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Exploring Duration of Lane Change Execution

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Abstract

Microscopic traffic simulation models are efficient and widely-used tools in traffic and transportation system analysis. Most simulations consider the lane-changing manoeuver as the decision-making process and treat lane-changing execution as an instantaneous action. Studies of lane changing indicate that the lane-changing action duration is generally in the range of 1s to 16s. The omission of lane-changing execution will significantly affect the outputs of the simulation. This paper analyses the characteristics of lane-changing execution and hypothesizes the duration of lane change execution has the positive relation with the traffic conflicts between the subject vehicle and the surrounding vehicles. Observed field data was used to test this hypothesis. Then a lane-changing execution duration predictive model is proposed for passenger cars and heavy vehicles separately. The models are estimated by using the video data collected from an arterial road in Melbourne.

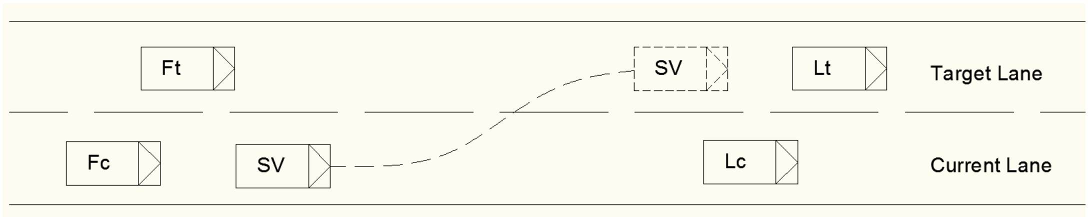
1. Introduction

Lane change is a behaviour that frequently occurs when vehicles are operating on arterial roads. Lane changes significantly affect the characteristics of traffic flow due to interference with the surrounding vehicles (Cassidy 1999; Hoogendoom 2001; Daganzo 2002; Mauch 2002; Banks 2003; Coifman et al. 2003; Laval 2006; Tang et al. 2007; Zhang et al. 2009; Jin 2010). Previous research and field observation show the duration of lane change ranges from 1.0s to 16.5s (Worrall et al. 1970; P.Finnegan et al. 1990; D.Chovan et al. 1994; S.Hetrick 1997; Tijerina et al. 1997; Hanowski et al. 2000; Toledo 2007b; Moridpour et al. 2010b). It is important to study the execution of lane changing and find out the influence factors leading to the different duration of lane change.

Microscopic traffic simulation is an efficient and widely-used tool in traffic and transportation system analysis. In order to improve the application of microscopic traffic simulations, it is important to increase the accuracy of drivers' behaviours models, like lane change models and car following models. Most of the existing lane change models emphasize the decision-making aspects (Gipps 1986; Yang et al. 1995; Ahmed 1999; Das 1999; Toledo 2007a; Xu 2007; Choudhury 2010), and few study the execution of lane changing. However the difference in duration of lane change indicates that the omission of lane change execution may have a significant impact to the traffic simulation process.

The subject vehicle's (SV) operational characteristics and the interaction between the SV and the surrounding vehicles may affect the execution (see Figure 1). In this paper, lane change execution types are classified as free lane change and forced lane change (FLC) according to the location of the surrounding vehicles. Traffic conflict is used as the indicator to explain the surrounding traffic conditions. FLC is defined as that kind of lane change where there is a traffic conflict with one or more surrounding vehicles during the lane changing event. Free lane change is a kind of lane change without any traffic conflict during the lane changing event.

Figure 1 Graphical representation of lane change



This paper will investigate the lane change execution characteristics, the factors influencing the duration of the execution and present an exploratory duration model of lane changing with respect to the surrounding traffic conditions.

2. Literature Review

Given the importance of lane changing in traffic situations, there are many research studies focusing on lane change decision-making over the past 30 years. However only recently have a small number of researchers mentioned lane change execution. These will be discussed below.

Toledo(2007b) studied the duration of lane change action and used the trajectory data from NGSIM dataset to estimate the lane changing duration to avoid the shortcoming of collected data by instrumented vehicles or driving simulator. His research indicated that lane changing duration was affected by traffic density, the direction taken to the adjacent lane and the character of the surrounding vehicles. In order to ensure the predicted lane-change durations are nonnegative, he proposed the following model:

$$\ln(d_n) = \beta X_n + \epsilon_n \qquad (1)$$

Where,

d_n = lane-change duration for diver *n*;

X_n =vector of explanatory variables;

β =corresponding parameters; and

ϵ_n =error term associated with observation.

In his research, he found the lane-changing behaviour of heavy vehicles differs from that of passenger cars. Therefore he gave the parameter values separately (See Table 1 and 2).

Table 1 Estimation results of passenger car lane-changing duration model (Toledo 2007b)

Variable	Parameter Value	*t*-Statistic
Constant	1.114	19.8
Traffic density (veh/km/lane)	0.01001	10.5
Change direction (left = 1, right = 0)	0.06314	2.04
min [0, ΔV_n^{front}] (m/s)	0.02470	3.99
Front vehicle spacing (m)	–0.0009627	1.93
min [0, $\Delta V_n^{lag,lead}$] (m/s)	0.01516	2.17
max [0, $\Delta V_n^{lag,lead}$] (m/s)	–0.01187	–1.81
Lag–lead spacing (m)	–0.001064	–3.83

Number of observations = 1,518, $R^2 = 0.205$, adj $R^2 = 0.201$.

