Evaluating the Effects of Road Hump on The Speed of Vehicles in an Institutional Environment

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Abstract: Vehicles travelling at speed above the permissible speed limit have jeopardized the safety of road users. The concern is greater at institutional environment whereby most road users travel by walking. Road hump is considered as an efficient traffic calming measure in reducing the speed of the vehicle. This paper investigates the effects of different road hump dimensions in decreasing the speed of vehicles at the main road of International Islamic University Malaysia. Six (6) road humps with different design profile were selected. The design profile and spot speed of the vehicles at all six (6) road humps were measured. The speed of vehicles at the road hump was analyzed by using descriptive analysis and t-test. The findings of this study suggest that road hump is effective in lowering the speed of vehicles in an institutional environment. The dimensions of road hump, especially height, influence significantly the speed reduction of vehicles.

Keywords: Road Humps, Traffic Calming, Speed of Vehicles, Institutional Environment.

1. INTRODUCTION

In an institutional area, where a large number of people practices walking and cycling, safety is no better than that on highways or residential streets. Vulnerability to severe injuries is higher for road users, especially pedestrians and cyclists, because they have to share the roadways with motorized vehicles. Speeding is one of the significant contributors to severe injuries, as stated by the Institute of Road Safety Research (2012). It is also agreed by Siegrist & Roskova (2001) that high speed influence negatively on the safety of road users, the proficiency of the traffic system and the surrounding environment. A 30 km/h speed limit was imposed to the main road of the institutional area. Generally, it is understood that lowering down the speed could reduce the average travel speed which can impact positively on the number of accidents and accident outcome severity (Archer, Fotheringham, Symmons, & Corben, 2008). A 30 km/h speed limit had shown improvement in the reduction of accidents as portrayed in a research done by Engel & K. Thomsen (1992) where 77 crashers and 88 causalities had been reduced in three years. Despite the implementation of the speed limit on the road to reduce the traffic speed, there are still several vehicles exceeding the posted speed limit. Traffic calming is considered a practical solution to address the issue as stated by Huang & Cynecki (2000). Additionally, road hump as one of the traffic calming measures was installed to encourage drivers to obey the posted speed limit. Jateikienė, Andriejauskas, Lingytė, & Jasiūnienė (2016) mentioned that after the implementation of road humps, the rate of fatal accidents declines 60% while, the number of people with injuries decreases by 63%.

The significance of this study is to ascertain the effectiveness of road hump on the change in the speed of the vehicle while approaching distinct road hump dimensions. The extent to which each different road humps affect the speed of a moving vehicle is essential to know the effectiveness of road hump installation. Road hump profiles or dimensions is considered as a factor that influences the efficiancy of a road hump and any incorrect hump profile would contribute to passenger discomfort and less effect in reducing vehicle speed (Antić, Pešić, Vujanić, & Lipovac, 2013; Parkhill, Eng, Sooklall, Sc, & Bahar, 2007). In addition to that, the installation of road humps is not all according to the guidelines provided by the Ministry of Work in the case of Malaysia. This resulted in various problems such as lack of standardization in dimensions, unsuitable locations, user confusion due to improper construction and no effect on driver behavior (Muhammad Marizwan & Alvin Poi, 2010).

Thus, the purpose of this paper is to evaluate the effects of road hump with different road hump profiles on vehicle speed in a university area. International Islamic University Malaysia (IIUM) was selected for this study as there are road humps present on the main road as part of the traffic calming measures. Besides, the design characteristics of the road humps are also considered to determine the effects of road humps on the speed of the vehicles.

1.1 Objectives

i. To evaluate the geometrical profile of the road and design characteristics of the selected road humps in the institutional environment;
ii. To analyze the speed of the vehicles at selected road humps with different design characteristics;
iii. To compare the speed measured at selected road humps with different design characteristics; and
iv. To formulate recommendations to improve the effectiveness of road humps in reducing the speed of vehicles at an institutional environment.

In this paper, section 2 narrates the effects of road humps on vehicle speed from various literature, section 3 explains on the study background, section 4 on the research approach of this study, section 5 on analysis and findings and lastly section 6 the conclusion of this study.

2. LITERATURE REVIEW

2.1 Traffic Calming in Malaysia

Traffic calming is a combination of physical measures that can lower the negative impact of motor vehicle use, alter the driver behavior and improve conditions for non-motorized road users (Lockwood, 1997). It is also said as a device which slows down the motorized speed. Abdul Azeez Kadar Hamsa (2013) highlighted that it is interesting that the landscaping elements are arranged to regulate the movement of the vehicles to be lesser than the speed of pedestrian sharing the road. Additionally, Gulden & De La Garza (2016) mention that traffic calming helps to increase the quality of life in urban, suburban, and rural areas by slowing down automobile speeds and traffic volumes. In accordance to that, Roess, Prassas, & McShane (2004) also agree with the statement by adding the benefits of traffic calming such as reduction of traffic volume and speed, avoidance of commercial traffic, lessen the negative impacts of traffic on environment and provision of a safer and welcoming environment for pedestrian usage.

However, the application of the traffic calming measures is mostly on an impromptu basis in the case of Malaysia. Marizwan et al. (2008) mentioned, traffic calming classified by Malaysia Highway Planning Unit (HPU) can be categorized into two categories namely vertical measures and horizontal measures. Vertical measures influence the driver's speed through vertical deflections of vehicles passing over the device. While horizontal measures influence the driver's speed through lateral deflections of vehicles that navigating the device. Furthermore, based on the Traffic Calming Guidelines published by the Highway Planning Unit (HPU) from the Ministry of Works list down the types of traffic calming in Table 1.

