A STUDY ON THE RELATIONSHIP OF ROAD HUMP SPACING TO SPEED SELECTION OF ISOLATED VEHICLES IN CASE OF EXCLUSIVE VILLAGES IN METRO MANILA

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Abstract: Over-speeding and reckless driving are important factors contributing to traffic accidents which sometimes result in the loss of lives and damage to property especially in residential and institutional areas where the movement of pedestrians should be given preference over the fast passage of motor vehicles. Accidents involving pedestrians have necessitated countermeasures such as traffic calming to reduce the risk of fatal injuries. The most common traffic calming measure being implemented in the Philippines is known as the road hump. Past studies in other countries have shown that road humps, or similar structures, significantly influences the speed of the vehicles. In order that humps be effectively used as a traffic calming device, the design aspects of humps that affect the speed selection behavior of drivers should be carefully studied and taken into consideration. Such factors include the proper location of humps, spacing between humps, the ideal width and height of humps. However, the Philippines has no definite guidelines and design criteria so far. Thus, the aim of this study is to identify relationship between the speed of vehicles and the spacing of humps as well as other design aspects.

1. INTRODUCTION

Traffic calming is widely recognized as necessary, mainly because of the hazard that vehicles bring if not controlled, especially in residential streets where pedestrian movement should be given preference over the fast passage of motor vehicles. Because of the potential problem caused by excessive vehicle speeds especially in residential areas, remedial measures have been implemented by introducing a traffic calming device to reduce the speed of vehicles effectively. An example of such device for this purpose is known as Road Hump. However, improperly constructed humps can cause serious damage to vehicles even at moderate running speeds. Local authorities or officials in residential areas who are responsible for their construction have little knowledge of the proper approach to constructing them such that it will give less negative impact to vehicles and their occupants, while still achieving the reduction of vehicle speeds. We notice that many of our residential areas constructed hump which are too close to one another and too short in terms of length. This problem is very evident in the old and newer residential streets where road humps are designed and placed in a manner that it not only restricts vehicle speed but also causes discomfort to vehicles and their occupants. This study developed an approach towards understanding the issues related to the proper design and installation of humps in residential streets in the Philippines. The design of road environment for local areas requires a better understanding of the behavioral pattern of driver in speed selection. Knowledge of this behavior is very useful in the design and implementation of appropriate traffic calming device such that it naturally restricts vehicle to a desired maximum speed.

Previous research has shown that many of the physical characteristics of the street's environment affect vehicle speed. An example of these physical characteristics is the spacing of humps as in the case of this study. Guidelines and design standards for installing humps still require study particularly in the Philippines where no definite guidelines and design criteria exist. Thus, this study hopes to make a major contribution towards formulating guidelines and design standard for the construction of humps in the Philippines.

Surveys were conducted in two different areas in Metro Manila. One was conducted in La Vista Village, Quezon City and the other is in Dasmariñas Village, Makati City. Both villages have good quality roads. The types of vehicles considered in this study were cars and vans only. It is also important to note that only isolated vehicles were considered in this study. A study conducted by Pitcher (1989) indicated that the presence of other moving vehicles on the same streets significantly affects the behavioral pattern of driver in speed selection. Thus, external factors (such as other vehicles) affecting the normal behavior of drivers in speed selection are minimized or eliminated by only recording information on single and isolated vehicle.

2. DATA COLLECTION

There are many ways in which the time it takes a vehicle to travel a given distance can be measured. Different procedures require almost different instruments to aid in measuring the speed of the vehicles as it travels from one point to the other. In this study, the use of a series of manually operated stopwatches was adopted.

