Research Journal of Applied Sciences, Engineering and Technology 7(13): 2741-2746, 2014
DOI:10.19026/rjaset.7.595
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: September 14, 2013 Accepted: September 25, 2013 Published: April 05, 2014

Research Article

Using Appropriate Speed Tables Regarding to the Speed Limit of Streets

Amir Falamarzi and Riza Atiq O.K. Rahmat
Department of Civil and Structural Engineering, Faculty of Engineering and Build Environment,
Sustainable Urban Transportation Research Centre (SUTRA), Universiti Kebangsaan Malaysia, 43600
UKM Bangi, Selangor Dural Ehsan, Malaysia

Abstract: In the present decade along the increasing trend of using private vehicles, calming the local streets and residential areas has been important for local authorities. There are many unsuccessful experiences of traffic calming implementations because of lacking knowledge and engineered assessment before implementing them. Considering the design speed of traffic, calming measure is an essential factor to employ these measures. Design speed of different size of speed humps is investigated in previous studies because of its circular shape but for speed tables it is unknown. In this research the design speeds of two common speed tables in the city of Tehran have been examined, 6.5 and 8.5 m speed table. For calculating the design speed of the speed tables, we asked 220 drivers to participate in our experiment by installing a GPS tracker in their vehicles and encouraging them to drive normally. Crossing speeds over 6.5 and 8.5 m speed tables have been analyzed by collecting totally 220 samples. We pick out 100 correct samples for each speed table and the 85th percentile speed has been calculated for them, consequently the results of 85th percentile calculation of the crossing speeds have been proposed as the design speeds. For 6.5 m speed table, design speed is calculated 41.5 km/h and for 8.5 m speed table, design speed is calculated 47.5 km/h. the comparison of recent findings and past finding of 9.5 m speed table which is used in Denmark with a design speed of 80 km/h reveals that 1 m increasing with the length of a 6.5 speed table plateau will result 3 km/h increase in its design speed. The findings of this research can help traffic calming experts to take in consideration of the relation between speed table physical characteristics and its design speed. Furthermore by finding the design speed of speed tables, we can choose suitable speed tables for streets with different speed limits according to the design speed of speed tables.

Keywords: Crossing speed, design speed, speed limit, speed table, traffic calming

INTRODUCTION

Vertical traffic calming measures are a group of physical measures including speed bump, speed hump and speed tables that their role is to slow down traffic speed and discourage through traffic or shortcut traffic to enter local areas. Speed table is a flat topped speed hump which is more common in local collectors, which has great impact on traffic safety condition. Ewing (2001) studied that speed tables reduce traffic speed by 18% and reduce traffic volume by 12%. In recent years using vertical traffic calming measure is widespread but in some cases there is not specific instruction or enough engineering knowledge behind it because implementing vertical traffic calming measure depends on the location, speed limit and the traffic volume (Transportation, 2001). The place of implementing of traffic calming measure is important, for example regarding to design speed of speed bumps, they can be implemented in the parking lot, shopping mall, pedestrian zone and the places where the pedestrian movement is high and the speed limit adjusted to its lowest amount respectively, speed humps and speed tables are suitable for local street and collector streets (Ewing, 1999).

Design speed of speed tables varies depending on different factors including length of ramp, height and length of the plateau. Length of speed tables' ramp in most speed tables is same and is about 1.8 to 2 m. Height of speed tables also varies from 7.5 to 10 cm; length of the plateau is normally 3 m or higher. For speed table there are no specific and systematic studies for determining the design speed of different sizes of speed tables, however according to past studies it has been estimated between 40 to 50 km/h in different sources for a 6.7 m speed table, ITE found that design speed for 6.7 m speed table with a height of 9 cm is about 43.5 km/h (Ewing, 1999). In Denmark design speed for 9.5 m speed table has been estimated 50 km/h (Weber and Braaksma, 2000). Contrary to speed tables,

Corresponding Author: Amir Falamarzi, Department of Civil and Structural Engineering, Faculty of Engineering and Build Environment, Sustainable Urban Transportation Research Centre (SUTRA), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor Dural Ehsan, Malaysia

design speed of different sizes of speed humps has been targeted because of the circular shape of speed hump which make it easier for experts to estimate the design speed. ITE found that there is a direct relation between the design speed and the radius of speed humps (Ewing, 1999).

