ACCELERATION BEHAVIOUR OF THE HEAVY VEHICLE DRIVERS DURING THE LANE CHANGING MANOEUVRE

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ABSTRACT

The speed and traffic flow oscillations reflect the macroscopic effects of heavy vehicle lane changing manoeuvres on traffic flows. The existing lane changing behaviour models mainly focus on drivers' lane changing decision and generally neglect the execution of the lane changing manoeuvre. However, several seconds is required for heavy vehicle drivers to complete a lane changing manoeuvre. Excluding the lane changing execution, may have a significant impact on estimated traffic flow characteristics, particularly in heavy traffic conditions. The acceleration behaviour of heavy vehicle drivers from the start of the lane changing until the end of the lane changing manoeuvre is analysed in this paper. The results show that the traffic characteristics of the surrounding vehicles in the current lane and the target lane have almost no effect on the acceleration behaviour of the heavy vehicle drivers in heavy traffic conditions.

Keywords**:** Acceleration behaviour; Lane changing manoeuvre; Heavy vehicles; Heavy traffic conditions.

1. INTRODUCTION

The lane changing manoeuvre of heavy vehicles has influence on macroscopic and microscopic characteristics of traffic flows. The speed and traffic flow oscillations reflect the macroscopic effects of heavy vehicle lane changing manoeuvres on traffic flows (Moridpour et al. 2008; 2009). The lane changing manoeuvres may generate shockwaves in both lanes and may cause a capacity drop and potentially reduce the freeway safety (Mauch and Cassidy 2002; Sasoh and Ohara 2002; Jin 2005).

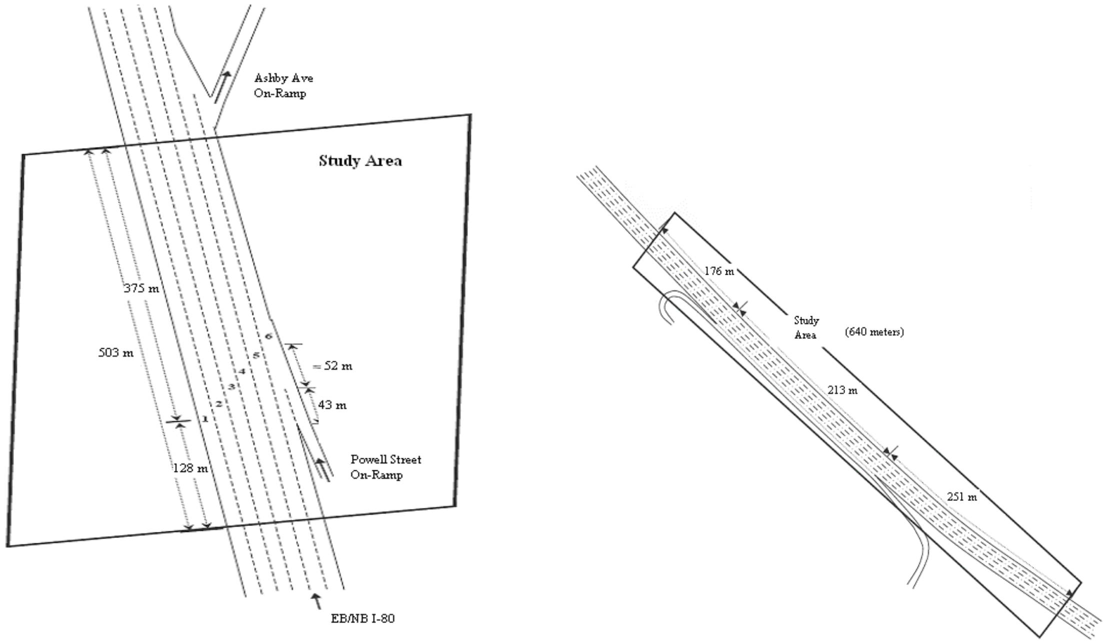
In general, several seconds is required for the heavy vehicle drivers to complete a lane changing manoeuvre. This is due to the physical (e.g. length) and operational (e.g. acceleration/deceleration) characteristics of the heavy vehicles. However, the existing lane changing behaviour models mainly focus on drivers' lane changing decision and generally neglect the execution of the lane changing manoeuvre. Excluding the lane changing execution, may have a significant impact on estimated traffic flow characteristics, particularly in heavy traffic conditions. Therefore, considering the lane changing execution could improve the accuracy of the heavy vehicle lane changing models which subsequently may improve the accuracy of the obtained results from microscopic traffic simulations.