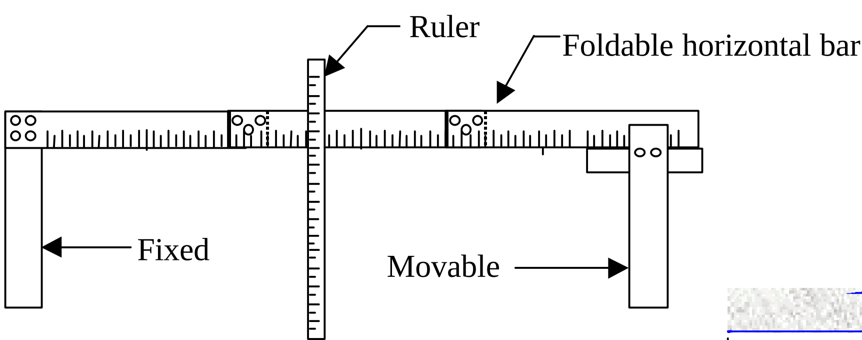
A preliminary survey was made to identify and select humps that are visible to the driver. Thus, humps should be well-painted and in good surface condition. Another important aspect that was considered during the site selection process is the length of road humps. Only road humps with length above 1.2m (4 feet) were considered in this study. Watts (1973) in his study entitled "Road Humps for the Control of Vehicle Speed" have indicated that below this length, hump is too risky and gives an unacceptable level of discomfort to vehicles and their occupants.

To obtain sufficient information on vehicle speed along a street having humps at both ends, a series of observation markers of predetermined spacing were installed. These markers were laid perpendicular to the road section and arranged in a manner that the moment a vehicle pass a given marker, it is visible to the time recorders. To determine the speed of a vehicle passing between single pair of observation markers, the time of passing is recorded for each marker. With this measured time, the speed of the vehicle can be calculated using the formula;

$$V=L/T$$

Where: V = Mean Speed Between Pair of Markers, kilometer per hour
L = Distance or spacing between pair of markers, meter
T = Difference of time recorded as the vehicle moves between a pair of markers, seconds

The geometric characteristics of the six different streets with different hump spacing were measured and recorded. The author developed a foldable-sliding "hump measuring device" capable of measuring different length and height of humps as can be shown in **Figure 2.1** below. This device can measure the humps up to 3.66m (12 feet) long by just sliding the movable leg. The cross sections (**Figure2.2**) of most humps under this study vary from circular to para-sinusoidal shape (i.e., combination of parabolic and sinusoidal shape). All humps selected have good surface condition and are well painted. **Table 2.1** shows the measured height and length of humps using the aforementioned device including other physical characteristics of streets.



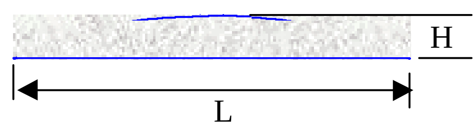


Figure 2.1: Foldable-Sliding Hump Measuring Device

Figure 2.2 The Road Hump

Table 2.1. Physical Characteristics of Streets and Humps

Name Of Street	Direction	Spacing of Humps m	Length of Entrance Hump m	Height of Entrance Hump cm	Road width m	Distance from nearest Intersection m	Posted Speed Limit KPH	Ave. No of Park Vehicle during Observation
Mahogany	Northbound	48	3.65	14.40	8.5	>100	none	1.02
Mahogany	Southbound	48	3.63	13.13	8.5	>100	none	1.02
Kamias	Northbound	54	3.41	12.38	8.5	>100	none	2.86
Kamias	Southbound	54	3.44	12.80	8.5	>100	none	2.86
Lumbang	Northbound	118	1.69	5.08	8.5	7	none	0
Lumbang	Southbound	118	3.13	8.05	8.5	6.5	none	0
Bagobo	Northbound	120	1.42	7.62	9	8	20	0
Bagobo	Southbound	120	1.56	6.99	9	14	20	0
N-Dasma	Northbound	163	3.28	9.84	10	6.7	none	1.47
N-Dasma	Southbound	163	1.98	5.08	10	>100	none	1.77
S-Dasma	Northbound	178	1.98	5.08	10	>100	none	2.85
S-Dasma	Southbound	178	2.91	6.78	10	6.5	none	2.63

3. ANALYSIS

3.1 General Analysis Approach

The relationships between the average speed, maximum speed, the 85^{th} and 95^{th} percentile representative vehicle in relation to the spacing of humps were examined. Linear regression was used to develop a model that describes the relation between the average speed, 85^{th} and 95^{th} percentile of speed with respect to hump spacing. Also, this study analyzes the critical area in which most vehicles attained their peak speed.

