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A study of traffic conflict with surrounding traffic during mandatory lane-changing execution

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Abstract

Lane change models are one of the basic driver behaviour interactions in microscopic traffic simulations of traffic, safety and transportation system analysis. However, many of the present traffic simulations mostly pay attention to the lane changing decision process, while the lane change execution process is often simplified or even ignored. This paper presents a study of mandatory lane change (MLC) execution and proposes a surrounding traffic impact model on MLC. It studies lane changing behaviours on an arterial road where there is a block occurring on the curb-side lane to investigate the execution process. When the mandatory lane-changing vehicle shifts from the current lane to the target lane, the driver adjusts its lane-changing execution behaviour to complete lane change safely by evaluating the conflict with the direct surrounding vehicles. It is assumed that the driver will adjust its execution if a surrounding conflict is detected and will continue the lane change if there is no conflict around. A probability model is proposed to interpret the surrounding traffic impact to driver's choice during the period of lane change execution. The surrounding traffic impact model associated with conflicts was estimated in this paper. In the conclusion, the paper provides a framework for future work in lane change execution models of traffic simulation to assess the traffic safety and road efficiency.

Key words: Lane change behaviour; Lane change conflict detection; Discriminant analysis method; Microscopic traffic simulation.

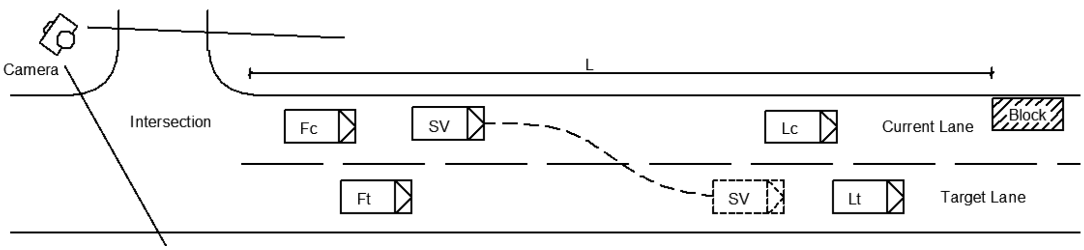
1. Introduction

Lane changing is a common driver behaviour that occurs when vehicles are operating on roads. Furthermore, mandatory lane changes (MLC) frequently occur on arterial roads when the drivers are shifting to the target lane at the intersection or approaching to a block or breakdown ahead. Different from the Discretionary lane change (DLC), which the driver perform to improve the driving speed, MLC has to be completed, moreover it needs to be completed before some certain point. Dividing the lane change into a series of stages is a convenient framework for analysing the entire individual lane change process. Lane change execution is the phase following the lane change is generated (D.Chovan, L.Tijerina et al. 1994, Louis Tijerina 2005). Many existing lane change models and those in the traffic simulations emphasize the lane change generation and pay little attention to the lane change execution. The lane change generation phase is the time interval from when drivers desire to change lane until they start the steering manoeuvre which is the initiation point of the lane change execution phase. The execution phase is the following phase, which starts from the initiation point and ends when the lane changing vehicle is stabilized in the target lane.

The wide range of lane change durations and different shapes of lane change trajectories from the investigation of previous studies, to some extent, reveal the lane change execution differs from one to another. Most existing traffic simulations pay few attention to lane change execution. Some consider the subject vehicle remains the same status during the whole execution process; moreover some just ignore the execution process. However, the observation of the durations and trajectories during lane change execution in real life reveals that those assumption contravenes the reality. To explore the execution of lane changes thus becomes important. There are many researches on MLC generation, while there are few about MLC execution. It is worth being studied to understand MLC deeply and improve the lane change models in traffic simulations.

This paper investigated the MLC in a certain traffic situation, where a curb lane is blocked by a parking car and focuses on the surrounding traffic impact to the lane change behaviour. The graphical representation of lane changes is presented in Figure 1. The subject vehicle's (SV) operational characteristics and the interaction between the SV and the surrounding vehicles (Lt, Ft, Lc, Fc) may affect the execution. In this study all lane changes are MLCs since the vehicle must move out of the blocked lane if they wish to proceed.

Figure 1 Graphical Representation of Lane Changing



Note: Lc: leading vehicle in the current lane; Fc: following vehicle in the current lane; Lt: leading vehicle in the target lane; Ft: following vehicle in the target lane

