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Evaluating Actual Speed Against the Permissible Speed of Vehicles During Free-Flow Traffic Conditions

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ABSTRACT

It is commonly seen that vehicles were moving above the speed limit on many expressways especially during free-flow traffic conditions. To ensure safe movement of vehicles, it is important to compare the actual speed of the vehicles against the posted speed limit. The main purpose of this paper is to evaluate and compare the actual speed of the vehicles with the allowable speed limit during free-flow traffic conditions. Duta-Ulu Kelang Expressway (DUKE) was selected as a case study. Major data were collected by using road geometrical survey and spot speed survey method. Around 400 vehicles' speed were measured at a selected road stretch for 4 hours during off-peak period. Systematic sampling technique was used to select samples from the targeted vehicle population. Descriptive statistical methods were used to analyze the speed trends and speed characteristics of the sampled vehicles. T-test was applied to test the actual speed between each selected hour and to test the differences between actual average vehicle speed and allowable speed limit for statistical significance. The results show most of the vehicles (66%), on average, were moving at a speed higher than the allowable speed limit of 90 km/h. The differences between actual average speed and allowable speed limit were tested for statistical significance which as a result indicates a clear difference between actual average speed and allowable speed limit. Few recommendations are drawn to discourage excessive speed in order to make the roads free from accidents and to improve the safety of the road users.

Keywords: Spot speed, road geometrical design, road safety, speed limit, DUKE

INTRODUCTION

A significant increase in the number of vehicles in Malaysia has directly led to various traffic issues especially road crashes. Road crashes are one of the major problems that this country has been facing over the years. As stated by World Health Organization (2004), road fatalities in Malaysia has increased as the country has been developing physically, economically, and socially. It is a common and well perceived notion that road accidents are usually related to speed of vehicles. Driving at speed higher than the allowable speed limit reduces the chances to react in time especially during emergency when controlling the vehicle movements. The chances to preclude an accident decrease as speed increases. The deviation of speed from the mean speed affects not only capacities but also safety of the road users. Driving at excess speed may lead to major crashes, deaths and serious injuries. Finch (1994) highlights that an increase in speed accelerates accident risks. It affects not only the safety of the drivers, but also safety of the other road users.

The Ministry of Works in Malaysia had set the posted speed limit for different road classes and it is required under law that the road users must obey the posted speed limit (Motor Vehicles Speed Limit Rules 1989). The posted speed limit can be defined as a guideline for road users in controlling their vehicles at maximum permissible speed on the road for their own safety as well other road users. According to the Malaysian Institute of Road Safety Research (MIROS), speeding has been ranked as the second highest factor contributing to road crashes in Malaysia especially during free-flow traffic conditions. This is supplemented with traffic statistics in 2016, which reported 7,152 people were killed in 521,466 road accidents in Malaysia. It is almost close to 20 road users who had lost their lives each day. The primary causes of the road accident are mostly due to excessive speed, which is speed above the speed limit (Rolison et al. 2018; Gonzales et al. 2005; Lam, 2003; Braitman et al. 2008; The Star 2017). Generally, all the vehicles do not travel at the same speed on the road. The actual speed of a vehicle on a route varies widely depending on several factors such as road geometrical features, traffic conditions, time, environment, driver preferences, distance travelled and posted speed limit.

Few previous studies mainly focus on the factors influencing the speed of the vehicles on highways with less attention on comparing the actual speed of the vehicles with the permissible speed limit (Adeke et al. 2018; Noor

Hafiza et al. 2014). The focus of this paper is to evaluate and compare the actual speed of the vehicles with the allowable speed limit on a selected expressway during free-flow traffic conditions. The road selected for this study was Duta-Ulu Kelang Expressway (DUKE). This paper is an attempt to look at the speed characteristics at the selected highway and to evaluate the differences in actual average speed with the permissible speed limit. This paper is divided into few sections. Section 2 narrates the literature review that are related to this topic followed by highlighting the main methodology used in this paper in section 3. The description of study area is given in section 4 and the major analysis and findings in section 5. Finally, discussion, recommendation and conclusions are drawn in section 6.