3.2 Analysis of Speed Selection Pattern

Though this study has a limited number of observed vehicles (378) and hump intervals (6) but the data gathered was able to show some significant results in the way drivers of isolated vehicles select their speed. **Figure 3.2.1** shows the speed profile of each vehicle for each direction of travel in between two humps. The speed profile of the average, 85^{th} and 95^{th} percentile representative vehicles were also presented in **Figure 3.2.2**. Each graph of the speed profile is oriented such that vehicles are entering from the left side of the plot. It can be observed from these graphs, that the plot of the speed profiles of a majority of the vehicles is skewed to the right. This shows that drivers normally accelerate gradually as they leave the entrance hump and up to a point where maximum speed is reached, then decelerate relatively faster while approaching the exit hump. With respect to the location wherein maximum speed is attained, drivers apparently select their speed to be within the third quarter of the interval between humps. A close examination of each graph shows that the maximum speed in which the vehicles select varied greatly among the drivers. This leads to the conclusion that other factors affect individual speed selection rather than just the spacing of humps and the entrance speed. The inconsistency of these behavioral patterns lead to the conclusion that there is a need for further study on the entrance speed of the vehicles rather than the spacing and type of humps itself that might affect the behavior of the driver in attaining maximum speed.

Click Figure Numbers

Figure 3.2.1: Speed Profile Diagram in Six Different Streets with Different Hump Spacing

Figure 3.2.2: Speed Profile of the Average Speed, 85^{th} and 95^{th} Percentile

The maximum speed which vehicles attained were categorized and analyzed as shown in **Table 3.2**. From this, we can see the proportions of vehicles corresponding to the maximum speed they attained as it travels between two humps. One important observation that can be drawn from this Table is that, a significant proportion of vehicles reached a maximum speed above 50 km/h for all streets with hump spacing above 100m. This result may be a cause for concern to local authorities since the fatality rate of pedestrians against impact speed is very high. In a recent review of the issues, the European Transport Safety Council (1995) reported that only 5% of pedestrians died when struck by a vehicle traveling at 20 mi/h (32 km/h); however, the proportion of fatalities increased to 45% at 30 mi/h (48km/h).

Table 3.2: Proportion of Vehicles Attaining Maximum Speed in Between Hump Spacing.

NAME OF STREET	Directions	Spacing of Humps	Percentage of vehicles According to Classification of Maximum speed Attained						
			<20kph	21-30kph	31-40kph	41-50kph	51-60kph	61-70kph	>71kph
Mahogany Street	Bothways	48	0	31	69	0	0	0	0
Kamias Street	Bothways	54	0	54	46	0	0	0	0
Lumbang Street	Southbound	118	0	0	28	50	22	0	0
Lumbang Street	Northbound	118	0	0	20	53	27	0	0
Bagobo Street	Southbound	120	0	0	21	53	26	0	0
Bagobo Street	Northbound	120	0	7	49	36	7	0	0
N-Dasma Street	Southbound	163	0	0	53	41	6	0	0
N-Dasma Street	Northbound	163	0	0	7	56	37	0	0
S-Dasma Street	Southbound	178	0	0	28	47	25	0	0
S-Dasma Street	Northbound	178	0	0	10	56	29	5	0

Another important observation that can be drawn from **Table 3.2** are for streets with hump spacing 118m and 120m long. These have similar distributions of vehicles attaining certain maximum speed, except for northbound traffic of Bagobo Street. In order to understand the cause of such circumstance, the relations between entry speed and hump design were investigated and are discussed in details in section 3.5

