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LANE CHANGING DECISION AND EXECUTION ON ARTERIAL ROADS

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Abstract

This study investigates the lane changing behaviour of passenger cars and heavy vehicle drivers on arterial roads. Lane changing has an important influence on traffic flow through its impact on the surrounding drivers. The impact of heavy vehicle lane changes can be even more serious compare to those of passenger vehicles due to the different characteristics of the vehicle and the consequent driver behaviour. Many models of the behaviour of heavy vehicles are limited to freeways. This is an unfortunate because the heavy vehicle impacts are more considerable on arterial roads since the level of interaction between vehicles is increased at intersections. It is exacerbated because the number of heavy vehicles and their proportion in traffic steam are increasing in many countries, in particularly Australia.

This paper applies a detailed vehicle trajectory data to explore the interactions between vehicles leading to the drivers' behaviour analysis. The findings of this research highlight the differences between heavy vehicle and passenger car drivers' behaviour in terms of decision making and execution of lane changing manoeuvres. A comparison between these findings and the outcomes of a former research reveals that the behaviour of drivers on arterial road differs from that of freeways.

Keywords: **Lane changing; Driver behaviour; Traffic analysis; Traffic congestion.**

1- Introduction

Freight movement plays a key role in a nation's economy. Truck transport is the most common mode used to move freight in terms of shipment value and weight (BITRE 2008). Further, the Australian Bureau of Statistics (ABS, 2008) showed that the number of freight vehicles is growing faster than passenger cars. For instance, during the period between 2003 and 2007 there was a 20.5 percent growth in tonne-kilometres travelled by heavy vehicles in Australia. This growth reflects the increase in the number and the loads carried by heavy vehicles. The Bureau of Transport and Regional Economics (BTRE 2003) investigated the number of motor vehicles in Australia. This study predicts the growth will continue such that the proportion of heavy vehicles in the traffic stream will increase from 16.2% in 2002 to 20.5% in 2020.

Notwithstanding the smaller proportion of heavy vehicles in vehicular traffic (18 percent in Australia in 2007 (ABS, 2008)), they cause significant impacts on geometric and alignment designs, infrastructure deterioration, and environment due to their physical and operational characteristics such as size, weight, turning radii, acceleration, deceleration capability and blind spots. In turn heavy vehicles affect traffic flow performance due to their size and lower acceleration / deceleration capabilities. Stuster (1999) and Kostyniuk et al. (2002) suggested that the presence of trucks can significantly influence on the driving actions of non-truck drivers.

In recent years heavy vehicle manoeuvres has received increased attention. The interaction between cars and heavy vehicles was investigated to model the behaviour of car drivers while they are following heavy vehicles (Peeta et al 2005). Differences in car-following behaviour of heavy vehicles and passenger cars were also highlighted and a specific model for heavy vehicle car-following behaviour was developed (Sarvi 2008). The findings of this research were used in traffic management to improve the capacity of freeway merging sections by transferring heavy vehicles from one lane to another lane (Sarvi and Kuwahara 2008).

Many issues must be considered for a realistic and reliable lane changing model to be developed. Because of this complexity the literature related to lane changing is less comprehensive compare to that of car following. This is unfortunate since empirical evidence indicates that lane changing may cause more instability in traffic flow. The lane changing manoeuvres initiate traffic flow instability (Daganzo et al 1999, Chen et al 2004, Al Kaisy et al 2005) and generate oscillations in traffic flow and cause shockwaves in the both entry and exit lane (Mauch and Cassidy 2002, Sasoh and Ohara 2002, Ahn and Cassidy 2007). Lane changes decrease the capacity of a road leading to flow breakdown under congested traffic condition (Jin 2005, Yang and Zhang 2007).

Despite the increasing number of heavy vehicles, previous studies of lane changing are mainly associated with passenger cars and the lane changing of heavy vehicles has received little attention (Moridpour et al 2010a). Moridpour et al (2010b, c) explored the lane changing behaviour of heavy vehicles on freeways by focusing on the behavioural differences between the heavy vehicles and passenger cars at the time of their lane changing manoeuvre. These studies did not consider lane changing behaviour on arterial roads. However, the influence of heavy vehicles on traffic flow can be more serious on arterial roads since intersections interrupt the traffic stream cause more acceleration and deceleration. This introduction can highlight the fact that there is a need to increase our understanding of the impacts of heavy vehicles on traffic flow on urban arterial.

