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A study of mandatory lane-changing execution behaviour model considering conflicts

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Abstract

Lane change models are one of the basic driver behaviour interactions in the microscopic traffic simulations for 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 an exploratory study of lane change execution and proposes a lane changing behaviour model on arterial road where there is a block occurring on the curb-side lane to fit this situation.

A video camera was used to collect data from an arterial road in Melbourne, Australia. 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 blockage impact and surrounding traffic impact. The lane change execution model is developed as a combined model with blockage impact model and surrounding traffic impact model. The blockage impact model is considering the emergency status to perform lane change, using distance to block as the indicator. The surrounding traffic impact model detects the traffic conflicts between lane changing vehicle and the surrounding vehicles, using Fisher discriminant analysis method.

A binary logit model is proposed to interpret the driver's execution choice according to both the blockage impact and the surrounding traffic impact. In the conclusion, the paper provides a framework for the future work of lane change execution models on traffic simulation to assess the traffic safety and road efficiency.

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

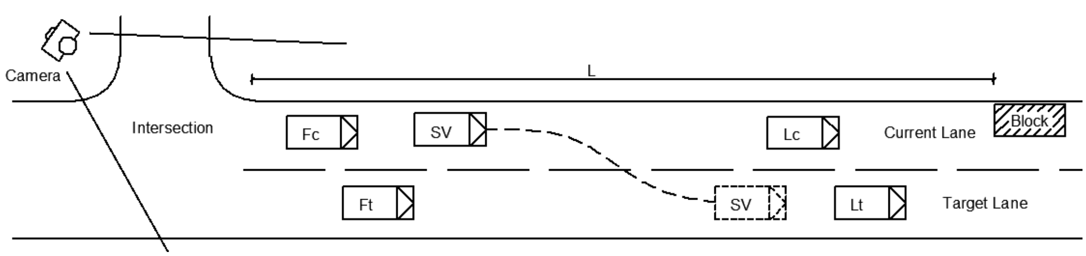
1. Introduction

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. The entire individual lane change process is considered as the combination behaviour of the lane change decision and the lane change execution. Lane change execution is the phase following the lane change is generated (D.Chovan, L.Tijerina et al. 1994, Louis Tijerina 2005). The lane change decision 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 lane change execution phase is the following phase, which starts from the initiation point of the steering manoeuvre 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. Subsequently, it cannot be treated simply. However, most existing lane change models in the traffic simulations emphasize the lane change generation and pay little attention to the lane change execution. Some simulations consider the subject vehicle remains the same status during the whole execution process; moreover some just ignore the execution process. The variation of the durations and trajectories during lane change execution in real life reveals that those assumptions contravene the reality. To explore the execution of lane changes thus becomes important. There is a lot of research on MLC generation, while there is 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 parked car, and focused 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 away from 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. L=140m.

2. Literature review

Lane change model is one of the basic driver behaviour interactions in 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 several decades, mostly focusing on the decision making to generate a lane change. 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 details of the execution process. Yang and Koutsopoulos (1996) 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 a latent plan. These studies paid more attention on the lane change generation and have made progress on improving the lane change models in traffic simulations. However, they barely considered the lane change execution phase.

