Australasian Transport Research Forum 2011 Proceedings
28-30 September 2011, Adelaide, Australia

Examining vehicle interactions during a vehicle-following manoeuvre

Kayvan Aghabayk[1], William Young[1], Majid Sarvi[1], Yibing Wang[1]

[1] Institute of Transport Studies, Department of Civil Engineering, Monash University, Australia

Kayvan.Aghabayk@monash.edu

Abstract

Heavy vehicles are significantly longer and heavier than passenger cars and consequently have quite different acceleration and braking capabilities. Heavy vehicle manoeuvres are therefore likely to influence drivers' vehicle-following behaviour differently to cars. Heavy vehicles can also influence the behaviour of drivers of other vehicles while following a heavy vehicle. This paper used data obtained from the Interstate-80 in California to show the impacts of the presence of heavy vehicles in a traffic stream on the vehicle-following behaviour of car and heavy vehicle drivers. Four vehicle-following combinations, based on the vehicle classes of the leader and subject vehicle, are considered in this study. These combinations are car-car, car-heavy vehicle, heavy vehicle-car and heavy vehicle-heavy vehicle.

The study analyses the space and time headways,, driver's reaction time and vehicle acceleration for the four vehicle-following combinations. The results highlight the different behaviour of the vehicles in the four combinations. In summary, the presence of heavy vehicles results in a larger headways, longer reaction time and smaller variation in acceleration variation during vehicle-following behaviour. Further research is required to determine the underlying reasons for these differences.

Keywords: Car following, Heavy vehicle, Vehicle interaction, vehicle following

1. Introduction

Heavy vehicles have different physical and operational characteristics than passenger cars . They are therefore likely to influence drivers' vehicle-following behaviour differently to that of cars. For instance, Huddart and Lafont (1990) and Sayer et al (2000) reported that passenger car drivers keep shorter space headway when following heavy vehicles than when following passenger cars. In contrast, McDonald et al (1997) and Yoo and Green (1999) concluded that the space headways in front of passenger cars are shorter when following another passenger car than a heavy vehicle. Peeta et al (2005) considered the interaction between cars and heavy vehicles by introducing a discomfort level for passenger car drivers in vicinity of heavy vehicles. These research studies point to the existence of heavy vehicles in the traffic stream having different impacts on the behaviour of the surrounding vehicles (Stuster 1999, Kostyniuk et al 2002) than that of passenger cars.

This influence is likely to increase as more heavy vehicles enter the traffic stream. The absolute number of heavy vehicles and their proportion in traffic flow has increased dramatically over the past decades (BTRE 2003 and Wright 2006). This trend is likely to continue. The road freight task in the Australian capital cities is expected to increase by 50% between 2006 and 2020 (Wright 2006). The Bureau of Transport and Regional Economics (BTRE 2003) has predicted a growth of 24.7% of the kilometres travelled by all vehicles in Australian metropolitan areas by 2020. The same study predicted that the kilometres travelled by heavy vehicles will increase by 74% between 2003 and 2020.

Notwithstanding, the influence of heavy vehicles on the traffic stream and the increasing number of heavy vehicles on roads, most car-following models of traffic flow do not specifically consider heavy vehicles and their interactions on other vehicles. The exceptions are Sarvi (2008) and Ossen and Hoogendoorn (2009). Sarvi (2008) examined three different vehicle-following types: car-following-car, truck-following-car and car-following-truck. It was found that the space and time headways between two successive vehicles are different for the three vehicle-following combinations. Ossen and Hoogendoorn (2009) reported that heavy vehicle drivers run their vehicles more robust than do passenger car drivers. This means they do not usually maintain the space gap in front of their vehicles when the gap changes are small. Ossen and Hoogendoorn (2009) also investigated the impacts of the presence of heavy vehicles on vehicle-following behaviour, using three vehicle-following combinations: car-following-car, truck-following-car and car-following-truck. The results confirmed the existence of the differences in vehicle-following behaviour among the combinations. These studies (Sarvi 2008, Ossen and Hoogendoorn 2009) attempted to explore heavy vehicle interactions in more detail but there is still a need for further research. The interaction between cars and heavy vehicles and its impacts on traffic flow characteristics requires more attention because of their direct impact on road capacity (Sarvi and Kuwahara 2007).

This paper uses a real world data set to explore the differences in drivers' vehicle-following behaviour not only in terms of headways but also reaction times and vehicle accelerations. To examine the interactions between heavy vehicles and the other vehicles, four combinations of vehicle-following were considered in this study:

- heavy vehicle following passenger car (H-C),
- passenger car following heavy vehicle (C-H),
- passenger car following another passenger car (C-C), and
- heavy vehicle following another heavy vehicle (H-H).

The next section (Section 2) describes the data set used in this study. Section 3 analyses time headways and space headways, driver reaction times and vehicle acceleration behaviour. The paper closes with some conclusions, remarks and directions for further research.

2. Data set

The Federal Highway Administration (FHWA) has provided a trajectory data sets for some of the freeways and arterial roads in California (FHWA 2005, 2006). This data was created by Cambridge Systematics Incorporated for the Federal Highway Administration (FHWA) as a part of the Next Generation Simulation (NGSIM) project. The data analysed in this paper was collected from a segment of the Interstate 80 in San Francisco (I-80), California on April 13 2005. Seven video cameras were mounted on the top of a 30 story building (Pacific Park Plaza), located adjacent to the freeway (I-80). The cameras covered about 503 meters of the northbound direction of the freeway. Figure 1 shows a sketch of this site, including the on-ramp at Powell Street and the downstream off-ramp at Ashby Avenue.

