Evaluating the Effects of Road Hump on Speed and Noise Level at a University Setting

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Abstract: This study is carried out to determine the effectiveness of road humps to reduce the traffic speed and traffic noise in institutional area. The difference in hump profiles in term of height, width and length are the main factors in determining the effectiveness of road humps. The difference in the profiles of the road hump will cause changing driving behavior of the users especially when approaching the road hump. The road humps with different design profiles are selected to measure the speed and noise level of the vehicles at, before and after each of the selected road humps. Radar speed gun and noise level meters are used to measure speed and noise level of the vehicles at each of designated points along the major circular road in IIUM. The changes in speed and noise level at different selected points at each of the different design profiles of the road humps are the expected findings of this study.

Keywords: Traffic Speed, Traffic Noise, Road Hump Profiles, Institutional Area

1. INTRODUCTION

A healthy, conducive and safe learning and research environment are vital for active involvement in research and learning activities. But, the increase in private vehicle use on-campus has caused an increase in speed and noise level and thus caused deterioration on campus environment. Huang and Cynecki (2000) noted that traffic calming is a viable solution for the deterioration of living conditions caused by increased vehicle speed and noise by giving an impression that the road is not meant for high-speed traffic. Considering several possibilities of traffic calming measures, several researchers have suggested that road hump has the ability to effectively control the speed and noise of the moving vehicles. The analysis of 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 *et al.* (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. On the other hand, Traffic Advisory (1994) highlighted that the presence of a speed cushion or road humps can result in a substantial drop in traffic noise levels. Meanwhile, Desarnaulds *et al.* (2004) mentioned that a report on the towns of Slough and York shows that the reduction of noise level and the difference in speeds between the cushions, from 2 to 12 km/h, is 0.45 dBA/km/h. However, the effectiveness of road hump on the changes in vehicle speed and noise level in an institutional area has yet to be investigated in depth. Hui Min and Che Ros mentioned in their study, road humps have been implemented in Malaysia especially in the 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 Bachok *et al*. (2016) also focusing on the effect of road hump in a residential area.

From the literature study, the road humps with different design characteristics in terms of its width, length and height have resulted in changes in driving behavior of the users when approaching these road humps. As a result, it is observed that road humps at a certain locations has provided positive effects in reducing the speed and noise level but at the same time, it was also observed that other road humps have induced almost no effects on speed and noise level of the vehicles. Thus, it necessitates the importance of knowing the changes in driving behavior of the users especially in terms of speed when approaching road humps with different design characteristics. Therefore, the purpose of this study is to identify how effective the road humps installation in controlling the traffic speed and traffic noise in campus area. Three different profile of road hump in term of height, width and length were selected as a determining factor to identify the effects of road humps on the traffic speed as well as traffic noise.

2. LITERATURE REVIEW

2.1 Road Hump Design in Malaysia

Muhammad Marizwan & Alvin Poi (2010) quoted that Highway Planning Unit, Ministry of Works, (2002) has listed non-standard design of road hump as one of the problems in traffic calming implementation in Malaysia (p. 4). Additionally, Highway Planning Unit, Ministry of Works (2002) also mentioned that road hump are raised areas of a pavement typically with a rounded or flat-top, usually 3.5 m to 4.0 m wide and 3.65 m, 6.71 m and 9.14 m long. Road humps also have profiles that are sinusoidal, circular, parabolic or flat-topped.

Malaysian Ministry of Road Works (2012) during the seminar in Kuala Lumpur suggests several road hump designs and specifications as follows:

Table 1.Road Hump Specification by Malaysian Ministry of Road Works (2012)

Material Used	Dimension
Asphaltic Premix Wearing Course	a) flat-top hump height: 75mm-100mm length: 2.5m-4m
	b) round-top hump height: 50mm-100mm length: 3.7m-4m
	c) sinusoidal hump height: 75mm-100mm length: 3.8m-4m

Source: Malaysian Ministry of Road Works (2012)

Positively, theoretical findings by Bachok *et al.* (2016) recommended hump heights of 50 mm -100 mm and lengths of approximately 3m - 4m to achieve vehicle speeds within the 35 km/h speed limit in Malaysian urban residential area. Further research by Bachok *et al.* (2017) also indicated the guidelines of road humps by Malaysian Ministry of Road Works (2012) and SIRIM, (2009) which is given in Table 2.

Table 2.Guidelines for Road Hump in Malaysia

Source	Dimension	Spacing	Others
Malaysian Ministry of Works, 2012	a) Flat-Top Hump; Height: 75mm-100mm, Length: 2.5m-4m	100m	1) Vehicle speed between 30km/h to 60km/h
	b) Round-Top Hump; Height: 50mm-100mm, Length: 3.7m-4m		2) Allowed on district road, residential road, access road, rural road
	c) Sinusoidal Hump; Height: 75mm-100mm, Length: 3.8m-4m		3) Road Geometry: 2-way and 2-lane roads with no kerbs
			4) Should not be located near road intersections
SIRIM, 2009	a) Parabolic Hump; Height: 75mm-100mm, Length: 3.7m-4.25m	Mentions that a spacing of 90m to 180m reduces 85th percentile speeds by 12km/h to 15km/h	1) Construction tolerance of +3mm
	b) Circular Hump; Height: 75mm-100mm, Length: 3.7m-4.25m		
	c) Sinusoidal Hump; Height: 75mm-100mm, Length: 3.7m-4.25m		

Source: Malaysian Ministry of Road Works, 2012; SIRIM, 2009

Table 2 indicates the differences between the suggested road hump dimensions by Malaysian Ministry of Road Works (2012) and SIRIM, (2009). This indicates that, there are no standardized guidelines for the implementation of road humps in Malaysia.

