Effect of Traffic Volume Towards Operating Speed Approaching Terowong Meru

Naslin Binti Jusoh[1], Muhammad Akram Adnan[2], Norliana Sulaiman[3], Tuan Badrol Hihsm Tuan Besar[4]

[1]Jabatan Kerja Raya, Malaysia

[2,3]School of Civil Engineering, College of Engineering, UniversitiTeknologi MARA, Shah Alam, Selangor, Malaysia

[4]Faculty of Business Management, UiTM Cawangan Selangor, Malaysia

DOI: https://dx.doi.org/10.47772/IJRISS.2024.803011

Received: 05 February 2024; Revised: 20 February 2024; Accepted: 25 February 2024; Published: 28 March 2024

ABSTRACT

The rising number of accidents has been associated with inconsistencies in the geometric design of highways. To evaluate design inconsistency, estimation of reduction in 85th percentile speeds is vital important. Therefore, to enhance the safety of the road it is crucial to produce road design that permits and encourages operating vehicles at uniform speed. This study was conducted at Terowong Meru located in Perak which is the South Bound of the expressway. Data collection was done at two sessions, the first session was between 12.30 p.m. until 1.30p.m. and the second session were conducted between 1.35p.m. until 2.35p.m. This research investigates and expands the use of operating speeds of vehicles influenced by the traffic volume when approaching the tunnel. From the analysis, it is found that the operating speed for Lane 1 has exceed the posted speed limit while the operating speed on Lane 2 is within the posted speed limit. The minimum speed or 15th percentile is also analysed in this study.

Keywords: 85th percentile speed, 15th percentile, flow rate

INTRODUCTION

The substantial rise in the vehicle count in Malaysia has directly resulted in numerous traffic issues, particularly an increase in road accidents. Road accidents on roads not only remain a concern to the nation but also globally. Accidents rarely stem from a solitary cause; typically, multiple factors influence the situation at any given time. These influences can affect the likelihood and severity of an accident.

Based on road accident data provided by Royal Malaysia Police in 2021, it shows that State Roads has the highest number of road accidents including death, major and minor accidents with a total of 6,348 reports followed by Federal Roads with 4,670 reports and 1,486 reports for Expressway (Polis Diraja Malaysia, 2021). Unless more comprehensive action is taken, the number of deaths and traffic accidents are likely to rise.

As a benchmark to achieve the vision of “Malaysia, A Country with Zero Road Fatality”, the government has targeted of reducing 50% in road fatalities in 2030 based on the total number of deaths in 2019. Safer infrastructure is among the 10 priority areas that will be focused on to achieve this vision (Malaysian Road Safety Plan 2022-2030 Ministry of Transport Malaysia, 2022). Better road infrastructure design will eventually help to improve road safety. Adoption of standard road design facilitates safer road and drivers to safely manoeuvre their vehicles.

Studies have indicated that the safest groups of vehicles are those traveling at or below the speeds within the 85th to 95th percentile range (Schurr et al., 2002). Commonly accepted highway design theory suggests that the design speed should be higher than the posted speed. However, in practical terms, it is advisable for the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue III March 2024

design speed, operating speed, and posted speed on a roadway to be roughly similar in magnitude. This approach encourages uniformity in vehicular speeds at a specific location, with the advantage that the likelihood of vehicle collisions decreases when motorists are traveling at approximately the same velocity.

Speed limits are used in most countries to set the maximum speed at which road vehicles may legally travel on particular stretches of road. Speed limit is set at a maximum or minimum depending on the road design to ensure a smooth and safe travel of the road users and also non road users. Speed limit also provide drivers with indication and information of the surrounding road stretch on traffic conditions on whether the road is located near residential areas, hospitals or school areas where there are a lot of pedestrian's activities which needs the driver's extra attention. (Rozaidi & Mashros, 2016)

For this study, data for Spot Speed Study was collected 50m before approaching the tunnel, before entering the tunnel, after exiting the tunnel and 50m from the exit. For analysis, only data 50m before the tunnel was analysed.