2. Literature review

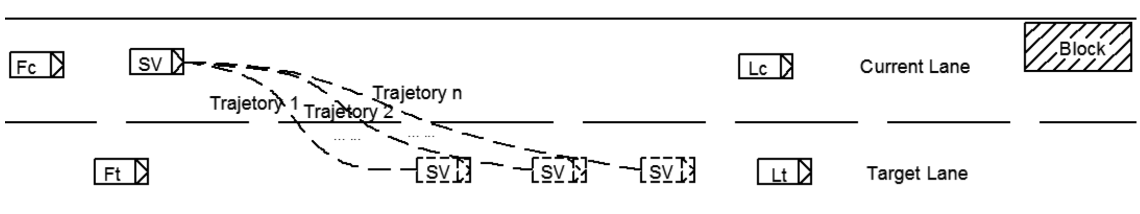
Lane change models are one of the basic driver behaviour interactions in the microscopic traffic simulations for traffic, safety and transportation system analysis. Given the importance of lane changing in traffic situations, there have been many research studies over the past 30 years, mostly focusing on lane change generation. Gipps (1986) proposed a framework for the structure of lane changing decisions in urban driving situations, which is the widely used framework for studying lane change behaviour. In the model, the driver's decision to change lane is the result of the answers to the following composite questions: whether it is possible to change lane; whether it is necessary to change lane; and whether it is desirable to change lane. He was concerned with how the decision to change lanes is reached, not the execution of the decision. Yang and Koutsopoulos(1995) built a probabilistic route choice model to capture driver's lane change decisions in the presence of real time traffic information. Ahmed(1996) also proposed a probabilistic model to describe lane changing generation. Das(1999) developed a traffic simulation called AASIM(Automous Agent Simulation package) based on fuzzy logic and used fuzzy IF-THEN rules depicting lane changing manoeuvre in highway. Toledo(2007, 2009) built an integrated driving behaviour model considering the inter-dependencies between lane changing and acceleration behaviours. Choudhury(2010) researched lane changing generation with latent plan.

Many studies have been done on the mandatory lane change, mostly focusing on the merging point. Daganzo (Daganzo 1981) modelled driver's merging from the minor leg of a stop-controlled T-intersection to the major leg using a probit model. Kita (KITA 1993) modeled driver's merging behavior from freeway on-ramp using a logit model for gap acceptance, later he developed a game-theoretic lane change model to analysis the merging-giveway interaction (Kita H. 2002). Meng (Meng and Weng 2012) used statistical methods such as the classification and regression tree to predict merging behavior near work zone tapers. Hou (Hou, Edara et al. 2012)developed a genetic fuzzy model to analysis mandatory lane change behavior at lane drops.

However, most of the lane change behaviour study pay more attention to the lane change generation, and treat lane-changing execution as an instantaneous action. In the current traffic simulations such as VISSIM, AIMSUN and PARAMICS (Quadstone 2009, VISSIM 2011, Aimsun 2012), the lane change execution is either ignored or is considered in a simple and continuous way, such as calculate all the lane change durations as the ratio of a given distance and vehicle velocities. Furthermore, the previous studies made the assumption that SV remains in the starting status and persists till the end of lane changes, once the lane change has started (K.I. Ahmed 1996).

The observation of lane change duration and trajectory from real traffic shows the lane change executions differ one from the other. Worrall (1970) studied the duration of lane change on multilane highways and found the range of duration was between 2.3s and 4.8s. Finnegan (1990) summarized lane changing behaviour studies and found the duration of lane change, including visual search time, to range between 4.9s and 7.6s. Wiedemann (1992) found the range of duration of passenger car's lane changing was between 2.18s and 2.69s; the range of duration of heavy vehicle's lane changing was between 2.08s and 4.51s. Chovan (1994) studied lane change duration finding that they ranged between 2.0s and 16s. Tijerina (1997) found that the range of lane change was between 3.5s and 6.5s in city streets and was between 3.5s and 8.5s on highways. Hetrick (1997) found the lane change duration was between 3.4s and 13.6s. Hanowski (2000) studied short-haul truck (speed< 45mph) and found out that the lane changing duration was between 1.1s and 16.5s. Toledo (2007) studied lane change execution, focusing on the duration of lane change action, and found that the lane changing duration was between 1.0s to 13.3s for both heavy vehicle and passenger car. Moridpour (2010a, 2010b) studied the lane changing execution of heavy vehicles on freeways and her research showed that the duration of lane change of heavy vehicle was between 1.6s and 16.2s, the mean value was 8.0s; while the duration of lane change of passenger car was shorter, between 1.1s and 8.9s, with a mean value of 4.8s. The observation of the lane change trajectory describes that the trajectories differ from each other (see Figure 2). Ghaffari et al (2012) studied lane change trajectory and represented it by a sine-shape curve. Xu (2012) classified the trajectories as careful and sudden trajectories. Cao (Cao, Young et al. 2013) investigated the lane change trajectory by using the video data and found out the lane change trajectories curves are different according to the traffic conflict.

Figure 2 Observation of lane change execution trajectories



3. Data collection

Previous studies have indicated a variation in the execution of lane changing. This paper presents the analysis of lane changing execution on an arterial road in the suburb of Clayton in Melbourne. The data was collected by a video camera mounted on a high building adjacent to the road (see Figure 1). This arterial road has 3 lanes in each direction and a car was parked on the left most lane. The total effective observed length is 140m. To record every movement of the lane change maneuvers, a mesh of points of 0.2 seconds was created by using a set of automatic screenshot software.

