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Article *in* Procedia - Social and Behavioral Sciences · October 2012

DOI: 10.1016/j.sbspro.2012.09.848

3 authors:


Nurul Hidayati
Universitas Muhammadiyah Surakarta


Ronghui Liu
University of Leeds


Frank Montgomery
University of Leeds

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Procedia - Social and Behavioral Sciences 54 (2012) 1339 – 1349

EWGT 2012

15th meeting of the EURO Working Group on Transportation

The Impact of School Safety Zone and Roadside Activities on Speed Behaviour: the Indonesian Case

Nurul Hidayati[a]* , Ronghui Liu[b], Frank Montgomery[b]

[a]*PhD Student, Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK*
[b]*Senior Lecturer, Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK*

Abstract

This paper is focused on heterogeneous traffic flows and roadside activity levels in urban streets as they relate to the safety management scheme's School Safety Zone (ZoSS). ZoSS is a time-dependent speed control zone consisting of road markings, traffic signs, optional traffic signals and rumble strips. The basic hypothesis is that ZoSS will improve the safety of pedestrian crossings by controlling and reducing traffic speeds. This study aims to quantify the effects of roadside activities and the ZoSS facility on speed behaviour in Indonesia. It uses the concept of 'side friction' to quantify the effect of roadside activities on travel speed, which takes into account vehicles in and outside the side area, vehicles parking on the street, vendors, pedestrians, and buses stopped in and around the area. The study of traffic calming for school travel in highly heterogeneous traffic conditions is a relatively neglected area in the transportation literature. This presentation helps to fill that knowledge gap.

Keywords: heterogenous traffic; school safety zone; roadside activities

1. Introduction

Transport processes are related to the interaction between components, consisting of land use (as transport demand), infrastructure and vehicles (as transport supply). This interaction causes traffic flow. The goal of organising transportation is to ensure the safety of road users. Safety involves the prevention of accidents due to either vehicles or infrastructure or human factors. The success of safety programmes can be measured by

* Corresponding author.
E-mail address: tsnh@leeds.ac.uk

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doi:10.1016/j.sbspro.2012.09.848

comparing the accident rates (per 1000 vehicles). Road traffic accidents are sometimes associated with the traffic conditions around a site, such as mixed traffic (Hussain et al., 2011) and pedestrians (Short and Pinet-Peralta, 2010)

Highly heterogeneous traffic and a high percentage of motorcycles in the vehicle fleet are common features in urban roads of some developing countries, for example Vietnam (Nguyen, 2007), Bangladesh (Haque and Imran, 2007), and Indonesia. The composition of vehicles in Indonesia during 2004-2009, as calculated by the Directorate General of Land Transportation (DGoLT, 2009b), was 70.83% motorcycles, 15.23% passenger cars, 8.89% trucks, and 5.05% buses. Motorcycles accounted for a high percentage in Indonesia as well as Malaysia (47.01% in 2009) (DoS, 2010), India (72.24% in 2006) (MoRTaH, 2011), and Bangladesh (51.7% in 2008) (Hoque et al., 2008). Soehodho (2007) stated motorcycles have become the single most dangerous mode of traffic. In addition, the Indonesian Government (DGoLT, 2011) confirmed, during 2010, that 60.63% of casualty accident fatalities involved motorcycles, 29.85% cars, 7.52% trucks and 2% buses. In contrast with Indonesia, only 5.6% of fatal single vehicle accidents and 10.9% of fatal multiple vehicle accidents involved motorcycles in Bangladesh (Hoque et al., 2008). Malaysia on the other hand shares a statistic with Indonesia, namely that 57% of accident fatalities involved motorcycles (Hussain et al., 2011).

Another common feature in densely populated urban areas in Indonesia is the high level of roadside activity, thereby disrupting pedestrian movements and affecting traffic movements. Pedestrian safety, either crossing the road or walking on the sidewalk, should also be considered in transportation. Pedestrians are often found surrounding intersection areas, offices, hospitals, and school areas. It is important to think about pedestrian safety around school areas located on the road with mixed traffic, especially for primary schools. Many schools in Indonesia, mostly nursery and primary schools, are located around the major roads. It means many children can be found on the streets at the beginning and the end of school hours.

