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VEHICLES SPEED IN PLATOON, CASE STUDY: PADANG – BUKITTINGGI ROAD

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ABSTRACT

The increase in vehicle ownership number will affect the increase in traffic flow, which will usually result in congestion on the road network. This phenomenon causes vehicles to tend to travel close to one another (platoon). Characteristics used in describing the platoon phenomenon are the distance between vehicles (headway), average speed, and the number of vehicles in the platoon. This study is to analyzes the effect of variations in the leader and platoon length on vehicle speed. This research was conducted on Padang – Bukittinggi Road. Based on the Decree of the Minister of PUPR No: 248/KPTS/M/2015, Padang - Bukittinggi Road is categorized as a primary arterial road. This research used the primary data, a field survey, by recording vehicle traffic flow (traffic platoon) for two days. A distance of 50 meters is taken to determine the speed, and the time is measured with a stop program. The average headway on weekdays is 1.32 seconds and on holidays is 1.47 seconds. The size of the platoon and the type of platoon leader have a significant effect on the average speed of the vehicle in the platoon if the headway is ≤ 2 seconds. At the addition of one vehicle in the platoon, which can change the vehicle's average speed, follows the equation y = -4.30x + 67.09.

Keywords: platoon, headway, average speed, leader vehicle

1. INTRODUCTION

The increasing vehicle ownership will affect traffic flow, which will usually result in congestion on the road network. This phenomenon causes vehicles to tend to travel close to one another (platoon). The characteristics used in describing the platoon phenomenon are the distance between vehicles (headway), average speed, and the number of vehicles in the platoon. (Mathew et al., 2013).

The distance between vehicles (headway) is defined as a control of the safe distance between the vehicle in a platoon to avoid a rear collision because the driver needs time and space to react to make safe braking (Ayres et al., 2002). Reaction and braking capabilities are closely related to vehicle speed and stop visibility.

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1.1. Traffic

Traffic is the movement of vehicles and people in the road traffic space (Transportation, 2009). Traffic flow is defined as the vehicles (number) that pass at a point on the road at certain time intervals. Traffic flow is measured in vehicles per unit time (vehicle/hour or pcu / hour).

On rural roads, vehicles are divided into five types, namely Light vehicles (LV), Medium-Heavy Vehicles (MHV), Large Trucks (LT), Large Bus (LB), Motor Cycle (MC) (Directorate, 1997). Non-motorized vehicles are not considered part of the traffic flow. Non-motorized vehicles include wheeled vehicles with people or animals as their driving force, including pedicabs, bicycles, horse-drawn carriages, and thrusts.

Based on the nature and movement of road traffic and transportation, road functions are divided into the arterial, collector, local, and environmental. The role of this road is contained in the primary road network system and the secondary road network system (Government of Indonesia, 2006).

1.2. Speed

Speed is defined as the rate of travel. Speed is expressed in kilometers per hour (km/h). Speed can also be defined as the ratio between the distance traveled and the time traveled (Khisty, CJ & Lall, 2005).

Speed can be expressed by the following formula:

$$v = \frac{d}{t} \tag{1}$$

Information:
v = speed (km / h)
d = distance traveled (km)
t = travel time (hours)

Vehicle speed can be influenced by several factors, including human factors, weather conditions, natural and surrounding environmental factors, vehicle and infrastructure factors. Traffic factors can also influence it in an area.

Due to the large variety of individual speeds within the traffic flow, average speeds are usually used. How to determine average speed :

1. Space average speed
   It is called space average speed because the use of average travel time basically calculates the length of time used by each vehicle in space.
2. Time average speed
   Time average speed is the arithmetic average of the measured speed of all vehicles crossing a point on the road at a particular time. The individual speed is called the spot speed.

1.3. Traffic Volume

Traffic volume is the actual number of vehicles observed or estimated through a point during a particular time. To get the traffic flow in a segment of the road, which consists of many types of vehicles, all kinds of vehicles are converted into passenger car units (pcu). An equivalent factor is needed to convert a vehicle into smp unit. **Table 1** shows the equivalent of a passenger car (pce) for roads outside the city.

