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The effect of Gross Vehicle Weight on Platoon Speed and Size characteristics on Two-Lane Road

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Abstract

This paper presents the results of a study that attempts to empirically explore the influence of Gross Vehicle Weight (GVW) of the platoon leader on platoon size and platoon speed characteristics on two-lane road. The aim of this study is to observe how the platoon leaders' vehicle dynamics capability affects the platoon size and platoon speed variation. A Weigh-in-Motion (WIM) based traffic data collection system was installed in a two-way rural road section to capture a set of platoon-based traffic data for a month, 24-hours a day. From a total of 173,778 vehicles passing the road section, 17,820 platoon data were detected and utilized in an analysis process. Collected data was grouped as according to their platoon leader weight, and then analyzed by two-way ANOVA to evaluate its relationship to platoon speed and size. Empirical analysis results show that there is a significant relationship between GVW of platoon leader and both platoon speed and platoon size. The findings suggest that platoon speed decreases and speed variation increases alongside the increasing of GVW of platoon leader. However, it is proven that the average size of platoons led by heavy vehicles is smaller than platoons led by passenger cars. The formation of platoon involving heavy vehicles indeed has a large impact on driving behavior of either psychological or physical action. Thus, in order to reduce the risk of dangerous overtaking maneuver, there is a high necessity for traffic flow of different opposing directions to be separated and an extra lane shall be designed for particularly overtaking activities at accident prone areas.

Keywords : Platoon, Heavy Vehicle, Vehicle Weight, Platoon Size, Platoon Speed

Introduction

Each year the number of road accident fatalities and casualties are constantly increasing and this situation seemingly burdens the capability of health services and national economy. In Malaysia for instance, the number of road accidents and fatalities are increasing every year and in the year of 2008, total number of road accident increased by 2.7% and road fatality increased by 3.9% from the previous year (Royal Malaysian Police). Moreover, based on accident data obtained from the Malaysian Institute of Road Safety Research (MIROS), the ratio of fatal accident involving heavy vehicle (FAIHV) against total road fatalities in year 2008 is 25.1% which is relatively substantial. This figure indicates that at least 25.1% of all road fatalities are due to fatal accidents involving heavy vehicles (because by definition a fatal accident is when at least one death occurs in that accident). Furthermore, an analysis of

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the accident fatality data further revealed that at least 41% of fatal accidents occurred involving heavy vehicles and motorcycles.

In addition to this matter, the growth amount of vehicle registration each year brings more vehicles travelling on the roads, as well as higher traffic volume that usually results to congestion in road networks. Consequently, various vehicles on the roads tend to move closely together in a group in some instances and this form of motion is defined as platoon. Vehicle platooning has become a part of the traffic flow nowadays, especially in single-carriage rural roads. Unfortunately, it has become a crucial safety issue since it can increase the risk of multiple vehicle rear-end collision.

According *to 4th Edition Highway Capacity Manual*, platoon is defined as "a group of vehicles or pedestrians travelling together as a group, either voluntarily or involuntarily because of signal control, geometrics, or other factors". To generate platoon-based data, most of previous researches (Athol, 1965; Jiang and Li, 2005) use time headway to separate free-flow moving and impeded vehicles in a platoon. Petigny (1967) found two classes of queuing vehicles: (a) a time headway of the order 1 sec to describe vehicles but waiting for a chance to pass, and (b) a time headway of 3.5sec to characterize vehicles that are queuing and are content to do so. In a study on vehicle following interaction, Pahl and Sands (1971) determine that interaction may occur at time headway between 2.5sec and 4.3sec, depending on lane number and traffic flow rate. Al-Kaisy and Karjala (2010) suggest car-following interactions on two-lane rural highways generally cease beyond a headway value of 6sec. The critical headway and interaction headway used in this research is modified based on experts' findings.