3.3 Analysis of Critical Area in Relation to Maximum Speed Attained

The critical area mentioned in this section refers to the position relative to the spacing of humps in which the majority of the passing vehicles reach their peak speed. To determine the critical area or section in which individual vehicle attained their maximum speed, the distance between two humps is divided into four quarters. **Table 3.3** shows the proportion of individual vehicles attaining maximum speed within the specified quarter. As can be observed from these percentages, most of the observed isolated vehicles attained their maximum speed in the middle two quarters of the street of which majority of them reached their peak speed in the third quarter of hump spacing. This suggests that for hump spacing between 48 meters to 178 meters, the maximum speed is usually attained within the 3rd quarter.

Table 3.3 Proportion of Vehicles Attaining Maximum Speed of Specified Quarter

Name of Street	Street Length (M)	Direction	Quarter in which Individual Vehicle Attained Maximum Speed				Total number of observations
			1st	2nd	3rd	4th	
Mahogany Street	48	Both directions	0%	18%	78%	4%	45
Kamias Street	54	Both directions	0%	11%	89%	0%	35
Lumbang Street	118	Southbound	0%	3%	94%	3%	32
Lumbang Street	118	Northbound	0%	0%	100%	0%	15
Bagobo Street	120	Southbound	0%	2%	98%	0%	43
Bagobo Street	120	Northbound	0%	4%	93%	3%	69
N-Dasma Street	163	Southbound	0%	6%	94%	0%	17
N-Dasma Street	163	Northbound	0%	3%	94%	3%	30
S-Dasma Street	178	Southbound	0%	16%	84%	0%	32
S-Dasma Street	178	Northbound	0%	7%	93%	0%	59

3.4 Relationships between Vehicle Speed and Hump Spacing

A model from the six different streets observed was derived using linear regression analysis. The generated result of linear fit of the average, 85th and 95th percentile representative vehicles is shown in **Figure 3.4.1**. R-square is highest for the model using hump spacing to explain the 95th Percentile representative speed. Likewise, the average speed is relatively better over the 85th Percentile representative speed in terms of its goodness-of-fit model. Moreover, for all models, hump spacing appears to be very useful explanatory variables, although more data may be needed to produce a more statistically supported conclusion.