2.2 Effects of Road Hump on Traffic Speeds

Not much literature has discussed the effects of road hump design, namely the profile and spacing, on traffic speed, noise and traffic volume in one study; the previous study done by Salau, *et al.* (2004) and Sundo & Diaz, (2001) focused only on the effects on traffic speed.

In the inhabited zones where a large number of pedestrians and other vulnerable road users are expected, like school zones, it is necessary to decrease the speed to such a level that the risk of vulnerability is the lowest possible (Antić *et al.*, 2013). Thus, increased vehicle speed in residential and other traffic calming areas have adverse effects on social street activities, particularly impacting the safety of pedestrians in the case of any pedestrian-vehicle conflicts (Appleyard *et al.*,1981; Muhammad Marizwan & Alvin Poi, 2010).In addressing the problem of increased vehicle speed, previous researches agree that road humps are effective at significantly reducing the 85th percentile of vehicle speed (Ewing, 2001; Huang & Cynecki, 2000).

A study also showed that with a spacing of 70m between road humps, the 85th percentile speed recorded 30m before and after the second hump was 31.88 km/h and 33.20 km/h (Yaacob & Hamsa, 2012). Parkhill *et al.*, 2007 has listed the hump profile as another factor affecting the effectiveness of a road hump; further elaborating that an incorrect hump profile would potentially cause discomfort to the users and reduces the effectiveness of a hump in encouraging drivers to slow down.

In addition, Antić *et al.* (2013) have evaluated the effectiveness of humps 30mm, 50mm and 70mm height in an inverse proportional to the traffic volume and found that all three heights were capable of significant speed reductions; nevertheless, they noted that the speed recorded reduced with an increase in height. Besides, it was further supported by Bachok *et al.* (2016); the height and length of the road hump should be between

50mm-100mm and 3m-4m respectively in order to achieve the vehicles speeds within 35 km/h in a residential area.

2.3 Effects of Road Hump on Traffic Noise

Research by Harris *et al.* (1999) indicates that humps with a sinusoidal profile have been reported as being more comfortable for cyclists, and possibly also for car drivers, but there has been little information as to the relative difference between the profiles regarding their impact on noise and ground-borne vibration levels. This is agreed by Kojima *et al.* (2011) and Sayer *et al*. (1999). Whereby from 1990 several researchers to reduce noise and vibration of road humps were conducted to find "sinusoidal" shape is the best from the viewpoint of noise and vibration as well as passenger's comfort. Additionally, sinusoidal humps cause little noise and vibration when cars pass over. It rather reduces noise as a result of the effect of speed reduction. Cause of the noise was not the shock of traffic passing through humps but the re-acceleration of cars after passing humps (Kojima *et al*., 2011).

From the previous studies done by Layfield and Webster (1997), the installation of traffic calming measures such as road hump resulted in reducing the traffic accidents, speeds as well as the traffic noise. As an example, lowering the speed of vehicles may mean that vehicle noise emission levels are lowered. In addition, after the measures are installed, traffic flows may be reduced which leads to the reduction in noise levels.

According to Hidas (1997), even though some studies indicated that residents are often concerned that the installation of traffic calming devices will raise noise levels in the community but it was proved by Clark (2000), study conducted in the United States which indicated that the lower speeds resulting from the proper design and application of traffic calming measures tend to lower noise levels. Furthermore, this statement was supported by the European studies, cited by Cline and Dabkowski (2005) that, alongside the speed reduction, there was a reduction in noise of around 10%.

3. GOAL AND OBJECTIVES

3.1 Goal

Investigating the effects of road hump profile on the speed of vehicles at an institutional area.

3.2 Objectives

1. To evaluate the design characteristics of road humps as a traffic calming measure with the recommended design characteristics for a University setting.
2. To analyse the speed and noise level of the vehicles at selected points near road humps along a major road in a University.
3. To compare speed and noise level measured at different design characteristics of road humps along a major road in a University.

4. STUDY AREA

International Islamic University Malaysia (IIUM) is located in Gombak district in Selangor. The campus situated at 10 kilometers away from Kuala Lumpur city center and covers about 710 acres of land. 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 RapidKL Bus. The vehicular road network system in this campus is based on a loop roadway concept. The road connects the main academic, administration, central facilities and residential areas. 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 block) and has single carriageway with two lanes (two-way traffic).

The increase in car registered vehicle (staff and student) in IIUM Gombak was from 8895 in 2015 to 8915 in 2016 (0.22% increase) meanwhile motorcycles from 4189 in 2015 to 4386 in 2016 (4.5% increase) according to IIUM Traffic Unit in 2016. The increasing number of vehicle may cause detrimental effect to the studying environment of the institution if not controlled properly.

Generally, International Islamic University Malaysia (IIUM) is one of the institutional areas that applies road humps as a safety measures as well to control the moving traffic within the posted speed limits (30 km/h). This study focuses on a one-way major road provided with road humps in IIUM campus. The major road on-campus consists of 19 road humps. However, only three road humps were selected for this study having different design profiles. The first road hump (RH1) is located in front of Kuliyyah (Faculty) of Engineering, the second road hump (RH2) is located near IIUM clinic and third road hump (RH3), located at Mahallah Salahuddin (Salahuddin residential block). The selection of these three road humps is due to the road hump profiles as well as the surrounding environment which will affect the speed produced. RH1 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. Besides, the location of RH2 and RH3 is at the slope area which will also affect the speed produced by the vehicles.