Table 1. Traffic calming based on Highway Planning Unit (HPU) guidelines

Vertical Measures	**Horizontal Measures**
1. Speed Hump	1. Traffic Circles
2. Speed Bump	2. Roundabout
3. Transverse bar	3. Chicane
4. Speed Table	4. Choker
5. Raised Crosswalk	5. Centre Island
6. Texture Pavement	
7. Raised Intersection	

Source: Highway Planning Unit. Ministry of Works (2002)

Highway Planning Unit. Ministry of Works (2002) also stated the specific dimensions and locations required in installing the traffic calming devices in the Traffic Calming Guidelines. Likewise, Highway Planning Unit (HPU) added that vertical measures are more effective compared to horizontal measures in reducing the speed of vehicles. This study focuses on speed humps which presented on the main institutional road. Malaysian Ministry of Road Works (2012) already set the design specifications for the speed humps as stated in Table 2.

Table 2. Design specification of speed hump by Ministry of Road Works

Material Used	**Dimension**
Asphaltic Premix Wearing Course	a) Flat-Top Hump Height: 75 mm -100 mm Width: 2.5 m - 4 m
	b) Round-Top Hump Height: 50 mm – 100 mm Width: 3.7 m- 4 m
	c) Sinusoidal Hump Height: 75 mm -100 mm Width: 3.8 m-4 m

Source: Ministry of Road Works (2012)

2.2 Effects of Road Hump Design on Vehicle Speed

Speed humps generally have at least 3 of 4 inches of height and approximately 12 feet for the travel length. Though, these dimensions may vary. Clement (1983) and Hallmark, Knapp, Thomas, & Smith (2002) mentioned that the ideal design shape was parabolic, 12 feet wide and 4 inches high. They also explain further that below the design speed of this type of hump, no discomfort imposed to the driver but above the design speed will increase the level of discomfort to the driver. Webster (1993) also said that road humps and raised tables are now permitted to be 50mm to 100mm in height and can have flat-tops. Ewing (1999) illustrated different types of road hump that are commonly implemented on the road as per Figure 1.

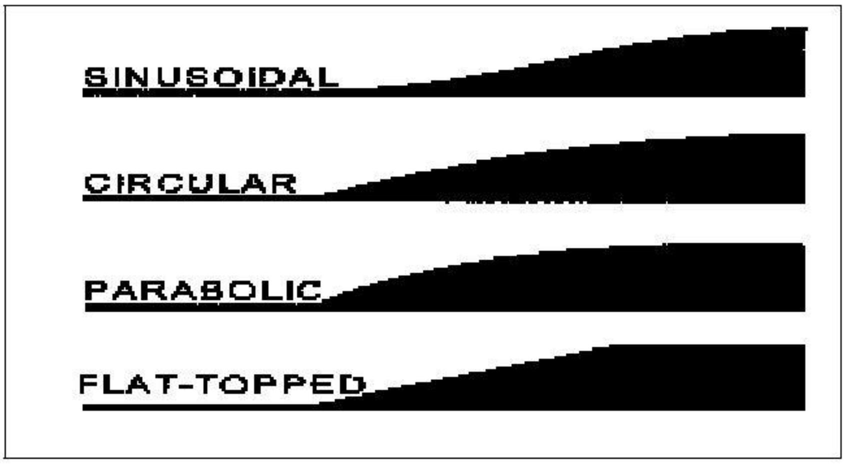


Figure 1. Types of road hump
Source: Ewing (1999)

Significant reduction of 85th percentile of vehicle speed ranging from 10 to 16 km/h is seen when road hump is applied (Antić et al., 2013; Appleyard, Gerson, & Lintell, 1981; Ewing, 1999; Huang & Cynecki, 2000; Sarah Bachok, Azeez Kadar Hamsa, Zin Mohamed, & Ibrahim, 2016; Sundo & Diaz, 2001). The design and placement of road humps affect traffic speed. Humps with higher heights and without flat sections will yield lower speed than lower humps with flat sections. Antić et al. (2013) also added that with an increase in the hump profile's height or severity, the post-entry speed and speed in between a series of humps would decrease. Smith & Giese (1997) mentioned that speed humps must be placed away from curves, transit routes or major emergency response routes.

Yaacob & Hamsa (2012) mentioned that more substantial speed variation was observed between a hump of 60mm heights with another hump of 80mm height. More vehicles exceed the speed limit 30 m before and after the 60mm hump. Antić et al. (2013) also evaluated the effectiveness of road humps with 30mm, 50mm and 70mm in height and found out that speed reduction occurs in all road humps.

3. STUDY BACKGROUND

Road humps were applied in International Islamic University Malaysia (IIUM) as a safety measures as well to control the moving traffic within the permissible speed limits (30 km/h) within the institutional area. The campus located in Gombak, Selangor. It covers 710 acres of land and is 10 kilometers away from Kuala Lumpur. The primary access is via Jalan Gombak and Middle Ring Road 2 (MRR2). It is easily accessible by public transport. The road network system inside the institution is based on loop roadway design. The main road connects important academic, administration and central facilities. It consists of two lanes with one-way traffic.

Six (6) road humps on the main road of International Islamic University Malaysia (IIUM) is selected for this study. These road humps are chosen based on height in comparison with the specification by the Ministry of Work (MOW). The height of Road Hump 1 (120mm) and 5 (110mm) are higher than the maximum height (100mm) of road hump required by MOW. Road Hump 3 (90mm) and 6 (80mm) are within the required height (75mm-100mm) while Road Hump 2 (30mm) and 4 (25mm) are below the required minimum height (75mm) as per stated in Table 4. The location of each road humps is illustrated in Figure 2.

