

## The innovative design of automatic speed limiter device for trucks and buses based on road location analysis

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### Abstract

The increasing number of vehicles every year has led to the rising potential of vehicle accidents. In 2015, there were 556 fatalities from 6,231 accident cases occurred in Jakarta, through regulation of the Minister of Transportation Republic Indonesia No: 111 in 2015, it has been issued firm vehicle speed restrictions, but there is no positive impact because the speed limit of each vehicle cannot be done automatically by the highway location, so the need for innovation to design a tool that can meet these needs. The method in this research is developing a device that can break the flow of fuel quickly to hold the vehicle's speed with a Global Positioning System (GPS) as a trigger to drive the relay that has been installed on the engine. The results of this study are devices that have been installed in truck and bus engines capable of holding the speed. The result shows that the voltage has been calculated was at 10 km/h produce 1.2 volts, and the highest speed of 70km/h produce 10.7 Volt. GPS in speed limiter is also compared with the Map application. The result shows a slight difference either in latitude or longitude, where the smallest differences in latitude and longitude were about 0.00" and 0.05", respectively. In addition, the GPS speed limiter well performs to limit the speed of trucks and buses for 32 km/h in pedestrians, 58km/h on the highway and 52 km/h on a toll road.

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### INTRODUCTION

In 2015 road accidents for the world recorded up to 85% of deaths, while for the achievement, it reached 90%, and this result represents a significant proportion. However, the highest number of accidents from the results obtained came from trucks and buses. Most of these accidents are caused by human error. In 2013 in the Americas, there were nearly 150,000 deaths from traffic injuries [1], and the World Health Organization recorded almost 85,000 deaths from traffic injuries [2].

The summary of road traffic fatality rates per 100,000 populations divided in each region

is shown in [Figure 1](#), where the highest rate is the Africa region, with a value of 26.6%.

Several factors caused traffic accidents, including behavior that did not record 27,035 cases, carelessness which recorded 21,073 cases and exceeding speed which recorded 9,278 cases. [Table 1](#) describes several factors that cause traffic accidents, such as external factors (34%), attitude (24%), fatigue (20%), over speed (17%) and vehicle technicality (lack of maintenance) (5%). This data is based on the National Public Safety Plan (2010). Another factor that increases road fatalities is the significant growth of vehicles and industry [3].

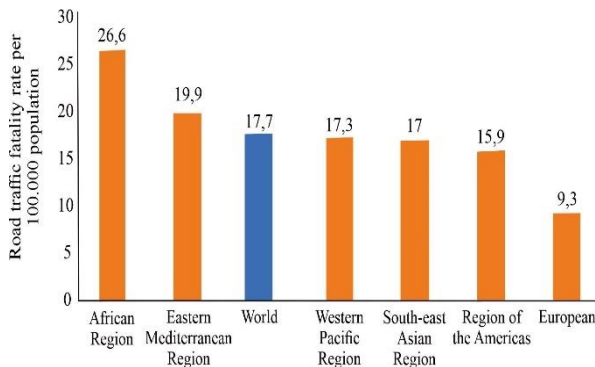


Figure 1. Road traffic fatality rates [2]

Table 1. A factor of traffic accidents in Indonesia [4][5]

The Factor of Traffic Accident	Percentage (%)
Fatigue	32
Over speed	15
Attitude	20
External	29
Technical vehicle	5

Vehicle accidents have become a primary concern in many countries, especially in South-East Asia. Every year, the increasing number of vehicles has led to the increased potential of vehicle accidents in Indonesia. In 2015, there were 556 fatalities from 6,231 accident cases in Jakarta. It may cause by drivers reckless or excess speed. At the same time, driving, fatigue, and several other cases related to attitude [6], road accidents in Malaysia are mainly influenced by the condition of the road.

