



AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com



## Heavy Vehicles-Cars Interaction Behavior For Urban Expressways

Hashim, W., Arshad, A.K., Mustafa, M., Kamaluddin, N.A.

Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam MALAYSIA

### ARTICLE INFO

**Article history:**

Received 25 January 2014

Received in revised form 12

March 2014

Accepted 14 April 2014

Available online 25 April 2014

**Keywords:**

heavy vehicles, speed, time headway, car-following behavior

### ABSTRACT

There are various types of vehicle being the user of expressways, which are designed to facilitate the flow of traffic. Cars and HVs are among the main users of expressway. Different types of vehicles result to various impacts thus creating problems in expressway operations and safety particularly those with a high proportion of heavy vehicles (HV). A certain understanding level of traffic behavior is important due to the growing presence of the heavy vehicles affecting other road users especially passenger cars which contribute to the largest vehicle group on the expressway. This study attempts to statistically justify the interaction of heavy vehicles and cars on typical urban expressways in Malaysia. Extensive data was collected through video recording method before being abstracted and processed by utilizing the TRAIS software. TRAIS applied the concept of creating a virtual line acting as the distance measurement to produce speed and time headway data. Then, statistical analysis showing comparisons between heavy vehicles and cars interactions are presented. The results showed a significant difference in the following behavior of HVs compared to cars in terms of speed and time headway. It was found that cars travel further behind HV, in time, than when following other cars. Similarly, compared to the car-following car situation, HV adopt longer time when following other HVs than following cars. This could bring into conclusion that the presence of heavy vehicles would increase the headway in the traffic stream, thus reducing the capacity of the lane and the total throughput of the freeway section. Furthermore, the results also proved that the relationship between speed and time headway is significant enough to describe the interaction between heavy vehicles and cars on expressways. With the existence of HVs, the time headway increase and the speed decrease.

© 2014 AENSI Publisher All rights reserved.

**ToCite ThisArticle:** Hashim, W., Arshad, A.K., Mustafa, M., Kamaluddin, N.A., Heavy Vehicles-Cars Interaction Behavior For Urban Expressways. *Aust. J. Basic & Appl. Sci.*, 8(5): 484-491, 2014

## INTRODUCTION

By simple definition, heavy vehicle (HV) is known to be a commercial vehicle used for transporting goods and materials (Huang, *et al.* 2005). The authority in Australia has a deeper definition of HV which is known as motor vehicle or trailer of gross vehicle weight (GVW) more than 4.5tonnes (Commonwealth of Australia, 2009). While in Malaysia, no exact definition of HGV have been learned so far yet the authority seems to rely on the term of commercial vehicle and goods vehicle (Road Transport Act, 1987).

With more demands due to the development progress, freight transport seems to grow rapidly around the world. The urban areas seem to contribute to the large portion of freight movements. Wright (2006) reported that the freight task is predicted to increase by 50% between 2006 and 2020 in the capital cities of Australia. Malaysia is no exception as the it is reported that the total volume handled at Port Klang will rise 7.7% to 197.70mil tonnes in 2012, while volume at the Port of Tanjung Pelepas will rise by 8.2% to 130.09mil tonnes. The scenario lead to high frequencies of heavy vehicles (HV) on the road, influencing on the traffic flow. As HV is characterized by the loading, speed, movement behavior, and dimension, they could affect the traffic flow characteristic and become a main rival to cars in getting the service of limited road spaces in urban area.

Expressways in urban areas of Malaysia consists of a minimum 2 lanes each way to serve the increasing traffic demand. It is reported that 535,113 new passenger cars were registered in Malaysia by the end of 2011 (Malaysia Association of Malay Car Importers and Sellers, 2011). Road Transportation Department (2012) reports on the total registered commercial vehicles of 997,649 at the end of 2011. The increase of HV will have a significant impact on the expressway capacity and performance.