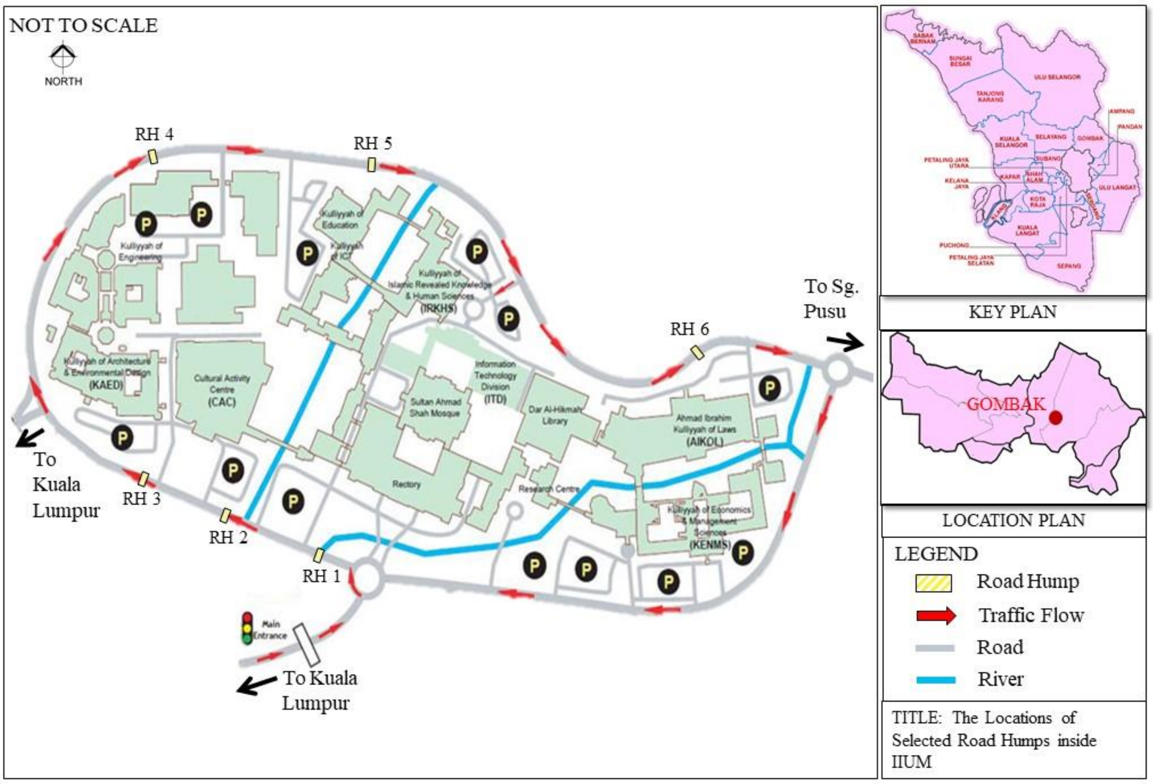


Figure 2. Location of selected road humps on the main road of IIUM
Source: Primary source, 2016

4. RESEARCH APPROACH

Research approach describes the methods applied in data collection to achieve the research objectives.

4.1 Road Inventory Survey

4.1.1 Road geometrical

Geometrical details on the selected roadways were obtained to assess the influence of road width on the speed of vehicles. Road cross-sectional elements were recorded under this survey that includes the width of the road and right of way (ROW). Measuring tape was used to carry out this survey and the units are in Meters (m) and Millimeters (mm).

4.1.2 Road hump characteristics

Road hump characteristics were obtained to determine the location of spot speed survey. The data on the type and dimension of road humps were included in this survey. Road humps dimension denotes the width, height, and length of the road humps. The equipment such as measuring tape was also used to carry out this survey in Meters (m) and Millimeters (mm).

4.1.3 Spot speed survey

Spot speed survey was conducted to measure the speed of the vehicles at the selected road humps. As it was being observed previously, on Tuesday, Wednesday and Thursday indicate only a slight change in traffic volume and the morning off-peak hour session is spotted between 9 am to 11 am each day. This observation is essential to avoid high traffic volume that can significantly affect the movement of vehicles as well as the speed of the vehicles. The average traffic volume for cars and motorcycles within 1 hour was calculated. The result indicates that 75 cars and 85 motorcycles traveled through the road humps within an hour.

Thus, the spot speed survey was administered within three (3) consecutive days (Tuesday, Wednesday, Thursday) and during morning off-peak hour duration (9 am to 11 am) with 1 hour each for six (6) different road hump locations to get the actual vehicle speed.

The survey started with Road Hump 1 then followed by Road Hump 2, 3, 4, 5 and lastly 6 numerically. Spot speed data at Road Hump 1 and 2 were collected on Tuesday with Road Hump 1 at 9 am to 10 am while Road Hump 2 at 1 0am to 11 am. This step was repeated on another road humps in which Road Hump 3 (at 9 am to 10 am) and Road Hump 4 (at 10 am to 11 am) on Wednesday while Road Hump 5 and Road Hump 6 at 9 am to 10 am and 10 am to 11 am respectively on Thursday.

