Evaluating the Effectiveness of Road Hump on Changes in Speed of Vehicles at Institutional Road in International Islamic University Malaysia

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Abstract: This paper investigates the effects of road humps with different design profiles in reducing the speed of vehicles at the institutional road in International Islamic University Malaysia. Road humps are installed along the campus area in order to control the speed of moving vehicles as well as the driver's behavior. Therefore, the study was conducted in order to ensure the effectiveness of road humps installation in the campus area. Field survey and spot speed survey were conducted to collect primary data for the research. The data collected were then analyzed using descriptive analysis and independent t-test. The major finding of this study entails that road hump is effective in reducing the speed of vehicles at the institutional area. The dimensions of road hump especially in height give greater influence on speed reduction of vehicles.

Keywords: Spot Speed, Road Humps, Traffic Calming, Institutional Area.

1. INTRODUCTION

Road users specifically pedestrians and cyclists are vulnerable to severe injuries whenever on road. This scenario can be seen especially on University campuses whereby the majority of the population practices walking and cycling in addition to the presence of motorized vehicles. As the speed increases, the severity of the injury during crashes also increases (Institute of Road Safety Research, 2012). This cumbersome situation arises when motorized vehicles exceed the stated speed limit causing fatal injuries to the vulnerable road users. As a result, the necessity to control the vehicle speed has become a major priority in many areas including University campuses. Considering several possibilities of traffic calming measures, several researchers have suggested that road hump has the ability to effectively control the speed of the moving vehicles. The analysis on fatal and injury accident data on the road sections with vertical traffic calming measures shows a significant decrease in fatal and injury accidents after the installation of this measure. Jateikienė, Andriejauskas, Lingytė, & Jasiūnienė (2016) mentioned that the rate of fatal accidents declines 60% while, the number of people with injuries decreases by 63% after the application of road humps.

However, the effectiveness of road hump on the change in vehicle speed in an institutional area has yet to be investigated in depth. As mentioned by Hui Min and Che Ros in their study, road humps has been implemented in Malaysia especially in residential area but the

effect of road hump installation in reducing the speed of vehicles in campus area is not well explored. Besides, the study by K.Bachok et al (2016) also focusing on the effect of road hump in residential area. Thus, the purpose of this paper is to evaluate the effects of road hump on vehicle speed in a campus area. International Islamic University Malaysia (IIUM) was selected for this study because of the presence of road humps along the major road of this campus in reducing vehicle speed. Besides, the design characteristics of the road humps are also considered to determine the effects of road humps on the speed of the vehicles.

2. LITERATURE REVIEW

2.1 Traffic Calming in Malaysia

Traffic calming can be defined as a device which slows down the motorized speed. It is appealing in Netherlands and Germany as highlighted by Abdul Azeez Kadar Hamsa (2013), whereby the landscaping elements are arranged to regulate the movement of the vehicles to be lesser than the speed of pedestrians sharing the road. In accordance to that, several purposes of traffic calming have been persuaded by Roess, Prassas, & McShane (2004) which mentioned the reduction of traffic volume and speed, avoidance of commercial traffic, lessening the negative impacts of traffic on environment and provision of safer and welcoming environment for pedestrian usage.

Apparently, in Malaysia, the implementation of the traffic calming measures is mostly on an ad-hoc basis. Based on the Traffic Calming Guidelines published by the Highway Planning Unit (HPU) from the Ministry of Works, there are 12 types of speed controlling measures under two major categories.

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)

According to the Highway Planning Unit (HPU) guidelines (2002), a vertical shift in the roadway is the most effective and reliable method for speed reduction. The deflection generally helps to increase the driver's awareness and hence reduces the vehicles speeds. Besides, the Traffic Calming Guideline by HPU stipulated specific dimensions and locations that are required for the installation of traffic calming measures. The different styles and designs of road humps could be subjected to inconsistent speed reduction as a result of different driving reactions, and hence, may lead the public to have negative perceptions regarding traffic calming measures.

2.2 Effectiveness of Road Hump

Basically, the effectiveness of the road humps can be determined based on three measured reasons. The measures are speed, volume and safety. The impact of road humps on traffic speed depends on the design and placement of the devices. Higher humps or bumps without flat sections will produce lower speeds than lower humps and humps with flat sections. According to Schroll (1999), the cross-section of the hump's ramp will also affect speed; lower speed can be achieved due to more severe designs (that is, designs that cause the quickest displacement of vehicle wheels). Besides, volume is unlikely to be affected by speed control measures if there is no alternate route (Schroll, 1999). Where such a route does exist, however, some shift in volume can be expected. Traffic calming uses physical design and other measures to improve safety for motorists, pedestrians, and cyclists. It aims to encourage safer, more responsible driving and potentially reduce traffic flow. Residents are often concerned about accident potential, which is much more difficult to quantify. The difficulty is compounded by the fact that residents may modify their behavior (for example, not allowing their children to play on the sidewalk) in reaction to the perceived dangers. However, the traffic calming has a positive impact on safety. As an example, in North America recently, in response to growing numbers of traffic accidents and speeding problems, cities across North America have begun creating traffic calming programs to improve safety and livability on residential streets with the development of guidelines by Weber & Braaksma, (2000).

2.3 Design of Road Hump

Speed humps normally have a minimum height of 3 to 4 inches and a travel length of approximately 12 feet. However, these dimensions may vary. In some cases, the speed hump may raise the roadway surface to the height of the adjacent curb for a short distance. Road humps are the most widely used traffic calming device because they are proved to be very effective in controlling speeds and applicable to most road layouts. There are various design shapes of road hump. The profile of road hump may be circular (a segment of a circle), sinusoidal (a sine wave), parabolic or flat-topped (refer figure below). Regardless of profile, the recommended height of road hump should be less than 3 inches (Transport Department for Regional Development).

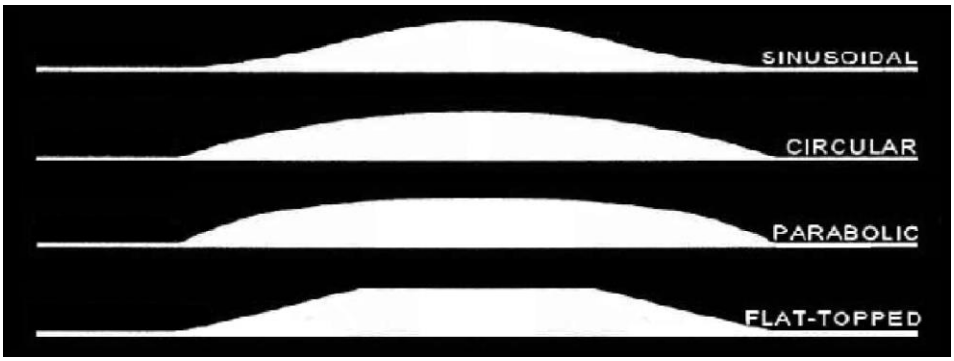

Figure 1. The design profile of road hump

3. GOAL AND OBJECTIVES

3.1 Goal

Studying the effects of road hump design profiles on the speed of vehicles at an institutional area.

