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Teguh Patriot
Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia, teguhptik61@gmail.com

Andyka Kusuma
Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia

Nahry Nahry
Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia

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Cover Page Footnote

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ANALYSIS OF SPEED LIMITING USING SPEED CAMERAS: CASE STUDY IN INDONESIAN TOLL ROAD

Teguh Patriot[1*], Andyka Kusuma[1], Nahry[1]

[1]*Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia*

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ABSTRACT

Indonesian Police attempt to reduce the fatality rate of traffic accidents by enforcing the law on speed restrictions using speed cameras. The National Police Traffic Corps (Korlantas), from 2017 to 2018, had installed 75 units of speed cameras along Jakarta Toll Roads including Cikampek, Jagorawi, Bitung, and many others. By the end of 2020, Korlantas is expected to install 75 more units on the arterial roads of Jakarta. This study aims to analyze the implementation of vehicle speed deceleration through signs and speed cameras in the control zone. The data analyzed by comparing the speed of vehicles when crossing the control zone using the normal distribution Z test, with a 5% margin of error. The research shows that speed deceleration policy using signs and speed cameras in the control zone reduces the speed by 9% or equal to an average speed of 8 km/hour. Drivers who obeyed the speed limit reach 76.6% or 230 vehicles from 302 vehicle samples, where most of them are buses, followed by passenger cars and freight cars, respectively. The application of speed deceleration using signs and speed cameras in the toll toad meets the planning target and is recommended to be implemented across the country.

Keywords: Speed management; Speed camera; Transport system technology; Security system

1. INTRODUCTION

Traffic accidents contribute to the world's mortality rate, where every 24-second a person dies due to an accident on roads. In 2016, the total number of annual road traffic deaths in the world reached 1.35 million. Injuries caused by traffic accidents have now become the leading cause of death in people aged 5-29 years, which dominated by pedestrians, cyclists, and motorcyclists (Friedman et al., 2007; World Health Organization, 2018). In Indonesia, there are over 3,000 traffic accidents occurred every year, injured more than 1,200 people, and took life 350 people at minimum (Korlantas Polri, 2018). Jakarta as the largest population of private vehicles dominated the number of accidents in both arterial roads and highways.

There is an urge to reduce the mortality rate on roads by using technologies, one of them is by adopting speed camera. This technology firstly initiated by developed countries mainly from Europe and some East Asian countries.

*Corresponding author's email: teguhptik61@gmail.com
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The speed camera is proven to reduce the number of fatalities, ensuring safety, driver order, and other positive consequences to prevent road users from speed violation leading to injuries and death. Based on the literature study, the increase of average speed about 1% may increase the risk of fatal accidents into 4% and increase the risk of serious accidents into 3% (World Health Organization, 2018). It is argued that vehicle speed greatly determines the risk of a driver being involved in an accident along with a certain severity level of injury (Friedman et al., 2007).

There is numerous research regarding traffic deceleration using various interventions to control vehicle speed by placing police officers, traffic signs (Siregar, 2018), speed restrictions in school safe zone (Hidayati et al., 2012), traffic lights (Hartanti et al., 2019), and many others. However, there is limited research found in the literature regarding the use of speed cameras to control vehicle speed, particularly in developing countries such as Indonesia. Currently, the Indonesian police department attempt to apply a new approach in law enforcement using radar, equipped with cameras to recognize the number of vehicles. Yet the lack of related research and evidence making the effectiveness of this technology remain in question.

This research attempt to evaluate the effectiveness of the speed camera to control the speed of vehicles by taking into account a case study in Jakarta's toll road, Indonesia. This research will discuss driver behavior to obey the maximum speed limit sign and reduce their speed in the control zone at the toll road. This study will only consider some components which include vehicle speed, average speed, and the momentary speed of vehicles.

2. LITERATURE STUDY

Traffic activities in the transportation system classified into two categories, namely macroscopic and microscopic parameters (Tamin, 2008). Macroscopic parameters describe the traffic flow as the overall operational system, while microscopic parameters evaluate the behavior of vehicles and how it may affect each other. From a macroscopic point of view, traffic flow divided into four types: flow, volume, speed, and density. Sugeng et al. (2019) formulated speed as the following equation;

$$V = d / t$$

Where,
V : speed (km/h),
d : distance (km),
t : time (hour).