Two (2) Stalker Lidar XS radar guns were used to collect the spot speed data at the road hump. Four (4) enumerators were involved during the survey. Enumerator 1 and 2 were assigned to use the radar guns to obtain the speed of cars and motorcycles (one for car and one for motorcycle) at the road hump while Enumerator 3 and 4 recorded the speed of both vehicles in tables (one type of vehicle for each person). During the survey, all four (4) enumerators were placed after the road hump to get a clear shot and were hidden from the driver's view. This was meant to avoid distraction to the drivers that could affect the speed of the vehicles. Enumerator 1 and 2 with their radar guns shot at the vehicles passing at the road hump and read the speed readings visible on the device while Enumerator 3 and 4 recorded the readings in tables. Systematic sampling procedures were applied during the data collection. Every 5th road users (confines only cars and motorcycles) passing at the road humps along the main road were selected as samples. This process continued for 1-hour duration. The steps are then repeated on every selected road hump. Figure 3 portrayed the position of enumerator with Stalker Lidar XS during the survey and Figure 4 illustrated the spot speed data collection.

Figure 3. Position of enumerator with Stalker Lidar XS during the survey

Source: Primary source, 2016

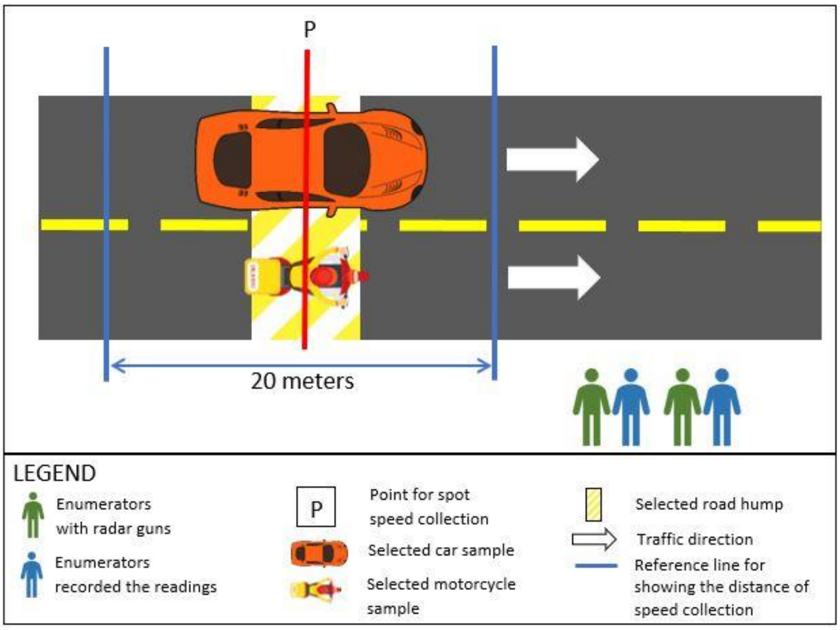


Figure 4. Illustration of spot speed data collection
Source: Primary source, 2016

5. ANALYSIS AND FINDINGS

5.1 Geometrical Design of the Road

The selected institutional road for this study is a straight road with 18 road humps being installed along the main road. It is a single carriageway road with two lanes and one-way traffic flow in a loop design. Even though the road humps are along the same road, each selected road hump comprises different measurement of the right of way (ROW). Figure 5 shows the road geometric for the main road and Table 3 recorded the measurement of the road right of way for selected road humps.

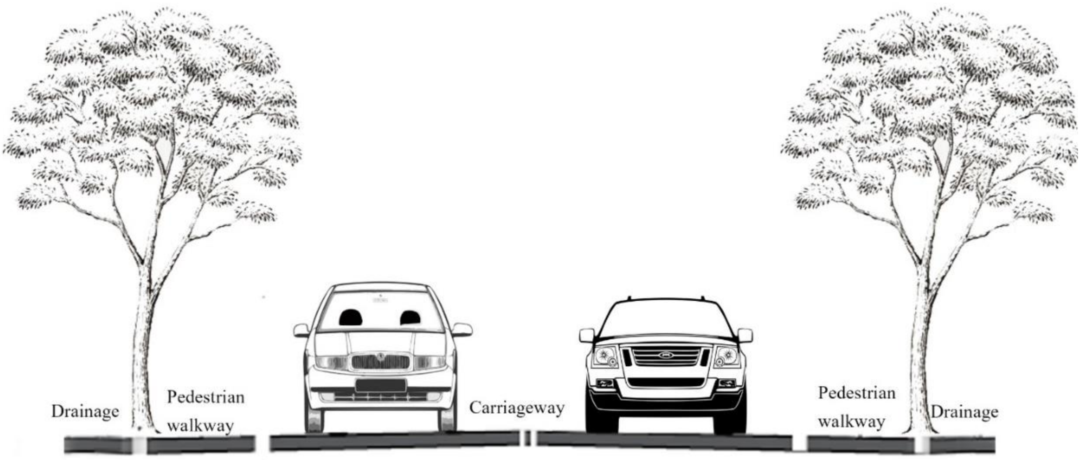


Figure 5. Road geometric for the main road
Source: Primary source, 2016

Table 3. Measurement of the right of way for selected road humps

Right of Way (ROW)	Road Hump (RH) 1	Road Hump (RH) 2	Road Hump (RH) 3	Road Hump (RH) 4	Road Hump (RH) 5	Road Hump (RH) 6
Drainage (Left)	0.70 m	0.70 m	0.85 m	-	0.77 m	0.85 m
Road Reserved (Left)	3.00 m	3.25 m	3.80 m	4.70 m	3.76 m	3.75 m
Carriageway	12.09 m	6.65 m	9.15 m	6.52 m	6.70 m	6.62 m
Road Reserved (Right)	2.30 m	1.73 m	1.00 m	1.33 m	1.18 m	1.20 m
Pedestrian walkway (Right)	1.36 m	1.64 m	2.17 m	2.22 m	1.73 m	2.13 m
Drainage (Right)	-	1.10 m	1.07 m	0.7 m	0.76 m	1.06 m

Source: Primary source, 2016

5.2 Design Characteristics of Road Hump

The design characteristics of road hump 1,2,3,4,5 and 6 was found to be similar in circular (a segment of a circle) design shape. However, each of the selected road humps were found to be different in terms of height, width and length. Figure 6 illustrated the height, length and width of road hump while Table 4 shows the design characteristics of the selected road humps in comparison with the specifications provided by the Ministry of Work.