3.2 Objectives

1) To evaluate the geometrical details of the selected roads and design characteristics of the road humps in the institutional area;
2) To determine the effectiveness of road humps with different design profiles in the selected road geometrics on speed reduction of vehicles at the selected road in the institutional area.

4. DESCRIPTION OF STUDY AREA

International Islamic University Malaysia (IIUM) is located in Gombak in the State of Selangor. The campus area covers 710 acres and located 10 kilometers away from Kuala Lumpur city center. The main access to this campus is via Jalan Gombak branching eastward towards underpass below Karak Highway. Another alternative is through the Middle Ring Road 2 (MRR2). Apart from that, this University also can be accessed by public transport mainly by LRT and RapidKL Bus. The vehicular road network system in this campus is based on a loop roadway concept. The roads branching out of the loop connects the main academic, administration and central facilities. This arrangement provides clear directions and greater control of traffic flows. There are two types of road networks identified in IIUM which are the major road and secondary road. The major road stretches along the loop with single carriageway consisting of two lanes (one-way traffic). On the other hand, the secondary road serves as a feeder road to Mahallah areas (residential blocks) and has single carriageway with two lanes (two-way traffic).

International Islamic University Malaysia (IIUM) is one of the institutional areas that apply road humps as a safety measure as well as to control the moving traffic within the posted speed limits (30 km/h). This study focuses on a major road provided with road humps in IIUM campus. The selected major road on-campus consists of 19 road humps. However, only three road humps were selected for this study for having different design profiles. The first road hump is located in front of Kuliyyah (Faculty) of Law while the second road hump is located near Mahallah Safiyyah (Safiyyah residential block) and the third road hump is located next to Kuliyyah (faculty) of Engineering. These three location is selected mainly because of the design profile of the road hump itself as well as the consideration of the surrounding environment. The location of Road Hump 1 and Road Hump 2 is near to the zebra crossing to allow the pedestrian to cross the road by making the vehicles to slow down. Thereby, to protect the safety of the pedestrian. Besides, Road Hump 3 is located near to intersection to decrease the speed of vehicles along the major road in order to allow the vehicles from the side road to clear the intersection.

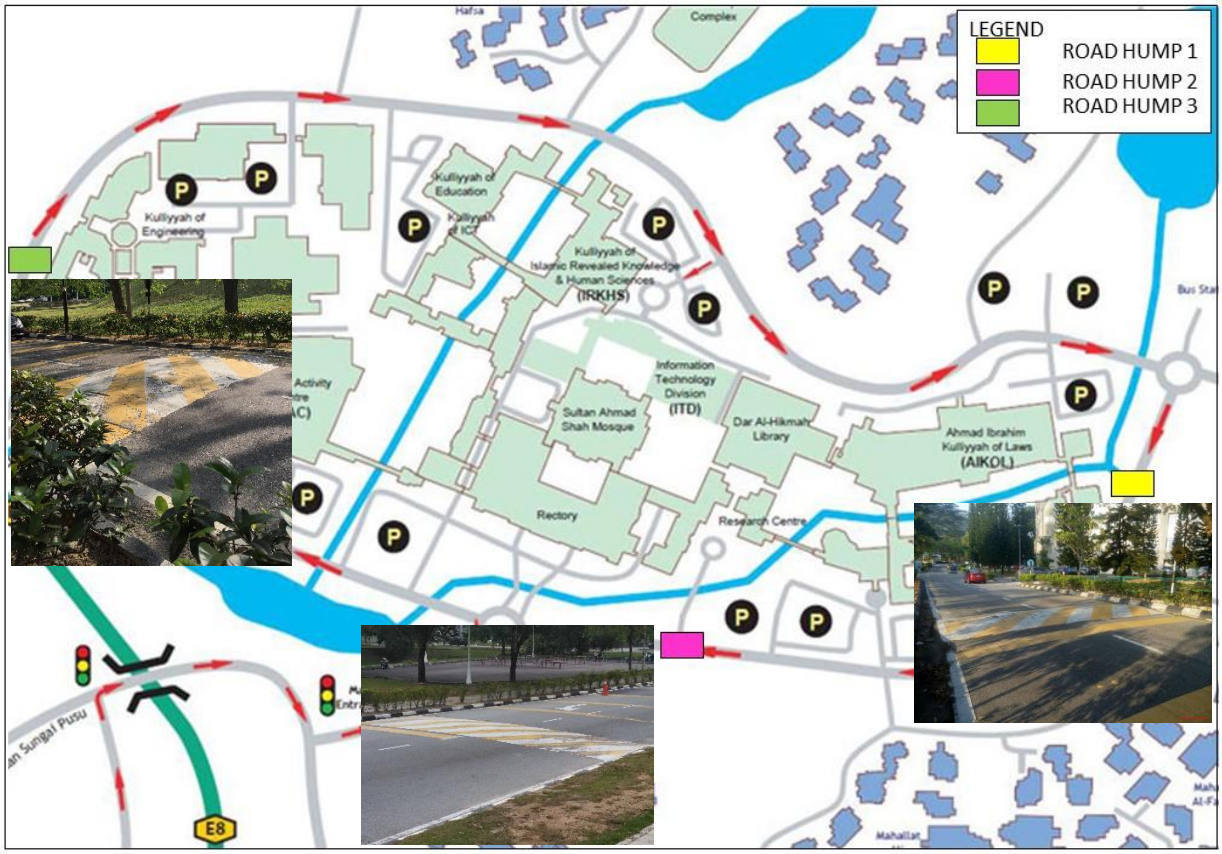

Figure 2. The location of road hump chosen

5. RESEARCH METHODOLOGY

5.1 Method of Data Collection

There are two types of data required in the research which are primary data and secondary data. Primary data for this research was collected by inventory survey and spot speed survey. The data collected from inventory survey was geometrical details of the road and road hump characteristics. Besides, the spot speed survey was conducted in order to collect the spot speed data at three different profile of road hump. The secondary data was collected from various reliable sources which are from IIUM Development Division, Ministry of Transport and Ministry of Works. The map of the study area and guidelines of road hump characteristics are the secondary data needed in this research.

The inventory survey method was conducted to collect geometrical details of the road with the installation of road humps. The dimension of the road which is the width of the road and the width of the right of way (ROW) are measured in this inventory survey. Furthermore, the inventory survey on the road hump characteristics also measured in this research. The characteristics investigated in this study include the dimensions of road hump and types of road humps. The road hump dimensions refer to the width, height, and length of the road humps. The research focuses on the effect of three road humps with different design profiles in reducing the vehicles speed. The equipment used in this inventory survey is measuring tape.