Trajectory data sets were derived at the resolution of 1 tenth of second from image processing of the digital video images for three time periods. The time periods include: 4:00-4:15pm (I1), 5:00-5:15pm (I2), and 5:15-5:30pm (I3) all on April 13 2005. Vehicles have been classified using the FHWA vehicle classification (FHWA 2010) into three different types in the NGSIM data sets: motorcycles, automobiles and heavy vehicles. Exhaustive data processing was conducted and detailed data sets of the vehicle class, size (length and width), two-dimension position, velocity, acceleration and deceleration for all vehicles were derived. Each vehicle also has information on the preceding and following vehicle as well as their lane identification.

The position, velocity and acceleration of the vehicles in the NGSIM data sets have some noise. Thiemann et al (2008) reported such variations for all NGSIM data sets. To overcome this variation, positions, velocities and accelerations were smoothed in each 0.5, 1 and 4 seconds, respectively, by applying a moving average method. Table 1 and Table 2 respectively summarise the number of vehicles observed and the traffic flow information at the site during the three observation periods. The approach presented in the highway capacity manual (HCM 2000) was used to determine the level of service (LOS) of the site. It was found that the LOS was "E". Level of service "E" means that the freeway is operating at capacity representing the minimum spacing between vehicles at which stable flow can be accommodated.

Figure 1: The study area, Interstate Freeway 80 (I-80), California

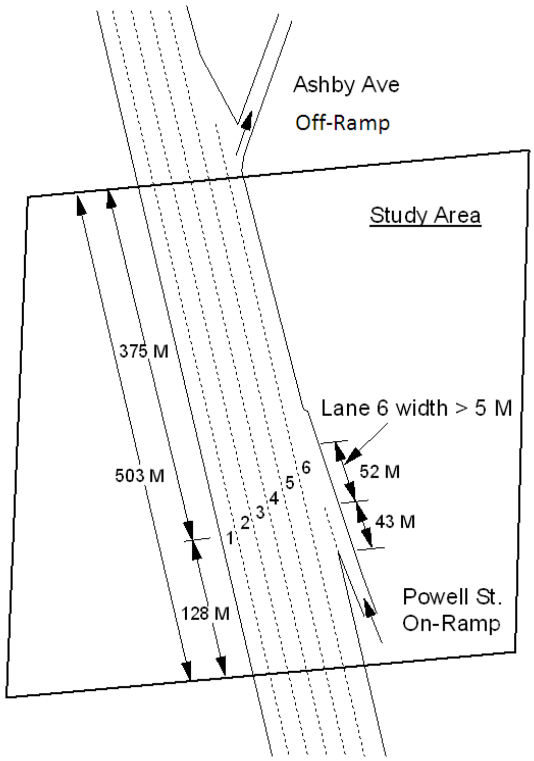


Table 1: Number of vehicles observed at the Interstate 80 site

	I1		I2		I3		Total	
Vehicle Type	**Num.**	**Percent.**	**Num.**	**Percent.**	**Num.**	**Percent.**	**Num.**	**Percent.**
Motorcycle	14	0.7 %	24	1.3 %	17	1.0 %	55	1.0 %
Passenger Car	1942	94.6 %	1742	94.9 %	1724	96.3 %	5408	95.2 %
Heavy Vehicle	96	4.7 %	70	3.8 %	49	2.7 %	215	3.8 %
Sum	2052	100 %	1836	100 %	1790	100 %	5678	100 %

Table 2: Traffic flow information

Traffic flow information	I1	I2	I3	Total
Flow (veh/hr)	8436	7968	8028	8144
Space mean speed (km/hr)	32.2	28.7	25.2	28.7
Density (veh/km)	262	278	319	283

Microsoft Visual Studio was used to identify vehicle-following combinations. Heavy vehicles were identified first. The leader of each heavy vehicle was identified next. If the leader was also a heavy vehicle this case was considered a "H-H" case. If the leader was a passenger car, this case was considered a "H-C" case. The leader of each passenger car was determined next. If the leader was a heavy vehicle, this case was considered a "C-H" case.

The other leaders of this passenger car were also determined. When they were also passenger cars, these cases were considered "C-C" cases. Table 3 presents the number of observations (frames in digital images) and the number of vehicle pairs for each vehicle-following combination. The identified cases for all combinations were considerable except the "H-H" case. This combination had only 36 heavy vehicles following another heavy vehicle.

Table 3: Number of vehicle pairs and observations for vehicle-following combinations

	I – 1		I - 2		I – 3		Total	
Case	**Obs.**	**Veh.**	**Obs.**	**Veh.**	**Obs.**	**Veh.**	**Obs.**	**Veh.**
HC	45255	90	50281	68	42011	46	137547	204
CH	47692	182	51418	129	46613	93	145723	404
CC	62465	153	56840	102	53322	72	172627	327
HH	8722	26	4808	7	2142	3	15672	36

3. Data analysis

To investigate different vehicle-following behaviour among the four combinations, data analyses of headways, reaction time and acceleration analyses were undertaken. They will be presented and discussed here.

3.1. Headway analysis

This section analyses the space and time headways between two successive vehicles to investigate drivers' vehicle-following behaviour on freeways. The four vehicle-following combinations explained in the previous section were considered for this purpose.