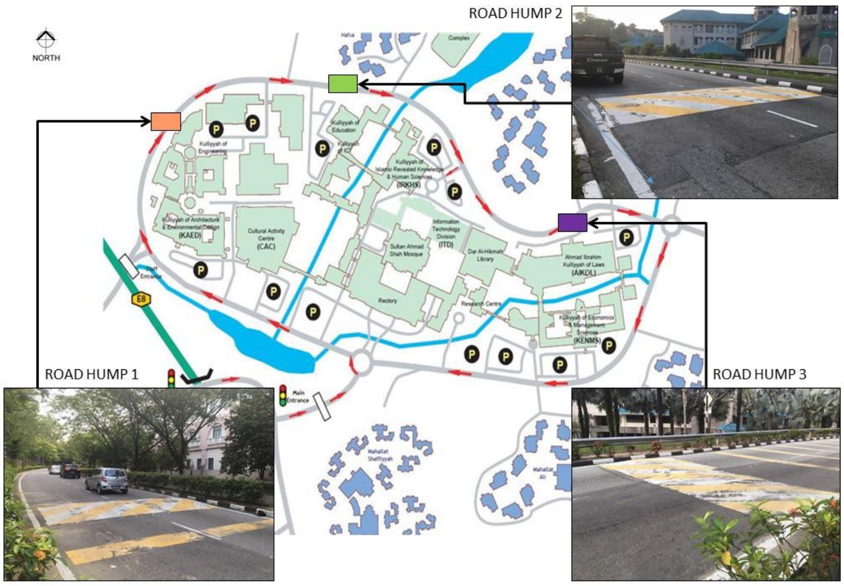

Figure 1. Photos of Each Selected Road Humps

5. RESEARCH METHODOLODY

5.1 Method of Data Collection

5.1.1 Road and road hump geometry

Field observation and inventory surveys were conducted to collect data pertaining to road and road hump geometry. Field observations were recorded using photographs. The data collected were the dimension of the road, hump profile and presence of road signs that indicate the presence of road humps. The inventory survey was conducted using a measuring tape to measure the road and road hump dimensions. The data collected include width of the road and the width of the right of way (R.O.W), road hump dimensions (height, width and length).

5.1.2 Traffic speed

Spot speed survey was conducted to collect the traffic speed. The spot speed data was measured by using Stalker Lidar XS radar guns and the survey was carried out simultaneously with noise level survey. Three enumerators were assigned to each road humps, with three points covered each day. Speed was measured for all types of vehicles (car, motorcycle, lorry and bus), which were then recorded in the survey form. In order to conduct the spot speed survey, three road humps have selected namely Road Hump 1, Road Hump 2 and Road Hump 3. The design profiles in terms of height, length and width of these road humps differ from each other. These humps were placed at different location along the institutional road. A straight stretch of the road with the installation of road humps was selected. A total of three points was selected for data collection at each road hump.

Point 1: 20 meters before the Road Hump
Point 2: at the Road Hump
Point 3: 20 meters after the Road Hump

Thus, the speed data were measured whenever the vehicles approaching these points. The spot speed survey was conducted during the weekdays specifically on Tuesday, Wednesday and Thursday. The sample size for motorcycle, car and bus/lorry are 300,300 and 100 respectively. Figure 2 illustrated the spot speed survey for data collection by using Stalker Lidar XS radar guns.

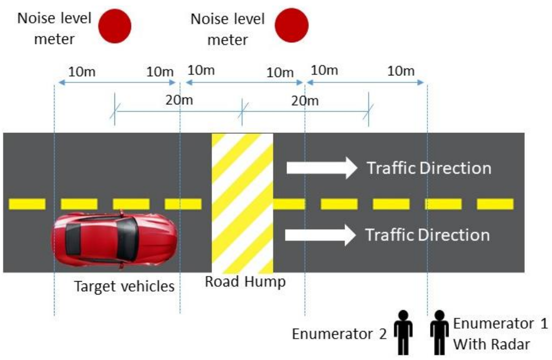

Figure 2. Illustration of spot speed survey

5.1.3 Traffic Noise

Traffic noise level survey was conducted to assess the noise levels caused by moving traffic. The noise level survey was conducted on 23rd May 2017, 24th May 2017 and 25th May 2017 and it was conducted simultaneously with the spot speed survey. Three road humps have been selected for the measurement of the noise level. The noise level meter were located at the edge of the sidewalk of the chosen road hump at a distance of 1 meter from ground level. Besides, the noise level was measured every 15 minute time interval. The data was recorded for a minimum 7 (7.15 am to 15.30 pm) hours maximum of 11 (7.15 am to 18.30 pm) hours, subjected to rainy weather conditions. The noise survey was conducted for a day at each selected point of the road hump (before Road Hump and immediately after the Road Hump).

