Modeling Traveller's Response to Incident Information provided by Variable Message Signs in Calgary, Canada

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Executive Summary

The purpose of this report is to investigate driver's response behaviour to intelligent transportation systems. It describes the results of a detailed survey and an econometric model for route diversion behaviour, in response to real-time information provided by variable message signs (VMS). The study location was Deerfoot Trail of the city of Calgary, Canada. In case of major delays due to accidents on Deerfoot Trail, the City of Calgary is using 12 VMS along Deerfoot Trail to divert drivers to alternative parallel arterials. A survey of 500 Deerfoot Trail commuters was conducted to examine the factors affecting drivers' compliance with VMS. A latent discrete choice model has been developed to model the responses of drivers to VMS. This model introduces behavioural variables within a discrete choice model by endogenously estimating the latent variables. The primary finding of the study is that the en-route information provided by VMS convinces few drivers to change their trip destination. Among the 500 respondents, a total of 63.7% of drivers alter their trip plans in light of the information provided. However, 36.7% of drivers experience inertia by not altering their route, despite the excessive delays due to route blockage. From the empirical model it becomes clear that, driving experience, familiarity with alternative routes, trip purpose, trip time, trip length and complementary sources, such as radio information are the most important factors influencing route switching behavior in response to VMS. In addition, drivers' attitude towards VMS was found to have the most significant impact on travellers' response to these systems.

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INTRODUCTION

Advanced traveller information systems (ATIS) are an integral part of intelligent transportation systems (ITS) and are intended to provide travellers with real-time information about traffic conditions and delays. The main objective of providing such information is to help travellers make more informed travel decisions by avoiding routes subject to severe congestion and, consequently, reducing their travel time as well as excessive delays on these routes. Variable message sign (VMS), also known as changeable message signs (CMS), are one of the most common sources of ATIS used to inform en-route travellers to take alternate route. The efficiency of ATIS depends on the responses of the travellers to such information. Thus, the understanding of travellers' responses to these ATIS services is critical for designing the message content and evaluating the effectiveness of these systems.

In the last two decades, various models have been developed to model travellers' responses to ATIS and to understand the contributing factors that affect the resulting trip changing behaviour. Most of the developed models belong to the family of discrete choice modelling, which mainly examines the role of driver's socioeconomic factors and trip characteristics on the decision to comply with the information provided. Research examining the quality and reliability of the ATIS information was often conducted separately. However, travellers' attitudes and perceptions towards ATIS are a critical factor that affects travellers' compliance with these systems. Recent studies indicate a declining rate of compliance with ATIS information over the years, which is due to travellers having a reduced trust in the information. This increasing distrust in the quality of information shows the important role that drivers' attitudes and perception towards the information plays in modelling their response to these systems

In this report, we describe further investigations of modelling travellers' response to VMS by integrating latent variables, such as attitude and perception towards these systems, with the decision making. This report models drivers' perceptions and attitudes towards VMS, in order to model their response to VMS on an urban freeway in Calgary, Canada, using a stated preference (RP) survey. The survey was developed to identify the factors that potentially influence drivers' route diversion decisions under the influence of VMS-based information. The survey consisted of 21 questions and included information on: 1) personal socioeconomic characteristics, 2) trip characteristics, 3) reliance on other sources of information for traffic updates, 4) level of satisfaction of the respondents with the clarity, accuracy and timeliness of the information provided and, finally, 5) driver stated response to VMS information regarding accidents and major delays due to lane blockage. Drivers' responses to VMS included five different possibilities with the option to change trip plans by changing destination choice. The attitude and perception of information provided by VMS were found to be critical contributing factors affecting the travellers' responses to these systems.

In the next sections, previous approaches for the modelling of drivers' responses to ATIS are reviewed. A brief overview of the study area is presented, followed by a description of the survey and the data collection technique. The mathematical model is then presented and is followed by a discussion and analysis of the model results. Concluding comments are presented in the final section.

LITERATURE REVIEW

Understanding of drivers' diversion from their normal routes using ATIS has attracted many researchers. ATIS has been shown to have a significant impact on the trip choice decisions of travellers [1, 2, 3]. However, the results differ from one city to another, depending on the network characteristics and congestion levels. Chatterjee and Macdonald (2004) [4] conducted an extensive survey in six European countries to examine the impact of VMS on traffic diversion and found that an average of 8% of all drivers diverted from their original routes based on the information displayed on VMS regarding recurrent delays. Foo and Abdulhai (2006) [5] showed that delay messages on VMS on Highway 401 in Toronto, Canada, resulted in an average diversion rate of 5.55% for the years 2003, 2004 and 2005.