This paper is arranged as follows. The trajectory data set used in this study is introduced in the next section. It will be followed by the data analysis section. The results of the data analysis will be discussed then. Some conclusive remarks are presented at the end of the paper.

2- Trajectory data set

Data on the lane-changing behaviour of vehicles can be obtained in many ways. One of the richest forms of data is collected using video cameras mounted on high buildings. Such an approach can provide data on vehicle characteristics such as type, size (in length and width), two dimensional position, velocity, acceleration and deceleration as well as their proceeding and following vehicles lane identification. Such data sets have provided by the Federal Highway Administration of the U.S. for two freeway stretches (Berkley Highway (I-80) and Hollywood Freeway (US-101)) and one arterial road section (Lankershim Boulevard) in California (FHWA 2005 and 2006).

The vehicle trajectory data used in this work was obtained from the NGSIM datasets. The Lankershim Boulevard data is used to examine and compare the lane changing behaviour of heavy vehicles and passenger cars on arterial roads.

Lankershim Boulevard (See Figure 1) is an arterial road running primarily north-south in Los Angeles, California. Five video cameras were mounted on a 36-story building, 10 Universal Plaza, which is located adjacent to the interchange between U.S. Highway 101 (Hollywood Freeway) and Lankershim Boulevard in the Universal City neighbourhood.

Data on vehicle trajectories were extracted from the video recorded between 8:28 a.m. and 9:00 a.m. on 16 June 2005 at an accuracy of 10 frames per second. The data collection site in Lankershim Bourlvard is approximately 480 meters in length, and has four signalised intersections and three to four lanes in each direction.

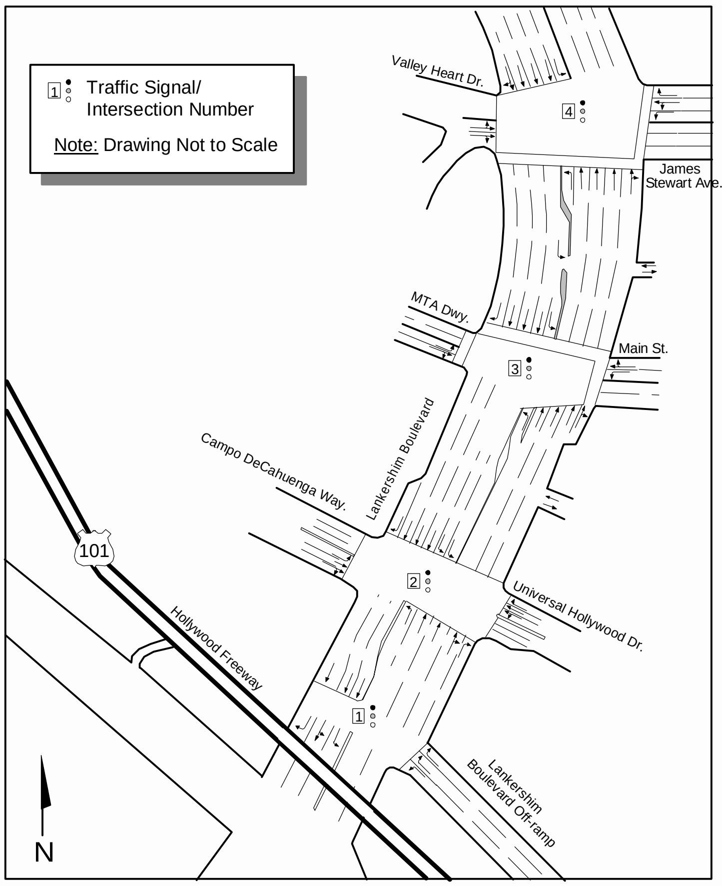


FIGURE 1 The study area in the Lankershim Boulevard

In this data set, vehicles are classified in three categories (motorcycles, automobiles and heavy vehicles). The classification is based on the FHWA vehicle classification which is last modified in 2008 (FHWA 2008). The percentage of heavy vehicles in the vehicular traffic stream is around 3%. The Level of Service (LOS) of the study section was determined as “E” with reference to the Highway Capacity Manual (HCM 2000).

