KSCE Journal of Civil Engineering (2015) 19(7):2262-2270
Copyright ⓒ2015 Korean Society of Civil Engineers
DOI 10.1007/s12205-014-0692-y

Transportation Engineering

pISSN 1226-7988, eISSN 1976-3808
www.springer.com/12205

Drivers' Diversion from Expressway under Real Traffic Condition Information Shown on Variable Message Signs

Xingang Li*, Yakang Cao, Xiaomei Zhao***, and Dongfan Xie******

Received November 20, 2013/Revised June 8, 2014/Accepted November 7, 2014/Published Online December 19, 2014

Abstract

To alleviate the traffic congestion on urban expressway, Variable Message Signs (VMS) have been widely employed for diverting some traffic to arterial streets in large cities. The diversion rate is a key parameter to design, operation and evaluation of the VMS. Many works have been done to study the diversion rate by stated preference survey. However, no consistent conclusion has been obtained on the key factors influencing diversion behavior. Therefore, this paper pays attention to analyzing the drivers' diversion from expressway behavior under different network and traffic conditions, and finding the key factors influencing diversion behavior by using stated preference survey. In the survey, graphical traffic information is provided as scenario simulation. Ordinal regression method is adopted to explore the key factors influencing diversion willingness. Binary logit model is used to explore the divert decision with given traffic information. It is shown that driving years, income, driving style, average trip length, and degree of trust in VMS are the significant factors to diversion willingness. Furthermore, the same VMS displaying state results in different diversion flow at different sites. Those findings are the foundation to optimize traffic information releasing strategy and improve the road network efficiency.

Keywords: *variable message signs, diversion behavior, ordinal regression, discrete choice model*

1. Introduction

Traffic congestion, especially in peak hours, has become a common problem among large cities around the world. And it is very difficult and challengeable to solve, because urban traffic has the properties of dynamics, randomness and complexity. In order to alleviate traffic congestion, Advanced Traveller Information System (ATIS) is widely adopted in urban traffic operation and management. It can acquire, analyze, and present real time traffic information to assist surface transportation travellers.

Variable Message Signs (VMS) are highly adopted by the transportation authorities as en route traffic guidance information providing devices. They can display information such as current traffic condition, weather condition, journey time information, accidents, road works, and other non-recurrent traffic events. Then travelers can make route choice to avoid congested roads. However, the route guidance information provided by VMS is just a kind of suggestion message, and it has no mandatory effect on travelers. This means that the travelers could comply with the VMS or not. The compliance rate determines the diverting flow on the downstream road sections directly, and impact the effectiveness of the route guidance information. In order to make full use of the VMS for improving the efficiency of road network, timely and appropriate traffic information releasing strategy is needed. Therefore, drivers' route choice behavior with en route traffic information is the fundamental issue for designing the traffic information releasing strategy for VMS.

Extensively works have been done to investigate travellers' responses to VMS by Stated Preference (SP) survey method (Gan and Ye, 2011; Zhong *et al.*, 2012; Majumder *et al.*, 2013). Various models were developed to identify the contributing factors that affect the route choice behavior. The main factors can be simply classified into the following four classes: drivers' socio-economic characteristics, trip attributes, VMS attributes, and local network conditions. The information shown on VMS has the form of text and/or graphic. Nowadays, the LED-based VMS, which can provide both text and graphic information, are widely adopted.

*Assistant Professor, MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China (Corresponding Author, E-mail: lixinang@bjtu.edu.cn)
**Graduate Student, MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China (E-mail: 11120928@bjtu.edu.cn)
***Associate Professor, MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China (E-mail: xmzhao@bjtu.edu.cn)
****Assistant Professor, MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology, Beijing Jiaotong University, Beijing 100044, China (E-mail: dfxie@bjtu.edu.cn)

In Beijing, there are more than 500 VMS, and most of them are LED-based. The graphic information shows the road traffic condition by three colors: green, yellow, and red, which correspond to free moving, generally crowded, and heavy congested, respectively. There is an urgent need to explore the route choice behavior influence by VMS. For it is the foundation for improving guidance effectiveness, optimizing information releasing strategy, alleviating local traffic congestion, and improving network traffic efficiency.

This paper investigates 1) the main factors influencing the drivers' diversion willingness after seeing that the downstream road section is heavy congested and 2) the drivers' diversion behavior with graphic traffic information provided by VMS. Statistical analysis is conducted based on the data of Stated Preference (SP) survey with scenario simulation. The main factors influencing the drivers' diversion willingness is analyzed by ordinal regression method. The drivers' diversion behavior with graphical traffic information provided by VMS is studied by binary logit model. The scenario simulation in the survey mainly refers to trip attributes and local network conditions, such as destination, extra length of alternative length, and degree of road congestion. Different from the previous work, the diversion rate under graphic traffic information is systematically investigated by considering all display states of two road sections. Note that each road section has three display states, i.e., green, yellow, and red. The results of this paper would be helpful in designing optimal information releasing method.