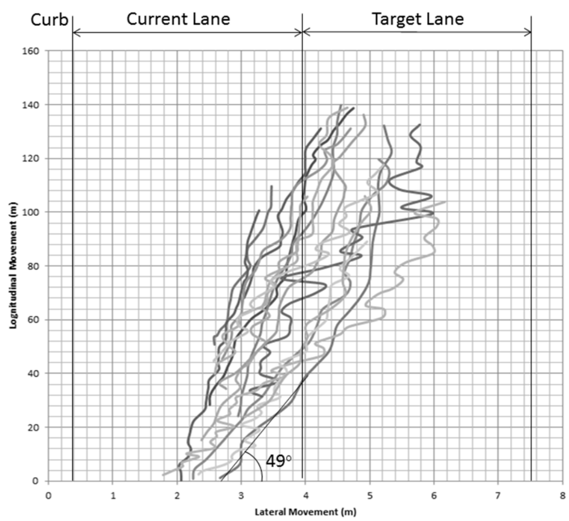
Most studies that have been done on the mandatory lane change are focusing on the merging point. Daganzo (1981) studied mandatory lane changes by modeling driver's merging from the minor leg of a stop-controlled T- intersection to the major leg using a probit model. Das (1999) developed fuzzy rules in AASIM (Automous Agent Simulation package) for the mandatory lane change generation. His MLC rules consider not only the distance to the merging point but also the number of lane changes required. Kita (1993) studied driver's merging behavior from freeway on-ramp using a logit model for gap acceptance, later he (2002) developed a game-theoretic lane change model to analysis the merging-giveway interaction. Meng (2012) used statistical methods such as the classification and regression tree to predict a mandatory lane change decision in the merging section near work zone tapers. Hou et al. (2012) developed a genetic fuzzy model to analyse mandatory lane change behaviour at lane drops. The configuration of the merging point from a ramp to highways or arterial roads is different from that occurring on a corridor caused by the lane change. This paper studied, instead of the merging point, the mandatory lane changes on the corridor which take place due to a blocked lane.

However, most of the lane change behaviour studies 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 calculating all the lane change durations as the ratio of a given distance and vehicle velocities. Furthermore, the previous studies made the assumption that SV would remain in the starting status and persist till the end of lane changes, once the lane change has started (K.I. Ahmed 1996).

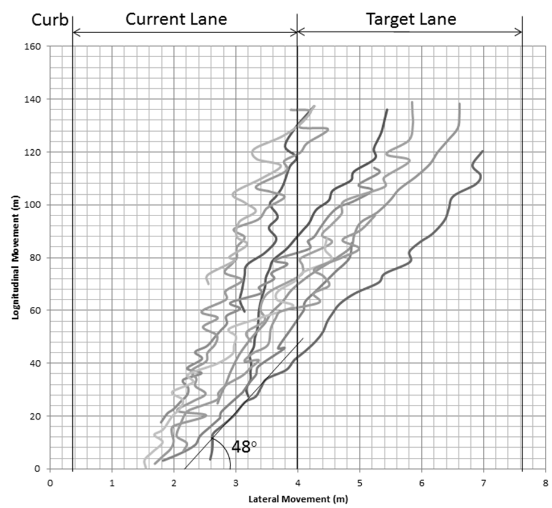
The observation of lane change duration and trajectory from real traffic shows the lane change executions differ one from the other. Worrall (1970) studied the duration of lane change on multilane highways and found the range of duration was between 2.3s and 4.8s. Finnegan (1990) summarized lane changing behaviour studies and found the duration of lane change including visual search time, the range of 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. 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 et al. (2013) investigated the lane change trajectory by using the video data and found out the lane change trajectories curves are different due to the existence of conflicts and different vehicle types. The observation of the lane change trajectory describes that the trajectories differ from each other (see Figure 2).

Figure 2 Observation of lane change execution trajectories (a) passenger cars (b) heavy vehicles (Cao et al. 2013)



(a)



(b)

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 manoeuvres, 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

The lane change related characteristics are recorded and listed in Table 2. In Table 2, T is used as the symbol for the duration of lane change execution. V_{SV} represents the velocity of SV; θ_{SV} is the angle between the direction of SV and the lateral direction, $\theta \epsilon (0, \frac{\pi}{2})$; V_{Lt}, V_{Ft}, $V_{Lc}$are the velocity of Lt, Ft and Lc separately; Δv_{Lt} is the relative speed of Lt and SV; Δv_{Ft} is the relative speed of Ft and SV; Δv_{Lc} is the relative speed of Lc and SV; φ_{Lt} is the angle between the radial direction of SV to Lt and the lateral direction, $\varphi \epsilon [\pi, \frac{3\pi}{2}]$; φ_{Ft} is the angle between the radial direction of SV to Ft and the lateral direction, $\varphi \epsilon [\frac{\pi}{2}, \pi]$; φ_{Lc} is the angle between the radial direction of SV to Lc and the lateral direction, $\varphi \epsilon (\pi, \frac{3\pi}{2}]$.

