Effect of Speed Hump Characteristics on Passenger Cars' Speed Reduction

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Abstract: This study was undertaken to investigate the effect of speed humps' dimension and vehicular speed at residential areas. Data collection was conducted from January to March 2020 at eight selected residential area in Klang Valley. Various speed humps with different height and width were identified. Passenger cars' speed crossing the speed humps were recorded. Multiple linear regression indicated that there was a U-shaped relationship between height of speed hump and speed reduction. The speed reduction decreases before the threshold of 17.35 cm and increases after the threshold. The relationship between the width of speed hump and speed reduction was an inverted U-shaped. For speed humps' width below 2.05 m, the speed reduction increases following a quadratic equation. However, beyond the width of 2.05 m, the speed reduction decreases. The findings of this study provide useful information for urban transportation authorities for planning, building, and modifying speed humps at residential area.

Keywords: speed hump, passenger cars' speed reduction, residential area

1. INTRODUCTION

Road traffic accidents and injuries are a public health concern worldwide. These problems are expected to increase as motorization increases annually. Malaysia recorded the third highest road fatality rate among ASEAN based on the statistics in 2013. The road fatality statistics in Malaysia indicated that 0.03% of the fatality was associated with speeding (Thomas, 2019). Crash rate and vehicular speed has a strong correlation that contributed to road traffic fatalities (Purnomo et al., 2018). Hence, a vital need for improving road safety is to control vehicle speeds on roads (Kanitpong et al., 2013).

One way to reduce road traffic accidents and fatalities related to speeding is by installing traffic calming devices such as speed hump especially along residential roads. Traffic calming device is a traffic control tool that facilitate the safety of pedestrian on the road (Manan and Hoong, 2009). Malaysia's Traffic Calming Guidelines indicated that traffic calming can be defined as an approach which permits behavioral modification of drivers, pedestrian and others who have interaction on roads and sidewalks in the communities. Mustafa and Hamsa (2018) reported that traffic calming is the strive to perform calm, safe and environmentally stepped forward situations on streets. Generally, there are many traffic calming devices such as speed humps, speed bumps, speed tables, roundabout, transverse rumble strips and etc. but the speed humps are considered as one of the most commonly used traffic calming devices in most countries (Shwaly et al., 2018). Due to speed humps' huge positively impact in its ability to significantly reduce vehicle speed to acceptable limits, it has been implemented in enhancing the dwelling surroundings of the residential areas. This is because people are cooperate to identify better ways to design new residential areas to be more liveable, pedestrian-friendly and walkable (Yaacob and Hamsa, 2013). Generally, speed hump is a raised area of pavement, with a standard measurement of 3.5 to 4.0 m wide and speed humps profiles are circular, sinusoidal, parabolic or flat-topped (Manan and Hoong, 2009). Table 1 shows standard speed hump type and dimension according to Ministry of Works Malaysia and SIRIM.

Table 1: Malaysian speed hump standards in Malaysia (Bachok et al., 2017)

Design Standard	Type and Dimensions		
	Type	Height (mm)	Length (m)
Ministry of Works Malaysia, 2012	Flat-Top	75-100	2.5-4.0
	Round-Top	50-100	3.7-4.0
	Sinusoidal	75-100	3.8-4.0
SIRIM, 2009	Parabolic	75-100	3.7-4.25
	Circular	75-100	3.7-4.25
	Sinusoidal	75-100	3.7-4.25

Werner (2015) indicated that speed hump is one of the long-term traffic safety resolutions and a physical reminder for road users to drive with caution. However, one the crucial problem is that the installation of speed hump in Malaysia especially at residential area were not following the design specifications as seen in Table 1. Hence, speed humps installed at residential area might cause a vertical acceleration or deceleration that not fulfil the needs of reducing vehicle speed and might jeopardizes the safety of drivers.

This research was undertaken with the objective to identify the speed hump dimension and vehicular speed at residential areas in Klang Valley. By measuring the dimension of various speed hump and capturing vehicle speeds traverse on various speed hump, simulation and modelling can be conducted to predict the factors affecting speed of vehicles approaching and when travelling at the speed hump and therefore suggesting a proper dimension of speed hump that could reduce the speed of vehicle and provide the most safety to drivers at residential area.

2. METHODOLOGY

This research was conducted at residential areas in Klang Valley where substandard speed humps were often found. Preliminary site survey was carried out in December 2019 to collect data such as the dimensions of the speed hump and the surrounding environment. Vehicle speed were also observed during the preliminary study to identify whether the dimension of speed humps affects the speed of vehicles. After preliminary survey, speed humps were categorized, and 8 substandard speed humps were selected for data collection as indicated in Table 2[1]. Passenger cars speed were observed due to this type of vehicles are majority found at these residential area[2].