2. Literature Review

Compliance rate is the key factor reflecting route guidance effectiveness. However it is quite different from Country to Country. Cummings (1994) found that only 4-7% of the drivers choose to switch routes according to VMS. Ramsy and Luk (1997) found that the drivers' compliance rate can reach to 30% in Australia. Davidsson and Taylor (2003) found that 6-41% of the drivers would choose the alternative path to avoid congestion in Sweden. Tsirimpa and Polydoropoulou (2009) found that 54% of the respondents would change route in Athens. Gan and Ye (2011) found that the diversion rate could be 47% in case of congestion or accident in China. Khoo and Ong (2013) found that 24% of the respondents will change to alternative route in Malaysia. Those results clearly show the huge difference in compliance rate or diversion rate in different countries. So the route choice behavior should be investigated separately in different cities.

As to the main factors influencing the route choice behavior, Bonsall (1992) proposed that drivers' route choice behavior was affected by overall expected journey time, existence of toll road, congestion and delay, the familiarity with the routes and the accuracy of VMS. Hato *et al.* (1995) built the Probit model of compliance rate considering the factors including the perception of the guidance information, the accuracy of VMS, destination, and the familiarity with the routes. Wardman *et al.* (1997) proposed that the drivers' route choice behaviors were affected by the content of VMS, local circumstances, previous network knowledge, and the drivers' characteristics. Chatterjee *et al.* (2002) revealed that the position of accidents and the content of VMS were the important factors that influence the drivers' route choice. Jou *et al.* (2005) found out that the quantitative and guidance information provided on VMS was easier to be accepted by freeway travelers, and the male drivers and drivers with a higher income would be more likely to switch to the best route. Zhong *et al.* (2012) proposed that the compliance rate was significant related to age, the driving years, the average annual mileage, monthly income, driving style, occupation, the trust degree in VMS, the familiarity with road network and the route choice style.

The display form of traffic information can affect driver's awareness. Pure text-based VMS was the traffic guidance information means of early times, and had received much attention from researchers (Anttila *et al.*, 2000; Cooper *et al*., 2004; Dutta *et al.*, 2004; Erke *et al*., 2007). Anttila et al. (2000) investigate the visual demand for bilingual text message simultaneously or alternatively shown on VMS. Dutta *et al.* (2004) conducted a driver simulator study with two consecutive screens presenting text messages, and found that the miss rate of unrepeated messages was significantly higher than the repeated ones. Erke *et al.* (2007) found out route guidance information shown on VMS induces speed reduction but high compliance rate. Gan and Ye (2011) and Gan (2013) explored urban freeway users' diversion response to the VMS by displaying the explicit travel time of both urban freeway and local streets. Graphic information has the properties of easy-to-understand and language-independent. Thus it allowed drivers from different countries to read after harmonization. Tay and Choi (2009) found out that most of the graphic information was easy to understand, but some were not, such as the information about traffic accidents, congestion and snow. Zhong *et al.* (2012) investigated the drivers' guidance compliance behavior when the road traffic conditions are displayed on graphic VMS by different colors.

Of course, pure graphic information was not enough sometimes, especially when the notification was presented, and supplementary text information might be needed. Some researchers compared the effects of text-based and graphic VMS on drivers' behaviors. Nuttall *et al.* (1998) pointed out the recognition process of graphics was very different from characters, it took drivers more attention and longer distance to read text messages. Rämä *et al.* (2004) found graphic VMS was preferred by drivers despite they might not understand it correctly. Shao *et al.* (2010) also pointed out that the drivers preferred the graphic VMS to the text-based VMS.

Note that the LED-based VMS can display the local network structure and road traffic condition of the network. As to a sequence of road sections, there are many combinations of display states, especially for the three colors representation system adopted in Beijing. Systematically analysis of the diversion behavior under each display state is urgently needed before designing effective information releasing strategy. This is the main concern of this paper.

3. Survey

3.1 Survey Purpose

In large cities, the expressway system plays a dominant role in accommodating road traffic. The driver prefers the expressway to the arterial streets for completing a trip. In order to alleviate the traffic pressure on expressway and divert some traffic to the arterial streets, VMS, which can provide traffic information of the downstream expressway, is implemented on most of large cities in China, especially in Beijing.

The survey is to investigate 1) main factors influencing drivers' diversion willingness and 2) drivers' divert decision with given graphical traffic information. Then two types of questions: 1) characteristics related questions and 2) scenario related questions, are considered in the survey. They correspond to the two survey purposes.

Characteristic related questions include drivers' socio-economic characteristics, travel characteristics, and VMS perception characteristics. The graphical information reflects different traffic conditions and different destinations.