5.2 Method of data analysis

After the site inventory and spot speed survey, the data collected need to be analysed. There are various methods of analysis that have been used in presenting the data collection in order to achieve the goal and objectives of the study. For primary data, the descriptive analysis and T-test analysis were applied. T-test used in order to analyse the significant level of the spot speed data and noise level data collected. Descriptive analysis was applied on the existing traffic speed and traffic noise data taken during the field survey as well as the inventory data on road and road hump geometrics. The spot speed data was tabulated for the calculation of the mean speed, median speed, 85^{th} percentile and standard deviation speed. In addition, the noise level was analysed using the NoiseTools software that comes with the Cirrus noise level meters, which identified L10, L90, Lmax, Lmin and LAeq at every 15-minute time interval during the selected measurement period. The variations in the noise level at different time intervals were shown by line charts.

In this research, the T-test analysis used in order to analyse the significant level of the speed and noise data collected. Independent T-test is used when we want to evaluate whether the means for two independent groups are significantly different from each other. This test was run using SPSS.

6. ANALYSIS AND FINDINGS

6.1 Geometrical Details of the Road

The selected institutional road is a straight road with the installation of 19 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 R.O.W recorded was different for every location of road hump. Refer table 3 for summarization of road geometric for each road hump selected. The geometrical details of the road also will affect the vehicles speed.

Table 3.The Road Geometric for Road Hump 1, 2 and 3

	Number of lane	Carriageway width (m)	Pedestrian walkways (m)	Drainage (m)	Reserved (m)
S1 (RH1)	2	6.38	2.10	2.15	3.15
S2 (RH2)	2	6.45	2.0	1.2	5.57
S3 (RH3)	2	6.62	2.10	0.85	8.3

6.2 Design Characteristics of Road Hump

From the inventory survey on the design characteristic of road humps, it is found that the design of these three road humps were circular but different in height and length. Table 4 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.

Table 4. Comparison of Design Characteristics of Road Humps

Design Characteristics	Road Hump 1	Road Hump 2	Road Hump 3	Ministry of work specification
Height	94 mm	70 mm	80 mm	75 mm - 100 mm
Width	6.38 m	6.45 m	6.62m	12.5 m
Length	2.88 m	2.42 m	2.66 m	3.7 m - 4.25 m
Colour	White-yellow striped	White-yellow striped	White-yellow striped	Black-yellow striped

In term of the length and width, these three road humps do not meet the minimum requirement by the Ministry of Works. 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 behaviour as well as the speed of vehicles in that area.

6.3 Spot Speed Analysis

6.3.2 Speed characteristics at road hump 1

Table 5 lists the speed characteristics for vehicles for Road Hump 1. The speed characteristics listed are the maximum and minimum speeds, mean speed, median/50th percentile speed, modal speed, standard deviation and 85th percentile speed for all types of vehicles. From the table, the mean speed recorded at all points for all type of vehicles except for motorcycle after the road hump is lower than the posted speed limit at the study area which is within 30km/h. It is presumed that the lower speeds are due to Road Hump 1 have the highest height compared to Road Hump 2 and Road Hump 3. Besides, the highest speed recorded at the road hump were posted by motorcycle which is 39km/h. For the other vehicles, the speed recorded are within the posted speed limit at the Road Hump 1.

Table 5. Speed characteristics for vehicles at Road Hump

Speed characteristics	Car (km/h)			Motorcycle (km/h)			Bus/lorry (km/h)		
	Before	At	After	Before	At	After	Before	At	After
Mean	25.38	18.57	28.58	29.70	25.42	33.49	22.39	14.82	25.71
Mode	24	18	29	30	26	32	25	18	27
Median	25	18	29	30	25.50	33	22	15	26.50
85th percentile spot speed	30	24	34	35	30	39.85	26	19	32
Standard deviation	4.769	4.649	4.904	5.342	5.230	5.364	3.944	4.496	5.088
Maximum	46	30	34	48	39	47	30	25	36
Minimum	11	7	14	15	4	19	12	3	13

6.3.3 Speed characteristics for road hump 2

Table 6 tabulates the speed characteristics for vehicles entering Road Hump 2. Bus and lorry posted lowest mean speeds at all points while the finding for motorcycles indicated otherwise. Even though the location of Road Hump 2 is slope area, the maximum speed recorded is 56 km/h which were posted by motorcycles. It is therefore concluded that heavy vehicles posted the lowest speed for these three points, while motorcycles posted the highest speeds at all points.

Table 6. Speed characteristics for vehicles at Road Hump 2

Speed characteristics	Car (km/h)			Motorcycle (km/h)			Bus/lorry (km/h)		
	Before	At	After	Before	At	After	Before	At	After
Mean	27.19	27.19	30.83	36.25	30.27	38.40	22.15	15.33	24.04
Mode	24	19	29	32	33	37	14	18	27
Median	26.75	20.40	30.76	36.03	30.03	37.71	22.25	15.44	24
85th percentile spot speed	32.68	25.03	35.74	43.90	36.59	45.94	29.70	20.82	30
Standard deviation	5.231	4.552	4.703	6.958	5.906	6.788	6.911	5.211	5.773
Maximum	47	37	45	56	47	56	40	29	38
Minimum	15	6	18	18	13	18	10	5	12

6.3.4 Speed characteristics for road hump 3

Table 7 tabulates the speed characteristics for vehicles for Road Hump 3, which the maximum and minimum speeds, mean speed, median/50th percentile speed, mode speed, standard deviation and 85th percentile speed for all types of vehicles. The height of this road hump meet the minimum requirement standard by Ministry of Work which is 80mm, but the location of this road hump may affect the speed of the vehicles. For 85th percentile speed, all vehicles except cars and bus/lorry at Road Hump 3 produced higher speed which is exceeded the posted speed limit. Compared to Road Hump 1 and 2, the maximum speed recorded for Road Hump 3 is the highest which is 71 km/h before approaching the Road Hump.