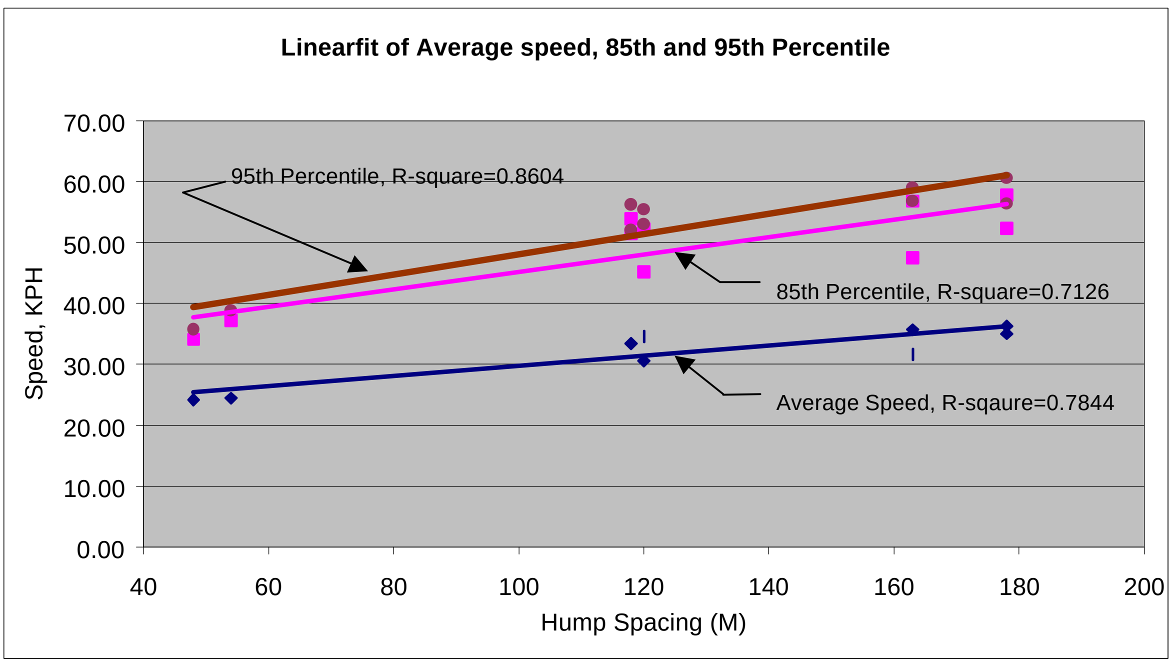
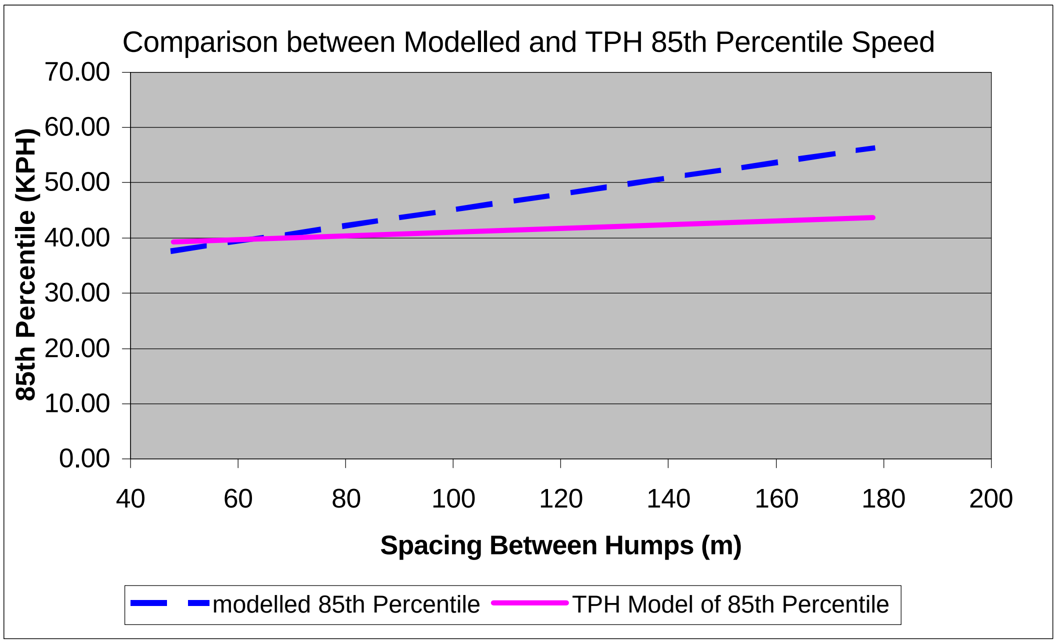


Figure 3.4.1: Linear Fitting of the Average Speed, 85th and 95th Percentile Speed in Relations to Hump Spacing

A comparison between the developed 85th percentile speed model based on Philippine survey data and the 85th percentile model presented in Transportation Planning Handbook of the Institute of Transportation Engineers was made as shown in **Figure 3.4.2**. It appears that vehicle speeds in the Philippines are more sensitive to hump spacing than the TPH counterpart. It can also observed from the graph that in order to maintain the maximum speed to within 40 km/h, road hump spacing must be about 60meters. Increasing the spacing to 100 meters would mean that the maximum speed could reach to 45km/h. Furthermore, the graph indicates that drivers are less sensitive to the residential street environment specifically to pedestrian's safety as indicated by the slope of the line of the 85th percentile speed. These results might be partly attributed to the driver's familiarity to a given residential street's environment, since a large portion of road users can be surmised to regularly pass the surveyed roads.