Traffic accidents involving children crossing the road were sometimes caused by drivers who could not see the presence of children in the middle of the road (Weiss et al., 2009). These types of accidents could also be caused by drivers who did not follow the rules, such as speed limits. On other occasions these accidents would come about because the sidewalk was blocked by vendors forcing the pedestrians to walk in the carriageway (Suttayamully, 2005). Therefore, pedestrian facilities are needed to provide for the safety of the public. Since 2006, the Government has been implementing the School Safety Zone (ZoSS) facility built around the school areas (DGoLT, 2006). This facility is provided to control the speed of vehicles in the school environment during a specific time. The speed limits of vehicles will also affect the degree of saturation of roads which could be seen by comparing the number of vehicles which pass through the location with the capacity of the road.

This study aims to quantify the effects of roadside activities and the ZoSS facility on speed behaviour in Indonesia. It incorporates data from an extensive survey of nine ZoSS facilities in the three most highly populated cities of Central Java and Yogyakarta Province. It uses the concept of ‘side friction’ to quantify the effect of roadside activities on travel speed, which takes into account vehicles in and outside the side area, vehicles parking on the street, vendors, pedestrians and buses stopped around the area. With this in mind, the present paper will firstly describe the School Safety Zone facility, before then detailing roadside activities, and finally assessing the impact on the speed of vehicles. As a comparison, this article will also illustrate the impact of activities and the facility on the composition of vehicles. The study of traffic calming for school travel in highly heterogeneous traffic conditions is a relatively neglected area in the transportation literature. This presentation helps to fill that knowledge gap.

2. School Safety Zone (ZoSS)

Slinn et al. (2005) stated traffic calming has two main purposes, which are to reduce traffic accidents and to improve the condition of the neighbourhood for people to live. Types of traffic calming include speed bumps, curved and narrow traffic lanes (Slinn et al., 2005, Weiss et al., 2009). Traffic calming techniques can be classified into legislation and enforcement, surface and signing treatment, vertical and horizontal deflection, entry treatment, and zones restriction (Harvey, 1995, Weiss et al., 2009).

There are many types of physical barriers used as traffic calming. In order to manage traffic movement, generally these barriers are often combined with road signs and/or road markings. The combination can be classified as zones restrictions, including home zones, 20 mph zones, and school zone. Home zones as defined by Slinn et al. (2005) are a facility provided around residential area, while school zones are built around school area especially kindergarten and elementary school (Suttayamully, 2005, Weiss et al., 2009, LTP, 2010, DGoLT, 2006).

According to DGoLT (2006), ZoSS is a time-dependent operation speed control zone, which is recommended for 2 hours in the morning and 2 hours in the afternoon during peak hour traffic flow. However, the operation hours can be adjusted to the needs of each school, such as at a full day primary school. This facility consists of road markings (including zebra crossing, dashed lines, the words 'school safety zone' and 'look right-left', as well as red block paving on the road surface), traffic signs (including warning sign and speed limit sign), and other optional supporting facilities (i.e. traffic signals and rumble strips).

ZoSS is provided to improve the safety of pedestrian crossings by controlling and reducing traffic speeds, especially near kindergarten and primary schools. The impact of a school located around the main road is related to the presence of side friction, caused by such as pedestrians, private vehicles stopped/parked, and public transport stops around the school. This condition will affect the traffic flow through the roads, for instance the decrease of vehicles' speed. The classification of this facility is derived from the type of road.