There are in total 190 samples collected from the arterial road, including 165 cases completing lane changes successfully, and 25 cases stopped lane changes after the lane change shift starts. Table 1 presents the data samples in different surrounding traffic conditions.

Table 1 Summary of surrounding traffic situation of SV

Sample size	Change lane	Stop	Total
SV with no surrounding vehicle	38	0	38
SV with Lt	30	0	30
SV with Ft	26	0	26
SV with Lc	8	0	8
SV with Lt and Ft	36	1	37
SV with Lt and Lc	12	2	14
SV with Ft and Lc	10	3	13
SV with Lt, Ft and Lc	5	19	24
Total	165	25	190

4. Model structure

Once the subject vehicle (SV) driver starts the first shift from the current lane to the target lane, he/she is in the lane change execution process and needs to make the choice of whether to continue their operation considering a variety of factors. For the MLC, there is a certain point where the SV has to complete changing lane before it, which is denoted by the emergency status in this paperMoreover the surrounding traffic impact is another important factor for the driver's behaviour of continuing lane change or not. The traffic conflict between SV and the surrounding vehicles is used to indicate the surrounding traffic impact. Previous study (Cao, Young et al. 2013) on the lane change execution characteristics shows that the vehicles with traffic conflicts perform lane changes differently from those without any traffic conflicts in the surrounding environment. The more likely the conflict is, the more likely the lane change execution will be ceased to keep safe.

During the whole process of lane changing action, as the distance to block keeps becoming shorter and the surrounding traffic keeps changing, the SV driver needs to adjust the lane changing execution at time t, $t \epsilon \{t_{start}, t_{end}\}$. If the utility of "Continue LC" is higher, the SV driver will perform lane changing. Otherwise, the driver will not continue lane changing to avoid a crash, such as brake or even stop changing lane.

The utility of execution decision for a mandatory lane change at time *t* to driver *n* is written as below:

$$U_{itn} = V_{itn} + \varepsilon_{itn} \qquad \forall i \in C_n$$

Where,

U_{itn} =utility for driver *n* at time *t* in choice *i*;

V_{itn} = systematic component of the utility;

C_n =choice set of execution modes of lane change, $C_n = (1: Continue\ LC, 2: Not\ Cont. LC)$; and

ε_{itn} =random term that varies across different time period.

The choice of lane changing performance may be affected by the following factors: the emergency situation of SV, the surrounding traffic impact and the driver's individual character. The total systematic utility of choice of continuing lane change or not for individual *n* at time *t* can be expressed as the function below:

$$V_{itn} = F(\lambda_n,\ S_{tn}, v_n) \qquad \forall i \in C_n$$

Where,

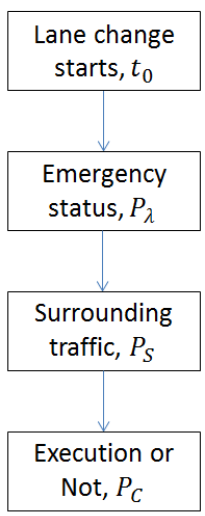
λ_n = the emergency situation of SV;

S_{tn} = the surrounding traffic impact; and

v_n = individual-specific feature.

The model framework is presented in Figure 3.

Figure 3 Lane change execution model framework



This paper proposes a framework of lane change execution model (Fig. 3) and focuses on the surrounding traffic impact model in the following section.

The probability of continuing lane change considering all the surrounding vehicles impact to the SV is given as below (conditional on individual feature):

$$P_n(S_{nt}|v_n) = \sum \alpha_{nm} P_{nm}(conflict = 0|v_n) \qquad m \in \{Lt, Ft, Lc\}$$

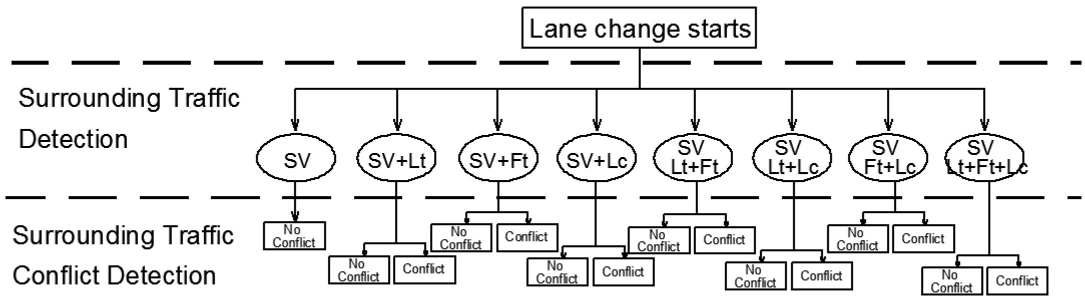
Where,

α_{nm}: Weight of impact of different surrounding traffic situation;

$P_{nm}(conflict = 0|v_n)$: Probability of no conflict between SV and the surrounding vehicle.

There is two steps in the surrounding traffic impact model: a. surrounding traffic detection; b. surrounding traffic conflicts detection (see Figure 5).