Table 2 Estimation results of heavy-vehicle lane-changing duration model (Toledo 2007b)

Variable	Parameter Value	*t*-Statistic
Constant	0.790	6.25
Traffic density (veh/km/lane)	0.02104	5.50
Change direction (left = 1, right = 0)	–0.178	–1.76
max [0, ΔV_n^{front}] (m/s)	–0.04775	–2.91
ΔV_n^{ave} (m/s)	0.02972	2.13

Number of observations = 112, $R^2 = 0.300$, adj $R^2 = 0.274$.

He concluded that lane changing durations were longer when the manoeuvrer is risker or when the task is complicated by the relation of the subject vehicle (SV) with other vehicles. This result shows the interaction between the subject vehicle (SV) and the surrounding vehicles affects the lane change event greatly.

Ramanujam (2007) studied an lane changing execution model for arterial traffic. He assumed lane changing execution decision was the third decision of drivers, following the target lane choice decision and gap acceptance decision, and it was a binary choice, with the alternatives being whether to execute a lane change or not to execute it in the current time instant. He used the random utility and corresponding systematic utility proposed by Toledo (2007a), and shown below:

$$U_{nt}^{l_{nt}} = \begin{cases} \beta X_t + \alpha^{l_{nt}} v_n + \varepsilon_{nt} & if\ l_{nt} = 1\ or\ -1 \\ 0 & if\ l_{nt} = 0 \end{cases} \quad (2)$$

$$V_{nt}^{l_{nt}} = \begin{cases} \beta X_t + \alpha^{l_{nt}} v_n & if\ l_{nt} = 1\ or\ -1 \\ 0 & if\ l_{nt} = 0 \end{cases} \quad (3)$$

Where,

$U_{nt}^{l_{nt}}$: the utility of execution lane changing to driver *n* at time *t*;

$V_{nt}^{l_{nt}}$: the systematic utility of alternatives;

l_{nt} :an indicator variable for the choice at this decision level, and defined as:

$$l_{nt}=\begin{cases} 1 \; or -1 & if \; execution \; lane \; change \; to \; left \; or \; right \; respectively \\ 0 & if \; not \; executing \; lane \; change \end{cases}$$

X_t : a vector of explanatory variables characterizing the decision to execute a lane change at the current time instant t;

β : the corresponding vector of parameters;

$\alpha^{l_{nt}}$:the parameter of the driver-specific random error term v_n that is used across the three decision levels and represents his individual characteristics; and

ε_{nt} : the random term.

Ramanujam (2007) proposed a binary logit execution model based on the utility calculated before, and a model of the form shown below:

$$P(l_{nt} | AG_{nt}, v_n) = \begin{cases} \frac{1}{1+\exp\left(-V_{nt}^{l_{nt}}\right)} & if \; AG_{nt} = \{1, -1\} \\ 0 & if \; AG_{nt} = 0 \end{cases} \quad (4)$$

Moridpour (2010a; 2010b) studied the lane changing execution of heavy vehicles in lane changing on freeways and related it to lane changing duration, speed and acceleration. She analysed the lane-change execution characteristics of heavy vehicles and passenger cars (see Table 3). She focused on the acceleration and deceleration behaviours during lane-change execution, and proposed acceleration models and deceleration models for heavy vehicles and passenger cars separately (Equations 5 to 8). She estimated the parameter values for these models.

Table 3 Lane-change characteristics of heavy vehicles and passenger cars (Moridpour 2010)

Variable	Mean	Standard Deviation	Minimum	Maximum
Heavy Vehicles				
Lane-changing duration (s)	8.0	3.7	1.6	16.2
Speed[a] (m/s)	8.6	0.5	7.4	9.1
Speed changes at each 0.5-s interval (m/s)	0.1	0.1	0.0	0.5
Passenger Cars				
Lane-changing duration (s)	4.8	2.1	1.1	8.9
Speed (m/s)	9.2	1.1	8.6	11.7
Speed changes at each 0.5-s interval (m/s)	0.2	0.3	0.0	1.0

$$a_H(t+\tau_H) = \alpha \times v_H(t+\tau_H) \times \frac{\Delta v_{lag}(t)^{\beta}}{\Delta x_{front}(t)^{\delta}} \quad (5)$$

$$d_H(t+\tau_H) = \alpha \times v_H(t+\tau_H)^{\beta} \times \frac{\Delta v_{lag}(t)^{\delta}}{\Delta x_{front}(t)^{\gamma}} \quad (6)$$

$$a_P(t+\tau_P) = \alpha \times v_P(t+\tau_P)^{\beta} \times \frac{\Delta v_{rear}(t)^{\delta}}{\Delta x_{front}(t)^{\gamma}} \quad (7)$$

$$d_P(t+\tau_P) = \alpha \times v_P(t+\tau_P)^{\beta} \times \frac{\Delta v_{lag}(t)^{\delta}}{\Delta x_{front}(t)^{\gamma}} \qquad (8)$$

Where,

$a_H(t+\tau_H)\ /d_H(t+\tau_H)$: heavy vehicle acceleration/deceleration measured at time $t+\tau_H$ (m/s^2),

$a_P(t+\tau_P)\ /d_P(t+\tau_P)$: passenger car acceleration/deceleration measured at time $t+\tau_H$ (m/s^2),

$v_H(t+\tau_H)\ /v_P(t+\tau_P)$: heavy vehicle/ passenger car speed measured at time $t+\tau_H/\ t+\tau_P$ (m/s),

$\Delta v_{lag}(t)$: lag relative speed in target lane at time *t* (m/s),

$\Delta x_{front}(t)$: front space gap in current lane at time t (m),

$\Delta v_{rear}(t)$: rear relative speed in the current lane at time *t* (m/s),

τ_H/τ_P : reaction time of heavy vehicle/ passenger car drivers, and

$\alpha, \beta, \gamma, \delta$: parameters.