Table 1. Passenger vehicle equivalent (pce) for roads 2/2 UD

Alignment type	Total of traffic flow/hour)	Emp					
		MHV	LB	LT	MC		
					Traffic lane width (meter)		
					<6	6-8	> 8
Flat	0	1.2	1.2	1.8	0.8	0.6	0.4
	800	1.8	1.8	2.7	1.2	0.9	0.6
	1350	1.5	1.6	2.5	0.9	0.7	0.5
	≥1900	1.3	1.5	2.5	0.6	0.5	0.4

Source: (MKJI, Highway Capacity Manual Project, 1997)

1.4. Traffic Platoon

Accompaniment (Platoon) is a traffic condition when a vehicle moves in a queue (platoon) at the same speed because it is being held back by the vehicle in front (platoon leader). The time between the vehicle is ≤ 5 seconds (MKJI, 1997).

There are four types of vehicle platoon: LV - LV, LV - HV, HV - HV, HV - LV, where LV is light vehicles and HV is heavy vehicles. Buses are included in heavy vehicles category and mini bus as public transportation including light vehicles. The highest platoon type is LV - LV, with headway values at intervals of 1.1 to 1.8 seconds. This value is relatively the same for surveys at three peak hours, morning, afternoon, and evening (Purnawan & Adilla, 2013).

There is a relationship between the leader platoon and the speed and size of the platoon based on the total vehicle weight (gross vehicle weight, GVW). Study shows that platoon velocity decreases with increasing GVW of the platoon leader. However, the average platoon size led by a heavy vehicle is smaller than that of a platoon led by a light vehicle. Platoon calculations are performed on the headway for up to 4 seconds (Syahira et al., 2014)

In traffic conditions consisting of platoon leaders and platoon followers, a vehicle is considered a follower if its headway time is less than 4 seconds or the distance is less than 250 ft (Ramezani, H., Benekohal, RF & Avrenli, 2008).

Padang - Bukittinggi Road is an arterial road in West Sumatra Province, and the number of vehicles crossing these roads will cause a platoon that can cause congestion. This study aimed to determine the effect of leader vehicle variation and platoon length on vehicle speed in a platoon. The benefit of this study is as a guide or reference for related parties to consider the characteristics of the platoon in road planning and traffic management.

2. RESEARCH METHODOLOGY

The research was conducted on the Padang - Bukittinggi road section, which can be seen in **Figure 1**. The surveyed road data are as follows: The road status is National Road, with the section name Lubuk Alung - Simp. Duku, section number 026, has length of 13.49 km and functions as an Arterial Road (Government of Indonesia, 2015). From the measurements in the field, it is obtained that the road width data is 6.5 meters with a shoulder width of 2.8 meters.

The survey was conducted by recording traffic conditions using a camcorder. The survey was conducted for two days, namely: 1 (one) day on holidays, which was conducted on Sunday,

25 August 2019 for 8 hours 30 minutes, namely from 07.00 WIB to 12.30 WIB and 13.15 to 16.15 WIB and 1 (one) days on working days conducted on Tuesday, 27 August 2019 for 5 (five) hours, namely from 16.00 WIB to 21.00 WIB. Observations were made in 2 (two) directions: Padang to Bukittinggi and Bukittinggi to Padang. The vehicles surveyed are: light vehicles (LV), medium-heavy vehicles (MHV), large buses (LB), large trucks (LT), and motorbikes (MC).

A distance of 50 meters is taken to determine the speed, and the time is measured with a stop program. Then the velocity data validation was carried out by comparing the velocity measurement with a camcorder with a speed gun measurement. The data obtained from the survey results are then displayed in tables and diagrams and analyzed statistically with the two-way ANOVA test to see the significant changes in the platoon's size and the type of vehicle leader of the platoon on the average speed.