3.2 Survey Scenarios

A typical trip with two routes, one through expressway and the other by arterial streets, is depicted in Fig. 1. The VMS can provide downstream traffic information. And it is just located

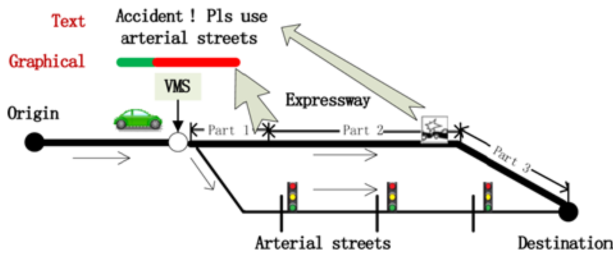

Fig. 1. Typical Route Choice Problem according to VMS on Expressway

upstream the off ramp, then the drivers on the expressway could make route choice decision after learning the traffic condition. They can remain on the expressway or divert to arterial streets. The survey scenarios are designed based on the binary choice problem under various traffic conditions.

The graphical VMS provides the downstream road traffic conditions. And the conditions of heavy congested, generally crowded and free moving are represented by red, yellow, and green, respectively. Two graphical VMS, VMS-1 and VMS-2, are selected to study the diversion behavior (Fig. 2). VMS-1 is located at the north of Fuchengmen Bridge on the 2nd ring road and VMS-2 is just at the west of Liangxiang Bridge on the 3rd ring road. Both the 2nd and the 3rd ring roads are expressway and have a speed limit of 80 km/h.

The graphical VMS shows the traffic condition on several downstream roads, and the driver just pays attention to the roads relevant to the travel destination. In the survey scenarios, the

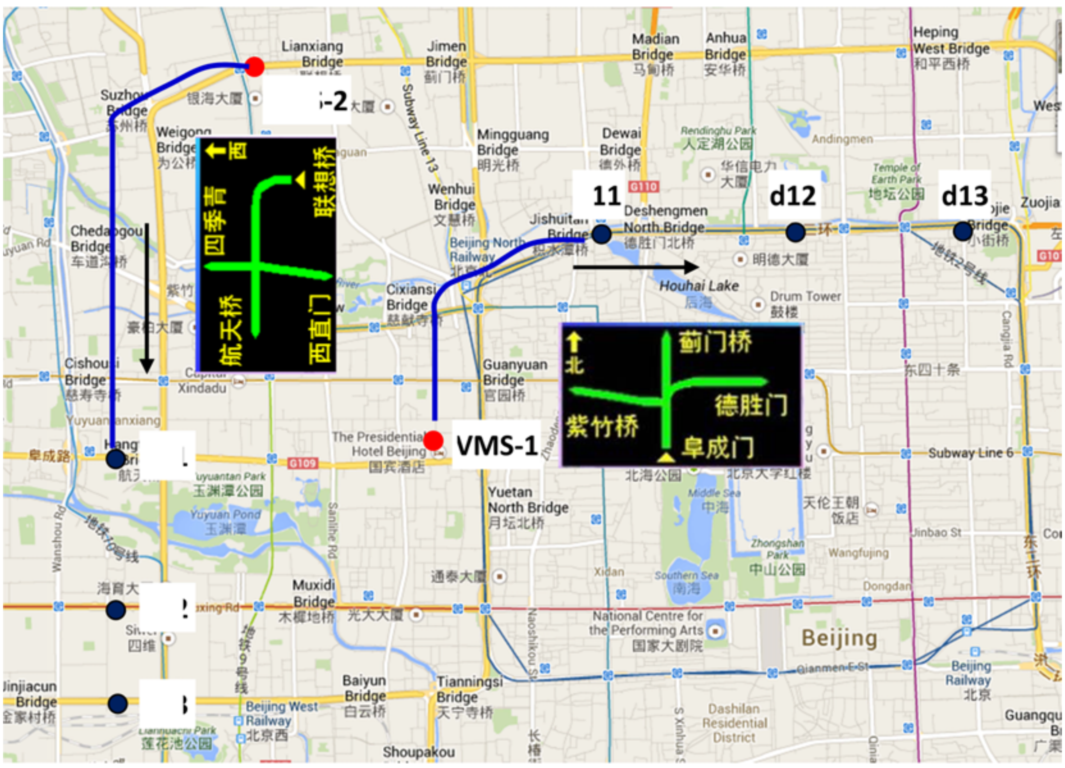

Fig. 2. Detailed Illustration of the Selected Graphical VMS and the Downstream Expressway

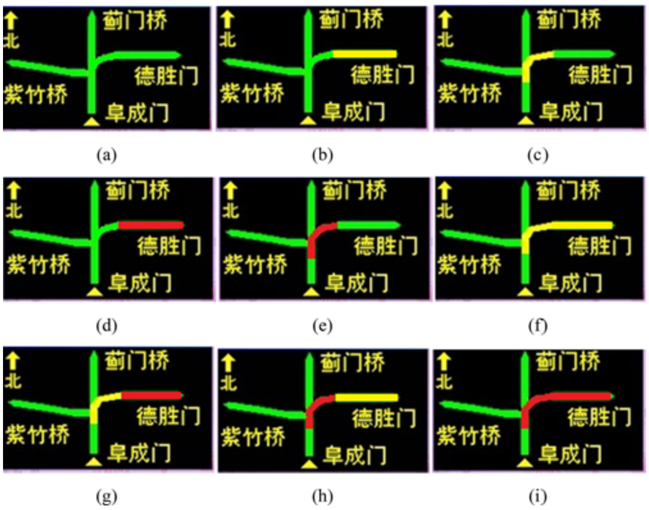

Fig. 3. Scenarios for Different Traffic Conditions on VMS-1

destinations are also on the ring road, thus only the downstream ring road shown on the VMS is considered. The sequential roads from VMS location to the destination can be divided into three parts (see Fig. 1): part 1, the traffic conditions can be obtained by eye and VMS; part 2, the traffic conditions can only be obtained by VMS; and part 3, the traffic condition is blind to the driver. The survey scenarios refer to different traffic conditions and destinations. Different traffic conditions are that on part 2 and different destinations can be represented by the length of part 3.