[1] The "type" of speed hump was not considered in the study as it was very difficult to differentiate between round top, circular, parabolic and sinusoidal type of speed hump at the study location. All speed humps in this study were parabolic shape.

[2] Motorcycles speed was ignored in this study due to: (1) Most of the motorcycle do not ride over the speed hump but they by-pass the speed hump from the edge of the speed hump, (2) It was difficult to capture the motorcycle speed using laser speed gun due to the size of vehicle is generally smaller compare to other vehicle such as passenger car.

The speed of passenger cars was taken at two location, (a) at a location 15 meter before approaching speed hump (V_B) and (b) when the passenger cars approaching the speed hump (V_A) using a laser speed gun as indicated in Figure 1.

Table 2: Study Location

Location	Road terrain	Speed Hump's Height (cm)	Speed Hump's Width (m)	Rumble Strips (Yes/ No)	Speed Hump's Painting (Yes/ No)
Taman Ampang Indah	Downhill	32	3.2	Yes	No
Taman Rasmi	Level	27	3.2	Yes	Yes
Taman Bukit Belimbing (Jalan Anggerik)	Level	27	1.6	No	No
Taman Bukit Belimbing (Jalan Bunga Raya)	Downhill	27	1.2	No	No
Taman Bukit Belimbing (Jalan Cempaka)	Downhill	27	2.0	No	No
Taman Bandar Tasik Selatan (Jalan Tasik Selatan 15)	Level	20	3.2	Yes	Yes
Taman Bandar Tasik Selatan (Jalan Tasik Selatan 16)	Level	17	3.2	Yes	Yes
Taman Bandar Tasik Selatan (Jalan Tasik Selatan 19)	Level	27	3.6	Yes	Yes

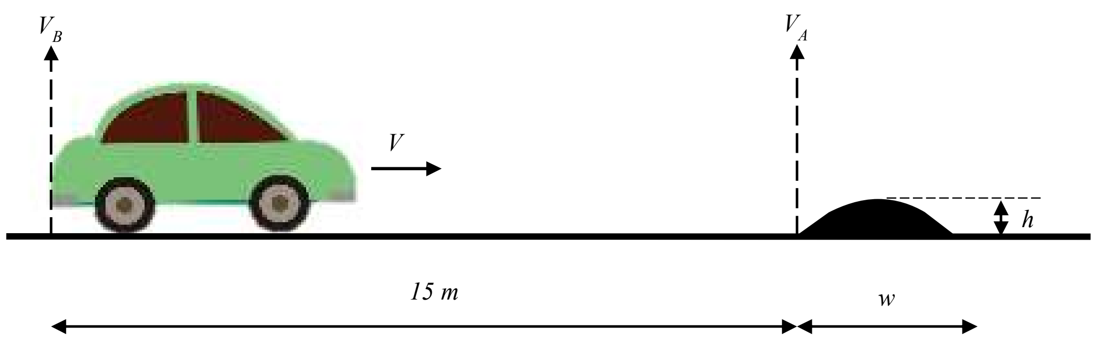

Figure 1: Passenger cars' speed observation point

The data collection was conducted on sunny day during morning and afternoon peak hours every Wednesday from January to March 2020. A minimum of 40 passenger cars' speed were observed at each speed hump that make up of 320 speed samples.

Multiple linear regression was used to model the relationship between the dependent variables: (1) speed of vehicles before approaching speed hump (V_B), (2) speed of vehicle approaching speed hump (V_A), (3) variations in the vehicle speed (ΔV) or V_B - V_A and various independent variables (height and width of speed hump, road terrain, speed hump's painting, rumble strips, speed limit and speed limit sign). The analysis considered few mathematical forms such as linear, quadratic, cubic, inverse and logarithm. The general relationship between the independent variable and dependent variables was as shown below:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 \quad (1)$$

where x_1 represents height of speed hump, x_2 represents width of speed hump, x_3 represents road terrain at study location, x_4 represents the presents of speed hump painting and x_5 represents the present of rumble strips approaching the speed hump b along the residential road. The β values are the linear regression coefficient. The positive value represents positive relationship while negative coefficient represents a negative relationship.