Table 7. Speed characteristics for vehicles at Road Hump 3

Speed characteristics	Car (km/h)			Motorcycle (km/h)			Bus/lorry (km/h)		
	Before	At	After	Before	At	After	Before	At	After
Mean	31.95	18.60	30.95	34.31	26.81	35.69	27.09	14.82	28.10
Mode	32	17	31	40	24	33	22	14	30
Median	32.09	18.16	31.38	33.61	26.46	35.06	26.33	13.83	28.26
85th percentile spot speed	39.71	23.62	38.29	40.86	32.88	41.41	34.89	19.80	35
Standard deviation	7.127	4.765	6.704	7.155	6.231	6.188	6.352	5.252	7.115
Maximum	50	37	47	71	52	58	42	35	45
Minimum	12	7	15	18	8	22	13	4	10

6.3.5 The changes in mean speed for road hump 1, road hump 2 and road hump 3

From table 8, for changes in speed at and after, 47.26% (acceleration in speed from 14.82km/h to 28.1km/h) was the highest percent in changes of mean speed which produce by bus and lorry at Road Hump 3. Moreover, Road Hump 3 also produce the highest speed increased for car and motorcycle which was 12.35km/h and 8.88 km/h respectively. Besides, for changes in speed before and at, the lowest average speed reduction was 4.29km/h (14.44%) which produced by motorcycle at Road Hump 1. For car and bus/lorry, the lowest changes in speed was 6.67km/h and 6.82 km/h respectively. The difference in the average speed reduction is due to the design profile of road hump. As an example in table 4.8, car and bus/lorry at Road Hump 2 produced the lowest changes in mean speed before and at the road hump, this is due to the height of this hump is lower compared to the height of Road Hump 1 and Road Hump 3.

Table 8. The changes in mean speed

Speed (km/h)	Before (B) (km/h)	At (A) (km/h)	After (Af) (km/h)	B-A (km/h)	%B-A	Af-A (km/h)	%Af-A
ROAD HUMP 1							
Car	25.38	18.57	28.58	6.81	26.83	10.01	35.02
Motorcycle	29.7	25.41	33.49	4.29	14.44	8.08	24.13
Bus/lorry	22.39	14.82	25.71	7.57	33.81	10.89	42.36
ROAD HUMP 2							
Car	27.19	20.52	30.83	6.67	24.53	10.31	33.44
Motorcycle	36.25	30.27	38.4	5.98	16.49	8.13	21.17
Bus/lorry	22.15	15.33	24.04	6.82	30.79	8.71	36.23
ROAD HUMP 3							
Car	31.95	18.6	30.95	13.35	41.78	12.35	39.90
Motorcycle	34.31	26.81	35.59	7.5	21.86	8.88	24.88
Bus/lorry	27.09	14.82	28.1	12.27	45.29	13.28	47.26

6.4 TRAFFIC NOISE

6.4.1 Noise characteristics for road hump 1

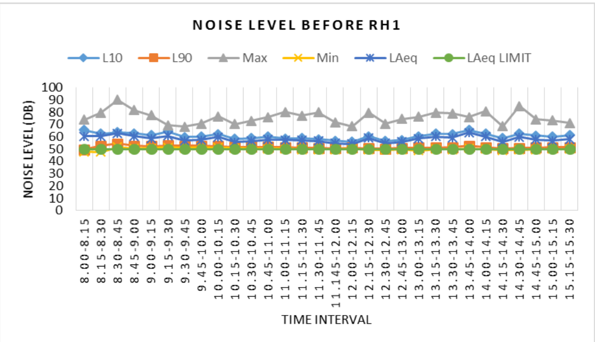

Figure 3. Noise Level before Road Hump 1

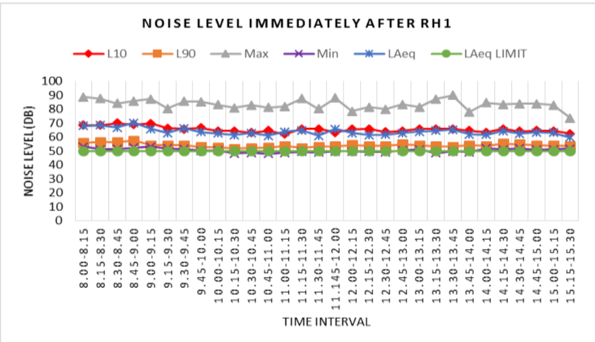

Figure 4. Noise Level immediately after Road Hump 1

Figure 3 and 4 indicate the noise level for Road Hump 1. As seen in the figures, the LAeq was above the permissible limit at this point. Throughout the survey period which was eight hours duration, the LAeq was above the permissible limit for institutional area at all interval. The highest noise produced was 90.10 dB which was between 13.15p.m to 13.30 p.m. for immediately after the hump while before the road hump, the highest noise produced was between 8.30 a.m to 8.45 a.m. The highest noise produced due to the height of the hump as well as the surrounding environment such as the slope area. Refer table 9 for noise characteristics for road hump 1.