Speed identified as one of the main factors in the occurrence of traffic accidents and contributed to the severity of injuries (World Health Organization, 2008). This is because the driver requires a certain reaction period to evade from a collision within a tight distance at a higher speed. In a collision, the transfer of energy to the human body that causes damage to the structure of cells, tissues, blood vessels, and other body structures causes injury. Toroyan (2013) mentions that in a collision in speed, a person's weight will increase twenty-fold - someone with a weight of 5 kg will be like weighing 100 kg in just seconds. In most accidents resulting in severe injuries and deaths, the human body unable to tolerate the mass and acceleration from some parts of the vehicle. Therefore, higher speeds will increase the risk of accidents where the driver may lose control of the vehicle, unable to anticipate the dangers in time and cause other road users to anticipate the speed of the vehicle (Aarts & Van Schagen, 2006).

WHO (2008) showed that a person's reaction time is between 1.5 and 4 seconds. This narrow window time should be managed properly by the driver to reduce the risk of accidents, injuries, and deaths and comply with the given speed limits. In the context of safe driving, the level of speed on each lane of roads plays a significant role in maintaining volume and mixture of traffic, environmental aspect, and life safety of road users.

Several factors might influence the choice of speed by the driver, consist of :
1. Driver.
2. Vehicle.
3. Road.
4. Traffic conditions.
5. Risk of accident and injury.
6. Enforcement and sanctions
7. Speed zone/limit.
8. Educational/media factors.

The speed limit needs to be supported by other factors such as law enforcement and speed limit sanctions to ensure driver compliance and accident prevention. OECD Transport Research Centre (2007) shows that the changes in average speed are only 25% of the speed limit value when speed limits sign is not accompanied by other measures such as enforcement regulations. It is argued that the changes in the speed limit by 10 km/h only contributed to the average real speed approximately 2-4 km/h.

There are several strategies to slow down the traffic, including:
1. Narrow the width of the junction,
2. Speed bumps.
3. Roundabouts at pedestrian crossing paths,
4. Equip junctions with stop signs, prohibited signs, and other signs.
5. Providing roads with shock tapes,
6. Coloring roads, such as in the School Safe Zone (ZOSS)

On the other hand, the speed control through various interventions can be performed through manual inspection, radar detection, and speed cameras (Siregar, 2018). The author argued that there are variables including the police presence, driver training, and display of roadside speed choices to decelerate vehicle speed. The combination of those three factors not only reduces the average speed by 14% and 10% but also increases compliance by 72% and 33%. The result also estimates the reduction of fatal injuries by 52% and 33%. Furthermore, a higher speed will increase the probability of accident occurrence and the severity of the consequences. Therefore, technical actions and law enforcement interventions need to be adopted and implemented (Parnell et al., 2017).

Martinez-Ruiz et al. (2019) conducted a study titled Impact Evaluation of Camera Enforcement for Traffic Violations in Cali, Colombia. This study aimed to evaluate the impact of camera enforcement on traffic violations in Cali, Colombia. The study was conducted by observing 38 intervention areas and 50 comparison areas (250 m radius), for 42 months before and 34 months after camera installation. The intervention area is compared to other areas where there are no cameras installed using buffers with the same radius (250 m). In intervention areas, after 12 months, there was a reduction of 19.2% of all crashes and a 24.7% reduction of injury and fatal crashes. In comparison areas, this reduction was 15.0% for all crashes and 20.1% for injury and fatal crashes. After adjusted comparisons, intervention sites outperformed comparison sites with an additional yearly reduction of 5.3% ($p = 0.045$) for all crashes.

3. METHODS

The study conducted in part of the Jakarta toll road that are relatively free from intervention and influence, making it easier for comparison in the later stage. The research carried out through several stages, from pre-research (preparation and proposal) to the reporting stage. The sites of the case study can be seen in Figure 1 and Figure 2.