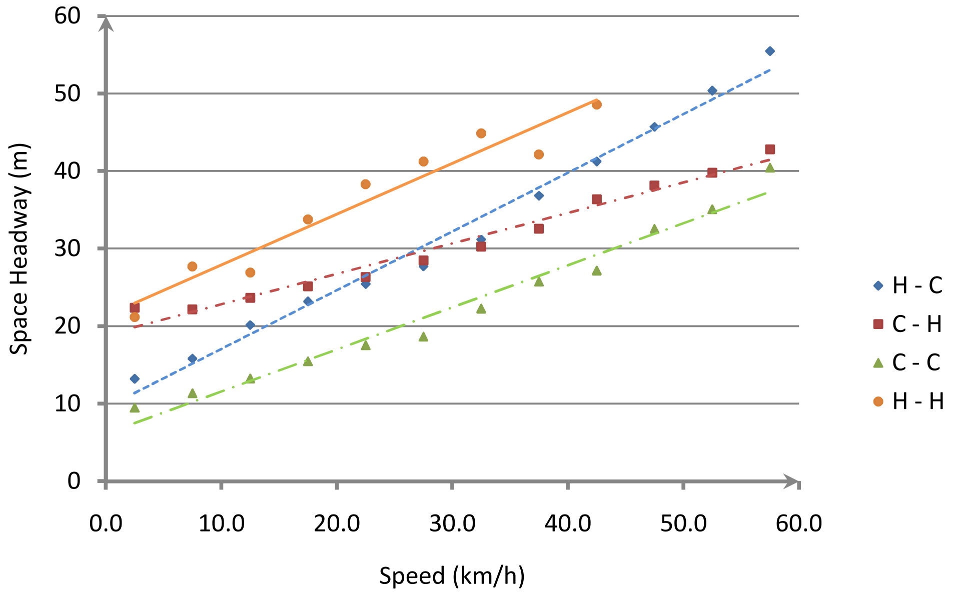
The space and time headways of two successive vehicles were extracted from the data set using a program written in the Microsoft Visual Studio. The headways were categorised based on the speeds of follower vehicles with 5 m/s intervals for each vehicle-following combination. Figure 2 shows the space headways of vehicles at the speed of 0 to 60 km/h. The middle point (median) of each speed interval is presented on the graph.

In the four combinations the space headway in the "H-H" case is largest and in the "C-C" case is smallest. Indeed, the distance kept by heavy vehicle drivers following another heavy vehicle is the largest among the other combinations and the distance kept by passenger car drivers following another passenger car is the smallest. It is also apparent the "C-H" and "H-C" cases are located between the other two cases. As long as the follower speed is less than 30 km/h the space headway in the "C-H" case in larger than the "H-C" case but when the speed exceeds from 30 km/h, the space headway in the "C-H" case will be smaller than the "H-C" case.

A two-sample test for two independent samples with unknown standard deviation was used to test the aforementioned hypotheses. The mean and standard deviation of each speed interval for each vehicle-following combination were determined. The aforementioned hypotheses were tested with 99% level of confidence for each corresponding speed interval of every two vehicle-following combinations. These two combinations are: "H-H" versus "H-C" (9 intervals), "H-H" versus "C-H" (9 intervals), "H-H" versus "C-C" (9 intervals), "H-C" versus "C-H" (12 intervals), "H-C" versus "C-C" (12 intervals), and "C-H" versus "C-C" (12 intervals).

In summary, all of the aforementioned hypotheses were supported statistically with 99% level of confidence except for 2 of the 63 speed intervals studied. The first one happened in H-H versus C-H case, when the speed of the following vehicle is less than 5 km/h and the space headway in the "C-H" case is larger than the "H-H" case. This case does not have a pronounced effect on the vehicle-following behaviour since it occurs when vehicles are about to start or stop moving. The second one happened in C-H versus C-C case in the last speed interval (55-60) although the space headway in the "C-H" case is still larger than the "C-C" case. The only issue is that the conclusion can be got with 98% level of confidence instead of 99% level of confidence.

Figure 2: Space headways



The time headways between two successive vehicles were also investigated in this study. Two studies (Sarvi, 2007 Ossen and Hoogendoorn, 2009); considered the impacts of heavy vehicle on the time headways in the vehicle-following process. The findings of these studies had some inconsistency. The current study investigated these previous study results by using the comprehensive data sets (NGSIM 2005, 2006) and statistical support. An additional combination, the "H-H", not included in these studies is also investigated.

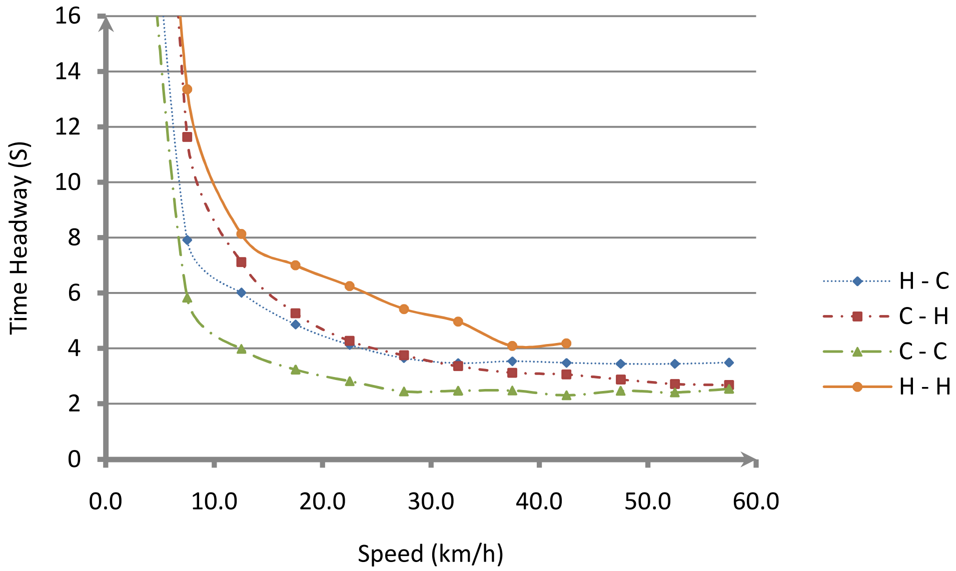
As explained above, both Ossen and Hoogendoorn (2009) and Sarvi (2008) found that heavy vehicle drivers keep longer time headway than passenger car drivers when following another vehicle. However, Ossen and Hoogendoorn (2009) found that the front time headways of passenger cars when following a heavy vehicle are smaller than the time following another car. Sarvi (2008) found the opposite.