PROBLEM STATEMENT

According to research conducted by MIROS, which analysed accident data from 2011, it is suggested that the primary factor behind road accidents in Malaysia is human negligence, contributing to approximately 80.6 percentage of these incidents. The condition of the road contributes 13.2 percentage of accidents, while vehicles themselves are only accountable for 6.2 percent of the total number of accidents (Kementerian Pengangkutan Malaysia, 2023).

One of the major contributors to traffic accidents is vehicles operating above the speed limits. According to (Rahman et al., 2023), impact of vehicles become more pronounce at higher operating speed conditions. This is supported by the inconsistency of the operating speed especially on minimum tangent length and abrupt changes on sharp curves and together with steep downgrades.

Motorists' decision on speed during off-peak hours is shaped by the traffic volume and posted speed limit despite their individual preferences and attitudes towards choosing a speed. This is elaborated in (Rozaidi et al., 2016) finding where the drivers speed choice during off-peak is influenced by the posted speed limit.

Several earlier studies primarily concentrate on the factors that affect the speed of vehicles on highways, giving less emphasis to the comparison between the actual vehicle speed and the posted speed limit (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 and also to evaluate the minimum speed of vehicles on a selected expressway. Therefore, this research proposes a model for evaluating the speed of 85th percentile operating speed and the 15th percentile minimum speed based on local empirical data.

OBJECTIVE

The purpose of this research is to develop regression model to evaluate the speed of 85th percentile or operating speed of passenger vehicles influenced by the traffic volume when approaching the tunnel. The model can be used to estimate and predict the operating speed of passenger vehicles.

The 15th percentile speed of the observation condition will also be evaluated in this study. The 15th percentile is classified as the minimum speed for this study area.

LITERATURE REVIEW

Literature review was undertaken to understand relevant elements before further research. It identifies gaps in current knowledge, which forms the research basis.

Speed

There are countries that adopts the design speed for road design and Malaysia practices this approach. The basis of the design speed concept is the selection and application of a design speed to which geometric design elements are related with the intention to ensure alignment consistency. To evaluate an existing stretch of road, alignment consistency can be measured with respect to the uniformity of operating speeds along the alignment. Contra to this approach, most European countries consider design speed as “the 85^{th} percentile of the speed distribution on the independent tangents or large radius curves, on road sections at low traffic volumes” (Polus et al., 1999).

A good road alignment is when there is consistency in the design and minimal differences of operating speeds of successive elements of an alignment. Improvement of the alignment is needed when there is difference greater than 20 km/h (Transportation Association of Canada, 1999).

According to AASHTO, design speed is used to determine the geometric parameters of the road. Nevertheless, there are countries which enhances the use of design speed by incorporating actual driver speed behaviour in terms of 85^{th} percentile operating speed (American Association of State Highway and Transportation Officials, 2018).

Jacob & Anjaneyulu (2013) study had found that it is not sufficient to estimate the speed or speed reduction for a single class of vehicle, as effect of geometry differs for each different classes of vehicle.

From the study conducted by Sun et al., (2010) the study recommends the 85^{th} percentile speed can be considered as a major factor in developing proper speed limits for freeways. In order for this, the study recommends that large vehicles are to be segregated from small vehicles to improve overall freeway performance.

The purpose of minimum speed implementation is to reduce the unsafe interactions between fast and slow moving vehicles by improving the uniformity of traffic flow and safety of operation. Minimum speed limit is yet to be implemented in Malaysia. This matter is deliberately explained by Ho Jen Sim et al., 2014 where thorough traffic investigation is needed to evaluate the locality effect, the rationale of implementation and the practicality of enforcement.

Geometric Design

According to M Gibreel et al., 1999, a good road design consistency is considered in three main areas, speed, safety and performance consideration. The findings from the study implies design consistency in roads promotes secure and seamless traffic flow. It is concluded that an accurate approach to design consistency should consider the interaction among horizontal alignment, vertical alignment, and cross section in a 3D projection.

