Research on vehicle lane selection behavior of variable guideway at intersections

Chen chen Li, Shu long Dong, Ying cui Du, Yuan Fu

School of Transportation and Vehicle Engineering, Shandong University of Technology, Zibo 255000, China

Abstract At present, urban road intersections have significant time-varying characteristics of each turning traffic ratio, and it is difficult to achieve the balance of supply and demand by adjusting signal timing alone, which causes traffic congestion. By changing the functional properties of the lane, the variable guide lane can alleviate the imbalance of traffic supply and demand by using the remaining capacity in the direction of light traffic flow to meet the traffic demand in the direction of heavy traffic flow. However, the driver's maladjustment to variable-guided lanes leads to poor utilization of variable-guided lanes, resulting in wasted road space resources; therefore, it is crucial to study the lane selection behavior of vehicles on variable-guided lanes.

1. Introduction

1.1 Survey design of observable significant variables

In the traffic behavior activities of drivers choosing lanes to drive in, it is necessary to focus on the socioeconomic attributes, traffic characteristics, alternative lane attributes, and latent variables of drivers, and the survey should involve reflecting detailed descriptions of each of these factors. The socio-economic attributes, traffic characteristics, and alternative lane attributes are considered as the significant variable factors of the survey. According to the actual situation, the socio-economic attributes considered in this study include seven aspects of drivers' gender, age, occupation, driving frequency, driving age, education level, and personality; traffic characteristics include two aspects of vehicle queue length and number of lane changes; alternative lane attributes include variable-guideway lane length, variable-guideway lane turning. The specific variables of individual socioeconomic attributes are defined as shown in Table 1.1.

Table 1.1: Variable definitions of individual socioeconomic attributes

Variable Category	Variable Name	Variable definition
Individual socioeconomic attribute variables	Gender	male; female
	Age	18-30; 31 and 40 years old; 41 to 50 years old; 50 years of age or older
	education	High school education or below; Specialized subject; Bachelor degree; Master degree or above
	Professional	Professional civil servants/staff of public institutions; Enterprise staff; Students; Unemployed/laid off/other
	Been driving	Driving experience of less than three years; 3 to 10 years; More than ten years

| | Driving style | Conservative driving style (calm, cautious, attention comparison); Ordinary type (responsive, energetic, easy to drive at medium speed); Aggressive (quick reaction, quick attention |
| | The driving frequency | Low driving frequency (≤2 times); General (2-4 times); High (> 4 times) |

In order to make the level values of each attribute as close to the real situation as possible, a field survey was conducted on multiple intersections with variable steering lanes in Zibo city before the implementation of the questionnaire survey, and the level values of each attribute determined are shown in Table 1.2.

Table 1.2: Attribute level values

Attribute	The level of value	
	Turn left	**Go straight**
Number of vehicles queued (vehicles)	0-3	0-3
	3-5	3-5
	5-10	5-10
	>10	>10
Number of lanes changed (lane)	0	0
	1	1
	—	2
	—	>3
Variable steering lane length	50	50
	55	55
	60	60

Considering that the excessive number of questionnaire items would cause drivers to lose patience to answer, the scenario design was carried out by orthogonal design method. The lane selection scheme with absolute advantages and disadvantages was deleted, and the scenario combination was carried out, as shown in Table 1.3.

Table 1.3: Questionnaire scenario design

Turn to	Scene	lane	number of vehicles queuing	number of changing lanes	Variable steering lanes Length (m)
Turn left	1	Left turn lane	>10	0	—
		Variable steering lane	0-3	1	55
	2	Left turn lane	3-5	2	—
		Variable steering lane	3-5	0	50
	3	Left turn lane	>10	1	—
		Variable steering lane	6-10	0	60
Go straight	1	Straight lane	>10	0	—
		Variable steering lane	0-3	1	55
	2	Straight lane	0-3	3	
		Variable steering lane	0-3	0	50
	3	Straight lane	6-10	2	—
		Variable steering lane	0-3	1	55

1.2 Scale design of potential variables

The potential variables proposed in this paper include drivers' information acquisition degree, lane understanding degree, worry, conformity and concentration degree. As potential variables cannot be measured directly, they need to be described and explained by measuring variables. Generally, two to three measurement variables are used for each potential variable. In this questionnaire, Likert's five-level scale was selected to describe each measurement variable, with 1 representing "strongly disagree" and 5 representing "strongly agree". The deeper the degree of conformity, the higher the score. In order to ensure the reliability of the designed scale, this study referred to a large number of driving behavior-related literature and consulted experts in the field of transportation, and combined with the actual design of the potential variable scale is shown in Table 1.4.

Table 1.4: Indicators for measuring latent variables

Potential		Variable measures
Worries about the psychological	WOR1：	You are concerned about a traffic violation while driving in the variable steering lane
	WOR2：	You are driving in a variable steering lane and are worried about a sudden change in the direction of the lane
	WOR3：	You are concerned that the vehicle in front does not understand the driving rules of the variable steering lane and blocks the driving
lane Understand the degree of	RF1：	Your understanding of the meaning of variable steering lane markings
	RF2：	How much do you know about the driving rules of variable steering lanes
	RF3：	To what extent do you understand the role of variable steering lanes
attention concentration	CON1:	misread or miss traffic signs
	CON2:	Missed the traffic sign and took the wrong lane
	CON3:	Do something distracting while driving, such as talking on the phone, talking, thinking.
A herd mentality	GP1：	When driving, you will follow the lane chosen by most vehicles
	GP2：	You will follow the public across the street on foot at red lights
	GP3：	When driving, you will follow the vehicle to change lanes at will
	GP4：	You choose a restaurant with a large number of people
Access to information The degree of	DOIA1：	The degree to which attention concentration affects traffic information acquisition;
	DOIA2：	The degree of influence of setting position of variable steering lane indicator on your choice of variable steering lane;
	DOIA3：	The impact of clarity and clarity of variable steerable lane signage on your choice of variable steerable lane
	DOIA4：	The influence of effective green pass time on your choice of variable steering lane
	ITN1：	Do you choose the variable steering lane when turning left
	ITN2：	Do you choose the variable steering lane when going straight
	BEA：	In different situations, your choice

2. Data statistics and analysis

2.1 Statistical analysis of explicit variables

The statistical results of the questionnaire on drivers' individual social and economic attributes are shown in Table 2.1.