Figure 3 shows that the time headway between two heavy vehicles is the longest and between two passenger cars is the shortest time headway among the four combinations in the NGSIM data set. When a heavy vehicle is following a passenger car (H-C), the time headway is longer than when a passenger car is following another passenger car (C-C). This finding has consistency with the findings of Ossen and Hoogendoorn (2009) and Sarvi (2008). The differences from the previous studies can be found in Figure 3. When a passenger car is following a heavy vehicle (C-H), the front time headway will be longer than when following another passenger car (C-C). This finding is different from the conclusion of Ossen and Hoogendoorn (2009). Figure 3 also shows that the time headway in "C-H" case is not always longer than "H-C" case as stated by Sarvi (2008). As long as the follower speed is less than 30 km/h the time headway in the "C-H" case in longer than the "H-C" case but when the speed exceeds from 30 km/h, the time headway in the "C-H" case will be shorter than the "H-C" case. These differences need further investigating to verify their validity.

To support the aforementioned findings a similar approach was used to study the space headways. The first speed interval was disregarded in this data analysis because the time headway between two stopped vehicles is infinite. Figure 3 also shows that the time headways for the first speed interval are out of range. The hypotheses were tested with

99% level of confidence. Every two vehicle-following combinations were tested for each speed interval.

Figure 3: Time headways



The time headways of H-H case were compared with the time headways of the other combinations (H-C, C-H, and C-C) with 5km/h speed intervals. The test results showed that the time headways of H-H case are the largest among the others with 99% level of confidence. Only in the last speed interval (45-50 km/h), was the time headway of the "H-H" case smaller than the "H-C" case.

The "H-C" and "C-H" cases were compared with each other. The result showed that when the speed of vehicles is less than 30 km/h, the time headway in the "H-C" following case is shorter than the "C-H" case. When the speed exceeds 30 km/h, the time headway in the "H-C" following case is longer than that in the "C-H" case.

The test results also revealed that the time headway in the "C-C" vehicle-following case is the shortest than the other combinations (H-H, H-C, and C-H cases). This conclusion is supported with 99% level of confidence except one case: the last speed interval in C-H versus C-C case (55-60 km/h). In this case the conclusion can be supported with 97% level of confidence instead of 99%.

3.2. Reaction time analysis

The reaction time describes the period between the occurrence or appearance of a stimulus such as a speed difference, and the driver's reaction. In the vehicle following process,

- the reaction can be the acceleration or deceleration of the subject (follower) vehicle and
- the stimulus can be define as the speed difference between the subject vehicle and its leader.

This section investigates the driver's reaction time for the four vehicle-following cases. The vehicle-following cases are "H-H", "H-C", "C-H" and "C-C" as explained above.

The reaction time of drivers was determined by using Equation 1. Indeed, the subject vehicle driver reacts after T seconds according to the relative speed between the subject vehicle and its leader.

$$a_n(t) \ \alpha \ \Delta v(t - T) \qquad (1)$$

Where $a_n(t)$ is the subject (follower) vehicle acceleration at time t,
Δv is the relative speed between the subject vehicle and its leader, and
T is the driver's reaction time.

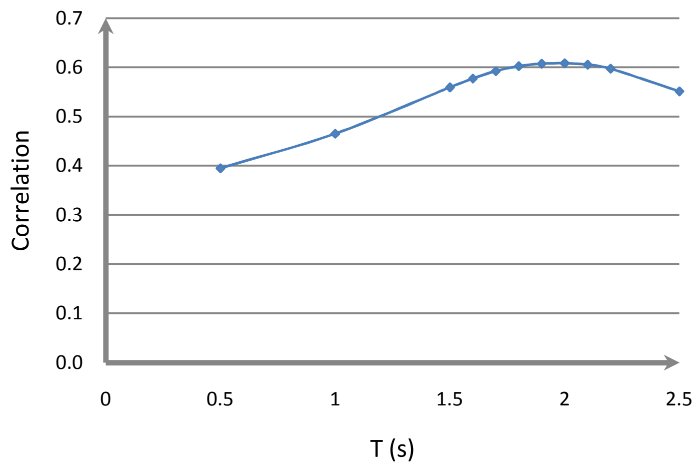
Different values of T were tested between 0.1 second and 2.5 seconds. The strongest correlation between the subject vehicle acceleration, $a_n(t)$, and the relative speed, Δv, was considered the reaction time.