3.2.1 Different Traffic Conditions

As for the selected two graphical VMS, part 2 shown on the VMS has two separately sections. Section 1 is upstream and section 2 is downstream. Each section has three states that represented by three different colors, so there are totally 9 different states that VMS can display (Fig. 3). Here only the scenarios for VMS-1 are shown, the colors of road section in each scenario for VMS-2 are the same. Assume that the perceived travel cost of the 9 scenarios (a) - (i) are C1-C9, respectively, it is easy to obtain that C1< C6<C9, but it is hard to compare the perceived travel costs of those with different color order, i.e., C2 and C3, C4 and C5, C7 and C8. Take C1, C2, and C3 as an example. C1 is the lowest, because both sections are in green color. C2 and C3 are higher than C1 as to one of the two sections is in yellow color. The perceived travel cost in the case that the downstream section with yellow color (C2) is higher or not higher than that in the case that the upstream section with yellow color (C3) is hard to determine. Which one has a higher perceived travel cost will be investigated by the survey results.

3.2.2 Different Destination

The destinations are all located on the downstream ring road (see Fig. 2). From the nearest to the farthest, for origin VMS-1 they are d11, d12, and d13, and for origin VMS-2 they are d21, d22, and d23. The length of each road sections is listed in Table 1.

3.2.3 Different Sites

As mentioned above, VMS-1 and VMS-2 are located on the 2nd and 3rd ring road respectively. Both the 2nd and 3rd ring road have a speed limit of 80 km/h. The different features between the two sites are: the 2nd ring road is more congested and there are less alternative routes instead of the ring road.

4. Questionnaire and Analysis

4.1 Questionnaire Design

The questions in the questionnaire can be classified as 1) scenario simulations; 2) drivers' socio-economic characteristics; 3) travel characteristics; 4) VMS perception characteristics; and 5) decision choice.

Scenario simulations refer to the drivers' decision on whether or not divert from the expressway (ring road) under different conditions. They are used to analysis the drivers' divert decision. And the other questions are used to investigate drivers' diversion willingness. Drivers' socio-economic characteristics include gender, age, driving years, educational level, yearly income and driving style (i.e., risky, steady or conservative). Travel characteristics are travel times per week, average trip length, and average trip time. VMS perception characteristic is trust degree on VMS. The decision choice is the willingness to divert after seeing red downstream road section on VMS, and the wil/ingness can be low, middle and high.

4.2 Data Collection

From October to November, 2012, on-the-spot surveys were carried out at car wash stores in the vicinity of the two selected VMS. The car wash usually lasts 10 minutes, which is long enough to complete a questionnaire. The interviewers were trained to be able to explain clearly the simulation scenarios and the questions to the respondents. Thus, the participant could have a good knowledge of the survey. After completing a questionnaire, the participant could gain a gift. Finally, 242 questionnaires were obtained, and 236 questionnaires were valid. The rate of valid reached at 97.5%.

4.3 Data Analysis

4.3.1 Survey Results for Drivers' Characteristics

Table 2 shows the statistical results of the survey. The distributions for the drivers' socio-economic characteristics are

Table 1. Length of Road Section

Road sections	VMS-1 to d11	d11 to d12	d12 to d13	VMS-2 to d21	d21 to d22	d22 to d23
Length (km)	4.0	2.4	2.1	6.4	1.8	1.2

Table 2. Statistical Results of the Survey

Attribute	Category: Value	Percentage	Attribute	Category: Value	Percentage
Gender	Male: 1	80.1%	Educational level	College degree and bellow: 1	32.2%
				Bachelor degree: 2	46.2%
	Female: 2	19.9%		Master and above: 3	21.6%
Age	18-25: 1	9.3%	Driving styles	Conservative: 1	34.3%
	26-45: 2	70.3%		Steady: 2	58.1%
	>45: 3	20.3%		Risk-based: 3	7.6%
Driving years	1-3: 1	23.3%	Average trip length	<15 km: 1	37.7%
	4-10: 2	44.9%		15-30 km: 2	34.7%
	>10: 3	31.8%		>30 km: 3	27.5%
Yearly income	<16K $: 1	49.6%	Degree of trust in VMS	Low: 1	33.5%
	16K-32K $: 2	38.1%		Middle: 2	40.7%
	>32K $: 3	12.3%		High: 3	25.8%

listed as follows: 80.1% of the respondents were male. 9.3% were 18-25 years, 70.3% were 26-45 years, and 20.3% were over 45 years old. As to driving years, 23.3% were new driver with less than 3 years experiences, 44.9% had 4-10 years driving experiences, and 31.8% were old driver with plentiful driving experiences. About 49.6% of respondents earned less than 16K $ a year, 38.1% earned 16K to 32K $ a year, and 12.3% more than 32K $ a year. The percentages of the educational levels with high school, degree and master and above are 32.2%, 46.2%, and 21.6% respectively. 34.3% of the respondents were conservative drivers, 58.1% were steady drivers, and 7.6% were risk-based drivers.