NOTE: TPH Model of 85th Percentile, can be found in the ITE's "Transportation Planning Handbook, 2nd Edition, 1998" (Courtesy of Portland Traffic Calming Program, Bureau of Traffic Calming, City of Portland, Oregon).

Figure 3.4.2: Comparison between the Actual and the Modeled 85th percentile Speed

3.5 Effects of Hump Design on Speed

To examine whether the physical characteristics of humps has influence the speed selection behavior of the drivers, the entry speed of each vehicle were classified and characterized as shown in **Table 3.5**. For the purpose of this study, the term "entry speed" refers to the speed of the vehicle just after it has cleared the entrance hump. This entry speed was taken from the first five-meter reading after the entrance hump. It was found that northbound vehicles of Bagobo Street recorded the highest proportion of vehicles (74%) using relatively lower entry speeds. A close examination to the physical characteristics of humps revealed that south hump of Bagobo Street had the shortest length (1.42 m or 4.67 ft.) among the humps surveyed but with a relatively higher height (7.62 cm or 3in.). It seems that this type of hump produces a relatively higher level of discomfort compared to other hump with longer length. A study conducted by Watts

(1973) entitled "Road Humps for the Control of Vehicle Speed", also indicated that for hump 7.62cm (3 inches) high and with length around 4 ft and below received the lowest acceptable ratings in terms of comfort and safety.

Table 3.5: Proportion of Vehicles of Different Entry Speed

Dimensions of Hump		Entry Speed of Individual Vehicle					Total # of Isolated Vehicles Observed
Length M (FT)	Height CM (in)	<10 KPH	10-15 KPH	16-20 KPH	21-25 KPH	>25 KPH	
3.64 (~12.00)	13.13 (5.17)	2%	36%	60%	2%	0%	45
3.42 (11.22)	11.96 (4.71)	0%	51%	43%	6%	0%	35
3.28 (10.75)	9.86 (3.88)	0%	29%	71%	0%	0%	17
3.13 (10.28)	7.62 (3.00)	0%	25%	69%	6%	0%	32
2.91 (9.55)	6.78 (2.67)	0%	27%	59%	12%	2%	59
1.98 (6.50)	5.08 (2.00)	0%	47%	40%	13%	0%	30
1.98 (6.50)	5.08 (2.00)	0%	38%	53%	9%	0%	32
1.69 (5.55)	5.08 (2.00)	0%	40%	47%	13%	0%	15
1.56 (5.13)	6.99 (2.75)	2%	42%	37%	19%	0%	43
1.42 (4.67)	7.62 (3.00)	1%	74%	25%	0%	0%	69

An attempt was made to clarify the relationship between entry speed and the height and length of humps, but this had a poor result. Only the average entry speed was explained to a limited degree as shown in **Figure 3.5.1**, when considering the relationship between the ratio of the height and length of humps (*H/L ratio*) with respect to different entry speed of the vehicles. The result of model of the 85^{th} and 95^{th} percentile speed as shown in the same Figure suggest that the H/L ratio is not a good explanatory variable. This lack of association suggests that other factors may need to be identified before a satisfactory model can be develop. The Department of Environment, Transport and Regions in the UK issued Traffic Advisory Leaflets under Traffic Management which indicated that the spacing of humps have more effect on mean speed than the height and length of humps. These two results suggest that entry speed itself may only be controlled to a limited degree.

