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ANALYSIS OF CAR FOLLOWING HEADWAY ALONG MULTILANE HIGHWAY

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Graphical abstract

Abstract

This study describes driver's car following headway on multilane highways. The aim of this study is to analyse the driver's car following headway along multilane highway at four selected locations. The objectives of this study were to determine car headway at Jalan Batu Pahat – Ayer Hitam multilane highway and to develop linear regression models to present the relationships between headway and speed. Videotaping method was used in field data collection during peak hours. Data were extracted from recorded video by using the image processing technique software. The distance headways and associated vehicles speeds were classified into vehicle following category by vehicle type: car following car, car following heavy goods vehicle, heavy goods vehicle following heavy goods vehicle and heavy goods vehicle following car categories. Linear regressions models were used to develop the relationships between headway and speed. Based on all headway distribution, it is found that patterns of the vehicle headways at four study locations were similar, which shown a significant number of the vehicles travel at headways less than 5 seconds. Furthermore, it can be concluded that many drivers tend to follow the vehicles ahead closely on multilane highways. The regression models were significantly reliable based on their R-square values which are ranging between 0.80 and 0.95. From the analysis, cars were found to maintain larger headways when following heavy goods vehicles compare to when following other cars.

Keywords: Car following; driver behaviour; headway

1.0 INTRODUCTION

A multilane highway can be described as a highway with a total of four or six lanes, counting both directions, and not completely access controlled which consists of at-grade intersections and occasional traffic signals [1]. Multilane highways are usually constructed along high-volume suburban and rural corridors which connect two cities for important activities generating a significant number of daily trips. Those kind of trips generate vehicles following behavior which vary due to many factors. Thus, driver's car following behaviour was studied and modelled by numerous researchers over the past decades and mostly focused on two-lane highway [2-7]. These studies and developed models were varied in objectives and ranged from empirical approach to simulation modelling approach as well as complex mathematical analysis. The empirical studies basically concern the analysis of real data and car following behavior determined from such studies is referred to car following distance. Meanwhile, additional lane on the highways has been constructed in order to provide smooth traffic flow to the increasing vehicles. Therefore, the average speed of vehicles may as well increase due to smooth flow. This phenomenon has been experienced along Batu Pahat to Ayer Hitam road which was upgraded to four-lane highway since 2005. The objectives of this study were to determine car headway along Batu Pahat-Ayer Hitam multilane highway and to develop linear regression models to present the relationships between headway and speed. In this study, car following headways were analysed based on the time of headway and operating speed along this multilane highway. This study focuses on the traffic flow characteristics such as volume, speed and headway. This study covers car headway using the data extracted from the image processing technique at free flow speed during peak hour.

2.0 RELATED WORKS

Many studies have demonstrate that car following distance depend on a wide range of factors such as driver behaviour, road geometry features, traffic condition, and personality. Moreover, a lot of car following models were developed to define the interaction between adjacent vehicles in the same lane, and even the whole traffic dynamics. Several studies provide detailed descriptions applications of headway and speed relationships in the analysis of road capacity and in road traffic safety studies [2-9].

The speeds and headways data of vehicles which were mixture of restrained and unrestrained vehicles are collected during this study. Only the headway data for the restrained or impeded vehicles were considered in this analysis. Hunt stated that no specific method of distinguishing the following vehicle has entered the zone of influence, or the follower was impeded by its leader in a traffic stream [9]. However, the Highway Capacity Manual 1994 suggests that the vehicle which is impeded by its leader within headway of 5 seconds or less [10]. While all vehicle headway was collected, only the vehicles having headway of less than 5 seconds were used in the analysis.

Vehicle longitudinal controls (or speed controls), in general, could be categorized into two regimes: free-flow and car-following. Free flow means that a driver's behaviour of speed control is voluntary and unaffected by upstream or downstream driving conditions [1]. It can be applied in reality, where there is little interaction between vehicles (such as there are no other vehicles involved or there are other vehicles but far away from the driver's vehicle). Free-flow driving is critical in the capacity analysis procedures for basic freeway segments and multilane highways described in the Highway Capacity Manual [1].