4.3.2 Survey Results for Scenario Simulations

The diversion rates under each condition are shown in Tables 2 and 3. It can be seen that the diversion rate is almost 0 when the ring road is in free flow state, while the diversion rate is very high when the ring road is in heavy congested state. The diversion rate is an indicator of perceived travel cost. High diversion rate means high perceived travel cost. From the survey results, the following conclusions can be obtained:

1) The diversion rate increases as the road traffic becomes more congested (the colors shown on VMS change from green to red);
2) The diversion rate increases as the destination becomes further;
3) The perception cost is different with different color orders on VMS;
4) The diversion rate on 2nd ring road is less than that on 3rd ring road.

The perceived travel costs of the VMS states with same color components but different color order have never been investigated in previous works. Now, this will be analyzed in detail by comparison the three pairs C2 and C3, C4 and C5, C7 and C8. From Table 5, one can see that for VMS-2, the condition that the upstream section is more congested has a higher perceived cost (C2 < C3, C4 < C5, C7 < C8); while for VMS-1, the condition that the upstream section is more congested has a higher perceived cost only when the destination is d11, and the inverse case will be obtained when the destination is further (d12 and d13).

5. Model Formulation and Discussion

5.1 Regression Models

As mentioned above, this paper focuses on the following two purposes: 1) main factors influencing drivers' diversion willingness, and 2) drivers' divert decision with given graphical traffic

Table 3. Diversion Rate under Different Conditions for VMS-1

Destinations \ Scenarios	a	b	c	d	e	f	g	h	i
d11	0%	6.70%	10%	63.30%	68.30%	26.70%	67.50%	68.30%	86.70%
d12	1.70%	10%	10%	81.70%	78.30%	34.20%	83.30%	72.50%	88.30%
d13	1.70%	30%	13.30%	83.30%	78.30%	47.50%	79.20%	68.30%	91.70%

Table 4. Diversion Rates under Different Condition for VMS-2

Destination \ Scenarios	a	b	c	d	e	f	g	h	i
d21	0%	8.50%	21.30%	72.90%	82%	42.50%	80.80%	89.20%	94.90%
d22	0%	23.70%	26.20%	81.40%	91.80%	50%	87.50%	90.80%	96.60%
d23	0%	23.70%	32.80%	83.10%	91.80%	53.30%	88.30%	91.70%	94.90%

Table 5. Comparison of Perceived Travel Cost with Different Color Orders

VMS-1		VMS-2	
Destination	Order	Destination	Order
d11	C2<C3; C4<C5; C7<C8	d21	C2<C3; C4<C5; C7<C8
d12	C2=C3; C4>C5; C7>C8	d22	C2<C3; C4<C5; C7<C8
d13	C2>C3; C4>C5; C7>C8	d23	C2<C3; C4<C5; C7<C8

information. The factors include drivers' socio-economic characteristics, travel characteristics, and VMS perception characteristics. Most of them are ordinal variables, thus the ordinal regression model is employed to investigate the main factors influencing drivers' diversion willingness. The drivers' divert decision is binary choice, so the widely used binary logit model is adopted to investigate the drivers' divert decision with given graphical traffic information.

In the ordinal regression model, the dependent variable is the willingness to divert after seeing that downstream road section is displayed by red on VMS. The independent variables are concerned characteristics shown in Table 2.

In the binary logit model, the dependent variable is the binary diversion choice, and the independent variables are travel cost of the upstream and downstream road sections given by graphical information. In this case, it is assumed that the drivers' characteristics are deemed as homogenous, only the traffic condition information is considered.

With given graphical traffic information, the utility of route through expressway is defined as:

$$U^* = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \theta_3 d \quad (1)$$

Here x_1, x_2 denote the travel cost of the upstream and downstream road sections respectively. And the d represents the length of part 3.

5.2 Results for Ordinal Regression Model

SPSS provides an efficient module to conduct the ordinal regression with five link functions: logit, negative log-log, complementary log-log, cauchit, and probit. The link function is a transformation of the cumulative probabilities of the dependent ordered variables that allows for estimation of the model. The recession results show that the complementary log-log type link function performs the best among the five types of link functions. So the complementary log-log type link function is used.

