(25) Analysis of Drivers' Lane-Changing Intentions on the Expressway for Realistic Traffic Simulation Models

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Lane-changing behavior has a significant impact on traffic flow and potentially reduces traffic safety. However, literature relating to the behavior is not comprehensive, largely owing to the inherent complexity of lane-changing and a lack of large-scale data to analyze such behavior. As an effort to find out the critical factors that greatly affect heavy vehicle and passenger car drivers' lane-changing intentions, a questionnaire survey was conducted in this study. Analysis results show that passenger car drivers are more aggressive than heavy vehicle drivers in making lane-changing decisions. In addition, heavy vehicle drivers are less affected by leading vehicles in lane-changing decisions, while for passenger car drivers the impact of leading vehicles are great. According to the models for the degree of lane-changing intentions, if the relative speed between the desired speed and assumed speed is more than 10 km/h most heavy vehicle drivers are likely to change lanes. The speed plays an important role in lane-changing decisions both for heavy vehicle and passenger car drivers.

Key Words : *lane-changing intention, heavy vehicle, expressway, questionnaire*

1. INTRODUCTION

Owing to the ability to capture the complexity of traffic systems, traffic simulation has become one of the most widely used approaches for traffic planning, traffic design, and traffic management. Various traffic simulation software packages are currently available in the market, and they are utilized by thousands of consultants, researchers, and public agencies [1)-3)]. With the popularity of traffic simulation, the car-following and lane-changing models, two of the most significant components in traffic simulation, have naturally attracted a lot of attention from traffic researchers [4)-5)].

According to previous studies, lane changing has a significant impact on traffic flow characteristics owing to the inference effect on surrounding vehicles [6)]. In addition, lane changing is also viewed as a key trigger in freeway breakdown [7)-8)], and it potentially reduces freeway safety [9)]. To describe such driving behavior more accurately, over the past two decades, several lane-changing models have been developed [10)-12)]. Compared to the car-following model, literature relating to lane changing is less comprehensive. This may be owing to two reasons: the inherent complexity of lane changing and the absence of large-scale data to analyze such behavior. Unlike car following, lane changing is influenced not only by preceding and following vehicles in the same lane but also by leading and lagging vehicles in adjacent lanes. It is well known that driver's decisions to change lane are also greatly affected by driver characteristics (age, gender, driving experience) and driving attitudes (aggressive or conservative driver). In addition, lane-changing maneuvers are different for different types of vehicles (heavy vehicle or car) [13)]. As a result, the prediction of driver's lane-changing decisions is extremely complicated.

The objective of this paper is to find out the critical factors that greatly affect the heavy vehicle and car driver's lane-changing intentions, by using the questionnaire survey. Detailed information about driver characteristics and the vehicle type was con-

tained in the survey. It is believed that the analysis results are very helpful for building more realistic traffic simulation models and evaluating ITS practices such as information provision on expressway.

2. OUTLINE OF QUESTIONNAIRE

Before changing the lane, drivers usually evaluate the traffic conditions in the current lane and the target lane. When traffic conditions in the current lane are not satisfying and traffic conditions in the target lane are better, drivers may determine to change the lane. If we can obtain the surrounding conditions that make the drive to change the lane, it is useful to investigate the driving behavior. However, it is impossible to observe the timing of driver's lane-changing decision by the video camera. We conducted a questionnaire survey to find out the lane-changing timing of truck and car drivers on the expressway. The survey answer sheet is presented in Table 1. The participants are 42 truck drivers, 41 bus drivers and 50 car drivers, who are between 30 and 50 years old. In following analysis, the truck and bus are viewed as heavy vehicles.

Table 1 The survey answer sheet

		Questions	Answers
Driver characteristics	1	The class of the vehicle	(a) car, (b) ~4 ton truck, (c) 10 ton truck, (d) heavy vehicle, (e) minibus (more than 11 passengers) (f)big bus (more than 30 passengers), (g) other
	2	Gender	(a) male, (b) female
	3	Age	(a) 20's, (b) 30's, (c) 40's, (d) 50's, (e) 60's, (f) above 70's
	4	Driving age	(a) less than 5 years, (b) 6~10 years, (c) 11~15 years, (d) more than 16 years
	5	Driving frequency	(a) some times in one year, (b) one time per month, (c) one time per week, (d) Everyday
	6	Frequency of using expressway	(a) some times in one year, (b) one time per month, (c) one time per week, (d) Everyday
	7.1	Driving distance everyday (truck driver only)	(a) less than 50 km, (b) 50~100 km, (c) 100~200 km, (d) more than 200 km
	7.2	Driving distance every week	(a) less than 50 km, (b) 50~100 km, (c)100~200 km, (d) more than 200 km
	8	The limited speed of the vehicle	(a) ( ) km/h, (b) No limited speed
Traffic conditions	9	The free speed in the running lane	( ) km/h
	10	The desired speed in the running lane	( ) km/h
	11	The gap with the leading vehicle	(a) ~10 m, (b) 20 m, (c) 30 m, (d) 40 m, (e)50 m, (f) 60 m, (g) more than ( ) m
	12	When determining to change lane the gap with the leading vehicle satisfying the right-hand conditions	(1) Relative speed: 10 km/h: leading vehicle: car (2) Relative speed : 20 km/h, leading vehicle: car (3) Relative speed: 10 km/h, leading vehicle: heavy vehicle (4) Relative speed: 20 km/h, leading vehicle: heavy vehicle
	13	At the K speed the patience of	k=100 (car only), 90, 80, 70 km/h (a) Right now (less than 5 s), (b) about 10 s, (c) about