**Corresponding Author:** Wardati Hashim, Faculty of Civil Engineering University of Technology MARA, Malaysia  
E-mail: wardatihashim@gmail.com

A certain understanding level of traffic behavior is important due to the growing presence of the HV affecting other road users especially passenger cars which contribute to the largest vehicle group on the expressway. HV car-following behavior relies quite much on the interpretation of headway study. Time and space headway between two successive vehicles give a general justification to interpret the following behavior in having HV on the road. HV drivers were reported to be more robust in handling their machine as compared to cars' drivers (Ossen and Hoogendoorn, 2009). Therefore, space gap in front of their vehicles cannot then be sure to be maintained. In situations where the maneuverability of a driver is influenced by the vehicles ahead of him, the driver needs to adjust speed and position to keep a safe following distance at all times.

Speed is one of the traffic parameter to influence the car-following pattern involving HV. In Malaysia, regulation has been enforced for HV to drive at the maximum speed of 90km/hr while as for the car, at maximum of 110km/hr on the expressway. However, 90km/hr speed could be achieved by un-laden compared to laden HV due to heavier loads. Though expressway in Malaysia provide the minimum of 2-lanes per way which allow for cars to maneuver and change lane at the presence of HV, the situation is comfort enough during low traffic condition.

The interactions between cars and heavy vehicles in terms of following behavior will give a significant contribution in understanding the fundamental microscopic study of traffic characteristic for microscopic study. Studies on significant interactions between vehicles are essential and would contribute to the capability of microscopic simulations for freeway sections under certain traffic flows (Toledo and David, 2007). There was also a study on discomfort level for car drivers in the vicinity of HV was introduced to explain more on the interaction between HV and cars (Peeta *et al*, 2005). Therefore, this study presents the statistical analysis on the field data set of HV-car-movement which is expected to give a better overview on the Malaysian urban expressway traffic condition.

#### **Approach:**

Vehicle following behavior involve the investigation various parameters. In this HV-car interaction study, three parameters were focused at which are as follows:

- Headway - Time or distance separation between the fronts of two successive vehicles passing a same point on a roadway.
- Speed - Rate of travel of an individual vehicle measured in km/h.
- Vehicle type - Vehicles are grouped into two major types, i.e. car (a vehicle having not more than two axles or having a total of not more than four wheels) and HV (a vehicle having more than two axles or more than two wheels on the rear axle).

#### **Field Data Collection:**

Field studies were carried out to collect and analyze all traffic data pertaining to the statistical analysis related to the HV-car-following interaction study. In general, the observation sites selected should be representative of urban expressways road layout and traffic would provide a high proportion of impeded vehicles. Therefore, the selection of location for data collection was based on the criteria as follows:

- (i) Road section provided with overhead or pedestrian bridge.
- (ii) Road section with distance of ramp is minimum at 1km.
- (iii) Road of high traffic volume
- (iv) Road with standard width and layout and representing a range of geometric design in term of alignments.
- (v) Good access and safety for the enumerators and equipment during the data collection process and good overhead vantage points for video recording purposes.

This study used the video recording method and utilized the TRAIS software which required the video image angle to be as closed to  $90^0$  from top. Video recording is one of the best method in evaluating traffic movement as the video image could be played repeatedly for the purpose of analysis. Othman (1999) explained on the advantages of using video camera recording method. One particular difficulty with the method is in finding a suitable vantage point with good visibility to acquire the data.

Urban expressway data collection is considered hazardous due to high speed allowance to vehicles. The authority did not allow the data collection process to be in the expressway area. As due to that, location with overhead bridges of local road crossing the expressway or pedestrian bridge was chosen and a custom-designed tripod was fabricated to allow the  $90^0$  angle of video image recorded, as shown in Fig. 1.

As for this study, data collection was conducted at Federal Highway and ELITE Expressway, mainly focused at the free-flow-speed regime. However, for a systematic evaluation of traffic parameters under range of traffic flows, the data was recorded at 8.00-10.00am, 11.00am-1.00pm and 3.00-5.00pm. For a typical urban expressway in Malaysia especially in Klang Valley, HVs are allowed onto road beginning at 9.00am to avoid impact on the traffic congestion. Both survey locations are 6-lanes expressways with typical lane width of 3.5m and only one stream observation was considered.