This paper focuses on traffic safety related to vehicle platoon. The two main variables investigated in this study are platoon speed and platoon size. Speed has been identified as one of the contributing factors to the severity and frequency of road traffic crashes (Derry et al., 2007). Several studies had been conducted to investigate the average speed effects on likelihood of road crash (Aljanahi et al., 1999; Pei et al., 2012). There have been conjectures that platoon speed and platoon size are correlated and highly related to traffic performance as well as driving behaviour. Most of drivers avoid travelling behind large size platoons which usually results in reduced driving speed. Benekohal (2011) mentioned some contributions made by Professor Joseph Treiterer related to platoon. One of his remarkable findings were the initial acceleration characteristics of the smaller-sized platoons (four to six vehicles) were higher than that of larger-sized platoons (10 to 13 vehicles). In a recent study, Al-Kaisy and Durbin (2011) presented empirical investigation into platooning on two-lane two-way highways in six states in Montana. They found that the amount of impedance to traffic is proportional to the size of platoon. Therefore, following vehicles within platoon are forced to move at lower speed than that of vehicle in front to prevent collision. At this point, some drivers tend to find an opportunity to overtake. This is relevant to the basic motivation of drivers to pass other vehicles is to avoid loss of time that results from travelling at lower speed forced by a slower moving vehicle ahead (Bar-Gera and Shinar, 2005). The overtaking maneuver on two-lane roads also has been associated as an important safety issue. Farah et al. (2009) analyzed passing maneuver behavior on two-lane rural roads and found that both speed overtaking vehicles and the lead vehicles influenced the incidence of dangerous overtaking. Regarding the speed that enhance the drivers' tendency to pass, Romana (1999) found the difference between the speed of the passing vehicle and the speed of the overtaken vehicle ranging from 6 km/h at low speeds, to 30 km/h at high speeds.

In normal situation, it is conjectured that platoons with larger size reduces vehicle speed, and will trigger driver's intention to overtake the front vehicle. Due to dependence on the lead vehicle, each of the drivers of rear vehicles in the platoon may have to be vigilant to adapt the speed and acceleration at specific time. Any kind of distractions caused negative effects on driving performance such as reduced longitudinal and lateral control, reduced situation awareness and impaired response times to roadway hazards (Young and Salmon, 2012). In addition, Navon (2003) stated that an increase in vehicle speed greatly increases perception distance (viz. the distance traveled by the car from the moment a stimulus is visible to the moment it is perceived by the driver), decision distance, braking distance and the physical impact of an accident on the body.

Occasionally, heavy vehicles move together in a platoon and sometimes lead a platoon. This creates greater critical safety factor as the disparity in dynamic composition involved different vehicle capacity. This is due to the reason that, in contrast to passenger cars, heavy vehicles have more complicated systems with a variety of possible failure modes and performance characteristics including locked-wheel braking, trailer swing-out, rollover, poor acceleration characteristics and longer braking distance (Saifizul et al, 2011b). Derry et al. (2007) found that the average travelling speed is also varied for different types of vehicles. They found that the average speed of private cars were the highest among other moving vehicle class, followed by large buses, medium buses and goods vehicle.

Vehicle platoon, especially caused by heavy vehicles gives high impact on traffic flow and drivers' behaviors'. Even though vehicle platoon were widely discussed in previous researches, most of the platoon models do not specifically consider the Gross Vehicle Weight (GVW) of platoon leader and their interactions with other vehicles in the platoon. The effect of following vehicle GVW has been studied and proven to have significance on the speed characteristics in vehicle following situation (Saifizul et. al., 2011b) and in free flow condition (Saifizul et. al, 2011a). This paper is a continuation of the Saifizul et al. (2011b) study in which they empirically analyzed how GVW of following vehicle and size of leading vehicle affect driver behavior under vehicle following situation for different compositions of leader-follower pairs. The findings highlighted both GVW of following vehicle and size of leading vehicle were significant sources of following vehicle speed and relative speed variation. Therefore, the aim of this study is to investigate the effect of GVW of platoon leader on platoon characteristics, particularly on vehicle platoon speed and platoon size.

Methodology

SData Collection

A developed Weigh-in-Motion (WIM) system was installed on a selected rural single carriage-way two lane road, with straight and flat road geometry which has a speed limit of 70 kmph. The configuration of WIM system is shown in Figure 1. The heart of data collection system is the WIM sensor which consists of loop detection and quartz sensor. Further description of the system utilized in this study is presented in Saifizul et al. (2010). Traffic data were gathered in a one-month period, 24 hours a day using the system.