Since the lane changing execution is an important stage in heavy vehicles' lane changing manoeuvre, it is essential to analyse the acceleration/deceleration behaviour of heavy vehicle drivers while performing the lane changing manoeuvre. A review of the existing lane changing execution models showed that there are limited studies in the literature regarding the acceleration behaviour of the drivers while performing a lane changing manoeuvre. Toledo (2003) developed a lane changing acceleration/deceleration model which captures the acceleration behaviour of passenger car drivers during the lane changing. In his lane changing acceleration model, the duration of lane changing manoeuvres is ignored and the lane changing manoeuvres are reported only at the end of the lane changing.

The aim of this research is to investigate the acceleration and deceleration behaviour of heavy vehicle drivers during the lane changing manoeuvre in heavy traffic conditions. The influence of the traffic characteristics in the current lane and the target lane on drivers' lane changing acceleration are analysed in this research. This paper is structured as follows. In the next section, the trajectory dataset which is used in this study is described. It is followed by a detailed examination of the heavy vehicle drivers' acceleration behaviour during the lane changing manoeuvre. The final section summarizes the findings and conclusions of the paper and provides suggestions for further research.

2. TRAJECTORY DATASET

The trajectory data used in this study was made available for two sections of highways in California: Berkeley Highway (I-80) and Hollywood Freeway (US-101). The schematic lane configuration for the two sites is shown in Figure 1.



(a) The section of US-101. (b) The section of I-80.

Figure 1: The schematic lane configuration for the two sites.

The section of I-80 (Figure 1a) is 503 meters long and comprises five main lanes with one auxiliary lane (FHWA 2005). There is one on-ramp in this section and one exit off-ramp downstream of the section. There are no lane restrictions for heavy vehicles in this section. The data were collected from 4:00 to 4:15 PM and 5:00 to 5:30 PM using a video capture rate of 10 frames per second. The second section considered in this analysis is on US-101 (Figure 1b). This section is 640 meters long and has five main lanes and one auxiliary lane (FHWA 2005). The section includes one on-ramp and one off-ramp and there are no lane restrictions applying to heavy vehicles. The data was collected from 7:50 to 8:35 AM with a video capture rate of 10 frames per second.

The dataset has classified vehicles as motorcycles, automobiles, and heavy vehicles. Table 1 shows the traffic composition details, along with traffic flow parameters for each study area. Over the time period when the data was captured, the number of heavy vehicle lane changing manoeuvres on I-80 and US-101 were 27 and 15 respectively. Therefore, 42 heavy vehicle lane changing manoeuvres are analysed in this study.

Table 1: The traffic composition details in each freeway section.

Site Name	Motorcycle Number (%)	Automobile Number (%)	Heavy Vehicles Number (%)	Flow (veh/hr)	Speed (km/hr)	Density (veh/km)	Level Of Service (LOS)
I-80	55 (1.0)	5408 (95.2)	215 (3.8)	7493	23.5	319	E*
US-101	45 (0.7)	5919 (97.0)	137 (2.2)	7603	35.2	216	E
Total	100 (0.8)	11327(96.2)	352 (3.0)	7548	29.4	268	E

* LOS E reflects an unstable flow and the traffic flow becomes irregular and speed varies rapidly, but rarely reaches the posted limit (Highway Capacity Manual 2000)

The trajectory dataset which is used in this study provides information on the heavy vehicles performing the lane changing manoeuvre as well as their surrounding traffic characteristics. Vehicles for which information is available during a lane changing manoeuvre are presented in Figure 2.