Different data collection techniques are used to model commuter response to disseminated information. The data can be of two types: stated preference (SP) or revealed preference (RP). An SP survey provides hypothetical ATIS scenarios and asks the respondents to respond through stated preference questionnaires or simulators. An RP survey is based on drivers' actual responses, is usually obtained from diaries and field experiments and is obviously more time-consuming than an SP survey. A number of decision choice models were developed from one or the other survey method to identify possible contributing factors that affect drivers' route switching behaviour under ATIS. Using binary logit [6, 7], multinomial logit [8] or ordered probit regression [9, 10], the results from various research efforts show that the likelihood of compliance with ATIS is mostly correlated with travellers' socioeconomic characteristics, trip and route characteristics, weather conditions and network familiarity.

Existing evidence shows that the driver's socioeconomic characteristics play an important role in affecting compliance with information provided by ATIS [11]. However, these results may differ significantly from one place to another. Carplice and Mahmassani (1992) [6] found that females were more likely to change their departure time under ATIS provision than male commuters. Contrary to these findings, Peeta and Ramos (2006) [12] found that young and male drivers were more willing to divert to an alternate route. Similarly, Emerrink et al. (1996) [13] found that women in Amsterdam were less likely to be influenced by traffic information provided by radio and VMS.

Trip and network characteristics have been found to be a major contributing factor to the likelihood of compliance to ATIS. Congestion levels and travel time have been revealed to be major variables affecting route switching behaviour under ATIS [14]. Drivers showed greater willingness to divert from their current route when the time delay was increased [15]. However, unfamiliarity and more traffic stops on alternate routes encouraged drivers to stay on their current route [9]. On the other hand, Khattak et al. (1996) [15] concluded that drivers exhibit some inertia for using their normal route, especially for home-to-work trips. However, incident-induced congestion forced more drivers to take alternate routes, as compared to delays caused by recurrent congestion.

In addition, bad weather seems to induce travellers to seek trip travel information [16, 17]. Peeta and Ramos [12] found that 70% of drivers stated that they would divert to an alternate route to avoid unexpected congestion under adverse weather conditions, if a VMS message recommended it.

Foo and Abdulhai (2006) [5] showed from field observation that the compliance rate with VMS decreased steadily over a period of 3 years on Highway 401 in Toronto, showing the increasing distrust of drivers with VMS. Similarly, Ben Elia and Shiftan (2008) [18] showed that drivers with limited driving experience tended to trust ATIS more, whereas drivers who already had a good knowledge of the possible travel conditions on the network were less likely to comply with ATIS. However, only a few studies examined the correlation between-route switching behaviour and latent variables, such as information quality [17] and travellers' perceptions and attitudes towards, and reliability on ATIS information [19, 20].

Based on the above review, it is clear that research directed at investigating the effect of travellers' level of satisfaction with the real-time information provided by ATIS has not been included in the decision choice model of travellers receiving this information. In this report, a latent discrete choice model is developed to analyze the factors affecting en-route diversion behaviour under the provision of information on major delays via VMS on an urban freeway in Calgary, Canada. The model introduces latent variables representing driver's perception and jointly estimates the latent variable and the response choice. The model examines most of the previously discussed factors, as well as the level of satisfaction with the information provided. Drivers' responses to VMS are reflected in five different possibilities, including the option to change trip destination.

STUDY AREA

This research uses Deerfoot Trail in Calgary, Canada, as a case study. Deerfoot Trail is an urban freeway that provides a north-south corridor through the city. As shown in Figure 1, Deerfoot Trail stretches nearly 50 kilometres from Country Hills Boulevard in the north and merges with Macloed Trail in the southern part of the city. The posted speed limit is 100 km/h, and the majority of the roadway is 6 lanes in width.

Deerfoot Trail is the most congested freeway in Calgary, especially its middle portion. In addition, Deerfoot Trail is identified with a high frequency of incident occurrence. Obviously, this non-recurrent congestion constitutes a major source of delay for drivers on Deerfoot Trail. The City of Calgary is currently using 12 VMS along Deerfoot Trail to divert drivers in case of major delays occurring on the freeway. Traffic is diverted to two alternative parallel arterials, namely Barlow Trail and Blackfoot Trail. Figure 1 shows the study area including the two alternative routes that are usually recommended. In addition to VMS, the City is also using a highway advisory radio and Internet website to inform drivers' of detours and major delays due to accidents occurring on Deerfoot Trail. The present focus of this research is on the en-route travel response via VMS.