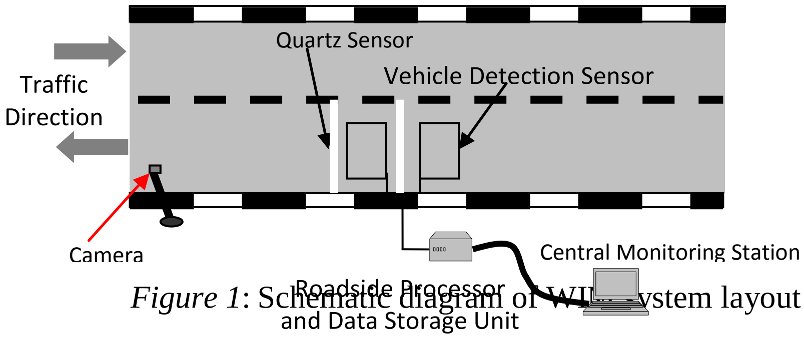

Figure 1: Schematic diagram of WIM system layout

Data Preparation

There were 17 820 vehicles travelling in platoons observed and recorded at the location site. All the data including every single non-platoon vehicles are used to calculate the 15-minutes flow rate which will be used to study traffic behavior. Because of the low traffic volume that there were at the selected road section, platoon based data is obtained and separated from other single vehicles by using 3.5sec critical headway. In this study, platoon leader is defined as the first vehicle in a platoon. Firstly, the data are grouped according to platoon leader GVW. There are three types of vehicle platoon leaders in traffic stream that will be considered as illustrated in Figure 2. The first case is the platoon led by passenger cars. The second case is the platoon led by heavy vehicle with GVW not more than 20tonnes, including light duty trucks such as vans and pickup trucks. The third case is the platoon led by heavy vehicle with GVW more than 20tonnes. Since the type of following vehicles is not within the interest of this study, all types of vehicles are included. The selected road section is generally a non-congested road for most of the time, except during peak hours.

Below are the definitions of terms and variables used in this paper:

Platoon leader : the first vehicle of the platoon.

HV : Heavy Vehicle

C_i : the successive following vehicles within a platoon, where $i = 1,2,3,...,n$.

Var : a set of traffic and vehicular variables captured together in the data set, where $Var\_C_i = \{speed, GVW, Acc, Wheelbase, Headway\ and\ Class\}$. However, some of the variables are not included since the study only focuses on speed.

Platoon size : the total number of vehicles involved in a platoon, including the platoon leader.

Platoon speed : the average speed of all the vehicles in the platoon.

15-min flow rate : number of vehicle passing through the road section in 15 minutes.

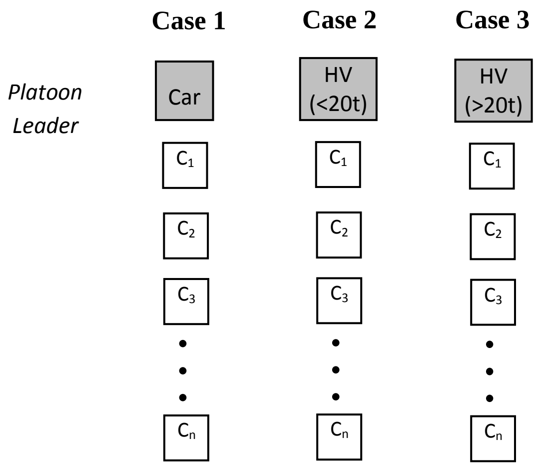

Figure 2: Three cases according to types of platoon leader.

In order to remove the influence of the surroundings and focus on drivers' behavior and vehicle performance capability in a vehicle platoon, data were then filtered based on following conditions:-

- A platoon is only considered if it has more than two vehicles. Therefore, $C_{i_{min}} = 2$.
- The headway between the first vehicle in the platoon (platoon leader) and the vehicle in front is not less than 4 seconds.
- Critical intra-platoon headway (from C_1 to C_n) is less than or equal to 3.5 seconds.

Results

The total number of sample for the month is 173,778 vehicles passing through the road section. After filtering the data, a total of 17,820 platoon-based data was detected. Majority of the platoon cases (73.4%) were led by passenger cars, while 15.5% led by heavy vehicle less than 20tonnes and 11.1% led by heavy vehicle more than 20tonnes. The total sample for each group which is divided by flow rate is represented in Table 1.