Based on locality, the number of road traffic deaths in a rural area (66%) is significantly higher than that in urban areas (34%). In Thailand in the year 2016, the trend of cars on the road is an upward one, with the fleet registering more vehicles older than ten years, typology of vehicles involved in road accidents variation truck and bus +104.0% (National Institute of Statistics, 2017 and Traffic Police, 2017). According to the data from the National Traffic Safety Committee of Vietnam, by 2015, as of November, there were nearly 21,000 traffic accidents, killing almost 8,000 people and injuring 19,000. Although deaths from traffic accidents have decreased, injuries and injuries remain high [7]. Brunei Darussalam reported 3,375 road accidents. Road traffic accidents and rate of people killed and injured in Brunei Darussalam (2011-2016).

The number of fatalities fell from 151 in 2015 to 141 in 2016. The road traffic fatality rate in Singapore has declined over the past five years. In 2016, the fatality rate per 100,000 persons fell to 2.51, from 2.73 in 2015. This is

the lowest fatality rate since 1981. In Cambodia, road fatalities, vulnerable road users (pedestrians, cyclists, and motorized two-wheelers) represented 80% of all road fatalities. This is unstable due to environmental factors or speed factors in avoiding accidents. In Laos road, accident statistics show a three-fold rise of deaths from road accidents, from 5.4 per 100,000 in 2005 to 15.6 per 100,000 in 2014. On average, one in ten accidents resulted in death in 2005, and by 2014, one in around five accidents resulted in death [8].

One out of eight traffic fatalities in 2014 resulted from a collision involving a large truck in 2014 [9]. Based on the analysis of accidents that occurred, it can be concluded that most truck drivers survive accidents. Still, only a small proportion of truck drivers are responsible for disproportionate safety violations and crashes. The analyzed data indicate that the truck driver has a lower crash than light vehicle drivers [10]. Excessive speeding by drivers reduces response time for the driver in an event and may increase risk due to speed-related increases in crash exposure. Speeding reduces a driver's ability to steer safely around objects, curves, or intersections in the roadway, extends the distance is required to stop a vehicle and increases the distance a vehicle travels.

In contrast, the driver reacts to a dangerous situation. Impact forces during a vehicle crash vary with the square of the vehicle speed. Therefore, even small speed increases have significant and lethal effects on the force at impact [11]. From Table 2, it can be seen that at higher speed, there is a higher chance or probability for a fatality to occur, and it is also found that pedestrians are the most high-risk victims of road users. For example, a vehicle with a speed of 50 km/h showed the possibility of a pedestrian being killed reached up to 87 %. Also, at a speed of 80 km/h had been ascertained by a pedestrian who was hit and died, safety driving behavior that is not at high speed will decrease the chances of a deadly accident [12].

Table 2. Effect of vehicle speed against fatality [13]

The current speed bump (km/h)	Estimates of the risks faced by the various users of vehicles and pedestrians		
	a injuries car driver who belted	Fatality belted car driver	Fatality pedestrian hit by a car
30	0,04	0,01	0,08
50	0,10	0,03	0,87
80	0,42	0,21	1,00
100	0,80	0,61	1,00
120	1,00	1,00	1,00

The major concerns in this research are trucks and busses because almost all of them are used as public transportation. Moreover, fuel trucks require safe driving since compliance distributes fuel, a hazardous material if an accident happens. Furthermore, based on regulation in the Republic of Indonesia, regarding speed restrictions on the highway by PP N0: 111 of 2015 that for commercial vehicles, trucks and buses, the maximum speed on the road is 60 km/hour, on the preservation road 30 km/hour and the alternative highway is 50 km/hour [14].

Based on the background above, it can be concluded that the existing speed limiter has some limitations. It is not integrated with GPS, changeable by the driver, and does not automatically limit the speed by cut-off fuel. Therefore, the development of a speed limiter is connected with GPS to generate the different speed limits on three different areas: pedestrian, highway, and toll roads. The novelty of this research is the speed limiter integrated with GPS, and it can be installed to various engine types through the voltage determination stages. This research will contribute to the truck and bus company monitoring and ensuring their vehicle meets the safety regulation and society and government to reduce the road accident and improve the safety device on the truck and bus.

## METHOD

The preliminary design consisted of calculation, concept verification, parameter determination, and specification of the data sheet component. The block diagram of the device design system is shown in Figure 2. The GPS provides input to the new features as a trigger to determine the vehicle's position on the highway, non-highway, and pedestrian road. In addition, GPS also gives instructions and information to the new features for limiting the speed according to government regulation.