Road Conditions

Free flow speed can be affected due to the physical condition of the road such as the lane width, number of lanes, median clearance and other factors. Nevertheless, roadway condition does not affect the capacity or maximum flow rate of the facilities. This matter is as stated in the Highway Capacity Manual 2011 Malaysia, 2011 and clearly shows the flow rate relates to vehicles passing a point at a predetermined time interval.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue III March 2024

Traffic Safety

Impact on crashes during accidents increase with speed, it was revealed that the importance of speed crash prediction seems to increase with speed. According to the study by (Rahman et al., 2023b, high-speed roads exhibited better geometric characteristics (such as wider lanes and shoulders) than low and medium-speed roads and vehicle tends to speed more on high-speed roads. This observation suggests that speed can serve as an indicator of the geometric condition of rural two-lane highways. The study has revealed that incorporating an additional category based on Annual Average Daily Traffic in conjunction with speed and developing models under each speed group leads to improved predictions compared to a single model

Under the Road Safety Manual produced by PIARC, designing for safe behaviour is addressed to encourage designing infrastructure that demonstrates safety impacts and value of human characteristics. A user-friendly road will give drivers the necessary time to adapt to new and unexpected situations.

METHODOLOGY

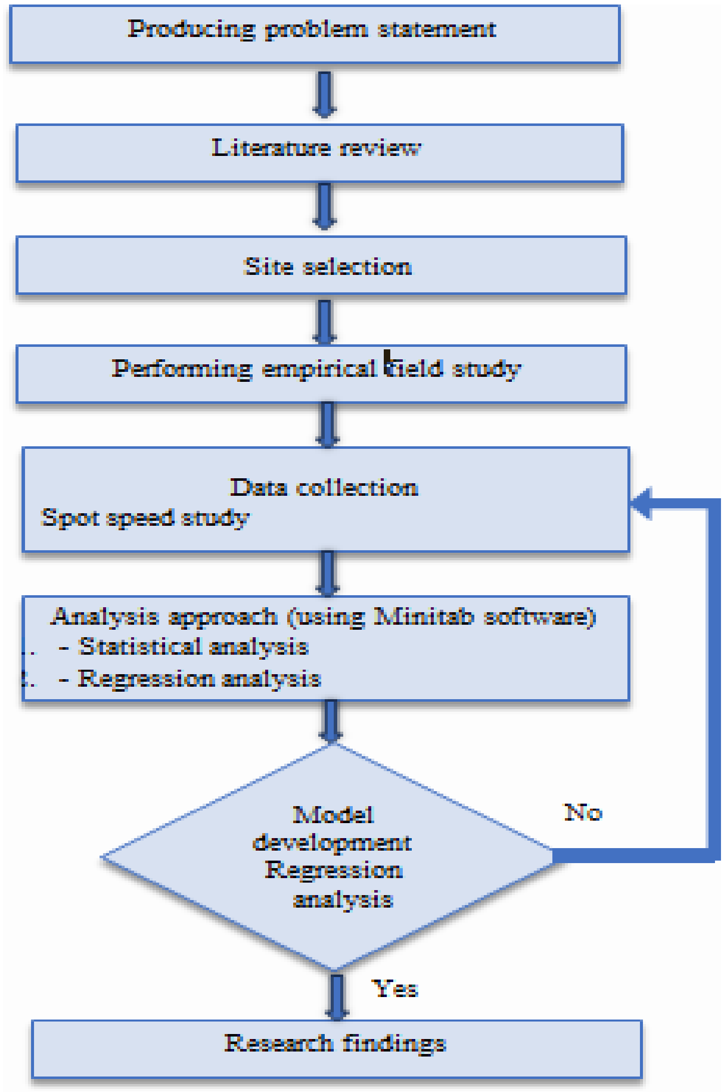

Figure 1 Process flowchart of study

Site Selection and Time of Study

Terowong Meru located in Perak was selected as the case study area. This road is designed according to expressway standards requirement. For this study, data collection was done only on South Bound (Meru Tunnel). Specifically, data was collected at 50m before approaching the tunnel, before entering the tunnel, after exiting the tunnel and 50m from the exit. The study was carried out on 16th December 2023, Saturday. Data collection was conducted within two sessions. The first session was conducted between 12.30 p.m. until 1.30p.m. and the second session was scheduled between 1.35p.m. until 2.35p.m. But due to heavy rainpour the second session had to stop halfway. It was raining throughout the day and the traffic started to buildup. As for this, the data collection had to stop earlier than as scheduled.

