implications on driving safety, such as safe visibility range and glare discomfort levels.

2.0 METHODOLOGY

In this research, ten field experiment sessions were set up along a road within the Universiti Tun Hussein Onn Malaysia (UTHM) campus. The sessions were carried out in ideal situations (i.e. during the day, in clear weather). The roadway path had typical geometric features of two lane-dual carriageways with an average width of 7.5 meters. The road was flat and had a high rate of road incidents (Prasetijo et al., 2017). The tests involved braking manoeuvres at a consistent speed of 60 km/h.

2.1 Field of Experiments

A road path of about 300 meters was selected within the UTHM campus for the experiment purpose. The path was chosen as it was straight, flat and was isolated from traffic – for safety reasons, the road was closed during all experiment sessions (Figure 2). The driver was briefed on the objective of the study and was allowed to perform practice driving as directed. The driver was then instructed to quickly apply the brakes when randomly signalled by a raised flag, and his actions were recorded in slow motion so that the car, and the brake light could be seen from the main station. Furthermore, the time between activation of the light and the initial onset of the activation of car brake light (i.e. stop light), was recorded.

(a) (b)

Figure 2: (a) Test car; (b) Road path based on common lane width

2.2 Experiment Setup

The 7.5-meter-wide road path was set up for the car to be driven at a velocity within the range of 20 km/h – 80 km/h. The camera and camcorder stands were placed (static) at the rear side of the driven car (Figure 3). Each stand was 130 centimetres in height according to the commonly used design. It was placed behind the driven car as shown in Figure 4. Several distances were recommended in the assessment (Prasetijo et al., 2018b). The longest distance was recommended as the minimum distance within the range of stopping distance. The camera used was EOS 80D while the camcorder was HDR-CX100 AVCHD (Figure 2).

Measuring of the brake reaction time and braking distance relied on the video and camera data. The equipment was placed on the lane-side and mounted on an adjustable stand at a height of 1.3 meters (Figure 4). As a vehicle passed through an observation site, its brake light was recorded and the camera recorded the time and distance. The camera kept a time signature of the passing vehicle, and this was used to determine the vehicle moving patterns. The field experiment on the local road within UTHM was conducted along a straight path of

300 meters. The experiment sessions were performed at 21:00 hrs and during dry weather condition. The test car (Myvi Perodua) was equipped with a common brake system. The system was manually controlled and conformed to the specifications. The car was driven at a speed of about 20 km/h – 80 km/h.

(a) (b) (c)

Figure 3: (a) Adjustable stand for camcorder/camera; (b) Camera; (c) HDR camcorder

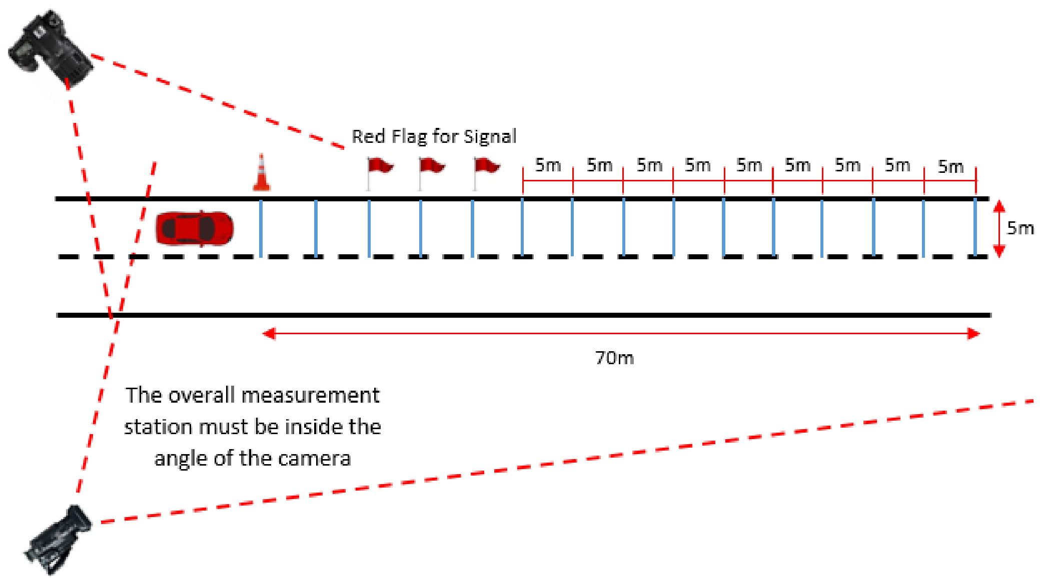

Figure 4: Equipment setup and measurement distances

2.3 Stopping Sight Distance (SSD) Experiments

All the equipment was set up on-site. The camera was placed to record all the actions and a cloth tape was attached to the pavement surface with a gap of five meters for each tape. The car was examined and the driver was asked to familiarize himself with the car, i.e., checking the seat, mirrors, safety belt, etc. as well as brake response. When the car had fully stopped, the distance of the braking was measured from the starting point when the flag was raised. The braking distance test was then repeated.