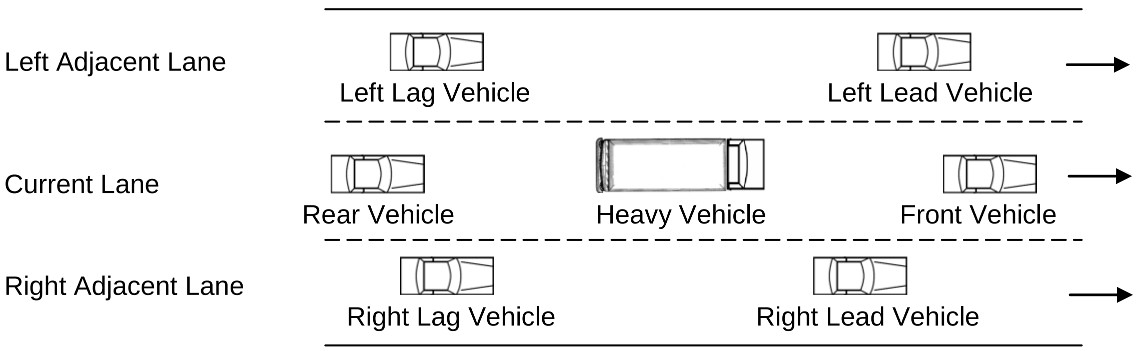


Figure 2: Surrounding vehicles in acceleration behaviour analysis during the lane changing.

The trajectory dataset makes it possible to determine the positions, speeds and accelerations of the surrounding vehicles (Figure 2) and the space gaps between the heavy vehicle and the surrounding vehicles at discrete time points.

3. THE ACCELERATION BEHAVIOUR DURING THE LANE CHANGING

Several seconds is required for a heavy vehicle driver to complete a lane changing manoeuvre. This makes the lane changing execution as an important stage in heavy vehicles' lane changing. Table 2 provides the summary of the required time for heavy vehicle and passenger car drivers to execute a lane changing manoeuvre. In addition, the heavy vehicle and passenger car speeds during the lane changing manoeuvre are presented in Table 2. This table is based on analysing 42 heavy vehicle and 42 passenger car lane changing manoeuvres.

Table 2: Summary statistics on the required time for lane changing execution and the speeds.

Variable	Mean	Standard Deviation	Minimum	Maximum
Heavy Vehicles				
Speed (m/sec)	8.6	0.5	7.4	11.1
Lane Changing Duration (sec)	8.0	3.7	1.6	16.2
Passenger Cars				
Speed (m/sec)	9.2	1.1	8.6	11.6
Lane Changing Duration (sec)	4.8	2.1	1.1	8.9

Table 2 highlights that the required time for heavy vehicle drivers to perform a lane changing manoeuvre is around 70% greater than the corresponding value for the passenger car drivers. In addition, the average speed of the heavy vehicles is about 7% lower than the average speed of the passenger cars during the lane changing manoeuvre. These differences may be due to the physical (e.g. length) and operational (e.g. acceleration/deceleration) characteristics of the heavy vehicles.

Due to large lane changing duration time of heavy vehicles, excluding the execution of the lane changing manoeuvre, may have a negative impact on estimated traffic flow characteristics. Therefore, the acceleration and deceleration behaviour of the heavy vehicle drivers from the start of the lane changing until the end of the lane changing manoeuvre are analysed in this section. The start and the end of the lane changing manoeuvre are the time that the lateral movements of the heavy vehicle are initiated and finished respectively.

The lane changing manoeuvres occur in two adjacent lanes: the current lane and the target lane. The target lane is either the left or the right adjacent lane depending on the side which is selected by the drivers to move into that lane. The traffic characteristics of the surrounding vehicles in the current lane and the target lane may have influence on the acceleration behaviour of the heavy vehicle drivers. Therefore, the relationship between the heavy vehicles' accelerations/decelerations and the surrounding traffic characteristics in the current lane and the target lane are analysed in two sections. The following figures are based on the 42 lane changing manoeuvres of heavy vehicles. To avoid complexity, the following figures are presented based on the aggregated trajectory data at each 0.5 second time intervals from the start of the lane changing until the end of the lane changing manoeuvre.

3.1. The surrounding traffic characteristics in the current lane

The space gaps between the heavy vehicle and the front and rear vehicles in the current lane may affect the acceleration behaviour of heavy vehicle drivers during the lane changing manoeuvre. The heavy vehicle drivers may increase their speed and perform acceleration when either large front space gap is available in front of them or the rear space gap is small. The relationship between the heavy vehicle acceleration and the front and the rear space gaps are shown in Figure 3.