The data of road traffic accidents around ZoSS facilities were not available. This data is usually provided by the Indonesian Police Department which has not classified or mentioned the location of accidents by the ZoSS area. The safety impact of these facilities can be described from the traffic conditions at the location. Based on the observations, it is evident that the road segment with ZoSS was used by high volumes of traffic consisting of a wide range of vehicle types, including large vehicles. For example, Walisongo Street (location of SD Tugurejo 1 Semarang) and Raya Semarang-Demak Street (location of SD Karangtowo 01-02 Demak) are major roads which connect two cities. Both segments are part of the North Coast lane of Java ('Jalur Pantura') which is the shortest path from East to West of Java through Central Java. Based on this information, if large and heavy vehicles were passing through the road segments, then the ZoSS facilities would be provided for pedestrian safety around the locations. In contrast, Veteran Street in Surakarta is a different type of road from Semarang. This road could not be categorised as an expressway, because there were many access roads (i.e. directly to residential area) on this road. However, this segment is also a connecting road of Central Java from East to West Java.

In the past, this facility was controlled by the central government of the Transportation Department, while recently it has been supported by local government. For example, the Local Government of Surakarta is still continuing to inform and explain the program of ZoSS to the schools. More than 50 schools (including high schools) are located around the roads in Surakarta, which required different supporting facilities of school safety.

3. School Safety Zone (ZoSS)

In developing countries such as Indonesia, many activities take place at road side, especially on the urban roads. Bang (1995) noted that the intensity of roadside activities in Asian cities could increase the side friction, while in Western countries the intensity was generally very small. These activities affected and reduced the speed of vehicle and road capacity either urban or rural roads (Bang, 1995, Marler, 1996). Therefore, side friction can be defined loosely as all sorts of activities on the roadside, either on the road or the sidewalk, which could constrain the movement of vehicular traffic.

The types and intensity of side friction which occur in certain areas are influenced by the type of land use. For example, pedestrians were often seen near the commercial area (i.e. intersections, traditional market or supermarket) every day, but only at the beginning and the end of school hours surrounding the school zone. Besides the presence of pedestrians crossing, the geometric design of intersection and turning vehicles either turn-left or turn-right as side friction for straight movement of vehicles at intersection (Prasetijo *et al.*, 2011, Liang *et al.*, 2011). Munawar (2011) used pedestrian movement, and entry-exit vehicles into the street as side friction factor (see also Bang, 1995), and concluded only temporary parking/stopping vehicles could be considered as side friction.

3.1 The type of roadside activities

In this research, the data pertaining to roadside activities contains the number of all friction types which were collected at the zebra crossing and around block marking. This research has modified four types classification from the Indonesian Highway Capacity Manual into nine types (see Table 1), whereby the types of vehicles or activities along the roadside are separated more specifically. This step was taken because the different types of vehicles in the location would have a different character. In this case, the different character of vehicles could be clearly seen from the use of road space (parking), and the flexibility to manoeuvre when moving in/out of the side of the road. A survey was conducted by the author in 2010 at nine road segments. Each location was surveyed two hours each during the morning peak (06:00-08:00), morning off-peak (10:00-12:00), and afternoon peak (12:00-14:00).

Table 1. List of the side friction f_w

	Type of side friction (f_w)	Weight factor (W_f)
f_1	Car in-out of side area (to/from access road or off street parking)	0.7
f_2	Motorcycles in-out of side area (to/from access road or off street parking)	0.7
f_3	Non-motorised vehicles in-out of side area (to/from access road or off street parking)	0.7
f_4	Cars on street parking	1.0
f_5	Motorcycles on street parking	1.0
f_6	Non-motorised vehicle on street parking	1.0
f_7	Pedestrian crossing and walking both of road side	0.5
f_8	Stall/vendor that used side walk or street area	0.5
f_9	Bus stopped for passengers up and down around zebra crossing	1.0

3.2 Determination of the side friction score and factor

With regards to the data of side friction frequencies (f_w) each type would be used to find the total score (S_{faj}^{t}) at location *a*, during the 15-min time period *j*. This value is influenced by the frequency of side frictions (S_{faj}), the weight factors (W_f), and length of school safety zone *z* at location *a* (L_a^{z}). The equation used to determine the side friction score is presented as follows.

$$S_{faj}^{t} = \left[\sum_{f=f_1}^{f_9} (W_f S_{faj})\right] \frac{50}{L_a^{z}} \tag{1}$$

The factor of total side friction is calculated based on the classification of side friction score. Range of the factor used in this analysis can be seen in Table 2.