3.0 RESULTS AND DISCUSSION

This section shall discuss the results of the research study in terms of brake reaction time, braking distance, and SSD from both theoretical aspect and analysis.

3.1 Brake Reaction Time

The brake reaction time experiment was conducted using a passenger car, the Perodua Myvi. The experiment sessions were set-up as shown in Figure 3. The purpose of the experiment was to determine the brake reaction time, braking distance and stopping distance. Based on ten experiment sessions or test drives, the study found the average brake reaction time in the range of 0.4s – 1.0s (Table 1). The study also found the average brake reaction time was 0.7 seconds. This was, therefore, still within the range of common practice of 0.55s – 2.55s (Davoodi et.al, 2012).

Table 1: Brake reaction time

Test no.	Average (seconds)	Test no.	Average (seconds)
1	0.9	6	0.6
2	0.7	7	0.9
3	0.6	8	0.7
4	1.0	9	0.6
5	0.6	10	0.4

3.2 Braking Distance

As discussed earlier, braking distance is the distance a car travels from the point when a driver starts braking until the car completely stops. It is very difficult to produce reliable calculations of the braking distance as road conditions and the car tyre grip may vary greatly. The braking distance may, for example, be ten times longer when there is ice on the road. The current study, conducted with a velocity range of 20 km/h – 80 km/h, found that the average braking distance was between 4.3 m – 45.2 m. The results are shown in Table 2.

Table 2: Average braking distance

Velocity (km/h)	Average Braking Distance (m)			Average (m)
	Test no.			
	1	2	3	
20	4.5	4.6	3.7	4.3
30	11.4	10	9.6	10.3
40	16.3	14.8	14.5	15.2
50	23.8	24.9	21.6	23.4
60	24.7	29.7	30.4	28.3
70	33.4	39.6	32.7	35.2
80	48.5	44.3	45.2	45.2

3.3 Stopping Sight Distance (Theoretical and Analysis)

The on-site reaction time was calculated using the equation below to produce the SSD graph (theoretical). It shows a smooth line curve as in Figure 5 which is based on the formula of SSD. Furthermore, Figure 6 shows SSD based on the brake reaction time and braking distance.

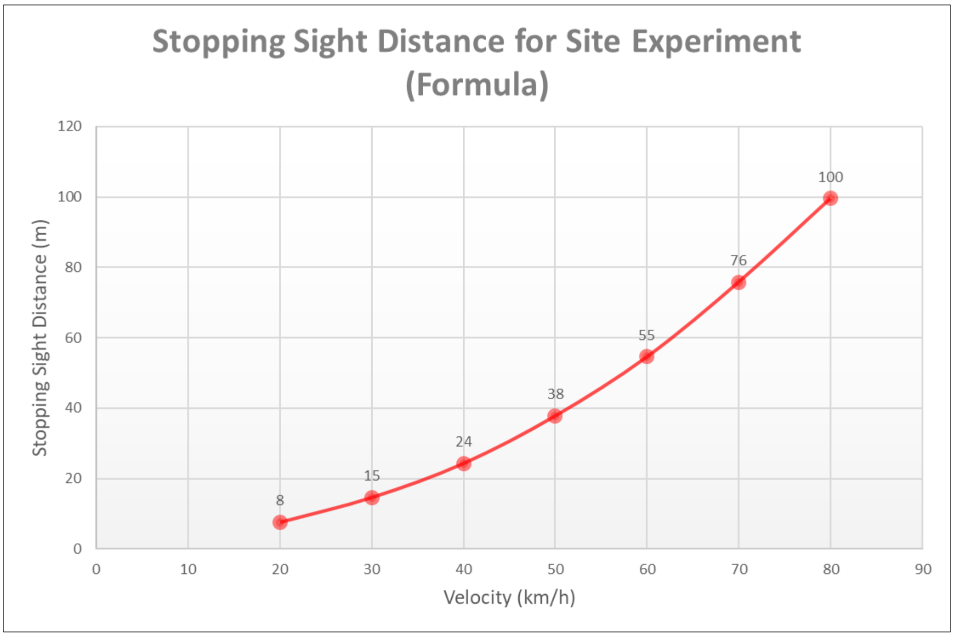

Figure 5: SSD (theoretical)