Previous studies of lane changing duration are shown in Table 4. It can be seen that the range of lane change duration is wide, from a minimum 1.0s to maximum 16.5s. Some reasons to explain that phenomena are the different vehicle types and the different road types. And there is another reason a few studies have mentioned. It is the different definition of the initiation and completion of lane changes. For example, some researches define the initiation of lane change as the drivers' intention of lane change, some define it as the first movement from the current lane to the target lane. Moreover, some of the lane-change definition is difficult to use in traffic simulation, for example, in some researches it is assumed that lane change is initiated when the driver decides to change lane, which is impossible to detect in simulation.

Table 4 Previous study of lane changing duration

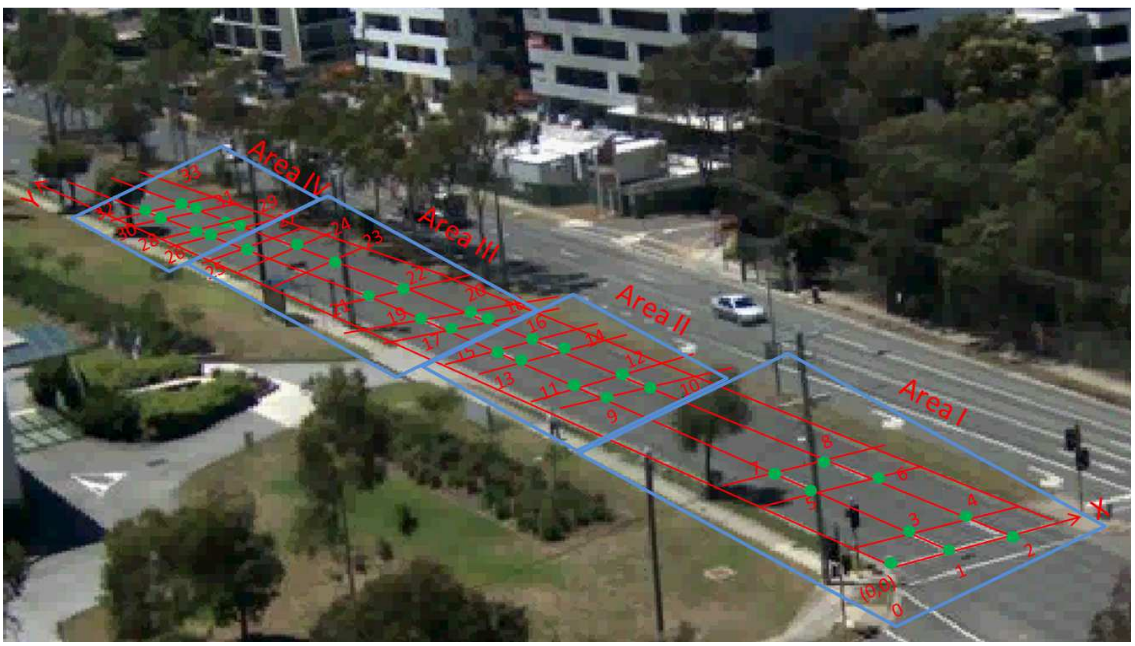
Source	Range	Notes
Worrall (Worrall et al. 1970)	2.3s~4.1s	
Finnergan (P.Finnegan et al. 1990)	4.9s~7.6s	Including visual search time
Chovan (D.Chovan et al. 1994)	2.0s~16s	
Tijerina (Tijerina et al. 1997)	3.5s~6.5s	City streets
	3.5s~8.5s	Highway
Hetrick (S.Hetrick 1997)	3.4s~13.6s	City and highway segments
Hanowski (Hanowski et al. 2000)	1.1s~16.5s	Local short-haul truck, speed <45mph
Todelo (Toledo 2007b)	1.0s~13.3s	Heavy vehicles and passenger cars
Moridpour (Moridpour et al. 2010b)	1.6s~16.2s	Heavy vehicles
	1.1s~8.9s	Passenger cars

Yet there might be another possible reason could be the traffic conflicts between the SV and the surrounding vehicles affecting the execution of lane change. The existence of traffic conflicts might lead to longer lane change execution time and different driver's behaviour (such as accelerate or decelerate) to complete lane-change and to avoid a collision. Moreover, the severe conflicts may cause the failure of lane changes.

3. Data Collection and Processing

The previous studies have indicated a variation in the execution of lane changing. There is a need to understand this variation. This paper presents that analysis of a study of lane changing execution on an arterial road (posted speed limit 70km/h) in the suburb of Clayton in Melbourne (see Figure 2) between 2pm~3pm on 17th December, 2012. The data was collected from a by video camera mounted on a high building adjacent to the road. The weather on the data collection day was clear with no precipitation, good visibility and dry pavement condition. This arterial road has 3 lanes in each direction. The observed field is from south to north, and the total observed length is 140m. A car was parked at the northern end in the outmost lane to replicate a situation where the road reduces from three to two lanes. To record every movement of the lane change manoeuvre, a mesh of points of 0.2 seconds was created and used in the automatic screenshot software.