Table 2 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
$\mathbf{V_{SV}}$	m/s	17.3	4.2	17.4	5.22	30.10
$\boldsymbol{\theta_{SV}}$	rad	1.52	0.05	1.53	1.06	1.57
$\mathbf{V_{Lt}}$	m/s	21.16	4.75	20.18	7.62	34.31

$\mathbf{V_{Ft}}$	m/s	18.36	3.34	17.46	10.87	28.03
$\mathbf{V_{Lc}}$	m/s	12.99	3.51	11.85	5.22	23.78
$\Delta\mathbf{v_{Lt}}$	m/s	-1.80	3.23	-1.33	-14.82	10.26
$\Delta\mathbf{v_{Ft}}$	m/s	0.41	4.62	1.17	-14.85	9.93
$\Delta\mathbf{v_{Lc}}$	m/s	1.73	4.11	0.67	-12.16	12.74
$\boldsymbol{\varphi_{Lt}}$	rad	4.61	0.07	4.63	4.42	4.69
$\boldsymbol{\varphi_{Ft}}$	rad	1.76	0.27	1.67	1.57	2.99
$\boldsymbol{\varphi_{Lc}}$	rad	4.64	0.08	4.68	4.30	4.71

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 paper. Moreover 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 subject vehicle drivers might decelerate to adjust their movement, or even cease the lane change to avoid a crash with the surrounding vehicles, if there are conflicts detected.

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 is more likely to perform lane changing. Otherwise, the driver will not continue lane changing to keep safe, 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, 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,

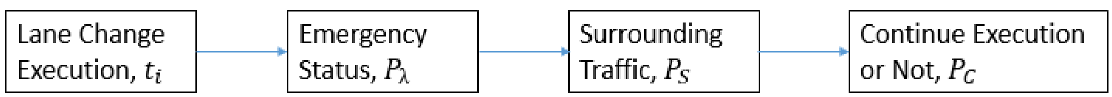
λ_n = the emergency situation of SV;

S_{tn} = the surrounding traffic impact; and

v_n = individual-specific feature.

This paper proposes a framework of lane change execution model (Figure 3).

Figure 3 Lane change execution model framework



The framework describes the lane change execution process at any time t_i. The lane change behaviour is not only impacted by the emergency status but also by the surrounding traffic. The combination of these two impacts thus determine the subject vehicle driver's lane change behaviour: either continue the lane change execution or not continue the execution. A logit model is applied to predict the probability of continuing lane change at time t_i. The model is obtained depending on the assumption made about the distribution of random term ε_{itn}. Assuming that the random terms are independently and identically extreme value distributed, the probabilities for execution choices, conditional on the individual-specific feature (v_n) are given as below:

$$P_C(i|v_n) = \frac{\exp(V_{itn}|v_n)}{1+\exp(V_{itn}|v_n)} \qquad \forall i \in C_n$$

