The Effect of Road Hump in Reducing Speed of Motorcars in a Residential Area in Kuala Lumpur

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In its most simple terms, traffic calming is about preserving the functions of local streets. As local streets are intended to provide primarily land-access services, hence, when traffic begins to use local streets for through movements, traffic volume and speed levels become incompatible with this primary function. To respond, a study on the effectiveness of traffic calming measures in reducing vehicles speed at Taman Setapak residential area was undertaken. Field observations and spot speed survey were conducted to collect primary data. The field observation was carried out to collect data on road geometrics and design characteristics of the road humps. The spot speed survey was administered to collect vehicles speed at different points near the road humps. The major findings include first, the road humps proved effective in reducing the speed of the vehicles and second the design characteristics of the road humps is an important factor in reducing the speed of the vehicles. The average speed of the vehicles before approaching the road humps was about 30 km/hr and at the road humps below 10 km/hr. The findings showed that the design profiles of the road humps have an impact on the speed of the vehicles; the gentle the design profiles of the road humps especially in terms of its height and slope, the higher the speed of the vehicles near and at the road hump. The findings also showed a clear difference in the average speed of the motorcars approaching the road hump and at the road hump.

Keywords: *spot speed, road hump, traffic calming measures, residential area, living environment*

1. INTRODUCTION

Nowadays, people are working together to identify better ways to design new residential areas or retrofit existing ones to be more interactive, walkable, enjoyable and livable. Many people seek residential areas to be equipped with parks, schools, and other activities nearby for their children and old folks. The desire for healthy, interactive neighborhoods is not a new phenomenon, but quite recently the real estate marketers are started to promote quiet neighborhoods streets as a main incentive to buy houses in particular neighborhoods.

Schroll (1999) in the Institute of Transportation Engineers has explained that traffic calming is the combination of mainly physical measures that reduce the negative impacts of motor vehicle use, alter driver behaviors, and improve conditions for non-motorized street users. Even though the measures are usually applied to residential streets, traffic calming can also be used in many other types of roadways. Two classes of traffic calming measures are generally available: those that mainly aim at physically discouraging spillover traffic due to nearby congested arterials from using local streets and those that aim principally at speed reduction.

The local streets are intended to provide primarily land-access services. Therefore, when traffic begins to use local streets for through movements, the volume and speed levels become incompatible with its primary function. As the drivers began to drive at speed greater than the speed limit of a local street in the residential areas, it has started to create unsafe environment to the residents especially the children and the elderly. One of the noticeable problems that can be seen in the residential areas is the vehicles exceeding the posted speed limit of 35kmph. Significantly, the choice of design speed is influenced by the geometric design of roadways. For instance, the design speed affects the choice of curve radius, the rate of elevation, and the required safe sight distances. Once applied, the design speed becomes a fundamental characteristic of the roadways. The speed limit is normally set below the design speed of the vehicles to minimize the frequency of unsafe conditions encountered by those drivers that, for what reason, choose to exceed it (Papacostas and Prevedourus, 2001). The selected roads (Jalan Meranti, Taman Setapak residential area) were identified having a wider carriageway that encourages the vehicle users to speed above the posted speed limit. Besides that, the wide road geometrics in the study area encourages people to speed within the neighborhood area. Generally, the provision of existing carriageway was found not specifically following the standard guidelines on road geometrics prepared by the local authority. Therefore, it might unintentionally persuade the vehicle users to drive at speed more than the speed limit whenever using the selected road (Jalan Meranti). To address the increase in vehicle speeds along wide carriageway in a residential area, several alternatives are needed to be considered. The installation of traffic calming measures along the residential roads can be considered as one of the alternatives.

This research was conducted to study the effects of the traffic calming measures on the vehicle speeds in the residential area of Taman Setapak, Kuala Lumpur. This study highlights on the roles of the traffic calming measure especially road humps in reducing the vehicle speeds in the residential areas. This study also assesses the effectiveness of the design characteristics of road humps such as its size, and shape on speed reduction. Schroll (1999) has enlightened that the goal of traffic calming measure is to improve the quality of life for citizens by reducing the impact of motor vehicles on non-motorist through reduction in accidents and accident-potentials, reducing traffic speed, reducing or eliminating cut-through traffic, encouraging the use of public spaces by pedestrians and cyclists, improving the aesthetic qualities of a street environment, and increasing the use of transit or other sustainable transport modes. The specific objective of many traffic calming projects is to reduce the volume, speed or both. As this study is focused on the residential areas, these efforts are aimed specifically at the speed of cars when approaching road humps in the selected residential areas.

