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The Effectiveness of Indonesian Speed Reduction Devices

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Keywords: speed reduction devices, government standard, effectiveness, traffic calming

The Government of Republic of Indonesia has developed standard for speed reduction devices, but, in practice, many communities tend to build the devices in their neighborhood without comply with the standard. For socialization purposes and further improvement, it is needed an information regarding the effectiveness of the device. Therefore, this study aims to investigate the effectiveness of speed reduction devices, namely speed hump and chicane, based on Indonesian standard. Parameters of speed and noise reduction were used to explain the effectiveness. The analysis shows that speed hump based on Indonesian standard have significantly reduced vehicle speed, as well as reduces noise pollution level. The combination of speed hump with chicane results better effectiveness compared with road hump without chicane.

The Effectiveness of Indonesian Speed Reduction Devices

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Abstract: The Government of Republic of Indonesia has developed standard for speed reduction devices, but, in practice, many communities tend to build the devices in their neighborhood without comply with the standard. For socialization purposes and further improvement, it is needed an information regarding the effectiveness of the device. Therefore, this study aims to investigate the effectiveness of speed reduction devices, namely speed hump and chicane, based on Indonesian standard. Parameters of speed and noise reduction were used to explain the effectiveness. The analysis shows that speed hump based on Indonesian standard have significantly reduced vehicle speed, as well as reduces noise pollution level. The combination of speed hump with chicane results better effectiveness compared with road hump without chicane.

Key Words: *speed reduction devices, government standard, speed hump, chicane, effectiveness*

1. INTRODUCTION

Transportation is one of the key elements which make a great contribution towards the development of a nation (Rodrigue, 2006). Many major cities in Indonesia are now facing problems with the growing numbers of motor vehicles as a result of the increasing of population number (Susanto, 2009). This increase creates an increasing need of road infrastructure, which its combination leads to higher accident risk for road users, especially pedestrians. The risk is a result of higher speed of the vehicle. One approach to tackling the speeding problem is the use of traffic calming measures as a means of enforcing speed restrictions along roads running through populated areas (Garrod et al., 2002).

Speed reduction devices, which also known as traffic calming devices, was defined as a facility which involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes (Institute of Transportation Engineers, 2009). According to County Surveyor’s Society et al. (1994), the objectives of speed reduction devices are improving driver's behavior, concentration, and awareness; reducing speed, disturbance, and anxiety; and enhancing the environment.

The findings of Tester et al. (2004) suggest that speed humps make children's living environments safer, while Bunn et al. (2009) explains that area-wide traffic calming in towns and cities may be a promising intervention for reducing the number of road traffic injuries and deaths. Furthermore, Sarkar et al. (1997) argued that traffic calming is one way of reclaiming the roads for a more equitable use by different users. In case of the existence of through traffic, traffic calming the through road has been successful compared with the bypass (Leden et al., 2006).

Although the majority of local residents enjoy benefits from traffic calming in terms of improved road safety and a reduction in community severance, but it is likely that some drivers may experience a loss in utility due to the impacts of traffic calming measures on their journeys (Garrod et al., 2002). Huang and Cynecki (2000) found that while traffic calming devices have the potential for improving the pedestrian environment, these devices by themselves do not guarantee that motorists will slow down or yield to pedestrians. On the other hand, to improve the comfort as well as to reduce vehicle speed, a combination of speed hump and chicane shows a good result in decreasing speed (County Surveyors Society, 1992).

Furthermore, the implementation of speed hump does not only reduce vehicle speed, but it also results some negative impacts, namely noise pollutions. Noise pollutions appeared when vehicle decelerated before passing the speed hump, when vehicle passed the speed hump, and when vehicle accelerated after passing the speed hump (Hardhy, 2008). Arianto (2008) explains that the noise pollutions level can be reduced if the distance between speed humps were calculated properly and if the speed humps dimension refers to the standard guideline.

Speed reduction devices must be constructed properly with high compliance to its standard in order to fulfill its objectives. Cline (1993) suggests that any agency which is considering speed humps on their public streets should follow the process before actually pursuing humps as speed deterrent on public streets, namely solicit technical input from the engineering staff; solicit an opinion relative to potential liability and risk management staff; and solicit public input relative to the magnitude of the problem. If these required standards are not met, the speed reduction devices will have negative impacts for the road users and endangering both of drivers and pedestrians as well as disrupt emergency services towards the neighborhood (Tjahyono et al., 2008). In fact, the government of Republic of Indonesia has developed standard for speed reduction devices (Departemen Pemukiman dan Prasarana Wilayah, 2004), but, the communities have not complied with the standard when they installed the speed reduction devices in their neighborhood. This practice creates potential in increasing accident risks, as a result of wrong implementation or design of speed reduction devices. According to Flaherty (1997), if an accident occurs at a high speed, the probabilities of the accident becomes fatal will also increase.