Before the ordinal regression was conducted, the test of parallel line should be carried out. The parallel lines assumption means that the regression coefficients are the same for all corresponding outcome categories. If the assumption fails, the ordinal regression should not be used. The results for the test of parallel line is shown in Table 6, one can see that the statistical significance level of the model is 0.783, so the parallelism assumption could not be rejected. That is to say, the coefficients can be deemed as the same for all categories. Therefore, ordinal regression was suitable.

Table 6. Model Information

Model	-2 Log likelihood	Chi-square	df	Sig.
Test of parallel lines				
Null Hypothesis	338.599			
General	328.891	9.707	14	.783
Model fitting information				
Intercept only	383.255			
Final	338.599	44.656	14	.000
Goodness of fit				
Pearson		347.424	362	.700
Deviance		306.774	362	.984

Besides the test of parallel line, the model fitting information is also shown in Table 6. Model fitting information is to test the null hypothesis (all the regression coefficients are zero except constant item). One could see that the two models were significantly different (P = 0.000), the null hypothesis was rejected and all the regression coefficients were not zero at the same time. The statistical significance level of Pearson and Deviance were 0.700 and 0.984, so the assumption that there was

Table 7. Results of Ordinal Regression

Independent variables		Estimate	Sig.	95% CI L	95% CI U
Gender	Male	.039	.874	-.444	.523
	Female	0^a	.	.	.
Age	18-25 years	-.246	.508	-.973	.481
	26-45 years	.091	.720	-.405	.587
	>45 years	0^a	.	.	.
Driving years	1-3 years	.435	**.076**	-.046	.915
	4-10 years	.129	.501	-.246	.503
	>10 years	0^a	.	.	.
Yearly income	<16K $	-.162	.616	-.793	.470
	16K-32K $	-.677	**.034**	-1.303	-.051
	>32K $	0^a	.	.	.
Educational level	College degree and below	-.063	.827	-.624	.499
	Bachelor degree	-.068	.796	-.582	.447
	Master and above	0^a	.	.	.
Driving styles	Conservative	-.746	**.073**	-1.562	.070
	Steady	-.397	.325	-1.186	.393
	Risk-based	0^a	.	.	.
Average trip length	<15 km	-1.001	**.000**	-1.517	-.485
	15-30 km	-.338	.231	-.890	.215
	>30 km	0^a	.	.	.
Degree of trust in VMS	Low	-1.056	**.000**	-1.599	-.513
	Middle	-.255	.348	-.789	.279
	High	0^a	.	.	.

Link function: complementary log-log. The significance of bold value is 0.05.
[a]This parameter is set to zero because it is redundant.

no obvious difference between predicted and observed value was accepted.

Table 7 shows the estimation results of ordinal regression, including the ordered complementary log-log regression coefficients, the p-values of the coefficients and the 95% confidence interval for regression coefficients. The lower p-values of the coefficients indicate the higher significance. Significant regression coefficient means the corresponding variable is closely related to the log odds. That is to say, the corresponding factor has a close relationship with the diversion behavior. Furthermore, the positive coefficients among the significant ones indicate that the log odds will increase with the increment of corresponding independent variable while the other variables keep unchanged, whereas the negative coefficients mean log odds decrease. Five independent variables (driving years, yearly income, average trip length, driving style, and the degree of trust in VMS) of the diversion behavior were significant at 0.10 level, while other three independent variables (gender, age, educational level) were not significant. Next we only focus on analyzing the results of significant variables.

The ordered log odds for drivers whose driving years were less than 3 years in a higher compliance degree were 0.435 more than driving years being over 10 years. Drivers with driving years being 4-10 years were not statistically different from drivers with driving years being over 10 years. So the drivers being less than 3 years are most likely to divert according to VMS, and over 10 years the least. Those results is consistent with that obtained by Zhong *et al.* (2012), but inconsistent with the results by Gan (2013), in which drivers with rich driving experience are more adaptable to expressway delays and more familiar with local street and thereby more likely to divert. As explained by Zhong *et al.* (2013), new drivers were lack of understanding of VMS and unfamiliar with local network, they always had no idea about the better route when they encountered the route choice problem, so they would most likely to make route choice according to the VMS. We believe that this is a common property in heavily congested network, because the alternative route is usually congested too. But reverse fact will exist in less congested network, because driver with more experiences could find shorter alternative route.

Similar with the previous works (Jou *et al.*, 2005; Zhong *et al.*, 2012), personal income had a positive relation with diversion rate under VMS. The diversion rate will increase as yearly income rises. Note that the log odd of drivers with yearly income being 16K-C32K $ in a higher diversion rate is 0.677 less than the ones with yearly income being over 32K $. This is easy to understand, because higher income group has a higher value of time, they expected to use more external information to select the shortest path and save more time.

The diversion rate will increase as the driving style becomes more risk. It is shown that there is a significant difference, which is 0.746, between the log odd for conservative driving style and that for risk-based driving style. The drivers with risk-based driving style have the highest diversion rate. It is believed that the drivers with risk-based driving style are mostly likely to divert from the original route which is heavily congested and find alternative route. But as to the drivers with conservative driving style, they can endure heavily congestion and are willing to keep moving on the congested route. This results is different form that in Zhong *et al.* (2012), in which the drivers with steady driving style have the highest diversion rate.