In general, the relationships between headway and speed are in a form of regression model as shown in Equation 1 [2].

$$H = A_0 + A_1V \qquad (1)$$

where,

H = distance headway (m),
V = speed of vehicle (m/s),
A_0 = vehicle length (meter)
A_1 = driver reaction time (s)

Halden carried out a Scottish REVS model for traffic on single carriageway section [8]. The model assumes that vehicle following distance does not vary with the speed, and that all vehicles have the same length. Vehicle following distance relationship is written as Equation 2.

$$H = L + 10 \qquad (2)$$

where,

H = headway measured from rear to rear (m)
L = vehicle length (m)

The vehicle length which is taken as 4 meter for a car (the length of a Heavy Goods Vehicle, HGV was not mentioned). In Equation 2, speeds are assumed all equal. This equation does not interpret actual driver behaviour. Hunt conduct a study of driver following behaviour for Great Britain's single carriageway roads in 1997 [9]. Hunt derived four types of car following headway relationships in the form of Equation 3 through 6:

Car following car, $H_{CC} = 2.124V - 4.31$ (3)
Car following HGV, $H_{CH} = 2.052V + 1.156$ (4)
HGV following HGV, $H_{HH} = 2.79V - 3.997$ (5)
HGV following car, $H_{HC} = 2.854V - 8.15$ (6)

where,

H = distance measured from front to front (m)
V = speed (m/s)

Hunt has advantages of indicate vehicle separation at zero speed which the use of a mean spacing of vehicle length plus 10 metres buffer for speed below 30 km/h [9].

3.0 METHODOLOGY

3.1 Data Collection

Raw data were obtained using video recording method followed with extraction by TRAIS software. The raw data were then screened for different type of driver's car following headway. As mention in Introduction, this study was carried out at four selected segments along Batu Pahat – Ayer Hitam Multilane Highway. The selection was based on the availability of pedestrian bridge to obtain a clear high vantage point for videotaping purposes. The study locations are as follow:

i. Site 1: In front of SMK Tun Aminah (KM-12)
ii. Site 2: In front of SMK Sri Gading (KM-18)
iii. Site 3: In front of SJK(C) Kong Nan (KM-22)
iv. Site 4: In front of SK Seri Sabak Uni (KM-24)

The analytical data that necessary for this study were described as follow:

i. Headway - Measure of the temporal space between consecutive vehicles. It is also defined as the elapsed time between the front of lead vehicle and the front of the following vehicle passing a same point on the roadway.
ii. Speed - The rate of motion of a vehicle, as distance per unit time, in kilometre per hour (km/h).
iii. Vehicle type - Vehicles were classified into two major types:
   a. Car (a vehicle having not more than two axles or having a total of not more than four wheels).
   b. Heavy Goods Vehicle, HGV (a vehicle having more than two axles or having more than two wheels on the rear axle). Busses were classified as an HGV.

However, motorcycles were not considered in the analysis due to their random movements on road and hardly no headway measurement can be made.

Field data collections were carried out at selected locations using video camera, fabricated tripod, walking measure and safety vest. Video cameras were used to visually record the traffic flow of every directions. Two video cameras were needed to record the traffic flow simultaneously at both directions of traffic flow. The cameras were placed on the pedestrian bridge and held by tripod at 90 degrees angle to the road surface. Figure 1 shows the layout of cameras placement on the pedestrian bridge.

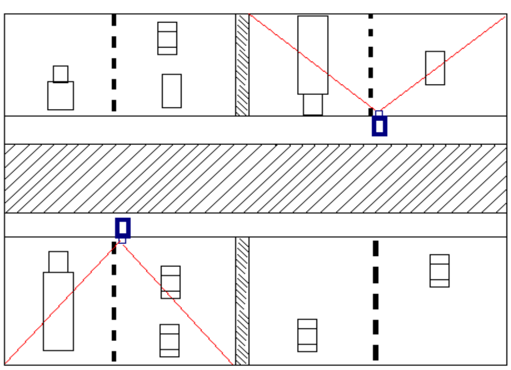

Figure 1 Layout of cameras placement on pedestrian bridge

Fabricated tripods were used to position the view of video perpendicularly to road surface to avoid angle error. Safety vest was used for safety purpose when working within close proximity to the cars such as lane width measurement. Walking measure was used to measure lane width and other geometry data.

Field data collection was carried out during peak hours in order to obtain headway data at restrained condition. Restrained condition means that the following drivers are impeded by the lead vehicle. This condition is preferable since the headway values will reflect the exact behaviour of drivers while following lead vehicle. Due to limitation of video required for the image processing technique, study period takes into consideration of clear weather since good lighting was essentially needed to ensure good extraction of data.