Table 1:
Number of sample for data analysis.

Platoon Type	15-Min Traffic Flow Rate (Vehicles)											
	<40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	>130	Total
Case 1	765	647	947	1357	2216	2542	1924	1480	1013	668	607	14166
Case 2	112	45	99	195	410	521	382	253	139	94	63	2313
Case 3	23	15	32	74	238	342	271	193	77	51	25	1341

Data Description

According to Jiang et al. (2003), vehicle platoon characteristics on a specific road vary over time because of the fluctuation of traffic flow rate. Thus, both flow rate and GVW are considered in this study to focus on the effect of GVW to the platoon speed and platoon size characteristics at different flow rate. However, analysis is done seperately to exclude their interaction and to focus on the effect of each of them. Normality test has been performed for each group of platoon speed data by observing their Skewness and Kurtosis and all data can be considered as having normal distribution.

Before analyzing platoon-based data, platoon size and platoon speed distribution are observed. Figure 3 illustrates the distribution of platoon size by the platoon leaders. A similar pattern observed between three cases wherein as the platoon size increases, the frequency of occurrence decreases. Table 2, 3 and 4 show the frequency of platoon sizes according to 15-minutes flow rates, for three cases of platoons.

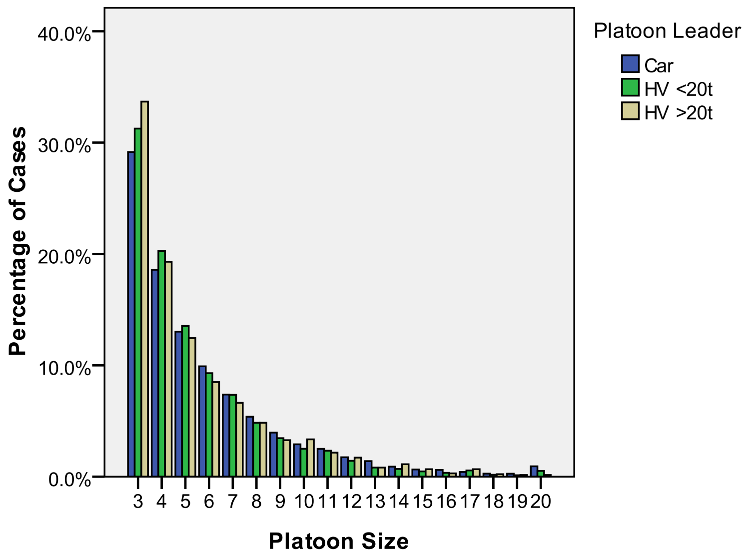

Figure 3: Percentage of platoon size frequency by cases

Table 2:
Frequency of platoon sizes for Case 1

Platoon Size	15-Min Flow rate (Vehicles)										
	<40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	>130
3	452	277	362	417	630	735	519	320	187	123	108
4	169	162	220	289	401	468	348	245	155	106	69
5	84	84	141	216	298	348	248	182	131	63	50
6	32	51	85	149	274	255	184	159	87	71	57
7	21	30	52	104	186	213	135	128	86	53	37
8	5	18	23	72	117	155	125	105	68	41	34
9	1	12	18	39	87	101	96	74	57	37	39
10	1	3	19	24	61	72	70	54	42	28	38
11	-	3	10	22	51	58	51	49	56	20	34
12	-	2	7	10	34	50	38	33	24	20	29
13	-	2	5	6	25	25	30	37	31	23	14
14	-	1	2	3	16	19	13	21	26	15	12
15	-	-	2	3	13	15	11	21	7	7	13
16	-	2	1	-	8	10	14	12	16	13	10
17	-	-	-	1	6	3	10	10	8	13	9
18	-	-	-	1	4	1	6	7	8	9	3
19	-	-	-	1	2	3	6	7	6	5	8
20	-	-	-	-	3	11	20	16	18	21	43
Total Platoons	765	647	947	1357	2216	2542	1924	1480	1013	668	607
Mean Platoon Size	3.73	4.37	4.66	5.05	5.58	5.61	6.01	6.56	7.13	7.52	8.40