LITERATURE REVIEWS

Speed is calculated by using two parameters, one is distance and the other is time. When the distance covered by a vehicle is divided by the total time taken to cover this distance will gives the speed of the vehicle (Murthy and Mohle, 2000, cited in Abdul, 2013). According to Hobbs (1979), spot speed is the instantaneous speed of vehicles at any specified point. Spot speed study characterizes the various speed parameters like mean speed, median speed, modal speed, percentile speed and standard deviations of speed at defined locations under the existing traffic and environmental conditions (Garber and Hoel 2009; Mohamed 1993). In addition, the spot speed is usually measured during free-flow traffic conditions in order to get the actual speed of the vehicles travelling at that time.

According to Garber and Hoel (2009), three location criteria are generally used to conduct a spot speed study. First, it should reflect different traffic conditions on the selected road for collecting data. Second, the mid-blocks of a road which is straight and levelled for speed trends analysis. Third, any locations that are used for arriving at solutions for a specific traffic planning problem. The samples for spot speed data must be at least 50 and preferably 100 vehicles (Ewing 1999). This is to ensure that the samples are well representing the targeted population at the study area.

Spot speed studies should be normally administered at time when the road segment experiences "free-flow" driving conditions or off-peak hours (Garber and Hoel 2009; WHO 2013). During this time, drivers will drive at their desired speed because of less traffic movement on the road. Mohamed (1993) claimed three suitable time to conduct spot speed studies which are from 9 am to 12 noon, 3 pm to 6 pm and lastly from 8 pm to 10 pm. These time periods are normally chosen to achieve the objectives of the spot speed studies (Garber and Hoel, 2009). Nordiana and Yuzairy (2016) had measured spot speed during off peak hours from 9.00 am to 11.00 am where the road was subjected to free-flow traffic conditions. The timing of speed measurement is very important to get the actual speed of vehicles during off-peak hours. This is because, the speeds during free-flow traffic conditions especially during off-peak hours are usually affected by several factors namely lane width, horizontal and vertical alignment, design speed, driver behavior, weather, sight distance, lateral clearance, and environmental conditions (Garber and Gadiraju 1989; Oppenlander 1966; Ottensen and Krammes 2000; Rowan and Keese 1962).

Road geometry characterizes the physical elements of a road. This includes the surface of the road, width of the road, road alignment, and the division between the road and the area adjacent to the road. The road geometrical design plays an important role in defining the traffic operational efficiency of any roadway. Besides, according to Hong & Oguchi (2005), the road geometrical design can affect the drivers' choice in controlling their vehicles speed on the highway. To exemplify, if the road design is straight, then the driver feels safe and as a result tend to drive at high speed perceiving it as a safe speed. Moreover, when the surface of the road is hard, it yields annoying noise and jolt which can be felt inside the vehicle. As a result, it necessitates to reduce the speed of the vehicle to counteract these unpleasant effects (Martens, Comte & Kaptein 1997). Road surface imposes difficulties to control the vehicles (Elliot, Mccoll & Kennedy 2003). Hence, they are not used as an engineering measure for speed control. Additionally, the speed is also affected by the road geometrical elements like width of traffic lane, number of traffic lanes, and width of road shoulder. When the width of a traffic lane is wider or number of traffic lanes is higher, the availability of road space area for the drivers increases (Elliot et al. 2003). The road width has different effects. It means wider the width of the road, higher the speed of the vehicles. The wider the lanes, the driver will feel safer to drive at their desired speed. However, it is not recommended to narrow the lanes as a speed control measure, otherwise it increases the risk of head-on and run-off road crashes (Fildes & Lee 1993). Mannering (2009) further emphasizes that few corrections are needed when dealing with narrow lanes because it allows traffic to slow down. As a result, it reduces the psychological comfort and limits on the driver maneuvering of the vehicles and thus decreasing the prevention of accidents. Thus, some of the countries such as Malaysia has set the standard design guidelines for the road lane width according to the hierarchy of road to ensure uniform similarity applications for all roads and safety of the road users.

The speed of vehicles may varies depending on driver's choice. Drivers, who prefer higher speeds perceived it to be safe speed (Goldenbeld et al. 2005). The fear of the people on speeding is not the same as they fear on height and as a result, they pay less attention believing that speeding, in fact, is strongly related to road safety (Rumar 1999). Besides, the driver also underestimates the impact of driving at high speed on road accidents. Moreover, it is generally notable that decreasing the travel time by the drivers is preferable than driving more safely because of the belief that they hold that they are driving at a speed safer than others (Kanellaidis, Golias and Zarifopoulos 1995). This psychological thinking and behavior are encouraged by the fact that nowadays vehicle technology and road design developments make drivers feel safer (Yannis, Louca, Vardaki et al., 2013). Few factors such as urgency of the situation, enjoyment and thrill were the reasons expressed by the drivers for speeding (Elvik, Christensen & Amundsen, 2004). This statement is also corroborated by SARTRE 3 (Social Attitudes to Road Traffic Risk in Europe) (2004) where almost 10% of the European drivers had agreed that they enjoyed driving fast.