Figure 5 Framework of surrounding traffic impact model



Step a:

For the surrounding traffic impact, three direct surrounding vehicles are considered here: Lt (leading vehicle in the target lane), Ft (following vehicle in the target lane) and Lc (leading vehicle in the current lane). In the real life, the three surrounding vehicles are not always occurring at the same time. Sometimes there is only one surrounding vehicle for the SV, and it could be any of Lt or Ft or Lc; sometimes there are two surrounding vehicles, and they could be any combination of Lt, Ft and Lc. In certain traffic environment, there is no surrounding vehicle around SV. There are in total 8 scenarios displaying as follows:

- Scenario 1: SV with no surrounding vehicle;
- Scenario 2: SV with one surrounding vehicle of Lt;
- Scenario 3: SV with one surrounding vehicle of Ft;
- Scenario 4: SV with one surrounding vehicle of Lc;
- Scenario 5: SV with two surrounding vehicles of Lt and Ft;
- Scenario 6: SV with two surrounding vehicles of Lt and Lc;
- Scenario 7: SV with two surrounding vehicles of Ft and Lc;
- Scenario 8: SV with three surrounding vehicles of Lt, Ft and Lc.

125m (d=125m) (NESTI, MASONE et al. 2012)is used as the perception distance threshold for the SV driver for the initial detection for the direct surrounding vehicles in this reportAt any time, the scenario could be anyone from scenario 1 to 8 and can be detected in the simulation.

For surrounding traffic scenario detection, in order to consider this situation in the model a dummy variable δ_{nt} is applied to represent the existence of the surrounding vehicle (see the following Eqn). For instance, if there is the scenario 2 which is SV with one surrounding vehicle of Lt, then $\delta_{nt}^{Lt} = 1$, $\delta_{nt}^{Ft} = 0$ and $\delta_{nt}^{Lc} = 0$.

$$\delta_{nt}^{Lt} = \begin{cases} 1 & if\ there\ is\ a\ Lt\ vehicle\ detected; \\ 0 & otherwise. \end{cases}$$

$$\delta_{nt}^{Ft} = \begin{cases} 1 & if\ there\ is\ a\ Ft\ vehicle\ detected; \\ 0 & otherwise. \end{cases}$$

$$\delta_{nt}^{Lc} = \begin{cases} 1 & if\ there\ is\ a\ Lc\ vehicle\ detected; \\ 0 & otherwise. \end{cases}$$

Then the surrounding traffic status is expressed as below:

$$\text{surrounding traffic status} = \delta_{nt}^{Lt} * Lt + \delta_{nt}^{Ft} * Ft + \delta_{nt}^{Lc} * Lc$$

Step b:

To investigate the surrounding traffic impact, the existence of conflict between SV and the surrounding vehicles is used as an influence factor to the lane change execution decision. From the observation of lane change action and stopped lane changes indicates the relation between surrounding traffic conflicts and the choice of whether continue lane changes (see Table 2). It can be seen that there are always conflicts between SV and the surrounding vehicles when the drivers stop lane changes (91% for SV-Lt, 95% for SV-Ft and 100% for SV-Lc respectively); while there are only 24% cases have conflicts between SV and Lt when the drivers choose to continue lane change (27% between SV and Ft; 22% between SV and Lc). The less conflicts are, the more likely SV drivers continue lane changes; and the more conflicts are, the less likely not continue lane changes.

Table 2 analysis of the relation between conflict and lane change execution

Existence of conflict between two entities	Percentage of conflict existence	
	Continue Lane Change (%)	Not Continue Lane Change (%)
SV-Lt	24	91
SV-Ft	27	95
SV-Lc	22	100

To identify the conflicts between SV and the surrounding vehicles, the concepts of Critical Region and Critical Gap are introduced (Cao, Young et al. 2014).When a vehicle is changing its state of movement during its operation on a road, there is a controllable area. It is the region the subject vehicle is able to take measures to avoid a crash when the surrounding vehicles are approaching.. This controllable area is called critical region. The radial direction requires the longest safe space, which means it has the critical distance to avoid a collision. It is called the “critical gap” (CG), which is used to measure lane change conflicts: if the real distance is smaller than CG, the conflict exists; otherwise, no conflict.

The probability for conflict detected (conflict=1) conditional on the individual-specific term (v_n) is given by a logit model:

$$P_n(\text{Conflict} = 1|v_n) = \frac{\exp(\beta_{nt}^m x_{nt}^m|v_n)}{1 + \exp(\beta_{nt}^m x_{nt}^m|v_n)}, \qquad m \in \{Lt, Ft, Lc\}$$

$$P_n(\text{Conflict} = 0|v_n) = 1 - P_n(\text{Conflict} = 1|v_n), \qquad m \in \{Lt, Ft, Lc\}$$

Where,

x_{nt}^{m} : the explanative variables, including $\mathrm{V_{SV}}, \theta_{SV}, \mathrm{V_{Lt}}, \mathrm{V_{Ft}}, \mathrm{V_{Lc}}, \Delta\mathrm{v_{Lt}}, \Delta\mathrm{v_{Ft}}, \Delta\mathrm{v_{Lc}}, \varphi_{Lt}, \varphi_{Ft}, \varphi_{Lc}$.