Table 3:
Frequency of platoon sizes for Case 2

Platoon Size	15-Min Flow rate (Vehicles)										
	<40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	>130
3	84	19	30	57	135	152	112	62	37	23	12
4	20	14	21	48	99	99	87	45	17	11	8
5	4	2	17	31	56	87	51	32	19	10	4
6	1	3	13	23	38	51	36	27	11	9	3
7	2	1	9	16	29	39	24	22	15	5	8
8	1	3	2	6	18	31	19	13	6	9	3
9	-	-	3	2	7	20	14	13	9	6	6
10	-	-	1	4	9	10	12	7	10	5	-
11	-	2	-	1	11	12	6	8	4	5	5
12	-	-	-	3	2	8	10	7	1	-	2
13	-	-	1	1	-	3	6	2	4	1	1
14	-	-	1	3	2	-	1	5	-	2	2
15	-	1	1	-	-	1	-	4	2	-	2
16	-	-	-	-	-	1	2	2	-	2	1
17	-	-	-	-	3	3	1	1	2	3	-
18	-	-	-	-	1	-	1	-	1	-	1
19	-	-	-	-	-	2	-	-	-	1	-
20	-	-	-	-	-	1	-	3	1	2	5
Total Platoons	112	45	99	195	410	521	382	253	139	94	63
Mean Platoon Size	3.39	4.64	5.00	5.01	5.00	5.39	5.41	6.21	6.36	7.09	8.32

Table 4:
Frequency of platoon sizes for Case 3

Platoon Size	15-Min Flow rate (Vehicles)										
	<40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	>130
3	13	7	11	25	87	124	88	62	17	15	3
4	3	3	6	14	55	61	53	34	17	10	3
5	5	1	2	11	26	45	39	24	7	6	1
6	1	2	4	10	16	32	21	16	6	3	3
7	-	1	3	7	17	22	15	12	7	4	1
8	-	1	3	2	7	18	17	6	5	2	4
9	1	-	2	1	8	9	7	8	4	3	1
10	-	-	-	2	8	12	10	5	6	1	1
11	-	-	1	-	4	8	6	3	2	3	2
12	-	-	-	1	3	3	8	3	1	3	1
13	-	-	-	-	4	2	-	3	-	1	1
14	-	-	-	-	1	3	2	5	2	-	2
15	-	-	-	-	1	1	1	5	1	-	-
16	-	-	-	-	-	1	1	1	-	-	1
17	-	-	-	1	-	1	1	3	2	-	-
18	-	-	-	-	-	-	1	1	-	-	1
19	-	-	-	-	-	-	1	1	-	-	-
20	-	-	-	-	1	-	-	1	-	-	-
Total Platoons	23	15	32	74	238	342	271	193	77	51	25
Mean Platoon Size	3.96	4.33	5.16	4.99	5.11	5.18	5.49	6.06	6.31	5.80	8.44

Note: - = No observation

Data Analysis

The analysis of data has been done for platoon speed and platoon size characteristics. Two-way analysis of variance was performed to observe the effect of platoon leader GVW and flow rate on both variables.

Platoon speed

The mean speed for all platoons through the study area was 69.45 km/hr. The two-way ANOVA results in Table 5 indicate that the main effects of platoon leader GVW and traffic flow rate on platoon speed were statistically significant, $F(2, 17787)= 415.870$, $p<0.001$ and $F(10, 17787)= 12.458$, $p<0.001$ respectively.

Table 5:
Two way ANOVA test for platoon speed.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	142620.495[a]	32	4456.890	72.633	.000
Intercept	1.393E7	1	1.393E7	226988.556	.000
FlowRateNum	7644.485	10	764.448	12.458	.000
PlatoonCase	51037.102	2	25518.551	415.870	.000
FlowRateNum * PlatoonCase	5410.761	20	270.538	4.409	.000
Error	1091444.316	17787	61.362		
Total	8.717E7	17820			
Corrected Total	1234064.811	17819			

a. R Squared = .116 (Adjusted R Squared = .114), dependent variable: platoon speed.