Figure 2 Demarcated areas and standard points on road



To build the connection between the video image to the real road plane, the method of two dimensional projective coordination(Horst 1990; Feng 2009) is used. The transformation of video image coordinates (x,y) to real road coordinates(X,Y) is given by using the two-dimensional direct linear transform formula presented in Equation 9.

$$\begin{cases} X = \frac{l_1x+l_2y+l_3}{l_7x+l_8y+1} \\ Y = \frac{l_4x+l_5y+l_6}{l_7x+l_8y+1} \end{cases} \quad (9)$$

Where, (x,y) =video image coordinates; (X,Y)= real road coordinate; $l_1 \sim l_8$= parameters which have relation with camera at position, focal length, physical coordinate system, photographic angle.

The coefficients $l_1 \sim l_8$ can be calculated if the coordinates of at least four standard points are known both in the video-image and on the road plane. It is obvious that the four standard points themselves have small errors in measurement, which might largely influence the accuracy of transformation. To minimise the errors, more standard points are needed to calculate in an iterative progress. An improve function presented in Equation10 is used to get the optimised outcomes. In this research, we defined totally 34 standard points which have the known x and y coordinates both in the video image and on the real road plane. Those standard points (point 0 ~ point 33) are shown in Figure 2.

$$\mathrm{F} = \sum_{k=1}^{n} \left[\left(Y_k - \frac{l_4 x_k + l_5 y_k + l_6}{l_7 x_k + l_8 y_k + 1}\right)^2 + \left(X_k - \frac{l_1 x_k + l_2 y_k + l_3}{l_7 x_k + l_8 y_k + 1}\right)^2 \right] \qquad (10)$$

To minimise errors, the observed field was derived into 4 areas (area I, area II, area III, area IV in Figure 2). A Matlab program is applied to calibrate the parameters. The calibrated results of direct linear transform parameters are shown in Table 5 and the error analysis in Table 6.

Table 5 Calibrated results of direct linear transform parameters

Area	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8
I	0.2840	1.5679	507.7720	0.1057	1.4766	514.3212	0.0004	0.0035
II	1.3231	1.9981	506.7557	1.3146	2.0081	525.6513	0.0025	0.0042
III	0.0474	3.1625	505.8886	-0.0784	3.3927	532.5045	.0000	0.0066
IV	0.7249	2.9157	505.3933	0.8876	3.5492	616.4176	0.0014	0.0058

Table 6 Error analysis of the each area

No.	Area	Image coordinate		Calculated Distance(m)	Expected Distance(m)	Difference(m)	Error Ratio	Direction
		x	y					
1	I	369	227	21.08474	21	0.08474	0.40%	Longitudinal
		295	195					
2		425	254	3.056959	3.15	-0.09304	-2.95%	Horizontal
		448	247					
3	II	276	177	9.198569	9	0.198569	2.21%	Longitudinal
		314	192					
4		256	179	3.294433	3.15	0.144433	4.59%	Horizontal
		276	178					
5	III	196	154	3.153461	3.15	0.003461	0.11%	Longitudinal
		210	150					
6		203	148	11.65129	12	-0.34871	-2.91%	Horizontal
		234	157					
7	IV	124	128	3.363852	3.15	0.213852	6.79%	Longitudinal
		139	123					
8		127	129	14.59182	12	2.591825	21.60%	Horizontal
		135	129					

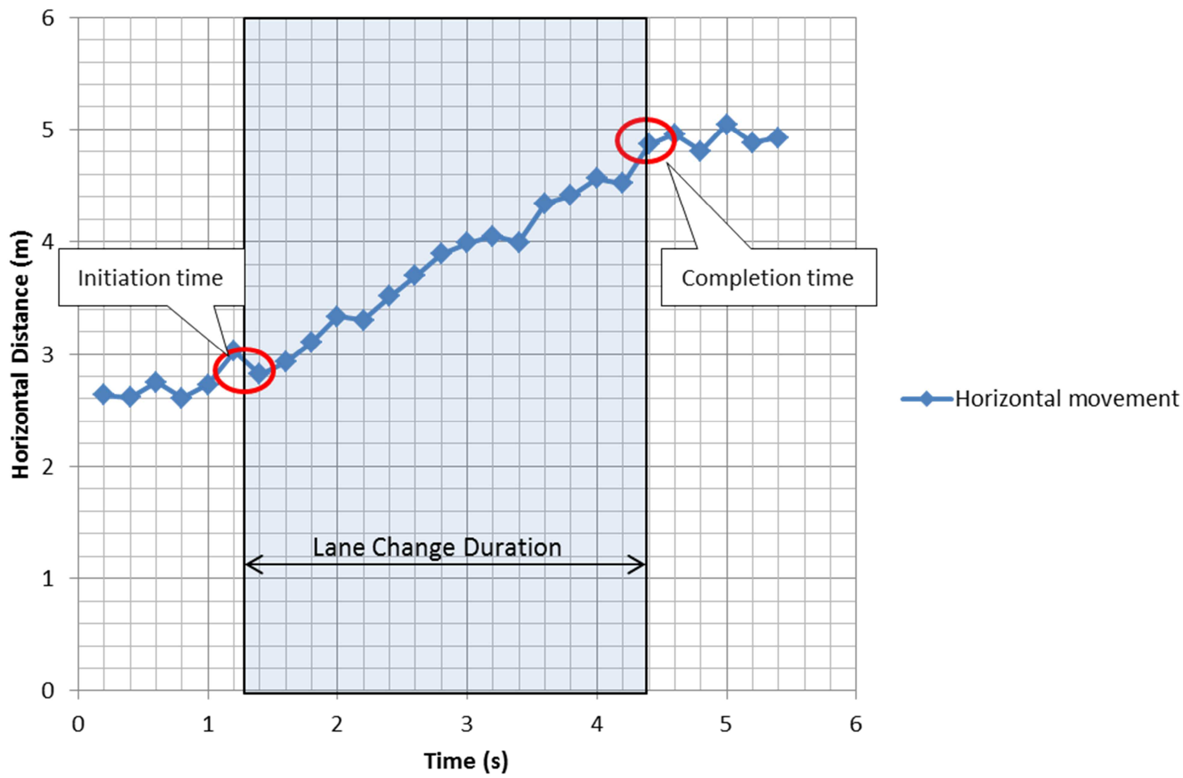
According to Table 6, area I ~III's error ratios in longitudinal direction are less than 2.3%, which means in 100 meters' measuring the error range is less than 2.3m; in horizontal direction, area I ~III's error ratios are less than 4.6%, which means in 10 metres' measuring the error range is less than 0.46m. This research is measuring the lane changing trajectory, the horizontal movement will approximately be 3.5m (the general width of one lane), therefore the maximum error for the recording for this research will be 16cm. So the data from area I ~III will meet the accuracy requirement and could be accepted. However, both the longitudinal and horizontal error ratios of area VI are large, which may lead to the mistakes when recording the trajectory of vehicles. In terms of the accuracy concern, only the lane changes during area I~III will be recorded.