Table 9. Noise characteristics for Road Hump 1

Point	Noise Level (dB)	Indicator				
		L_{10}	L_{90}	L_{max}	L_{min}	L_{Aeq}
Before RH	Mean	60.71	51.64	75.82	50.04	58.26
	Min	56.10	49.60	68.23	47.70	54.32
	Max	65.60	54.60	90.20	51.90	63.60
	SD	2.53	1.01	5.23	0.94	2.31
Immediately after RH	Mean	65.47	53.96	83.45	50.43	63.84
	Min	62.10	51.70	73.60	47.90	59.60
	Max	70.00	57.60	90.10	47.90	70.10
	SD	2.03	1.36	3.59	1.41	2.42

6.4.2 Noise characteristics for road hump 2

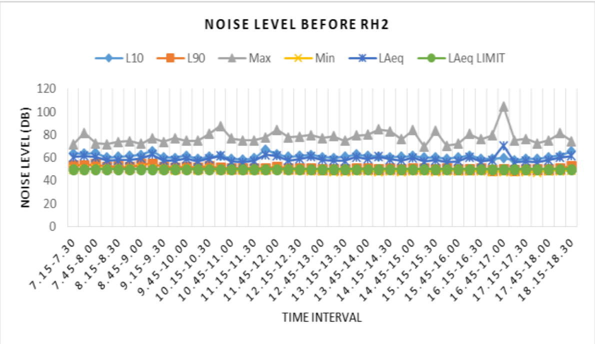

Figure 5. Noise Level before Road Hump 2

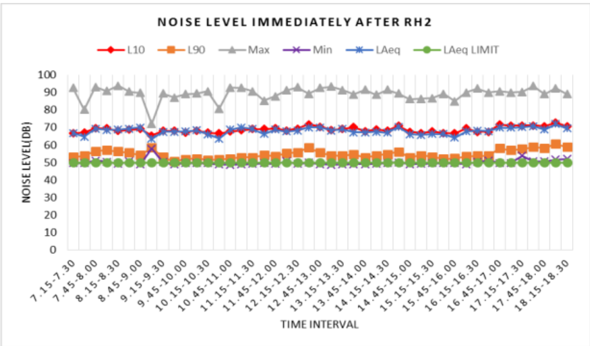

Figure 6. Noise Level immediately after Road Hump 2

Figure 5 and 6 illustrates variation of traffic noise over 11 hours. The noise level meter which was located before and immediately after road hump 2, measures the vehicle approaching and passing the road hump. The fluctuation of noise level at Road Hump 2 for every 15 minutes interval shown in Figure 4.29 and 4.30. From both figures, it clearly shown that the noise produce before the road hump is lower than the noise produce immediately after the road hump. This is because the vehicles was decelerate when approaching the road hump and start to accelerate after passing the road hump. The location of this road hump affect the noise produced. This hump is located at the slope area. So, the vehicles need to accelerate their vehicles which will produced more noise. Table 10 shows the noise characteristics for road hump 2.

Table 10. Noise characteristics for Road Hump 2

Point	Noise Level (dB)	Indicator				
		L_{10}	L_{90}	Lmax	Lmin	LAeq
Before RH	Mean	61.11	50.95	77.68	48.88	58.93
	Min	57.40	48.90	69.41	47.40	55.86
	Max	67.20	54.70	104.93	50.60	70.38
	SD	2.0	1.39	5.88	0.84	2.58
Immediately after RH	Mean	68.82	54.75	89.39	49.99	68.05
	Min	65.40	50.60	72.00	48.60	63.40
	Max	72.70	60.70	93.90	57.90	72.00
	SD	1.65	2.37	4.00	1.57	1.90

6.4.3 Noise characteristics for road hump 3

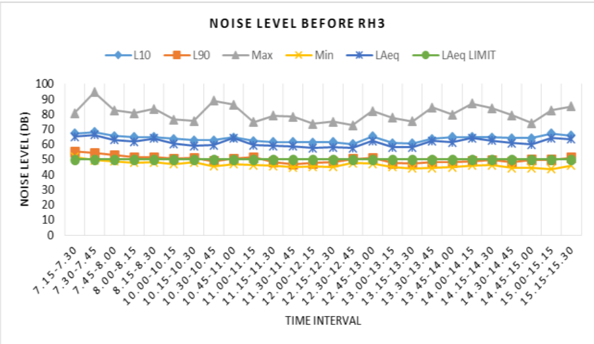

Figure 7. Noise Level before Road Hump 3

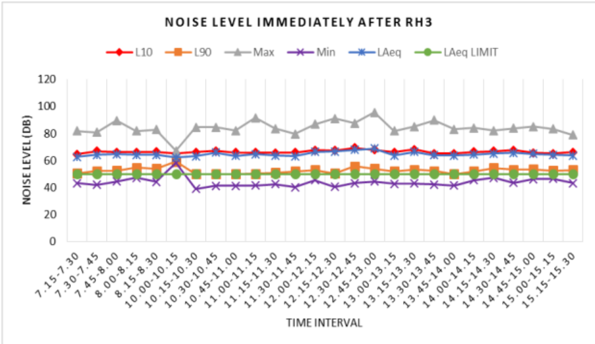

Figure 8. Noise Level immediately after Road Hump 3

The noise levels for Road Hump 3 can be seen in Figure 4.31 and 4.32. The LAeq was above the permissible limit by Department of Environment for all survey period of seven hours and at both point (before the RH and immediately after RH). Compared to other road humps, this hump produced the highest noise level (immediately after RH) which was 95.50 dB. The higher noise level produced was during off-peak hours. Refer table 11 for overall noise characteristics for road hump 3.