Table 2.1: Statistics of personal attributes of the survey sample

Variable	Variable attribute	Percentage (%)
gender	male	51.24
	female	48.76
	At the age of 18 to 30	46.76
age	31-40 years old	36.15
	41 to 50 years old	9.48
	50 years of age or older	7.61
	High school and below	8.08
	Specialized subject	39.44
	Undergraduate course	29.77
	Master degree or above	22.72
	Civil servants/public institution personnel	4.69
	Enterprise staff	70.99
Education Level	students	7.04
	Unemployed/laid off/retired/other	17.28
	Less than three years;	31.17
	3 to 10 years	46.76
	More than ten years	22.07
	1-2 times/day;	55.12
	3-4 times/day;	38.59
	> more than 4 times/day;	6.29
professional	radical	15.97
	conservative	27.69
	ordinary	56.34

2.2 Statistical analysis of potential variables

Detailed scores of potential and measured variables are shown in Table 2.2.

Table 2.2: Mean scores of latent and measured variables

Potential variable	variable attribute	mean	variance	standard deviation
	RF1: Understanding of the meaning of variable steering lane markings	3.03	1.364	1.168
Lane awareness	RF2: Variable steering lane driving rules	3.31	1.314	1.146
		3.17	1.339	1.157
	RF3: Knowledge of variable steering lane driving action		3.17	
		3.32	1.315	1.157
Worries about the psychological	Average score for lane awareness	3.27	1.302	1.138
		3.29	1.308	1.144
	WOR1: Worried about breaking traffic rules		3.29	
		2.92	0.977	0.989

A herd mentality	WOR2: Worry about sudden changes in lane direction	2.07	1.239	1.113
		1.82	0.857	0.926
	WOR3: You are concerned that the vehicle in front of you in the variable steering lane does not know the driving rules and blocks the traffic	2.83	0.935	0.967
		2.41		
	Average worry score	2.50	1.126	1.216
attention concentration		2.42	1.246	1.234
	GP1: Follow the lane chosen by most vehicles	2.23	1.168	1.021
		2.38		
	GP2: Follow the public across the street on foot at a red light	3.18	1.315	1.147
		3.27	1.302	1.141
Information accessibility	GP3: Follow traffic to change lanes at will	3.29	1.308	1.144
		3.26	1.263	1.087
	GP4: Choose a restaurant with a large number of people	3.25		

As can be seen from the above table, the average scores of information acquisition degree, lane understanding degree, worry psychology, conformity psychology and concentration degree are respectively 3.25, 3.17, 3.29, 2.41 and 2.38, indicating that drivers are greatly affected by information acquisition degree, lane understanding degree and worry psychology when choosing lanes. It is less affected by conformity and concentration.

3. Modeling and analysis of lane selection behavior of variable steering lanes based on potential variables
In order to fully consider the extent to which drivers are affected by potential factors when choosing variable steering lanes, this section incorporates potential variables such as information acquisition degree, lane understanding degree, conformity psychology, worry psychology and attention concentration degree into the traditional BL model.
The ICLV constructed in this paper is essentially a BL model considering potential variables. With fixed turning lane as the reference group, STATA software is used to estimate its parameters by maximum likelihood method. In this paper, the variables that have no significant influence on the lane selection behavior of vehicles are successively removed by the stepwise screening strategy, and the obtained parameter calibration results are shown in Table 3.1.

Table 3.1: Parameter estimation results

Factors affecting the	Variable definitions	Variable steering lane	
		Estimated parameters	T-test
The driver Socioeconomic attribute	intercept（constant）	2.369*	1.739
	Been driving（dra）	0.463*	2.372
	Driving style（pers）	0.168*	1.673
	The driving frequency（freq）	0.321*	1.854
Traffic characteristic variable	Queue Length of vehicles（que）	-0.812***	-2.826
	Lane Change（lac）	-0.596**	-2.218
	Variable Steering Lane Length（val）	-0.086*	1.673

Lane attribute variable	Variable Steerable Lane turn（vas）	-0.528*	-1.723
Latent variables	Information Acquisition（DOIA）	0.629**	2.314
	Lane awareness（RF）	0.532*	-2.631
	Worry（WOR）	-0.953***	2.863
	Herd mentality（GP）	-0.198*	-1.835
The total number of samples	1167		
Maximum likelihood	-86.32		
Likelihood ratio test	LR chi2(66) = 1282.36，Prob > chi2 = 0.0000		
Coefficient of goodness ratio	0.7682		

In ICLV with potential variables, driving style, driving age, driving frequency, information acquisition degree and lane understanding degree have significant positive influence on lane choice behavior of variable steering lane. Queuing length, number of lane changing, variable steering lane length, variable steering lane turning, worry psychology and conformity psychology have significant negative effects on lane choice behavior of variable steering lane.

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