4. Data Analysis

There are totally 192 successful lane changes during the observation period, among which 111 lane changes are in area I~III. These are studied in detail. Among the identified lane changes, 42 (38%) are heavy vehicles and 69 (62%) are passenger cars. Hyden(Hyden 1996)defined different conflict levels according to different Deceleration Rate(DR). According to his conflict levels definition, the traffic conflict exists when the DR<-1 m/s^2. Therefore the lane change will be identified as the forced lane change, if the subject vehicle or the surrounding vehicles has DR<-1 m/s^2 during lane change execution. From the collected data, there are totally 49 free lane changes (44%), and 62 forced lane changes (56%).

The beginning of a lane change is defined using criteria adopted from Lee (2004): The start of the lane change occurs when the vehicle begins to move laterally relative to the source lane. The completion of the lane changes is when the whole body of vehicle has been moved into the target lane and no more lateral movement occurs. More specifically, in the video data processing of the lane change duration is defined as shown in Figure 3. The initiation time of lane change is the time when the SV is still driving in the current lane and is about to swerve out. The completion time is at the point that after crossing a lane, the SV is driving longitudinally and no obvious lateral movement occurs in the new lane.

Figure 3 Definition of lane change duration of the observed data



The trajectories of the vehicles are recorded separately based on difference in the lane change types (free or forced) and vehicle types (passenger cars or heavy vehicles). The positions of the subject vehicle is recorded every 0.2s by the (X,Y) coordinates. The coordinate origin (0,0) is shown as the standard point 0 in Figure 2. Every gap between two points in the figure means the distance the vehicle is traveling in 0.2s. The starting endpoint and the ending endpoint represent the starting position and the ending position of the vehicle. Figure 4a and 4b present the free lane change trajectory and forced lane change trajectory of passenger car. Figure 5a and 5b present the free lane change trajectory and forced lane change trajectory of heavy vehicle.

It can be seen from Figure 4a and 4b that, for passenger car there are more points during FLC execution (23 points) than that during free lane change execution (17 points). This indicates that vehicles making FLC execution spends more time than those in free lane change execution.

It can be seen from Figure 5a and 5b that, for heavy vehicle there are more points during FLC execution (50 points) than that during free lane change execution (20 points). This indicates that heavy vehicles making FLC execution spend more time than those in free lane change execution. It also can be found out that heavy vehicle drivers spend more time on lane changing than do passenger car drivers.

Figure 4a Free LC trajectory of passenger car(PC)

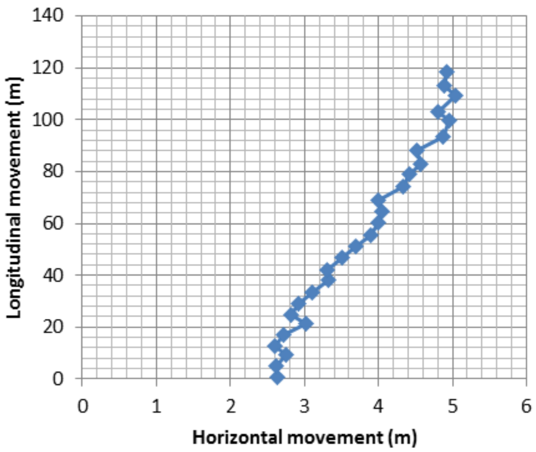


Figure 4b FLC trajectory of PC

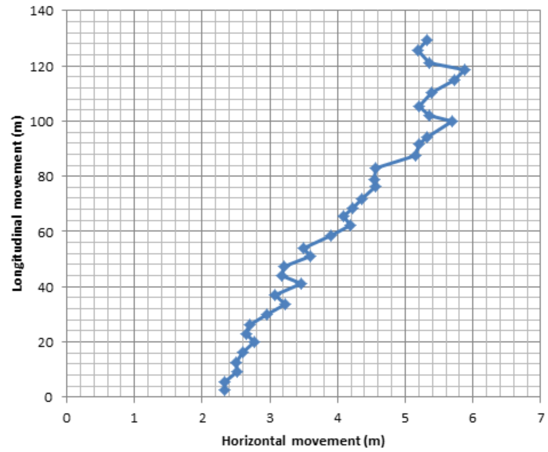


Figure 5a Free LC trajectory of heavy vehicle(HV)