3. AGGREGATE ANALYSIS OF TRAFFIC CONDITIONS FOR DRIVERS' LANE CHANGING INTENTIONS

Fig.1 shows the gap distribution and cumulative gap distribution for heavy vehicle drivers when they decide to change lanes. The results indicate that the impact of the relative speed on lane changing is more significant than the impact of the vehicle type.

Fig.2 illustrates the percentile of lane-changing patience at the relative speed between desired speed and assumed speed. By the figure, with the increase of the relative speed the patience of lane-changing intentions decrease. We can also see that when the relative speed in more than 10 km/h the number of drivers who want to change lane rise dramatically. Therefore, the relative speed of 10 km/h is a critical value in lane-changing decisions of heavy vehicle drivers.

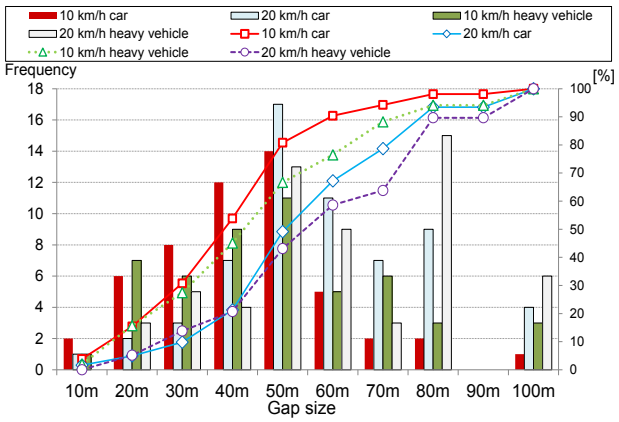

Fig.1 Gap distribution and cumulative gap distribution for heavy vehicle drivers with lane changing intention

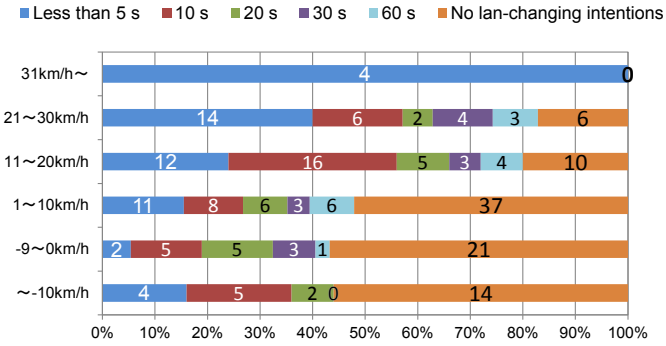

Fig.2 The percentile of lane-changing patience at the relative speed between desired speed and assumed speed (N = 222)

Table 2 presents the lane-changing intentions of car drivers. Except in condition 1, the lane-changing percentile of car drivers is dramatically higher than that of heavy vehicle drivers, particularly when the leading vehicle is the heavy vehicle. Due to the speed and visibility obstructions from heavy vehicles, car drivers are more likely to change lanes.

The statistical summary of the gaps of heavy vehicles and cars are listed in Table 3.

By the Table, we note that for heavy vehicles when following the same class of the leading vehicle at the different relative speed the differences in gaps are statistically significant at 1% confidence level.

Table 2 Lane-changing intentions of car drivers

	Leading vehicle	Relative speed	Lang changing	No lane changing	Lane changing percentile (%)
Condition 1	Car	10 km/h	34	16	68.00
Condition 2	Car	20 km/h	42	8	84.00
Condition 3	Heavy vehicle	10 km/h	44	6	88.00
Condition 4	Heavy vehicle	20 km/h	46	4	92.00

Table 3 The statistical summary of the gaps of heavy vehicles and cars (unit: m)

Conditions			Subject vehicle	Number of samples	Mean	SD	T value
1	Leading vehicle: car	Relative speed: 10 km/h	Heavy vehicle	52	43.27	18.09	1.27
			Car	34	38.53	14.80	
2		Relative speed: 20 km/h	Heavy vehicle	61	58.11	20.05	5.43*
			Car	42	49.29	15.36	
3	Leading vehicle: heavy vehicle	Relative speed: 10 km/h	Heavy vehicle	51	49.31	22.80	-0.31
			Car	44	50.68	19.22	
4		Relative speed: 20 km/h	Heavy vehicle	58	62.24	22.87	0.18
			Car	46	61.52	18.85	
1+2	Leading vehicle: car		Heavy vehicle	113	51.28	20.48	2.56**
			Car	76	44.47	15.95	
3+4	Leading vehicle: heavy vehicle		Heavy vehicle	109	56.19	23.64	-0.01
			Car	90	56.22	19.69	
1+3	Relative speed: 10 km/h		Heavy vehicle	103	46.26	20.68	0.30
			Car	78	45.38	18.35	
2+4	Relative speed: 20 km/h		Heavy vehicle	119	60.13	21.48	1.61
			Car	88	55.68	18.24	
1+2+3+4			Heavy vehicle	222	53.69	22.17	1.36
			Car	166	50.84	18.95	