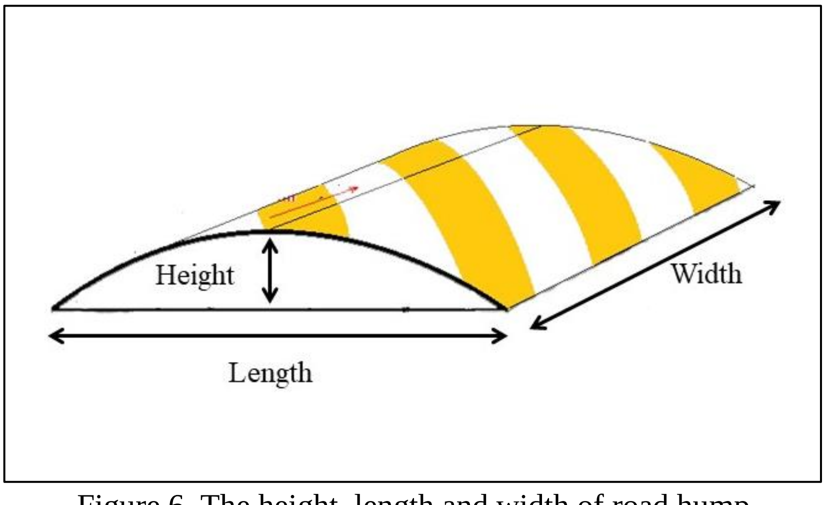


Figure 6. The height, length and width of road hump
Source: Primary source, 2016

Table 4. Comparison of design characteristics of selected road humps with Ministry of Work design specification

Road Hump (RH)	Design Characteristics					Picture
	Height	Width	Length	Color	Type	
RH 1	120 mm	12.09 m	2.79 m	White-yellow striped	Circular	
RH 2	30 mm	6.65 m	4.17 m	White-yellow striped	Circular	
RH 3	90 mm	9.15 m	2.59 m	White-yellow striped	Circular	
RH 4	25 mm	6.52 m	2.13 m	White-yellow striped	Circular	
RH 5	110 mm	6.70 m	2.60 m	White-yellow striped	Circular	
RH 6	80 mm	6.62 m	2.66 m	White-yellow striped	Circular	
Spec. from Ministry of Work	75 mm - 100 mm	12.5 m	3.7 m - 4.25 m	Black-yellow striped	-	

Source: Primary source, 2016

Based on Table 4, Ministry of Work (MOW) stated that the minimum and maximum height of road hump should be 75mm and 100mm respectively while the length must be at least 3.7m and 4.25m at maximum. Thus, Road Hump 1 and 5 exceeds the maximum height of road hump while Road Hump 2 and 4 are below the minimum height requirement provided by MOW. Road Hump 3 and 6 however, are within the range of 75mm to 100mm. These resulted in distinctive vehicle speed for each road humps. The lengths of the selected road humps are mostly less than 3.7m but only Road Hump 2 with 4.17m falls within the MOW specification for length. However, to categorize the road hump, the length must be addressed with height to be considered as following the standard guidelines. Thus, Road Hump 2 is still not following the MOW specification. Nevertheless, the width of Road Hump 4 is the lowest.

5.3 Spot Speed Analysis

5.3.1 Speed characteristics for cars

Table 5 shows the spot speed characteristics of cars at all six (6) road humps. Figure 7 shows the comparison of mean speed and standard deviation for all road humps. The mean speed of cars at Road Hump 1 was the lowest while at Road Hump 4 was the highest. This indicates that at Road Hump 1, on average, the cars were driven approximately 15 km/h while at Road Hump 4, were about 23 km/h. These variation in mean speed were due to the different height of road humps possessed individually.

Looking into the median speed of cars at all road humps, it clearly stated that most of the cars travelled below the permissible speed limit (30 km/h). Moreover, the mode speed of cars for each road humps was also recorded below and at the speed limit. These can be said that the installations of road humps manage to keep the speed of cars below and maximum at 30 km/h.

Sufficient and adequate speed limits can be determined by speed percentile. The 85th percentile of speed is observed to be the highest safe speed for a roadway section. The speed of 85% of the cars for all selected road humps was recorded below the posted speed limit (30 km/h). The 85th percentile of car speed at Road Hump 1 was recorded the lowest (20 km/h) while at Road Hump 4 was recorded the highest (30 km/h).

Standard deviation was used to indicates how far the speed distribution spreads around the mean speed. From Table 5 and Figure 7, Road Hump 4 shows a wider variety of speed of cars (6.55 km/h) compared to the other road humps while the least was Road Hump 5 (3.46 km/h). Moreover, Road Hump 1,2,3 and 6 spread at 4.15 km/h, 5.11 km/h, 5.67 km/h and 5.50 km/h respectively. In conclusion, all of the road humps show the speed of cars spread in a heterogeneous pattern.