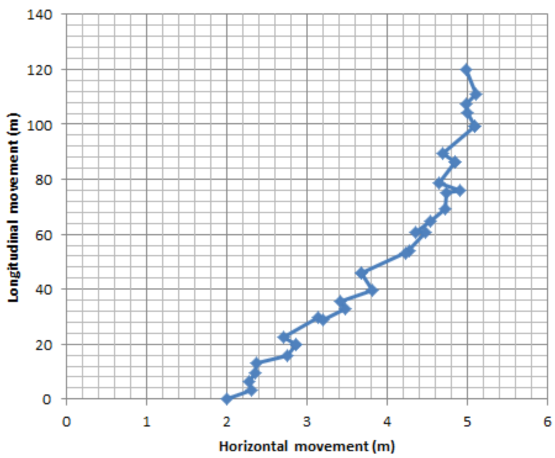
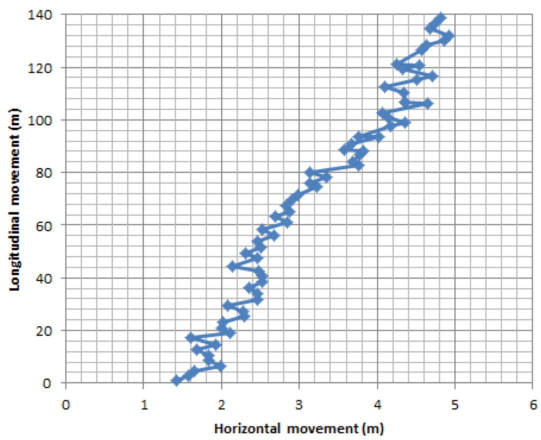


Figure 5b FLC trajectory of HV



Further analysis for free lane changes of passenger car trajectories shows that in relation to the position in the current lane the SVs' swerving angles are from 47°. When they enter the target lane, their trajectories are more spread (see Figure 6).

While the FLC trajectories (see Figure 7) of passenger car trajectories shows that in relation to the position in the current lane the SVs' swerving angles are from 55°. This is larger than that in free lane changes. The possible reason is the SVs are adjusting their horizontal movements to avoid the collision to the surrounding vehicles. When the SVs enter the target lane during FLC, the trajectories are mostly gathered in a region, not as spread as those in free lane changes. This is because that the SV's driving behaviours are depend on the surrounding vehicles.

Figure 6 Trajectories analysis for free lane changes of passenger car

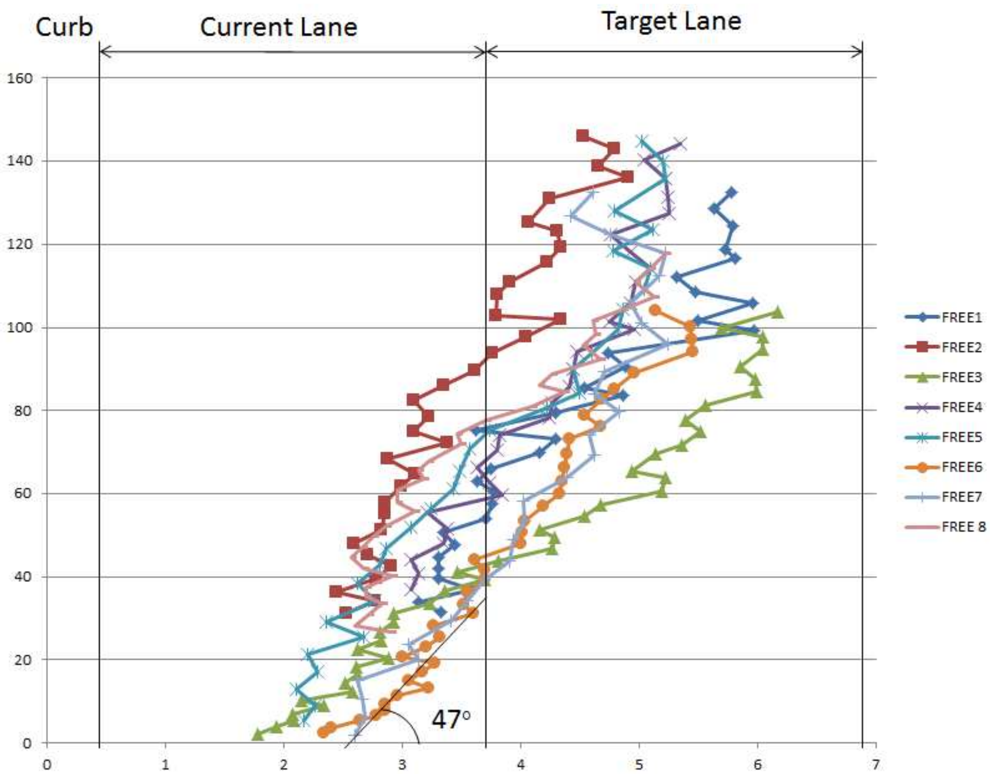


Figure 7 Trajectories analysis for forced lane changes of passenger car

However the trajectory of heavy vehicle exhibits a completely different characteristics from that of passenger car (see Figure 8 and 9). The swerving angles in the current lane for both free lane change and forced lane change are similar (42° and 39°). The free lane change has wider swerving angle ranges, which means the trajectories are more spread. While the swerving angles of forced lane change are bounded in a narrower specific range. The trajectories of forced lane changes and those of some free lane changes are similar. A possible reason for that is most of heavy vehicles can only follow some certain lane changing trajectory due to their large physical sizes, and the main difference between free lane change and forced lane change is the lane changing speed.