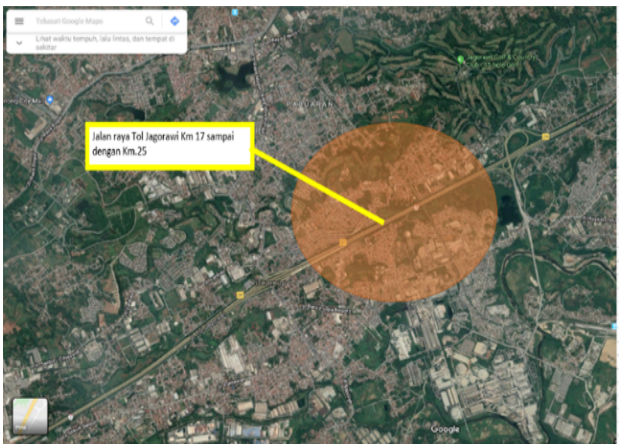

Figure 1. Research location

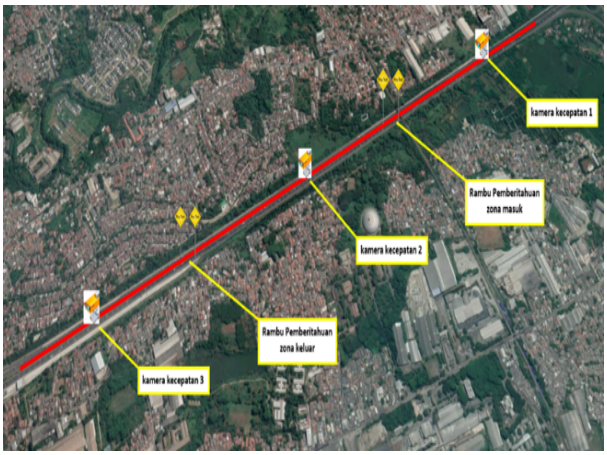

Figure 2. Research Instrument Arrangement.

The survey conducted from 6 to 8 November 2019, between 13:00 - 16:00 in the morning. The speed from vehicle measured and recorded by a hidden speed camera when the driver passes a certain point zone. In total, there is 10 km used for survey purpose which divided into three sections: 2 Km in zone 1, 6 Km in zone 2, and 2 Km in zone 3. To evaluate driver behavior, zone 2 installed several speed-limiting signs and notice boards of entering speed restriction zone.

The primary data classified based on vehicle types. According to Law No. 22 of 2009 concerning Traffic and Road Transportation (LLAJ), Article 47, the type of motorized vehicle consists of motorcycles, passenger cars, buses, freight cars, and special vehicles. However, vehicles that will be recorded only those from passenger cars, freight cars, and buses due to toll road restrictions for motorcycles and special vehicles. The survey conducted by a team of surveyors in one direction from Jakarta to Bogor on the toll road and the data uploaded to be further processed. The position of the speed camera and the method in conducting the survey shown in Figure 3.

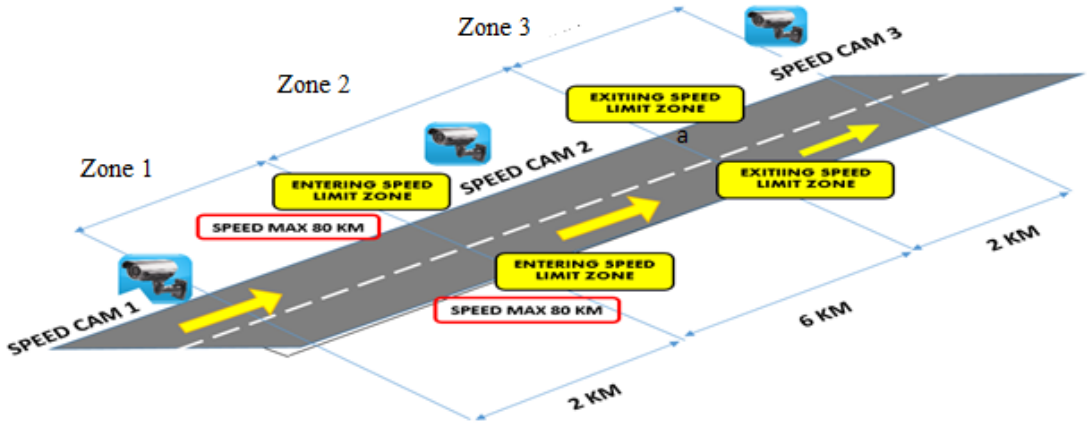

Figure 3. Research Scheme

3.1. Data Collection technique

The data collected in this research include both quantitative and qualitative data. Quantitative data is obtained from vehicle speed extracted from a survey measuring vehicle speed. The method used is a pretest and post-test using speed cameras. The primary data is collected from direct observations and supporting data. Afterward, vehicle speed data compared among others, and the Z test is conducted as follows:

$$\text{Speed average}_{(Vr)} = \frac{\sum Fx}{n} \quad (1)$$

$$\text{Variant}_{(Sv)} = \frac{(\sum Fx^2).(Vr^2)}{n-1} \quad (2)$$

$$\text{Standard deviation}_{(Sd)} = \sqrt{Sv} \quad (3)$$

$$\text{Standard error}_{(Se)} = \frac{Sd}{\sqrt{\sum n}} \quad (4)$$

$$Z_{(Hit)} = \frac{(Vr) - (80)}{Sd/\sqrt{n}} \quad (5)$$

Where:
Fx = Sum of values speed vehicle
n = Sample size
Z count = The value to be calculated
α 5% value of Z table = 1.645

If the calculated Z value compared to the Z table, then the obtained conclusions are:

a. a. Z count ≥ Z table, meaning that the speed limit on the road is following the maximum vehicle speed limit with an error rate of 5%.
b. b. Z count <Z table, meaning that the speed limit on the road is not following the maximum vehicle speed limit with an error rate of 5%.