β_{nt}^{m} : the corresponding vector of parameters

The explanations of all the mentioned explanative variables are listed below:

$\mathrm{V_{SV}}$: the velocity of SV;

θ_{SV} : the angle between the direction of SV and the lateral direction, $\theta \epsilon (0, \frac{\pi}{2})$;

$\mathrm{V_{Lt}}$: the velocity of Lt;

$\mathrm{V_{Ft}}$: the velocity of Ft;

$\mathrm{V_{Lc}}$: the velocity of Lc;

$\Delta\mathrm{v_{Lt}}$: the relative speed of Lt and SV;

$\Delta\mathrm{v_{Ft}}$: the relative speed of Ft and SV;

$\Delta\mathrm{v_{Lc}}$: the relative speed of Lc and SV;

φ_{Lt}: the angle between the radial direction of SV to Lt and the lateral direction, $\varphi \epsilon [\pi, \frac{3\pi}{2}]$; $\varphi = \pi$ means the SV and Lt are traveling side by side in different lanes, $\varphi = \frac{3\pi}{2}$ means SV has changed lane to the target lane;

φ_{Ft} : the angle between the radial direction of SV to Ft and the lateral direction, $\varphi \epsilon [\frac{\pi}{2}, \pi]$; $\varphi = \frac{\pi}{2}$ means the SV has changed lane to the target lane, $\varphi = \pi$ means SV and Ft are traveling side by side in different lanes;

φ_{Lc} : the angle between the radial direction of SV to Lc and the lateral direction, $\varphi \epsilon (\pi, \frac{3\pi}{2}]$; $\varphi \neq \pi$ due to the position of SV and Lc, $\varphi = \frac{3\pi}{2}$ means SV is just behind the leading vehicle in the current lane.

Combined model with step a and b:

The lane change execution starts when the SV performs the first swerving to the target lane (t_{start}) and ends when the SV stops swerving and drives stably in the target lane (t_{end}). During lane changing process, at any time t ($t\epsilon\{t_{start}, t_{end}\}$), the surrounding traffic situation could be in any of the scenario among the scenario 1~8 (see step a). After the scenario is determined, the relative relations between SV and the surrounding vehicles will be explored, using the indicator of traffic conflicts. It should be noticed that for scenario 1, which is the SV without any surrounding vehicle, there is no traffic conflict. The combined model has considered each scenario and every direct surrounding vehicle which is included in the scenario.

$$P_j(S_{nt}|v_n) = \delta_{nt}^{Lt} * \alpha_{jn1} * P_n^{Lt}(conflict = 0|v_n) + \delta_{nt}^{Ft} * \alpha_{jn2} * P_n^{Ft}(conflict = 0|v_n) + \delta_{nt}^{Lc} * \alpha_{jn3} * P_n^{Lc}(conflict = 0|v_n)$$

$$j \in \{Scenario\ 1, Scenario\ 2, \dots, Scenario\ 8\}$$

Where,

$\alpha_{jn1}, \alpha_{jn2}, \alpha_{jn3}$: the weight for different scenarios.

5. Data analysis and model estimation

5.1 data analysis

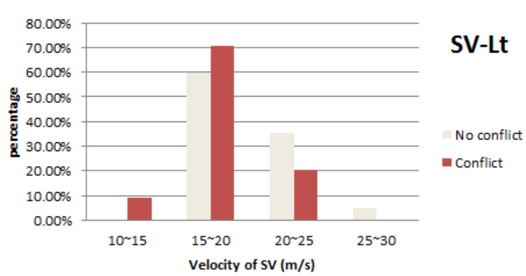
The estimation dataset includes 165 samples of various vehicles for a total of 1815 observations at a 0.2 second time resolution. The whole duration of lane change execution process was observed for each subject vehicle and the its direct surrounding vehicles. T is used as the symbol for the duration of lane change execution. The summary of characteristics of the observations is shown in Table 3.

Table 3 Summary of characteristics of the observations

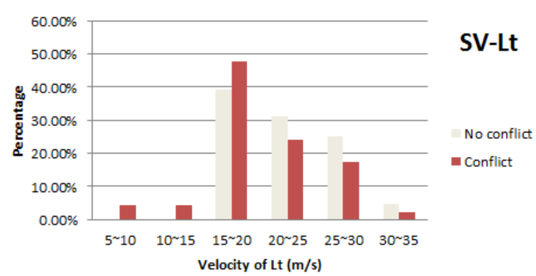
Symbol	Unit	Mean	Std Dev	Median	Minimum	Maximum
T	s	2.6	0.9	2.4	1	6.8
V_{SV}	m/s	17.3	4.2	17.4	5.22	30.10
θ_{SV}	rad	1.52	0.05	1.53	1.06	1.57
V_{Lt}	m/s	21.16	4.75	20.18	7.62	34.31
V_{Ft}	m/s	18.36	3.34	17.46	10.87	28.03
V_{Lc}	m/s	12.99	3.51	11.85	5.22	23.78
Δv_{Lt}	m/s	-1.80	3.23	-1.33	-14.82	10.26
Δv_{Ft}	m/s	0.41	4.62	1.17	-14.85	9.93
Δv_{Lc}	m/s	1.73	4.11	0.67	-12.16	12.74
φ_{Lt}	rad	4.61	0.07	4.63	4.42	4.69
φ_{Ft}	rad	1.76	0.27	1.67	1.57	2.99
φ_{Lc}	rad	4.64	0.08	4.68	4.30	4.71