The spot speed survey was conducted to observe the effectiveness of the road humps in reducing the speed of vehicles in the institutional area. In this study, radar meter method was selected to collect the spot speed data. The speed of cars that passed through the nine points is

recorded and this process continued until the total speed of 150 and 379 cars has been collected. Three points at the Road Hump 1, Road Hump 2 and Road Hump 3. The points were placed 30 meters before the Road Hump 1, at Road Hump 1 and 30 meters after the Road Hump 1. Similarly with Road Hump 2 and Road Hump 3. Thus, the data were collected whenever the cars approaching these points (refer figure 3). The spot speed survey was conducted during the weekdays which are on Wednesday and Thursday (6th and 7th April 2016) and Tuesday (23rd May 2017), Besides, the survey was also conducted during off-peak hours for Road Hump 1and 2 (10 a.m. to 1 p.m.) because the high traffic volume will affect the movement of traffic as well as the speed of vehicles, while for Road Hump 3, the survey was conducted for 12 hours which is from 7a.m to 7p.m to know the actual speed of cars during peak hours and off-peak hours. In this spot speed survey, two enumerators placed in each road hump. Enumerator 1 recorded the speed of the cars at three points which are 30-meter approaching road hump, at the road hump and 30 meters passing the road hump, while enumerator 2 jot down the speed of vehicles that recorded by enumerator 1 on the survey form (refer figure 3). Systematic sampling procedures were applied to collect data on spot speed. In this study, the spot speed recorded every 5th road users (which confine only to the cars) passing the road humps along the selected road at an institutional area was selected as samples and the procedures continued until 679 samples are collected. As three different road humps are evaluated, the samples selected at each road hump were 150 samples for Road Hump 1 and 2 and 379 samples for Road Hump 3. The different sample size is due to the expansion of the study.

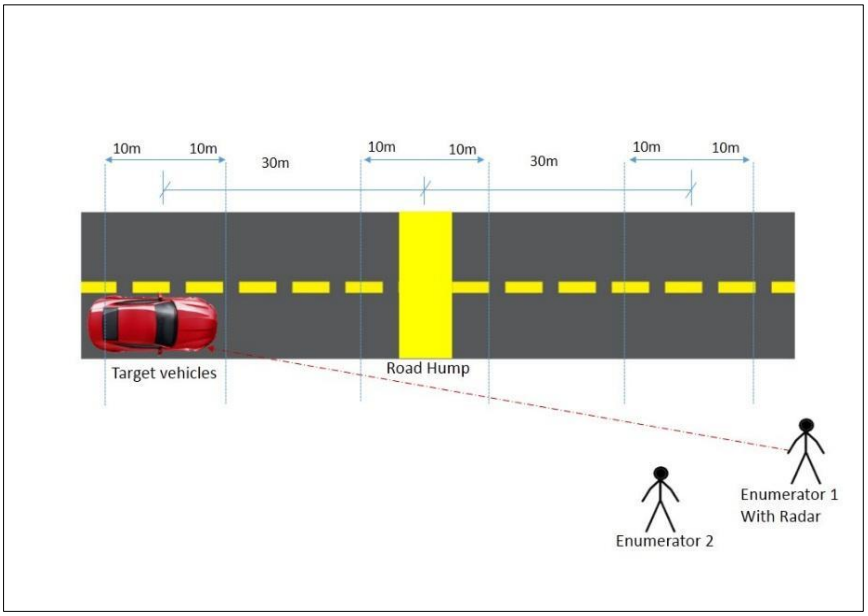

Figure 3. The illustration of spot speed survey.

5.2 Method of Data Analysis

The method of analysis for primary and secondary data was analyzed by using different methods of analysis. For primary data, the descriptive analysis has been used. Additionally, the t-test analysis used in order to analyze the significant level of the speed data collected. While, for the secondary data, all the data were compared and evaluated with the primary data.

The data for road geometric and road humps characteristics were presented in diagram. While the analysis for spot speed data involved the calculation of measures of central tendency

(mean and median speed), measures of relative position (85th and 15th percentile) and measures of variability (standard deviation) which meant to evaluate the relationship of road humps in speed reduction. In addition, independent t-test also was applied to test the statistical differences in the speed at different points of the three selected road humps. In this research, a t-test was applied to test the statistical differences in the mean speed at Road Hump 1, at Road Hump 2 and at Road Hump 3.

6. ANALYSIS AND FINDINGS

6.1 Geometrical details of the road

The geometrical design of the selected institutional road is a straight road with the installation of 16 road humps along the road. Furthermore, the geometrical design of this road is based on the loop design with single carriageway (two lanes) of one-way circulation system. The right of way (R.O.W) width of the selected road was 11.4 meters. The carriageway was recorded at 7.0 meters with 3.5 meters per lane. On the other hand, the measurement of the drainage system reserve was about 1.0 meters while reserve pedestrian walkways were recorded at 1.2 meters. Figure 4 illustrated the road geometrics of the selected road.

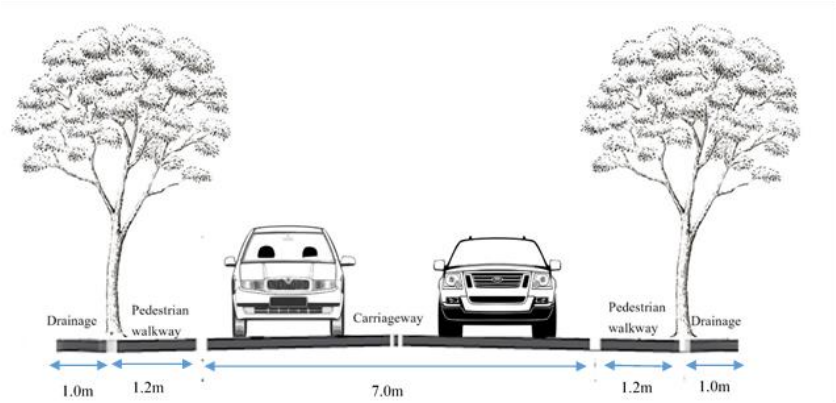

Figure 4. Geometrical details of the road

6.2 Design characteristics of road hump

Table 2. Comparison of Design Characteristics of Road Hump

Design Characteristics	Road Hump 1	Road Hump 2	Road Hump 3	Ministry of work specification
Height	120 mm	70 mm	94 mm	75 mm - 100 mm
Width	7 m	7 m	7 m	12.5 m
Length	2.4 m	3.5 m	2.88 m	3.7 m - 4.25 m
Color	White-yellow striped	White-yellow striped	White-yellow striped	Black-yellow striped

Source: Site Survey, 2016

From the inventory survey on the design characteristic of road humps, it is found that the design of three road humps were circular but different in height and length. Table 2 showed the road humps design characteristics for three road humps (Road Hump 1, Road Hump 2 and Road Hump 3) as well as the comparison of design characteristics between Road Hump 1, Road Hump 2 and Road Hump 3 in terms of dimension with the specifications provided by the Ministry of Work.