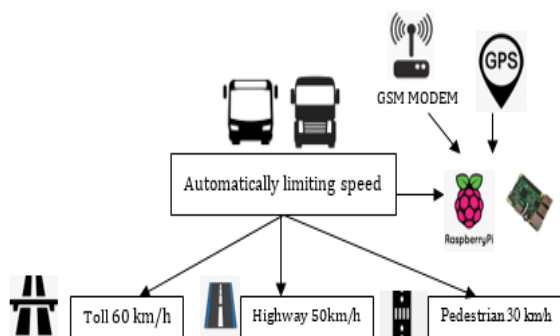


Figure 2. The device design system

For example, in Indonesia, the speed is limited if on the toll road (60 km/h), on the pedestrian road (30km/h). The restriction is done automatically for the highway (50 km/h) to follow the location in this concept.

The developed speed limiter prevents road accidents by limiting the speed through a cut-off fuel system. That system will be work when the truck and bus speed on the speed limit or tend to higher than the speed limit. The system will automatically restrict the fuel consumption, which led speed reduction, and it is unable to increase the speed to exceed the limit.

The GPS application based on latitude and longitude has been determined based on three different areas: pedestrian, highway, and toll roads. The speed limiter will automatically change the speed limit when the vehicle enters a specific area.

The stages of developing new features started from determining the types of trucks and buses to measuring the appropriate voltage with its types because the raw data of trucks and buses would be used to limit the speed. Therefore, it is essential to convert the frequency to voltage. In making this device, a somewhat complicated stage is determining which parts of the parameter are. The whole methodology for this research is described in Figure 3.

The mathematical equation used and applied in SLIFA development is based on parameter development such as voltage determination and speed limit determination from the observation before SLIFA design. It is customized by the research object, which is a truck and bus with a diesel engine.

## Voltage Determination

Voltage determination was conducted by calculating the input frequency into the voltage using (1) to (6). In the development of new features, the most important things are how to resolve the equation to change the input frequency value to the desired output in this system, which was voltage [15][16]. The result of the output voltage was used to perform a trigger in moving the relay connected to the engine cut-off motor in diesel engines.

$$I3(\text{avg}) = Q/t = (Q \text{ Charge} + Q \text{ discharge})/(1/f) = 2 \times Q \times f = 2 \times C_1 \times (V_{cc}/2) \times f = C_1 \times V_{cc} \times f \quad (1)$$

This average current was flown across R1, giving the needed output voltage.