**Data Abstraction and Processing:**

As mentioned earlier, TRAIS video based data analyzer was used to abstract video image and process the data acquired from the video recording. TRAIS is a software which provide an automated virtual line in the video image that is in accordance with real world line marked on the road. The virtual line represents the distance and act as the detection line which is vital to generate the parameters of vehicle length, speed, time headway and time gap.

As the video recording requires for the angle being as close to 90<sup>0</sup>, the detection line is in parallel to the viewers eye and reduce the parallax error. Having been tested and complied to the ASTM for the standard error, TRAIS has been recognized by the Highway Planning Unit (HPU) of Malaysia. Fig. 2 shows the TRAIS dashboard in the process of extracting the traffic parameter. The green line is the detection line.



**Fig. 1:** Specially fabricated tripod for CCD camera.



**Fig. 2:** TRAIS video based data analyzer dashboard

Vehicle length will allow for vehicle classification to be made and according to TRAIS, there are four classifications of vehicle as shown in Table 1.

**Table 1:** Vehicle classification according to TRAIS

Class	Classification
1	Cars/Small Vans/Utilities
2	Lorries/Large Van
3	Trucks/Buses
4	Motorcycles

All the data extracted is saved in the Excel spreadsheet and was filtered and sampled accordingly before being analyzed using Minitab 16.0. The parameters generated from TRAIS is mainly time-based. The headway is

measured as the time between successive vehicles in a traffic stream, as measured from front bumper to front bumper.

This headway measurement method includes the inter-vehicle distance and vehicle length. The speed of each vehicle was computed using the time taken to travel between the two consecutive detection lines and considered as spot speed due to short distance detection line.

## RESULT AND DISCUSSION

All of the parameters were evaluated for the individual vehicles. A preliminary data analysis was carried out using Excel to evaluate the validity of headway and the corresponding speed to identify unrestrained and impeded vehicles in the traffic stream and to evaluate the inconsistencies in the tabulations of the data.

### Data Overview:

A total of 55,129 vehicles were recorded and is a mixture of restrained and unrestrained vehicles. Class 4 type of vehicle has been eliminated from further analysis. A situation where the follower is impeded by its leader, or the following vehicle has entered the zone of influence is best to describe the following behavior. Therefore, the analysis will only consider the headway data for the impeded vehicles that require the headways data for the impeded following vehicles to be separated from the headways for the free flowing or unrestrained vehicles.

Hunt (1997) mentioned that there is no specific method to identify the impeded vehicle in a traffic stream. However, it is generally accepted that most impeded vehicles are at relatively very small time headways and will travel at a speed relatively similar to their corresponding leader. The Highway Capacity Manual (1994) suggests that the headway of 5 seconds or less represents a vehicle which is impeded by its leader. Othman (2004) practiced the same understanding for the rural carriageway headway study. Saifizulet *al*(2011) considered the assumption of headway less than 4s for the follower and the leader to have influence on each other. This study therefore considered the headway of 5s and less for further analysis.

Sampling and filtration have been made to analyze the impeded vehicle headways grouped according to the type of vehicles. Four vehicle interactions were produced which are car-following-car (C-C), car-following-HV (C-HV), HV-following-car (HV-car) and HV-following-HV (HV-HV). Due to sampling and filtration process including eliminating those inconsistent data, 170 samples were considered for each interaction. The histogram curve fit in Fig.3 shows that all samples are normally distributed.