2. LITERATURE REVIEW

According to Zegeer and Seiderman (1999), traffic calming is a way to redesign streets so that traffic is tamed to a level that allows it to coexist more peacefully with people. Another definition of traffic calming developed by a British group of engineers and surveyors was, "the application of traffic engineering and other physical measures designed to control traffic speeds and encourage driving behaviours appropriate to the environment". Apart from the definitions as stated, Lockwood has come into conclusion that traffic calming is the combination of mainly physical measures that reduce the negative impacts of motor vehicle use, alter driver behaviours, and improve conditions for non-motorized street users. The same definition, however being explained by Schroll (1999).

The descriptions are intended to outline different classes of techniques, for instance road closures and diverters, horizontal deflections, vertical deflections and others. Under the horizontal deflections techniques, it includes chicane, choker, half closure, and mid-block island, narrowing lanes, neck down, on street parking and so on (Schroll, 1999). The vertical deflection consists of raised crosswalk, raised intersection, speed hump, speed bump, speed table, and speed cushion. According to Institute of Transportation Engineers (1999), traffic calming measures which includes vertical deflection, horizontal shifts and road narrowing fall under the categories of calming measures to reduce speed and enhance the street environment for non-motorists. On the other hand, calming measures which highlight the road closures are intended to reduce cut-through traffic by obstructing traffic movements in one or more directions.

2.1 Road hump

Local Transport Note 01/07 (March 2007) produced by Department of Regional Development (Northern Ireland) stated that, "road humps 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". According to the Department of Transport, the primary legislation on this subject is contained in sections 90A to 90F of the Highway Act 1980 (as amended by Transport Act a981). It stated clearly in section 90A and 90B that road hump can only be constructed on roads with speed limits of 30 mph or less. However, it must include the requirements to advertise and consultation with the police (section 90C).

According to Transport for London guidelines, the original Road Hump Regulations have allowed round-top humps featuring 100 millimetres high and 3.7 meters long to be installed on roads in England and Wales with speed limit of 30 mph or less. However, in 1986, the revised regulations had approved the height of hump between 75 and 100 millimetres. After that, Hump Regulations also permitted flat-top, or round–top humps between 50 to 100 millimetres high. In the early 1970s, a suitable profile for road humps was carried out by Transport Research Laboratory (TRL) as the trial humps with 3.7 metres long and 100 millimetres high was successful in reducing the speed. From this experiment, the humps less than 3.7 metres long became less effective when speed increases. Apart from that, the location of the road hump should also being taken into consideration especially adjacent to the junctions with traffic signals, as drivers may increase their speed through the junction and then approach the hump at very high speed. Hence, adequate warning (e.g.: traffic signing) should be provided before drivers are encountered with road humps.

2.2 Advantages and disadvantages of road humps

According to Transport for London (TfL), the advantages of road hump include: it reduces traffic flows on average by 25 per cent and as vehicles can be parked on the humps, thus, there is no loss of parking space for simple hump designs; it also enhances the appearances of a road if designed and built to a high standard; it helps pedestrians to cross the road.

On the other hand, the drawbacks of the traffic calming measures stated by Transport for London (TfL), especially the road hump are: it causes discomfort to two-wheeled vehicles, drivers and passengers of buses, and to ambulances and commercial vehicles; it increases the journey time for buses and causes delay to the emergency vehicles; it increases the flow of vehicles on the surrounding untreated roads; it causes nuisances at locations adjacent to humps because of noise and vibration emanating from the vehicles especially if there is a significant flow of commercial vehicles in the traffic stream; it is unpopular with some residents and drivers due to discomfort, fear of damage to vehicles and perceptions of increased noise and vibration; poorly designed schemes may lead to aggressive driver behaviours with high levels of braking and acceleration as a result increasing the noise and pollutant emissions from individual vehicles.

2.3 Studies on road humps in reducing vehicle speed

Speed humps are quite widely prevalent almost all over the world except for Japan where people are very nervous about noise and vibration caused by traffic on speed humps (Aya Kojima et al, 2011). Even in countries where speed humps are popular, the noise and vibration have become serious issues (Harris et al, 1999; Lahrmann et al, 1992). The vehicle speeds measured at or near road humps intervals of 30m, 40m, 60m and 100m were from 15 km/h to 20 km/h in one of the neighborhoods in Japan. However, the study also states that the longer the intervals between the speed humps, the higher the vehicle speed (Aya Kojima et al, 2011). The residents (about 73%) at one of the residential neighborhoods in Kokubunji city in Tokyo, Japan, have agreed that the number of vehicles slow down increased because of the installation of speed humps (Aya Kojima et al, 2011).

Excessive speed and high traffic volume are the most common problems reported on residential streets (Farzana Rahman et al, 2007). Experiences throughout Europe, Australia and North America has shown that traffic calming, if done appropriately can reduce traffic speeds and the number and severity of crashes (Farzana Rahman et al, 2007). The experimentation of traffic calming devices in Nagaike-cho, a suburb of Osaka, Japan showed average vehicle speeds were as low as 5 km/h, with a maximum speed observed of 8 km/h (Farzana Rahman et al, 2007).
Speed hump is the most widespread traffic calming devices because of its effect in speed reduction and low cost. In the case of city of Albuquerque, 96% of all devices are speed humps and West Sacramento, California, 85% of the devices are speed humps (Farzana Rahman et al, 2007). Research has shown that properly designed and installed speed humps can reduce vehicle speeds to 23.4-31.2 km/h when traversing speed humps and 39-46.8 km/h in between properly spaced speed humps (Farzana Rahman et al, 2007).