Having the design speed of vertical traffic calming measure, help traffic experts to choose the functional measures according to the road speed limit. If we can find the relation between physical characteristics of speed tables and their design speed, so we can assign the suitable speed table for roads with specific speed limit. In this research we want to expand our knowledge about the design speed of speed tables by examining our experiments on the implemented speed tables in the city of Tehran. Because of carrying out the field experiments and the fact that the length of speed table ramp in most speed tables is about 1.8 m in Tehran and also the height of speed tables is fixed (about 10 cm) therefore the only variable to examine and analysis is the length of the speed table plateau. In the city of Tehran there are different implementations of speed tables with different sizes of the plateau. In our research we examined the design speed of the speed tables with regard to the length of the speed table plateau.

MATERIALS AND METHODS

Using a traffic calming measure without considering their design speed of and a speed limit of the roads make traffic calming schemes unsuccessful. If the design speed of traffic calming measure is lower than the speed limit, it causes vehicles to stop in slow points and sudden braking which will make residential unsatisfied and also raise air pollution adjacent to traffic calming measures. Vice versa if the design speed of traffic calming measures is greater than the speed limit, traffic calming measures will be ineffective because in this case traffic calming measures cannot force drivers to slow down. It must be a proper correlation between design speed of traffic calming measures and a speed limit of the roads. According to experiences, traffic calming manual and expert recommendations, for warning drivers toward their speed and also enforcing them to adjust their speed to speed limit, design speed of traffic calming measure must be set between 5 to 8 km/h lower than the speed limit also it is recommended that for setting speed at 40 km/h the proper distance between measures is 100 m and for speed limit equals 50 km/h, distance between measure should not exceed more than 150 m (Engineers, 2001).

For measuring the crossing speed of vehicles in transportation engineering studies, there are different methods. LIDAR gun, Radar gun, stopwatch method and GPS tracking are common methods for collecting speed data of moving vehicles. Stopwatch method is a conventional and inexpensive way for collecting speed. In this method of marking two points as a start point and end point and considering a length between these two points as a constant length, the time while a vehicle passes from the start point and reaches to end point will be stored by an observer and then the speed will be calculated through dividing the length by the stored time. Stopwatch method is simple and easy but regarding to the short length of speed tables this method is not accurate for determining the crossing speed of speed tables.

Fig. 1: The LIDAR speed gun (the stalker LIDAR LR)

Radar gun is a commonly used method to collect speed of moving vehicles. This could be portable or installed at a specific location (Currin, 2011). The radar speed gun is a type of Doppler radar where by sending a signal toward a moving vehicle and then detecting the frequency changes coming from the reflection, can determine the speed of objects. Reflected waves are different while an object moving toward or away from the gun so the observer can detect the direction of vehicles. It must be taken into account that the performance of the speed guns is acceptable if there is no angle between moving objects and observer. LIDAR gun is more complicated and recently used by police forces for enforcing the speed limit on highways. The LIDAR gun function is similar to radar speed gun but the difference is using the laser technology and makes it more reliable than a radar speed gun (Daniel *et al.*, 2012). Applying radar speed gun and the LIDAR gun in city of Tehran for our research were needed to be approved by police and authorities. Hence using these devices for our research were not accessible. Figure 1 illustrates the LIDAR speed gun.

In our research a GPS tracker is used. The GPS tracker is an electronic device which can store data related to speed and movement of vehicles. By having the distance and speed, we can derive a speed profile for moving vehicles. Figure 2 illustrates a diagram of speed profile providing by a GPS tracker before and after passing traffic calming measures in the city of the Genovese (García *et al.*, 2011).