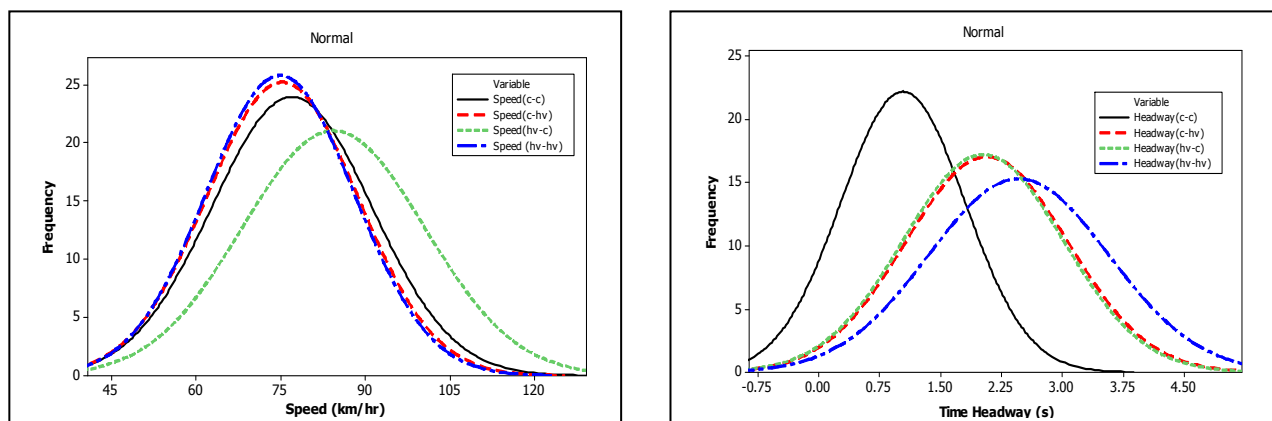


Fig. 3: Curve fit of histogram for speed and time headway.

### Data Analysis & Discussion:

As 170 samples of vehicle interaction in accordance to vehicle classification have been chosen for further statistical analysis, it is important for the skewness and kurtosis to be checked for the purpose of ascertaining the normality distribution. Skewness is a statistical number that indicates if the distribution is symmetric or not while kurtosis indicates a statistical number that tells us if a distribution is taller or shorter than a normal distribution.

Except for C-C interaction, other interactions show normal distribution among the data frequency for all parameters tested in which the skewness and kurtosis value is closed to zero as shown in Table 2. However, each normality is different in term of positive and negative skewness and kurtosis. While as for C-C, the results show that the data frequency is normally distributed for the speed and log-normal distributed for time headway and time gap.

**Table 2:** Skewness and kurtosis number for parameter tested.

Parameter	Speed		Time Headway	
	Skewness	Kurtosis	Skewness	Kurtosis
C-C	0.58	0.16	1.67	2.15
C-HV	0.23	-0.30	0.91	0.45
HV-C	-0.04	-0.95	0.83	-0.03
HV-HV	0.34	-0.61	0.55	0.78

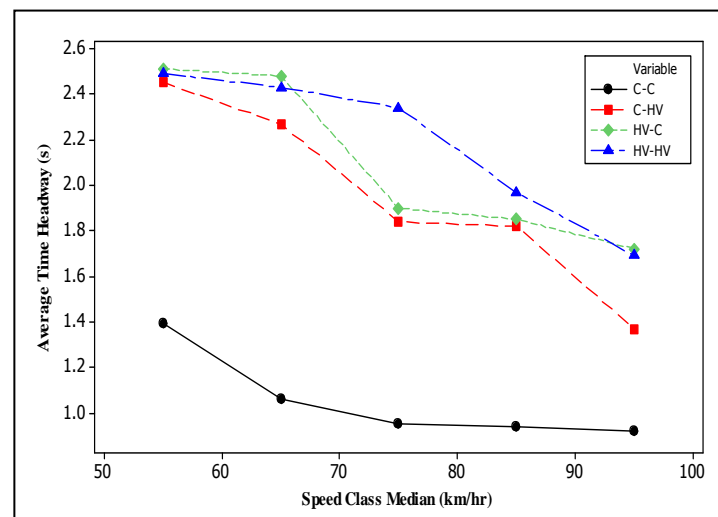
The fundamental traffic flow characteristics of speed, time headway and time gap are important to look at for their impact on the vehicle interaction on expressway. Various car-following studies indicated that the lane changing is primarily made based on the distance headways between the lead and following vehicles in the target lane. Headway is not only a good measure of degree of congestion, it is also a good measure of safety as close following and lane changing may lead to conflicts and likelihood of crashes.