Based on table 2, the maximum height of road humps from Ministry of Work is 100mm and this height is applicable for all types of road humps in the study. While the minimum and maximum lengths of any types of road hump are 3.7 meters and 4.25 meters. Figure 5, 6 and 7 display the road hump dimensions.

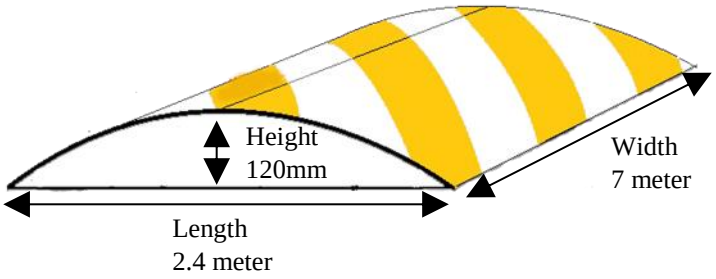

Figure 5. Dimension of Road Hump 1

Figure 5 shows the dimension of Road Hump 1. The height of the Road Hump 1 is 120mm which exceeds the maximum specification by the Ministry of Work. However, the width and length of Road Hump 1 is 7 meters and 2.4 meters respectively. The length of road hump does not meet the minimum requirement by the Ministry of Work.

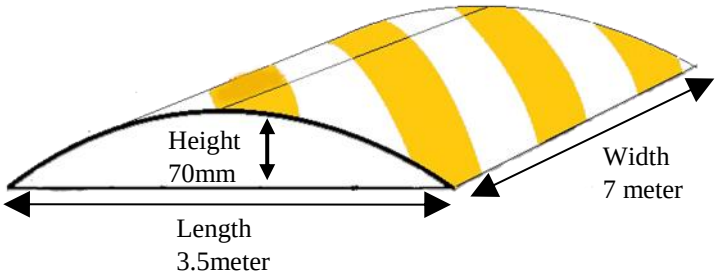

Figure 6. Dimension of Road Hump 2

The dimension of Road Hump 2 is illustrated in figure 6. The height of Road hump 2 is 70 mm in which it does not meet the minimum specification by the Ministry of Work. Besides, the width of Road Hump 2 is 7 meters while the length is 3.5 meters.

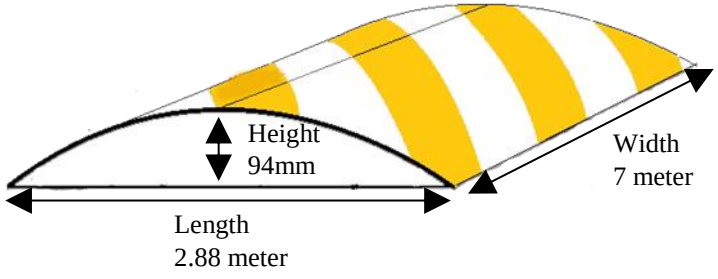

Figure 7. Dimension of Road Hump 3

Figure 7 shows the dimension of Road Hump 3. The height of Road Hump 3 is 94 mm which meet the requirement standard by the Ministry of Work. However, the width and the length of Road Hump 3 does not meet the minimum specification by the Ministry of Work which is 7 meters and 2.88 meters respectively.

In terms of the length, these three road humps do not meet the minimum requirement by the Ministry of Work. But in term of height, only Road Hump 3 meet the requirement standard by the Ministry of Work. The design characteristics of the road humps should follow the guidelines provided in order to prevent and avoid any discomfort or difficulties to the road users and provide minimum discomfort at the same time maintaining the effectiveness of road hump in reducing the speed of vehicles. Hence, the changes made in designing the road humps might change the driving behavior as well as the speed of vehicles in that area.

6.3 Spot speed analysis

The spot speed data showed that the lowest speed recorded for 30 meters before approaching Road Hump 1 was 12 km/h and the speed dropped to 10km/h then started to increase to 15km/h 30 meters after the road hump. Meanwhile, the lowest speed recorded for Road Hump 2 was 21 km/h. The speed for road hump 2 has the similar pattern with road hump 1 in which speed started to drop at the road hump and increase after the road hump. For Road Hump 3, the lowest speed recorded was 11 km/h and started to increase to 17 km/h (at the road hump) and 25 km/h (after the road hump).

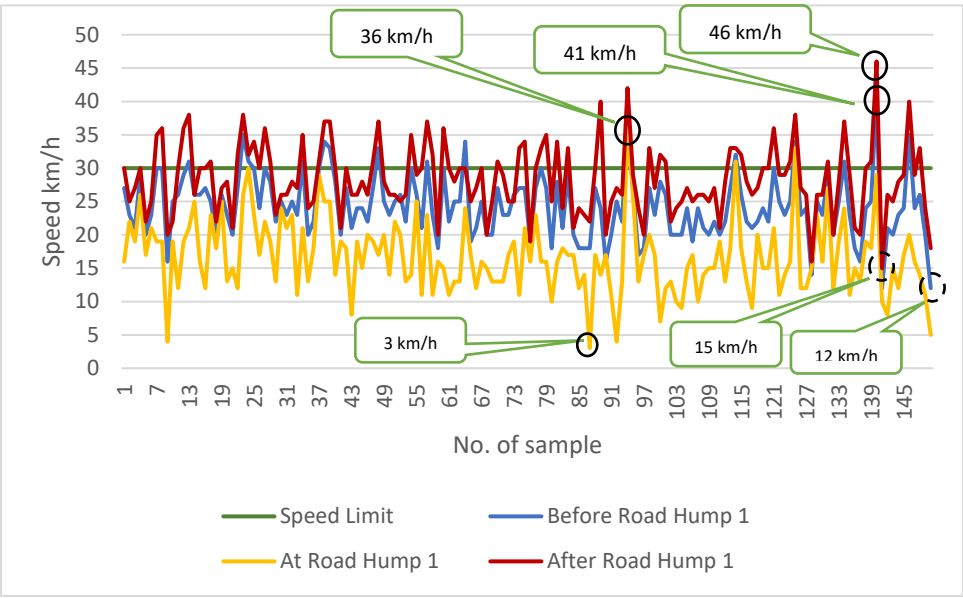

Figure 8. The Spot Speed Data of 150 vehicles for Road Hump 1

Figure 8 shows the overall spot speed data for Road Hump 1. The graph indicates the highest speed recorded was 46 km/h after the road hump, while before the road hump, the highest was 41 km/h and at the road hump was 36 km/h. The lowest speed recorded at the road hump was 3km/h, while the lowest speed before and after the road hump was recorded at 12 km/h and 15 km/h respectively. From the speed recorded, it shows that there were vehicles that were exceeding the speed limit at Road Hump 1. From the findings, 42% (63) of the sample size were found to exceed the speed limit for the Road Hump 1.