3- Data analysis

A computer program written in Microsoft Visual Studio was applied to determine the lane changing vehicles. The program identifies lane changing by tracking the lane position using identification codes. Whenever a vehicle crosses its lane, the lane identification code will change in the NGSIM data set.

The program identified lane changing manoeuvres. However, these lane line crossings needed to be investigated further to determine if they were lane changes. Some of these lane changes did not result from real lane changing but actual deviations of vehicle position from the centre of the lane and moving over a lane line and then returning immediately to the original lane. These lane line crossings were related to drive deviations and were not associated with formal lane changing. In addition, it was observed that vehicles usually crossed some lanes when they turned into Lankershim Boulevard. Likewise, since the process of moving into the exit bay is different from a real lane changing, these manoeuvres were also removed from the data base used in this study. Consequently, 63 lane changing vehicles including 49 passenger cars and 14 heavy vehicles were selected to analyse drivers' behaviour on arterial roads.

The subject vehicle is the vehicle which conduct the lane changing manoeuvre (see Figure 2). The lane that a subject vehicle is currently travelling on is referred to as the current lane, and the target lane is the lane that the subject vehicle intends to move into. Accordingly, the front, rear, target lead, and target rear vehicles are also defined and shown in Figure 2. The parameters that are used to examine the lane changing of manoeuvre are also presented in Figure 2. The alternative lane is either the right or the left adjacent lane which is not selected as the target lane.

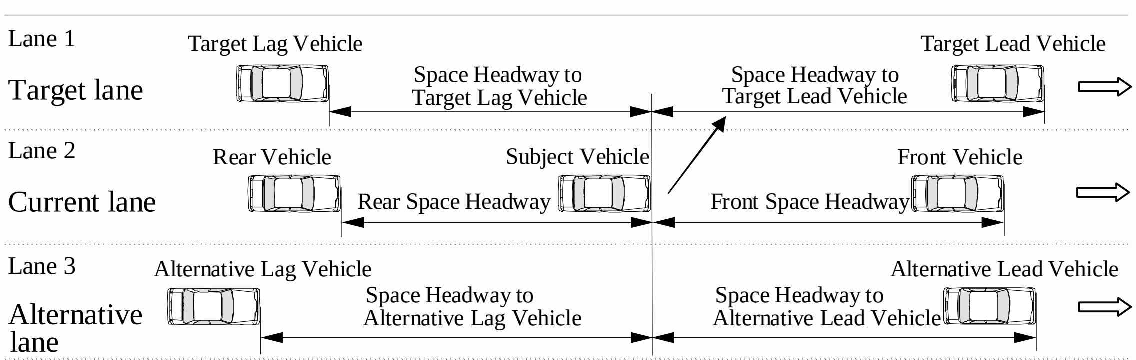


FIGURE 2 Sketch of lane-changing manoeuvre

The traffic characteristics (e.g. position, speeds, and acceleration) of all subject vehicle and their surrounding vehicles were extracted from the NGSIM data set using the program written in Microsoft Visual Studio.

The space headways between the vehicles were determined at the next stage. The space headway of each vehicle is calculated as the difference between the position of that vehicle and the position of the subject vehicle (Figure 2).

To investigate and compare the lane changing behaviour of heavy vehicle and passenger cars on arterial roads, the space headways and the speeds of the subject vehicle and all surrounding vehicles are examined and explained in the following section.

4- Results

In this section, the lane changing decision and lane changing execution of passenger car and heavy vehicle drivers are examined. The space headway and speed profiles for passenger car and heavy vehicle lane changing manoeuvres are provided and discussed. The "X" axis shows the time from 8 seconds before the start of the lane changing until 10 seconds after the start of the lane changing manoeuvre. The "Y" axis shows either the space headways between the vehicles or the speed of the vehicles.