Literatures show that study on traffic calming, especially speed hump and chicane, mainly was conducted in developed countries. It is very rare to find a study regarding traffic calming with a context of developing countries, like Indonesia. Thus, this study aims to investigate the effectiveness of speed humps in Indonesia. The effectiveness is measured in two conditions, i.e. with and without chicane, using two parameters (vehicles speed and noise pollution). This study was completed by conducting full scale experiment, where the installed speed hump and chicane was designed based on Indonesian standard.

After this introduction, a brief description regarding speed reduction devices is provided in section two. Section three explains the study method, while section four provides data description and analyses. Last section concludes this study.

2. SPEED REDUCTION DEVICES

2.1 Definition and Dimensions

Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users (Lockwood, 1997). The definition of traffic calming and its interpretation were developed to be broad enough to apply to many places and situations, but narrow enough to have a definite meaning. It is recognized that different combinations of goals and objectives will apply to different situations (Lockwood, 1997). Traffic calming essence lies not only on the use of specific measures but in the overall objectives to create safer roads and better environmental conditions (County Surveyors et al., 1994). Some of these objectives are to improving driver behavior, concentration, and awareness; reducing speed, disturbance, and anxiety; and enhancing the environment.

Also known as road humps, undulations, or "sleeping policemen," speed humps have the purpose of promoting the smooth flow of traffic at speeds of about 32 to 40 km/h (20 to 25 mph) (Huang and Cynecki, 2000). Speed hump is an elongated bump with a circular arc cross-section (round top) or flat top, rising to a height of 76 mm (3 in) above the normal pavement surface and having a length of 3.7 m to 6.7 m (12 ft to 22 ft) in the direction of vehicular travel (Huang and Cynecki, 2000). Speed humps usually extend the full width of the road, excluding the gutter to allow for drainage (ITE Technical Council Speed Humps Task Force, 1993). Common shapes of speed hump devices are parabolic, circular, or sinusoidal. They are generally 12 to 14 feet (3.7 to 4.25 m) in length and span the width of the road, while the height of humps ranges from 3 to 4 inches (7.5 to 10 cm). These speed humps dimension are vary from one country to another. In Denmark, the shapes of speed humps are found mainly in circular shapes with the length up to 9.5 m and are used to reduce speed up to 50 km/h for automobiles and 35 km/h for buses (Vejdirektoratet, 1991). In Australia and the Netherlands, the dimension of speed hump can be as much as 12 m in length (Hass-Klau et al., 1992).

Partington (1999) explained that the length and height of the speed humps determines the speed at which traffic will travel over the devices. Shorter lengths and greater heights slow cars most drastically. Partington (1999) also says that when speed humps is placed in a series of 350 up to 550 feet (100–170 m) apart, it will reduces 85-percentile speeds by 8 up to 10 mph (13–15 km/h).

Speed hump works by transferring an upward force to a vehicle, and its occupants, as it traverses the hump (Weber and Braaksma, 2000). The force induces a front-to-back pitching acceleration in vehicles having a wheelbase similar to the length of the hump that increases as the vehicle travels faster. This differs from a speed bump, which induces a high vertical acceleration at low speeds because it is significantly shorter than the wheelbase of a vehicle. The acceleration decreases with higher speeds due to absorption of the impact by the vehicle suspension (Weber and Braaksma, 2000).

Like other countries, Indonesia also have speed hump standard. This standard was developed by *Departemen Pemukiman dan Prasarana Wilayah* (2004). According to this standard, the total length of the speed humps is 4 meters and 10 centimeters in height. The material for this speed humps is asphalt concrete (see Figure 1).

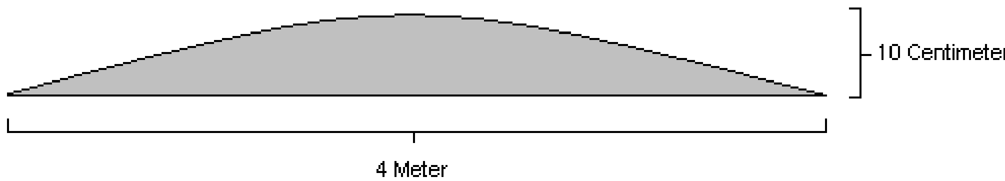

Figure 1 Specification of Standardized Speed Hump (*Departemen Pemukiman Dan Prasarana Wilayah*, 2004)

This Indonesian standard was adopted from UK Department of Transport. From past experience, there are a few notes that have to be considered, namely (1) this kind of device was proven effective to decrease vehicle speed; (2) this device causes no disturbing noise so it can be implanted on neighborhood area; (3) this device has to be planned and constructed according to the standards to avoid accidents and vehicle damage; and (4) this device needs a support from traffic signs and other supporting facilities in order to increase its effectiveness (*Departemen Pemukiman Dan Prasarana Wilayah*, 2004). Two criteria for the installation of this facility so it can provide effective implementation are that (1) the lane must be high in vehicle activities with high intensities of pedestrian crossing and (2) it must be installed on class roads. It cannot be installed on arterial or collector road, while it can be installed on one-way or two-way streets, either divided or undivided.