4. The impact of roadside activities and the ZoSS

This article is part of the research carried out in the ZoSS area at five road segments in Central Java and four roads in Yogyakarta Province. Each segment was divided into four loci corresponding to the locations of the camcorder, namely Locus B (before), Locus Z (at zebra crossing), Locus A (after) and Locus O (outside area). Roadside activities have been counted at Locus Z as the main ZoSS facility. Therefore, the impact of these activities is only presented in this location, while the impact of the entire ZoSS will describe the values at all loci.

Table 2 Range of the factor of total side friction (F_{faj}^{t})

Side friction class	Total side friction score, S_{faj}^{t}		F_{faj}^{t}
	(per hour)	(per 15 minutes)	
Very low	<100	<25	0.81-1.00
Low	100 - 299	25 - 75.9	0.61-0.80
Medium	300 - 499	75 - 125.9	0.41-0.60
High	500 - 900	125 - 225	0.21-0.40
Very high	>900	>225	0.00-0.20

4.1 At Locus Z

Figure 1 shows the impact of roadside activities at Locus Z on Sukowati West Street. The impact is reviewed based on a) percentage of vehicles, b) total flow, c) speed of vehicles and d) total score of side friction around morning peak hour. An interesting finding was that the total score of side friction, as road side activities, increases during school opening times, and it is also correlated with traffic composition and travel speed in this locus. This figure presents the highest total score of side friction at 06:45 (d) whilst at the same time representing the highest total flow (b) and the lowest vehicle speed (c). The percentage of vehicles has a different pattern with other figures. These values are not only correlated with roadside activities, but also with the existence and number of each type of vehicle. Figure 1(a) indicates that a motorcycle has the same pattern with side friction, while the car is different.

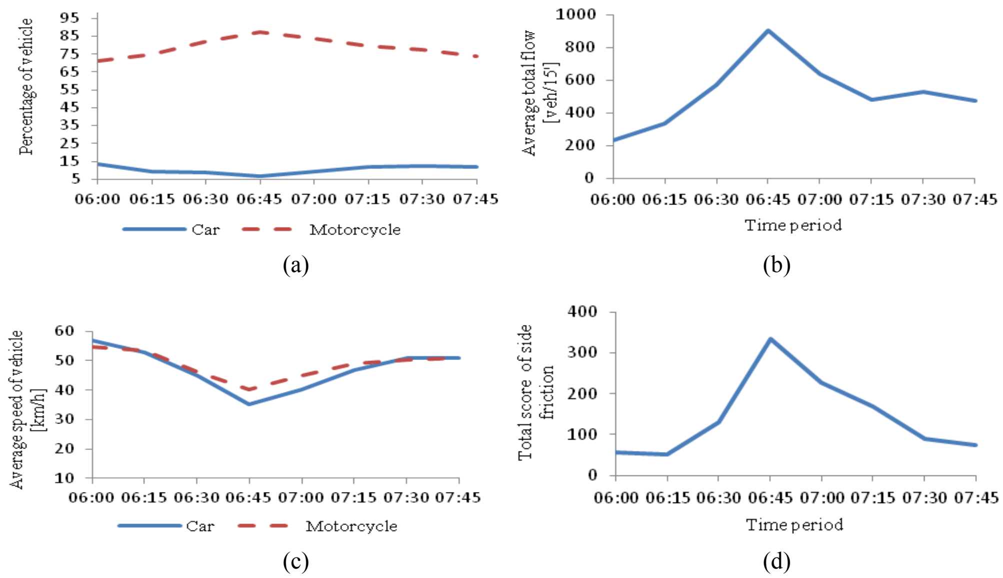

Figure 1. The impact of roadside activities at Locus Z on a) percentage of vehicles, b) total flow, c) speed of vehicles, and d) total score of side friction.

Table 3 shows the percentage of all recorded vehicles at all locations. Motorcycles have the highest percentage on all locations with a range between 74.04% on Sukowati West Street up to 87.18% on Pakem Street. The second rank is achieved by cars on almost all locations, with the exception of Cantel Street by bicycle. The dominant presence of the motorcycle would be very influential in the traffic flow. This is related to the flexibility of motorcycles when manoeuvring on the road.