$$V_o = R_1 \times C_1 \times V_{cc} \times f \quad (2)$$

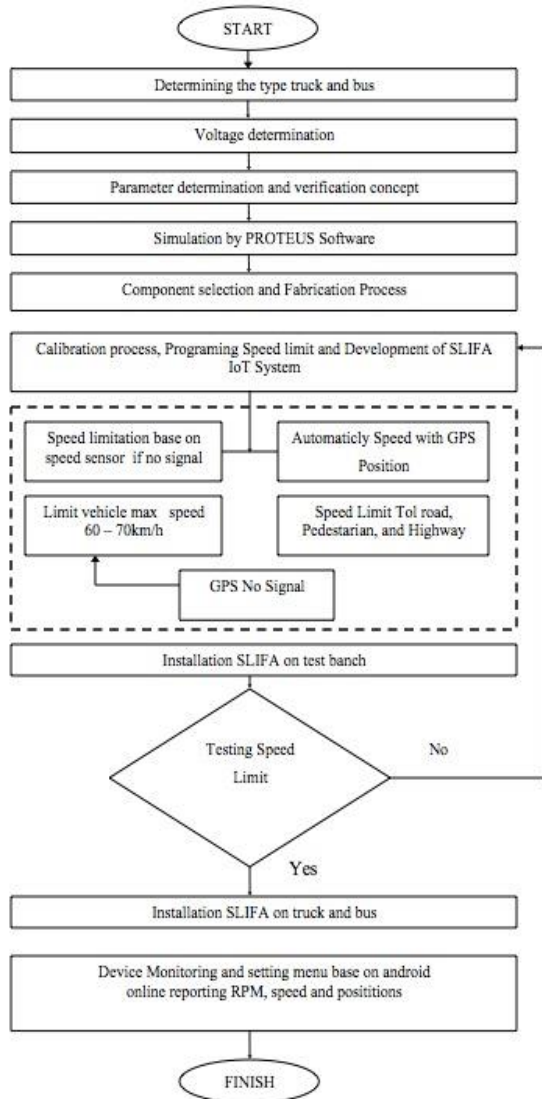


Figure 3. Flowchart of the research

While the output voltage to input frequency ratio depends on supply voltage, for adjusting it, we can easily combine a resistor and a capacitor, R1 and C1. So, to calculate the expected output voltage, the formula is shown in (3).

$$V_{out} = V_{cc} \times f \times C_1 \times R_1 \quad (3)$$

### Speed Limit Determination

In the determination of speed reduction, the speed limiter was divided by two inputs based, which was based on GPS and frequency value from the speed sensor, using the formula determining latitude and longitude.

$$\Delta\psi = \ln(\tan(\pi/4 + \varphi/2) / \tan(\pi/4 + \varphi_1/2)) \quad (4)$$

The speed obtained from GPS data directly sends a voltage change component. The frequency changes to that voltage are used to

trigger the engine fuel cut-off motor relay that attaches to the position on the side of the engine on the accelerator pedal.

$$\eta_v = \frac{a}{b} = \frac{(m_{ao}^o)_{real}}{(m_{ao}^o)_{th}} \text{ with } b = \frac{nV_d \omega P_a}{4\pi r T_a} \quad (5)$$

The expression  $m_a^{yo}$  was usually considered as a function of the engine speed and intake manifold pressure [17]. Where  $\eta_v$  was the volumetric efficiency;  $\omega$  was the engine speed state;  $V_d$  was the cylinder volume displacement;  $n$  was the number of cylinders;  $P_a$  was pressure,  $\pi$  as pi,  $T_a$  was the initial temperature, and  $r$  was the radius.

The efficiency can be evaluated using the polynomial function [17].

$$\eta_v = \alpha_0 + \alpha_1 \omega + \alpha_2 \omega^2 \text{ with } \alpha_0, \alpha_2 > 0 \text{ and } \alpha_1 < 0 \quad (6)$$

### Safety Device Development

The development process is carried out with several stages after determining parameters in (2) to (5) afterwards then selecting components with the equation requirements mentioned in the speed determination section. The development stages include;

Simulation of components that will be used in making devices. The electronic components of the new features were designed and simulated using Proteus software. Proteus was the software used to design PCB, which also came with a simulation at a schematic level before the schematic circuit was upgraded to PCB. Therefore, before the PCB is printed, one will know whether the PCB print is correct or not. Two PCBs was designed and simulated in this study.

The new features microcontroller and Analog to Digital Converter (ADC) connected with SLIFA sequence before PCB printed based on SLIFA design. The GPS simulation on the PCB simulated by Proteus will be effectively work based on latitude and longitude of pedestrian, highway and toll roads. The GPS will automatically change the speed limit when entering a certain road.

Component selection and main component assembly. The Assembly process of the electronic component was conducted after an electronic simulation component by Proteus software. Then, the new features' electronics circuit was engineered, and rafts to control the engine's operation stopped the motor and were installed in the fuel injection pump. So, suppose this circuit works on an engine with a control mechanism. In that case, the circuit acts to resist movement of the accelerator cable and when installed on a machine-based electronic control module (ECM).

It can compare the different resistant values in the accelerator pedal with the resistant value of the speed sensor cable connected to the engine to stop the motor.

### GPS Development

The development of GPS in this device is obtaining the latitude and longitude data where the device is located. The GPS device help to obtain them, and then the data will be translated to address with the help of online maps. The address will be used to get the vehicle's position and determine it on a toll road or the pedestrian road.

The integration is held when the address arrives from GPS; the address data will filter the maximum speed in a different situation based on the device program, such as in toll road, pedestrian road, and on the regular road. If the vehicle passes the maximum limit speed, the device will inform the speed sensor to work, so the speed of the vehicle decreases slowly because of the work of the speed sensor.