Figure 8 Trajectories analysis for free lane changes of heavy vehicles

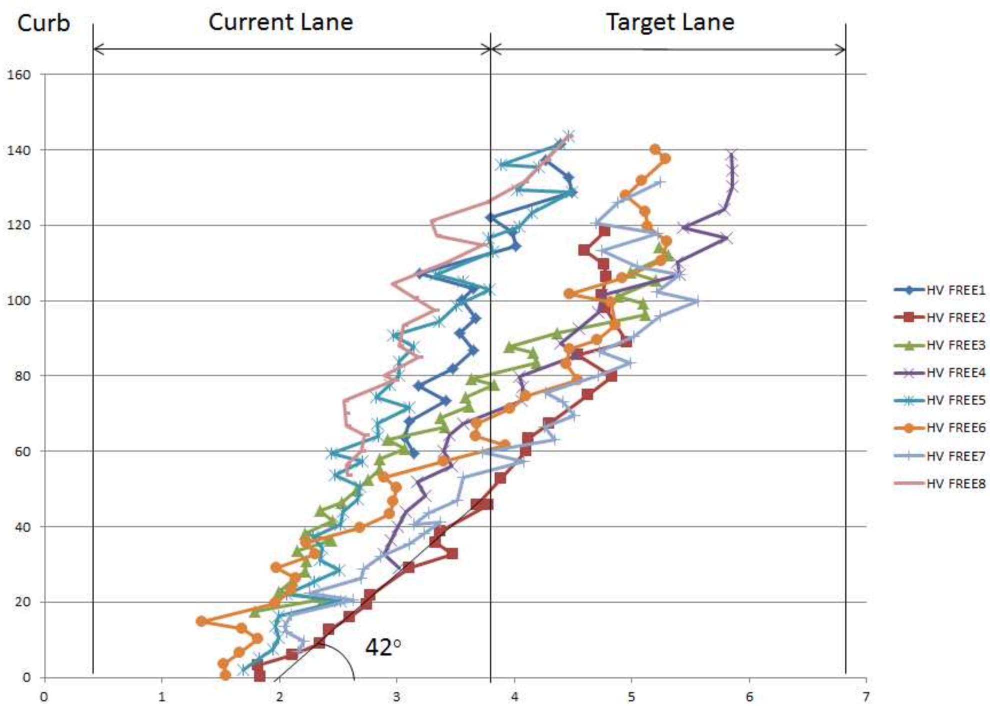


Figure 9 Trajectories analysis for forced lane changes of heavy vehicles

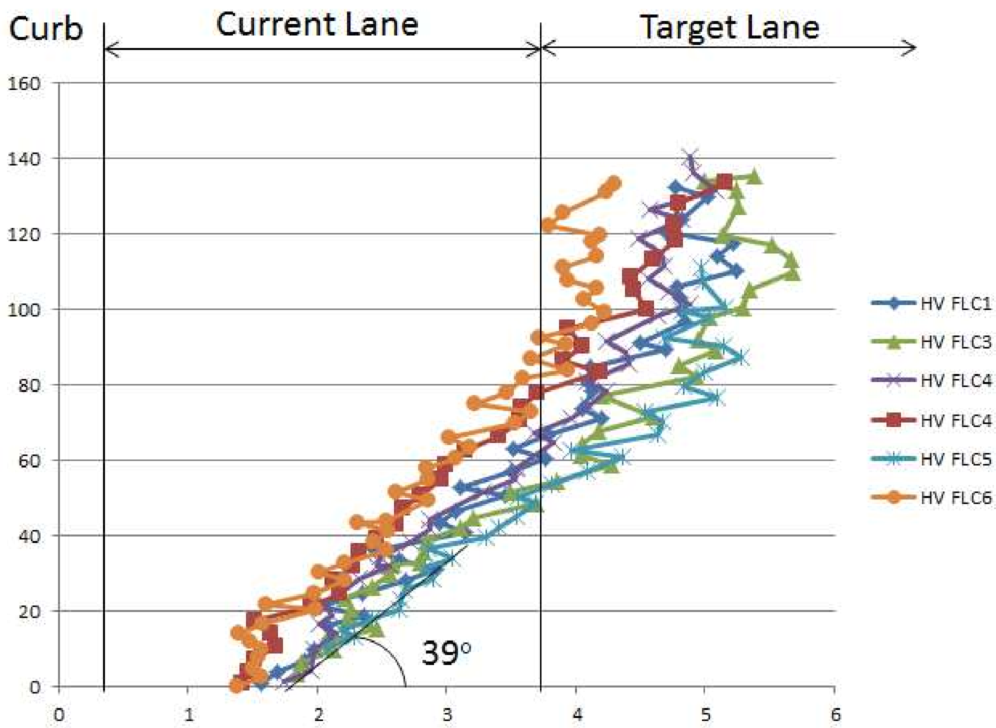


Table 7 shows the summary statistics for lane change execution duration based on both the lane change types and vehicle types. It can be seen that heavy vehicles take more time for implement lane changing than passenger cars, and in both vehicle types forced lane changes spend more time than free lane changes.