The distributions of velocity, relative velocity and angles between SV and the surrounding vehicles with surrounding traffic impact or without the impact, are shown in the following figures.

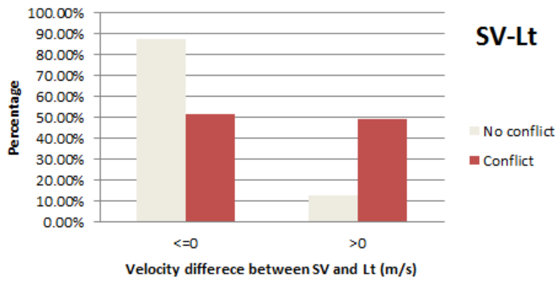
Figure 8 Data distributions of SV with Lt



(a)



(b)



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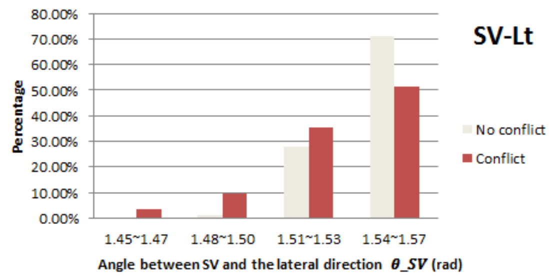
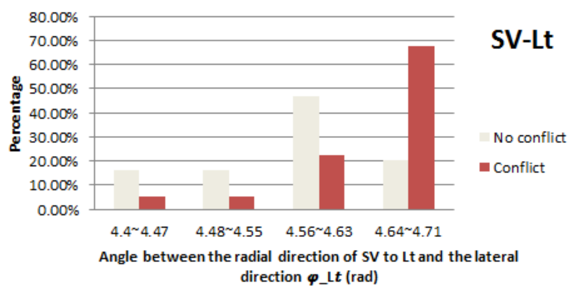


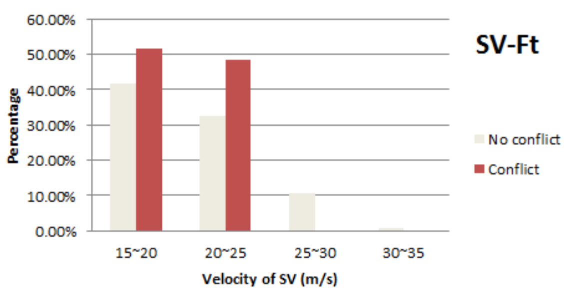
(d)



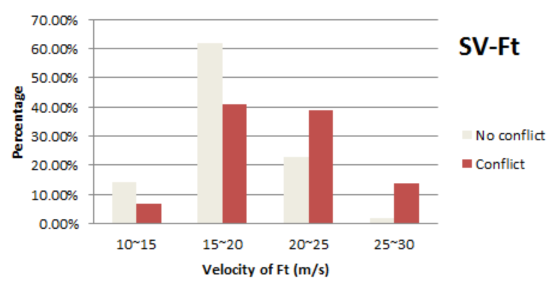
(e)

For the traffic situation of SV with Lt, in Figure 8 (a) and (b) the velocities of SV with lane change conflicts are in the lower speed range than those without conflicts; while there is no obvious difference between the velocities of Lt with conflicts and without conflicts. From Figure 8 (c) the SV speeds are mostly less than Lt speeds when there are no traffic conflicts; while with conflicts there is no obvious difference tendency between SV and Lt speeds. The angle between SV and the lateral direction is in the range of 0 to $\frac{\pi}{2}$. In Figure 8 (d), the angles without conflicts are generally larger than those with conflicts. The angle between the radial direction of SV to Lt and the lateral direction is in the range of π to $\frac{3\pi}{2}$. From Figure 8 (e), the angles with conflicts are generally in the larger range than those without conflicts.