The line plots of average and standard deviation of platoon speed corresponding to flow rate are demonstrated in Figure 4 and Figure 5. Different with platoon size, the increase in flow rate results in descending average platoon speed. The discrepancy of the average platoon speed between the three cases can be clearly distinguished. Figure 4 shows that the mean speed for platoon following a passenger car is higher than mean speed for platoon following heavy vehicle less than 20tonnes, whereas platoon led by heavy vehicle more than 20tonnes travel has the lowest mean speed. It is clear that the speed standard deviation is remarkably high at lowest group of traffic flow.

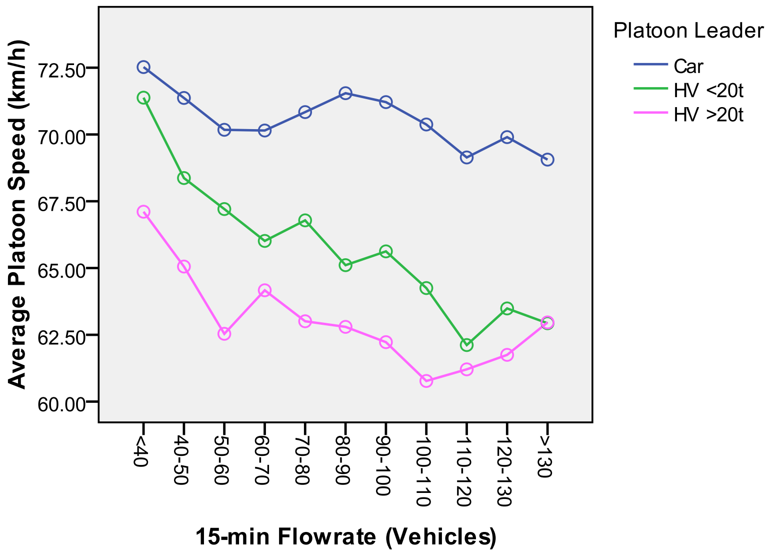

Figure 4: Average platoon speed corresponding to flow rate.

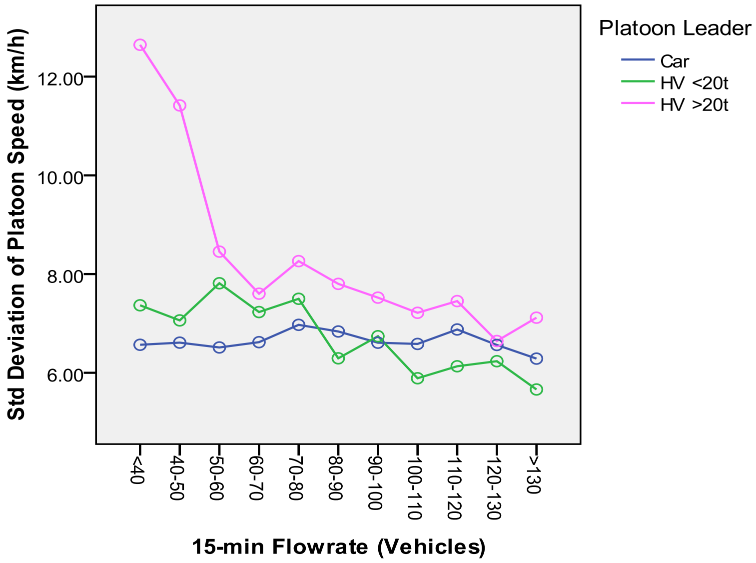

Figure 5:Standard deviation of platoon speed corresponding to flow rate.

Platoon size

Since the platoon size data for each group was exponentially distributed, the data was normalized subjected to a log transformation. The Skewness and Kurtosis obtained after transformation is checked (S=0.726, K=-0.282) before further analyzed. Table 6 shows the result of two-way ANOVA test performed on normalized platoon size data. The result shows that both GVW of platoon leader, $F(2,17787)=6.126$, $p<.001$ and flow rate, $F(10,17787)=35.270$, $p<.001$ have significant effects on platoon size. To isolate exactly where the significant differences lie between the three groups, a post-hoc analysis was conducted on platoon leader cases. Tukey's HSD method is chosen for post-ANOVA to compare the three groups of cases with inequal sample size. The post-hoc test failed to reveal a statistically reliable difference between the mean platoon size of Case 2 (M = 0.686, s = 0.200) and Case 3 (M=0.684, s=0.204), *p* = .924. However, Case 1 (M = 0.707, s = 0.211) has shown a significant difference between mean platoon size of Case 2 and Case 3, with p=.000 for both tests. The result of the post-hoc analysis is shown in Table 7. Taken together, the results show that the average platoon size for Case 1 is significantly higher than Case 2 and Case 3.