### GPS Simulation

In this section, we simulated the GPS simulation to get the latitude and longitude and differentiate between toll road, highway road, and pedestrian road, based on Figure 2. The speed limiter device will be integrated with GPS and GPS as a tool for the input device, especially for latitude and longitude. Data from GPS will be processed to get the current address of the data. Figure 4 describes the GPS simulation process.

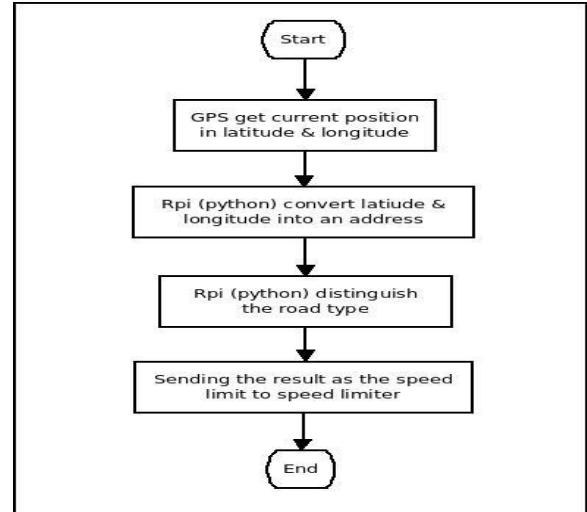


Figure 4. GPS simulation

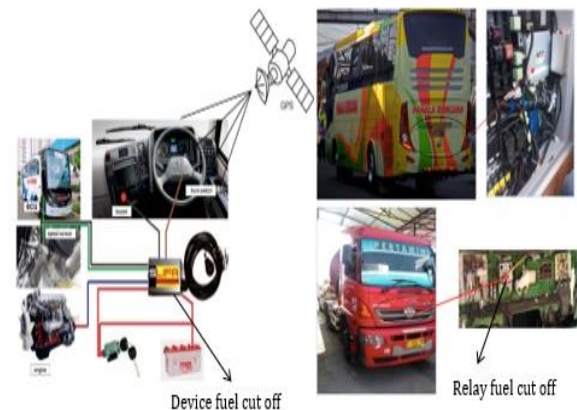


Figure 5. Installation of speed limiter devices on truck and bus

## RESULTS AND DISCUSSION

### Trial and Test Devices

A trial session was conducted to determine the length of success of the device development applied in the truck and bus.

Before, the device was used in a real vehicle. The device was tested on a diesel engine stand test bench. This step was needed to minimize potential failure in the device.

The device was connected to the vehicle battery or accumulator as a power supply. The horn switch was connected to the device. The function of the horn switch was as a reset switch of the speed limiter function. The device installation improved the electrical wire placed and connected with the machine. The speed clustering in this study was based on the Indonesian government regulation depending on the urban or highway area.

The device development was adjusted based on that government regulation to fulfil the requirement when the product has been successfully developed.

The Schematic diagram of device installation is shown in Figure 5, where it consists of the buzzer, ECU, speed sensor, engine, and the speed limiter control box. The device's working principle was as follows when the vehicle speed exceeds a specified speed limit. Speed limiting system uses two main inputs based on speed sensor and input based on GPS location, which will send a signal through the Raspberry Pi to be able to send frequency to the fuel cut of relay shown in Figure 2. The speed sensor at the transmission output sent the frequency signal to the accelerator pedal and then based on GPS location.

Then the frequency signal was transformed into a voltage signal at the IC program. The voltage signal was later transformed into the comparators components, forwarded to relay and followed by sound a warning alarm buzzer. When the driver still performed additional speed, the fuel shutoff solenoid reduced the fuel consumption into the engine. It automatically reduced the speed/RPM to the average speed (below max.

speed). Meanwhile, the buzzer alarm stopped and returned to the average speed when the driver decreased. The truck and bus completed with the device's location used in this study are as shown in Figure 5.