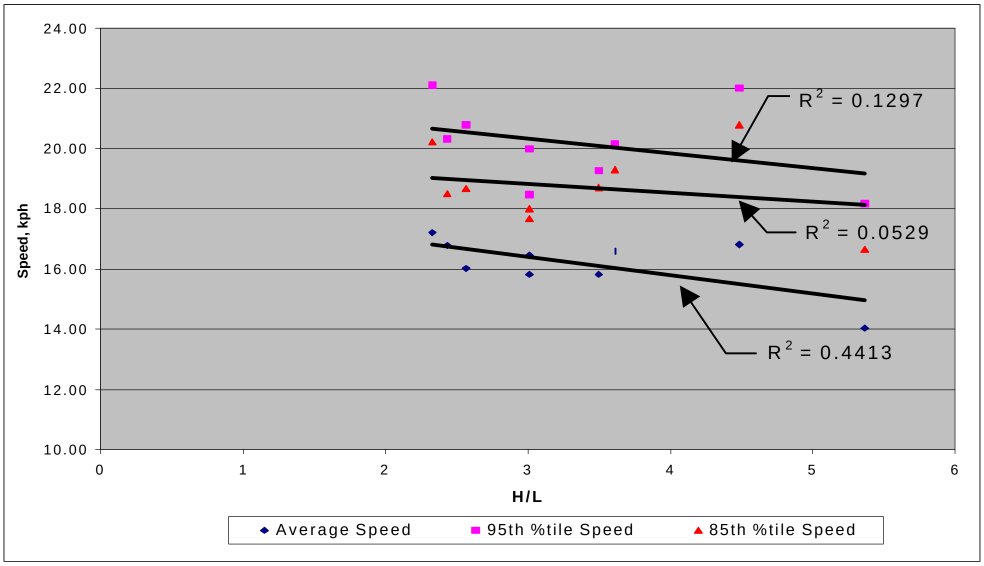


Figure 3.5: Linear Fit of the H/L ratio and Entry Speed

4. CONCLUSIONS AND RECOMMENDATIONS

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This study established some trends which maybe useful in formulating the design standards of road humps in the Philippines.

- For all streets in which data was collected, speeds appeared to have a large variation between humps but were less varied near the entry and exit humps.
- Road humps with length less than 1.5 m (5 feet) and a height of 7.5cm (3 in) was recorded the lowest entry speed than any other humps greater than 1.5 m in length of any height but not above 13.13cm.
- For all humps with a spacing ranging from 118 m to 178 m, majority of isolated vehicles attained a maximum above 31 kilometer per hour and a significant proportion (21.5%) has attained a maximum speed above 50 km/h.
- Majority of the isolated vehicles attained their maximum speed within the third quarter of hump spacing in both directions.
- Recommending for future guidelines in constructing road humps, this study suggests that, in order to limit the speed of vehicles to below 45 kph, the spacing of the humps must be around 100meters.

There are many instances where the difference in observed speed behavior is very evident and seems to lack association to the physical characteristics of the street environment. This suggests that other factors such as psychological also have an impact on the driver's behavior and thus there is a need for further research.

References:

Watts, G.R.: *"Road Humps for the Control of Vehicle Speeds*". TRRL Laboratory Report, Transportation and Road Research Laboratory, Department of Environment, 1973.

Pitcher, Ian : " *Speed Profiles of Isolated Vehicles in Residential Streets*": Civil Engineering Working Papers, Department of Civil Engineering, Monash University, Australia, 1989

Smith, Duane E. and Giese, Karen L.: "*Speed Humps"* : Research Publication, Center for Transportation Research and Education, Iowa State University, Ames. 1997: http://www.ctre.iastate.edu/Research/roadhump.

Transportation Planning Manual, 2nd Edition, Institute of Transportation Engineers; Edwards, John D. Jr., P.E, Editor, 1998

Traffic Advisory Leaflets (02/96): "*75mm High Road Humps"*: Traffic Management, UK Department of the Environment, Transport and the Regions: http://www.roads.detr.gov.uk/roadnetwork/ditm/tal/traffic/index.htm

European Transport Safety Council*, "Reducing Traffic Injuries Resulting From Excess and Inappropriate Speed,"* Brussels, 1995