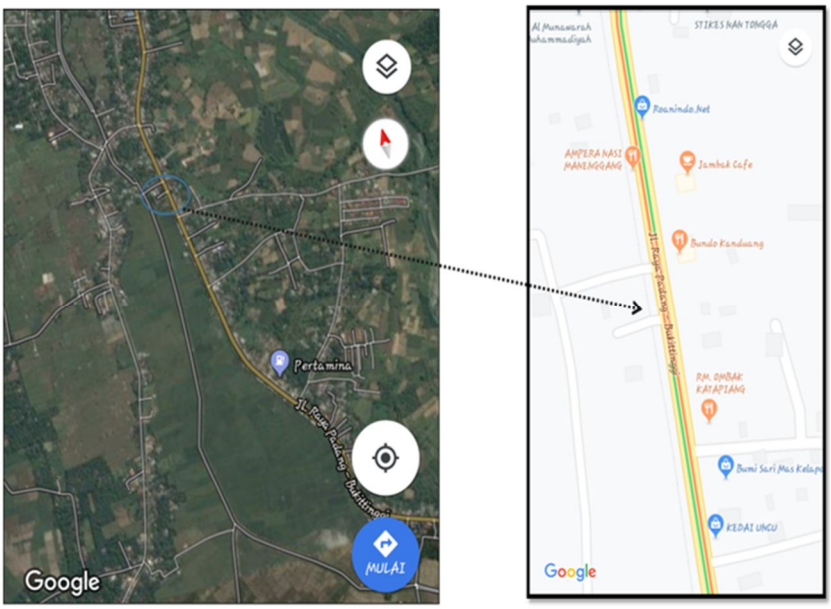

Figure 1. Survey location

3. RESULTS AND DISCUSSION

3.1. Vehicle Volume

On a working day (Tuesday), the Traffic volume from Padang to Bukittinggi is higher dan Bukittinggi to Padang, where the survey was carried out for 8 hours 30 minutes (**Table 2**). On Sunday (a non-working day), the traffic volume from Bukittinggi to Padang is higher than from Padang to Bukittinggi; the survey was conducted for 5 hours.

Table 2. Recapitulation of vehicle volume

Day - direction	Transportation type					total (pcu)
	LV	MHV	LB	LT	MC	
Tuesday						
Padang - Bukittinggi	3230	1177	14	176	4774	9578.6

Day - direction	Transportation type					total (pcu)
	LV	MHV	LB	LT	MC	
Bukittinggi - Padang	2959	1171	19	132	4381	9400.3
Sunday						
Padang - Bukittinggi	2987	406	17	110	2629	5765.7
Bukittinggi - Padang	3219	383	17	45	3943	6693.3

3.2. Determination of peak hours and off-peak hours

The determination of 'peak and off-peak hours' can be seen in **Table 3** (based on the direction). The table shows that the heaviest traffic is from Bukittinggi to Padang from 19.00 WIB to 20.00 WIB. The phenomenon occurs due to the large movements back to the town of Padang as the economic center.

Table 3. Recapitulation of peak and off-peak times

Day	Hour	Traffic Volume (pcu / hour)	Information
Tuesday			
Padang - Bukittinggi	09.45 - 10.45	1248.9	Peak hours
	07.45 - 08.45	1003.6	Off-peak hours
Bukittinggi - Padang	14.30 - 15.30	1335.4	Peak hours
	07.15 - 08.15	1032.3	Off-peak hours
Sunday			
Padang - Bukittinggi	16.15 - 17.15	1359.8	Peak hours
	19.00 - 20.00	1019.4	Off-peak hours
Bukittinggi - Padang	19.00 - 20.00	1479.9	Peak hours
	18.00 - 19.00	1199.4	Off-peak hours

3.3. Speed Distribution Based on Platoon Size

Figure 2 provides an overview of the average speed of vehicles in a platoon decreases with the increase in platoon size. It can also be seen that the average speed during peak hours is higher than the average speed during off-peak hours.