**Calibration Test**

Before installing a device on the engine truck and bus, speed calibration was necessary to reset the data speed between the speed out of the transmission output via the pulse speed sensor with the value of the voltage available at the speed limiter sensor in the circuit device as shown in Figure 6.

The result of the calibration test Table 3 was referred for the installation of speed limiters in trucks or buses, so the installation of speed limiters should not require the release of the propeller shaft of the gearbox.

**Speed Testing**

Figure 7 mentions the rate of response speed set when the speed limiter worked based on the input value obtained to determine the lowest tolerance value in the determination of speed and speed reduction response. From Figure 7, the speed test results are obtained that when within 30 s/min, the speed at a set speed is 90% the fuel consumption stops within 0.5 min max when the engine is in a fuel cut off condition, the vehicle can glide 30 s/min, and will re-consume fuel normally when the reflex driver presses the throttle.

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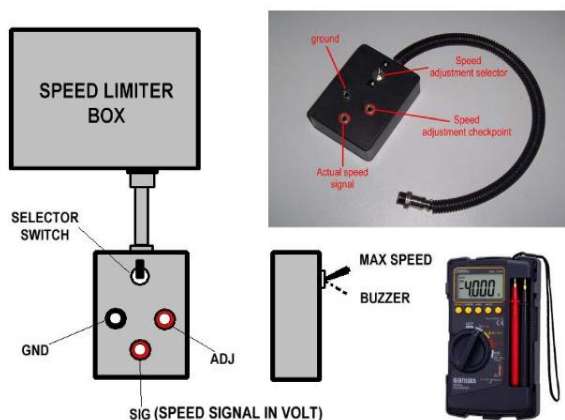


Figure 6. Calibration tools speed limiter device

Table 3. Result of calibration test

No.	Speed (km/h)	Voltage (Volt)
1	0	0
2	10	1.2
3	20	1.8
4	30	3.6
5	40	5.3
6	50	7.1
7	60	8.9
8	70	10.7

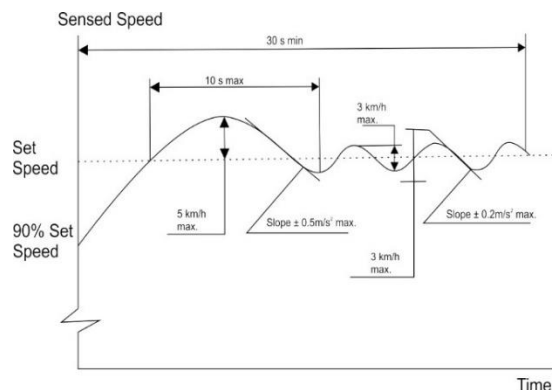


Figure 7. Determine lowest speed tolerance and decrease speed response

**GPS Testing**

The accuracy of GPS in the SLIFA device was tested in the real road with the same route and takes the data three times, and the result position will be compared with data from the application of map in Smartphone device. We assumed that data from a map application, such as Google Maps [18], in Smartphone is more precise than the GPS SLIFA because the map application has been released for a long time in the past. To find the accuracy, we transform the GPS data from DD (degree, decimal) format into DMS (degree, minutes, second) format [19]. And the result from the comparison, data from GPS is the only difference in under a second. Table 4 shows some comparison data between GPS data and data from map applications. GPS data obtained based on latitude and longitude will be updated based on Google Maps update. Therefore, this device can capture a real-time longitude and latitude position.

From the result in Table 4, there is quite a slight difference between GPS SLIFA and Map Application data. The differences of data from the result, from our analysis, depends on the processing time that occurs in the SLIFA device, so the GPS is late giving the data. The speed result for every type of road will be described in Table 5. We also show the average speed every time the GPS sends data to the server in Figure 7.