Moreover, the specification of chicane in Indonesia refers also to the manual published by Departemen Permukiman dan Prasarana Wilayah (2004). The materials used for this device is concrete curbs, where the typical system of chicane appears in Figure 2. As a matter of fact, limited users are being accustomed with this device. The curb in this system has a height as much as 25 cm while 5 cm of the curb are planted to the ground. This planted section keeps the applied curbs become sturdy. The bottom and upper widths of the curb are 21 cm and 18 cm, respectively. The upper part has a dull shape to avoid bumps and to minimize damage on vehicles. Curbs was arranged to make a shape of narrowing street, but still provides enough space for the vehicle to maneuver.

2.2 Noise Pollutions

The policy from the Ministry of Environmental of Republic of Indonesia No.49/MenLH/11/1996 defines noise pollutions as an unwanted sounds that can cause health and environmental disturbance. The hearing level for normal people ranges from 20 up to 20.000 Hz (Berglund et al., 1999). The human hearing system has a certain degree of differences in sensitivity and frequency. This means that the level of high and low frequency that a human can take is different from one to another. Salameh (2006) says that the noise level with dB's measure actually did not represent human hearings because it can not measure high and low frequency. Therefore, a dBA's measure was used to overcome this problem. The noise level with the scale of dBA can simulate the frequency of normal human hearings.

The Ministry of Environmental of Republic of Indonesia No.Kep-48/MENLH/11/1996 sets standard level of noise (see Table 1). This standard was measured based on the mean value of the equivalent noise level, L_{eq} (Departemen Permukiman dan Prasarana Wilayah, 2005). According to the standard from Departemen Permukiman dan Prasarana Wilayah (2004), the noise pollutions area is a parallel lane with a certain width located on both sides. The noise pollutions area (see Table 2) is determined for a certain degree of noise pollutions (Leq), the exposed time (hours/days), and the category of the road sides in residential area.

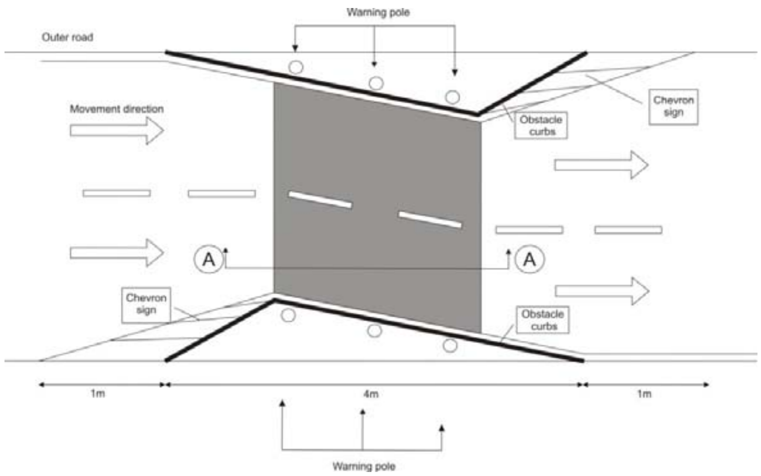

Figure 2 Chicane (*Departemen Permukiman dan Prasarana Wilayah*, 2004)

Table 1 Standard noise level (Departemen Permukiman dan Prasarana Wilayah, 2005)

No.	Area	Noise Level (dBA)
a.	Area	
	Residence Area	55
	Commerce	70
	Office	65
	Park	50
	Industrial	70
	Government and Public Facilities	60
	Recreation	70
	Certain case:	
	Airport	-
	Train Station	70
	Sea port	60
	Cultural Heritage	-
b.	Activity Area	
	Hospital	55
	School	55
	Religious places	55

Tabel 2 Noise Pollutions Area (Departemen Permukiman dan Prasarana Wilayah, 2003)

Noise Area	Street Width (m)	Noise Level (dBA)	Exposed Time (Hours/Days)
Noise Secure Area (DAB)	21 - 30	< 65	Max 12
Moderate Noise Area (DMB)	11 - 20	< 65 s/d 75	Max 10
Noise Area (DRB)	0 - 10	< 75	Max 10

3. STUDY METHOD

3.1 Speed Measurement on Speed Hump

The location of this full scale experiment is in the residence area, i.e. Jalan Batununggal Indah

Raya, Batununggal Residence Area, Soekarno-Hatta, Bandung. The layout of this selected segment is shown in Figure 3 and the standardized speed humps is provided in Figure 4. Detail information regarding this study can be found in Adipratama (2010), Puar (2010), and Jaganaputra (2010).