Table 3. Average percentage of 15 minutes each type of vehicle each location

Vehicle types	Average percentage of vehicle each location [%]								
	Sukowati West	Sukowati East	Cantel	Bantul	Magelang	Pakem	Kalasan	Veteran	Gadjah Mada
Car	14.47	12.63	3.21	8.20	12.30	8.87	15.16	9.83	18.43
Pickup	4.44	3.58	2.98	2.59	1.28	0.88	2.17	1.55	1.51
Small truck	2.16	1.97	1.08	0.84	0.65	1.17	1.85	0.49	0.15
Motorcycle	74.04	75.37	80.11	80.54	83.02	87.18	75.26	74.48	71.38
MC-3 wheels	0.03	0.13	0.11	0.19	0.01	0.10	0.01	0.05	0.06
Microbus	0.64	0.72	2.22	1.15	0.75	0.39	0.31	2.90	1.21
Big bus	0.82	0.32	-	0.09	0.75	-	1.68	0.81	0.08
Big truck	1.27	1.26	0.09	0.19	0.30	-	0.38	0.23	-
Pedicab	0.50	0.99	2.49	0.64	-	-	-	1.72	2.99
Bicycle	1.63	3.03	7.70	5.56	0.92	1.42	3.17	7.92	4.15

Figure 2 describes the average speed at Locus Z compared to the speed limit at each location. This figure illustrates the average speed by which vehicles at each location exceed the speed limit, with the exception of Veteran Street and Gadjah Mada Street. The highest speeds of approximately 50 km/h occurred on Magelang Street (to Magelang), while the lowest speed was slightly below 20 km/h on Veteran Street (to Sraten).

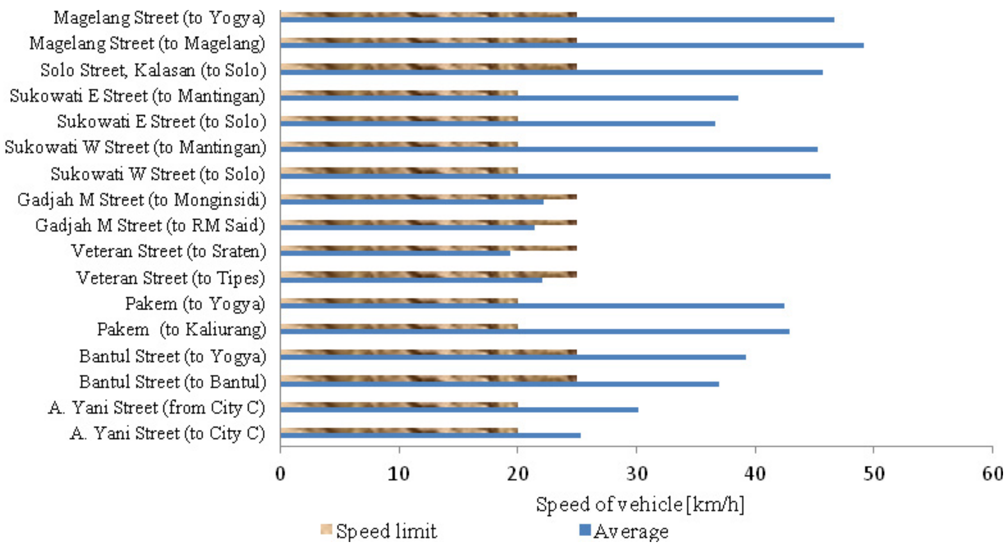

Figure 2. Average speed of vehicles each location at Locus Z compared to the speed limit

4.2 Traffic flow along the ZoSS

The impact of ZoSS will be explained by comparing the values at each locus and both directions of traffic. Table 4 presents the differences between the percentages of vehicles at two loci. It is clearly evident that these are very similar. For example, motorcycles form the highest percentage with the range value spanning approximately 72.51% - 75.86% of traffic towards Surakarta and 83.21% - 84.37% to Mantingan. This table also shows that the motorcycle and non-motorised vehicles which passed to Mantingan have higher percentages when compared to Surakarta. This was because the road segment was located at the West of Sragen City Centre. Consequently more riders or cyclists were going to Mantingan in the morning.