Speed humps in Montgomery County, Maryland, typically reduced 85th percentile speeds by 6.6 to 11.7 km/h and reduced accident frequency (Huang and Cynecki, 2000; Loughery and Katzman, 1998). Five speed humps were built along a half-mile stretch of Grey Rock Road in Agoura Hills, California and the 85th percentile speeds fell by 10 to 15 km/h after the humps were installed (Huang and Cynecki, 2001; Cline, 1993). In three Australian cities, Corio and Croydon in Victoria and Stirling in Western Australia, the 85th percentile speeds at speed humps dropped by half or more after installation. Mid-hump speeds fell by about one-fourth to one-third (Huang and Cynecki, 2001; Hawley et al, 1992; McDonald and Jarvis, 1981; Richardson and Jarvis, 1981).

3. RESEARCH APPROACH

The research objectives, research methodology and limitations of the study are covered in this section. Each of these elements is given in the following sub-sections.

3.1 Research objectives

1) To evaluate the design characteristics including geometrical elements of the selected road humps in the residential area

2) To determine the effectiveness of road humps on vehicle speeds along the selected residential streets

3.2 Research methodology

The purpose of the research methodology is to apply data collection and analysis methods to achieve the formulated research objectives. It explains the process involved in collecting and analyzing the data to arrive at the study findings and interpretations.

3.2.1 Background of study area

The study area is located in Mukim Setapak under the jurisdiction of Federal Territory of Kuala Lumpur. The Mukim Setapak is situated in the north-eastern part of Kuala Lumpur and has an area of 62 square miles (160 km^2). It is one of the major suburbs in Kuala Lumpur. The straight road of Jalan Meranti at the Taman Setapak residential area is selected as the study area. It can be accessed through the major road namely Jalan Gombak and it is located towards southern direction from International Islamic University Malaysia (IIUM), Medan Idaman Business Centre (Ong Tai Kim Supermarket) on the east, and not far away from Titiwangsa Recreational Park. Taman Setapak is surrounded by several other residential areas such as Taman Ibukota, Medan Idaman, Kampung Bandar Dalam and Taman Pelangi Jaya. Figure 1 shows the site plan of the study area.

Figure 1: Site plan
Source: www.maps.google.com.Retrieved June 1st, 2011

3.2.2 Field observation and road inventory survey

In this research, field observation was made to collect data on the selection of road and road humps. The field observation was also made to identify the general issues and problems of the residential area and its immediate surroundings. The selected roads were clearly marked to collect data on geometrical details of the road which includes the width of the carriageway and right of way (R.O.W) width. The design profiles and characteristics of the road hump such as shape, length, width were also collected. The field observation was carried out during weekday, which is on Tuesday starting around 10 o'clock and ending in the evening at 5 o'clock. The observations on the images of road network and road humps were recorded by using a camera; measurement of design characteristics of road hump and road geometrics by a measurement tape. The weather on the data collection day was sunny and windy. However, in the late afternoon after completing the survey, it has started to drizzle.

3.2.3 Spot speed survey

Systematic sampling procedures were applied to collect data on the spot speed of the vehicles. By systematic sampling method, each element in the population has a known and equal probability of selection. Using the systematic sampling method, every 5th road users (which confine only to the cars) passing the road humps along the selected road at a residential area was selected as samples and the procedures was continued until 150 samples were collected. As two different road humps were being evaluated, the samples selected at each road hump were 75 samples. The total number of motorcars selected to measure spot speed is 150 at the two selected road humps.

Spot speed survey was administered to understand the users' driving behaviours in terms of reducing speed whenever approaching a road hump. The data on the spot speed was collected when cars are at a distance of 30 meters before the road hump, at the road hump and 30 meters after passing the road hump. The alignment of road selected was a straight road. Road humps were located at few locations along the straight road in the selected residential area. The spot speed data was measured by using a speed measurement device – a hand-held digital radar gun known as *Stalker Lidar* and direct timing procedure method. The direct timing procedure method was used because of the lack of radar guns in the laboratory. The direct timing procedure applies the theory of calculating speed which equals to a known distance covered by a vehicle divided by the time taken by the vehicle. The spot speed at location P1 and P3 (Refers to Figure 2) was calculated by using direct timing procedure while P2 was measured by using radar gun. Three enumerators were stationed, one at each location, to measure the spot speeds (Refer to the Figure 2).