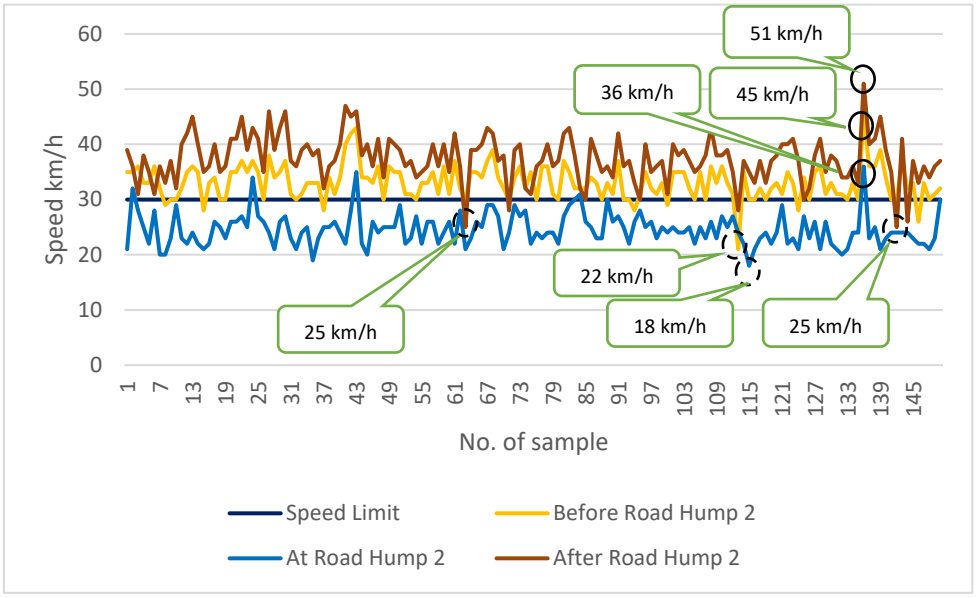

Figure 9. The Spot Speed Data of 150 vehicles for Road Hump 2

The overall spot speed data for Road Hump 2 are shown in figure 9. The graph illustrates the highest speed recorded after the road hump is much higher than the speed recorded before the road hump which was 51 km/h as compared to 45 km/h. The data also shows a whopping 78% (117) of the vehicles were driving above the speed limit when approaching the road hump while there similarly 96% (144) of vehicles was found speeding after passing the road hump. In addition, at the road hump, the vehicles were driven beyond the speed limit which comprises of 3.3% (5). Meanwhile, the lowest speed recorded before the road hump, at the road hump and after the road hump was 22 km/h, 18 km/h and 25 km/h respectively.

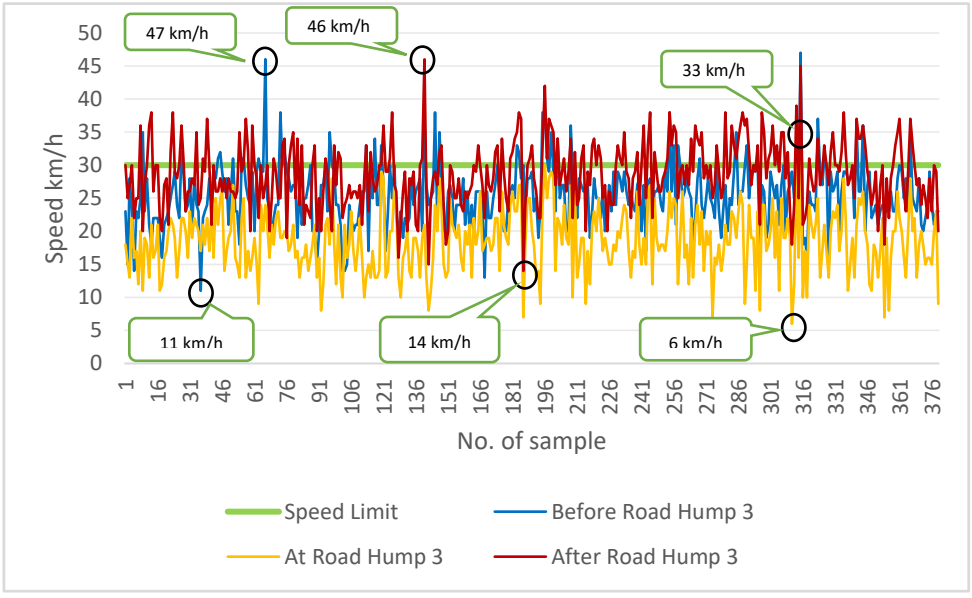

Figure 10. The Spot Speed Data of 379 vehicles for Road Hump 3

Figure 10 shows the overall spot speed data for 379 vehicles for Road Hump 3. The graph indicates the highest speed recorded was 47 km/h before the road hump, while after the road hump, the highest was 46 km/h and at the road hump was 33 km/h. From this graph, it shows

that the highest speed at these 3 points are beyond the speed limit which is 30 km/h. Meanwhile, the lowest speed recorded before, at and after the road hump was 11 km/h, 6 km/h and 14 km/h respectively. Therefore, from this graph, it can be concluded that 42.74 % (162) of vehicles were driving beyond the speed limit while the other 217 vehicles were travel below or within the speed limit.

From figures 8, 9 and 10 most of the drivers drove their cars higher than the posted speed limit at Road Hump 2 especially before approaching the road hump and after the road hump. In contrast, for Road Hump 1 and Road Hump 3, most of the speeds recorded were lower than the speed limit even though there were a number of cars that drove above the posted speed limit. Therefore, it can be clearly indicated that the drivers tend to speed their cars at Road Hump 2 compared to Road Hump 1 and Road Hump 3 and further suggests that the different design characteristics of road humps give a different effect on vehicle speed.

6.3.1 Frequency Distribution of Spot Speed

Road hump 1

Based on figure 11, the highest frequency of the vehicles speed among all points is 62 which is after Road Hump 1. Besides, based on the following illustration, most of the vehicles move below the posted speed limit at Road Hump except for 3 cars which were between 31 km/h to 40 km/h. Apart from that, the lowest vehicles speed is 3km/h which was at the Road Hump. From the frequency curve, it showed that the vehicles move at a lower speed at the road hump. From the graph, frequency curve at road hump is slightly inclined to the left. This is because the deceleration occurred when the vehicles started approaching the road hump. In contrast, the frequency curve after the road hump shows a slight incline to the right because the vehicles move at the higher speed when leaving the road hump which the drivers started to accelerate.