Speed limits are used in many countries to regulate the vehicle speed on road and act as a basis for enforcement. Speed limits are vital to ensure that the drivers maintain the same allowable speed when using the same road that would help increase safety (Ibrahim, 2011). The allowable speed limits are decided by the policy makers (Prama, 2011). However, the posted speed limits also will be verified and set according to other factors based on evaluation by the traffic engineers. When it comes to fixing speed limit, traffic engineers use both operating speed method and road-risk method and then use the 85th percentile speed as the design speed. Then, the base speed limit is adjusted according to traffic, infrastructure conditions such as pedestrian use, effect of the driveway and conditions to surrounding land use and past accident records in order to evaluate the safety of the road users (Federal Highway Administration, 2012; Roess 2003 as cited in Nordiana and Yuzairy 2016).

The vehicle speeds were studied at various speed limits conducted at three different locations with different posted speed limits varying from 60 km/h to 80 km/h (Nordiana and Yuzairy, 2016). About 1670 vehicles speed data were obtained in this study. The samples were classified into three classes of vehicles which are light vehicles, medium vehicles and heavy vehicles. The light vehicles consist of motorcycles, individual car and taxi while medium vehicles comprise of light transport vehicles, small vans, medium sized vehicles and medium sized lorries. Big lorries and busses are classified as heavy vehicles. The number of vehicles was seen to drop sharply as the speed range increases above the posted speed limit. In general, only 13.4 % of the vehicles were traveling above the posted speed limits at one of the selected sites. Specifically, only about 15% of light vehicles were speeding above the allowable speed limit at site 1, 2 and 3. While, the other vehicle types were mostly traveling at speed at or below the speed limit (Nordiana and Yuzairy, 2016).

OBJECTIVES AND METHODOLOGY

The main objectives of this study are: 1) to identify the road geometrical design of the selected stretch of DUKE highway and relating it with the actual speed of the vehicles, 2) to measure the spot speed of the vehicles at different pre-selected time periods during off-peak hours and 3) to analyze the changes in the actual vehicles speed with the posted speed limit during off-peak hours and 4) to analyze the actual vehicle speed between each hour of the pre-selected time periods. Road geometrical elements and spot speed of the vehicles at the selected road stretch are the main data for this study. These data were collected by using different survey methods. Two methods were used to collect these main data namely road geometrical inventory method and spot speed survey method. One of the factors that affect speed of the vehicles is the road geometrics especially the width of the carriageway, median and road shoulder. The width of road dimensions of the selected road was measured by using a measuring tape.

The spot speed survey was administered on Sunday from 8 am to 12 noon to acquire the actual speed of the vehicles during free flow traffic conditions. A straight flat road stretch with no clear obstructions was selected to measure the spot speed of the vehicles. The speed limit of the selected road stretch was 90 km/h (DUKE Highway). This road was selected due to substantially higher number of vehicles were seen driving at speed more than the speed limit. Additionally, the inclination of the drivers to drive above the posted speed limit of 90 km/h along this selected road stretch is much higher due to lower speed limit than 110 km/h and roadway width and other related facilities closer to 110 km/h expressways. Two enumerators were involved in measuring the spot speed of the vehicles. Systematic sampling technique was applied in selecting the samples by targeting every 5th motorcar of the targeted population. The spot speed was measured by using a radar gun by targeting vehicles when approaching the pre-defined point on the road stretch. A radar gun was stationed at an inconspicuous location at the road side and targeted approaching vehicle at a distance of 10 m from the position of radar gun to measure the spot speed. Figure 1 shows the set-up of the radar gun for the measurement of spot speed and Figure 2 indicates the measurement of spot speed which is being captured in a radar gun.

The collected data was analyzed by using descriptive statistical methods and dependent t-test method. Descriptive analysis technique was used to compute measures of central tendency, measures of relative position and measures of variability. On the other hand, dependent one-sample t-test was applied to test the statistical differences in the change of actual vehicle speed between each hour of the selected time period and differences between actual mean vehicle speed and allowable speed limit.