Figure 3 Layout of selected segment on Batununggal Indah Raya Street (Google_maps, 2008)

Figure 4 Standardized Speed Humps

The selected road section was divided into five sections to observe vehicle speed using video camera (see Figure 5 to see the locations of the placement of the camera). This article only reports the speed of passenger cars (minibuses, SUV, and sedan), although other types of vehicle were also recorded. It can be seen that the V-50i means a point located 50 m before the speed hump. The V-25i and V+25i have a meaning as a point located 25 m before and after the speed hump, respectively. The V-0i is a point located just before the speed hump, while and the V+0i is located just after the speed hump. This experiment was carried out on week day (Thursday 3 June 2010) and weekend as well (Saturday 5 June 2010) in two periods, i.e. 9.00 am - 11.00 am and 2.00 pm - 4.00 pm.

3.2 Noise Level Measurement on Speed Hump

The noise level was measured on Thursday 3 June 2010 and Saturday 5 June 2010 with three periods, i.e. 9.00 am - 11.00 am, 11.00 am - 1.00 pm, and 3.00 pm - 5.00 pm. Sound level meter was used in this experiment to measure the noise level from the vehicle (see Figure 6). Sound Level Meter is a device that measures the noise level in a certain area and usually used in the noise pollutions studies. This device was used to measure the noise level in industrial area, environmental area, and airport (Colby et al., 2009).

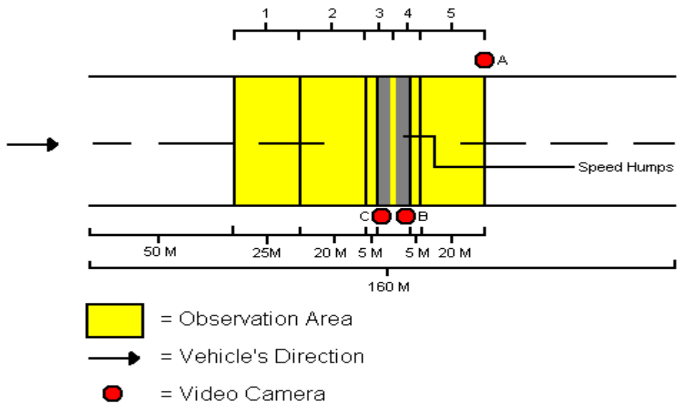

Figure 5 Observation Sections and Video Camera's Positions

Figure 6 Sound level Meter

This study employed eight units of Sound level Meter devices, where the measurement follows the standard published by Departemen Permukiman dan Prasarana Wilayah (2004). The gathered data from the device was L_{eq}, L_e, L_{max}, L_{min}, PK, L_{01}, L_{05}, L_{10}, L_{50}, L_{90}, and L_{99}. The subscript value explains the percentage of time when the noise level exceeds the value (Departemen Permukiman dan Prasarana Wilayah, 2005). The device was positioned one meter from the road side as can be seen in Figure 7. In order to obtain more reliable data, four additional surveyors were needed at five meter behind the first devices. The 1st (X1.a) and 4th surveyor (Y1.a) were located 50 m before and after the vehicle passes the speed hump, respectively. 2nd (X2.a) and 3rd surveyor (Y2.a) measure the noise level on 10 m before and after the vehicle passes the speed hump, respectively.

3.3 Speed Measurement on Speed Hump with Chicane

In this experiment, the chicane device was implemented together with speed hump. This experiment was held on Friday, 4 June 2010 and Sunday, 6 June 2010 from 9.00 am to 11.00 am and 2.00 pm to 4.00 pm. In this study, the curbs were replaced by traffic cones as the cones are easier to be noticed by the driver rather than curbs. Traffic cone was arranged to have the same function with curbs, which is placed approximately one meter before and one meter after the road hump. The position of traffic cone appears in Figure 8, while the positions of the video cameras are explained in Figure 9.