The diversion rate will increase as the average trip length becomes longer. One can see that drivers with average trip length being less than 15 km were significantly different with the ones with average trip length being more than 30 km. The degree of compliance with average trip length being less than 15 km was lower than the latter category. As to the drivers with longer average trip length, there will be more alternative route for them to choose, so they have a higher diversion rate.

The diversion rate has a closely positive relationship with the degree of trust in VMS. This is widely accepted by researchers (Bonsall and Joint, 1991; Hato *et al.*, 1995; Janssen and Vander Horst, 1992; Zhao *et al.*, 1995). Compared with the drivers who deeply trust the VMS (i.e., trust degree is high), the drivers who distrust it (i.e., trust degree is low) had a significant lower diversion rate.

5.3 Results for Binary Logit Model

As to the graphical traffic information, the average speeds corresponding to different colors shown on VMS are the same as adopted by Zhong *et al*., (2012) (Table 9). As we know that the road sections with different colors shown on the VMS are usually equally divided, thus each road section is assumed with equal length. Then the travel cost is just inversely proportion to the average speed. If the travel cost of the road section with green color is deemed as 1, then those corresponding to yellow and red can be directly calculated (see Table 8).

The calibrated results are shown in Table 9. One can see that θ_1 and θ_2 have different values, thus the utility is also different when the two roads has the same color components but different color order. Furthermore, it can be seen that for VMS-1, $\theta_1 < \theta_2$ and for VMS-2, $\theta_1 > \theta_2$. Thus, for VMS-1, the downstream road section takes a high weight in evaluating the utility or perceived travel

Table 8. Average Speed and Travel Cost Correspond to Different Color

Color	Green	Yellow	Red
Average Speed (m/s)	8.1278	4.9222	2.0694
Travel Cost	1	2.3786	3.9276

Table 9. Calibrated Results of Eq. (1)

	VMS-1		VMS-2	
Parameters	Value	Std error	Value	Std error
θ_0	-5.51	0.62	-4.47	0.59
θ_1	0.98	0.15	1.13	0.13
θ_2	1.07	0.15	0.84	0.13
θ_3	0.12	0.09	0.20	0.12
Adj. R-square	0.78		0.80	

cost, while for VMS-2, the upstream road section plays a dominant role in evaluating the perceived travel cost. It is common sense that the driver will pay much attention to the upstream road section which will be first reached. The reason for the driver care about the traffic condition of the downstream road section on VMS-1 may be that the 2nd ring road is usually congested and the traffic condition of part 3 is highly related to the downstream section, which means that on the 2nd ring road, if the downstream of part 2 is in heavy congested state, part 3 would be heavy congested too.

6. Conclusions

This paper studied the drivers' diversion from expressway response to traffic guidance information by SP survey method. Survey questionnaire are designed and survey results are analyzed to explore the main factors influencing the drivers' diversion willingness after seeing the downstream road section is heavy congested and the drivers' diversion behavior with graphic traffic information provided by VMS. Scenario simulations are adopted to study the diversion rate under different traffic conditions, destinations and sites. The following conclusions are obtained:

1. Driving years, income, driving style, average trip length, and degree of trust in VMS are the significant factors influencing the diversion behavior. The diversion rate is high with short driving year, high income, risk-base driving style, longer trip length, and higher degree of trust in VMS.
2. The same VMS displaying state results in different diversion flow at different sites. The diversion rate on the 2nd ring road is less than that on 3rd ring road. The reason may be that there are more alternative routes around the 3rd ring road.
3. The perceived travel costs of the VMS states with same color components but different color order are different to the driver. The drivers pay much attention to the traffic condition of the downstream road section shown on VMS on the 2nd ring road, while they pay much attention to that of the upstream road section shown on VMS on the 3rd ring road.

According to the results obtained in this paper, further research should be done to explore the optimal information release strategy. Then relevant models could be adopted in the daily operation of traffic guidance system in Beijing.

Acknowledgements

This work was financially supported by the National Basic Research Program (2012CB725400), the National Natural Science Foundation of China (Nos. 71371001, 71301007, 71271025, and 71131001), and Beijing Higher Education Young Elite Teacher Project (No. YETP0553).

References

Anttila, V., Luoma, J., and Rama, P. (2000). "Visual demand of bilingual message signs displaying alternating text messages." *Transportation Research Part F*, Vol. 3, No. 2, pp. 65-74, DOI: 10.1016/S1369-8478(00)00016-4.

Bonsall, P. W. (1992). "The influence of route guidance advice on route choice in urban networks." *Transportation,* Vol. 19, No. 1, pp. 51-73, DOI: 10.1007/BF01130771.

Bonsall, P. W. and Joint, M. (1991). "Driver compliance with route guidance advice. The evidence and its implications." *Vehicle Navigation and Information Systems Conference,* Vol. 2, pp. 47-59.