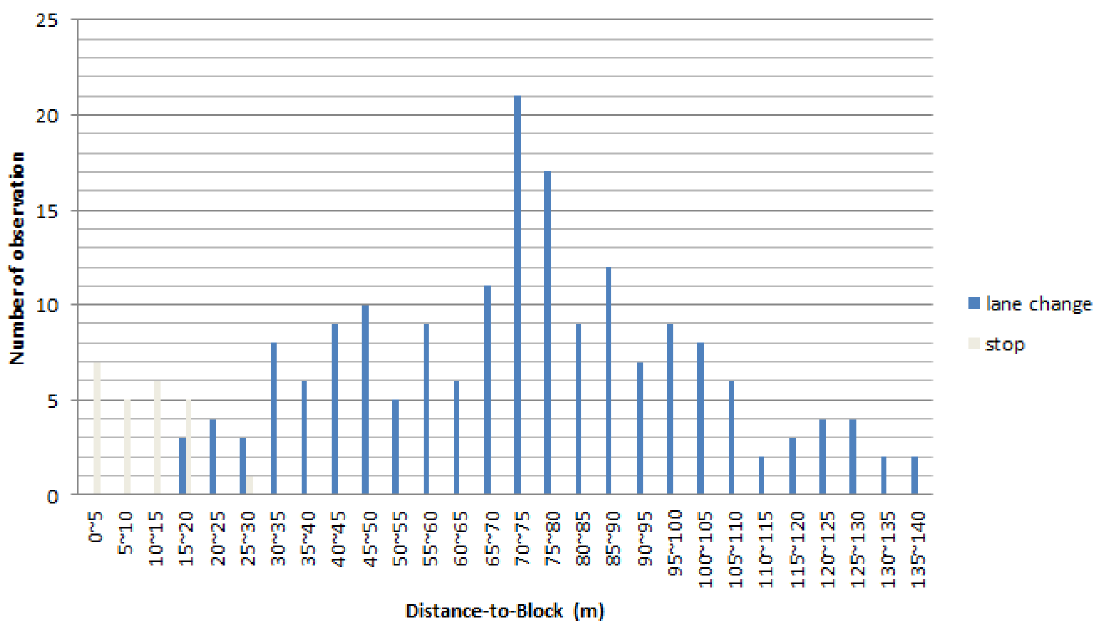
4.1 Emergency situation impact to the execution: blockage impact model

The emergency situation of SV may influence execution behaviour of the mandatory lane changes. The distance between SV and the block may explain how emergent the situation is. The Distance-to-block is the distance between the lane changing vehicle and the block where the SV has to change lane to avoid crash. Since every MLC has to change lane before encountering the block, at any time every MLC has a certain distance between SV and the block. In this study, the block is the parked car on the leftmost lane. Generally, the less distance between the SV and the block, the more emergency situation the driver is facing, accordingly the more likely the driver will not continue lane change execution to avoid crash.

The behaviour of execution is almost opposite to the behaviour of lane change generation. In the lane change decision-making phase, the more emergency situation is, the more likely the lane change will be generated. In the current lane change models of the traffic simulations, the closer to the block, the probability of generating a lane change is higher. While during lane change execution, the more emergency situation is, the more likely the lane change execution will be ceased. Figure 4 shows the result that, after a certain threshold, the closer to the block the SV is; the more likely the driver will stop lane changing execution.

From Figure 4, it can be seen that in the range of less than 15m to the block, all the SV stopped and waited for a chance to change lane; in the range of 15m to 30m, some SVs changed lane successfully and some stopped; in the range of larger than 30m to the block, all SV change lane successfully to avoid the block. In terms of the distribution of lane change locations, the 1-sample K-S test with the significance level of 0.05 shows the distribution of the distance-to-block for lane change starting point is normal (mean μ=70.369, standard deviation σ=25.72).

Figure 4 Distribution of Distance-to-Block of lane changing and stopping location



The function of emergency situation of SV is expressed as below:

$$\lambda_n = \begin{cases} f(x_n) \sim N(\mu, \sigma^2) & if\ x > 15 \\ 0 & if\ x \leq 15 \end{cases}$$

When $x \leq 15$, the SV is in emergency situation, and it will stop to avoid a crash. After the ceasing of lane change execution, the SV will wait and observe the surrounding traffic environment to generate another lane change. when $x > 15$, the function of emergency situation of SV follows normal distribution.