Figure 3 and 4 show the space headway profiles in the target lane respectively for passenger car and heavy vehicle lane changing manoeuvres on arterial roads. The target lead and target lag space headways for passenger car lane changes are much smaller than the corresponding values for heavy vehicles before the start of the lane changing manoeuvre. The existing target gap for passenger car lane changing is about 22 metres while the corresponding value for heavy vehicle manoeuvre is about 170 metres. This difference may not be explained only by different vehicle characteristics such as vehicle length. This finding can apparently reveal that the behaviour of heavy vehicle drivers fundamentally differs from that of passenger car drivers. Different lane changing behaviour of passenger car and heavy vehicle drivers cannot be capture by model parameters tuning as all of the existing micro-simulation do.

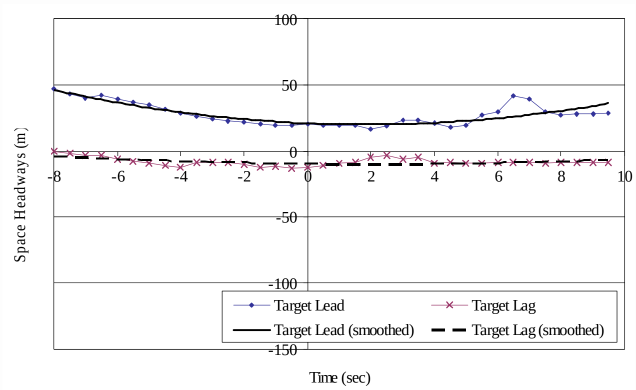


FIGURE 3 Space headway profiles in passenger car lane changing manoeuvres on arterials

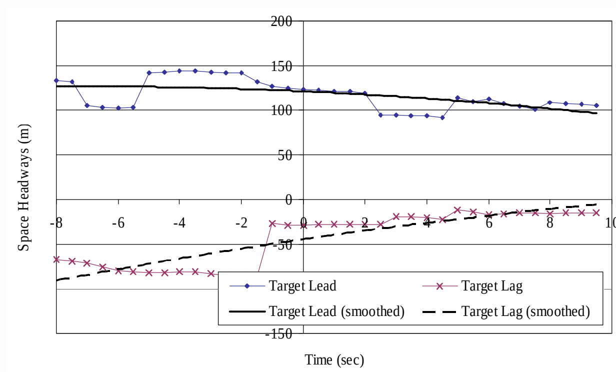


FIGURE 4 Space headway profiles in heavy vehicle lane changing manoeuvres on arterials

Figure 5 shows the speed profiles in passenger car lane changing manoeuvres on arterial roads. As it can be seen in this figure, passenger cars have almost a constant speed before the start of the lane changing and during the lane changing execution. However, Moridpour et al (2010c) reported passenger car drivers on freeways generally execute a lane changing manoeuvre to gain a speed advantage. This type of lane changing on freeways is a discretionary lane changing (DLC). This difference implies that having speed advantage may not be an important factor for passenger car drivers to change lanes on arterial roads. The subject vehicle drivers may change lanes to be in the correct path according to their route choice. This type of lane changing manoeuvres on arterial roads is a mandatory lane changing (MLC). In MLC, the subject vehicle driver may accept smaller gaps to execute the lane changing manoeuvre. MLC is often executed either through the target lag vehicle courtesy or by forcing the target lag vehicle. A comparison between the freeway and arterial space headways supports this hypothesis. Moridpour et al (2010c) reported that the target gap in passenger car lane changing was about 38 metres on freeways while the corresponding value in this study is about 22 metres. These findings specify that the lane changing behaviour of drivers on arterial roads is significantly different from that on freeways since the reasons for the manoeuvre and the lane changing types are mostly different.