Table 4. Average Percentages of Vehicles on Sukowati-West [06:00-08:00]

Vehicle type	Average percentage [%/15 minutes] each locus							
	To Surakarta [index S]				To Mantingan [index M]			
	O_S	B_S	Z_S	A_S	B_M	Z_M	A_M	O_M
Car	11.88	11.53	11.86	12.25	8.45	9.05	8.66	9.09
Pickup	2.68	2.47	3.42	3.17	2.27	2.59	2.62	2.07
Small truck	2.84	3.35	3.56	3.07	0.50	0.33	0.40	0.38
Motorcycle	75.86	75.26	74.40	72.51	84.02	83.21	83.97	84.37
MC-3 wheels	0.10	0.11	0.03	0.03	0.10	0.03	0.03	0.10
Micro bus	0.76	0.81	0.77	0.72	0.62	0.79	0.46	0.62
Big bus	1.07	1.14	1.03	1.33	0.43	0.26	0.31	0.18
Big truck	3.49	3.94	3.77	5.52	-	-	-	-
Pedicab	0.29	0.30	0.25	0.40	0.71	0.59	0.50	0.61
Bicycle	1.03	1.10	0.90	0.98	2.90	3.16	3.05	2.58

4.3 Speed of vehicles along the ZoSS

As previously mentioned, one of the supporting facilities of the ZoSS is the traffic sign which specifies the speed limit. Therefore, this section will explain the impact of the ZoSS on the average speed of vehicles, including the average at each locus. Table 5 shows the comparison of the average speed of vehicles (i.e. light vehicle, motorcycle, and heavy vehicle) between two surveyed locations at different data collection times. It can be seen that the speeds of vehicles are different before (2004) when compared with after (2007 and 2010) the implementation of the ZoSS on Veteran Street. The table also shows that the speed values of heavy vehicles are significantly different between 2007 and 2010 (but note that the definition of ‘heavy vehicle’ changed between 2007 and 2010). A comparison of vehicles’ speeds in this study with another study is also shown in Table 6.

Table 5. Comparison of the average speed of vehicle on Veteran Street and Gadjah Mada Street, Surakarta

Type of vehicles	Speed on Veteran Street [km/h]			Speed on Gadjah Mada Street [km/h]	
	2004[1)]	2007[2)]	2010[3)]	2007	2010
Light vehicle	40.27	20.24	23.15[*)]	23.37	23.16
Motorcycle	45.77	24.59	25.12[*)]	24.76	24.19
Heavy vehicle	37.18	12.45	23.70[*)]		22.99

[1)] Hidayati *et al.* (2004); [2)] Susilo *et al.*(2008); and [3)] Data survey (2010)
[*)] Vehicle type is classified into three not used the same classification of field study.

Table 6 provides information regarding the various speeds of vehicles at four locations. DGoLT (2009a) has classified the values into two groups – before and at the ZoSS. The definitions of these two groups used by DGoLT were slightly different from this research. In the evaluation conducted by the Government, 'before' meant before the whole area of the ZoSS (without any supporting facilities) and 'at ZoSS' meant all areas. In contrast, this study has declared Locus O as without any supporting facilities, and the whole area was divided into three loci, namely Locus B (before zebra crossing), Locus Z (at zebra crossing), and Locus A (after zebra crossing).

Table 6 also shows the speeds of vehicles at all of four locations were exceeding the speed limit (in this case 25 km/h, see Figure 2). The values observed after implementation were somewhat different. For example, the average speed of motorcycles at the ZoSS of Veteran Street was 34.40 km/h in 2009 but dropped to 27.69 km/h in 2010. Another example is the fact that the speed of light vehicles at the ZoSS of Gadjah Mada Street reached 31.78 km/h in 2009 and 35.82 km/h in 2010. The speed patterns around the ZoSS area are also shown in Figures 3 and 5.