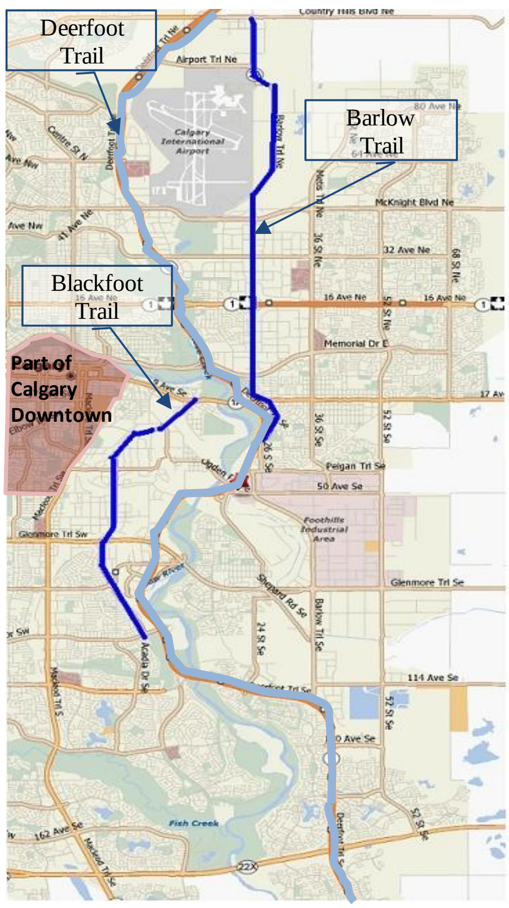

Figure 1: Deerfoot Trail and the Two Parallel Recommended Routes: Blackfoot Trail (left) and Barlow Trail (right) (source MapQuest)

DATA COLLECTION

The data stemming from this research was used to investigate the role that VMS plays in drivers' en-route decision making when information on an accident is provided. Data on travellers' route making decisions were obtained by conducting an SP survey on a sample of users of Deerfoot Trail in Calgary. The reviewed literature provided empirical evidence of the effect of drivers' socioeconomic characteristics, trip and network characteristics and weather conditions on route switching decisions. So, in addition to these factors, the survey in this research was designed to capture the effects of latent variables, such as the reliability of VMS and the relevance of the information on route switching behaviour. Moreover, questions on additional sources of traffic information were included. The survey included 21 questions grouped into five parts:

(a) Personal socioeconomic information, such as age, gender, education level, household size, household income, driving experience;

(b) Trip characteristics, frequency of using Deerfoot Trail, trip purpose, trip length as reported by trip travel time, trip time, vehicle occupancy, familiarity with alternative routes, familiarity with VMS;

(c) Use of other sources of traffic information: en-route, such as radio; and, pre-trip, such as TV and Internet;

(d) Attitude and perception towards VMS message content: level of satisfaction of the respondents with the clarity, accuracy and timeliness of the information provided. Responses were recorded on a five-point ranking scale (1-5), where 1 means extremely dissatisfied and 5 means extremely satisfied; and,

(e) Stated response to VMS message.

The respondents were asked to identify their usual response to VMS messages as follows:

(a) Usually divert to suggested route,

(b) Occasionally divert to suggested route,

(c) Choose another route,

(d) Stay on same route, and

(e) Change destination.

The survey was a face-to-face survey. In total, 500 respondents who were frequent users of Deerfoot Trail were interviewed. Each interview was voluntary and confidential, but as a rule of pre-qualification to participate in the survey, each respondent was asked verbally whether he/she uses Deerfoot Trail. The objective of this screening process was to include only frequent travellers of Deerfoot Trail as potential respondents.

A number of the following on-site survey locations were chosen for data collection:

(a) The University of Calgary, which is comprised of a diverse community commuting daily from different parts of Calgary using Deerfoot Trail;

(b) Parking lots and offices in downtown of Calgary, because downtown is the central business district (CBD) of the city and is a major employment location;

(c) Prestwick and McKenzie Towne communities and Deerfoot Meadows, which is a major shopping district, located in the southeast part of Calgary and Deerfoot Trail is the most efficient road network to commute to and from these regions.

(d) The town of Airdrie and Deerfoot Outlet Mall on the north part of Deerfoot.

Sample Characteristics

The socioeconomic attributes and trip characteristics of the surveyed respondents are summarized in Table 1. As shown in the table, 48.7% of the respondents were males. Most of the respondents were between the ages of 20 and 40, with some college education or higher and with household incomes in the range of 45K to 100K per year. The majority of the respondents had more than 10 years of driving experience and use Deerfoot Trail 2-3 times per week.

The distribution of trip purposes were work (41.3%), school (14%), shopping and leisure (19%) and other (25.7%), respectively. With regard to other sources of traffic information, 29.9% of the survey respondents listened to radio traffic reports, 20% sought pre-trip information through TV, 1.6% accessed pre-trip information through the City of Calgary's Traveller Information System website and 43.9% reported not seeking any information. The diversion rate to the suggested route was found to be 37.7%, 21.4% of respondents diverted to other than the suggested route, 4.2% of respondents reported changing their destination as well, and the remaining 36.7% stayed on their original route. The high divergence rate is explained by the fact that VMS use in Calgary is confined to reporting major delays due to lane blockage caused by accidents or major construction on Deerfoot Trail.