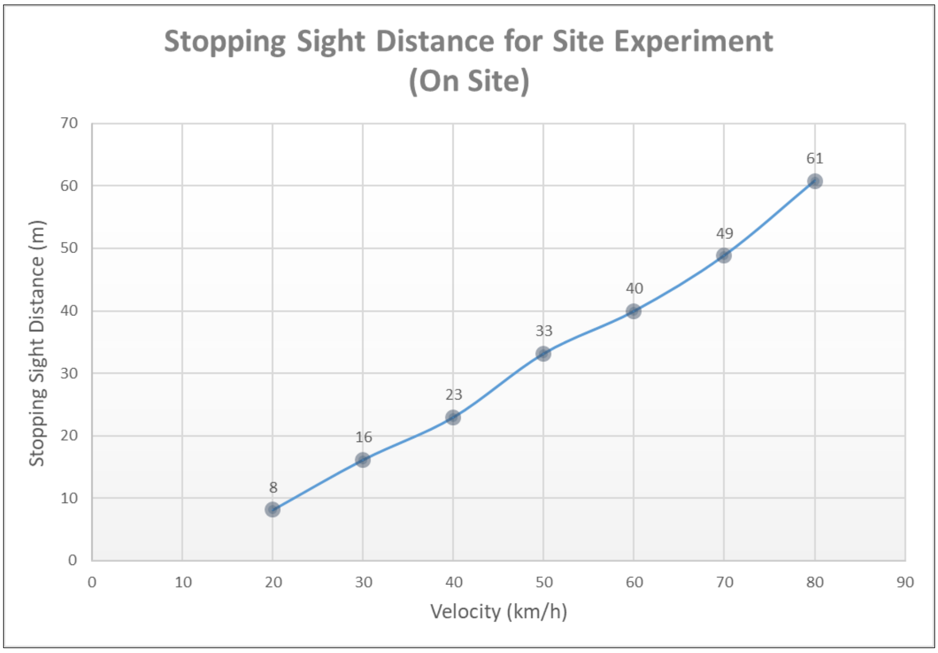

Figure 6: SSD (analysis)

The two graphs show a significant difference in SSD which may be caused by inaccurate measuring of the brake reaction time. Further studies may be applied for a position of object as seen by the driver, randomly. A larger time gap should be expected. The following Figure 7 shows the comparison between the SSD in the United States (levelling), Japan (levelling) (Mannering et al., 2007), JNCAP – Toyota and that of the current experiment. The graph shows a significant difference between the study and the JNCAP. The US and Japan studies found a higher rate of SSD due to the levelling road condition that was required. However, a further study is necessary to determine the causes for the different findings between JNCAP and the current study.

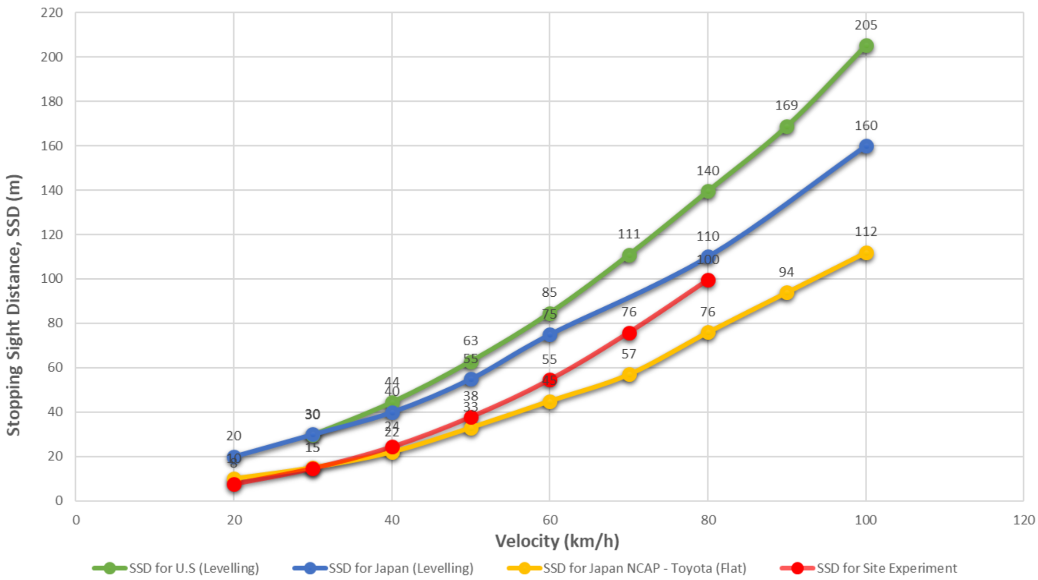

Figure 7: All SSD's – US (levelling), Japan (levelling), JNCAP (flat), and from this study

4.0 CONCLUSION

The findings of the current research study and the measurements as summarized in this report suggest that stopping distance systems offer substantial promise in determining the significance of three main factors, namely brake reaction time, braking distance and stopping sight distances, as opposed to the glare from the high beam headlights. Therefore, the study has produced substantial results for safety improvements of high beam headlight performance, for night time driving. This is turn leads to the criteria for braking system and headlight system performance. Further experiments are required for consistent and repeatable results by using a higher specification of cars and camera recording.

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