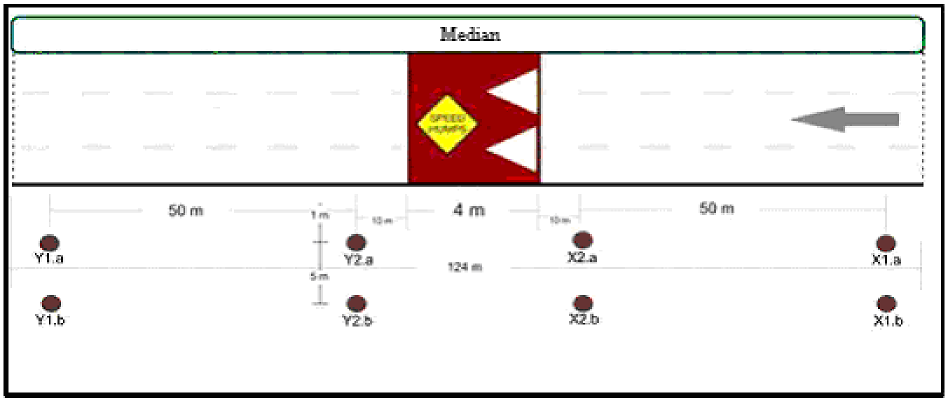

Figure 7 The positions of the surveyor in measuring noise level

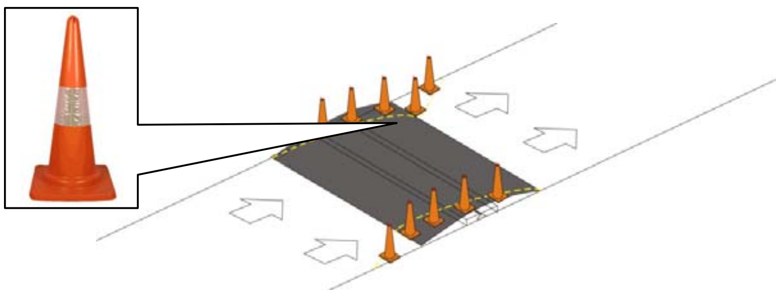

Figure 8 The arrangement of chicane

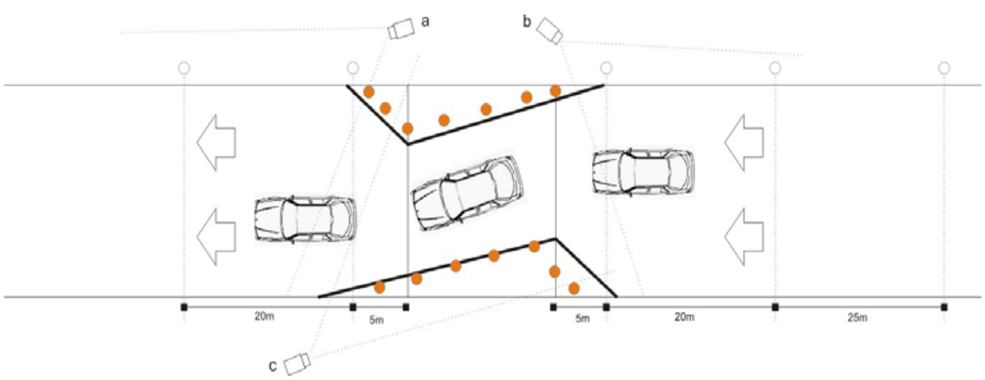

Figure 9 The arrangements of video camera in the experiment of chicane

4. ANALYSIS

4.1 Analysis of Speed as a result of Speed Hump Installment

The data from this experiment were analyzed using one-way ANOVA to determine the difference of vehicle speed among locations. Before conducting analysis, the equality variances must be evaluated using the Levene equality test of variances. If the variances are equal, further analysis will be conducted using the Newman-Keuls Analysis. Otherwise, the Tamhane Analysis will be used. The hypothesis used in the one-way ANOVA is H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$ and H_1: Not H_0.

Table 3 reports four results of Levene equality test for each time of measurement. All analyses show very low *p*-value, which explain that there are significant different among variances in each observation. In other words, the variances are not equal. Furthermore, the results of ANOVA are provided in Table 4. With the confidence level of 95%, it can be concluded that at least one of the vehicle speed data at certain spot is significantly different. Since the ANOVA's results show that at least one data is different from the rest, thus further analysis using Tamhane statistical method is conducted. The Tamhane analyses use α as much as 0.05, where the results for each time of measurement are shown in Table 5.

Table 3 Result of Levene Equality of Variances Test

	Levene Statistic	$d.f._1$	$d.f._2$	Sig.
1st Session Weekday	3.291	4	355	0.011
2nd Session Weekday	26.127	4	355	0.000
1st Session Weekend	2.712	4	355	0.030
2nd Session Weekend	16.842	4	355	0.000

Table 4 Result of One-way ANOVA for the Effect of Speed Hump

	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	*p-value*
1st Session Weekday	Factor	13532.8	4	3383.2	85.56	0.000
	Error	14037.0	355	39.5		
	Totals	27569.8	359			
2nd Session Weekday	Factor	24793.6	4	6198.4	128.02	0.000
	Error	17188.0	355	48.4		
	Totals	41981.6	359			
1st Session Weekend	Factor	12145.2	4	3036.3	186.37	0.000
	Error	5783.5	355	16.3		
	Totals	17928.7	359			
2nd Session Weekend	Factor	25669.9	4	6417.5	277.62	0.000
	Error	8206.0	355	23.1		
	Totals	33875.9	358			

In the first session of weekday, vehicle speed around the speed hump is significantly lower than the speed in 25 meter before or after the device. The existence of speed hump significantly reduces vehicle speed, as the speed at 25 before the speed hump is significantly different. Thus, it can be concluded that the existence of speed hump effectively reduces vehicle speed at the first session of weekday's observation.