3.2 Data Extraction

Videos obtained from field data collection were then incorporated in the TRAIS software to extract data such as volume, vehicle classification, headway and speed. TRAIS software applies the intelligent image processing technique for data extraction. The image processing analysis was carried out for every lane at a study location in order to obtain entire headway data. Image processing was so far the best method to analyse headway at multilane highway. If pneumatic tube detector is used at multilane highway, the obtained data may be questionable due to its disability to differentiate the successive movements of two vehicles at one direction which should be considered only at one lane. Figure 2 shows how TRAIS software extracts data from captured video.

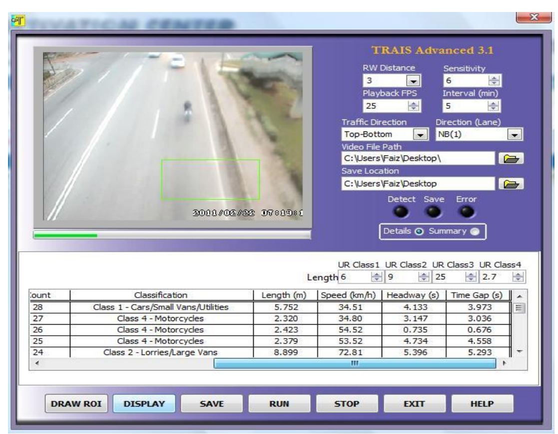

Figure 2 Image processing analysis by using TRAIS software

The output of data extraction consists of several raw data namely vehicle classification, speed, time headway and gap. In order to analyse driver's car following behaviour, raw data need to be filtered to types of vehicles time headway consist of car following car, car following HGV, HGV following HGV and HGV following car. However, time headway data were converted into distance headway by using equation (7).

$$\text{Distance Headway} = \text{Time Headway} \times \text{Speed} \quad (7)$$

Each type of vehicles headway were also screened to obtain sensible data for further analysis. Boxplot technique was used for data screening or reduction. Individual data were screened using boxplot to identify any outliers or data which has large different in value from the majority of the data. Screening was needed to obtain best linear regression without any influence from outliers.

4.0 RESULTS AND DISCUSSIONS

4.1 Speed Distribution

Speed distribution was analyzed to observe the relationship between frequencies and class speed. The distribution of speeds in all impeded vehicle on multilane highway was plotted in Figure 3.

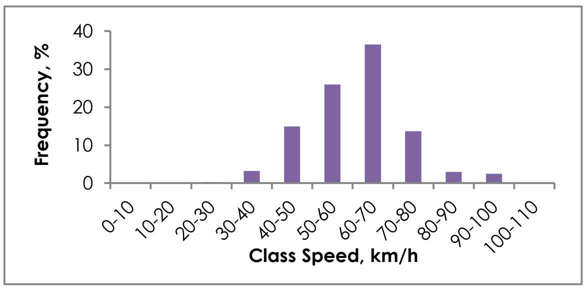

Figure 3 Distribution of speed for all vehicles on multilane highway

Based on previous study, as expected, most impeded vehicle were travelled at relatively low speed. Speed classes were determined to find reasonable sample frequencies for each class followed by type of vehicle. Distance headway data were used to the frequencies in each class for each vehicle following types. Figure 4 shows the percentage of frequency according to classes of time headway in second, for all type of vehicles.

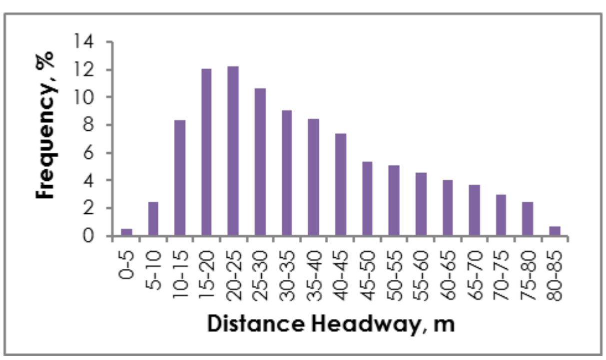

Figure 4 Distance headway for all type of vehicles

Referring to Figure 4, the distance headway data for impeded all type of vehicle is 7266 vehicles. Based on data extracted by TRAIS software, 13 percent of the distance headway data was in 0 to 5-second headway. These data were used in regression analysis. Figure 5(a) to (d) shows the frequency of vehicles with respect to time headway for car following car, car following HGV, HGV following HGV and HGV following car, respectively.