Table 1: Summary of Socioeconomic and Trip Characteristics of the Surveyed Respondents

Attribute	Range	Distribution (%)
Gender	Male	48.7
	Female	51.3
Age Group	Less than 20	14.4
	20-30	34.9
	30-40	24.6

	40-50	16.8
	50-65	7.6
	More than 65	1.8
Education	High School or Less	16.8
	Some College	34.5
	College Graduate	26.1
	Post Secondary	22.6
Marital Status	Married	50.5
	Single	49.5
Household Occupancy	1	4.0
	2	28.1
	3	29.5
	More than 3	38.3
Income	Less than 30K	15.4
	30k-45K	20.4
	45K-60K	29.1
	60K-100K	23.2
	More than 100K	12.0
Drivers' Experience	3 or less	27.1
	4-10	33.7
	More than 10	39.1
Frequency of Driving on Deerfoot Trail	Daily	24.2
	2-3 times per week	32.5

	Once a Week	24.0
	Once a Month	19.4
Trip Purpose	Work	41.3
	School	14.0
	Shopping/Leisure	19.0
	Others	25.7
Travel Time on Deerfoot Trail	10-30	35.5
	30-45	44.7
	More than 45	19.8
Trip Departure Time	8:00 AM - 10:00AM	41.5
	10AM-3:00PM	28.3
	3:00PM-6:00PM	20.0
	6:00PM-8:00AM	10.2
Seeking Pre-trip and En-route Traffic Information	106.5 FM	29.9
	City Traveler Info Web	1.6
	TV Traffic	20
	Text Message / Email	4.6
	None	43.9
Reported Response to VMS	Usually Divert to Suggested Route	21.4
	Occasionally Divert to Suggested Route	16.4
	Choose Another Route	21.4
	Stay On Same Route	36.7

	Change Destination	4.2

The stated response to VMS was related to the respondents' perceptions and attitudes towards the VMS message content. This hypothesis formed the basis for the investigation presented in this report. The challenge was to model the response to VMS as a function of perception or attitude, which we cannot observe. However, using the scaling that respondents indicated for message content on the VMS, we can use a latent variable model to link the response to VMS with variables that define perception or attitude towards VMS. The next section describes the modelling framework.

ECONOMETRIC MODEL

Let us consider the individual driver's utility (*U*) of choosing one of the five traveller's response option is defined by the following utility function:

$$U_j = \beta_j x_j + \alpha_j y + \varepsilon_j \qquad \mathrm{j} = 1, 2, ...5 \tag{1}$$

Here, *x* indicates a vector of observed variables and *y* indicates a vector of latent variable. Corresponding to x and y, β and α are coefficients or utility weighting factors. The error term, ε_j, indicates a random error component to capture the unobserved and random component of the utility function of the corresponding alternative decisions. The latent variable in this case indicates the driver's perception to the VMS, which is a behavioural factor and cannot be quantified directly. In order to capture the variability of perception across the population and, at the same time, quantify the latent perception in terms of observed variable, we further express it as the following function:

$$y = \gamma z + \theta \tag{2}$$

Here, z_j indicates a vector of observed variables and γ indicates the corresponding coefficients or perception weighting factors. It is considered that the random component, θ, captures unobserved and random factors influencing the perception of VMS.

In order to formulate the probability of an individual driver's response to VMS, we have to assume the distribution functions of the random error components in Equations 1 and 2. Considering the choice of various response options as alternative discrete choices, the usual assumption is to consider that the random error term of the utility function in Equation 1 is of independent and identically distributed (IID) type I extreme value distribution. The advantage of this assumption is that it gives a closer functional form of the probability function of choosing an alternative response under a random utility maximization approach [21]. However, such a restrictive assumption may lead to error in parameter interpretation, because some of the alternative options considered in this study may have overlapping properties. For example, usual diversion and occasional diversion may be two distinct alternatives in considering the impact of VMS application, but behaviourally these two options may have shared the utility to choose. A similar condition may apply to between the choosing another route and changing destination options. The best way to overcome all of these problems is to consider the error term in the utility function of Equation 1, ε_j, as normally distributed. However, this normal distribution assumption incurs a heavy computational burden, due to the lack of a closed-form educational form of the corresponding probability functions. To overcome both the overlapping property problem as well as the non-closed functional form of probability function, we divide the error term, ε_j, into two components:

$$\varepsilon_j = \xi_j + \varepsilon'_j \qquad (3)$$

Here, ξ_j is considered to be normally distributed with a zero mean and σ^2_j variance, and $\varepsilon_j^{/}$ is considered to be of IID type I extreme value distribution. On the other hand, the random error term of measuring the latent variable in Equation 2 is considered to be normally distributed with a zero mean and $\sigma^{/2}$ variance.

$$\begin{aligned} &\xi_j \approx N(0, \sigma_j^2) \\ &\theta \approx N(0, \sigma^{/2}) \end{aligned} \qquad (4)$$