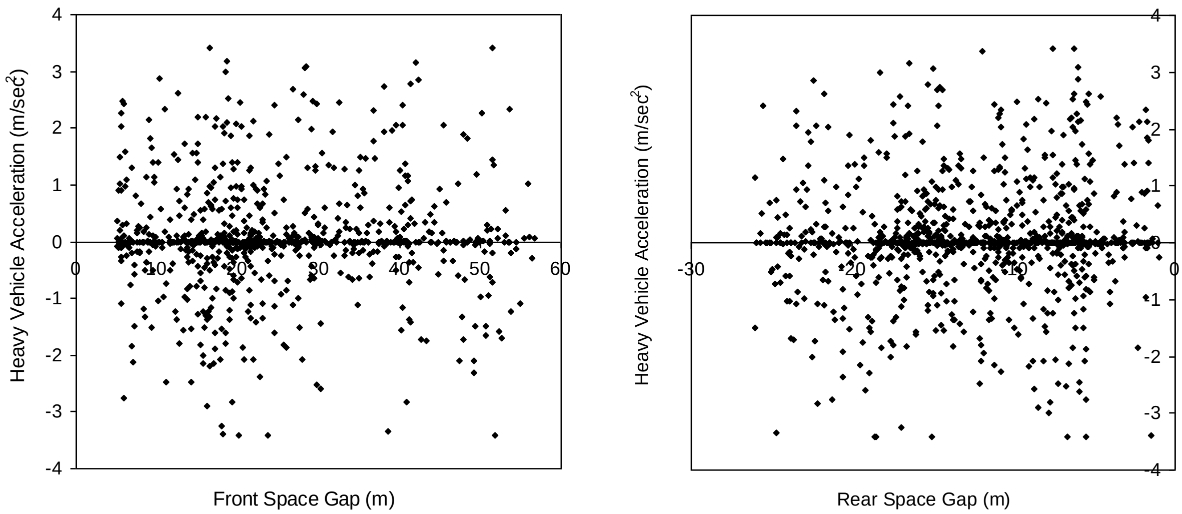


Figure 3: Relationship between heavy vehicle acceleration and space gaps in current lane.

The results in Figure 3 show that there is no causal relationship between the acceleration of the heavy vehicles and the front and the rear space gaps in the current lane. This implies that the large values of the front space gap or the small values of the rear space gap (tailgating) are unimportant in motivating the heavy vehicle drivers to alter their acceleration profile. The heavy vehicle drivers may decelerate when the front vehicle speed is low or they may accelerate when the rear vehicle speed is high. Figure 4 highlights the relationship between the heavy vehicle acceleration and the relative speeds of the front and rear vehicles in the current lane.