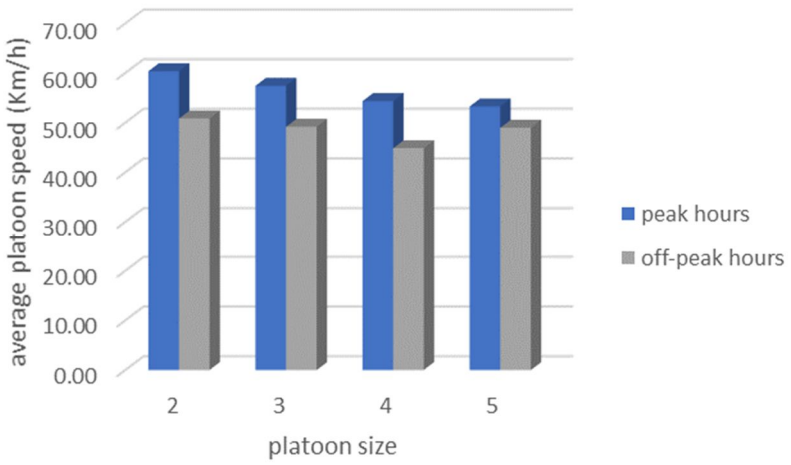

Figure 2. Distribution of vehicle speed based on platoon size on weekdays from Padang to Bukittinggi

As shown in **Figure 3**, the average speed of vehicles in a platoon decreases with the increase in platoon size. It can also be seen that the average speed during off-peak hours is higher than the average speed during peak hours.

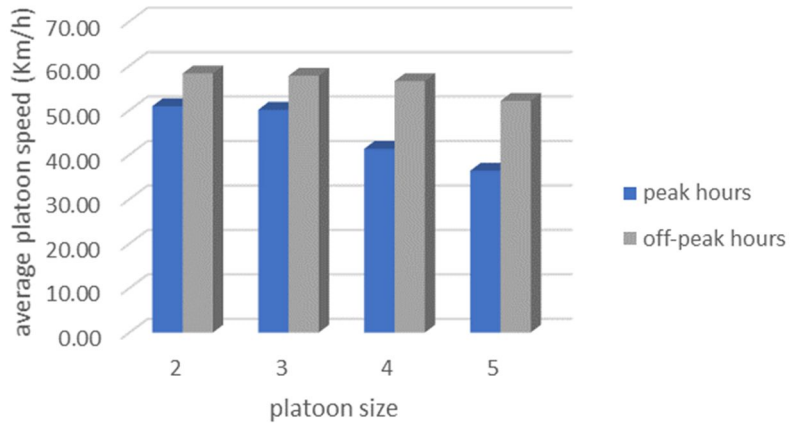

Figure 3. Distribution of vehicle speed based on platoon size on weekdays from Bukittinggi to Padang

The average speed of vehicles in a platoon decreases with the increase in platoon size, as shown in **Figure 4**. It can also be seen that the average speed during off-peak hours is higher than the average speed during peak hours. Vehicle speed during rush hour decreased by an average of 6.62% for each additional one vehicle on the platoon. Meanwhile, during off-peak hours, the average vehicle speed decreased by 4.53% for each additional one vehicle on the platoon.

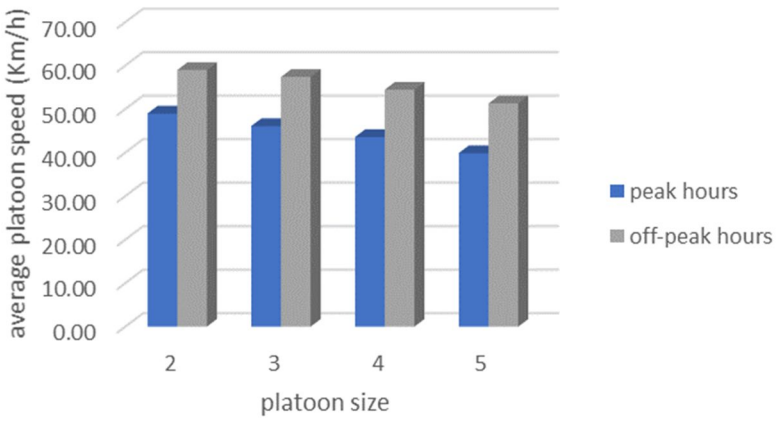

Figure 4. Distribution of vehicle speed based on platoon size on holidays from Padang to Bukittinggi

Figure 5 presents the survey result; the average speed of vehicles in a platoon decreases with the increase in platoon size. It can also be seen that the average speed during off-peak hours is higher than the average speed during peak hours.