It is interesting to note that the analysis of simultaneous comparisons for the second session of weekday, as well as first and second sessions of weekend, show similar result. These three observations show that vehicle speed at 50 meters before the speed humps is the highest. The existence of speed hump significantly reduces the speed, which is measured at 25 meter before the device. At 25 meters after the device, the speed does not significantly different with 25 before the device. The important thing is that the speed around the speed hump is significantly the lowest than the other locations of measurement.

From these analyses, it can be concluded that the existence of speed hump have significantly reduced the vehicle speed. The lowest vehicle speed exists around the devices, which shows that the drivers tend to reduce their vehicle speed up to the lowest around the devices. Thus, it can be inferred that the speed hump is effective in reducing vehicle speed.

Table 5 Result of Tamhane Analysis for Speed Hump at Different Location and Time of Measurement

		N	Subset for alpha = .05		
			1	2	3
1st Session Weekday	V-0PD	72	19.8888		
	V+0PD	72	21.1366		
	V-25PD	72		26.4854	
	V+25PD	72		26.7774	
	V-50PD	72			37.2512
	Sig.		0.960	1.000	1.000

		N	Subset for alpha = .05			
			1	2	3	4
2nd Session Weekday	V+0SD	72	10.7175			
	V-0SD	72		19.0847		
	V-25SD	72			23.8501	
	V+25SD	72			24.9110	
	V-50SD	72				36.1835
	Sig.	72	1.000	1.000	0.945	1.000

		N	Subset for alpha = .05			
			1	2	3	4
1st Session Weekend	V+0PW	72	10.3435			
	V-0PW	72		13.4990		
	V-25PW	72			22.1950	
	V+25PW	72			23.2958	23.2958
	V-50PW	72				24.9110
	Sig.	72	1.000	1.000	0.754	0.218

		N	Subset for alpha = .05			
			1	2	3	4
2nd Session Weekend	V+0SW	72	10.3869			
	V-0SW	72		13.4672		
	V+25SW	72			24.3825	
	V-25SW	72			24.6468	
	V-50SW	72				33.7651
	Sig.	72	1.000	1.000	1.000	1.000

4.2 Analysis of Noise Level as a result of Speed Hump

Table 6 provides descriptive statistics of noise levels for all measurement positions as well as time. The mean value of noise level on 50 m (X1) and 10 m (X2) before the vehicle passed the speed hump slightly lower than the mean at 10 m (Y2) and 50 m (Y1) after the speed hump. It is the case for weekend and weekday measurements as well.

In order to find out the effect of the implementation of speed hump towards noise level, statistical analysis was completed. Table 7 shows the results of t-test for two independent samples. The hypothesis for this test is H_0: $\mu_1 = \mu_2$ and H_a: $\mu_1 \neq \mu_2$ where μ_1 is the level of noise pollutions before the vehicle passed the speed hump and μ_2 is the level of noise pollutions after the vehicle passed the speed hump.

Table 6 Noise Level for Weekday and Weekend Measurement

Time	Measuring Position		Mean (dBA)	St. Dev. (dBA)
Weekday	Before speed humps	X_1	63.51	2.62
		X_2	62.40	2.74
	After speed humps	Y_2	66.73	3.22
		Y_1	68.85	3.76
Weekend	Before speed humps	X_1	64.80	2.71
		X_2	64.87	2.08
	After speed humps	Y_2	66.56	2.39
		Y_1	70.94	2.27

As can be seen in Table 7, the noise level at 10 meter before vehicle passes the device is significantly different with the noise level at 10 meter after vehicle passes the device. It is also the case for the noise level at 50 meter before and after the vehicle passes the device. The result for weekday measurement is different with the analysis result for weekend measurement. In weekend measurement, only the noise level at 10 meter before and after the device is significantly different.

In one side, analyses show that the noise level does not significantly different between 10 meter and 50 meter before the speed hump. In the other sides, the noise level is significantly different between 10 and 50 meter after the speed hump, although this result only appears in weekend measurement. It shows that the implementation of speed hump reduce the noise level as the driver slow down their vehicle speed. It can be inferred that the speed hump is effective in reducing noise level.