Table 11. Noise characteristics for Road Hump 3

Point	Noise Level (dB)	Indicator				
		L10	L90	Lmax	Lmin	LAeq
Before RH	Mean	63.84	49.98	80.55	46.37	61.19
	Min	60.10	47.00	72.71	43.80	57.58
	Max	68.10	55.30	94.61	51.70	66.41
	SD	2.15	2.09	5.35	1.88	2.59
Immediately after RH	Mean	66.44	52.52	84.21	43.88	64.74
	Min	64.80	49.90	67.10	39.10	62.30
	Max	69.30	59.30	95.50	58.30	69.00
	SD	1.09	2.13	5.26	3.65	1.58

Therefore, as a summary of noise level produced by these three road hump, it can be concluded that, the dimensions as well the surrounding environment will affect the noise produced by the vehicles.

6.5 COMPARISON BETWEEN NOISE LEVEL AND VEHICLES SPEED

6.5.1 Road hump 1

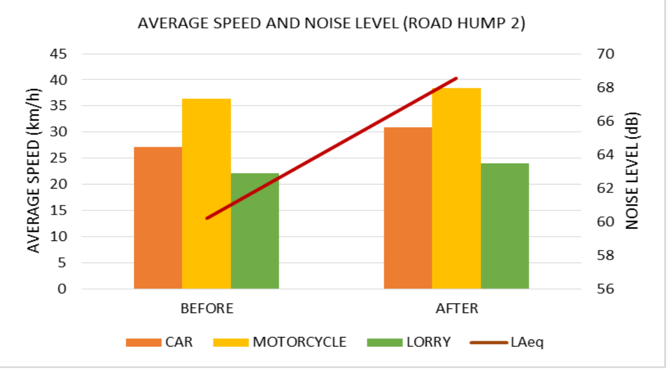

Figure 9. Average speed and noise level (Road Hump 1)

Figure 9 show the relationship between speed and noise levels for road hump 1. The speed of vehicles traveling at this road hump still within the speed limit except for motorcycle after the road hump. This is due to the height of this road hump which is 94mm. However, the noise levels peaked immediately after the road humps. This is because the vehicles accelerate at road humps, which would result in higher noise levels.

6.5.2 Road hump 2

Figure 10 show the relationship between speed and noise for Road Hump 2. From the graph, motorcycle produce high speed which is above the speed limit. Eventhough this hump has lower height but the noise produced immediately after the road hump was higher due to the road gradient which have required extra effort for vehicles to accelerate.

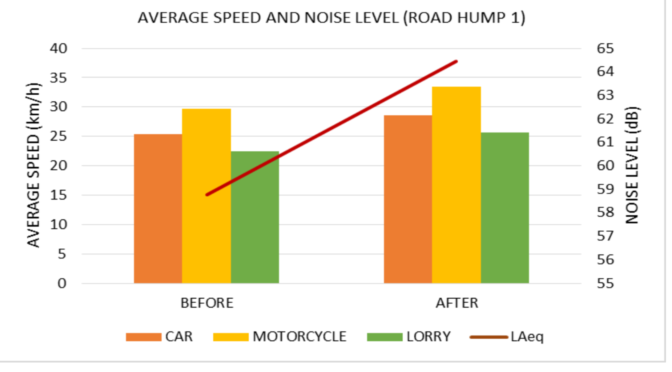

Figure 10. Average speed and noise level (Road Hump 2)

6.5.3 Road hump 3

Figure 11 show the relationship between noise level and speed for Road Hump 3. The location of this hump is near to downgrade gradient, therefore the noise produced before the hump is lower compared to immediately after the road humps.

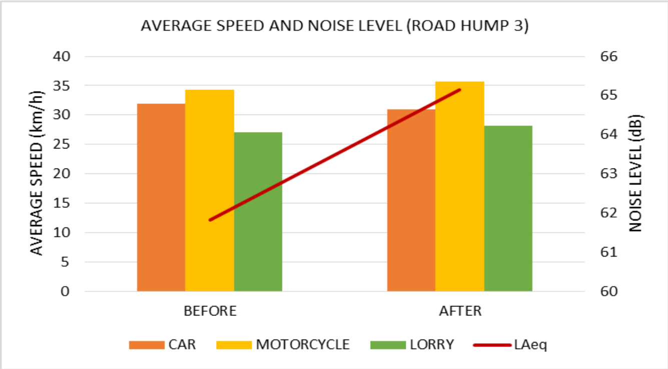

Figure 11. Average speed and noise level (Road Hump 3)

6.6 SUMMARY OF T-TEST RESULT FOR TRAFFIC SPEED AND TRAFFIC NOISE

Table 12 shows the overall T-test result for traffic speed and traffic noise. From the table, the T-test result for heavy vehicles are statistically insignificant for all three pairs. Therefore, the different in road hump dimensions does not affect the changes in speed of bus/lorry.