On average, HVs adopt the lowest speed and highest time headway when following other HVs. It seems that HV will affect the speed and headway, similarly to when a car follows another HV and when a HV follows another car, as shown in Table 3. This is similar to the findings conducted at Interstate-80 Carolina (Khagbayak et al, 2011).

**Table 3:** Calculated average value of parameters for each vehicle interaction

	Speed (km/hr)	Time Headway (s)
C-C	81	1.08
C-HV	77	2.10
HV-C	79	2.02
HV-HV	75	2.50

It is also learned that as the speed increase, depending on the type of vehicle interaction, the time headway decrease as shown in Fig. 4. The relationship is made based on the majority of the speed classes that provide high number of impeded vehicles. Majid and Ejtemai (2011) acquired the same finding related to the interaction when conducting a study at freeways in Tokyo and Melbourne.

**Fig. 4:** Speed-time headway relationship based on real traffic.

#### Prediction of Time Headway and Speed Relationship:

Theoretically, the time headway will decrease with the increase of speed as shown in Fig. 4. It is found that as the speed increase, the time headway generally decrease but of the difference distribution between vehicle interactions. As the data acquired is normally distributed, correlation test was conducted to evaluate the actual association between speed and time headway of HV-cars interaction on expressways. Two hypothesis were formed which are as follows:

$H_0$  = there is no correlation between speed and time headway

$H_1$  = there is correlation between speed and time headway.

**Table 4:** Correlation test between time headway and speed

	Speed-Headway <sub>C-C</sub>	Speed-Headway <sub>C-HV</sub>	Speed-Headway <sub>HV-C</sub>	Speed-Headway <sub>HV-HV</sub>
Pearson correlation, r	-0.01	-0.186	-0.26	-0.144
Significance(p-value)	0.896	0.015	0.001	0.024

Table 4 shows the correlation test result with significance ( $p < 0.05$ ) meant for the null hypothesis  $H_0$  to be rejected. The results show that speed and time headway is negatively correlated to each other for every vehicle interaction, which conclude to the earlier theory that as the speed increase, the time headway decrease. However, the results state that the correlation is only significant for vehicle interactions C-HV, HV-C and HV-HV, but not for C-C with the  $p = 0.896 > 0.05$  and therefore the null hypothesis cannot be rejected for C-C.

Regression analysis was then conducted to see a further relationship between the time headway and speed. This study derived a median (and hence taken as mean) following time headway relationship. The median headway in each speed class was used in view that the arithmetic mean would lead to a biased interpretation of log-normally distributed data. This approach is similar to the approach adopted by Daou (1966).

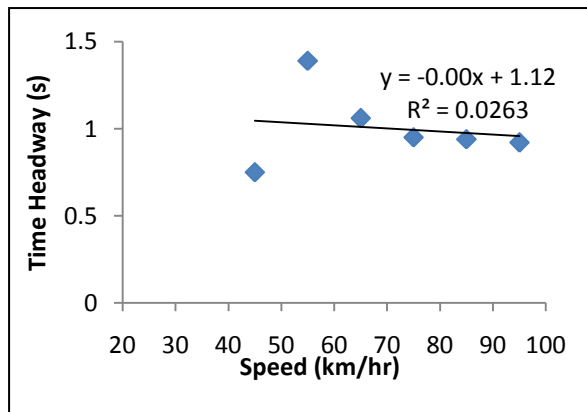


Fig. 5(a): Car following car (C-C).