Table 7 Comparison Analyses regarding Noise Level

	Hypotheses	t	Sig.	H_0
Weekday	$H_o : \mu_{X2} = \mu_{Y2} ; H_a : \mu_{X2} \neq \mu_{Y2}$	-3.55	0.002	Rejected
	$H_o : \mu_{X1} = \mu_{Y1} ; H_a : \mu_{X1} \neq \mu_{Y1}$	-4.04	0.001	Rejected
	$H_o : \mu_{X1} = \mu_{X2} ; H_a : \mu_{X1} \neq \mu_{X2}$	1.02	0.319	Accepted
	$H_o : \mu_{Y1} = \mu_{Y2} ; H_a : \mu_{Y1} \neq \mu_{Y2}$	-1.48	0.152	Accepted
Weekend	$H_o : \mu_{X2} = \mu_{Y2} ; H_a : \mu_{X2} \neq \mu_{Y2}$	-1.85	0.078	Accepted
	$H_o : \mu_{X1} = \mu_{Y1} ; H_a : \mu_{X1} \neq \mu_{Y1}$	-6.02	0.000	Rejected
	$H_o : \mu_{X1} = \mu_{X2} ; H_a : \mu_{X1} \neq \mu_{X2}$	-0.07	0.943	Accepted
	$H_o : \mu_{Y1} = \mu_{Y2} ; H_a : \mu_{Y1} \neq \mu_{Y2}$	-4.6	0.000	Rejected

4.3 Analysis of the Effect of Chicane

In the experiment of the implementation of chicane, vehicle speed was measured. Table 8 represents the descriptive statistics of vehicle speed for the case when the speed hump was implemented without chicane, as well as in the case when speed humps was implemented with chicane. Graphical representation of these conditions is provided in Figure 10. It shows that for all positions, the speed when vehicle passed the combined devices (speed hump with chicane) is lower than the speed when vehicle passed the speed hump only.

To obtain a conclusion, statistical inferential analysis is applied. The results of one-way analysis of variance are provided in Table 9, which reports the analysis for four different periods of observation (i.e. weekday and weekend, as well as morning and evening). All analyses show very low *p-value*, which explains that there is significant different of vehicle speed among positions. Since it is found that at least one vehicle speed is different, thus further analysis is needed to show the order of vehicle speed based on location. The results of Newman-Keuls analyses are provided in Table 9.

Table 8 Descriptive Statistics of Speed Hump with and without Chicane

	Section	Mean (km/h)	St. Dev	Min (km/h)	Max (km/h)
Speed Humps without Chicane (n=280)	V_{+25}	24.3	5.39	10.74	48
	V_{+}	16.47	5.58	5.04	36
	V_{-}	13.19	6.59	5.72	50.4
	V_{-25}	24.86	4.57	15.31	40
	Section	Mean (km/h)	St. Dev	Min (km/h)	Max (km/h)
Speed Humps with Chicane (n=280)	V_{+25}	16.76	5.30	7.34	30.50
	V_{+}	5.018	1.31	2.27	10
	V_{-}	4.517	1.14	2.27	9.23
	V_{-25}	20.38	4.71	9.90	35.12

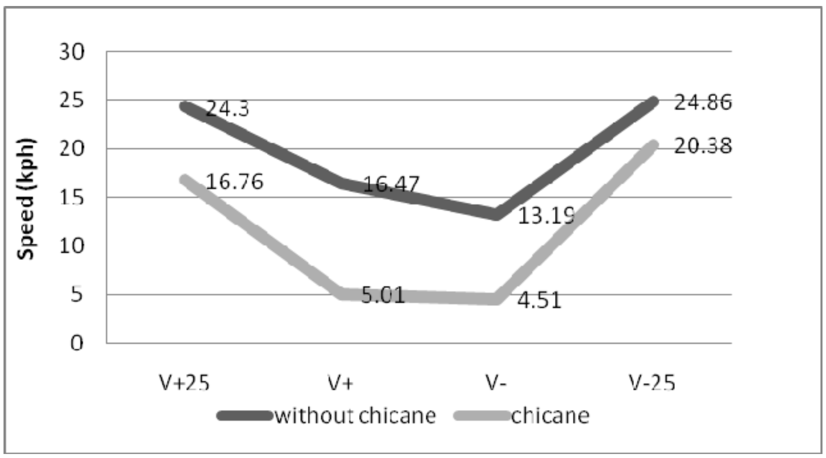

Figure 10 Vehicle Speed of Road Hump with and without Chicane

Table 10 presents the results of simultaneous comparisons for four different observation periods. It is interesting to note that the vehicle speed at 25 meter before the combined speed hump and chicane is the highest. The analyses also show that the lowest speed exists in the combined system, i.e. in the front and back side. Results show that the drivers tend to reduce their vehicle speed after they experienced the system.