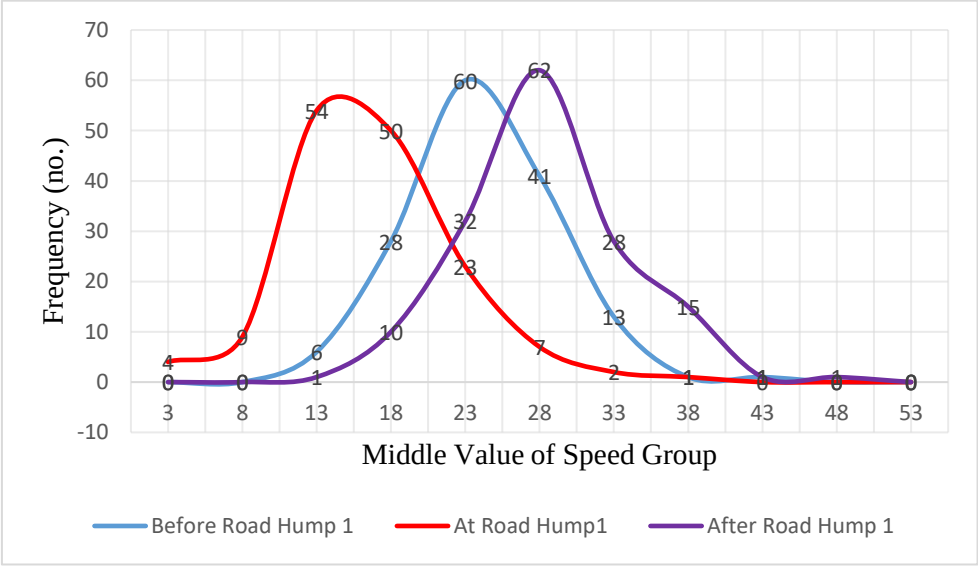

Figure 11. Frequency curve of vehicle speed for Road Hump 1

Road Hump 2

According to figure 12, the lowest vehicles speed is 18 km/h, which is at Road Hump. From the figure below, most of the vehicles exceed the posted speed limit (30km/h) especially after the

road hump which comprises of 94%. At the Road Hump 2, most of the vehicles travel at the speed of 23 km/h indicating 94 vehicles. In this case, 23km/h is considered as a high speed because drivers usually slow down their vehicle at the road hump. Due to the road hump design profile as not following the minimum height from the guideline, the drivers tend to speed their vehicles despite the presence of a road hump.

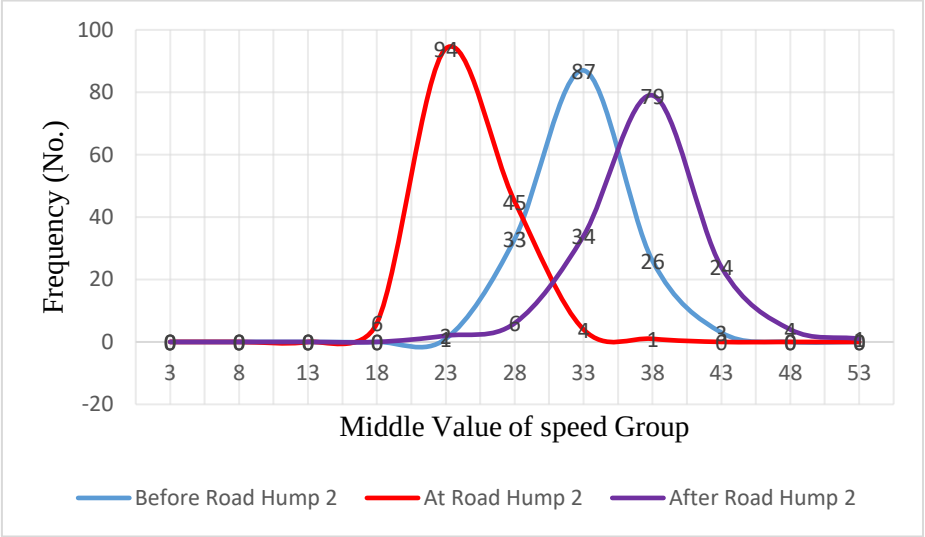

Figure 12. Frequency curve of vehicle speed for Road Hump 2

Road Hump 3

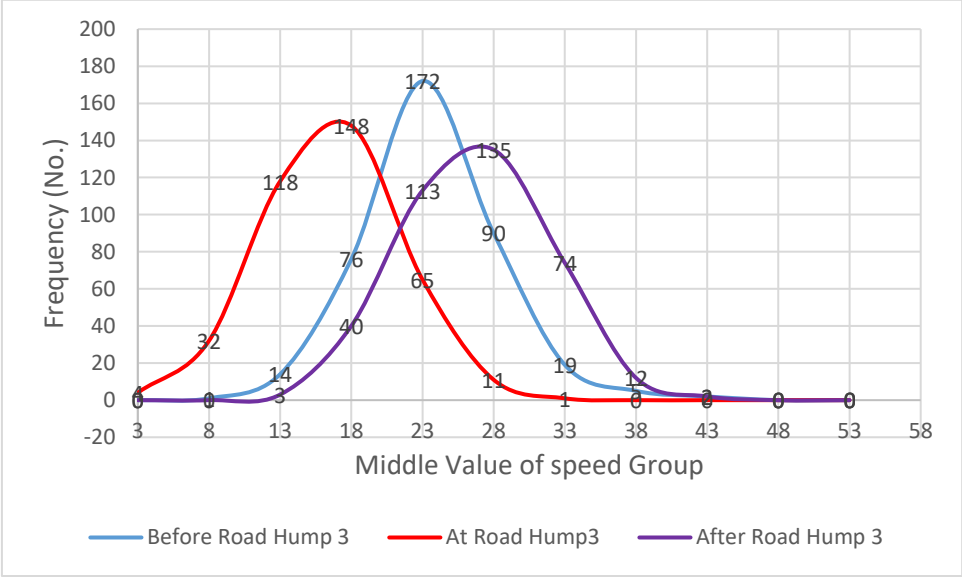

Figure 13. Frequency curve of vehicle speed for Road Hump 3

Based on figure 13, the highest frequency of vehicles speed among all points is 172 which is before the road hump and the speed is between 23 km/h to 27 km/h. Besides, the frequency curve also indicates that only 1 vehicles move beyond the speed limit at the Road Hump 3. At the road hump, most of the vehicles are moving at the speed of 18 km/h to 22 km/h with the frequency of 148 cars. Furthermore, the pattern of the frequency curve after the road hump is slightly incline to the right due to vehicles started to accelerate when leaving the road hump.

The pattern of the frequency curve for Road Hump 1 and 3 is slightly same due the dimensions of the road hump itself.