Table 6. Speed vehicle evaluation of the ZoSS by DGoLT (2009a) compared to data survey

Location	Average speed of vehicle [km/h]					
	Before ZoSS)*			*At ZoSS**) (classified by DGoLT)*		
Motorcycle	Min	Max	Average	Min	Max	Average
Veteran	17.54	62.50	40.92	17.25	72.70	34.40
Gadjah Mada	19.17	77.28	49.39	12.21	76.04	42.26
Kalasan	18.95	97.38	54.88	6.41	86.94	47.54
Magelang	31.73	74.53	49.94	12.12	84.69	44.74
Light vehicle						
Veteran	14.42	45.00	30.39	9.66	46.22	27.94
Gadjah Mada	19.03	72.91	36.82	15.77	62.11	31.78
Kalasan	9.73	105.88	49.98	8.98	79.34	47.36
Magelang	14.06	53.16	32.26	10.92	57.00	30.61
Motorcycle	*Locus O*)*			*Locus B, Z, and A**) (classified by author)*		
Veteran	23.92	30.95	27.37	15.49	32.45	27.69
Gadjah Mada	32.02	35.41	34.26	20.75	45.12	34.07
Kalasan	45.72	54.76	51.33	32.42	55.48	45.53
Magelang	43.68	56.31	49.99	38.17	56.93	47.19
Light vehicle						
Veteran	23.80	33.96	26.73	12.82	34.19	25.48
Gadjah Mada	27.24	32.13	30.52	30.02	43.17	35.82
Kalasan	57.01	68.58	62.64	34.99	65.82	51.10
Magelang	41.25	58.98	50.66	33.16	62.23	50.12

*) DGoLT assumed before ZoSS as before zone that same meaning with Locus O, while **) at the ZoSS as at zone that same meaning with Locus B, Z and A on the survey

Figure 3 describes the pattern of the average speed of all vehicles taken in the same period (06:00 – 08:00) on Sukowati West Street. Four loci were chosen as locations for the camcorders to collect data. Locus B_S was located at 113.26 m before the zebra crossing (Z_S as 0 m), Locus A_S was 127.1 m after Z_S, and (O_S) was 228.6 m before Z_S. The speed of vehicles at these locations should be less than 20 km/h according to the speed limit.

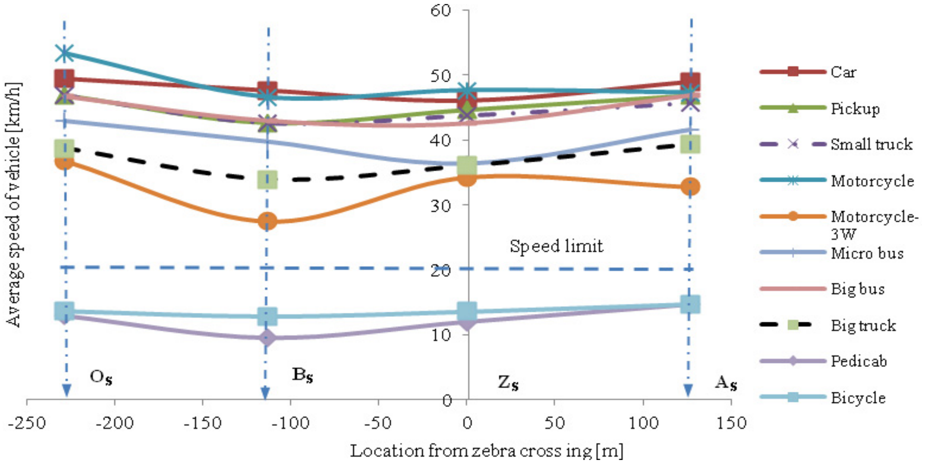

Figure 3. Average speeds [km/h] of all vehicles on Sukowati West Street [Mantingan – Solo, 06:00 – 08:00]

Theoretically and also as expected, the vehicle speed was reduced when cars were heading towards the zebra crossing before increasing again as the vehicle got further away from the zebra crossing. Based on the Figure 3, it is evident that the average speeds of all motorised vehicles were over the speed limit. In addition, the speeds of vehicles at Z_S were also higher than B_S. For example, three-wheeled motorcycles are very rare on the road, but tended to increase their speed sharply on the way to zebra crossings. This is probably due to the fact that the physical barrier at B_S was not thick, and was only a marking flat surface pavement at the zebra crossing (without any other physical barriers, see Figure 4). For people who are less disciplined when it comes to traffic regulations related to speed limits, if there are no physical barriers they can quite easily break the rules which are written on the traffic signs. Therefore, public awareness is essential when it comes to complying with the rules which are in place to protect the road and environment for all users.