Chatterjee, K., Hounsell, N. B., Firmin, P. E., and Bonsall P. W. (2002). "Driver response to variable message sign information in London." *Transportation Research Part C*, Vol. 10, No. 2, pp. 149-169, DOI: 10.1016/S0968-090X(01)00008-0.

Cooper, B. R., Freeman, M., and Mitchell, J. C. (2004). *MS4 off-road research summary report*, TRL Report TRL604, TRL Limited. Berkshire, United Kingdom (revised version of TRL556).

Cummings, M. (1994). "Electronic signs strategies and their benefits." *Proceedings of the Seventh International Conference on Road Traffic Monitoring and Control*, London, UK, pp. 141-144.

Davidsson, F. and Taylor, N. (2003). *ITS modelling in Sweden using CONTRAM*, TRL Ltd., Berkshire, United Kingdom.

Dutta, A., Fisher D. L., and Noyce, D. A. (2004). "Use of a driving simulator to evaluate and optimize factors affecting understandability of variable message signs." *Transportation Research Part F*, Vol. 7, Nos. 4-5, pp. 209-227, DOI: 10.1016/j.trf.2004.09.001.

Erke, A., Sagberg, F., and Hagman, R. (2007). "Effects of route guidance Variable Message Signs (VMS) on driver behavior." *Transportation Research Part F*, Vol. 10, No. 6, pp. 447-457, DOI: 10.1016/j.trf.2007.03.003.

Gan, H. (2013). "Investigation of driver response to the enhanced urban freeway variable message sign information." *KSCE Journal of Civil Engineering*, KSCE, Vol. 17, No. 6, pp. 1455-1461, DOI: 10.1007/s12205-013-0231-2.

Gan, H. and Ye, X. (2011). "Urban freeway users' diversion response to variable message sign displaying the travel time of both freeway and local street." *IET Intelligent Transport Systems*, Vol. 6, No. 1, pp. 78-86, DOI: 10.1049/iet-its.2011.0070.

Hato, E., Taniguchi, M., and Sugie, Y. (1995). "Influence of traffic information on driver's route choice." *World Conference on Travel Research*, Sydney.

Janssen, W. and Vander Horst, R. (1992). "Descriptive information in variable route guidance messages." *3rd International Conference on Vehicle Navigation and Information Systems, IEE*, Oslo, pp. 214-220.

Jou, R. C., Lam, S. H., Liu, Y. H., and Chen, K. H. (2005). "Route switching behavior on freeways with the provision of different types of real-time traffic information." *Transportation Research Part A*, Vol. 39, No. 5, pp. 445-461, DOI: 10.1016/j.tra.2005.02.004.

Khoo, H. L. and Ong, G. P. (2013). "Evaluating perceived quality of traffic information system using structural equation modeling." *KSCE Journal of Civil Engineering*, KSCE, Vol. 17, No. 4, pp. 837-849, DOI: 10.1007/s12205-013-0248-6.

Majumder, J., Kattan, L., Habib, K. N., and Fung, T. S. (2013). "Modelling traveller response to variable message sign." *International Journal of Urban Sciences*, Vol 17, No. 2, pp. 259-280.

Nuttall, E. D., Ginsburg, E., and Beerlage, R. (1998). "LEDs spell it out: The future of traffic signs." *Traffic Technology International*, pp. 182-184.

Rämä, P., Schirokoff, A., and Luoma, J. (2004). "Potential harmonisation of variable message signs in Viking countries." *Nordic Road and*

Transport Research, Swedish Road and Transport Research Institute, Linkoing, Sweden, pp. 4-5.
Ramsy, E. and Luk, J. (1997). *Route choice under two Australian travel information systems*, ARRB Research Report ARR 312.
Shao, C. F., Dong, C. J., Zheng, C. Q., and Qiao, L. (2010). "Analysis of VMS information service with SP survey." *Control Theory & Applications*, Vol. 27, No. 12, pp. 1681-1685, DOI: 1000-8152(2010)12-1681-05. (in chinese)
Tay, R. and Choi, J. (2009). "Evaluation of pictograms in dynamic lane control systems in the Republic of Korea." *Journal of Transportation Systems Engineering and Information Technology*, Vol. 9, No. 2, pp. 56-61, DOI: 10.1016/S1570-6672(08)60054-9.
Tsirimpa, A. and Polydoropoulou, A. (2009). "Travelers response to VMS in the athens area." *Proceedings of Research in Transport and Logistics*, pp. 179-187.
Wardman, M., Bonsall, P. W., and Shires, J. D. (1997). "Driver response to variable message signs: A stated preference investigation." *Transportation Research C*, 1997, Vol. 5, No. 6, pp. 389-405, DOI: 10.1016/S0968-090X(98)00004-7.
Zhong S. Q., Zhou, L. Z., Ma, S. F., and Jia. N. (2012). "Effects of different factors on drivers' guidance compliance behaviors under road condition information shown on VMS." *Transportation Research Part A*, Vol. 46, No. 9, pp. 1490-1505, DOI: 10.1016/j.tra.2012.05.022.