DESCRIPTION OF THE STUDY AREA

Duta-Ulu Kelang Expressway (DUKE) is one of the expressways in Klang Valley, Malaysia and its length is about 18 km long. It provides a direct connection between the North Eastern and North Western parts of Kuala Lumpur with a strategic link to the Kuala Lumpur-Karak Highway and East Coast Expressway. It also links with NKVE at Jalan Duta and MRR 2 at Ulu Kelang, thus providing uninterrupted traffic flow between the western and the eastern parts of Kuala Lumpur via Jalan Duta and

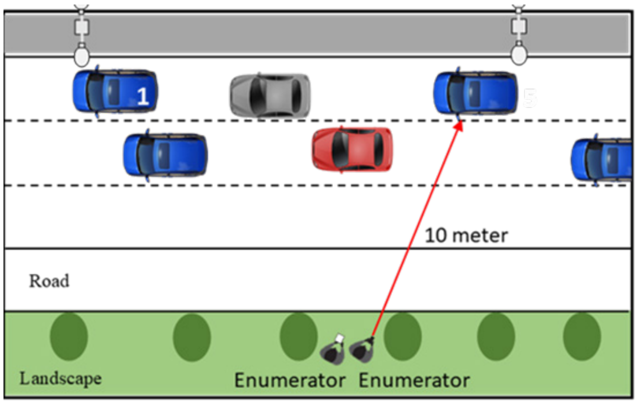

FIGURE 1. Illustration of Spot Speed Measurement

FIGURE 2. Radar gun showing the measurement of spot speed

Ulu Kelang Link. DUKE is chosen as study area because it is one of the popular alternative highways providing many direct links to major areas in Klang Valley and thus helps to smoothen the traffic flow conditions. Besides, the road geometrical design of DUKE is also suitable for the purpose of this study to acquire the actual vehicle speed on the highway. This highway was also selected due to higher number of vehicles were seen driving at speed more than the posted speed limit. A straight and levelled road stretch with a speed limit of 90 km/h (GPS Coordinate: 3.215806, 101.693475) along the DUKE was selected to measure the spot speed of the vehicles. Figure 3 shows the selected road stretch and Figure 4 shows pictorial view of the selected road respectively.

ANALYSIS AND FINDINGS

ROAD GEOMETRICAL DESIGN

The selected stretch of the DUKE highway is a dual carriageway with three lanes on each direction. The right of way (R.O.W) width of this selected road was 40 meters. The total width of each carriageway was 10.5 m and traffic lane width of 3.5 m. The dual carriageway has a median at the center of the road with a width of about 2.5 m. The width of road shoulder on each side was about 3 m. The width of landscape strip on each side was about 3.75 m and width of drainage on each side was 1.5 m. The road geometrical design of the selected road was found to follow the road guidelines standard of Town and Country Planning Malaysia.

SPOT SPEED CHARACTERISTICS

In this study, a total of 400 vehicles' speed was measured at the selected road stretch along DUKE highway from 8 am to 12 noon during off-peak hours at the rate of 100 vehicles each hour. The vehicles were found to be driving at a minimum speed of 75 km/h and maximum speed of 135 km/h. Figure 5 shows the spot speed distribution of the selected samples. The average vehicles speed was 96.56 km/h which is higher than permissible speed limit of 90 km/h.

The findings also show that the number of vehicles exceeding the allowable speed limit was found to be increasing from one hour to another (Figure 6). Overall, most of the vehicles (66%) were found to be speeding, driving at a speed higher than the allowable speeds limit of 90 km/h. On the other hand, only 34% of 400 vehicles were found moving at or below the allowable speed limit during off-peak hours. The high number of vehicles traveling at speed more than the allowable speed limit is due to low volume of vehicles and wider road geometrical design.