Considering all of the assumptions, the utility functions of the alternative response options become:

$$\begin{aligned} U_1 &= \beta_1 x_1 + (\gamma z + \theta)\alpha_1 + \xi_1 + \varepsilon_1^{/} \\ U_2 &= \beta_2 x_2 + (\gamma z + \theta)\alpha_2 + \xi_2 + \varepsilon_2^{/} \\ U_3 &= \beta_3 x_3 + (\gamma z + \theta)\alpha_3 + \xi_3 + \varepsilon_3^{/} \\ U_4 &= \beta_4 x_4 + (\gamma z + \theta)\alpha_4 + \xi_4 + \varepsilon_4^{/} \\ U_5 &= \beta_5 x_5 + (\gamma z + \theta)\alpha_5 + \xi_5 + \varepsilon_5^{/} \end{aligned} \qquad (5)$$

The random component, θ_j, of the latent variable is specified as:

$$\theta = \sigma^{/} \eta^{/} \qquad (6)$$

Here, $\eta^{/}$ is a standard normal variable (zero mean and unit variance). For the normally distributed fraction (ξ_j) of the main error term of the utility function, the specification can be:

$$\begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \\ \xi_4 \\ \xi_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \sigma_1 & & & & \\ 0 & \sigma_2 & & & \\ 0 & 0 & \sigma_3 & & \\ 0 & 0 & 0 & \sigma_4 & \\ 0 & 0 & 0 & 0 & \sigma_5 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \end{bmatrix} \qquad (7)$$

Here, η_j is a vector of standard normal variables (zero mean and unit variance). The correlation and heterogeneity of the alternative response options can be induced by error nesting. The lower triangular matrix of Equations 6 and 7 is the Cholesky factor of the corresponding variance-covariance matrix [22]. Considering the off-diagonal elements of the Cholesky factor simplifies the estimation, but ensures capturing the heterogeneity. The nested relationship between the alternatives, in this case, can be very easily induced by forcing the corresponding diagonal elements to be equal. After rigorous specification tests, in this report we specify that the unobserved factors influencing alternative options 1 and 2 may be correlated. Similarly, the unobserved factors of alternatives 3 and 5 may be correlated. Hence, the resulting nested error components become:

$$\begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \\ \xi_4 \\ \xi_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \sigma_1 & & & & \\ 0 & \sigma_1 & & & \\ 0 & 0 & \sigma_2 & & \\ 0 & 0 & 0 & \sigma_3 & \\ 0 & 0 & 0 & 0 & \sigma_2 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \end{bmatrix} \tag{8}$$

Now, considering specification of the error term of $\varepsilon_j^{/}$, the probability of choosing any alternative response option (j) can be formulated as in Train (2002) [22]:

$$\Pr(j) = \int \frac{\exp(\beta_1 x_1 + (\gamma z + \theta)\alpha_1 + \xi_1)}{\sum_{j=1}^{J} \beta_j x_j + (\gamma z + \theta)\alpha_j + \xi_j} d\theta \, d\xi_j \tag{9}$$

The integration of Equation 9 remains, due to the presence of random error components (θ and ξ). This probability function has multidimensional integration. The simulated likelihood approach is an efficient way of estimating the parameters for such open-form equations. In the simulated likelihood function, the error terms (θ and ξ) are simulated and plugged into Equation

9 to calculate the probability. For a sufficiently large number of simulations, the average of all simulated probability functions is equivalent to Equation 9. Hence, the likelihood function of any observation, *i*, can be written as:

$$L_i = \frac{1}{D}\sum_{d=1}^{D}\left(\frac{\exp(\beta_1 x_1 + (\gamma z + \theta_d)\alpha_1 + \xi_{1d})}{\sum_{j=1}^{J}\beta_j x_j + (\gamma z + \theta_d)\alpha_j + \xi_{jd}}\right) \quad (10)$$

Here, D indicates the total number of simulations, and the error terms, θ_d and ξ_d, indicate simulated values from corresponding parameters. In this equation, the latent variable is not an observed variable, rather it is further specified as a function of several observed variables and an error term (as shown in Equation 2). The relationship of the latent variable with observed variables as expressed in Equation 2 describes the structural relationship of the latent variables with observed variables. However, in order to ensure efficiency of the parameter estimation, we need to identify the measurement equations of the latent variables.

In our case, the latent variable, which is the perception of VMS, was measured on a longitudinal scale (1 to 5) considering several characteristics of the VMS used on Deerfoot Trail. The number of measurement criteria used in this study was 6. Respondents expressed their perceptions towards the concerned criteria by a number between 1 to 5. Although the response scale in this case was ordered, the consideration of the measurement of criteria as continuous numbers does not induce too much bias, as we also took into account a random error component in the structural equation [23]. This also helps to simplify the measurement equation as follows:

$$M_k = \nu_k(\gamma z + \theta) + \psi_k \quad (11)$$

Here, v_k indicates the coefficient of the latent perception corresponding to *k* criteria, and ψ_k is an normal error term with a zero mean and τ_k variance. So, combining the measurement equations with the likelihood function, we get:

$$L_i = \frac{1}{D}\sum_{d=1}^{D}\left(\frac{\exp(\beta_1 x_1 + (\gamma z + \theta_d)\alpha_1 + \xi_{1d})}{\sum_{j=1}^{J}\beta_j x_j + (\gamma z + \theta_d)\alpha_j + \xi_{jd}} \prod_{k=1}^{K}\frac{1}{\tau_k}\phi\left(\frac{M_k - v_k(\gamma z + \theta_d)}{\tau_k}\right)\right) \quad (12)$$

For the above likelihood function, the variance, τ_k, is restricted to 1 for simplification and also in consideration of the fact that estimating this parameter does not add any additional value to the modelling process (23).