The research samples are 302 vehicles from a population of 7,022 vehicles with an intervention condition and 9,280 vehicles with an existing condition. The samples are selected using a purposive sampling method, where the sample is selected based on the researcher's considerations using desired characteristics. The technique selects vehicles with the same identity, the same vehicle in the previous time, temporarily and after passing through the zone with speed slowing control based on the plate number.

4. RESULTS AND DISCUSSION

4.1. Spot Speed Deceleration Analysis

4.1.1. Average Spot Speed Recapitulation

There are two average speeds seen as a comparison between the average speed of the initial conditions without the speed limit intervention, with the average speed of the intervention through speed cameras (see table 1).

Table 1. Comparison of average speed data

No	*Conditions*	*No. of Samples*	*Speed (km/hr)*		
			Zone 1	*Zone 2*	*Zone 3*
1.	Average speed without speed limit intervention	302	74.7	76.1	77.5
2.	Average speed with speed limit intervention	302	76.9	68.0	78.6

The data shows that there are significant differences, especially in zone 2, where the average speed with the existing condition is 76.1 km/hour, and the average speed with intervention in zone 2 or the control zone is 68.08 km/hour. Based on these findings, it can be concluded that the installed signs and speed cameras in the control zone may reduce vehicle speed by 8 km/h or 9% slower than the existing condition. Figure 4 shows a significant change in speed between zones. Zone 2 is the control zone experienced decelerating behavior from the driver, where the initial speed is 74.9 km/h lower to 68.0 km/h. Subsequently, the driver started to accelerate their vehicle in zone 3 where it increases to 77.6 km/h.

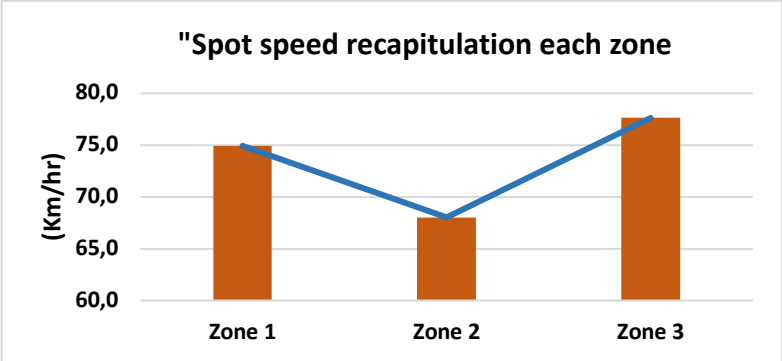

Figure 4. Speed decrease graph.

4.1.2. Recapitulation of Average Speed per Vehicle Types

Most of the drivers in every vehicle type (passenger cars, freight cars, and bus cars) tend to obey the signage instructing decelerating their speed, particularly when crossing zone 2 or the control zone (See table 2 and figure 5). From field observations, most road users reduced their speed when crossing Zone 2 as most drivers saw speed limit signs. The installation of speed limiting signs also contributed to driver behavior to slow down, read, pay attention, and understand the purpose of the sign.

Table 2. Recapitulation of average speed per vehicle types

No.	Vehicle Types	No. of vehicles	Speed km/hour.		
			Zone 1.	Zone 2.	Zone 3.
1.	Passenger cars	164	82.3	69.9	80.0
2.	Freight cars	104	68.3	66.0	74.0
3.	Buses	34	71.9	65.4	77.1