*1% Confidence level **5% Confidence level ***10% Confidence level

While, when keeping the same relative speed with different classes of leading vehicles there are no significant differences. In conditions 2 and 1+2, the lane-changing differences between heavy vehicles and cars are observed from the T values. However, the relative speed between heavy vehicles and cars are not significantly different. This means for heavy vehicle and car drivers when the leading vehicles are cars their lane-changing decisions are apparently different.

4. THE MODELS FOR THE DEGREE OF LANE-CHANGING INTENTIONS

According to the answers to the question 13 in the survey sheet, we divide the degree of lane-changing intentions into two scales, the urgent lane-changing intention and no lane-changing intention. The urgent lane-changing intention is defined when the lane-changing patience is less than 60 seconds. The logistical regression model is employed to investigate the degree of lane-changing intentions. The models are listed in Tables 4 and 5.

From Table 4, due to the fact that the signs of the variable of the number of lane changes are all positive in the three models, the degree of lane-changing intentions will increase for the drivers who frequently want to change lane. From the sign of the desired speed variable, we know that for the heavy vehicle drivers with the higher desired speed they are more likely to change lane. Meanwhile, when the relative speed between the desired speed and assumed speed in model 2 is large, the degree of lane-changing intentions will increase. By the dummy of driving 200 km one day, the heavy vehicle drivers who usually drive long distance are likely to make lane changing. In model 3, since the sign of the minimum gap variable is negative the smaller the gap the more possible the drivers change lanes. And, from the dummy of relative speed of ±10 km/h between desired speed and assumed speed, when the desired speed is close to the assumed speed the drivers are reluctant to change lane.

In Table 5, from the dummy of the driver in 20's and 30's the young drivers are more likely to change lane. Besides, in model 2 the sign of the relative speed between free speed and assumed speed is positive, when the relative speed is too great the drivers intend to make lane changes.

Contrasting the models in Tables 6 and 7, the variables relating to speed are all statistically significant, which indicates that speed plays an important role in lane-changing intentions. Furthermore, the gap variable in Table 4 is significant at 1% confidence level, while in Table 5 this variable is not significant. This result implies that heavy vehicle drivers pay much attention to the gap, but car drivers are nearly not affected by the gap when they make the lane-changing decisions.

Table 4 The model for the degree of lane-changing intentions of truck drivers

Variables	Model 1	Model 2	Model 3
Constant	-4.903*	-1.791*	1.716*
Number of lane changes	0.515*	0.519*	0.486*
Desired speed	0.042*	-	-
Relative speed between desired speed and assumed speed	-	0.049*	-
The dummy of driving 200 km one day	-	0.815***	-
The minimum gap	-	-	-0.035*
The dummy of relative speed of ±10 km/h between desired speed and assumed speed	-	-	-1.828*
The percentile of correct predictions	72.5	70.7	76.1
Nagelkerke R^2	0.233	0.295	0.407
The number of samples	222	222	222
*1% Confidence level **5% Confidence level ***10% Confidence level			

Table 5 The model for the degree of lane-changing intentions of car drivers

Variables	Model 1	Model 2
Constant	-6.931*	-0.776*
The dummy of the driver in 20's and 30's	0.703***	0.853***
Free speed	0.075*	-
Relative speed between free speed and assumed speed	-	0.096*
The percentile of correct predictions	72.0	77.0
Nagelkerke R^2	0.187	0.393
The number of samples	200	200
*1% Confidence level **5% Confidence level ***10% Confidence level		

5. CONCLUSIONS

Traffic simulation has been widely used for traffic planning, traffic design, and traffic management, owing to its ability to capture the complexity of traffic systems. With the popularity of traffic simulation, lane-changing models, as one of the most significant components in traffic simulation, has attracted a lot of attention from traffic researchers. However, due to the inherent complexity of lane changing and a lack of large-scale data to analyze such behavior, literature relating to lane changing is not comprehensive, As an effort to find out the critical factors that greatly affect heavy vehicle and car drivers' lane-changing intentions, the questionnaire survey was carried out in this study. Detailed information about driver characteristics and the vehicle type was contained in the survey.

Analysis results show that car drivers are more aggressive than heavy vehicle drivers in making lane-changing decisions. In addition, heavy vehicle drivers are less affected by leading vehicles in lane-changing decisions, while for car drivers the impact of leading vehicles are great. According to the models for the degree of lane-changing intentions, if the relative speed between the desired speed and assumed speed is more than 10 km/h most heavy vehicle drivers are likely to change lanes. The speed plays an important role in lane-changing decisions both for heavy vehicle and car drivers. It is believed that the analysis results are very helpful for developing more realistic traffic simulation models.

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