Thus, From the figures (Figure 11, 12 and 13), it can be seen clearly that most of the vehicle move beyond the posted speed limit at the Road Hump 2 compared to at Road Hump 1 and 3 due to the design characteristics of road humps, precisely the height, and length of road hump. However, the height of the road hump plays a major factor in influencing the speed of vehicles.

6.3.2 Speed characteristics

Mean, Modal and Median Speed

Table 3. Mean, Modal and Median Speed (km/h) of vehicles for Road Hump 1, Road Hump 2 and Road Hump 3

	Dimension of Road Hump			30 m before			At			30 m after		
	Height (mm)	Width (meter)	Length(meter)	Mean Speed	Median Speed	Modal speed	Mean Speed	Median Speed	Modal speed	Mean Speed	Median Speed	Modal speed
Road Hump 1	120	7	2.4	24.39	24.12	20	16.75	16.21	13	28.39	28.06	30
Road Hump 2	70	7	3.5	33.11	33	30	24.58	24.24	24	37.37	36	37.37
Road Hump 3	94	7	2.88	25.47	25	23	18.56	19	18	28.69	29	30

Table 3 shows the mean, modal and median speed for the Road Hump 1, Road Hump 2 and Road Hump 3 at the selected three points. For Road Hump 1, the average or the mean speed before and at the road hump are reduced by roughly 8 km/h, and accelerated to by 12 km/h from the road hump to after the road hump. The table also shows that 50% of the vehicles drove approximately 24 km/h before approaching the road hump, 16 km/h at the road hump and 28km/h after passing the road hump. Besides, for Road Hump 2, the mean speed reducing from 33.11 km/h before the road hump to 24.58 km/h at the road hump, and accelerating to 37.37 km/h after the road hump. Furthermore, 50% of the vehicles were driven approximately 33 km/h before approaching the road hump and 36 km/h after passing the road hump. Meanwhile for Road Hump 3, the average speed before and at the road hump are reduced by roughly 7 km/h and accelerated from the road hump to after the road hump by 10 km/h. Besides, the table also shows that 50% of the vehicles drove below the speed limit at the three points which is 25 km/h, 19 km/h and 29 km/h respectively.

It can be summarized that the mean speed for Road Hump 2 in these three points (30m before road hump, at road hump, 30m after road hump) is higher compared to the mean speed for Road Hump 1 and Road Hump 3. This is due to the different design profiles of road humps. The dimensions of the road hump affect the speed of vehicles. For example, the Road Hump 1 and Road Hump 3 has 120 mm and 94 mm of height while Road Hump 2 has 70 mm in height; therefore, the drivers tend to slow down their vehicles at the higher hump compared to the lower height. As stated in the table above, it is clearly shown that the mean speed at Road Hump 2 is higher compared to the Road Hump 1 and Road Hump 3 which is 24.58km/h compared to 16.75km/h and 18.56km/h.

In addition, from median speed which also known as 50th percentile speed, most of the vehicles are traveling below the posted speed limit (30 km/h) except before and after the road hump 2. Even though road hump installation reduced the speed of the vehicles while approaching the road humps, it is still lacking in ensuring the vehicles move at or below the posted speed limit.

85th and 15th Percentile Spot Speed

Speed percentiles are the tools used to determine effective and adequate speed limits. The 85th percentile of speed is normally assumed to be the highest safe speed for a roadway section.

Table 4. 85th and 15th Percentile of Spot Speed (km/h) at Road Hump 1, Road Hump 2 and Road Hump 3

	Dimension of Road Hump			30 m before		At		30 m after	
	Height (mm)	Width (meter)	Length(meter)	85th Percentile	15th Percentile	85th Percentile	15th Percentile	85th Percentile	15th Percentile
Road Hump 1	120	7	2.4	29.54	19.70	22.67	11.53	34	23.13
Road Hump 2	70	7	3.5	35.97	30.07	27.47	21.61	41.20	33.42
Road Hump 3	94	7	2.88	29	25	24	13	34	24

From the table 4, for Road Hump 1, the 85th percentile indicated that the vehicles speeding 29.54 km/h before the road hump, 22.67 km/h at the road hump and 34 km/h after the road hump. At 85th percentile, the vehicles move below the posted speed limit at 2 points which before and at the road hump but they started to accelerate after passing it which the speed is exceeding the speed limit. While for the 15th percentile, the vehicles move below the speed limit at 3 points which are before (19.70km/h), at (11.53 km/h) and after (23.13 km/h) the road hump.

Besides, for Road Hump 2, table 4 shows 15 percent of the vehicles traveling at or below the speed limit (30km/h) at the road hump and before the road hump which was 21.61 km/h and 30.07 km/h respectively. While after the road hump, 15 percent of vehicles move at speed of 33.42 km/h which is above the speed limit. The 85th percentiles indicated that 15% of the vehicles were speeding more than 35.97 km/h before approaching the road hump, more than 27.47 km/h at the road hump and more than 41.20 km/h after passing the road hump. While, for Road Hump 3, at 85th percentile, the vehicles move beyond the speed limit after passing the road hump which is 34 km/h. At 15th percentile, the vehicles move below the speed limit at 3 points which are before, at and after.

Thus, it can be concluded that 85 percent of the vehicles move at or below the speed limit at these three road humps at the speed of 22.67 km/h (at road hump 1), 27.47 km/h (at road hump 2) and 24 km/h (at road hump 3). Therefore, the installation of road humps encourages the drivers to reduce the speed of their vehicles at the road hump. In addition, 15 percent of cars are traveling at or below the posted speed limit (30km/h) at all selected points except before Road Hump 2 and after Road Hump 2. However, the vehicles had the tendency to increase their speed depending on the design profile of road humps. The design profile of Road Hump 2 fails to encourage the drivers to slow down their cars, in turn, accelerating their vehicles due to the unfit design of the road hump.

Standard Deviation of Spot Speed

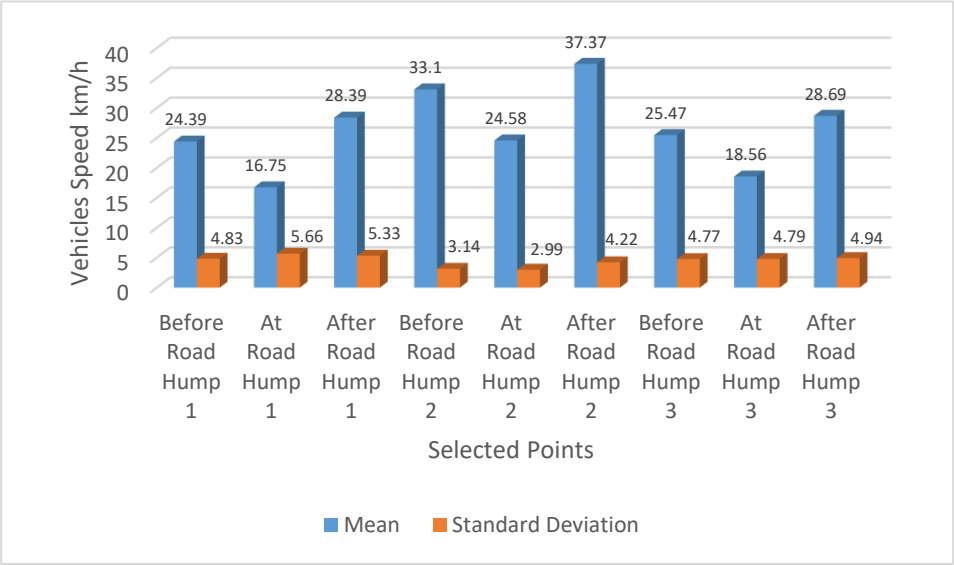

Figure 11. Comparison of Mean Speed and Standard Deviation for Road Hump 1, 2 and 3