Table 4. Comparison of GPS data between SLIFA GPS and Map Application

GPS SLIFA (DMS)		Map Application (DMS)		Differences	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
-6° 12' 32.31"	106° 44' 16.75"	-6° 12' 32.62"	106° 44' 16.8"	0.31"	0.05"
-6° 13' 12.59"	106° 44' 21.4"	-6° 13' 12.59"	106° 44' 21.77"	0.00"	0.37"
-6° 12' 49.68"	106° 44' 33.85"	-6° 12' 49.05"	106° 44' 33.5"	0.63"	0.35"

Table 5. Result of Average Speed from GPS SLIFA data

GPS SLIFA	Map Application	Road Type	Average Speed (km/h)
-6.208974, 106.737985	-6.209062, 106.738000	Pedestrian	32
-6.220164, 106.739278	-6.220164, 106.739380	Highway	58
-6.213799, 106.742736	-6.213624, 106.742640	Toll	52

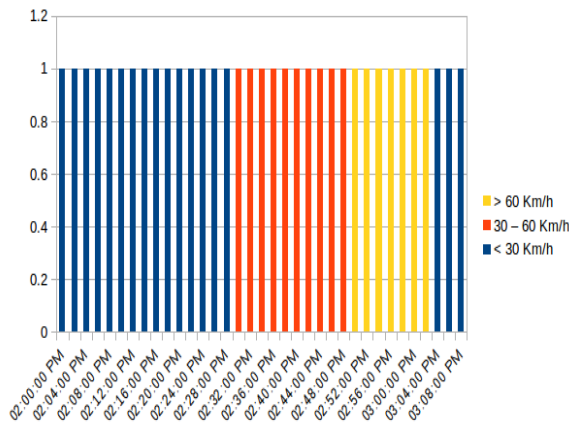


Figure 8. Average speed in every time GPS send data to the server

The blue line in Figure 8 shows the average speed under 30 Km/h, which is a pedestrian area. The situation in the pedestrian road a little bit crowded because the wide of the road only for two vehicles. And the orange line shows the average speed between 30 – 60 Km/h. This is because the vehicle at that moment is on highway road. The highway road consists of 3-4 rows for a vehicle in the same direction, so there is no crowded on the highway road.

Meanwhile, the yellow line shows an average speed above 60 Km/h. It describes the vehicle in toll road, and the toll road is a road without obstacles, such as traffic lights, speed bumps, etc. The real route for testing the GPS is shown in Figure 9. The route consists of three types of road, pedestrian, highway, and toll road.

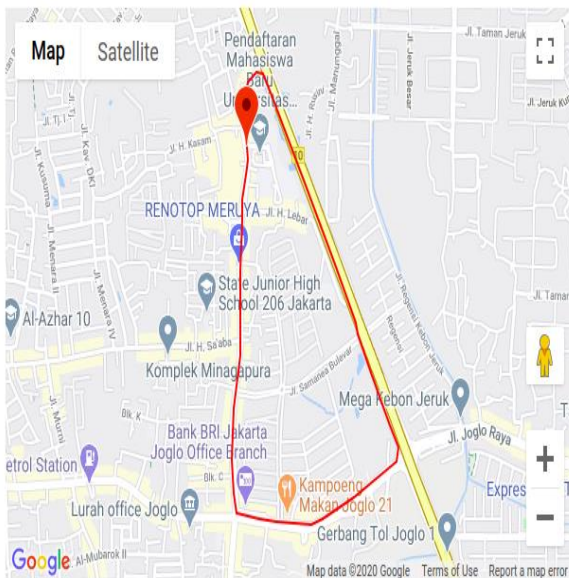


Figure 9. Actual route for testing GPS

The GPS success limits the speed of the truck and bus with different road types. Therefore, the driver meets the traffic regulation requirement that mentions the speed limit in pedestrian, highway, and toll roads.

### CONCLUSION

The development and analysis of speed limitation devices were successfully conducted, starting from developing its system, fabrication, trial test, and installation on trucks and buses. Several analyses such as speed testing and GPS accuracy percentage with a fuel cut off the device installed on the engine when on a toll road, highway, and pedestrian road have been performed. The monitoring of speed by using GPS shows an effective monitoring and limitation process. The average speed performed by the truck and bus was 32,58,52 km/h for pedestrian, highway and toll road types, respectively. The GPS was effective in the automatic clustering process based on the location. It automatically changes the speed limit of the truck and bus when it enters a different location, either pedestrian, highway or toll road. It will conclude that this study is very recommended to apply to improve the attitude and driving behavior of the driver to obey the traffic regulation.

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