In order to examine the crossing speed at a speed table at first we decided to select streets which speed tables are implemented on. According to traffic calming manual it is recommended to install speed table on collector streets or local streets and it must be avoided to install them on arterial streets or street with high traffic volume. A collector street is the street which its function is to collect traffic volume from local streets and transfer them to arterial streets or main streets (AASHTO, 2004). Usually trip generator developments

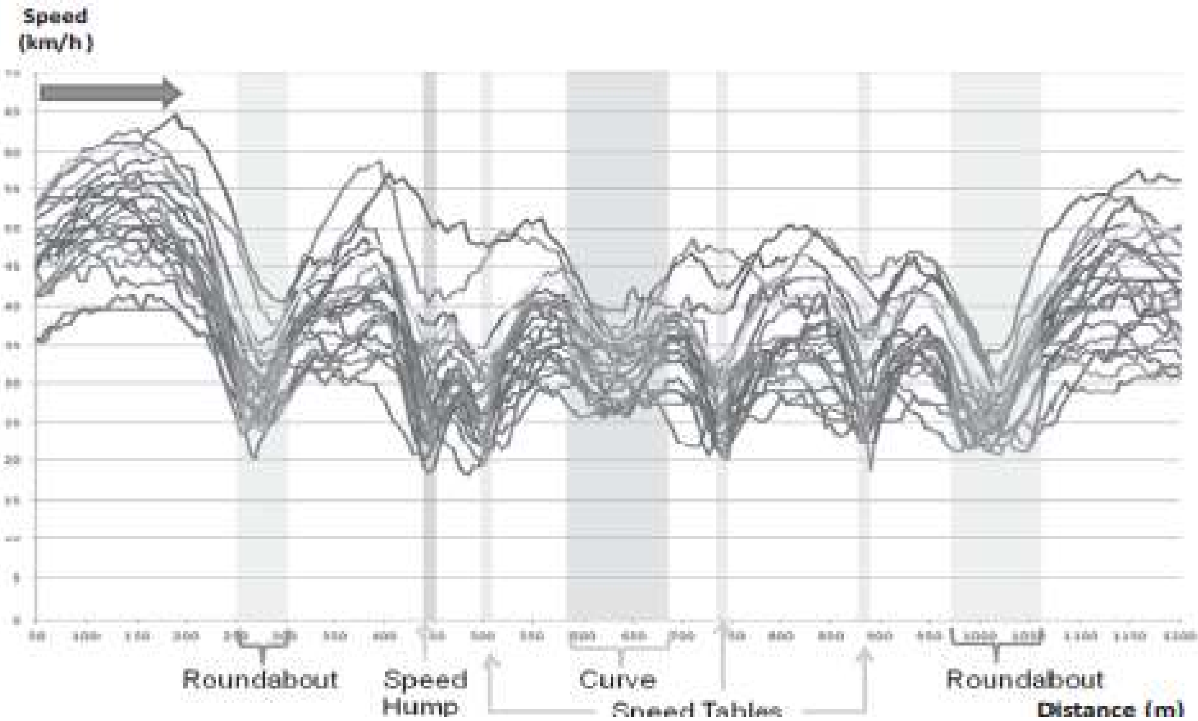

Fig. 2: Speed profile before and after passing traffic calming measures in Genovese (García *et al*., 2011)

which serve residential areas and local streets are located in collectors such as local schools, parks and small shops.

In this study for investigating the design speed of speed tables, two sizes of speed table have been selected. The length sizes of selected speed table are 6.5 and 8.5 m and these two speed tables have been implemented at midpoint of streets. These speed tables have 1.8 m ramp and the height of them is almost 10 cm (the length of plateau for the 6.5 m speed table is about 3 m and for the 8.5 m speed table is about 5 m after subtracting the length of speed table ramp from the total length) and both of them are installed in collector streets in the north of Tehran. We found other sizes of speed table, but the problem was the location and design of them, implementation at the beginning of streets is not acceptable because the vehicle is not still accelerated, also, implementation at the end of the streets cannot be acceptable because of slowing down of speed. Furthermore, the length of speed table ramp in some implemented speed tables was below 1.5 m and in some cases the height of speed tables was higher than 10 cm so they have been rejected for our study.

To examine the crossing speed of speed tables, for each speed tables we stopped drivers randomly and asked them to cooperate with us. We installed the GPS tracker in their car and recommend them to drive normally. García *et al*. (2011) experimented same successful method, in that study, the GPS tracker had been employed to store the speed profile of vehicles before and after the traffic calming measures.