3.2.4 Method of analysis

The spot speed data was analysed by calculating the mean speed, median speed and modal speed. The mean, median and modal speed is calculated by using the following expressions:

i. **Mean Speed,** $X = \frac{\sum fm}{\sum f}$

Where
X = arithmetic mean of all recorded cars' speed
$\sum f$m = Sum of frequency times the middle speed of each class
$\sum f$ = total frequency

ii. **Median Speed,**

$$ý = \text{Real Lower Limit (RLL)} + \left[\frac{\sum f\,(0.5) - Cf\,(\text{below})}{f} \right] \times i$$

Where
ý = middle speed in a series of spot speeds that are arranged in ascending order
RLL = the real lower limit of the speed class interval containing the median speed

$\sum f$ = total frequency
Cf(below) = cumulative frequency below the speed class containing the median speed
f = frequency containing median speed
i = interval size

iii. **Modal Speed, ň = ź km/hr**

Where
ň = speed values that occur most frequently in a sample of spot speeds
ź = middle speed value of speed class interval containing the highest frequency

The calculation of average speed is to interpret the relationship between road humps' characteristics and the speed of cars. These relationships are shown in the form of graphs. A cumulative frequency curve (upper limit speed vs cumulative frequency) was also prepared to determine 85th and 95th percentile speeds. The output from the analysis is expected to ascertain to what extent the provision of road humps reduces the speed of the vehicles along the residential streets.

The existence of the statistical differences in the average speed of the vehicles at the selected points can be tested by using t-test. The vehicle speeds before the road hump and on the road hump are normally different as the driver is prepared to reduce speed when approaching close to the road hump and the speed is further

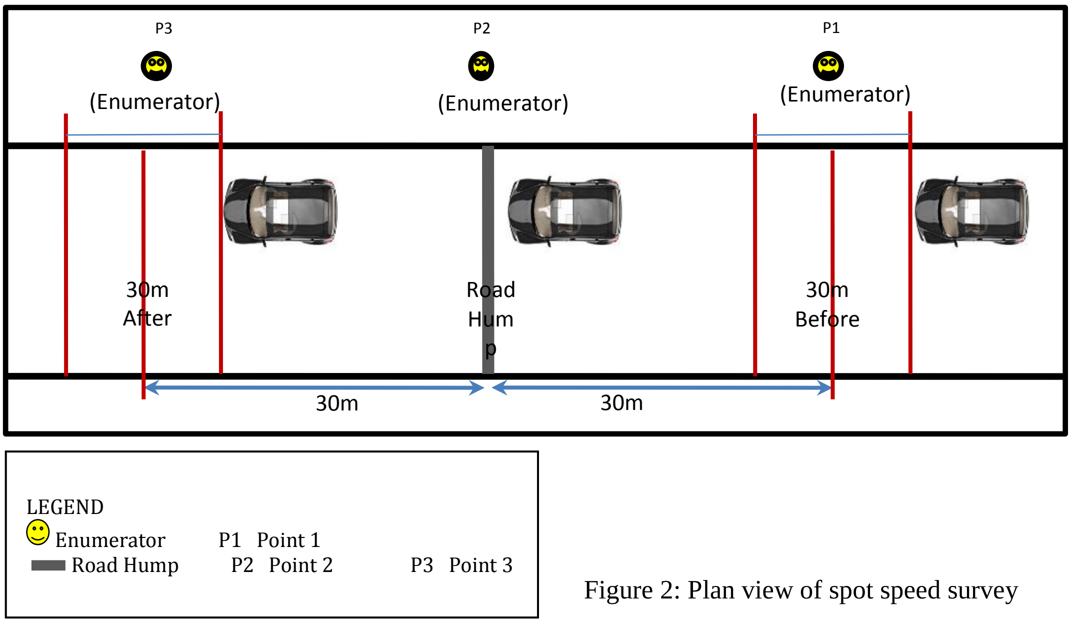


Figure 2: Plan view of spot speed survey

reduced on the road hump. A t-test was applied to test the statistical differences in the mean speed of the vehicles traveling 30m before the road hump and on the road hump for the selected road humps in the residential area.

3.3 Limitation of the study

The effect of road humps on speed reduction is mainly applicable to residential areas as the study was administered at a residential neighborhood. The type of vehicles chosen for this study is motorcars because they constitute as the main mode of transportation along the residential streets. The effects of road humps in reducing vehicle speeds in this study are mainly related to motorcars as the other vehicles behave differently in terms of reduction in speed when traversing before or on or after the road humps. The selected sample size is another major limitation of this study. Finally, the traffic volume along residential roads is normally low compared to commercial land use because the residents living in the residential areas are the main and frequent users of the residential streets. As a result, the vehicle speeds at residential and commercial areas are different. Even though, the vehicle speeds at these two types of land uses are different, but the design profiles of road humps, if provided with equal dimensions, may alter the drivers behaviours in terms of vehicle speed insignificantly when approaching road humps.