The spot speed characteristics are shown in table 1. Most of the cars were moving above the posted speed limit of 90 km/h. The findings on the hourly spot speed show that the highest mean vehicle speed of 97.8 km/h was observed between 10 am and 11 am. On the other hand, the lowest

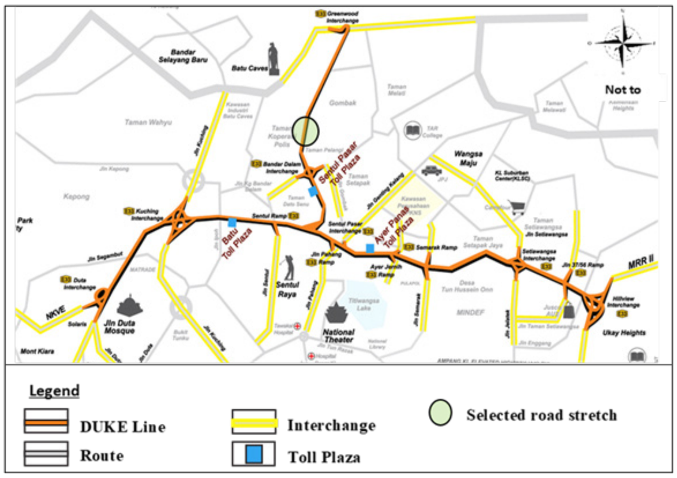

FIGURE 3 Selected road stretch along DUKE

FIGURE 4. Pictorial illustration of DUKE

mean vehicle speed of 95.2 km/h was observed between 8 am and 9 am. During this time, it was observed that high number of vehicles were traveling at speed below 90 km/h when compared with other off-peak hour.

During this 4-hour period, the 85th percentile speed of the vehicles was higher than the allowable speed limit of 90 km/h. The 85th percentile speed of 115.2 km/h was observed between 10 am and 11 am and the average 85th percentile speed was 111.9 km/h. It shows that most of the vehicles (85% of the sampled vehicles) were travelling at a speed of 112 km/h and below. The standard variation of the speed of the samples was between 12.64 km/h to 14.74 km/h from 8 am to 12 noon. The spread of spot speed shows a heterogeneous speed pattern as the standard deviation is much larger than 0. The standard deviation increases from 12.64 km/h to 14.14 km/h between 8 - 9 am and 9 am - 10 am as the mean speed also increases. The highest standard deviation was 14.74 km/h during 10 am – 11 am. This is due to the increasing number of vehicles moving at a speed higher than 90 km/h. The frequency of vehicles travelling at different speed is shown in Figure 7. It clearly depicts that most of the vehicles were travelling at speed higher than the permissible speed limit.

TESTING THE DIFFERENCES IN ACTUAL VEHICLE SPEED BETWEEN EACH HOUR OF THE SELECTED TIME PERIOD

The differences in actual vehicles speed between each hour of the selected time period were tested for statistical significance by using dependent t-test. The vehicle speeds were paired between hours. The results show all but one differences in vehicle speed paired between hours were statistically significant at 95% confidence interval. The results are shown in Table 2.

TESTING THE DIFFERENCES BETWEEN ACTUAL MEAN SPEED AND PERMISSIBLE SPEED LIMIT

A one-sample t-test to test the differences between actual mean speed and speed limit for statistical significance was conducted. The findings show that the differences between actual mean speed and allowable speed limit was statistically significant at 95% confidence interval. It clearly shows that the actual average speed of 400 vehicles during off-peak hours were moving at speed different from the posted speed limit. The actual average vehicle speeds were higher than the speed limits of 90 km/h. Table 3 and 4 shows the results of the one-sample t-test.

Overall, most of the drivers were clearly driving at speed higher than the permissible speed limit along DUKE highway during free-flow traffic conditions. Obviously, the road geometrical design and low traffic volume are the factors that influence the drivers to drive at a speed higher than the speed limit. Most importantly, the free-flow traffic conditions had made drivers to feel that they were driving at a speed that they perceived as a safe speed.