The probability of “Continue lane change” under the condition of emergency situation (λ_n) is shown below:

$$P\ (\lambda_n|v) = \iint f(x_n) f(v_n)\ dxdv$$

4.2 Surrounding traffic impact to the execution: surrounding traffic impact model

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 indicating the surrounding traffic status which are displaying as follows:

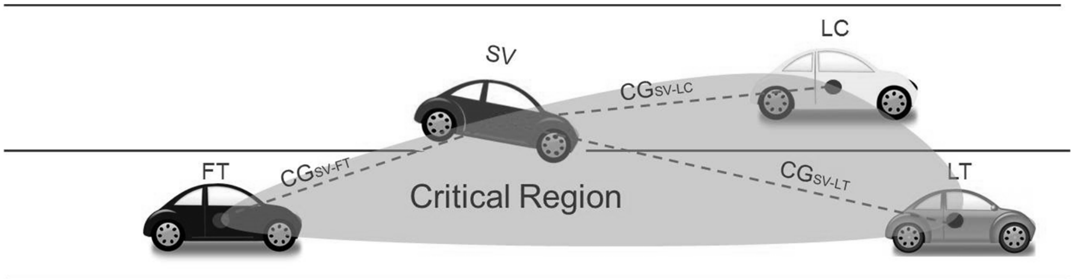
– Scenario 1: SV with no surrounding vehicle;
– Scenario 2: SV with one surrounding vehicle of Lt;
– Scenario 3: SV with one surrounding vehicle of Ft;
– Scenario 4: SV with one surrounding vehicle of Lc;
– Scenario 5: SV with two surrounding vehicles of Lt and Ft;
– Scenario 6: SV with two surrounding 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.

To investigate the surrounding traffic impact in the above 8 scenarios, the lane change conflict between SV and the surrounding vehicles (Lt, Ft and Lc) is considered as an influence factor to the lane change execution decision. A widely accepted definition of Conflict is stated as "…an observable situation in which two or more road-users approach each other in time and space to such an extent that there is a risk of collision if their movements remain unchanged" (Amundsen and Hyden 1977). Gettman and Head's (2003) research indicated that most current surrogate measurements, such as TTC, are not proper for lane change conflict because lane change conflict should be represented by a conflict line instead of a conflict point.

To identify the lane change conflicts, 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. The region subjects to vehicles' characteristics, the initial speed of SV and the angles between SV and the surrounding objects. 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 between two entities is smaller than CG, the conflict exists; otherwise, no conflict.

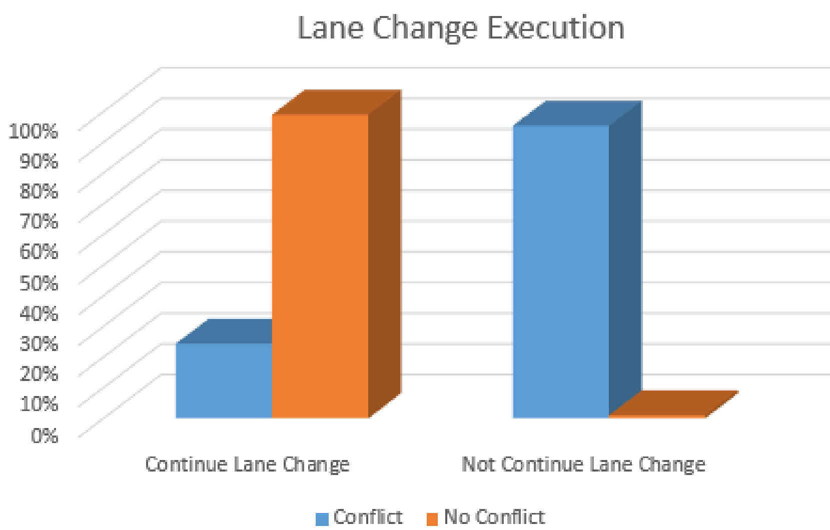
Figure 5 shows the critical region and critical gaps between SV and the surrounding vehicles. The grey area around SV is the critical region, and it can be extracted into several critical gaps. The critical gaps are the minimal controllable length of SV driver. The critical gap for the nth individual differs from individual to individual and differs from time to time as well.