Table 5. Mean, median, mode, 85th percentile and standard deviation of speed for cars

	Road Hump (RH) 1	Road Hump (RH) 2	Road Hump (RH) 3	Road Hump (RH) 4	Road Hump (RH) 5	Road Hump (RH) 6
Mean Speed (km/h)	15.15	16.63	18.68	23.11	18.36	18.77
Median Speed (km/h)	15	16	19	23	19	18
Mode Speed (km/h)	13	15 & 16	20	18 & 30	20	21
85th Percentile spot speed (km/h)	20.00	22.00	25.60	30.00	22.00	23.00
Standard Deviation (km/h)	4.15	5.11	5.67	6.55	3.46	5.50

Source: Primary source, 2016

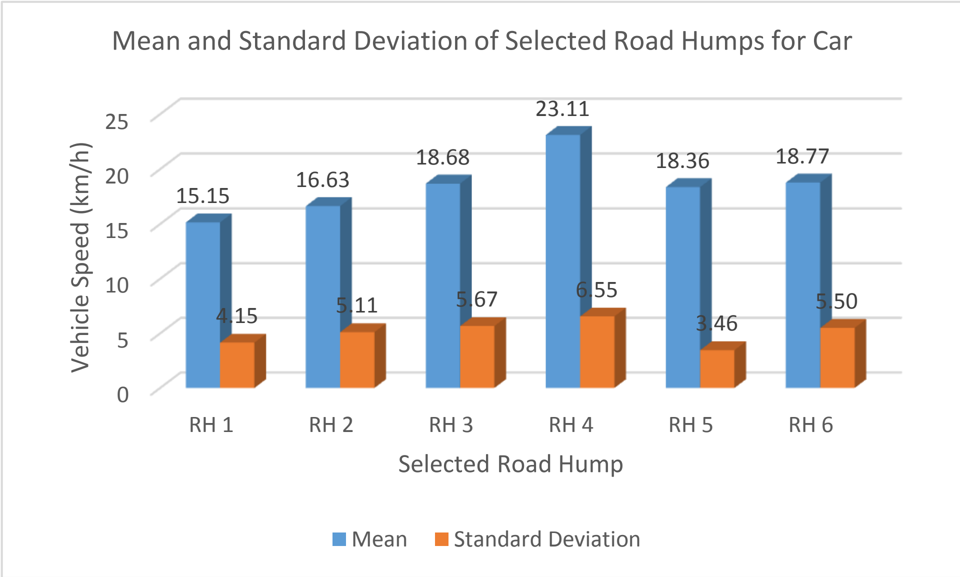


Figure 7. Comparison of car mean speed and standard deviation for all road humps
Source: Primary source, 2016

5.3.2 Speed characteristics for motorcycles

Table 6 shows the spot speed characteristics of motorcycles at all six (6) road humps. Figure 8 shows the comparison of mean speed and standard deviation for all road humps. The mean speed of cars at Road Hump 3 was the lowest while at Road Hump 2 was the highest. This indicates that at Road Hump 3, on average, the cars were driven approximately 23 km/h while at Road Hump 2, were about 30 km/h. These variation in mean speed were due to the different height of road humps possessed individually.

The median speed at all road humps was recorded below and around the permissible speed limit (30 km/h). Moreover, the mode speed of motorcycles for each road humps was also recorded below and at the speed limit. These can be said that the installations of road humps manage to keep the speed of motorcycles below and maximum at 30 km/h.

In addition, the speed of 85% of motorcycles for all of the selected road humps was recorded differently for each road humps. The 85th percentile of motorcycles speed at Road Hump 2, 4 and 6 was recorded above the speed limit while at Road Hump 1,3 and 5 were below the speed limit. This indicates that most of the samples drove above the permissible speed limit for Road Hump 2,4 and 6.

Moreover, from Table 6 and Figure 8, Road Hump 2 shows a wider variety of speed of motorcycles (7.59 km/h) compared to the other road humps while the least was Road Hump 5 (3.70 km/h). Moreover, Road Hump 1,3,4 and 6 spread at 4.54 km/h, 6.31 km/h, 5.48 km/h and 5.01 km/h respectively. In conclusion, all of the road humps show the speed of cars spread in a heterogeneous pattern.

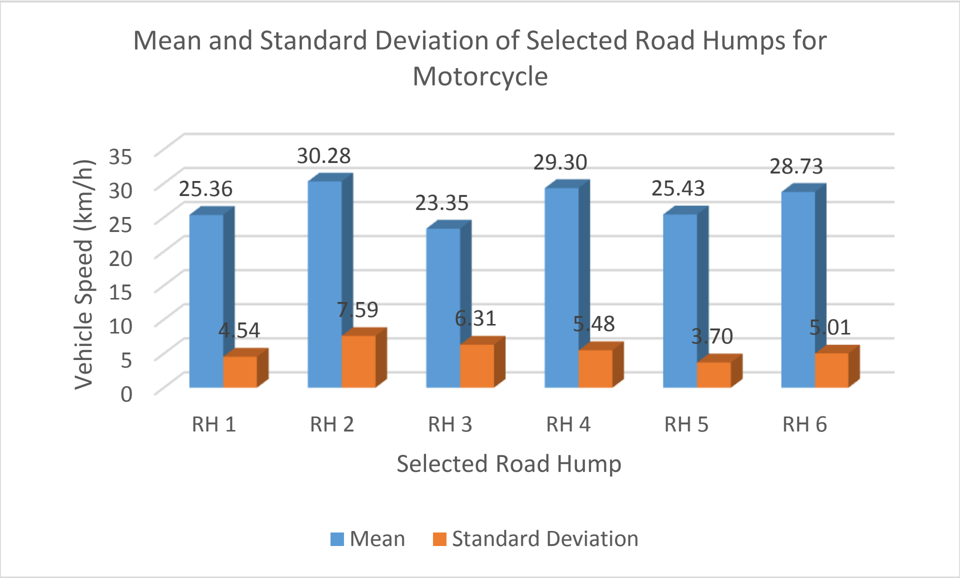
Table 6. Mean, median, mode, 85th percentile and standard deviation of speed for motorcycles