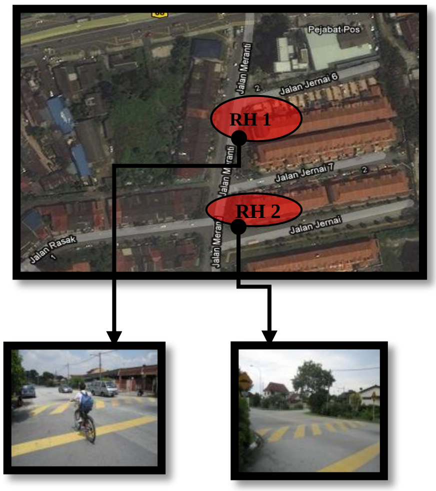
4. ANALYSIS AND FINDINGS

4.1 Road geometrics

According to the Guidelines on Geometric Standards of Road Network System provided by Federal Department of Town and Country Planning, Peninsular Malaysia, the selected road namely Jalan Meranti is categorized as local distributor road (Refers to Figure 3). The geometrical design of the selected local road is a straight road with the installation of the three road humps along the road. The local road (Jalan Meranti) was a single carriageway (two lanes) with two-ways circulation system. This road is connected to a major road known as Jalan Gombak. The right of way (R.O.W) width of the selected road was 13.2 meters with 3.5 meters per lane, drainage system width was 1.5 meters, and pedestrian walkway was 2.4 meters. The total width of the local road should be at least 12.5 m according to the Planning Standard and Guidelines by the Federal Department of Town and Country Planning Malaysia.

4.2 Road hump design and its characteristics

There were three road humps along Jalan Meranti in Taman Setapak residential area, Kuala Lumpur. However, only two road humps were selected for this study because of its location (Figure 3). The speed limit along the residential street was about 30 km/hr. The observation showed that the selected road humps were sinusoidal type according to the standard guidelines by the Department for Transport (DfL), London. The Sinusoidal type of road humps is more comfortable for ride because of its initial rise is slower and also it serves as a best form from the view point of noise and vibration as well as passenger's comfort (Farzana Rahman et al, 2007; Aya Kojima et al, 2011; Sayer et al, 1999).



Road Hump 1 Road Hump 2

Figure 3: Road humps location
Source: Field observation survey, 2011

The measurement of the first road hump was 12 meters length, 3.7 meters width and 80 millimeters height. It was located at a distance of approximately 45 meters from the intersection between Jalan Gombak (major road) and Jalan Meranti. Sufficient warning to the road users in terms of road marking and road signs about the location of the road hump was given. The second road hump was located at a distance of approximately 70 meters from the first road hump. The length of the second road hump was 11.3 meters, width 3.5 meters and height 60 millimeters. The dimensions of the second road hump are slightly lower than the first road hump. Table 1 shows the design characteristics of the road humps.

It is important that humps are carefully designed and built to minimise discomfort for those travelling at appropriate speeds. It is highly advisable that the design characteristics of the road humps should follow the guidelines to prevent discomfort to the road users. Generally, the height of a road hump should be within 100 millimeters, but humps of 75 mm in height are recommended, as these could lead to minimum discomfort whilst maintaining effectiveness of the hump in reducing vehicle speeds. A slight change in the construction of road hump can have significant effects in terms of discomfort and it is therefore important that humps are built according to the local authority design specifications. This is especially true for certain types of hump, such as sinusoidal humps. The speed humps for residential roads are normally varies between 75mm and 100mm (maximum) with 7m wide at the base along collector roads and 4m wide along local roads (Farzana Rahman et al, 2007). The analysis of the selected road humps along Jalan Meranti showed that its design characteristics follow local authorities' guidelines and standard on road humps.

4.3 Spot speed analysis

The spot speed data showed that the lowest speed recorded at a distance of 30 meters before approaching road hump (L1) was 18 km/hr with the speed further decrease to 6 km/hr at the road hump (L2) (67% speed decrease). While the highest speed 30 meters before approaching the road hump was 42 km/hr and decrease to 5 km/hr at the road hump (88% speed decrease). Whereas, the lowest speed at a distance of 30 meters after approaching the road hump (L3) was 19 km/hr (68% increase from L2-L3). The highest speed at a distance of 30 m from the road hump was 44 km/hr (an increase of 89% from P2-P3). The average speed of cars 30 meters before approaching the road hump was 28.04 km/hr, 7.2 km/hr at the road hump and 28.42 km/hr at 30 m after passing the road hump. Figure 4 shows the variation of speed at the three different locations of the first road hump.