Table 6:
Two-way ANOVA test for platoon size.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	70.468[a]	32	2.202	54.994	.000
Intercept	1525.553	1	1525.553	38098.121	.000
FlowRateNum	14.123	10	1.412	35.270	.000
PlatoonCase	.491	2	.245	6.126	.002
FlowRateNum * PlatoonCase	1.195	20	.060	1.492	.073
Error	712.240	17787	.040		
Total	9575.690	17820			
Corrected Total	782.708	17819			

a. R Squared = .090 (Adjusted R Squared = .088), dependent variable: platoon size.

Table 7**:**
Post hoc analysis on platoon leader GVW groups

logPsize- Tukey HSD

(I) Types of Platoon Leader	(J) Types of Platoon Leader	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Car	HV <20t	.0208*	.00449	.000	.0103	.0313
	HV >20t	.0234*	.00572	.000	.0100	.0368
HV <20t	Car	-.0208*	.00449	.000	-.0313	-.0103
	HV >20t	.0026	.00687	.924	-.0135	.0187
HV >20t	Car	-.0234*	.00572	.000	-.0368	-.0100
	HV <20t	-.0026	.00687	.924	-.0187	.0135

Based on observed means.
The error term is Mean Square (Error) = .040.
*. The mean difference is significant at the 0.05 level.

Figure 6 shows the average platoon size at different traffic flow rates. On the whole, regardless of the platoon leader, higher flow rate results in higher platoon size because of the number of vehicles travelling on the road increases. The platoon size is observed to diverge at congested traffic flow.

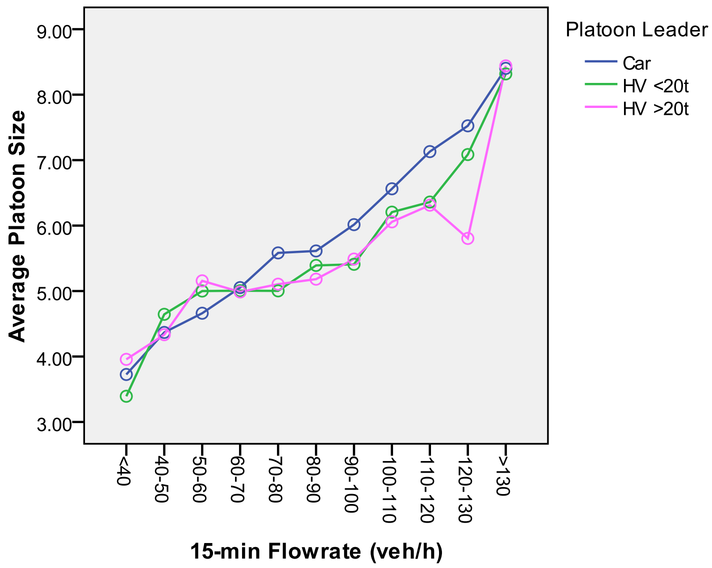

Figure 6. Average platoon size corresponds to flow rate.

Discussion

The main finding of this paper indicates that the traffic flow rate significantly affects both the average platoon speed and the average platoon size. It is proven from the results obtained that higher GVW of the platoon leader reduces platoon average speed. On the other hand, the average platoon size is observed as increasing when platoons are being led by passenger cars.