Figure 5 The description of critical region and critical gaps (CGs) at time t



From the observation of lane change action and stopped lane changes indicates the relation between surrounding traffic conflicts and the choice of continuing lane changes or not (see Fig. 6). It can be seen that the drivers choose not to continue lane change execution more than to continue lane changes when there are conflicts between SV and the surrounding vehicles. While if there is no surrounding traffic conflicts, almost all drivers choose to continue lane changes.

Figure 6 Analysis of the relation between conflict and lane change execution



During lane changing process, at any time t ($t\epsilon\{t_{start},\ t_{end}\}$), the existence of conflict can be expressed as below:

$$Conflict_n(t) = \begin{cases} 1 & if\ G_{nm}(t) \leq\ G_{nm}^{cr}(t), \qquad m \in\ \{Lt, Ft, Lc\} \\ 0 & if\ G_{nm}(t) >\ G_{nm}^{cr}(t), \qquad m \in\ \{Lt, Ft, Lc\} \end{cases}$$

Where,

$G_{nm}(t)$: at time t, the gap between SV and the surrounding vehicle;

$G_{nm}^{cr}(t)$: at time t, the critical gap of SV and the surrounding vehicle.

The previous study of traffic conflicts found out that the existing conflict detection methods may not be suitable for the lane change conflict (Gettman and Head 2003). Cao (2014) proposed Fisher discriminant analysis to detect lane change conflicts. The Fisher discriminant function is:

$$u = \sum c_j x_j$$

Where,

x_j: the influencing factors; and

c_j: the parameters for the influencing factors.

The threshold u_0 for the conflict discriminant function is determined using the following equation, considering the sample size (n_1 and n_2) the variance (σ_1 and σ_2). A and B denote two classes: conflict and non-conflict.

$$u_0 = \frac{1}{2}\left[\frac{\mathrm{w^T}\ (\mathrm{n_1}\bar{\mathrm{x}}_\mathrm{j}^\mathrm{A} + \mathrm{n_2}\bar{\mathrm{x}}_\mathrm{j}^\mathrm{B})}{\mathrm{n_1} + \mathrm{n_2}} + \frac{\mathrm{w^T}\ (\sigma_2\bar{\mathrm{x}}_\mathrm{j}^\mathrm{A} + \sigma_1\bar{\mathrm{x}}_\mathrm{j}^\mathrm{B})}{\sigma_1 + \sigma_2}\right]$$

Where,

w is the best projected direction;

$\bar{\mathrm{x}}_\mathrm{j}^\mathrm{A}$: the jth factor in class A; and

$\bar{\mathrm{x}}_\mathrm{j}^\mathrm{B}$: the jth factor in class B.

From the previous study of Cao et al. (2014), the influencing factors and the parameters for the discriminant function *u* for the conflicts detection between SV and the surrounding vehicles are listed in Table 3.

Table 3 Parameters for the discriminant function of conflict detection between SV and surrounding vehicles

Parameter	Description	SV and Lt	SV and Ft	SV and Lc
$\mathrm{V_{SV}}$	Velocity of SV	0.0118	-	-
$\mathrm{V'_{SV}}$	Velocity of SV in longitudinal direction	0.0054	-0.008	-0.0033
$\mathrm{V''_{SV}}$	Velocity component of SV in the longitudinal direction	-0.0114	0.0084	-
ΔV	Velocity difference between SV and the surrounding vehicle (Lt /Ft /Lc)	0.0123	-0.0075	0.0186
$\mathbf{V_{surr}}$	Velocity of the surrounding vehicle	-	-	0.0136
Dist	Distance between SV and the surrounding vehicle (Lt /Ft /Lc)	0.0004	-0.0075	0.0012