Figure 9 Data distributions of SV with Ft



(a)



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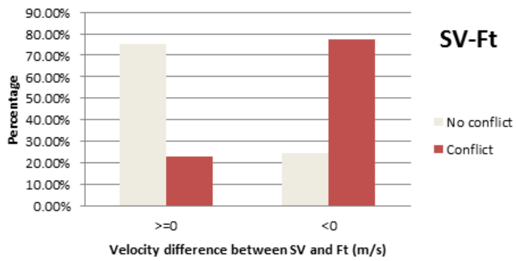
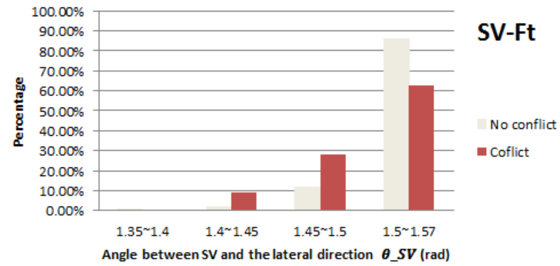


(c)



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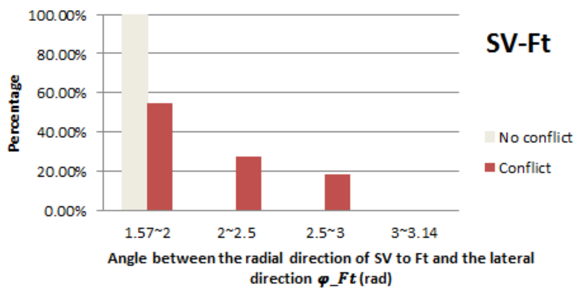
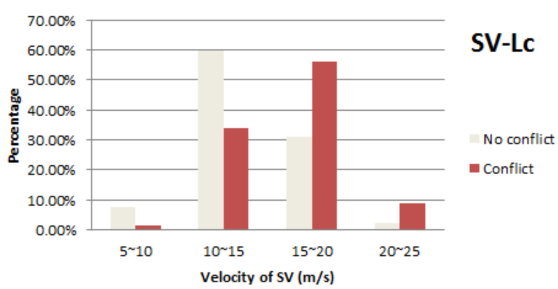


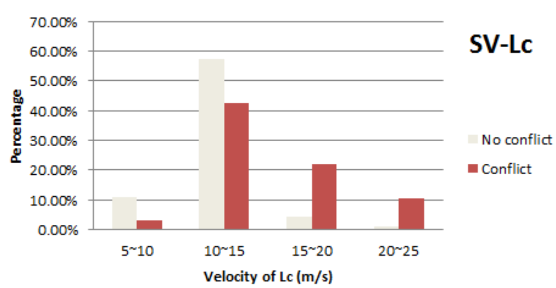
(e)

For the traffic situation of SV with Ft, in Figure 9 (a) and (b) the velocities of SV with lane change conflicts are in the lower speed range than those without conflicts; while there is no obvious difference between the velocities of Ft with conflicts and without conflicts. From Figure 9 (c) the SV speeds are mostly less than Ft speeds when there are traffic conflicts existing; while without conflicts the SV speeds are mostly larger than Ft speeds. The angle between SV and the lateral direction is in the range of 0 to $\frac{\pi}{2}$. In Figure 9 (d), the angles of SV without conflicts are mostly in a certain range of 1.5~1.57, while the angles of SV with conflicts are scattered. The angle between the radial direction of SV to Ft and the lateral direction is in the range of $\frac{\pi}{2}$ to π. From Figure 9 (e), the angles of SV without conflicts are only in a certain range of 1.57~2.0, while the angles of SV with conflicts are much more scattered, in a wider range of 1.57~3.0.

Figure 10 Data distributions of SV with Lc



(a)



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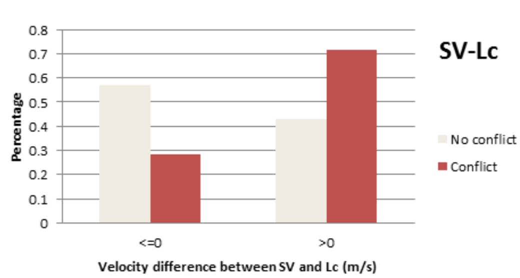

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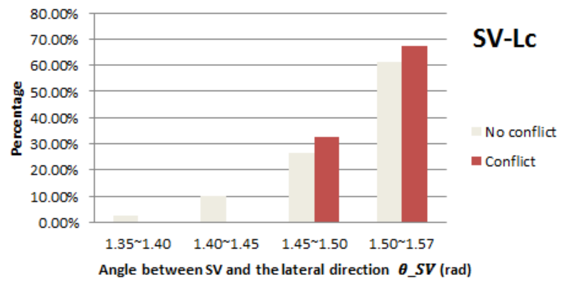
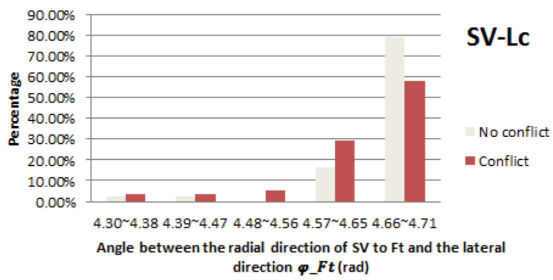


(d)



(e)

For the traffic situation of SV with Lc, in Figure 10 (a) and (b) the velocities of SV and Lc with lane change conflicts are in the higher speed range than those without conflicts. From Figure 10 (c) the SV speeds are mostly larger than Lc speeds when there are traffic conflicts; while without conflicts there is the SV speeds are less than Lc speeds. The angle between SV and the lateral direction is in the range of 0 to $\frac{\pi}{2}$. In Figure 10 (d), the angles of SV with conflicts are mostly in a certain range of 1.45~1.57, while the angles of SV without conflicts are scattered. The angle between the radial direction of SV to Lc and the lateral direction is in the range of π to $\frac{3\pi}{2}$. From Figure 10 (e), the angles of SV without conflicts are mostly in a certain range of 4.66~4.71, while the angles of SV with conflicts are more scattered.