Figure 2 Key plan and location plan of study area

Spot Speed Data

Speed data is gathered by using laser speed gun detector and radar gun. Due to insufficient laser speed gun detector, radar gun had to be used despite its accuracy on detecting speed. Calibration of the radar gun had to be done before collecting data. The speed detectors was targeted at selected vehicle to measure the spot speed of the vehicles. This is done in a period of 5 minutes interval for an hour. Data was collected and tabulated according to lane and location.

Traffic Counting

Vehicle classification data was obtained from PLUS's automated census and classified according to five categorizes.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue III March 2024

Sample Size

According to Roess et al., (2011), the sample size of spot speed can be determined based on the equation below:

$$N \geq \frac{1.96^2 s^2}{e^2}$$

Based on the equation, 1.96^2 is used only when if the confidence is 95% and if the confidence is 99.7%, 1.96^2 should be replaced with 3^2. For this study, the speed characteristics are unidentified, confidence will be assumed as 95%, standard deviation (s) is 5mi/h and tolerance or limit of acceptable error in the averagespeed estimate (e) is 0.8 mi/h. The sample size determined from the above equation is 150 vehicles and shall be adopted in this study.

Abbreviation

The abbreviation used for this study to indicates the location and directional lane of each location are as follow:

1. A1: Lane 1, 50m before entering Terowong Meru
2. A2: Lane 2, 50m before entering Terowong Meru

Figure 3 Lane labelling

Data Classification Strategies

Data collected on site are further tabulated in excel worksheet to ease evaluation of data. In order to develop a speed profile model, linear regression analysis is required to predict the 85th percentile speed and 15th percentile speed. The linear regression analysis is perform by using Minitab Statistical Software to develop a model that will represent the speed characteristics for the selected area.

ANALYSIS AND RESULTS

Data screening was carried out to exclude those parts of the speed database that could have been disturbed. Data screening attainment in any multivariate analysis is crucial and serves as the foundation for any meaningful outcome from a quantitative research. The quality and the output of an acceptable analysis are subject to the quality of initial data screening.

After completing screening the data, cumulative frequency graphs are plotted using Minitab software. The minimum speed (15th percentile) and operating speed (85th percentile) are obtained for each location. The posted speed limit is 80km/hr for this stretch of road. Figure 4 below shows the 85th percentile for Lane 1, 50m before tunnel (A1) is 84km/hr whereas Lane 2, 50m before tunnel (A2) is 78km/hr. By comparing the operating speed with the speed limit of 80km/hr, it shows that the operating speed for A1 exceed the speed limit but A2 complies to the posted speed limit. This shows that there are vehicles operating above the speed limit despite being alerted on the speed limit with road signages. The 15th percentile speed are 50km/hr and 68km/hr. Based on the data obtained, vehicles that are manoeuvring on the road with speed 50km/hr and below will impede the traffic flow.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue III March 2024