3. RESULTS

Table 3 shows the descriptive statistics of the passenger cars' speed before approaching speed hump *(V_B)* and approaching speed hump *(V_A)*. Generally, passenger cars' speed was reducing when they approached speed hump. This implies that drivers tend to slow down their vehicle when driving approaching speed hump. The skewness and kurtosis of the passenger cars' speed were in between +1 and -1 indicating the distributions of the speed data were normal.

Table 3: Descriptive statistics for passenger cars' speed at study location

	Passenger cars' speed (km/h)	
	V_B	V_A
N	320	320
Mean	25.059	21.019
Standard Error of Mean	0.399	0.386
Median	25.000	20.000
Mode	21.000	20.000
Standard Deviation	7.134	6.907
Variance	50.890	47.711
Skewness	0.336	0.288
Standard Error of Skewness	0.136	0.136
Kurtosis	-0.528	-0.647
Standard Error of Kurtosis	0.272	0.272
Minimum	10.000	8.000
Maximum	44.000	39.000

A total of 320 speed data samples were used in the multiple linear regression analysis. Three models were developed, and these models described the variables which highly correlated with the passenger cars' speed. Table 4 showed the parameter estimates for the multiple linear regression model.

Model A compares the height of speed hump (H), width of speed hump (W), road terrain (RT), the availability of speed hump painting (HP) and the availability of rumble strips (RS) with passenger car's speed 15m before approaching speed hump. Model B compares the independent variables with passenger car's speed approaching speed hump while the Model C compares the independent variables with the variations in passenger car's speed.

The analysis demonstrated that only 4 variables were highly correlated with the speed of passenger cars and variation of the speed. These variables were height of speed hump (H), width of speed hump (W), road terrain (RT) and the availability of the speed hump painting (HP). Thus, these independent variables were included in the final model.

Table 4: Parameter estimates for multiple linear regression analysis

DV	Model A	Model B	Model C
IV	V_B	V_A	$\Delta V = V_B - V_A$
H^2	-0.039***	-0.067***	0.024***
H	1.180***	2.152***	-0.832***
W^2	-	2.401***	-2.089***
W	9.917***	-	8.629***
RT (Downhill = 1, Level = 0)	3.867***	2.295**	1.540***
HP (Yes = 1, No = 0)	-12.871***	-17.421***	4.117***
R-squared	0.951	0.935	0.777

Remarks

*** indicate p-value < 0.001; ** indicate p-value < 0.05

The R^2 value for the multiple regression models A, B and C were 0.95, 0.93 and 0.78, respectively. This indicated that the independent variables had strong relationship with the dependent variables. According to Larson-Hall (2009), models with R^2 value greater than 0.5 was considered strong relationship.

3.1 Results for Model A

Model A indicated that there was an inverted U-shaped relationship between the height of speed hump and passenger cars' speed 15 m before approaching speed hump. The model showed that speed increases before the threshold and decreases after the threshold of 15.12 cm as indicated in Figure 2. Meanwhile, there was a positive and significant relationship between the width of speed hump and passenger cars' speed. When the width of speed hump increases by 1 unit, the speed of passenger car will increase by 9.92 unit. Similarly, the road terrain variable was significant and positive, implies that downhill terrain increases the speed of passenger car by 3.87 unit. The speed hump painting variable was negative and statistically significant, indicating that the presents of speed hump painting reduce the speed of passenger cars by 12.87 unit.

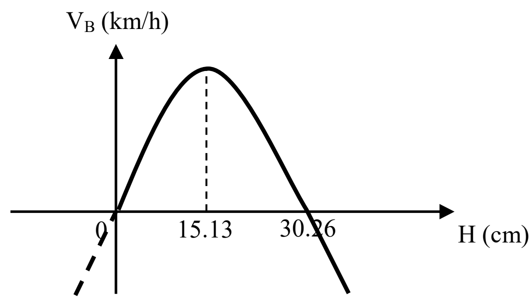

Figure 2: Speed before approaching speed hump versus width of speed hump.

3.2 Results for Model B

Similar to Model A, there was an inverted U-shaped relationship between height of speed hump and passenger cars' speed approaching the speed hump. This implies that the passengers' car speed increases before the threshold and decreases after the threshold of 16.06 cm. The width of the speed hump has quadratic effect on speed. The road terrain coefficient is positive and significant. When the road terrain is downhill type, the speed of passenger will increase by 2.30 unit. The speed hump painting coefficient was statistically significant and negative with the effect of the present of speed hump painting reduces the passenger car speed by 17.42 unit.