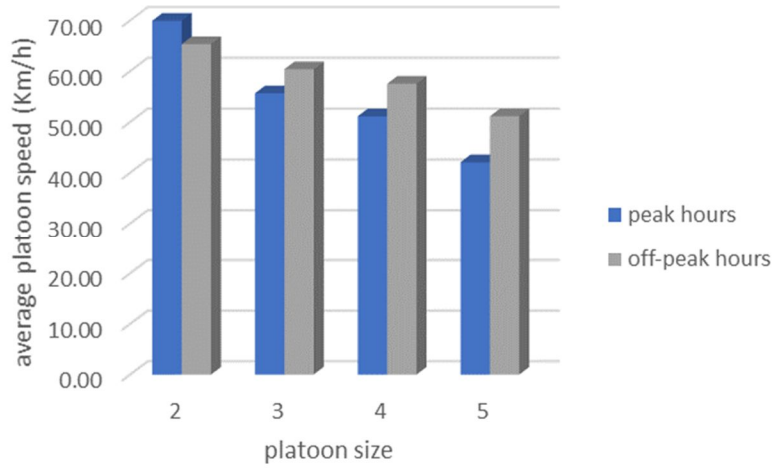

Figure 5. Distribution of vehicle speed based on platoon size on holidays from Bukittinggi to Padang

Figure 6 shows the average vehicle speed based on the size of the platoon. If linear regression is carried out, it can be seen that if the average headway speed of up to 2 seconds follows the equation -4.308x + 67.09. In the platoon measurement up to 2 seconds, the average speed decreased by 8.36% for each additional 1 (one) vehicle on the platoon. Vehicles moving in a larger platoon reduce vehicle speed but tend to trigger the driver's intention to overtake the vehicle in front due to dependence on the vehicle leading the platoon (Syahira et al., 2014).

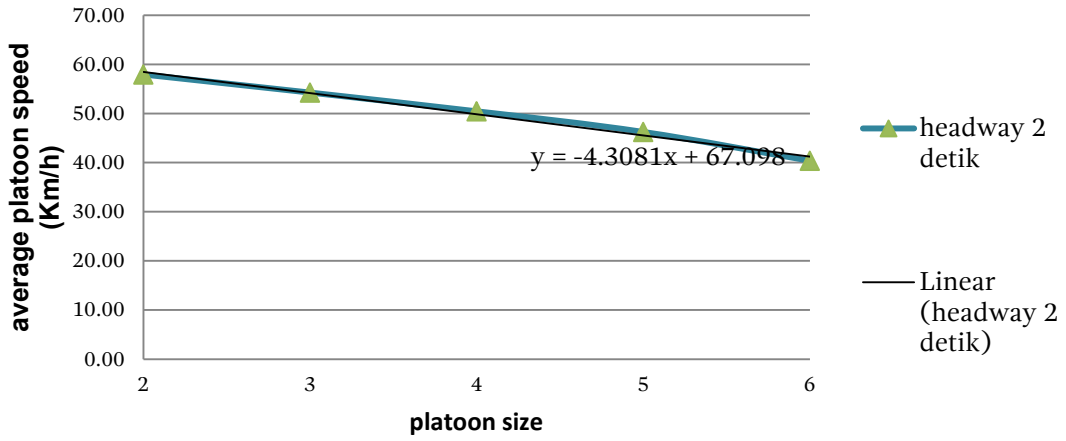

Figure 6. Average velocity based on platoon size

3.4. Speed Distribution by Platoon Leader Type

Figure 7 provides the results obtained from the preliminary analysis of speed distribution by platoon leader type. It is shown that the average speed of vehicles in a platoon for the kind of leader of light vehicles is higher than that of medium-heavy vehicles and large trucks. It can also be seen that the average speed during peak hours is higher than the average speed during off-peak hours.