Table 1 : Design characteristics of hump1 and hump 2

Road Hump	Length (m)	Width (m)	Height (mm)
Road Hump 1	12	3.7	80
Road Hump 2	11.3	3.5	60

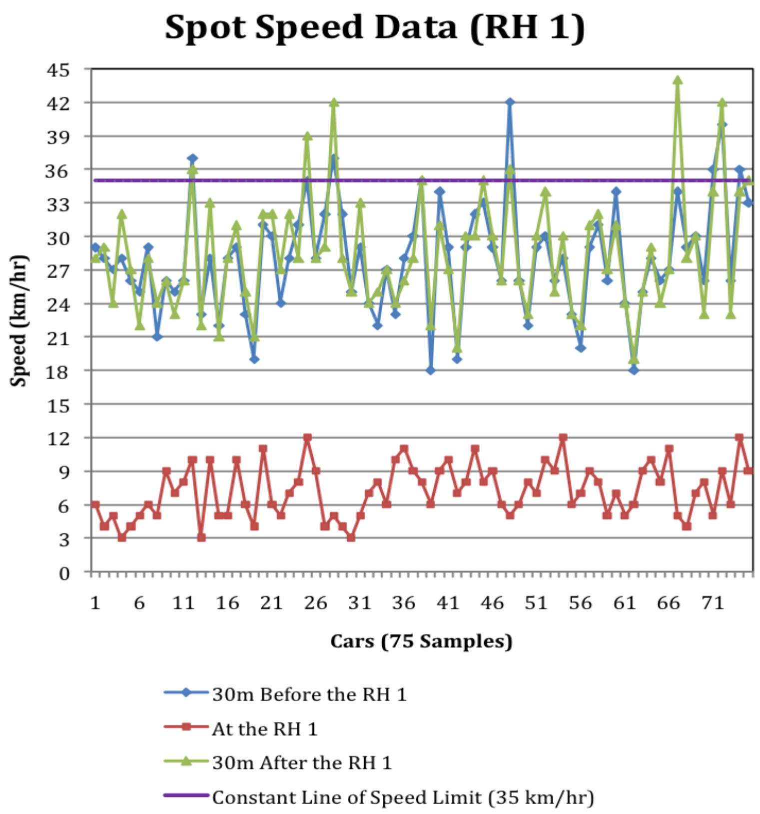


Figure 4: Spot speed variation at Road Hump 1

The findings showed that there exists a wide variation between the speeds of cars. It showed that several drivers drove their vehicles lower than the posted speed limit while others drove higher than the posted speed limit. For instance, the graph shows approximately 6 cars were found speeding (above the speed limit which is 35 km/hr) at 30m before approaching the road hump while the rest are below the posted speed limit (Refer Figure 4). On the other hand, there were also 6 cars recorded speeds above the 35 km/hr at 30 meters after approaching the first hump. It showed that 16% of the total cars were found speeding along the selected residential street. The lowest speed at the road hump was around 3 km/hr and the highest speed was 12 km/hr. Studies have shown that properly designed and installed road humps can reduce vehicle speed to 23.4-31.2 km/h when traversing road humps and 39-46.8 km/h in between properly spaced road humps (Farzana Rahman et al, 2007). The interval between the road humps is one of the important factors in reducing the speed of the vehicles. The vehicle speed become around 15 km/h to 20 km/h near or on the road humps but as the interval between road humps increases, the speed of the vehicles increases (Aya Kojima et al, 2011). Based on the observation, it was found that the speeds of the vehicles at the road hump were greatly influenced by the design characteristics of the road hump. The findings showed that the design characteristics of the road hump is an important consideration in reducing the speed of the vehicles whenever approaching the road hump.

Figure 5 shows the speed variations at three different locations of the second road hump. There were 7 cars found exceeding the posted speed limit at 30 meters before approaching the second road hump. The graphs also showed that 9 cars were speeding (above the speed limit) at 30 meters after approaching the road hump 2. The number of vehicles exceeding the speed limit at 30 m before and 30 m after the road hump was slightly higher in the case of the second road humps than the first. It is due to the design characteristics of the second road hump which was gently sloped than the first. As the second road hump was provided with gentle slope than the first, it gave an opportunity to the cars to speed above the posted speed limit when approaching the second road hump.