The presence of heavy vehicle as a platoon leader slows down the platoon speed, increases speed variation, thus increases delays vehicle traveling time. This is expected due to the dynamic limitation of heavy vehicle related to acceleration and braking function. Consequently, platoon drivers will decrease their speed to adjust to the speed of front vehicles. Usually, heavy vehicle encompasses large size where the drivers may notice a distance away. Sayer et al.(2003) argued that large size of lead vehicle which restrict the driver view to see traffic beyond the lead vehicle may reduce a driver’s awareness of traffic conditions ahead, but may not inhibit close following behavior. Similar to vehicle following situation, driver behavior in the platoon is much related to vehicle performance capability. Most of the drivers are not able to tolerate when dealing with heavy vehicle leading a platoon at low speed. The condition becomes worse at high traffic demand, where the platoon size grows bigger. Usually this situation would cause hasty, anxiety, impatience, and eventually trigger the driver of following vehicles to find an opportunity to overtake. However, most of them prefer taking safety precautions when they see a heavy vehicle leading a platoon ahead of them. Common reaction would be driving at lower speed to keep a distance with the front vehicle. This is due to drivers’ understanding of the heavy vehicle physical and operational capability. On the other hand, light vehicles especially passenger cars have more stable performance capability which takes shorter time to accelerate and decelerate faster as compared to heavy vehicle. Most of the researches using Automated Highway Systems (AHS) highlighted the “slinky effect” phenomenon in platoon caused by human driver which causes disturbance amplification in the inter-vehicular spacing between following cars. This is always due to inadequate information about actions of lead vehicle. As compared to automated system, manual driving using human mind is erratic and the response to deal with any emergency deceleration sometimes unpredictable. Moreover, the presence of heavy vehicle in traffic stream as a platoon leader indeed has significantly influenced vehicle platoon characteristics. The drivers who are further back in a platoon usually have limited vision and can only be making judgment of vehicle movements by observing brake light of several vehicles ahead of them.

Furthermore, overtaking has become a major concern on such roads where traffic flow of opposite lanes is not separated. Drivers maneuver to pass other vehicles at prohibited area or in reckless behaviour, highly leads to severe consequences and chances are to involve in a head-on, rear-end and sideswipe collision. Drivers' inability to pass other vehicles consequently results a long queue and heavy traffic in a platoon for a long time. This particular occurrence has caused increasing delays and capacity reduction. This explains the high frequency of the case of heavy vehicle leading a platoon in rural roads. Nonetheless, it is proven that platoons led by heavy vehicles do not enhance an increment in platoon size. On the contrary, platoons led by passenger cars had significantly increase the platoon size. This implied that vehicles in Case 1 platoons are more challenging to overtake because of their higher number of average travelling speed compared to heavy vehicles. Another factor might contribute to this finding, such as the occurrence of heavy vehicles following in a platoon- which is not studied in this paper.

Some recommendations have been drawn based on the above finding. To overcome the problem caused by platoons trapped behind a heavy vehicle, improvements has to be made on road geometric design for safety purpose. First, traffic flow for different opposing directions need to be seperated at accident prone area. In addition, an extra lane should be designed for overtaking activities, especially on steep road where most of heavy vehicles are moving at a slow pace. For example, Sweden provides these facilities of safe overtaking zone and lane seperation using safety barrier system on rural roads where traffic is too light to upgrade major routes to motorways. Few studies has also been carried out in attempt to solve this matter. Polus and Pollatschek (2004) developed a formulation of criteria and thresholds for the widening of a two-lane road and converting it to a four-lane highway. In addition, Koorey (2007) analyzed passing opportunities and effectiveness of using slow-vehicle bays or "turnouts" in New Zealand two-lane rural roads. The study showed that on average 45.4% of platoon leaders moved to slow-vehicle bays to let following vehicles passess by. Another method includes in this effort is signs installation on roads with more than two lanes, to instruct heavy vehicle to drive at left-most lane (Malaysia is a left-hand traffic) except for those who tend to overtake. Through this method, vehicles with high speed have more oppurtunity to overtake the slow vehicles with better road traffic safety assured.

Conclusion

The research findings presented in this paper investigated platoon speed and platoon size characteristics based on GVW of platoon leader. Real data set was collected on two-lane rural road by using developed WIM based traffic data collection system.
The important findings of this research are:

1. GVW of platoon leader is significantly influencing platoon speed and platoon size characteristics.

2. The study confirmed that flow rate affects platoon speed and platoon size distribution pattern.
3. Heavy trucks reduce platoon speed and increase speed variation when they lead a platoon.
4. It is proven that platoons led by heavy vehicles posses smaller platoon size in average, compared to those being led by passenger cars.
5. The study suggests improvement on road geometric design to overcome traffic delay and risk of collision caused by platoon.

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