Table 7 Summary statistics of lane change execution duration

Vehicle Type	Lane Change Type	Sample Size	Duration(s)				
			Mean	Median	Standard Deviation	Minimum	Maximum
Heavy Vehicle	-	42	4.01	4	1.25	2	9.8
Passenger Car	-	69	2.54	2.2	1.29	1	6.8
Heavy Vehicle	Free Lane Change	23	3.56	3.4	0.83	2	5
	Forced Lane Change	19	4.57	4.2	1.45	2.6	9.8
Passenger Car	Free Lane Change	26	1.55	1.4	0.29	1	2.2
	Forced Lane Change	43	3.24	2.8	1.25	1.8	6.8

The Wilcoxon–Mann–Whitney test with statistical significance established at 5% level is employed to detect statistical differences between the duration of free lane change and the duration of forced lane change in different vehicle types. The result in Table 8 ($p<0.05$) indicates that the difference in duration of heavy vehicle is statistically significant compared to the duration of passenger cars. For the duration of the free lane change and that of forced lane change, the result in Table 8 ($p<0.05$) indicates that, for both heavy vehicles and passenger cars, the difference in duration of forced lane change is statistically significant compared to the duration of free lane change.

Table 8 Results of Wilcoxon–Mann–Whitney test

Vehicle Type	P-Value	Lane Change Type	P-Value
Heavy Vehicle(HV)	1.921e-08	HV-Forced Lane Change	0.02602
		HV-Free Lane Change	
Passenger Car(PC)		PC-Forced Lane Change	1.142e-10
		PC-Free Lane Change	

5. An exploratory lane change duration model

The relationship between the lane changing duration and the variables influencing it can be explored using a regression equation:

$$T_n=\alpha_0+\alpha_n x_n+\varepsilon \qquad (11)$$

Where,

T_n= lane change duration for driver *n*;

α_0= constant;

x_n= vector of explanatory variables;

α_n= corresponding parameters; and

ε = error term.

The previous data analysis shows that the existence of conflicts has a relationship with the lane change execution duration. This factor should be included. The lane change conflict is described as a dummy variable, “0” for non-conflict, that is free lane change; “1” for conflict, that is forced lane change.

There may be other factors affecting lane change duration. Toledo (2007b) indicated that the following factors may influence lane change execution: traffic density, change direction, subject vehicle’s velocity, velocity difference with the lag vehicles and gaps between subject vehicle and lag vehicle.

The conflicts are identified by the deceleration rate (DR) during lane change manoeuvres in this research, and the conflict between SV and the following vehicle is calculated by the velocity difference and the distance. Since the deceleration rate and the conflict between SV and the following vehicle are directly related to the conflict variable described above, there should not be included in the relationship. The surrounding conflicts variables takes both these variables into account.

Because of the limitation of the data collection, almost all lane changes are from left lane to right lane. Lane change direction couldn't be used as an explanatory variable in this model.

The estimation results of heavy vehicle and passenger car are presented in Table 9 and 10.

Table 9 Estimation results of heavy vehicle lane-changing duration model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.5429	0.1640	21.601	<2e-16
Conflict	0.7349	0.2414	3.044	0.00428
Density	0.05059	0.01314	3.85	0.000452
Velocity	-0.08027	0.04246	-1.890	0.0666

R^2=0.2003, adjusted R^2=0.1787

Table 10 Estimation results of passenger car lane-changing duration model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.5462	0.1954	7.911	3.48e-11
Conflict	1.6306	0.2476	6.586	8.28e-09
Density	0.05670	0.01168	4.853	7.60e-06
Velocity	-0.14308	0.05296	-2.702	0.00873

R^2=0.3930, adjusted R^2=0.3839

Both estimated results of conflict are significant at 95% confidence. This reinforces the fact that the lane change conflict is an influence factor to the lane change execution duration. The estimated coefficients of other variables are significant at 95% confidence, except that of velocity for heavy vehicle lane changing duration model which is at 90% confidence. A possible reason for that is heavy vehicles always maintain the stable and slow speed during normal driving operation and lane changing operation due to their large physical sizes.

The result dedicates that the lane change conflict is an influence factor to the lane change execution of both passenger cars and heavy vehicles.

6. Conclusion

Lane changes have a significant impact on the characteristics of traffic flow. However most of the lane change research has focused on the lane change decision-making models, and generally neglected lane change execution. Most traffic simulations consider the lane changing execution as the instantaneous action as the decision-making section. This paper analyses lane change execution trajectory and duration. The results indicate that traffic conflict during a lane change event is an influential factor in lane change execution. Previous research indicated that lane change duration is longer when the manoeuvre is risker or when the task is complicated by the interrelationship between the SV and the surrounding vehicles. Such situation can be explained and also quantified by traffic conflict.

Further research will focus on the lane change execution acceleration and deceleration by using the indicator of traffic conflict, and focus on improving the lane change execution simulation models in order to develop the more accurate output of traffic simulation. Although the data collected site is considered to be representative of typical arterial roads in suburb areas (with the signalised intersections spaced 1.6km apart), it is likely that results will differ from lane changes just after an intersection to the other scenarios (i.e. lane change along road corridors, or lane change immediately after a turn). Further work will explore that in the future. Since it is legally permitted for 2-wheelers (motor bicycles and bicycles) to share roads with vehicles on arterial roads, it can occur that the vehicles change lane to avoid following the slow 2-wheelers. Future research will also put effort on the lane change execution characters of the subject vehicle with the impact of 2-wheelers.

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