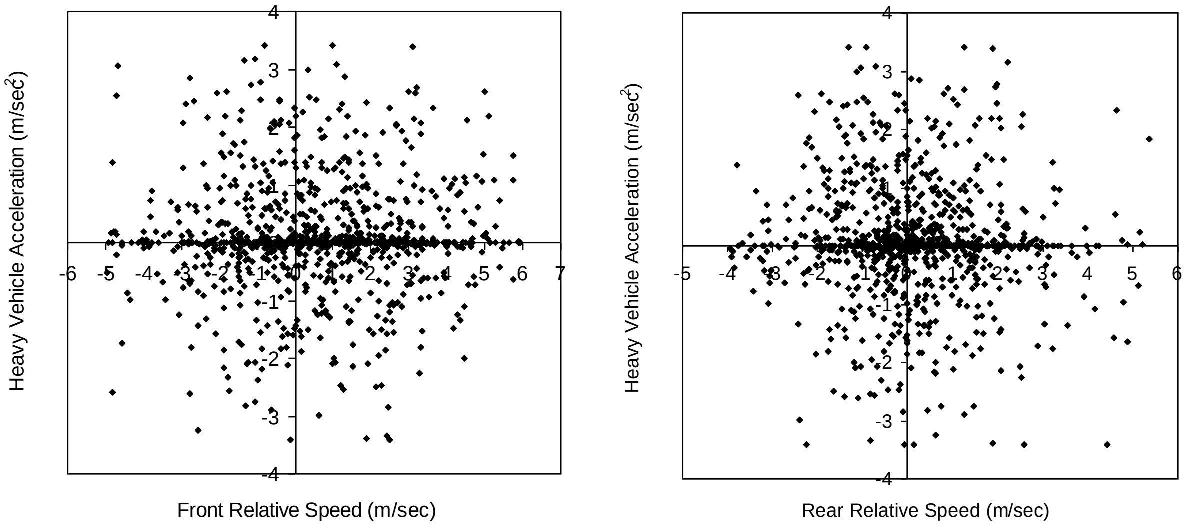


Figure 4: Relationship between heavy vehicle acceleration and relative speeds in current lane.

This figure shows that the front and the rear relative speeds are not influencing factors in the acceleration/deceleration behaviour of heavy vehicle drivers in heavy traffic conditions.

3.2. The surrounding traffic characteristics in the target lane

This section analyses the effect of the surrounding traffic characteristics in the target lane on the acceleration/deceleration patterns of heavy vehicles during the lane changing manoeuvre. Figure 5 shows that the lead and lag space gaps in the target lane do not have considerable effect on heavy vehicles acceleration behaviour during the lane changing manoeuvre.

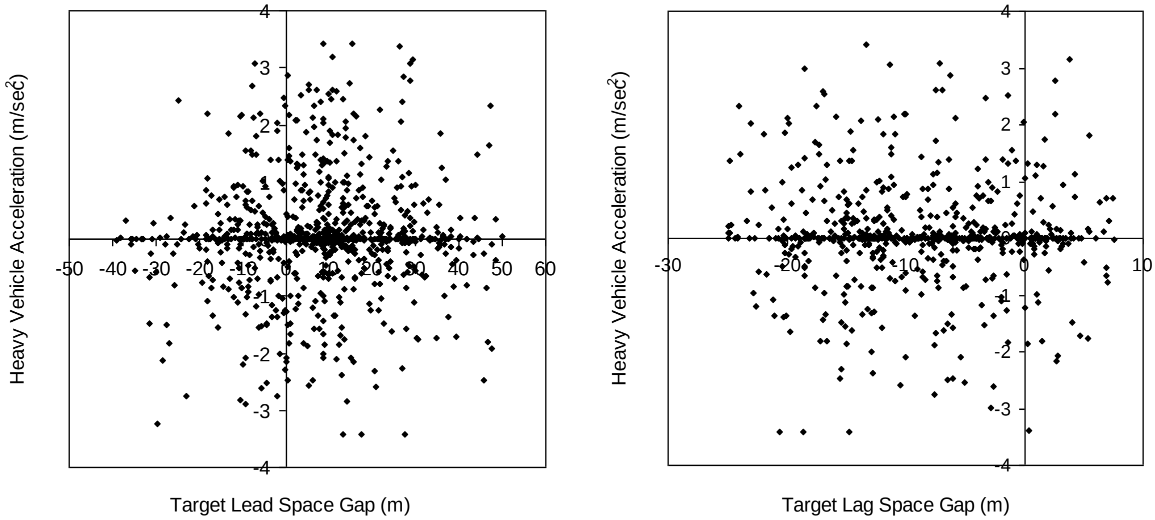


Figure 5: Relationship between heavy vehicle acceleration and space gaps in target lane.

The obtained results show that the size of the target lead and lag space gaps does not have a considerable influence on the heavy vehicle drivers' acceleration profile. Furthermore, there is no relationship between the heavy vehicle acceleration and the speeds of the lead and lag vehicles in the target lane shown in Figure 6.