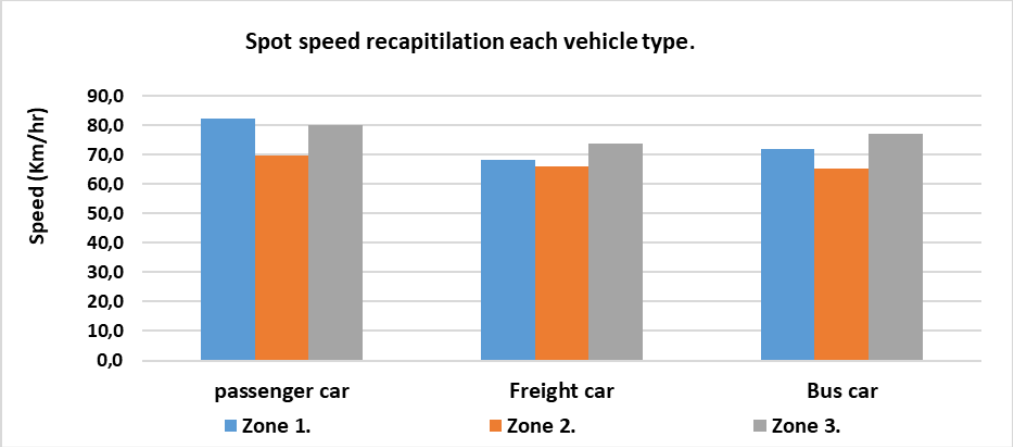

Figure 5. Comparison of vehicle speeds and types in the area before, during and after the control zone

4.1.3. Effectiveness of Speed Deceleration in Toll Road

From the total sampling of 302 vehicles passing in zone 2, 230 vehicles or 76% decelerate their speed, and 72 vehicles or 24% still maintain their current speed (see table 3). It can be concluded that there is a significant effect for the deceleration of vehicle speed by 76% of the total vehicle samplings.

Table 3. Global data of speed deceleration

No	Vehicle types	No/ of Vehicles	Zone 2	
			Decelerate	Accelerate
1.	Passenger cars	164	146	18
2.	Freight cars	104	54	50
3.	Buses	34	30	4
	Total	302	230	72
			76%	24%

4.1.4. Z test analysis with a designed speed limit of 60-80 km/hr

Table 4 shows that the Z value of table 0.05 is 1.645 and three types of vehicles, either passenger, freight cars, or buses, have a Z hit value over the Z value. This finding shows that vehicle speed deceleration on the road is following the provisions of the maximum speed limit of 60-80 km/hour with an error rate of 5%.

Table 4. Z test with α:5% and the speed limit of 60-80 km/hour

No	**Type**	**Sampling**	**Vr**	**Sv**	**Sd**	**α 5%**	**Z hit**	**Conclusion**
1.	Passenger cars	164	69,87	98,3	9,9	1,64	13,1	According to plan
2.	Freight cars	104	65,9	91,9	9,6	1,64	14,9	According to plan
3.	Buses	34	65,4	156,9	12,5	1,64	6,8	According to plan

4.1.5. Effectiveness of speed deceleration in Zone 2

In general, there are two types of deceleration; within 60-80 km/hr or outside 60-80 km/h. Most drivers or 120 vehicles decelerate within 60-80 km/hr as expected. While the other 26 passenger

cars slowed down but below 60 km/hour or above 80 km/hour, not following the expected speed. On the other hand, more than 50% of freight cars also slowed down but only 30 cars within 60-80 km/hr while the other 24 cars decelerate outside 60-80 km/h. Last, buses are the highest vehicle type that complies with the speed limit signage where more than 90% of the buses slowed down within 60-80 km/hr. The effectiveness of speed deceleration in Zone 2 shown in table 5.

Table 5. Effectiveness of speed deceleration

No.	Vehicle types	No. of Samplings	Decelerating Vehicles	Decelerating on 60 – 80 km/hr	Decelerating outside 60-80 km/hr
1.	Passenger cars	164	146	120	26
2.	Freight cars	104	54	30	24
3.	Buses	34	30	27	3
	Total	302	230	177	53
			76%	77%	23%

5. CONCLUSION

Based on the research findings that considered 5% error of tolerance, some conclusions can be obtained as follows:

1. The average speed on the case study through speed limiting signs and speed cameras is 68.0 km/hour, more effective in reducing speed compared to the average speed without speed limiting signs or speed cameras of 76, 1 km/hour.
2. The average Spot speed from three vehicle types shows a typical average speed where passenger cars are 69.9 km/hour, buses are 66.0 km/hour, and freight cars are 65.4 km/hour.
3. Most of the drivers have complied to decelerate their speed when crossing the control zone or Zone 2, reaching 230 vehicles or 76% of 302 vehicle samples.
4. The findings also show that there are 177 vehicles or 77%, lowering the vehicle speed within 60-80 km/hr. While the remaining 56 vehicles or 23 % reduce speeds outside 60-80 km/h.

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