Thus, it can be concluded that the combined system of speed hump and chicane effectively reduce vehicle speed. Even though there are variations vehicle speed values, the pattern shows that drivers tend to reduce vehicle speed when approaching the system as well as after experiencing the system. It shows that the system is successfully in reducing vehicle speed.

Table 9 The Result of one-way ANOVA for the Effect of Speed Hump with Chicane

		Sum of Squares	df	Mean Square	F	Sig.
Morning Weekday	Between Groups	8948.37	3	2982.79	491.21	0.00
	Within Groups	1675.95	276	6.072		
	Total	10624.33	279			
Evening Weekday	Between Groups	21067.12	3	7022.37	794.65	0.00
	Within Groups	2439.03	276	8.837		
	Total	23506.16	279			
Morning Weekend	Between Groups	13656.73	3	4552.24	567.59	0.00
	Within Groups	2213.57	276	8.020		
	Total	15870.30	279			
Evening Weekend	Between Groups	15976.17	3	5325.39	670.04	0.00
	Within Groups	2193.59	276	7.94		
	Total	18169.76	279			

Table 10 Result of Newman-Keuls for Speed Hump with Chicane

		N	Subset for alpha = .05			
			1	2	3	4
Weekday Morning	V_-	70	4.70			
	V_+	70		5,54		
	V_{+25}	70			9,51	
	V_{-25}	70				18,95
	Sig.		1.000	1,000	1,000	1,000

		N	Subset for alpha = .05		
			1	2	3
Weekday Evening	V_-	70	4.67		
	V_+	70	4.86		
	V_{+25}	70		19,82	
	V_{-25}	70			23,92
	Sig.		0.706	1,00	1,00
		N	Subset for alpha = .05		
			1	2	3
Weekend Morning	V_-	70	4.22		
	V_+	70	4.75		
	V_{+25}	70		17,94	
	V_{-25}	70			18,93
	Sig.		0.27	1,00	1,00
		N	Subset for alpha = .05		
			1	2	3
Weekend Evening	V_-	70	3.93		
	V_+	70		5,42	
	V_{+25}	70			19,71
	V_{-25}	70			19,78
	Sig.		1.00	1,00	0,89

5. CONCLUSIONS

This study reports the evaluation of the effectiveness of speed reduction devices based on Indonesian standard. As there are many standard regarding traffic calming devices, thus it is needed to have a specific standard that referring to Indonesian driver and road characteristics. The Ministry of Public Works, ROI, have developed the standard which covers the design standards of speed hump and chicane. As a matter of fact, the general communities have not familiar with this formal standard, which results in widely implementation of non-standard devices. The most general speed reduction device in Indonesian neighborhood area is speed bump (which is well known as “sleeping policeman”). This device is built using so many variations of dimension and distance between devices. Based on this condition, it motivates to conduct study as a way to provide scientific information for the socialization purpose. It is hoped that the result of this study will encourage general public in neighborhood area to build traffic calming devices which complies with the standard.

There are many indicators which can be applied to measure the effectiveness of speed reduction devices. In this study, the effectiveness is expressed by vehicle speed and noise reduction. The reason for using these two indicators is the fact that this standard has not been investigated in full-scale experiment, which implies that the basic indicators of the effectiveness of these standardized devices have not been investigated. Thus, these two basic indicators seems as the most important to investigate the effectiveness of the devices.

This Indonesian standard covers two devises, but it is not explicitly suggested to apply the devices in combined module. Thus, this study does not investigate individual module only, but also to investigate the effect of combined module between speed hump and chicane.

Study results show that the standard speed hump, based on Indonesian standard, effectively reduced vehicle speed. Based on analyses for different position and time of measurement, it is found that vehicle speed can be reduced and effectively reduces noise level as well. Investigations for different point and time measurement support this conclusion.

Moreover, the combined module of speed hump and chicane provides better results compared with the implementation of speed hump only. It means the module is able in reducing vehicle speed more effective.

Finally, it can be concluded that the speed reduction devices based on Indonesian standard is effective in reducing speed and noise level. It can also be said that the standard is suitable to be implemented in Indonesian neighborhood, as it has been experimented in full-scale using real condition of neighborhood. Besides reducing vehicle speed, this standardized device produces less noise pollution.

Further research is still needed to provide more information regarding other aspects of these standardized devices, namely safety and comfort aspects to the people in the neighborhood. Another suggestion that can be made is to measure a different type of vehicle to complete the analysis of the effect of this standardized speed hump. It is also suggested to extend the length of the observation time to get deeper information regarding the long term behavior of the drivers. The effects of vehicle queue before passing through a chicane is also interesting to be investigated in the future.

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