Figure 4. Zebra crossing at Sukowati West Street, Sragen

Figure 5 describes the speed patterns of cars, and as expected the lowest speeds were observed at 06:45. However, these speeds did not comply with the speed limit (all over 20 km/h). In this period, especially during the 15 minutes before school entry times, the speed of cars decreased sharply from B_S before significantly increasing after Z_S. Besides this period, the speed patterns of cars were not as expected to decrease moving to the zebra crossing. This was especially true at 06:00 – 06:30. This can be linked to the amount of traffic flow around this period usually less than 30 minutes before classes start. When traffic conditions are still quiet on the road, there is a tendency for some people to not follow the traffic laws.

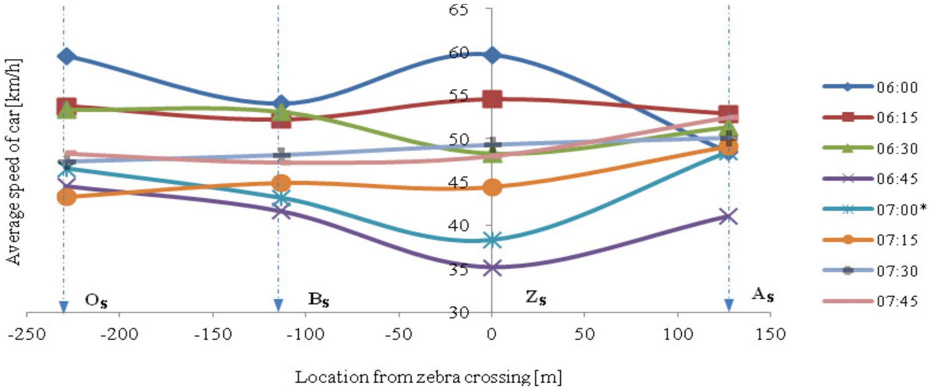

Figure 5. Average speeds (km/hr) of car on Sukowati West Street [Mantingan – Solo, 06:00 – 08:00]

5. Conclusion

Findings thus far indicate that the percentage of motorcycles reached more than 70% on all locations and the implementation of the ZoSS was not effective in reducing the speed of vehicles. Almost all of the studied locations had an average vehicle speed which exceeded the speed limit, with the exception of Gadjah Mada Street and Veteran Street in Surakarta which were below 25 km/h. On Sukowati-West Street, the average speed of cars was found to be over 30 km/h which was higher than the speed limit of 20 km/h. However, results were as expected in that the average speed of the cars was declining around the beginning of school (06:45-07:15) when heading towards the zebra crossing (from O_S to Z_S) and then increasing again to A_S.

Indonesian authorities - both Central and Local Governments - provided infrastructure not only for drivers, but also for other road users including pedestrians. The Government was offering the ZoSS which was supported by law and regulations to improve the safety of both drivers and pedestrians around the school areas. This facility cannot be effective because:

- → There are people who are less disciplined when it comes to speed limit related traffic regulations. Therefore, public awareness is vital when it comes to complying with the rules which are in place to protect the road and environment for all users.
- → The physical barrier before and after zebra crossing are not thick, and at the zebra crossing is only a marking flat surface pavement. Therefore, redesigning the facility needs to be done to achieve the expected goals.

Acknowledgements

The first author would like to thank the Directorate General of Higher Education (DGHE) of the Ministry of National Education of Indonesia that has provided the funding of this study and also to Universitas Muhammadiyah Surakarta (UMS) for their support.

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