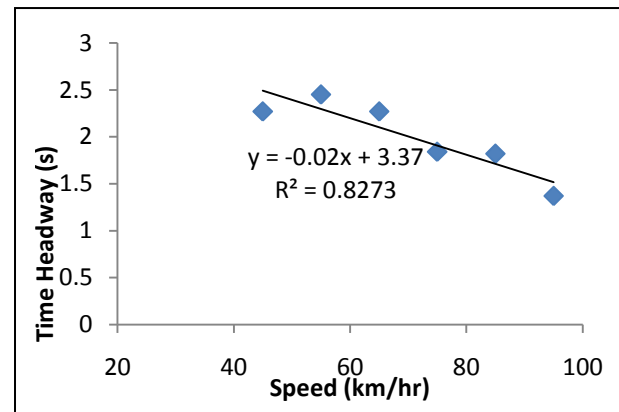


Fig. 5(b): Car following HV (C-HV).

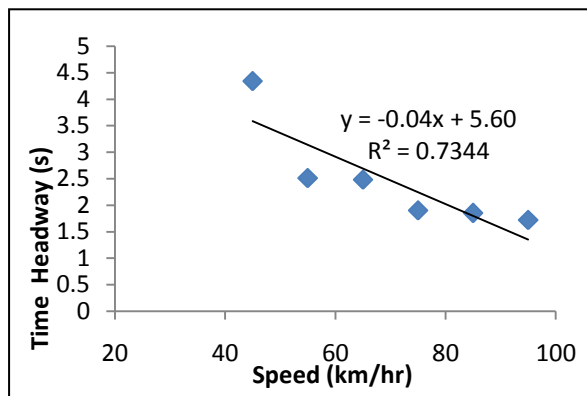


Fig. 5(c): HV following car (HV-C).

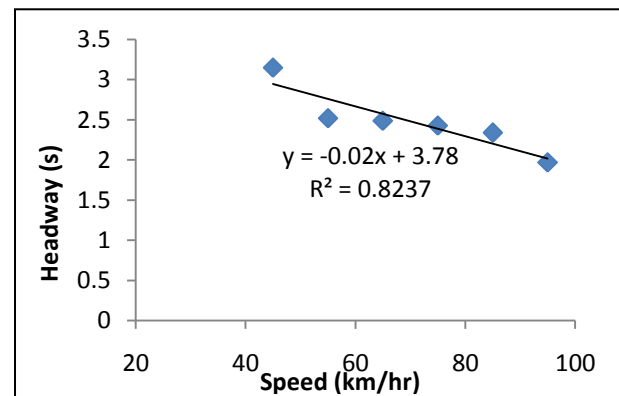


Fig. 5(d): HV following HV (HV-HV).

Fig. 5: Time headway and speed regression analysis for various vehicle interactions.

The regression analysis shown in Fig.5 conclude the correlation test conducted earlier which indicate that time headway is related to the speed linearly. The equations with negative sign (-ve) implies that drivers will keep a shorter following headway in term of time as they increase the speed. This is in contrast with the study conducted by Othman [15] which indicated that a driver would keep a longer following distance with the leader as the speed increases. However, the study focused on single rural carriageway in which drivers have not much option than following.

Among the four vehicle interactions, C-C, as shown in Figure 5(a) seems not to give any association between the time headway and speed as compared to the situation when the HV exist. With the HV being the leader, the speed and time headway of cars or other HVs are related strongly. Furthermore, the analysis also shows that the time headway increase with the existence of HVs on the expressways. This result indicates that with HVs being on the expressways, the speed of the other following vehicle tend to be influenced, thus affecting the time headway entirely. Higher time headway will reduce the lane capacity and the total throughput of the expressway.

**Conclusion:**

The effects of HV on the capacity and overall performance of Malaysian expressway under free-flow-speed regime has been explored in this study. Comprehensive microscopic data at two sites were collected, provided a sound database for performing traffic characteristics analysis of HV in terms of the interaction between HV and other class of vehicles. Through image processing technique by utilizing the traffic video analyzer software called TRAIS, the following behavior of 170 samples comprising of vehicles following other vehicles according to classification were analyzed to provide an understanding of HV-car-following behavior process.

Results showed a significant difference in the following behavior of HVs compared to other vehicles. It was evident that in the presence of HVs, drivers keep a smaller speed compared to no-HV following behavior. The free-flow-speed is also not achievable in the presence of HVs considering the typical speed limit of Malaysian expressway is 80km/hr.