Table 4 and Figure 4 show the correlation values for the "H-H" case. In Table 4 values are also provided for each of the three time periods: 4:00-4:15pm (I1), 5:00-5:15pm (I2), and 5:15-5:30pm (I3). Since the correlation is highest at 2 seconds, it can be concluded that the reaction time of a heavy vehicle driver is 2 seconds when following another heavy vehicle.

Table 4: Correlations in the "H-H" case

Time	I1	I2	I3	Total
0.5	0.360	0.504	0.379	0.395
1.0	0.430	0.596	0.419	0.465
1.5	0.532	0.693	0.489	0.559
1.6	0.554	0.710	0.500	0.577
1.7	0.571	0.723	0.509	0.592
1.8	0.584	0.732	0.514	0.602
1.9	0.591	0.737	0.515	0.607
2.0	0.593	0.737	0.513	0.608
2.1	0.590	0.732	0.506	0.605
2.2	0.583	0.723	0.497	0.597
2.5	0.535	0.680	0.451	0.551

Figure 4: Correlation between Acceleration and Relative velocity in the "H-H" case



Similar to what was explained for the "H-H" case, Tables 5 to 7 and Figures 5 to 7 are presented for the other cases. As can be seen different reaction times can be derived for each case. The reaction times for the "H-C", "C-H" and "C-C" cases are respectively 1.9, 1.9 and 1.8 seconds. Table 8 summarises the reaction times for all vehicle-following combinations.

Table 5: Correlations in the "H-C" case

Time	I1	I2	I3	Total
0.5	0.373	0.451	0.416	0.414
1.0	0.426	0.508	0.466	0.468
1.5	0.489	0.571	0.517	0.527
1.6	0.500	0.582	0.526	0.538
1.7	0.508	0.591	0.533	0.546
1.8	0.513	0.596	0.537	0.551
1.9	0.514	0.598	0.538	0.552
2.0	0.511	0.596	0.535	0.550
2.1	0.505	0.591	0.529	0.544
2.2	0.495	0.582	0.519	0.534
2.5	0.449	0.541	0.473	0.490

Figure 5: Correlation between Acceleration and Relative velocity in the "H-C" case

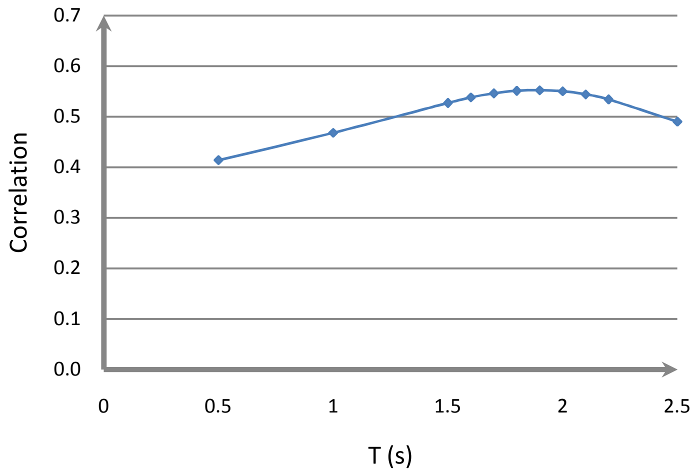


Table 6: Correlations in the "C-H" case

Time	I1	I2	I3	Total
0.5	0.341	0.429	0.442	0.402
1.0	0.413	0.501	0.516	0.474
1.5	0.496	0.581	0.593	0.554
1.6	0.511	0.595	0.606	0.568
1.7	0.521	0.606	0.615	0.578
1.8	0.527	0.612	0.619	0.584
1.9	0.529	0.614	0.619	0.585
2.0	0.525	0.611	0.614	0.581
2.1	0.518	0.603	0.605	0.573
2.2	0.506	0.591	0.592	0.561
2.5	0.448	0.532	0.531	0.502

Figure 6: Correlation between Acceleration and Relative velocity in the "C-H" case

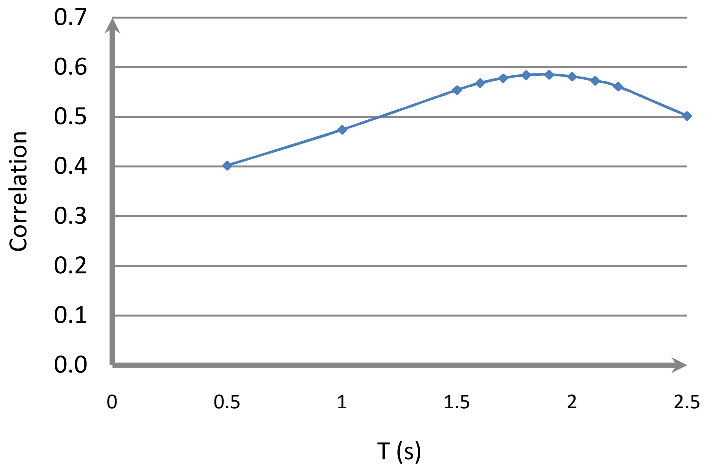


Table 7: Correlations in the "C-C" case

Time	I1	I2	I3	Total
0.5	0.403	0.432	0.461	0.426
1.0	0.461	0.499	0.520	0.488
1.5	0.523	0.567	0.577	0.550
1.6	0.534	0.578	0.586	0.560
1.7	0.541	0.587	0.592	0.567
1.8	0.544	0.592	0.594	0.571
1.9	0.543	0.593	0.591	0.570
2.0	0.539	0.590	0.584	0.566
2.1	0.532	0.582	0.573	0.558
2.2	0.520	0.571	0.557	0.545
2.5	0.469	0.519	0.491	0.490