	Road Hump (RH) 1	Road Hump (RH) 2	Road Hump (RH) 3	Road Hump (RH) 4	Road Hump (RH) 5	Road Hump (RH) 6
Mean Speed (km/h)	25.36	30.28	23.35	29.30	25.43	28.73
Median Speed	26	30	23	30	25	29

(km/h)						
Mode Speed (km/h)	24	30	20	30	25	27
85th Percentile spot speed (km/h)	30.00	39.85	30.00	35.00	28.00	34.00
Standard Deviation (km/h)	4.54	7.59	6.31	5.48	3.70	5.01

Source: Primary source, 2016

Figure 8. Comparison of motorcycle mean speed and standard deviation for all road humps
Source: Primary source, 2016



5.3.3 Percentage of speed reduction for cars

Figure 9 shows the percentage reduction in the speed of cars from the permissible speed limit of 30 km/h. The speed of cars travelled at Road Hump 1 with the height of 120mm were significantly reduced by 49.50 % compared to Road Hump 4 with the 25mm height that only reduced by about 22.97%. This indicates that the height of the road hump gave a massive impact on the speed of cars passing through it. However, at Road Hump 2 with the height of 30mm recorded 44.57% of reduction. This was due to some external factors such as narrow carriageway and on-street parking that contributed to higher speed reduction.

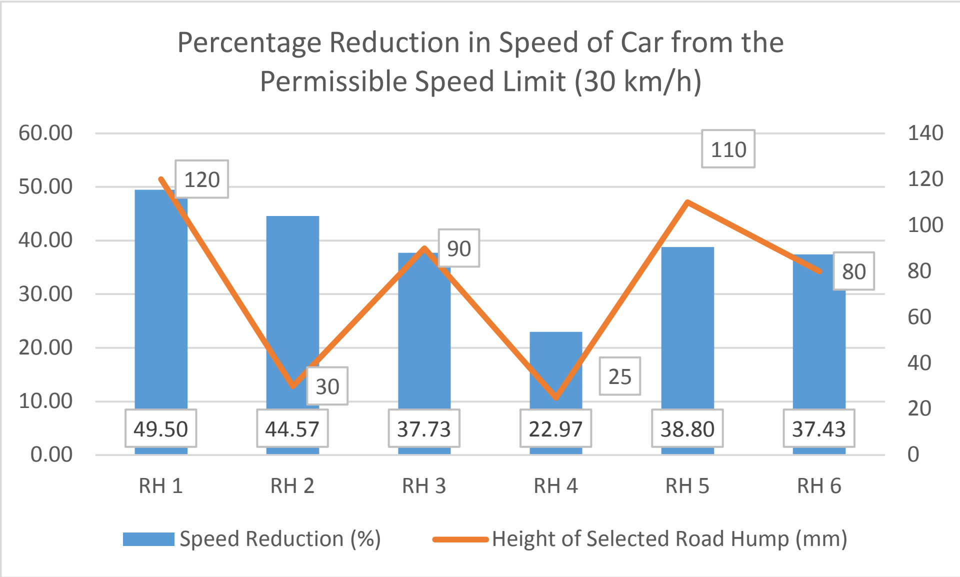


Figure 9. Percentage reduction in the speed of car from the permissible speed limit for different road humps

Source: Primary source, 2016

5.3.4 Percentage of speed reduction for motorcycles

Figure 10 illustrates the percentage reduction in the speed of motorcycles from the permissible speed limit of 30 km/h. The speed of cars travelled at Road Hump 3 with the height of 90mm (height within the MOW specification) were significantly reduced by 22.17% compared to Road Hump 1 with 120mm height that recorded only 15.47% reduction. This indicates that the height of the road hump is not the leading indicator for the decline in speed of motorcycles passing through it. However, at Road Hump 2 with 25mm height showed an acceleration in speed above the speed limit for 0.92%.This was due to the lower in road hump height that fails to encourage the drivers to slow down.

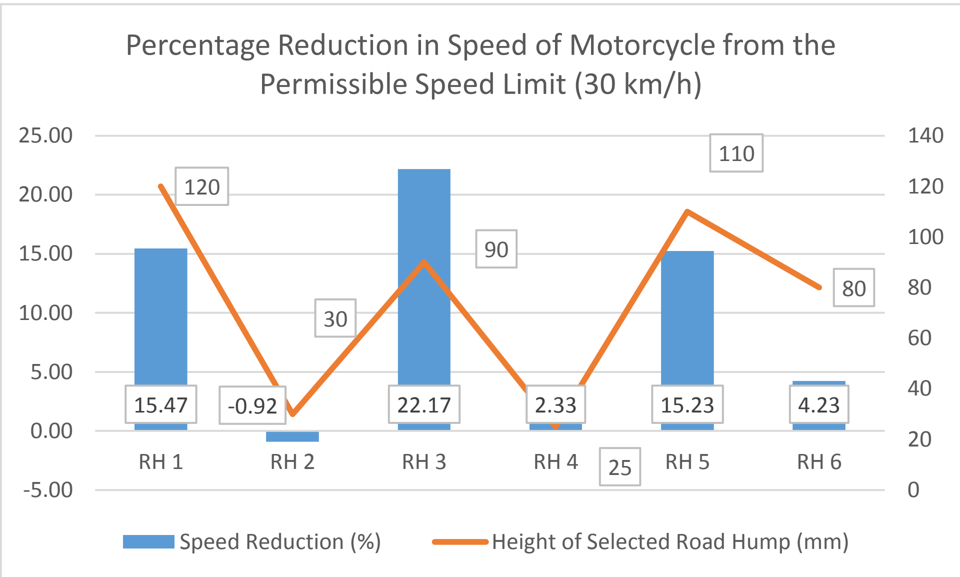


Figure 10. Percentage reduction in speed of motorcycle from the permissible speed limit for different road humps