5.2 Estimation of the surrounding traffic impact model

Different surrounding traffic impacts of SV with Lt, Ft or Lc are studied separately.

Table 4 and 5 present the estimation results and parameter estimates of the conflict existence model for SV and each surrounding vehicles.

Table 4 estimation summary of surrounding traffic impact model

	model for SV and Lt	model for SV and Ft	model for SV and Lc
-2 log-likelihood	73.733	86.956	64.718
Number of cases	151	158	141
Number of parameters	6	6	6
Cox & Snell R Square	0.535	0.367	0.550
Nagelkerke R Square	0.580	0.578	0.641

Table 5 Parameter estimations results of surrounding traffic impact model

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Model for SV and Lt						
Constant	-29.602	13.015	5.173	1	.023	.000
V_{SV}	.187	.077	5.937	1	.015	.829
φ_{Lt}	7.089	2.833	6.263	1	.012	1198
Model for SV and Ft						
Constant	62.770	14.165	19.637	1	.000	1822
θ_{SV}	-46.427	9.829	22.309	1	.000	.000
V_{Ft}	.339	.104	10.600	1	.001	1.403
Δv_{Ft}	-.423	.090	22.230	1	.000	.655
Model for SV and Lc						
Constant	-6.027	1.181	26.026	1	.000	0.002
V_{SV}	.352	.070	25.364	1	.000	1.421
Δv_{Lc}	1.550	.536	8.350	1	.004	4.712

From Table 3, it is obvious that for different surrounding vehicles, the influence factors are different. For the model between SV and Lt, V_{SV} and φ_{Lt} are the significant influencing factors and both have the positive impact. The result means the higher V_{SV} is, the higher probability of conflict existence, subsequently, the lower probability of continuing lane change; the higher of φ_{Lt} between SV and Lt is, which represents the smaller relative position between the two entities, the higher probability of conflict existence, subsequently, the lower probability of continuing lane change.

For the model between SV and Ft, θ_{SV} , V_{Ft} and Δv_{Ft} are the significant influencing factors. θ_{SV} and Δv_{Ft} have the negative impact to conflict existence. θ_{SV} is the angel between the SV trajectory and the lateral direction, which represents the lateral movement of SV. The result shows the higher θ_{SV} is, the lower probability of conflict existence, subsequently, the higher probability of continuing lane change. Δv_{Ft} is the velocity difference between SV and Ft. The result shows the SV velocity is larger than Ft velocity, the less probability of conflict existence, subsequently, the higher probability of continuing lane change will be. V_{Ft} is another influence factor and the coefficient indicates it has the positive impact, which means the higher Ft velocity is, the higher probability of conflict existence, then the less probability of continuing lane change.

For the model between SV and Lc, V_{SV} and Δv_{Lc} are the significant influencing factors and both have the positive impact. The result shows when V_{SV} is higher, the probability of conflict existence is higher, then the probability of continuing lane change is lower. The SV velocity is larger than the Lc velocity, the higher probability of conflict existence, subsequently, the less probability of continuing lane change will be.

6. Conclusion

As one of the basic driver behaviour, lane change behaviour has been studied for several decades. However, most the lane change models in the traffic simulations pay attention to the lane change generation and just treat the lane change execution process simply. The paper uses the video data collected from an arterial road in Melbourne to analysis the lane change execution considering the surrounding traffic impact. The mandatory lane changes were performed from the leftmost curb lane to the middle lane to avoid the blockage ahead.

A framework of lane change execution model was proposed, which includes 2 sections: emergency impact model and surrounding traffic impact model. This paper emphasised the impact from the surrounding vehicles to the lane change execution. When the mandatory lane-changing vehicle shifts from the current lane to the target lane, the driver adjusts its lane-changing execution behaviour to complete lane change safely by evaluating the conflict with the direct surrounding vehicles. It is assumed that the driver will adjust its execution if a surrounding conflict is detected and will continue the lane change if there is no conflict around. To evaluate the surrounding traffic impact, the surrounding traffic scenario is identified first to determine what the direct surrounding vehicles are. To detect the conflicts between SV the surrounding vehicles, a binary logit model was proposed in the paper and the parameters in the model were estimated.

The future work will focus on the development of the lane change execution model, then the model calibration and validation. The comparison of the simulation outputs with and without lane change execution plugin model will be explored in the following work to achieve the more precise result.

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