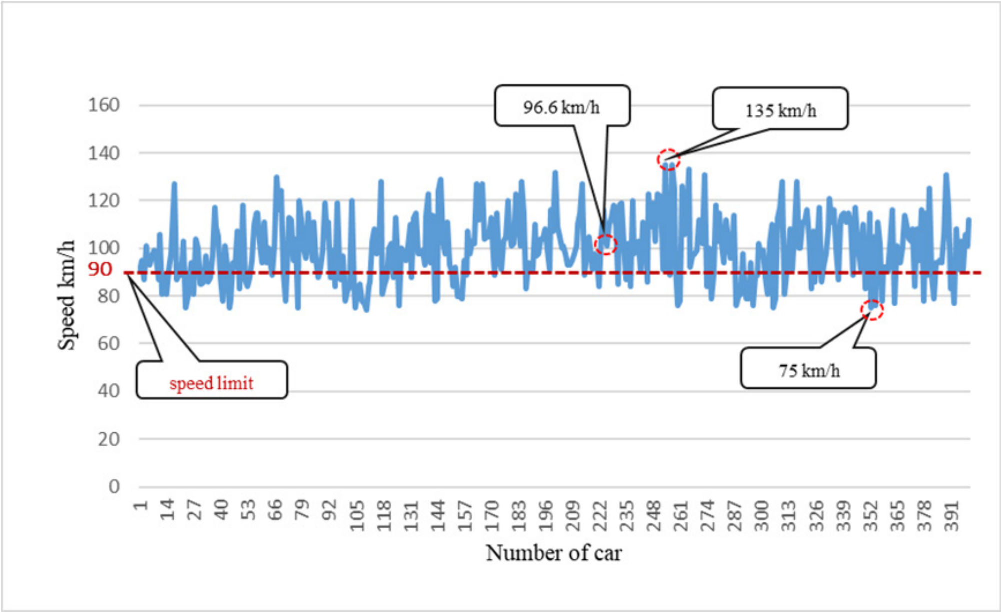

FIGURE 5. Spot Speed Distribution of 400 Vehicles on DUKE

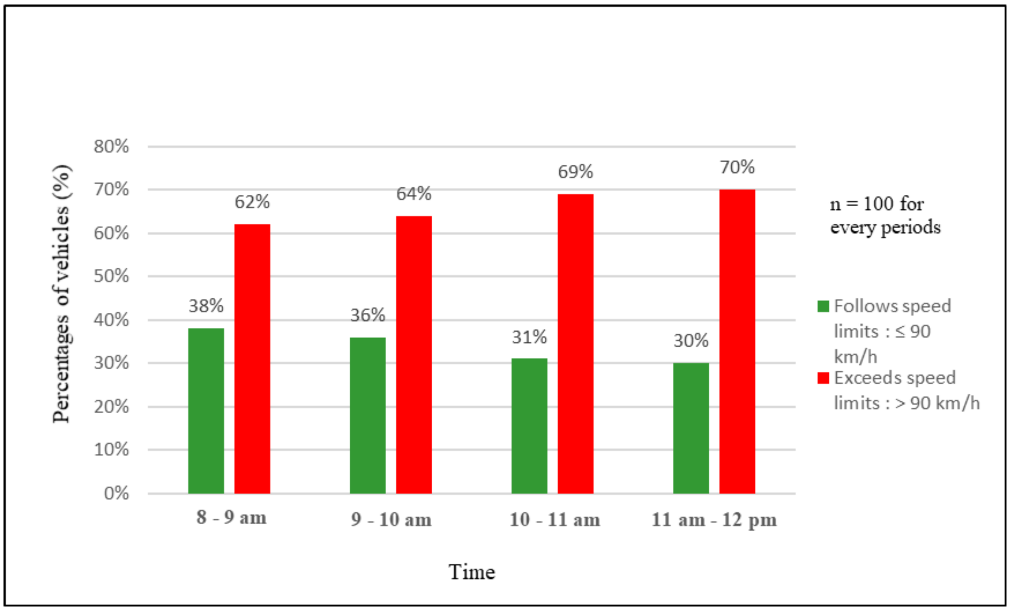

FIGURE 6. Percentage of vehicles following and exceeding speed limit

TABLE 1. Spot speed characteristics

Speed characteristics	Time range				
	8-9	9-10	10-11	11– 12	8-12
Mean speed (km/h)	95.2	96.1	97.8	97.3	96.6
Modal speed (km/h)	103	103	93	98	98
Median speed (km/h)	97.6	98.1	98.1	97.4	97.7
Standard deviation (km/h)	12.6	14.1	14.7	14.0	13.9
85^{th} percentile (km/h)	109	112.7	115.2	112	111.9