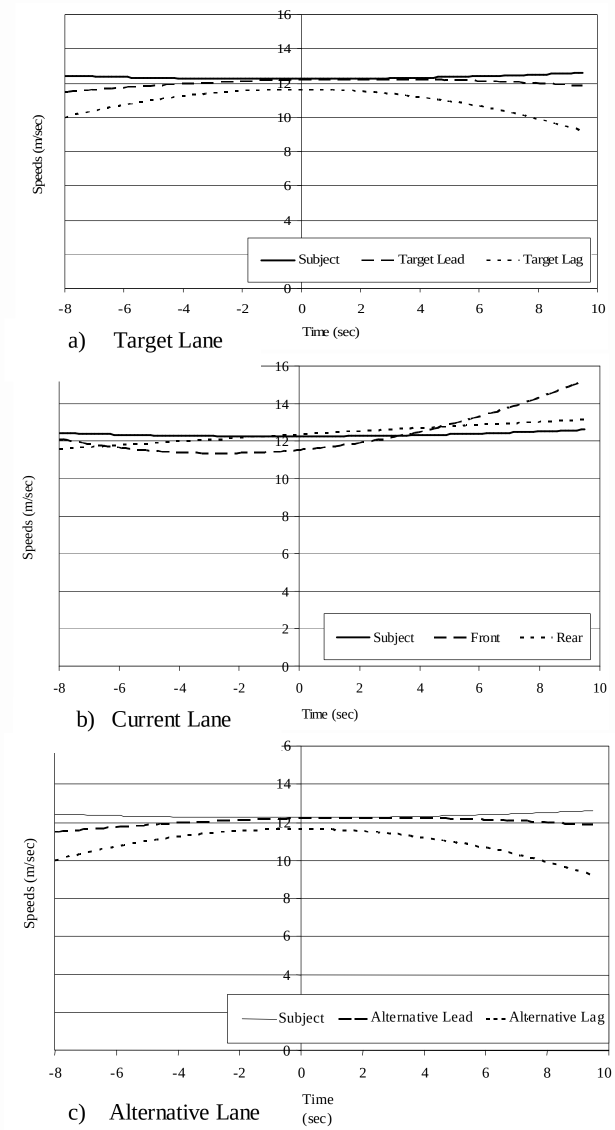


FIGURE 5 Speed profiles in passenger car lane changing manoeuvres on arterials

So far, it was found that the lane changing behaviour of passenger car and heavy vehicle drivers is different on arterial roads. It was also found that passenger car drivers' behaviour on arterial roads varies from that on freeways. The next step is the exploration of heavy vehicle drivers' behaviour on arterial roads and freeways. Recalling the previous study on freeway (Moridpour et al 2010c) can reveal that the space headway in the target lane during a heavy vehicle lane changing manoeuvre is almost 4 times greater that the corresponding value on freeways. This behaviour is in contrast to passenger car drivers' lane changing behaviour: passenger cars accept smaller space headways on arterial roads compare to freeways but heavy vehicles accept much larger space headways on arterial roads from those on freeways. The behaviour of passenger car drivers was explained before. The behaviour of heavy vehicle drivers during lane changing manoeuvres on arterials can be explained by considering Figure 6 and Figure 7.