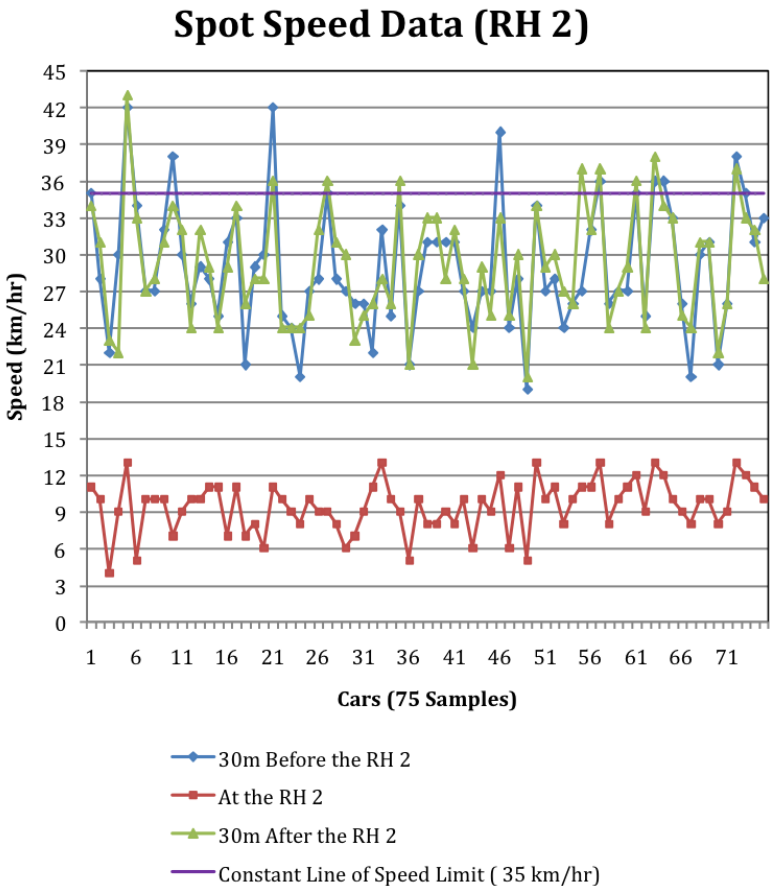


Figure 5: Spot speed variation at Road Hump 2

The gradient of the road humps can affect speed – the steeper the gradient the larger the speed reducing affect. However, according to UK guidelines, the gradients should not be steeper than 1:10 and side gradients not steeper than 1:4 (Farzana Rahman et al, 2007). From this analysis, it shows that the design characteristics of the road hump and the speed reduction of the cars are interrelated as the drivers tend to speed near the road hump having favourable design characteristics more frequently. In other words, as the design characteristics of the road hump having lesser interference to the vehicles in terms of its dimensions is more prominent, the number of vehicles exceeding the speed limit increases.

4.3.1 Speed characteristics

The spot speed characteristics such as mean, median, modal and percentile speed were calculated and analysed.

About 43% of the road users were driving at a speed between 27 km/hr and 30 km/hr at 30 m before approaching the first road hump. The modal speed was about 6 km/hr and the mean speed was about 7.7 km/hr at the road hump. The average speed of the cars before approaching the hump decreases from 28 km/hr to 8 km/hr at the hump. The 85^{th} percentile and 95% percentile speed at 30 m before approaching the first road hump were 30.64 km/hr and 31.04 km/hr respectively. It showed that the most of the drivers were driving within the speed limit before approaching road hump 1. The average speed of the vehicles at a distance of 30 m before approaching road hump 2 was 29.64 km/hr. The average speed of the vehicles at road hump 2 was about 10 km/hr which is slightly higher than the road hump 1. The difference in the vehicle speed is attributed to the design characteristics of the road humps in which road hump 2 was gently sloped than road hump 1. The average speed of the vehicles at 30 m after passing road hump 1 and road hump 2 was 29 km/hr and 30 km/hr respectively. The 85^{th} percentile and 95^{th} percentile speed at road hump 2 showed that most of the drivers

Table 2: Mean and median speed at the road humps

	30 m before		At		30 m after	
	Mean Speed (km/hr)	Median Speed (km/hr)	Mean Speed (km/hr)	Median Speed (km/hr)	Mean Speed (km/hr)	Median Speed (km/hr)
Road Hump 1	28.59	26.92	7.7	7.12	29	24.56
Road Hump 2	29.64	24.56	9.93	8.68	30.05	25.64

Table 3: 85th percentile and 95th percentile speed at the road humps

	30 m before		At		30 m after	
	85th Percentile (km/hr)	95th Percentile (km/hr)	85th Percentile (km/hr)	95th Percentile (km/hr)	85th Percentile (km/hr)	95th Percentile (km/hr)
Road Hump 1	30.64	31.04	9.34	11.08	28.84	35.28
Road Hump 2	31.88	32.28	9.38	11.00	29.92	33.20

Table 4: One-Sample Test

	Test Value = 7.20 km/hr					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RH1	36.626	74	.000	20.840	19.71	21.97

Table 5: One-Sample Test

	Test Value = 9.43 km/hr (speed at the RH2)					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RH2	33.235	74	.000	19.583	18.41	20.76

were driving within the speed limit. Table 2 and table 3 show the speed characteristics of the vehicles at the selected road humps. On average, road humps reduced 85th percentile travel speeds by about 11.5 km/h after road humps were installed. The average speed over the road humps was about 40 km/h. The 85th percentile vehicle speed when traversing on the road humps depends on the shape of the road humps. The vehicle speed increases as the gradient of the road humps become gentle and decreases as the gradients become steep (Farzana Rahman et al, 2007).

4.3.2 Testing the differences in the average speed of the vehicles at the road hump

A t-test was conducted to examine whether the differences in the average speed of the vehicles at 30 m before approaching road hump and at the road hump was statistically significant. The following subsections show the findings of the t-test.