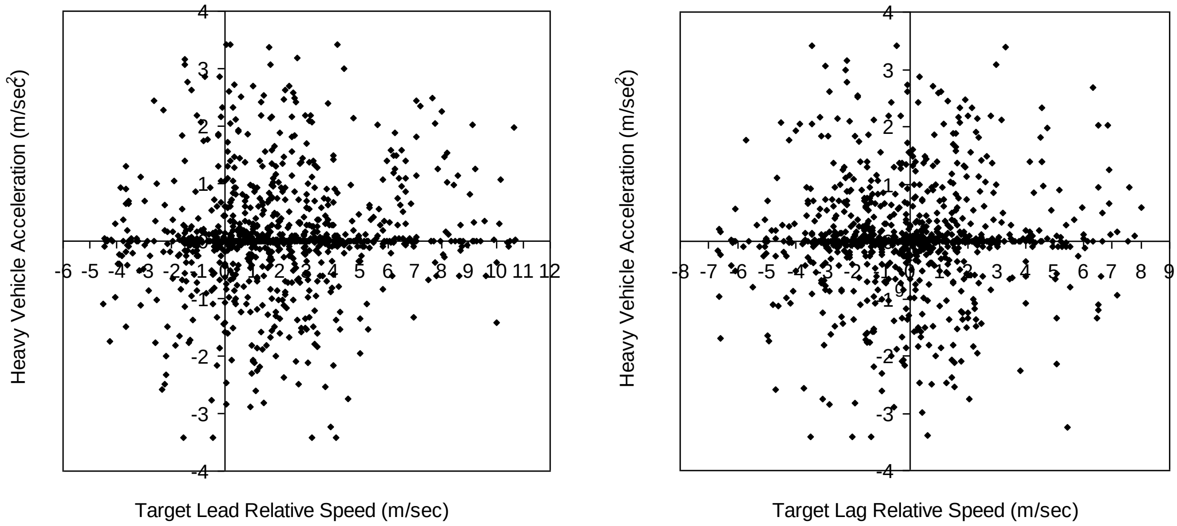


Figure 6: Relationship between heavy vehicle acceleration and relative speeds in target lane.

This implies that the heavy vehicle drivers keep an almost constant speed during the lane changing manoeuvre. Therefore, the lag vehicle drivers may provide courtesy for the heavy vehicles or they may be forced by the heavy vehicle drivers to reduce their speed and provide gaps of sufficient size during the heavy vehicles' lane changing. In general, the gaps of sufficient size are mainly unavailable in heavy traffic conditions and they are created by either the lag vehicle drivers' courtesy or the heavy vehicle drivers' forcing.

To provide an alternative perspective, heavy vehicles' speed during the lane changing manoeuvre is shown in Figure 7. This figure is based on the aggregated speeds from all available manoeuvres (42 heavy vehicle lane changing manoeuvres). The heavy vehicles' speed is represented by the Y-axis. The position of the Y-axis represents the point in time when the heavy vehicles started to move into the target lane, based on the subjective judgement of the observer.

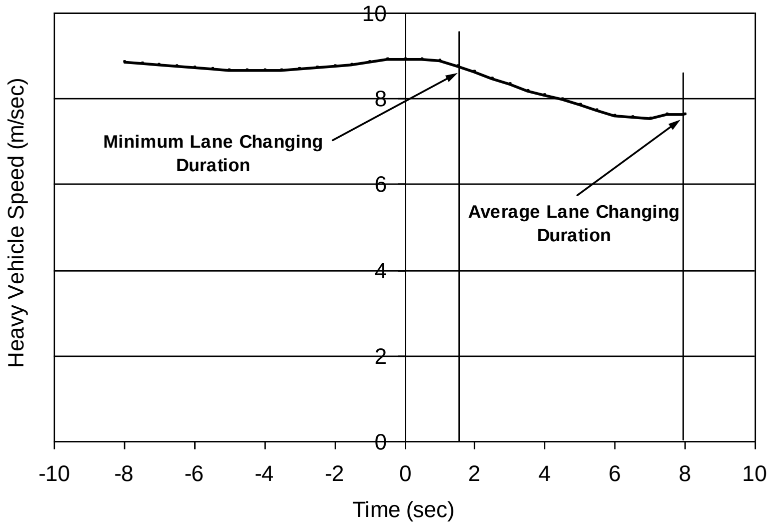


Figure 7: The average speed of the heavy vehicles during the lane changing manoeuvre.