To determine the existence of conflicts, the following equation is used, where Class A means the conflict exists of point $\vec{x}$ and class B means no conflict exists of point $\vec{x}$.

$$\begin{cases} \vec{x} \in class\ A, & if\ u > u_0 \\ \vec{x} \in class\ B, & if\ u \le u_0 \end{cases}$$

5. Calibration and validation

The lane change execution is studied using the emergency situation, the surrounding traffic status and the surrounding traffic impact. 80% samples in the dataset were used for calibration and the rest was for validation. The variables of the lane change execution model are listed in Table 4. Table 5 presents the parameter estimation results of the lane change execution model.

Table 4 Description of variables of the lane change execution model

Parameters	Variables	Description
β_0	Const	Constant
β_1	x_{sv}	The emergency situation of SV. x_{sv} :The distance between SV and the block (m)
β_2	S	The surrounding traffic status. S = 0, if there is no surrounding vehicle; S = 1, if there is 1 surrounding vehicle (Lt, Ft or Lc); S = 2, if there are 2 surrounding vehicles (Lt and Ft, Lt and Lc, or Ft and Lc); S = 3, if there are 3 surrounding vehicles (Lt and Ft and Lc).
β_3	C	The surrounding traffic impact. C=0, if there is no conflict; C=1, if there is conflict between SV and the surrounding vehicles.

Table 5 Parameter Estimation Results of the Lane Change Execution Model (Sample Size=178)

Variable	B	S.E	Wald	df	Sig.	Exp(B)
Constant	.593	.270	4.835	1	.028	1.809
x_{sv}	.032	.004	67.868	1	.000	1.033
S			3.033	3	.387	
S (1)	-.365	.366	.994	1	.319	.695

S (2)	-.339	.278	1.485	1	.223	.713
S (3)	-.461	.266	3.012	1	.083	.631
C	-2.314	.187	153.557	1	.000	.099

From table 5, it can be seen that the emergency situation (x_{sv}) and the surrounding traffic impact (C) influence the lane change execution significantly. While the surrounding traffic status is not a significant influence factor. Only when there are 3 vehicles around the SV, the traffic environment impacts lane changing driver's execution in 90% confidence. When the surrounding vehicles are less than 3, the traffic environment does not impact the lane change execution much. It also can be seen that the emergency situation (x_{sv}) has the positive impact, which means when the SV is closer to the block the probability of continue lane changes is lower. While the lane change conflicts have the negative impact to the execution choice, which means with the lane change conflicts the probability of lane change execution reduces.

For validation, 14 lane changes are chosen randomly from the dataset and the lane change execution is recorded every 0.2s. There are totally 124 lane change executions for validation. The model predicts 99 cases correctly out of the 124 cases. The validation result is shown in table 6.

From table 6, it can be seen that the overall correct percentage is 81%. The prediction of Execution 1 is quite accurate, which correct percentage is 93%. Most incorrect prediction come from Execution 0, which correct percentage is only 68%.

Table 6 Validation Results of the Lane Change Execution Model (Sample Size=124) (Cut value=0.5)

Observed		**Predicted**		
		Execution		**Percentage Correct**
		0	**1**	
Execution	**0**	44	21	68
	1	4	55	93
Overall Percentage		-	-	81

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 smoothly if there is no conflict around. To evaluate the surrounding traffic impact, the surrounding traffic status is identified first to determine what the direct surrounding vehicles are. Fisher discriminant functions were used to detect the conflicts between SV the surrounding vehicles. A binary logit model for lane change execution was proposed in the paper combining the emergency impact and surrounding traffic impact, and the parameters in the model were estimated.

The future work will focus on the further calibration and validation of the lane change execution model. The comparison between the simulation outputs, the lane change execution model results and the real life data will be explored to assess the development of the lane change study. Ultimately, the lane change execution model will be plugged in the traffic simulations to achieve the more precise result.

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