Road Hump 1

Table 4 shows the findings of the t-test. It can be seen that the calculated t-value (= 36.626) which is higher than the critical t-value with a degree of freedom = 74. The findings showed that there exists a clear difference in the average speed of the vehicles at 30 m before approaching the road hump and at the road hump both at 99% and 95% confidence interval. It shows that the provision of the road hump along the residential street is effective in reducing the speed of the moving cars.

Road Hump 2

The difference in the average speed of the cars at road hump 2 was also tested for statistically significance. The calculated t-value (= 33.235) at road hump 2 which is found higher than the critical T-Test with a 74 degree of freedom. Table 5 shows the findings of the t-test. It can be concluded that the difference in the average speed of the cars showed the effectiveness of road hump 2 in reducing the speed of the vehicles (cars).

The findings showed that the selected road humps have controlled the drivers' behaviour in reducing the speed of the moving vehicles. The design profiles of the road humps have played an important role in reducing the speed of the vehicles.

5. CONCLUSIONS

A pleasant, harmonious and safe residential neighborhood is very important for a better quality of life. The increasing traffic movement especially by private motorcars traveling at speed greater than the stipulated speed limit in the residential areas has been posing a greater threat to the living quality of the residents. Generally, the higher the speed of the vehicles in the residential areas, the greater the noise level and lower the safe living conditions of the residents. The movement of traffic at speed higher the speed limit has warranted the provision of traffic calming devices including speed hump. The provision of speed hump in many residential areas has become a common phenomenon to arrest the speed level of the moving vehicles. Studies have shown that properly designed and installed road humps can reduce vehicle speed to 23.4-31.2 km/h when traversing road humps and 39-46.8 km/h in between properly spaced road humps (Farzana Rahman et al, 2007). The interval between the road humps is one of the important factors in reducing the speed of the vehicles. The vehicle speed become around 15 km/h to 20 km/h at near or on the road humps but as the interval between road humps increases, the speed of the vehicles increases (Aya Kojima et al, 2011).

The measurement of speed near the road humps along the residential street in Taman Setapak has indicated that the most of the motorcars were following the stipulated speed limit. The findings show that approximately 6 cars were found speeding (above the speed limit which is 35 km/hr) at 30m before approaching the road hump while the rest are below the posted speed limit. On the other hand, there were also 6 cars recorded speeds above the 35 km/hr at 30 meters after approaching the first hump. It showed that 16% of the total cars were found speeding along the selected residential street. The lowest speed at the road hump was around 3 km/hr and the highest speed was 12 km/hr. It also showed that the design profiles of the road humps have an impact on the speed of the vehicles.

The gentle the design profiles of the road humps especially in terms of its height and slope, the higher the speed of the vehicles near and at the road hump. The speed variations at three different locations at the second road hump were different than that of first road hump. There were 7 cars found exceeding the posted speed limit at 30 meters before approaching the second road hump. It also showed that 9 cars were speeding (above the speed limit) at 30 meters after approaching the road hump 2. The number of vehicles exceeding the speed limit at 30 m before and 30 m after the road hump was slightly higher in the second road humps than the first. It is due to the design characteristics of the second road hump which was gently sloped than the first. As the second road hump was provided with gentle slope than the first, it gave an opportunity to the cars to speed above the posted speed limit when approaching the second road hump. The gradient of the road humps can affect speed – the steeper the gradient the larger the speed reducing affect. However, according to UK guidelines, the gradients should not be steeper than 1:10 and side gradients not steeper than 1:4 (Farzana Rahman et al, 2007).

It is also found that the difference in the average speed of the motorcars before approaching the road hump and at the road hump is statistically significant at both 99% and 95% confidence interval. In other words, there exists a clear difference in the average speed of the motorcars approaching the road hump and at the road hump. This study focuses only on the sinusoidal road humps at the residential area. The average, median and 85th percentile speed at other types of road humps namely parabolic, circular and speed table along the residential roads may be different than that of sinusoidal road humps. Further studies to evaluate the effects of other road hump types on vehicle speed reduction along the residential areas are required. This is imperative to understand the characteristics and design profiles of other types of road humps in reducing vehicle speeds and thus selecting the appropriate type of road humps for the residential areas.

It is evident from the study that road humps along the residential street help to reduce not only the speed of the vehicles but also allow vehicles to adhere to the stipulated speed limit. However, the location of road humps at close intervals would increase the noise level of the vehicles especially after passing the road humps. As a result it affects the peacefulness, tranquility and calmness of the community in the residential areas. To arrest this dilemma, it is highly important to identify appropriate spacing between the road humps to enhance its function of reducing vehicle speed without causing unnecessary inconveniences to the community in the residential neighborhoods. The road humps when planned, designed and located at the appropriate intervals would increase the living environment of the residential neighborhoods.

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