In our research, for each speed table, we repeated the experiment by 100 drivers. To ensure that drivers have the enough time to accelerate and speed up from the starting point we installed a GPS tracker in vehicles 200 m prior to speed tables and replaced it 200 m after speed tables for letting the driver to decelerate and slow down gradually without minimum effect on their speed when crossing over the speed tables. The traffic condition when the experiment is carried out must be in free flow traffic otherwise the function and the impact of speed table cannot be monitored accurately. Totally 220 times the experiment has been carried out and about 10% of them were excluded because of non-free flow traffic, stopping before speed tables and an unusual behavior of drivers when driving their car at the speed tables.

In order to determine the design speed of speed tables, we have to consider 85^{th} percentile speed as a reliable method to measure speed. (85^{th} percentile) speed is the speed in which 85^{th} percentile of moving vehicles at or below that Roess *et al*. (2004). (85^{th} percentile) speed is not the peak of speed but it is assumed that 85 percentile of drivers, drive at a safe speed. Transportation (2000) stated that 85^{th} percentile speed is important because the majority of drivers are cautious and responsible and avoid road accidents also reaching their destinations in minimum delay and shortest distance is their desire. To calculate the 85^{th} percentile speed, firstly speed distributing frequency must be calculated from our data, the speed distributing frequency determines a number of vehicles driving at a certain speed, for example, driving at a speed of 35 km/h. Cumulative frequency is the summation of speed distributing frequency adding to each other from lower speed to higher speed (first row to last row). Cumulative percentages represent the percentage of cumulative frequency.

In most cases the 85th percentile speed cannot be achieved without sorting the data. In this regard we have employed the Eq. (1) to achieve the 85th percentile speed as follows:

$$S_{85} = \frac{85-P_{min}}{P_{max}-P_{min}}(S_{max} - S_{min}) + S_{min} \quad (1)$$

where,

S_{85} = Represents the 85th percentile speed which is our target
P_{max} = Represents the higher amount of cumulative percent, e.g., 86th %
P_{min} = Represents the lower amount of cumulative percent, e.g., 79th%
S_{max} = Represents the speed of P_{max}
S_{min} = Represents the speed of P_{min}

RESULTS

After collecting the crossing speeds for the speed tables from the GPS tracker, 85th percentile speed for each speed table is calculated through Eq. (1). By substituting the collected data into Eq. (1), 85th percentile speed for the 6.5 m speed table calculated: 41.5 km/h. Table 1 illustrates the frequency distribution of the crossing speeds for the 6.5 m speed table also Fig. 3 illustrates a cumulative speed distribution plot for the 6.5 m speed table:

$$S_{85} = \frac{85-80}{90-80}(42 - 41)\ 41 = 41.5 \quad (2)$$

Respectively, in the 8.5 m speed table, the 85th percentile speed is obtained 47.5 km/h regarding with 100 speed samples. Table 2 illustrates the frequency distribution of the crossing speeds for the 8.5 m speed table. Cumulative speed distribution plot for the 8.5 m speed table has been illustrated in Fig. 4:

$$S_{85} = \frac{85-78}{92-78}(48 - 47) + 47 = 47.5 \quad (3)$$

According to the findings and the 85th percentile speed calculations, design speed of the 6.5 and 8.5 m speed is 41.5 and 47.5 km/h. In this regard 85th percentile speed has been increased associated with the speed table length. By Increasing 2 m in the length of the 6.5 m speed table, design speed increased around 6 km/h from 41.5 to 47.5 km/h at a 8.5 m speed table. Two meter increase in speed table length will result 6 km/h increase in design speed of speed tables it proves the theory that longer speed table have higher design speed. Table 3 summarized the results of the current study of design speed for 6.5 and 8.5 m speed tables and the previous study in the 9.5 m speed table in Denmark.