Standard deviation is a statistical measure of dispersion used to determine how far the observed spot speeds in the speed distribution spreads around the mean speed that has been calculated. In this study, the standard deviation was calculated automatically using SPSS.

Figure 11 shows that the speed of samples collected has a wide variation between 4.83 km/h to 5.66 km/h for Road Hump 1 while 2.99 km/h to 4.22 km/h for Road Hump 2. Therefore, the spread of spot speed collected is in the heterogeneous pattern. The wide spread of speed can be seen at all six points of the road humps especially after the road hump 2 (33.15 km/h) and before the road hump 2 (29.96 km/h). In conclusion, the speed spread for Road Hump 2 is wider compared to the Road Hump 1 and Road Hump 3.

6.3.3 Testing the Difference in Spot Speed

In order to identify the significant differences in the speed of vehicles that are traveling along the institutional road, the vehicles speed at Road Hump 1, at Road Hump 2 and at Road Hump 3 are tested using t-test. The variable and hypothesis tested are as below:

i) Variables
   - Speed of 150 vehicles at Road Hump 1
   - Speed of 150 vehicles at Road Hump 2
   - Speed of 379 vehicles at Road Hump 3

ii) Research Hypothesis
   H1: Differences in road hump dimensions can cause the changes in speed of vehicles.

The results of the t-test generated for vehicles speed are as below.

Table 5. Testing the Differences in Spot Speed at Road Hump 1 and At Road Hump 2

TESTING THE DIFFERENCES IN SPOT SPEED AT ROAD HUMP 1 AND AT ROAD HUMP 2						
T-Test: Two-Sample Assuming Unequal Variances | 95% Confidence Interval						
Variable	Means	Std Dev.	df	t	p-value	M Diff.
At Road Hump 1	16.75	5.66	226	14.96	0.000	7.83
At Road Hump 2	24.58	2.99				

Table 6. Testing the Differences in Spot Speed at Road Hump 1 and At Road Hump 3

TESTING THE DIFFERENCES IN SPOT SPEED AT ROAD HUMP 1 AND AT ROAD HUMP 3						
T-Test: Two-Sample Assuming Unequal Variances | 95% Confidence Interval						
Variable	Means	Std Dev.	df	t	p-value	M Diff.
At Road Hump 1	16.75	5.66	238	3.45	0.000	1.81
At Road Hump 3	18.56	4.79				

Table 7. Testing the Differences in Spot Speed at Road Hump 2 and At Road Hump 3

TESTING THE DIFFERENCES IN SPOT SPEED AT ROAD HUMP 2 AND AT ROAD HUMP 3						
T-Test: Two-Sample Assuming Unequal Variances | 95% Confidence Interval						
Variable	Means	Std Dev.	df	t	p-value	M Diff.
At Road Hump 2	24.58	2.99	430	17.33	0.000	6.02
At Road Hump 3	18.56	4.79				

Table 5, 6 and 7 shows the t-test result for Road Hump 1 and Road Hump 2, Road Hump 1 and Road Hump 3 as well as Road Hump 2 and Road Hump 3. Based on the result of the t-test, it shows that the mean speed at the road humps has been identified that three independent variables had been tested indicate the p –value of 0.000. This illustrates that there was a statistically significant change in speed of vehicles.

Based on table 5, the mean speed at Road Hump 1 and Road Hump 2 which (16.75 ±5.66) and (24.68±2.99) respectively was lower than the posted speed limit (30km/h). It can be defined that the mean speed at the road hump was statistically lower by 7.83 t (14.96), p= 0.001<0.05. Besides, the t-test result for Road Hump 1 and Road Hump 3 (refer table 6) shows the different in mean speed between both road hump was statistically lower by 1.81km/h. In addition, the p-value also shows 0.001<0.05, which statistically indicates that the installation of the road hump does reduce the vehicles speed in an institutional area. Table 7 shows the mean speed at the Road Hump 2 and Road Hump 3 which (24.58±2.99) and (18.56±4.79) respectively was below than the speed limit in the study area which is 30 km/h. Besides, the mean speed at the road hump (Road Hump 2 and Road Hump 3) was statistically lower by 6.02 t (17.33), p=0.001<0.05. It can be concluded that the road hump does reduce the speed of vehicles on the road hump.

Thus, the result of the t-test shows that there was a significant change in terms of speed of vehicles. The changes in the speed of vehicles depends on the road hump design characteristics. Therefore, it can be said that the design profile of the road hump played an important role in reducing the speed of the vehicles. As the Road Hump 1, Road Hump 2 and Road Hump 3 have different design characteristics, the speed changes are also slightly different.

7. CONCLUSIONS

The effect of road humps in reducing the vehicle speed is undeniable. Based on the Local Transport Note (March 2007) produced by Department of Regional Development (Northern Ireland), “road hump are the most widely used form of traffic calming device because they proved to be effective at controlling speeds and are generally applicable to most layout”. It was further supported by Papacostas and Prevedourus (2001), road humps are the most popular traffic calming devices in the United States to reduce the vehicles speed.

Therefore, this research was conducted to identify the effectiveness of the road hump installation in IIUM Gombak Campus. This research was executed on three road humps in IIUM circular road which are Road Hump 1, Road Hump 2 and Road Hump 3. The spot speed data of vehicles before, at and after the road hump were collected in order to analyse the speed changes at three different points for three road hump. The finding portrayed there are significant differences in the speed at the selected points. The design profile of road hump especially the height of the road hump influence the changes in speed of vehicles that passing it. This can be seen by the different pattern of speed recorded for three road humps. Hence, the changes made in designing the road humps might change the speed of vehicles especially in campus area as well as change the driving behavior of the driver. However, further studies are needed for a comprehensive understanding of the issues and providing a new dimension in the to the study area in ensuring heightened conducive living environment in the campus area. Nevertheless, currently, road hump is still perceived as one of the best methods to reduce the speed level at the institutional area.

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