For estimating the model, in this report we used the Halton sequence and 1,000 iterations for simulation estimation. The model was estimated by using code written in GAUSS and the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm [24]. The standard errors of the parameters were calculated using the inverse of the Hessian procedure. As the model becomes very complex, the variances of the error terms of the measurement equations are restricted to unity, which is a common practice in this type of complicated situation [25]. The next section discusses the estimated model parameters.

EMPIRICAL MODEL FOR DRIVER'S RESPONSE OF VMS

Estimated Model

Table 2 lists the results of the model. In general, the model fitted the data with very large chi-square statistics (-4703.528), relatively large pseudo-R-squares and small p-values.

Note that many of the contributing factors were recorded using ordered or unordered categories; thus, several dichotomous variables were created to capture the effects of each of these factors, giving a total of 44 variables classified under 11 factors. For example, there were three categories used for driving experience: less than 3 years, 3-10 years and more than 10 years. Therefore, three dichotomous variables were created to capture this factor. However, one of these variables will be used as the reference case and omitted from the analyses to avoid the perfect multicollinearity problem.

Considering the relatively small data set compared to the large number of parameters to be estimated, the estimated coefficients were considered statistically significant if the corresponding two-tailed t-statistics satisfied the 90% confidence interval (p-value ≤ 0.10). However, some variables with statistically insignificant parameters were also retained in the model, because they provide considerable insight into the behavioural process. Retention of some of the insignificant variables was also due to the expectation that, if a larger data set was available, these parameters may show statistical significance.

Table 2 shows an alternative specific constant of the main utility function with respect to choice 2 “Occasionally divert to suggested route”, choice 3 “Choose another route” and choice 4 “Stay on the same route”. All these alternative specific constants were above one. Choice 4 “Staying on the same route” had the highest alternative specific constant and was highly significant ($p < 0.00$). These results support the findings of Khattak et al. (1996) [15], who showed that drivers usually exhibit some inertia for using their normal route. The second highest alternative specific constant was choice 3 “Choose another route” followed by choice 2 “occasionally divert to suggested route”; however, these latter two coefficients were not statistically significant.

Table 2: Estimated Parameters of the Empirical Model

<u>Chocie Model: Response of VMS</u>

Explanatory Variables		*Usually divert to suggested route*	p-Value	*Occasionally divert to suggested route*	p-Value	*Choose another route*	p-Value	*Stay at same route*	p-Value	*Change Destination*	p-Value
Constant				1.85	0.14	2.54	0.15	6.63	0.00		
Driving Experience	*less than or equal to 3 years*	1.45	0.01	1.04	0.06	0.82	0.05				
	between 4-10 years					0.85	0.01				
Frequent Use of Deer Foot trail	*Once a Week*					0.31	0.28				
	Once a Month									0.64	0.23
Familiar with Alternative Routes		0.34	0.38			0.59	0.19	-0.91	0.04		

Purpose of Trip	*Work*	-0.55	0.11					1.27	0.00	
	School	-0.75	0.14					1.67	0.00	
Usual Travel Time on Deer Foot Trail	*30-45 Minutes*	-0.30	0.35							
	More than 45 Minutes	-1.53	0.02	-1.62	0.01					
Time of Day	*AM Peak (8 am -10 am)*					-0.56	0.07			
Traffic Information Source	*Traffic Radio*	0.61	0.05			0.29	0.32			
Driver's Age	*31-40 Years*	-1.05	0.02							
	41-50 Years	-1.31	0.05	-1.06	0.09					
	More than 50 Years	1.20	0.01							
Driver's Level of Education:	*High School or Less*	1.46	0.19	1.18	0.30	1.03	0.34	1.55	0.15	
Household Size of the Driver		0.19	0.23					0.53	0.00	

Household Income of the Divers	*45,000-60,000 Per year*	1.50	0.09	1.92	0.03	1.51	0.05	0.85	0.29		
	Less than 45,000 Per year	-0.40	0.40	-0.44	0.38			-0.92	0.01		
Latent Variable: Perception to VMS		2.34	0.00	1.92	0.00	0.94	0.00			2.05	0.00
σ1: Variance of Nested Random Error		2.35	0.01	2.35	0.01						
σ2:Variance of Nested Random Error						0.13	0.82	0.13	0.82		
σ2:Variance of Non-Nested Random Error								1.00	---		