Figure 7: Correlation between Acceleration and Relative velocity in the "C-C" case

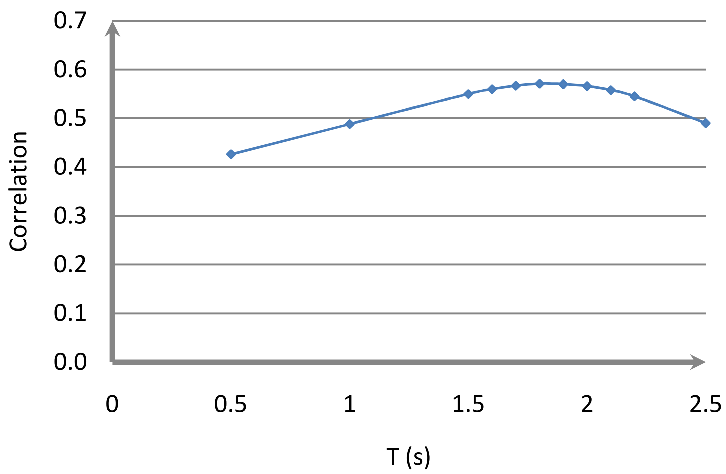


Table 8: Reaction times in different vehicle-following combinations

Case	H-H	H-C	C-H	C-C
Reaction time	2.0 (s)	1.9 (s)	1.9 (s)	1.8 (s)

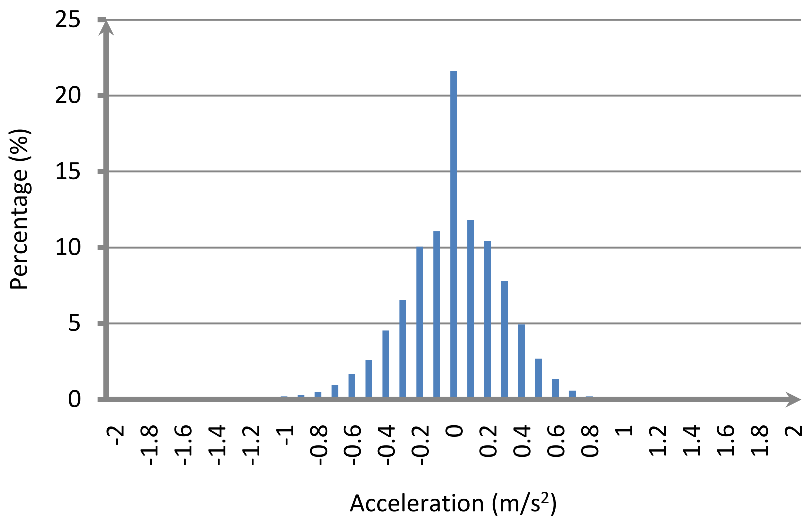
3.3. Acceleration Analysis

Heavy vehicle have a lower power to mass ratio than passenger cars (Ramsay 1998). They also have better sight distance than passenger cars due to the higher driver sitting positions. Because of these reasons it is expected that heavy vehicle apply lower acceleration than passenger cars. The results of acceleration analysis are presented in this section. In this section not only heavy vehicles and passenger cars are analysed as a following vehicles but also the impact of the leader type is explored. The same four vehicle-following combinations are considered.

The acceleration of the following vehicle was categorised with 0.1 m/s^2 intervals. The range of acceleration across all vehicles was between -2 m/s^2 and +2 m/s^2. The number of observations in each acceleration category was calculated as a proportion of the total number of observations.

Figure 8 shows the proportion of observations in each acceleration group for in the "H-H" case. As expected, due to the central limit theorem, the acceleration distribution follows a normal distribution. The mean and the standard deviation of this distribution were 0 and 0.283 m/s^2 respectively.

Figure 8: Following vehicle acceleration in the "H-H" case



Figures 9 to 11 show the acceleration of the following vehicles for "H-C", "C-H" and "C-C" cases respectively. The following vehicle accelerations in all cases are normally distributed but with different means and standard deviations. The values are summarised in Table 9. In the "H-C" case the mean and standard deviation of the distribution are 0 and 0.316 m/s^2 respectively, 0 and 0.335 m/s^2 for the "C-H" case, 0 and 0.376 m/s^2 for the "C-C" vehicle-following case.

Figure 12 provides a comparison of the acceleration distribution of the four vehicle-following combinations. Heavy vehicles have the lowest and smoothest acceleration when following another heavy vehicle among the other combinations. Passenger cars exhibit the largest range of acceleration among the others when following another passenger car.

The acceleration distribution of the "H-C" case and "C-H" case are located between the two aforementioned distributions ("H-H" and "C-C"). The "H-C" case distribution is located below the "H-H" case. The "C-H" case distribution is located above the "C-C" vehicle-following case but below the "H-H" case. These indicate that heavy vehicles apply lower acceleration and follow the preceding vehicle with smaller range of variability in observed acceleration rather than passenger cars. The leader vehicle class has also effects on the acceleration rates of the follower. When the leader is a heavy vehicle, the acceleration rate of the follower is lower and it moves smoother.