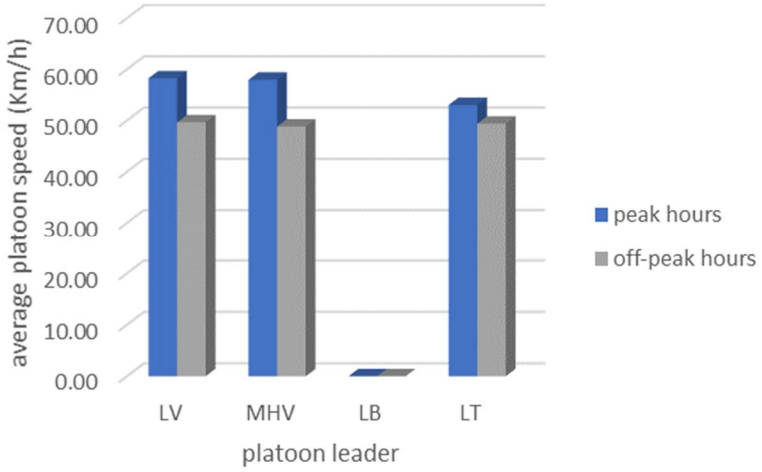

Figure 7. Distribution of vehicle speed based on platoon size on weekdays from Padang to Bukittinggi

Figure 8 compares platoon leader type, and the vehicle's average speed. It can be seen that the average speed of vehicles in a platoon for the type of leader of light vehicles is higher than that of medium-heavy vehicles and large trucks. It can also be seen that the average speed during peak hours is lower than the average speed during off-peak hours.

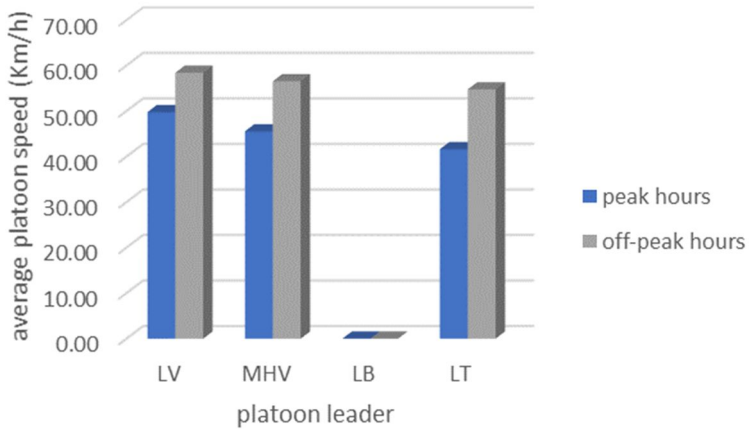

Figure 8. Distribution of vehicle speed based on the type of platoon leader on weekdays from Bukittinggi to Padang

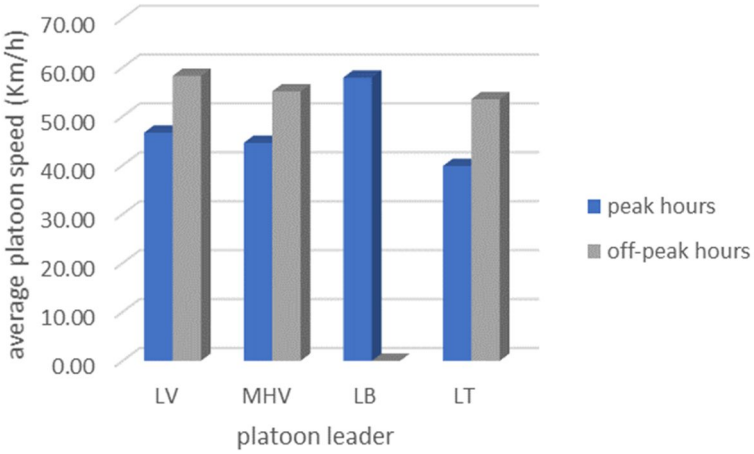

Figure 9. Distribution of vehicle speed based on the type of platoon leader on holidays from Padang to Bukittinggi