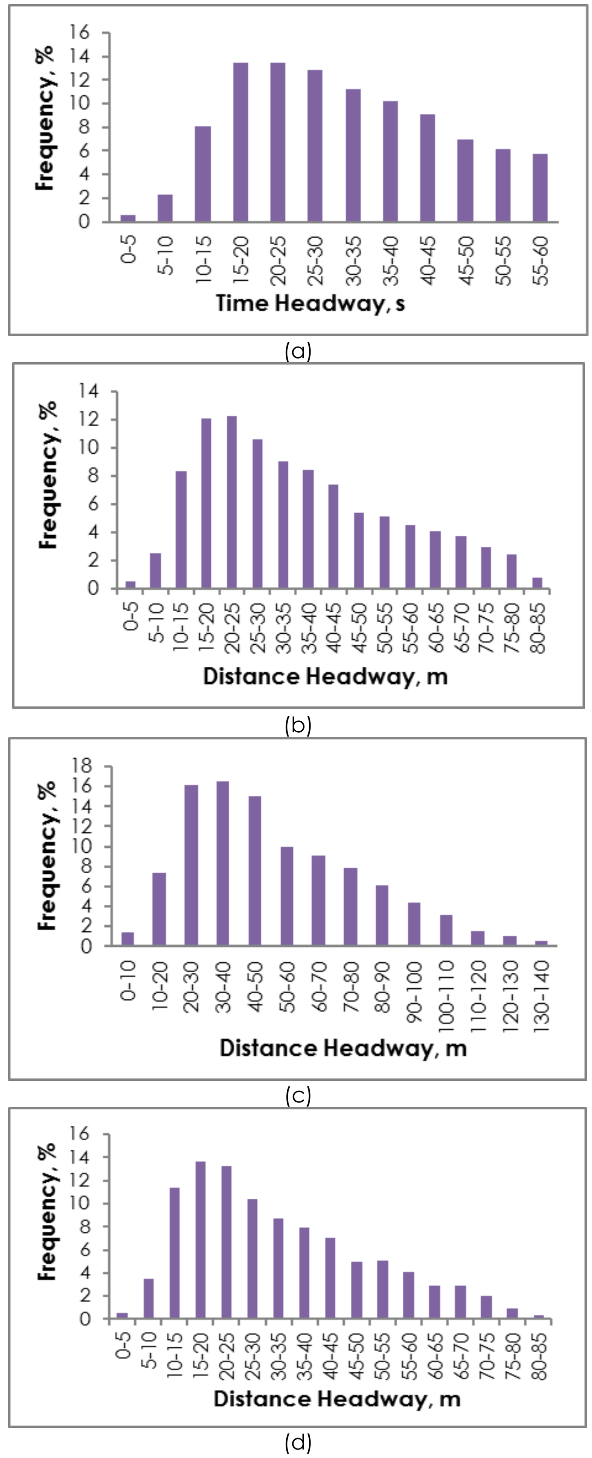

Figure 5 Distance headway for (a) car following car; (b) car following HGV; (c) HGV following HGV; (d) HGV following car

Referring to Figure 5, the distance headway data for Car following Car is 5827 vehicle, Car following HGV is 5975 vehicles, HGV following HGV is 1433 vehicles and HGV following Car is 2340. As expected, many drivers choose to follow the vehicles ahead at very short headways where they would not be able to avoid a collision.

4.2 Car Following Models

Tables 1 through 4 provide summary of the regression analysis for all vehicles following category by vehicle types at Site 1, 2, 3 and 4, respectively. The outputs from regression analysis were compared to Equation 1 where the constant and coefficient of speed values were equal to average vehicle length (A_0) and driver reaction time (A_1), respectively. Result for each type of following vehicles shows that as the driver reaction time increases, other variables, such as speed of vehicle and headway increase. Clearly, average driver reaction in this study is in a range of 1 and 2 seconds. Based on the regression results indicated that there was a significant difference in the vehicle-following behavior of HGV compared to that of car. Car following HGV headways were found to be longer than HGV following car headways. Therefore, it concluded that the presence of a HGV in a leading position in the traffic stream had a significant negative effect on the headways kept by trailing vehicles (resulted in longer headways by trailing drivers). A strong relationship between vehicle headway and vehicle speed was identified (r^2 = 0.80-0.99). It was found that the speed is largely related to headway in the regression models.