Analyzing the data collected from the GPS which is represented by the speed-distance profile show that most of vehicles decelerate and slow down their speed about 50 to 25 m prior to speed tables and crossing

Table 1: Frequency distribution of the crossing speed for the 6.5 m speed table

Speed (km/h)	Frequency	Cumulative frequency	Cumulative (%)	Percentile speed
35	5	5	5	
36	10	15	15	
37	8	23	23	
38	14	37	37	
39	16	53	53	
40	12	65	65	
41	15	80	80	85th speed
42	10	90	90	
43	5	95	95	
44	2	97	97	
45	3	100	100	

Table 2: Frequency distribution of the crossing speed for the 8.5 m speed table

Speed (km/h)	Frequency	Cumulative frequency	Cumulative (%)	Percentile speed
40	4	4	4	
41	7	11	11	
42	9	20	20	
43	9	29	29	
44	10	39	39	
45	10	49	49	
46	14	63	63	
47	15	78	78	85th speed
48	14	92	92	
49	5	97	97	
50	1	98	98	
51	2	100	100	

Table 3: Summarization of the design speed for the tested speed tables

Speed table length (m)	85th percentile design speed (km/h)
6.5 m speed table	41.5
8.5 m speed table	47.5
9.5 m speed table	50.0

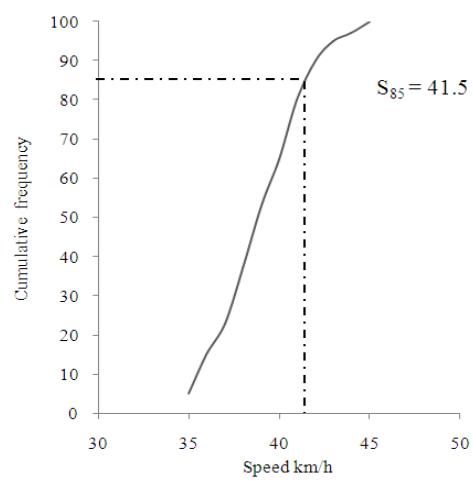

Fig. 3: Cumulative frequency distribution for the 6.5 m speed table

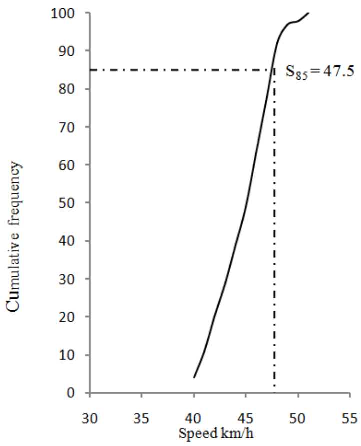

Fig. 4: Cumulative frequency distribution for the 8.5 m speed table

speed reaches to its lowest speed at the top of speed tables. After passing speed table vehicles accelerate and speed up. While conducting our experiments we found that, behavior of drivers encountering speed tables is not same and it changes in drivers' age, sex and vehicle type. We found out that due to a lower level of risk in elder drivers and women drivers, they tend to slow down their speed around 40 to 50 m before speed tables and usually drive cautiously in this regard, on the other hand, younger drivers and male drivers put lower distance about 20 to 30 m before heading speed tables to slow down. Furthermore drivers of four wheel cars pass speed tables with higher crossing speed than a normal sedan car due to their confidence in their vehicle safety.

During the field experiment randomly we asked some drivers to express their ideas about their satisfaction and comfort when passing speed tables, most of them answered that they are more satisfied with speed tables than speed humps due to higher crossing speed and passing them without needing to slow down or stop their vehicles close to speed tables. On the one of collector streets, during collecting the speed data of the 6.5 m speed table, local drivers expressed that before implementation of the current speed table, there was a speed hump instead of speed table and that measure caused dozen of drivers to break suddenly and regarding to the large number of vehicles passing the street daily, traffic accident was unavoidable. Also local drivers and neighborhoods commented that, the design of speed tables is more effective than speed hump in term of speed adjustment, because in addition of forcing drivers to decrease their speed it can give drivers the flexibility and time to adapt their speed with the design speed of speed table due to the long surface of speed tables.