The speed of the heavy vehicle drivers has inconsiderable variation prior to the start of the lane changing manoeuvre. According to Figure 7, the average speed of the heavy vehicles has insignificant changes until the minimum lane changing duration time and has a decreasing trend afterwards. However, this trend is not due to decrease in heavy vehicles' speed during the lane changing manoeuvre. The speed profiles of the individual lane changing manoeuvres show that the heavy vehicles have almost constant speed while changing lanes. As it was discussed earlier, this figure is based on the aggregated traffic characteristics from all available manoeuvres. To better understand the relationship between the heavy vehicles' speed and the lane changing duration, these two values are presented for the 42 heavy vehicle lane changing manoeuvres in Figure 8. This figure shows that the duration of the lane changing manoeuvre increases while the heavy vehicle speed decreases (Figure 8). Therefore, the heavy vehicles with the slower speeds have greater lane changing duration time. This can explain the decreasing trend in the heavy vehicles' speed after the minimum lane changing duration shown in Figure 7.

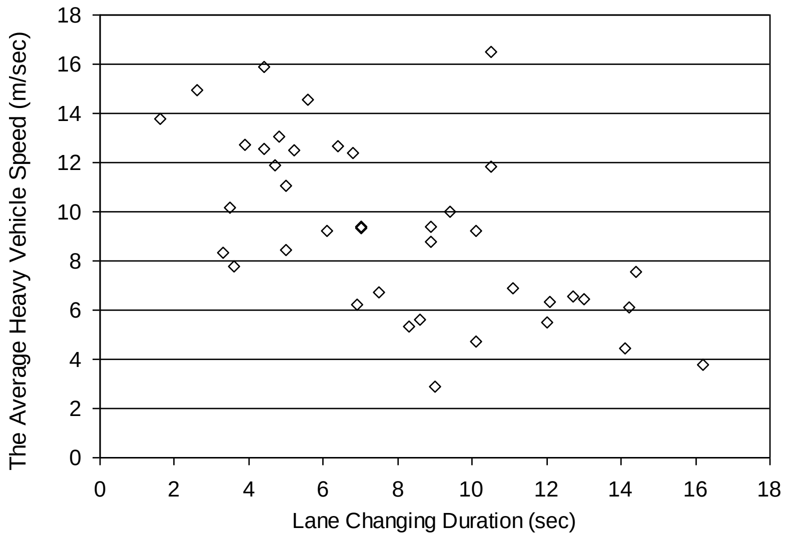


Figure 8: The relation between the heavy vehicles' speed and their lane changing duration.

Analysing the heavy vehicle drivers' lane changing behaviour shows that the heavy vehicles' speed has insignificant changes during the lane changing manoeuvre in heavy traffic conditions. In other words, the heavy vehicle drivers keep almost constant speed during the lane changing manoeuvre. They do not accelerate or decelerate to adjunct their speed according to the speed of the surrounding traffic in the target lane.

4. CONCLUSIONS

Heavy vehicles' lane changing manoeuvre has influence on macroscopic and microscopic characteristics of traffic flows. The speed and traffic flow oscillations reflect the macroscopic effects of heavy vehicle lane changing manoeuvres on traffic flows. The existing lane changing behaviour models mainly focus on the drivers' lane changing decision and generally neglect the execution of the lane changing. However, several seconds is required for heavy vehicle drivers to complete a lane changing manoeuvre. Excluding the lane changing execution, may have a significant impact on estimated traffic flow characteristics, especially in heavy traffic conditions.

The effects of the surrounding traffic characteristics in the current lane and the target lane on the acceleration/deceleration behaviour of heavy vehicle drivers were analysed in this paper. The results showed that the traffic characteristics of the surrounding vehicles in the current lane and the target lane are not influencing factors in acceleration/deceleration behaviour of heavy vehicle drivers. In addition, the heavy vehicles' speed has inconsiderable variation during the lane changing manoeuvre. Heavy vehicle drivers' mainly do not accelerate or decelerate to adjunct their speed according to the speed of the surrounding traffic in the target lane.

Modelling the heavy vehicle drivers' lane changing execution would enhance the accuracy of the heavy vehicle drivers' lane changing behaviour models and may improve the performance of the existing microscopic traffic simulations. Further research is required to analyse the acceleration/deceleration behaviour of the passenger car drivers during the lane changing manoeuvres and under different traffic conditions. In addition, exploring the lane changing execution of the heavy vehicle drivers in free flow or semi-congested traffic conditions could be regarded as a promising direction for future research.

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