Figure 9: Following vehicle acceleration in the "H-C" case

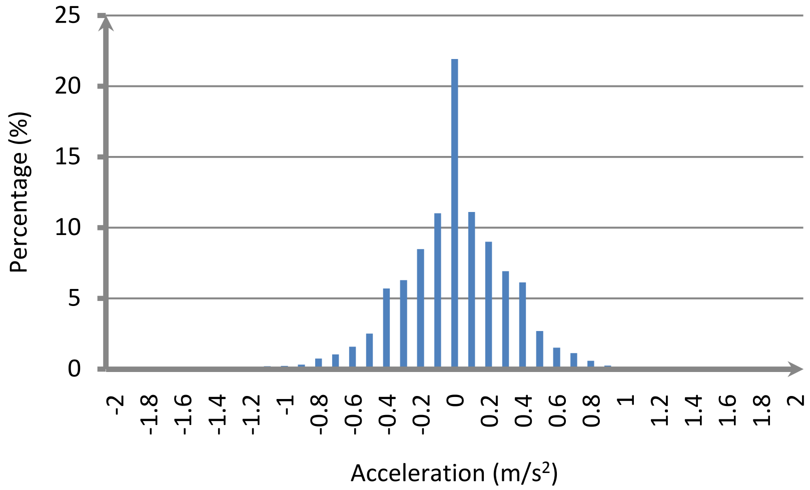


Figure 10: Following vehicle acceleration in the "C-H" case

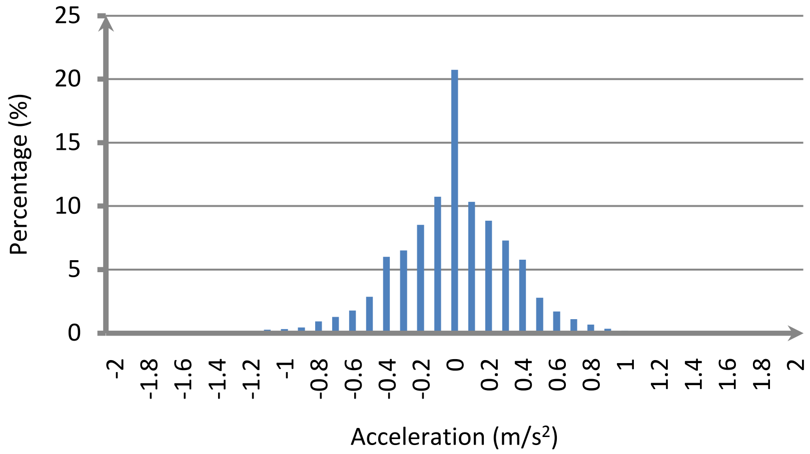


Figure 11: Following vehicle acceleration in the "C-C" case

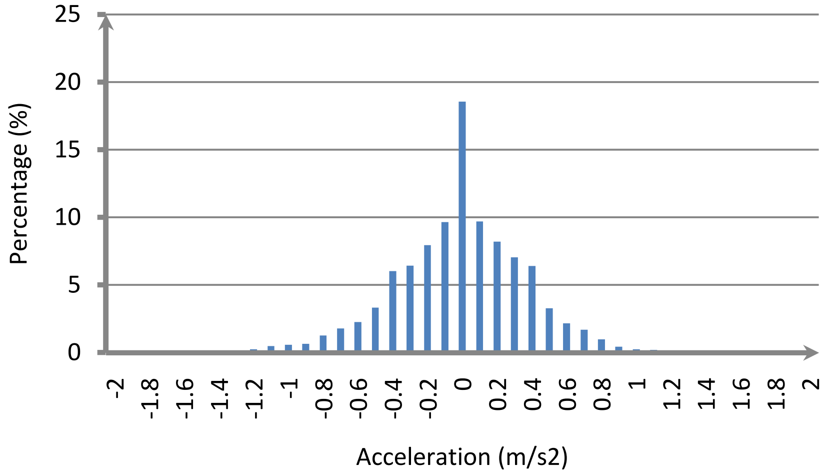
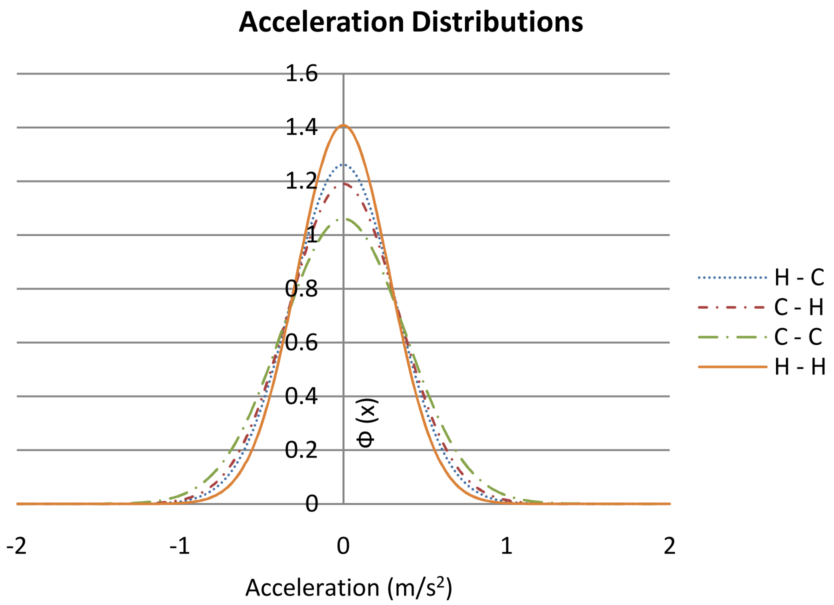


Table 9: Acceleration means and standard deviations

Case	H-H	H-C	C-H	C-C
Mean	0	0	0	0
Standard Deviation	0.283	0.316	0.335	0.376

Figure 12: Following vehicle acceleration distributions



4. Conclusion

A real world data set was used in this paper to examine the impacts of heavy vehicles on the vehicle-following behaviour of drivers. Four vehicle-following combinations were considered to assess the heavy vehicle impacts:

- A heavy vehicle follows a passenger car (H-C),
- A passenger car follows a heavy vehicle (C-H),
- A passenger car follows another passenger car (C-C), and
- A heavy vehicle follows another heavy vehicle (H-H).