DISCUSSION AND CONCLUSION

The main contribution of this research is to develop our findings about the relation between physical characteristics of vertical traffic calming measures especially speed tables and design speed of them and help traffic calming experts to select measure according to the road speed limit. The assessment of our experimental results in Tehran represents that increasing the length of speed table for only 1 m will averagely increase the design speed of speed tables about three km/h. It means that if we add 2 m to the length of 6.5 m speed table with a height of 10 cm, design speed will change from 41.5 to 47.5 km/h. It can be predicted that decreasing length of speed table can reduce the design speed of speed tables inversely.

There is no conflict between the present study and the finding of ITE for the 6.7 speed table, because the difference between the design speed in the present research and the past research is due to the height of the speed tables. In earlier research, the 6.7 m speed table with 9 cm height has been investigated and the design speed of 43.5 km/h has been recorded whereas in present study 6.5 m speed table with a height of 10 cm has been investigated and the design speed of 41.5 km/h has been recorded. It can be referred to this fact that the higher height enforces drivers to slow down their speed to pass speed tables more safely and avoid shocks (Weber and Braaksma, 2000).

The recommendation for the differential between design speed of speed table and road speed limit is 5 to 8 km/h therefore for collector street with 45 km/h and considering the differential speed, the proper design speed of speed table is 37 to 40 km/h hence 6.0 m speed table with approximate design speed of 40 km/h may be suitable respectively, for collector street with speed limit of 50 km/h the proper design speed of speed table is 42 to 45 km/h hence 7.5 m standard speed table with approximate design speed of 44.5 km/h is suitable. For a collector street which is allocated for bus route or street with a speed limit of 55 km/h or higher, the 9.5 m speed table with a design speed of 50 km/h is recommended. For collector streets with speed limits of 40 km/h or lower, the standard speed table cannot be implemented due to minimum 2 m length for the length of the speed table plateau, in this regard, using speed hump with the total length of 4.2 m is appropriate.

It must be mentioned that in this research only changing the length of the speed table plateau has been examined. The height of speed table is also a critical issue which can affect the function of speed tables, it is recommended for future studies to examine the effect of changing the length and height of speed tables simultaneously and with more sample cases in order to propose a mathematic model (linear or nonlinear) including the height and the length of speed tables as the independent variables and the design speed as the dependent variable. Traffic simulating software such as AIMSUN NG and VISSIM can help researchers to generate the samples for future studies if the number of samples in physical experiment is limited. Furthermore it must take into consideration that maximum height of speed table recommended in the different manual and standard is about 10 cm hence more than this height may disrupt the natural function of speed tables (Engineers, 2001).

REFERENCES

AASHTO, 2004. A Policy on Geometric Design of Highways and Streets. American Association of State Highway and Transportation Officials, Washingtn, DC.

Currin, T.R., 2011. Introduction to Traffic Engineering: A Manual for Data Collection and Analysis. Nelson Engineering, Cengage Learning, Independence, KY.

Daniel, B.D., A. Nicholson and G. Koorey, 2012. The effects of vertical speed control devices on vehicle speed and noise emission. Proceeding of the ARRB Conference. Perth, Western Australia, Australia.

Engineers, D., 2001. Traffic Calming Protocol Manual. Municipality of Anchorage, Anchorage, Alaska.

Ewing, R.H., 1999. Traffic Calming: State of the Practice. Institute of Transportation Engineers, Washington, D.C.

Ewing, R., 2001. Impacts of traffic calming.Transport. Quart., 55(1): 33-46.

García, A., A.J. Torres, M.A. Romero and A.T. Moreno, 2011. Traffic microsimulation study to evaluate the effect of type and spacing of traffic calming devices on capacity. Proc. Soc. Behav. Sci., 16: 270-281.

Roess, R.P., E.S. Prassas and W.R. McShane, 2004. Traffic Engineering. 3rd Edn., Pearson/Prentice Hall, Upper Saddle River, NJ.

Transportation, T.D.O., 2000. Procedures for Establishing Speed Zones. State or Province Government Publication, Austin, Texas.

Transportation, P.D.O., 2001. Pennsylvania`s Traffic Calming Handbook. Pennsylvania Department of Transportation, Pennsylvania.

Weber, P.A. and J.P. Braaksma, 2000. Towards a North American geometric design standard for speed humps. ITE J., 70(1): 30-39.