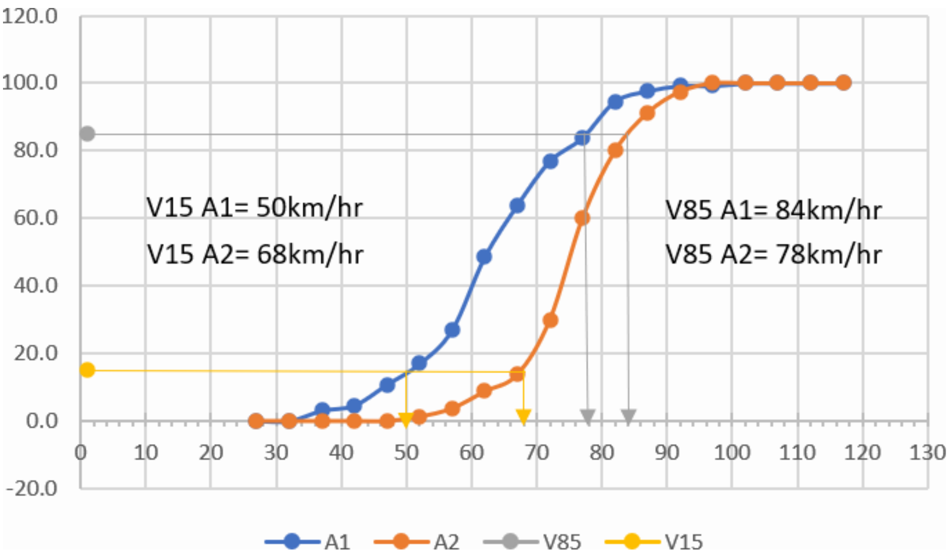

Figure 4 Percentage of cumulative frequency vs Speed

The descriptive statistics after the data screening are shown in Table 1. Referring to Table 1 the values of the skewness and kurtosis for most of the variables were near to zero. A normal distributed sample with fairly symmetrical has a skewness and kurtosis value close to zero as explained by Hatem et. Al (2022). This shows that the data in general are normally distributes following the empirical rule with 95% confident level.

Table 1 Summary of Descriptive Statistic

Variable	Mean	SE Mean	StDev	Minimum	Median	Maximum	Skewness	Kurtosis
V85 A1	74.81	3.31	9.35	65.00	72.00	92.00	0.83	0.04
V85 A2	83.31	1.63	4.61	77.00	83.00	90.00	0.13	-1.36
SMS A1	66.97	2.45	6.93	57.06	68.33	76.36	-0.28	-1.22
SMS A2	76.25	1.58	4.47	68.94	77.37	80.38	-1.12	-0.34
Flow rate	10423	33.0	93.4	10336	10423	10511	-0.00	-2.80

Multiple linear regression analysis was conducted to evaluate the empirical data. Multiple linear regressions is a method of statistics in regression that are used to analyse the relationship between single response variable (dependent variable) with two or more controlled variables (independent variables). V85 A1 and A85 A2 are parameters used as the dependent variables in the analysis. The independent variables used in the analysis were identified as SMS A1, SMS A2 and Flow rate. The multiple regression equation for V85 model for 50m before entering the Terowong Meru is shown in the equation below. The equation shows that at Lane A1, for the predictor variable of SMS A1 has a positive sign, it implies that with the increase of spot mean speed and also a decrease of flow rate (indicated by a negative sign), will lead to the decrease of V85 operating speed. Whereas for Lane A2, with the increase of space mean speed and increase of flow rate, will lead to the increase value of V85 operating speed at the studied area. These equations which are opposite effect with the other equation shows that the study is unreliable and further study is required to evaluate this data. Nevertheless, further evaluation is done to further analyse the situation.

V85 A1	=	283 + 0.996 SMS A1 – 0.0263 Flow rate	R^2 = 62.25%
V85 A2	=	-10 + 0.894 SMS A2 + 0.0024 Flow rate	R^2 = 71.21%

R^2 = coefficient of determination

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue III March 2024

Table 2 below shows that for A1 and A2, the space mean speed is significant whereas for flowrate it is insignificant to predict V85th percentile for the studied area. The p-value of 0.043 and 0.028 are less than 0.05 indicates the significant on both parameters of SMS A1 and SMS A2 in prediction of V85th percentile for Terowong Meru.

Table 2 Descriptive statistic

Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	283	288	0.98	0.372	
SMS A1	0.996	0.371	2.69	0.043	1.00
Flow rate	-0.0263	0.0275	-0.96	0.382	1.00

Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	-10	160	-0.06	0.954	
SMS A2	0.894	0.293	3.05	0.028	1.41
Flow rate	0.0024	0.0141	0.17	0.872	1.41

To analyse the relationship between percentile speed with flow rate, scatter plots of V85 and V15 against traffic flow rate (Figure 5 and 6) was generated. For the operating speed on Lane 2, V85 A2, the range of traveling speed based on the graph line is ranging from 82km/hr during high traffic volume condition and increases to 86.5km/hr during low traffic volume condition. A mathematical relationship was established based on prediction of V85 as per Equation 1. As for minimum speed on Lane 2, V15 A2, the speed percentiles illustrate descending value with increasing number of traffic volume. Mathematical relationship prediction of V15 is as per Equation 2. Nevertheless, it is highly recommended to conduct in depth study with more data collected at different location and period of study to improve the accuracy of the determination of the empirical data.