Table 12. Summary of T-test result for traffic speed and traffic noise

	Means	Std Dev.	df	t	p-value	M diff.	Remarks
				TRAFFIC SPEED			
CAR							
Pair 1							
At Road Hump 1	18.57	4.64	598	-5.18	0.000*	-1.95	Statistically significant
At Road Hump 2	20.52	4.55					
Pair 2							
At Road Hump 1	18.57	4.64	598	-0.06	0.95	0	Statistically insignificant
At Road Hump 3	18.57	4.76					
Pair 3							
At Road Hump 2	20.52	4.55	598	5.05	0.05*	1.95	Statistically significant
At Road Hump 3	18.57	4.76					
Motorcycle							
Pair 1							
At Road Hump 1	25.41	5.23	589	-10.67	0.000*	-4.86	Statistically significant
At Road Hump 2	30.27	5.90					
Pair 2							
At Road Hump 1	25.41	5.23	581	-2.97	0.003*	-1.4	Statistically significant
At Road Hump 3	26.81	6.23					
Pair 3							
At Road Hump 2	30.27	5.90	596	6.98	0.000*	3.46	Statistically significant
At Road Hump 3	26.81	6.23					

Bus/Lorry							
Pair 1							
At Road Hump 1	14.82	4.49	194	-0.74	0.45	-0.51	Statistically insignificant
At Road Hump 2	15.33	5.21					
Pair 2							
At Road Hump 1	14.82	5.23	193	0	1.0	0	Statistically insignificant
At Road Hump 3	14.82	6.23					
Pair 3							
At Road Hump 2	15.33	5.21	198	0.68	0.49	0.51	Statistically insignificant
At Road Hump 3	14.82	5.25					
			Traffic noise				
Pair 1							
Immediately after Road Hump 1	63.84	2.42	52	-8.01	0.000*	-4.21	Statistically significant
Immediately after Road Hump 2	68.05	1.90					
Pair 2							
Immediately after Road Hump 1	63.84	2.42	50	-1.67	0.10**	-0.90	Statistically insignificant
Immediately after Road Hump 3	64.74	1.58					
Pair 3							
Immediately after Road Hump 2	68.05	1.90	60	7.85	0.000*	3.31	Statistically significant
Immediately after Road Hump 3	64.74	1.58					

*p < 0.05: statistically significant (95% confident interval)
**p < 0.01: statistically significant (99% confident interval)

7. CONCLUSIONS

Based on the findings, the average speed of vehicles for these three road humps (Road Hump 1, Road Hump 2 and Road Hump 3) after passing the road hump were higher than the average speed of vehicles before approaching the road hump except for cars at Road Hump 3. Besides, from the average speed, all types of vehicles travelled within the speed limit at all road humps except for motorcycles at Road Hump 3 which travel above the speed limit (30.27 km/h). At other points of road hump, cars traveled above the speed limit; before and after the Road Hump 3 and after Road Hump 2, for Road Hump 1, car moved within the speed limit of institutional area. From this finding, it confirms that the design profile of road hump influenced the speed of the vehicles. Likewise, the height of Road Hump 2 (70 mm) and Road Hump 3 (80 mm) is much lower than the height of Road Hump 1 (94 mm); thus, the drivers tend to speed the vehicles at Road Hump 2 and 3 as compared to the Road Hump 1. Besides the road hump dimensions, the location of the road hump installation also influence the driving behavior especially for motorcyclist. The 85th percentile, speed recorded for motorcycles were above the speed limit for all road humps and all points except at Road Hump 1. Besides, cars speed recorded were above the speed limit; before approaching Road Hump 2 and Road Hump 3, and after Road Hump 1, Road Hump 2 and Road Hump 3. In addition, at 85th percentile speed for lorry and bus were recorded below the speed limit at these three road humps.

Regarding the noise level, Road Hump 2 recorded the highest noise levels while Road Hump 1 recorded the lowest noise levels. This is due to the differences in the road hump profiles especially height, where the highest of Road Hump 1 was higher than Road Hump 2. From the noise survey result, the noise recorded at all points at all road humps were above the permissible noise limits as determined by the Malaysian Department of Environment. The permissible noise limit for institutional area is 50dB. The changes in noise level before the road hump and immediately after the road hump shows the increasing in noise level produced by vehicles.

Furthermore, the T-test was used to test the statistical significance of traffic speed and noise changes at road humps, from which it was identified that the road humps were effective in significantly differences in mean speed of the vehicles except for buses/lorries. While, for noise level, the result of T-test was found to be significantly differences in mean of traffic noise at two points which were at Pair 1 (Road Hump 1 and 2) and Pair 3 (Road Hump 2 and 3).

Therefore, it can be summarised that the provision of the road humps in the institutional area helps to reduce the speed of the vehicles even though some of the vehicles were still moving beyond the posted speed limit. The road hump characteristics will determine the speed of vehicles as it highly impacted the vehicles speed. The design profiles of road humps especially the height, affects the speed of vehicles approaching and at the road hump. Therefore, road humps should be properly planned and executed to be more effective. As some of the road humps were constructed ad-hoc with no monitoring after the road hump was built, their functioning could be less effective in reducing the speed of vehicles as per the example depicted for the Road Hump 2 as it does not meet the minimum requirement for the height of the road hump design.

The findings portrayed that the use of road humps does have a significant impact towards the speed level at the institutional area. Therefore, the findings can be used to better understand the effectiveness of road hump implementation in various environments and conditions. However, further studies are needed to better understand the issue and provide new dimension in the direction study area to ensure heightened conducive living environment in the campus area. However, currently, road hump is still seen as one of the best methods to reduce the speed level at institutional area.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to the Ministry of Higher Education (MOHE), Government of Malaysia for awarding this research fund under the Research Initiative Grant Scheme bearing the project ID RIGS15-024-0024.

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