Source: Primary source, 2016

5.3.5 Testing the differences in spot speed between road humps

The selected road humps have different design characteristics in terms of height, width and length that resulted in different speed pattern. The difference in speed of the selected vehicle at the road humps was tested to determine whether there is a significant statistical change in vehicles speed. A t-test was applied to examine the differences in speed at all of the road humps. Table 11 shows the results of the paired t-test at Road Hump 1,2,3,4,5 and 6 for cars and Table 12 shows the results of the paired t-test at all road humps for motorcycles.

Table 11. Paired sample t-test for cars at all road humps

Pair of Road Humps	Mean Diff.	df	t	p-value	Remarks
RH 1-RH 2	-1.480	142	-1.947	0.027	Statistically Significant
RH 1-RH 3	-3.533	136	-4.357	0.000	Statistically Significant
RH 1-RH 4	-7.960	125	-8.891	0.000	Statistically Significant
RH 1-RH 5	-3.213	143	-5.152	0.000	Statistically Significant
RH 1-RH 6	-3.627	138	-4.560	0.000	Statistically Significant
RH 2-RH 3	-2.053	146	-2.330	0.011	Statistically Significant
RH 2-RH 4	-6.480	40	-6.754	0.000	Statistically Significant
RH 2-RH 5	-1.733	130	-2.432	0.008	Statistically Significant
RH 2-RH 6	-2.147	147	-2.476	0.007	Statistically Significant
RH 3-RH 4	-4.427	145	-4.426	0.000	Statistically Significant
RH 3-RH 5	0.320	122	0.417	0.339	Statistically Insignificant
RH 3-RH 6	-0.093	148	-0.102	0.459	Statistically Insignificant
RH 4-RH 5	4.747	112	5.549	0.000	Statistically Significant
RH 4-RH 6	4.333	144	4.388	0.000	Statistically Significant
RH 5-RH 6	-0.413	125	-0.551	0.291	Statistically Insignificant

Source: Primary source, 2016

Table 12. Paired sample t-test for motorcycles at all road humps

Pair of Road Humps	Mean Diff.	df	t	p-value	Remarks
RH 1-RH 2	-4.913	129	-4.968	0.000	Statistically Significant
RH 1-RH 3	2.013	144	2.317	0.011	Statistically Significant
RH 1-RH 4	-3.938	153	-4.950	0.000	Statistically Significant
RH 1-RH 5	-0.063	152	-0.096	0.462	Statistically Insignificant
RH 1-RH 6	-3.363	156	-4.449	0.000	Statistically Significant
RH 2-RH 3	1.550	137	1.524	0.065	Statistically Insignificant
RH 2-RH 4	0.975	144	0.931	0.177	Statistically Insignificant
RH 2-RH 5	4.850	114	5.139	0.000	Statistically Significant
RH 2-RH 6	1.550	137	1.524	0.065	Statistically Insignificant
RH 3-RH 4	-5.950	155	-6.369	0.000	Statistically Significant
RH 3-RH 5	-2.075	127	-2.539	0.006	Statistically Significant
RH 3-RH 6	-5.375	150	-5.968	0.000	Statistically Significant
RH 4-RH 5	3.875	138	5.244	0.000	Statistically Significant
RH 4-RH 6	0.575	157	0.693	0.245	Statistically Insignificant
RH 5-RH 6	-3.300	145	-4.741	0.000	Statistically Significant

Source: Primary source, 2016

The results show that there are statistically significant and insignificant difference in the spot speed of cars and motorcycles between the stated road hump pairs.

6. CONCLUSIONS

In conclusion, the significant findings from this paper display that the speed of cars reduced when approaching all of the road humps. The recorded mean speed was less than the permissible speed limit. Additionally, the documented standard deviation showed a heterogeneous pattern. It is also observed that the percentage of reduction was ranging from 22.97% to 49.50 %. This indicates that all road humps gave a significant reduction in the speed of cars, which was influenced solely by the height of the road humps. However, in the case of the motorcycle, Road Hump 2 was ineffective in reducing the speed of motorcycles while another five road humps are effective. On the other hand, the mean speed was recorded below the speed limit for all of the road humps. The standard deviation also showed a heterogeneous pattern. Additionally, the percentage of reduction was ranging from 2.33% to 22.17%. Road Hump 2 however, showed an increase of speed from the permissible speed limit by 0.92%. Moreover, height was not the only factor contributed to the speed reduction of motorcycles when approaching the road humps as there were inconsistent results for the reduction of speed from the speed limit.

Overall, the different in hump profiles gave a significant impact on the speed of vehicles. It is noted that further studies are needed to improve the effectiveness of road humps in maintaining the safety of road users. Several recommendations that can be formulated which are standardizing the road humps dimension accordingly, imposed stricter rules on the speed limit and revise the location of road humps to maximize the impact.

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