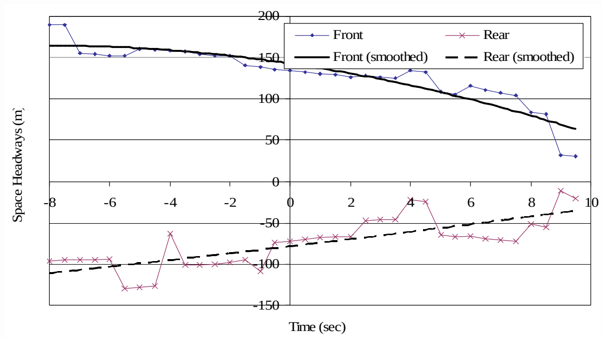
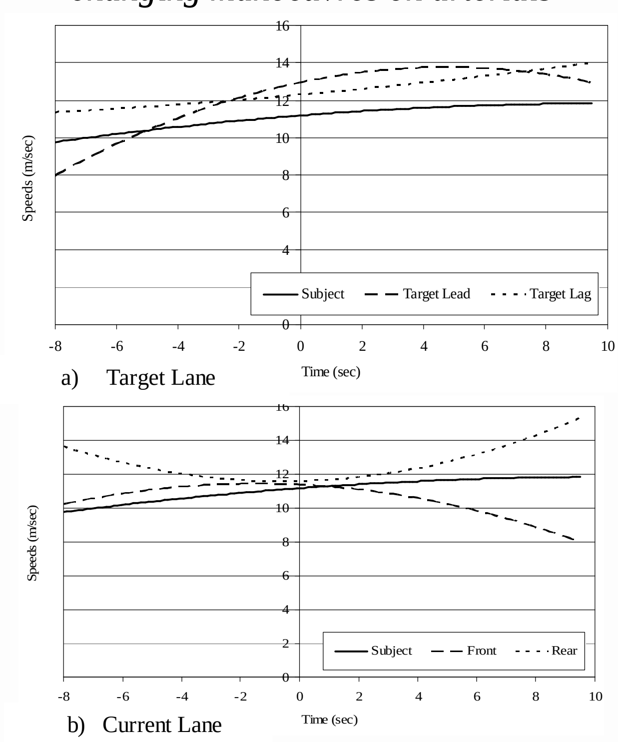
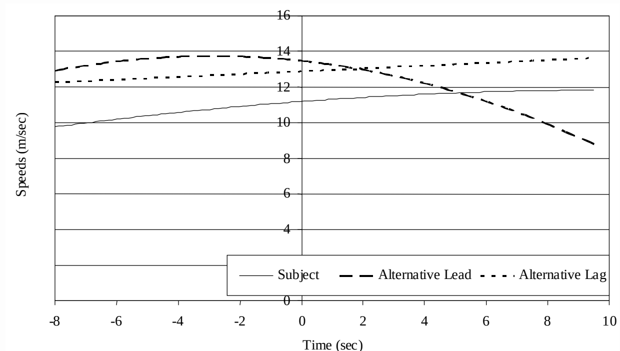


FIGURE 6 *Current lane space headway profiles in heavy vehicle lane changing manoeuvres on arterials*





C) Alternative Lane

FIGURE 7 Speed profiles in heavy vehicle lane changing manoeuvres on arterials

Figure 6 presents the space headway profiles in the current lane during heavy vehicle lane changing manoeuvres on arterial roads. According to this figure, heavy vehicle drivers prefer to change their lanes when the surrounding vehicles are far from their vehicles. Note that the distance between the intersections in the arterial site is not more than 200 meters. These drivers are not looking for speed advantages nor they want to let a faster vehicle to pass since the front and rear vehicles are very far from heavy vehicles (see also Figure 7). Such an opportunistic decision might be made due to a future plan with consideration of the lower manoeuvrability of the heavy vehicles and difficulties of lane changing execution on arterial roads. Although the level of service in the arterial road is “E”, such an opportunity may happen due to traffic interruptions caused by traffic lights. In arterial roads, the heavy vehicle drivers take advantage of the interrupted traffic to change lanes. On freeways, heavy vehicle drivers may force the target lag vehicle to reduce speed and provide enough space for heavy vehicles to execute lane changing manoeuvres.

It should be noted that the speed of the surrounding vehicles do not influence the heavy vehicle lane changing manoeuvre on arterial roads, since the vehicles are far from each other. Indeed, the speeds of vehicles are themselves affected by the traffic interruptions or maintaining the front gap in the car following process.

5- Conclusion

This paper highlighted a gap of knowledge extracted from an extensive literature review. It was pointed out that the existing lane changing models focus primarily on passenger cars and may not consider the behaviour of heavy vehicle satisfactorily. There is no model considering heavy vehicle lane changing manoeuvre on arterial roads. However, the existing microsimulations attempt to model this behaviour only by tuning the parameters of passenger car models.

This study compares the behaviour of passenger car and heavy vehicle drivers when executing a lane changing manoeuvre using a real world data set. It was found that the lane changing behaviour of passenger car drivers is significantly different from that of heavy vehicle drivers. It was also discussed that the lane changing behaviour of drivers on freeways differs from their behaviour on arterial roads. As a result, it was concluded that the existing models are not capable to replicate the lane changing behaviour of heavy vehicles on arterial roads.

Due to the limited data set used in this study the conclusions drawn from this work are tentative. Nevertheless, the results could serve as initial guidance for modelling heavy vehicle lane changing manoeuvre on arterial roads. Further, the results of this work could be of notable interest for researchers attempting to replicate heavy vehicle acceleration behaviour in micro-simulation models.

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