From the result, it was found that cars travel further behind HV, in time, than when following other cars. Similarly, compared to the car-following car situation, HV adopt longer time when following other HVs than following cars. This could bring into conclusion that the presence of heavy vehicles would increase the headway in the traffic stream, thus reducing the capacity of the lane and the total throughput of the freeway section. Time headways have also shown to be shorter at higher speeds for all observed classes of vehicles.

Furthermore, there is a significance correlation between the time headway and speed and both parameters are related linearly in the presence of HVs. In the condition of cars following other cars, the speed and time headway seems not to associate quite much. This might come to a conclusion that a car's driver on expressway maintain their distance with the leader not in accordance with the leader's speed. When cars following other cars, the ability to speed is about the same, thus making no influence on each other's time headway.

**ACKNOWLEDGEMENT**

The authors would like to acknowledge Ministry of Education Malaysia (MOE) and Research Management Institute (RMI), UiTM for the funding and financial supports of Fundamental Research Grant Scheme (FRGS); Ref: 600-RMI/FRGS 5/3(58/2012). Special thanks to the management of Faculty of Civil Engineering, UiTM for the constant support.

**REFERENCES**

- Aghabayk, K., W. Young, S. Majid and Y. Wang, 2011. Examining vehicle interaction during a vehicle-following manoeuvre. *Australasian Transport Research Forum Proceedings*.
- Commonwealth of Australia, 2009. *Road Transport Reform (Heavy Vehicles Registration) Act 1997; Section 2*. Attorneys General Department. Canberra.
- Daou, A., 1966. On flow within platoons. *Australian Road Research*, 2(7): 4-13.
- Huang, W., Li Xu-hong, Ju Peng, He Jie, 2005. Site survey and analysis of highway trucks overloading status quo in Anhui. *Journal of Eastern Asia Society for Transportation Studies*.
- Hunt, J.G., 1997. *Level of Service On Single Carriageway Roads – A Study Of Following Headways*, Report to TRL Scotland, Cardiff School of Engineering, Cardiff University of Wales. unpublished.
- Malaysia Association of Malay Car Importers and Sellers, 2011. [www.pekema.org.my](http://www.pekema.org.my). (accessed 26th May 2013).
- Majid, S. and O. Ejtemai, 2011. Exploring heavy-vehicles car following behavior. *Australasian Transport Research Forum Proceedings*.
- Othman, C.P., 1999. *A Simulation Study Of Speed And Capacity Of Rural Single Carriageway Roads*. PhD Thesis, University of Wales Cardiff, Wales, U.K., 1999, unpublished.
- Othman, C.P., 2004. Driver's car following headway on single carriageway roads. *Jurnal Kejuruteraan Awam*, 16(2): 15-27.
- Ossen, S. and S.P. Hoogendoorn, 2009. *Heterogeneity In Car-Following Behavior: Theory And Empirics*. Transportation and Traffic Theory.
- Peeta, S., P. Zhang, W. Zhou, 2005. Behaviour-based analysis of freeway car-truck interactions and related mitigation strategies, *Transportation Research Part B* 39: 417-45.
- Road Transport Act, 1987 (2006). Government of Malaysia.
- Saifizul, A.A., H. Yamanaka and M.R. Karim, 2011. Empirical analysis of gross vehicle weight and free flow speed and consideration on its relation with differential speed limit. *Proceedings of The Eastern Asia Society for Transportation Studies*, 8.
- Toledo, T. and Z. David, 2007. *Modeling the duration of lane changes*. Transportation Research Board 86th Annual Meeting.
- Transportation Research Board, 1994. *Highway Capacity Manual*, Special Report 209. 3rd Edn. Transportation Research Board, National Research Council, Washington D.C.
- Wright, S.J., 2006. *Review of urban congestion trends, impacts and solution*. Traffic Management Systems for Australian Urban Freeways, Prepared by ARRB Consulting for Council of Australian Governments: Canberra.