To examine the impacts of the presence of heavy vehicles on the vehicle-following behaviour of drivers, the following issues were considered:

- Time headways and space headways between two successive vehicles,
- Driver's reaction time in each of the aforementioned combinations, and
- Following vehicle accelerations in each of the four vehicle-following combinations.

It was found that the space headway between two heavy vehicles (H-H case) is the largest space headway among the others and the space headway between two passenger cars (C-C case) is the smallest space headway among the other vehicle-following combinations. The space headways for the "C-H" and "H-C" cases are located between the "H-H" and "C-C" cases. It was also found that the space headway in the "C-H" case in larger than the "H-C" case when the vehicle speed is less than 30 km/h. It will be smaller than "H-C" case if the speed exceeds from 30 km/h.

Likewise, it was shown that the time headway between two heavy vehicles (H-H case) is the longest and the time headway between two passenger cars (C-C case) is the shortest among the other time headways. It was also concluded the time headway in the "C-H" case is longer than “H-C” case when the vehicle speed is less than 30 km/h. The sequence will change when the speed becomes more than 30 km/h.

The reaction time of drivers was determined for each vehicle-following combination. It was found that a heavy vehicle driver reacts to a stimulus after 2 seconds when following another heavy vehicle. The reaction time was 1/10 of second less if the driver follows a passenger car. It was concluded that a passenger car driver reacts to an action after 1.8 seconds when following another passenger car. This reaction time increases 1/10 of second when the passenger car driver follows a heavy vehicle.

In terms of acceleration analysis, it was found that a heavy vehicle driver applies a lower acceleration and follows a preceding vehicle with smaller range of variability in observed accelerations than a passenger car driver. The acceleration distribution of each vehicle-following combination was determined. They were all normally distributed but the “H-H” distribution is the narrowest (smallest standard deviation) and the “C-C” distribution is the widest (largest standard deviation). It was found that the average acceleration decreased from the “H-H” case to the “C-C”. In descending order is “H-H”, “H-C”, “C-H” and “C-C”.

References

BTRE (2003) “Urban pollutant emissions from motor vehicles: Australian trends to 2020”. Bureau of Transport and Regional Economics, Department of Transport and Regional services, Report for Environment Australia.

FHWA (2005) “NGSIM data set”. Freeway data set. Federal Highway Administration. Available on: http://www.ngsim.fhwa.dot.gov

FHWA (2006) “NGSIM data set” Arterial data set. Federal Highway Administration. Available on: http://www.ngsim.fhwa.dot.gov

FHWA (2010) “Vehicle classification”. Federal Highway Administration. Available online: http://www.fhwa.dot.gov/policy/ohpi/vehclass.htm access in 2010.

HCM. (2000) “Highway Capacity Manual”. TRB, National Research Council, Washington, D.C.

Huddart K.W. and Lafont R. (1990) “Close Driving - Hazard or Necessity?” Proc. of the 18th PTRC Meeting - Seminar G, P334, pp 205-217.

Kostyniuk L.P., Streff F. M., and Zakrajsek J. (2002) “Identifying unsafe driver actions that lead to fatal car–truck crashes”. University of Michigan, Transportation Research Institute, Report prepared for AAA Foundation for Traffic Safety.

McDonald M., Brackstone M.A., Sultan B., and Roach C., (1997) “Close following on the motorway Initial findings of an instrumented vehicle study” 7th Vision in Vehicles Conf., Marseille, France.

Ossen S. and Hoogendoorn S.P. (2009) “Heterogeneity in car-following behavior: Theory and empirics “. *Transportation and Traffic Theory*.

Peeta S., Zhang P., Zhou W. (2005) “Behaviour-based analysis of freeway car–truck interactions and related mitigation strategies”. *Transportation Research Part B 39, pp 417–451.*

Sarvi M. (2008) “Measuring and modelling the dynamic of heavy commercial vehicles and their interactions with other vehicles”. TRB, Annual Meeting CD-ROM.

Sarvi M., Kuwahara M. (2007) “Observing freeway ramp merging phenomena in congested traffic”, *Journal of Advanced Transportation, Issue 2, Volume 41.*

Sayer R., Merfford M.L., and Huang R.W. (2000) “The Effect of Lead-Vehicle Size on Driver Following Behavior”, *UMTRI-2000-15.*

Stuster J. (1999) “The unsafe driving acts of motorists in the vicinity of large trucks”. Project report prepared for Office of Motor Carrier Research (OMCR), DTFH61-97-C-00090, Washington, DC.

Thiemann C., Treiber M., and Kesting A. (2008) “Estimating Acceleration and Lane-Changing Dynamics from Next Generation Simulation Trajectory Data”. *Transportation Research Record 2008, pp. 90-101.*

Wright S. J. (2006). Review of urban congestion trends, impacts and solutions (Consultancy Report). Traffic Management Systems for Australian Urban Freeways, Prepared by ARRB Consulting for Council of Australian Governments: Canberra.

Yoo H., and Green P. (1999). “Driver Behavior While Following Cars, Trucks, and Buses”. http://www.umich.edu/~driving/publications/UMTRI-99-14.pdf