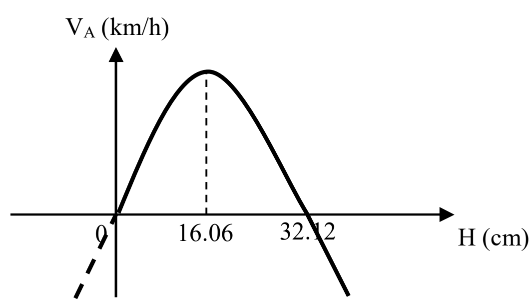

Figure 3: Speed approaching speed hump versus width of speed hump.

3.3 Results for Model C

Model C indicated that there was a U-shaped relationship between height of speed hump and speed reduction. The model showed that speed reduction decreases before the threshold and increases after the threshold of 17.35 cm as shown in Figure 4. Meanwhile, there was an inverted U-shaped relationship between the width of speed hump and speed reduction. For speed humps' width below 2.05 m, the speed reduction increases following a quadratic equation. However, beyond the width of 2.05 m, the speed reduction decreases as shown in Figure 5.

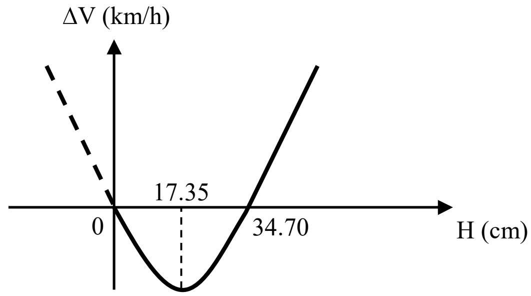

Figure 4: Speed reduction versus height of speed hump.

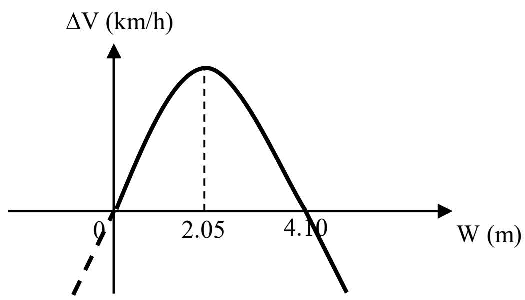

Figure 5: Speed reduction versus width of speed hump.

Two other variables, road terrain and speed hump painting were also positively correlated with speed reduction. The road terrain was a categorical variable where 0 represents level road while 1 represents downhill road. The positive coefficient indicated that when the terrain is downhill, the effect of speed reduction will increase by 1.54. Similarly, speed hump painting, also a categorical variable indicated that speed hump painting could enhance the speed reduction by 4.12.

4. DISCUSSIONS AND CONCLUSIONS

In this study, 4 independent variables (height of speed hump, width of speed hump, road terrain and speed hump painting) were found significantly correlated with passengers' car speed 15 m before approaching speed hump, passengers' car speed approaching speed hump and speed variation. The results of the multiple regression models were statistically significant with a high R-squared value (> 0.7) and very low p-value.

Even though the speed hump's design at residential area in this study was not following the standards of SIRIM nor Ministry of Works Malaysia, it was found that the size of speed hump at study location was within the characteristics of speed hump as specified by Gedik et al. (2019) study in Turkey. Therefore, the results from this study could provide additional information for authority to consider specific design standard for speed hump at residential area.

The objective of constructing a speed hump at residential roads is to reduce the speed of vehicles traverse at the residential area. From the speed variation model (Model C), it was found that an optimum speed hump height of 17.35 cm and an optimum speed humps width of 2.05 m generally produce the maximum speed reduction. Similar with previous study, Lav et al. (2018) also suggested that an optimal width of speed hump to provide the highest degree of speed reduction. Moreover, this study also demonstrated that the speed hump should be painted to increase the visibility in order to achieve the maximum speed reduction.

There are some limitations for this study. First, this study was only conducted at 8 speed humps at selected residential area within Klang Valley due to Malaysia has launched a series of Movement Control Order due to Covid-19 pandemic effective 18 March 2020 that prohibited outdoor activities. Second, this study only collects passenger car speed during day-time under good weather condition, hence, the behaviour of drivers traverse at speed hump at other time such as night-time or rainy day were unknown. Therefore, it is recommended that future study to look into the potential of increasing data collection for more speed humps at residential area and also different data collection time zone to obtain more useful information.

In conclusion, the findings of this study provide useful information for urban transportation authorities for planning, building, and modifying speed humps at residential area. Speed hump could alert drivers to reduce the speed of vehicle and create a safer environment for the pedestrian and neighbourhood at residential area.

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