<u>Latent Variable Model: Perception to VMS</u>

Structural Model

	Coefficient	**p-Value**
Driver's Gender: Male	0.240	0.01

Driver's Age: Less than 20 Years	1.373	0.00
Driver's Age: Less than 21-30 Years	1.014	0.00
Driver's Education: Equal or Higher than College	0.491	0.00
Driver's Marital Status: Married	0.671	0.00
Driver's Household Income: 61,000-100,000 Per Year	0.295	0.01
Driver's Household Income: 100,000+ Per Year	0.482	0.00
Driver's Familiarity with VMS	1.101	0.00
Purpose of Trip: Shopping/Leisure	0.287	0.01
Usual Vehicle Occupancy of the Car	0.286	0.00
$\sigma 3$: Variance of Random Error	1.164	0.00
Measurement Model		
Clarity of Information	0.900	0.00
Up to the minute information	0.883	0.00

Accuracy of information	0.946	0.00
Level of detail of information	0.950	0.00
Provision of alternate routes	0.956	0.00
Overall satisfaction with service	1.000	---
Log Likelihood Value	-4703.528	
Number of Observation	501	
Adjusted Rho-Quare Value against Null Model	0.759	
Adjusted Rho-Quare Value against Constant-Only Model	0.141	

Driver Characteristics

Age was found to be an important factor when exploring the influence of driver characteristics on the likelihood of route diversion due to VMS. While drivers in the age groups of 20 to 30 and 30 to 45 were less likely to "Usually divert to suggested route" and "Occasionally divert to suggested route" (all p values < 0.1), drivers older than 45 years were more inclined to "Usually divert to suggested route" (statistically significant with $p = 0.01$). In addition, household size was found to have a positive correlation with the likelihood of staying on the same route, which supports the earlier findings by Madanat et al. [19] that transportation-related decisions are a function of household size. Thus, the larger the size of the household, the more likely the drivers are going to stay on their usual route (statistically significant with $p = 0.00$). These results may be explained by the added complexity of the decision process when the decision can affect more than one person. This added complexity may be reflected by greater reluctance of drivers to take a risk and change their route. However, our study shows that education level was not statistically significant in explaining the likelihood of diverting from the normal route with VMS (all the coefficients were not statistically significant with $p > 0.1$).

Our study also found that household income affected the likelihood of diverting from the usual route. The positive sign for the variable of drivers with average household income between 45K to 60 K indicates that this population group exhibited a greater likelihood to "Usually divert to suggested route" and "Occasionally divert to suggested route" ($p = 0.09$ and 0.03, respectively) or to "Divert to another route" (statistically significant with a p-value = 0.05). The lower income group (less than 45 K) were found to be less likely to divert to the suggested route; however, these results were not statistically significant. These findings may be explained by the fact that higher income groups associate higher values for their travel time and are thus more sensitive to delays on their route.

Driving Experience

Our study shows that driving experience had a significant impact on route switching behaviour. Having less than 3 years of driving experience made drivers more likely to comply with the information displayed on VMS by "Usually diverting to suggested route" (significant with p-value = 0.01), "Occasionally diverting to suggested route" (marginally significant with p-value = 0.06) or choosing another route (significant with p-value = 0.05). While more experienced drivers tried to explore their knowledge and experience of prevailing traffic conditions by choosing other than the suggested route. These findings were also supported by Ben Elia and Shiftan (2008) [18] who showed that drivers with limited driving experience tend to trust ATIS, whereas drivers who already have a good knowledge of the possible travel conditions on the network are less likely to comply with ATIS. However, our result did not show a significant correlation between the frequency of driving on Deerfoot Trail and compliance with VMS.

Familiarity with Alternative Route

Familiarity with alternative routes was found to be negatively correlated with the likelihood of staying on the same route (significant with p-value = 0.04). Familiarity with alternative routes was also found to be positively correlated with the likelihood of "Diverting to suggested route" or "Choosing another route"; however, these latter coefficients were not statistically significant. These results are also supported by other studies, e.g. Bonsall, P. and Palmer, I. (1999) [8] who showed that unfamiliarity with the alternative route encouraged drivers to stay on the same route.

Trip Purpose

Compared to other trip purposes, drivers were more likely to stay on the same route when the trip purpose was either school or work (significant with p-value < 0.00 for both trip purposes). This finding may be explained by the fact that work- and school-related trips are usually more stressful and time constrained than other trips (i.e. shopping, leisure and other), which make the driver less prone to take the risk of diverting from his regular route. These results were also reported by Emmerink et al. (1996) [13] and Khattak et al. (1996) [15], who found that work commuters exhibited some inertia for using their normal route, possibly due to the habitual behaviour of commuters.

Trip Time

Our study found a negative correlation between trips that occurred during the morning peak and the likelihood to divert to other than the suggested route (marginally significant with p-value 0.06). The negative sign indicates that, when trip occurred during the morning peak, drivers were less likely to divert to a route not suggested by VMS. One possible explanation to these findings is that most morning trips are work- or school-related, which makes drivers less likely to take a risk in diverting to a route not suggested by VMS.