V85 A2 = 299.5 – 0.02074 Flow rate ....(1)

V15 A2 = 544.6 – 0.04578 Flow rate ....(2)

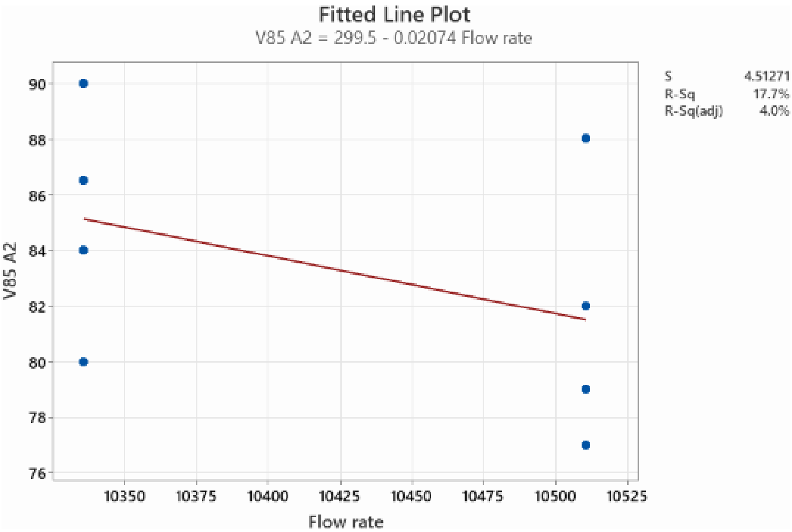

Figure 5 Scatter Plot of V85 vs Flow Rate

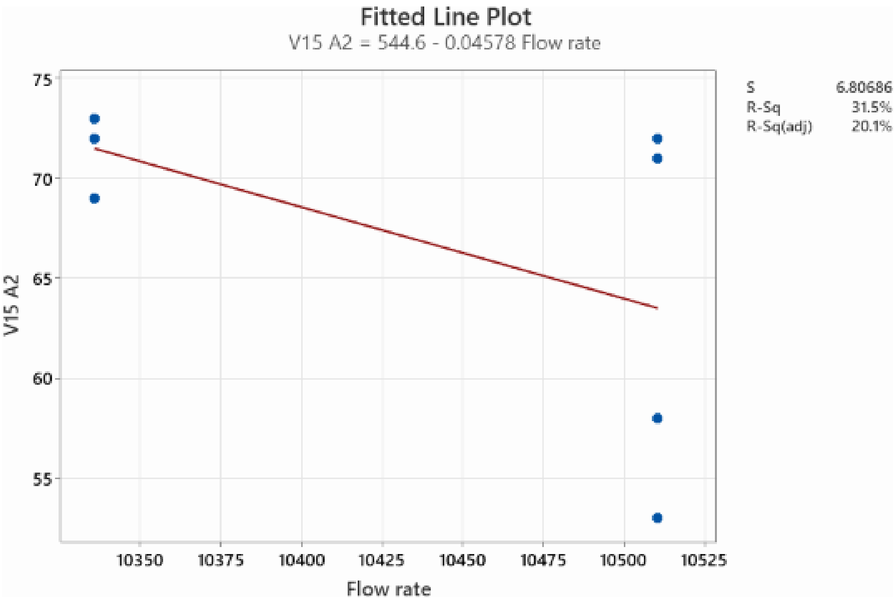

Figure 6 Scatter Plot of V15 vs Flow Rate

DISCUSSION AND CONCLUSION

Two objectives were explored in this study which includes the operating speed influenced by the trafficvolume and minimum speed evaluation. In this study, we can conclude the following:

1. The operating speed of vehicles on the slow lane (A1) on Terowong Meru exceeds the posted speed limit whereas the fast lane (A2) complies to the posted speed limit.
2. The increase of spot mean speed value on lane A1, SMS A1, implies that with a decrease value of flow rate (indicated by a negative sign), will lead to the decrease of V85 operating speed. Whereas forLane A2, with the increase of space mean speed and increase of flow rate, will lead to the increase value of V85 operating speed.
3. The above points shows that detailed study is needed to further analyse this stretch of road.
4. If is to maintain the existing speed limit, then enforcement needs to increase by taking extra measures such as by installing automated enforcement system to increase compliance to posted speed limit.
5. On the condition that most of the operational speed exceeds the posted speed limit, revising the postedspeed limit together with road safety precautions are needed for the stretch of road.

REFERENCES

1. American Association of State Highway and Transportation Officials. (2018). *THE GREEN BOOK APolicy on Geometric Design of Highways and Streets*. www.transportation.org
2. Hafiza, N., Maksid, M., Azeez, A. & Hamsa, K. (2014). EVALUATING THE EFFECTS OF ROAD GEOMETRICAL DESIGN TOWARDS SPOT SPEED DISTRIBUTION ON ARTERIAL ROAD. In *PLANNING MALAYSIA: Urban Planning and Local Governance: Vol. III*.
3. *Highway Capacity Manual 2011 Malaysia*. (2011).
4. Ho Jen Sim, Nusayba Megat Johari & Sharifah Allyana Syed Mohamed Rahim. (2014). *Review ofSetting Minimum Speed on Expressway*.
5. Jacob, A. & Anjaneyulu, M. V. L. R. (2013). Operating speed of different classes of vehicles at horizontal curves on two-lane rural highways. *Journal of Transportation Engineering*, *139*(3), 287–294. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000503

6. Kementerian Pengangkutan Malaysia. (2023). *Buku Statistik Keselamatan Jalan Raya*.
7. M Gibreel, B. G., Easa, S. M., Hassan, Y. & El-Dimeery, I. A. (1999). State of The Art of Highway Geometric Design Consistency. *JOURNAL OF TRANSPORTATION ENGINEERING*.
8. *MALAYSIA ROAD SAFETY PLAN 2022-2030 MINISTRY OF TRANSPORT MALAYSIA*. (2022).
9. Polis Diraja Malaysia. (2021). *Laporan Perangkaan Kemalangan Jalan Raya Malaysia*.
10. Polus, D. A., M. Poe, C. & M. Mason, D. J. (1999). Review of International Design Speed Practices on Roadway Geometric Design. *Transportation Research Board*.
11. Rahman, F., Zhang, X. & Chen, M. (2023a). Evaluating Effect of Operating Speed on Crashes of Rural Two-Lane Highways. *Journal of Advanced Transportation*, *2023*. https://doi.org/10.1155/2023/2882951
12. Rahman, F., Zhang, X. & Chen, M. (2023b). Evaluating Effect of Operating Speed on Crashes of Rural Two-Lane Highways. *Journal of Advanced Transportation*, *2023*. https://doi.org/10.1155/2023/2882951
13. Roess, R. P., Prassas, E. S. & McShane, W. R. (2011). *Traffic engineering*. Pearson.
14. Rozaidi, Y. & Mashros, N. (2016). *Effect of Posted Speed Limit On Drivers Speed Choice During Off-Peak Period*.
15. Rozaidi, Y., Rohaizan, B., Mashros, N. & My, M. (2016). *Effect of Posted Speed Limit On Drivers Speed Choice During Off-Peak Period*.
16. Schurr, K. S., Mccoy, P. T., Pesti, G. & Huff, R. (2002). *Relationship of Design, Operating, and Posted Speeds on Horizontal Curves of Rural Two-Lane Highways in Nebraska*.
17. Sun, X., He, Y., Wang, S. & Wang, Y. (2010). Characteristics of Operating Speed for Proper Speed Limit. *International Conference of Chinese Transportation Professionals*.
18. Transportation Association of Canada. (1999). *Updates to the Geometric Design Guide for Canadian Roads*. www.tac-atc.ca