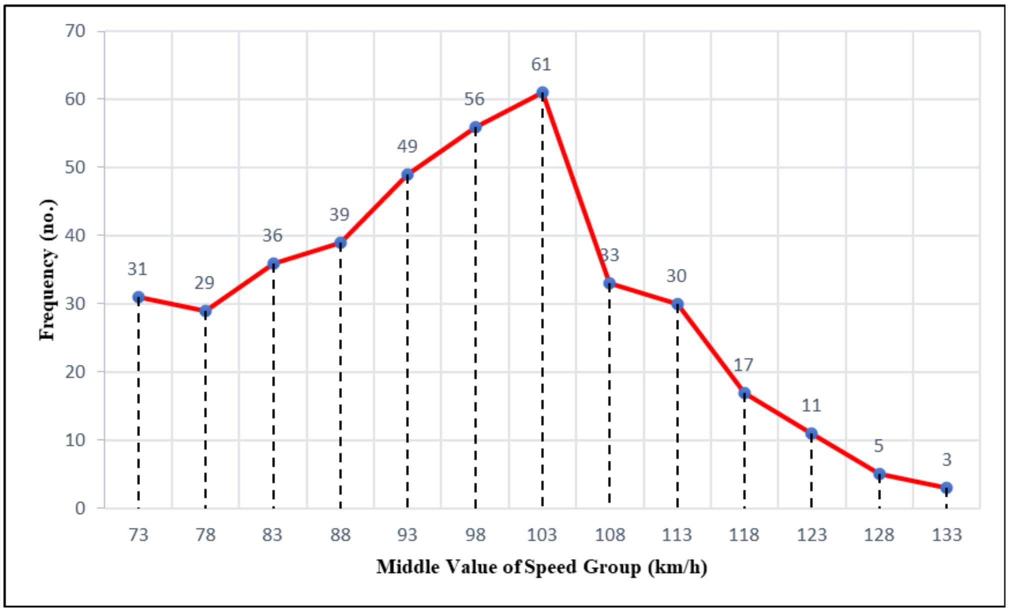

FIGURE 7. Frequency Distribution of Vehicles Speed at the Selected Road

TABLE 2. Spot speed characteristics

		Paired Differences					t-value	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	8am-9am – 9am-10am	-.900	2.787	.279	-1.453	-.347	-3.229	.002
Pair 2	8am-9am – 10am-11am	-2.65	3.292	.329	-3.303	-1.997	-8.050	.000
Pair 3	8am-9am – 11am-12pm	-2.10	2.859	.286	-2.667	-1.533	-7.346	.000
Pair 4	9am-10am– 10am-11am	-1.75	2.694	.269	-2.285	-1.215	-6.495	.000
Pair 5	9am-10am– 11am-12pm	-1.20	.763	.276	-1.748	-.652	-4.342	.000
Pair 6	10am-11am– 11am-12pm	.550	3.006	.301	-.047	1.147	1.829	.070

TABLE 3. Statistics of One-Sample T-test

	N	Mean	Std. Deviation	Std. Error Mean
SPEED	400	96.56	13.874	.694

TABLE 4. Results of One-Sample T-Test

	Test Value = 90					
	t	df	Sig (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SPEED	9.460	399	.000	6.562	5.20	7.93

DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

Speeding is an important that must be addressed ectively to ensure not only a safe driving behavior but most importantly reducing the number of road fatalities. Unfortunately, the number of accidents on the roads in Malaysia has been increasing the years. It was found that speeding is one of the major factors that attribute towards an increase in the number of road fatalities. This paper is an attempt to evaluate and compare the actual speed of the vehicles with that of the allowable speed limit along an expressway during s. It is imperative and pertinent to observe the speed of the vehicles during conditions as it sets a stage in providing the actual adherence to the posted speed limit. It is due to very low of with an inclination to accelerate vehicle's speed well above the permissible speed limit. The from this study show that the actual average speed of the vehicles was higher than the allowable speed limit at the selected expressway. It is a norm that drivers were tend to drive at excessive speed resulting in as one of the major contributing factors to road fatalities (Rolison et al. 2018). It has been becoming a common practice that vehicles were seen moving at a speed above the speed limit on many expressways especially during The share of vehicles exceeding the speed limit is notably high (40%) during free- conditions (Ibrahim, 2011). It shows that most of the drivers were driving at speed higher than the permissible speed limit and as a result they were not following the speed limit. To arrest the speeding of the vehicles and to make the road safe, some of the recommendations that were proposed are; strengthening the enforcement by increasing the number of speed cameras, implementing stricter penalties for speeding and educating the public on the importance of following rules including adherence to the allowable speed limit on highways and expressways. It is expected that these measures will help to alleviate the increase in the number of fatalities on the major roads due to speeding of the vehicles.

DECLARATION OF COMPETING INTEREST

None.

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