The average speed of vehicles in a platoon for the type of leader of light vehicles is higher than that of medium-heavy vehicles and large trucks, as shown in **Figure 9**. It can also be seen that the average speed during peak hours is lower than the average speed during off-peak hours. In **Figure 10**, it can be seen that the average vehicle speed in the platoon for the light type of leader vehicle is higher than that of medium-heavy vehicles and large trucks.

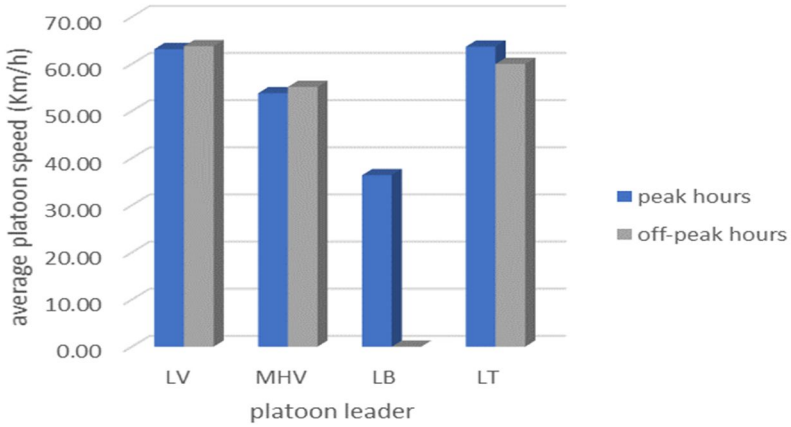

Figure 10. Distribution of vehicle speed based on the type of platoon leader on holidays from Bukittinggi to Padang

3.5. Validation Test

The speed data validation is conducted by comparing the speed measurement data from the video recording with the speed measurement from using a speed gun. After calculating the correlation coefficient (r), the calculated r-value = 0.929, while the r table value is 0.339, the calculation is carried out with a significant value of 5%. By comparing the calculated r-value with the r table where r count> r table, then the data is valid.

3.6. Statistic test

Statistical test with two way ANOVA test was conducted in this study.

3.6.1. Platoon size statistical test on the mean velocity

The initial hypothesis, there is no significant effect of changes in platoon size on the mean vehicle speed (Ho). The alternative hypothesis is that platoon size has a significant effect on the mean velocity (H1). The initial hypothesis is rejected if the F count ≥ F table. The calculation is done with a significance level of 5%. From the statistical test obtained, F count 5.78> F table 2.71, meaning that the initial hypothesis is rejected, there is a significant effect of changes in platoon size on the mean velocity.

3.6.2. Statistical test of the type of platoon leader on the mean velocity

The initial hypothesis, there is no significant effect of changes in the type of platoon leader on the mean vehicle speed (Ho). The alternative hypothesis is that the type of platoon leader significantly affects the mean velocity (H1). The initial hypothesis is rejected if the F count ≥ F table. From the statistical test obtained F count 5.12> F table 3.73, meaning that the initial hypothesis is rejected, there is a significant effect of changes in the type of platoon leader on the average speed. Statistical tests were carried out on three types of platoon leaders, namely light vehicles (LV), medium-heavy vehicles (MHV), and large trucks (LT), while large buses (LB) were not tested due to insufficient data.

4. CONCLUSION

Based on the study, it can be concluded as follows:

1. The size of the platoon and the type of vehicle leading the platoon have a significant effect on the average speed of the platoon, on the platoon measurement with a headway of up to 2 seconds.
2. In the platoon measurement up to 2 seconds, the average speed decreased by 8.36% for each additional 1 (one) vehicle on the platoon.
3. On weekdays, the average headway is 1.32 seconds, and the average headway on holidays is 1.47 on the platoon measurement with a headway of up to 2 seconds.

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