Table 1 Regression results for each type of following vehicles at Site 1

Following Type	Sample Size	Headway = $A_0 + A_1V$		
		A_0	A_1	R^2
All Vehicle	7266	1.74	2.03	0.98
Car-Car	5827	1.84	1.93	0.99
Car-HGV	5975	1.43	2.12	0.96
HGV-HGV	1433	6.96	2.94	0.86
HGV-Car	2338	2.14	0.40	0.94

Table 2 Regression results for each type of following vehicles at Site 2

Following Type	Sample Size	Headway = $A_0 + A_1V$		
		A_0	A_1	R^2
All Vehicle	13764	2.76	2.13	0.87
Car-Car	11432	7.19	1.30	0.80
Car-HGV	11432	3.89	1.63	0.99
HGV-HGV	2333	4.81	1.89	0.97
HGV-Car	13766	0.80	2.13	0.80

Table 3 Regression results for each type of following vehicles at Site 3

Following Type	Sample Size	Headway = $A_0 + A_1V$		
		A_0	A_1	R^2
All Vehicle	7297	10.53	1.68	0.89
Car-Car	5596	1.56	2.05	0.85
Car-HGV	1704	4.80	1.99	0.93
HGV-HGV	7297	3.70	2.27	0.91
HGV-Car	10408	13.7	2.30	0.83

Table 4 Regression results for each type of following vehicles at Site 4

Following Type	Sample Size	Headway = $A_0 + A_1V$		
		A_0	A_1	R^2
All Vehicle	2376	2.81	2.06	0.95
Car-Car	311	0.54	2.11	0.90
Car-HGV	2066	1.18	2.23	0.98
HGV-HGV	425	3.45	1.94	0.90
HGV-Car	735	2.46	1.97	0.89

4.3 Comparison between others Car Following Models

The model of car following derived from this study were compared with other developed models in the previous studies. Figure 6 shows the plots of following distance for all vehicle together with those developed by Othman Che Puan [11], Hunt [8] and from this study. The model on this study obtained similarity from those in term of characteristic. This study models is also indicate that most drivers have a relatively shorter reaction time than what is expected. A short reaction time is one of the characteristics of aggressive drivers. These explain that most Malaysian drivers adopt a close following behaviour.

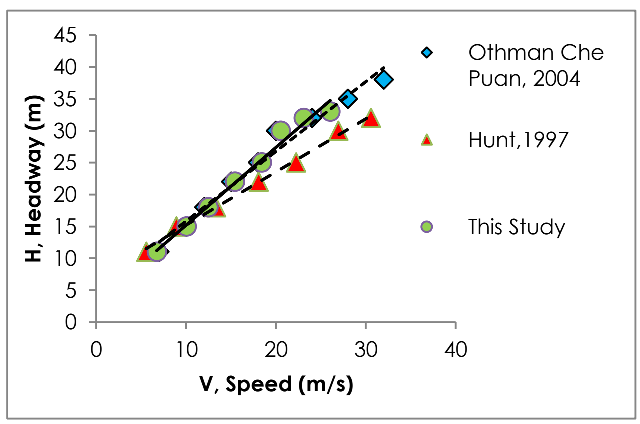

Figure 6 Comparison following distance (all vehicles)

The above plots are consistence with the typical characteristics of traffic flow on Malaysian roads where vehicle are observed to travel in platoons. This behaviour would lead to a multiple rear end collision when the follower failed to adjust their distance and speed with sudden braking by leading vehicle.

5.0 CONCLUSION

Based on all headway distribution patterns discussed, it is found that patterns for the vehicle headways of four observation sites are most similar, which is shown a significant number of the vehicles travel at headways less than 5 seconds and consistent interpretations comparison of following distance. In general, passing restrictions on multilane highways largely affect headway distribution and contribute to formation of platoons. So, this study is proved in the high concentration of 5-second headway. In additions, this study adopts time headway of equal to or less than 5 seconds for regression analysis. Vehicles with very short headways have very little time to react when the corresponding lead vehicles slow down rapidly, thus they have a higher chance of being involved in a rear-end collision.

Results from all of the regression models are greater than 80 percent confidence levels. The regression models that are considered statistically significant with R-square values ranging between 0.80 and 0.95. Speed has the most significant contribution to the headway value. The type of lead vehicle does influence headway with drivers following to HGV and cars at the same speed. From the analysis, cars are found to maintain larger headways when following HGV compare to when following other cars.

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