Travel Time on Deerfoot Trail

More route choices are available to drivers with longer trips; thus, more route switching behaviour is expected to result. However, our results do not support this statement. Similar results were reported by Emmerink et al. [113]. Compared to shorter travel times on Deerfoot Trail, a longer travel time on Deerfoot Trail was found to be negatively correlated to the willingness to divert. These results were statistically significant for travel time on Deerfoot Trail of greater than 45 minutes (p-value of 0.02 and 0.01 for “Usually divert to suggested route” or

“Occasionally divert to suggested route”, respectfully). However, these results were not statistically significant for travel time on Deerfoot Trail in the range of 30 to 40 minutes. As mentioned earlier, the middle section of Deerfoot Trail is the area where most of the accidents and delays occur and route diversion accordingly takes place. Therefore, one possible explanation of the findings related to travel time is that drivers who commute longer distances are usually familiar with the road network at both ends of their trips but not with the road network in the middle section of their journey and, consequently, may be more reluctant to change their route when they are asked to divert in the middle portion of Deerfoot Trail. However, drivers who are travelling shorter distances on Deerfoot Trail will be exiting the freeway in the next few exits anyway, in order to reach their destination and are, thus, more willing to leave Deerfoot Trail a little bit earlier.

Listening to En-route Traffic Information

As reported previously, only 29.9% of drivers listened to radio traffic information while driving. Our results found a positive correlation between listening to radio traffic information and the likelihood of diverting to the suggested route (p-value of 0.05). These results also conform with other studies conducted by Caplice and Mahmassani [6] and Emmerink et al. [13]. These results are expected, since the source of information for both VMS and the radio is the same. Therefore, the drivers listening to the radio get further reinforcement of the information displayed on VMS. The confirmation of the information on congestion seems to convince drivers to divert to the suggested route. In addition, a positive correlation was found between the likelihood to divert to other than the suggested route and listening to the radio; however, the coefficient was not found to be significant.

Latent Variable

It is clear that the latent variable – perception of VMS – had a strong correlation with the compliance likelihood of the drivers with VMS or with changing their destination due to the impact of VMS content. It should be noted that this latent variable had the highest coefficient with respect to the utilities of "Usually divert to suggested route", "Occasionally divert to suggested route" and "Choosing another route" (all statistically significant with $p = 0.00$). These findings are intuitive and indicate that the users' perception toward VMS was the most important factor for Deerfoot Trail drivers to comply with VMS information.

It is found that the perception of drivers to VMS had a significant positive correlation with changing the destination of the trip (statistically significant with $p = 0.00$). As reported previously, 4.2% of the respondents stated that they usually change their destination in response to VMS information. These findings must be mostly related to shopping and leisure trips, which can take place in locations other than the initial intended destination of the travellers. The positive correlation reveals the importance of VMS information quality in convincing drivers to adapt their travel plans by changing their destination. These results indicate the important role of VMS in alleviating congestion not only on Deerfoot Trail but probably on other congested routes, by convincing some drivers to change their destination choice and probably reduce their trip length.

The latent variable representing perception towards VMS was modeled as a function of a number of variables, as presented in Table 2 under the heading of 'Latent Variable Model'. Our model shows that the variable "Driver's Age: Less than 20 Years" was the most important variable defining perception. Drivers' familiarity with VMS gave the second highest positive perception towards VMS. This finding supports the fact that familiarizing drivers with an information device has a positive effect on their attitude. The variable related with familiarity with VMS was followed by people aged between 20 and 30 years. The rest of the variables had coefficients of less than 1 for the latent perception towards VMS. It is interesting that male, married, high income and highly educated drivers had positive perceptions towards VMS. Additionally, drivers with trip purposes of shopping and leisure had a more positive perception towards VMS than those on work and school trips. Finally, the latent variable model showed that the higher the occupancy of the vehicle, the higher the perception towards VMS.

The measurement model was not part of the causal relation process, and explanations of the coefficients were not important in this case. However, incorporation of the measurement model obviously contributed to the above findings, which was proven by estimation of a simple multinomial logit model of the reported usual response to the VMS message as a function of variables used in the structural model. All of the parameters became statistically insignificant in that case (we found it unnecessary to report that model, as it would overwhelmingly increase the size of the report), whereas almost all variables were statistically significant in this joint model.

CONCLUSION AND RECOMMENDATION

This study modelled travellers' response tendencies of survey respondents to VMS information on non-recurrent delays on Deerfoot Trail in Calgary, Canada. A latent variable model combined with a discrete choice model was developed to model travellers' responses to VMS. The critical factors that influence drivers to switch from their normal route were found to be:

(a). Driver characteristics, such as age, household size and household income,

(b). Driving experience,

(c). Familiarity with alternative routes, (d). Trip purpose,

(e). Trip time,

(f). Trip length on Deerfoot Trail,

(g). Listening to en-route traffic information, and

(h). User's level of satisfaction with VMS modelled as a latent variable.

Among the above variables, the latent variable – user's perception toward VMS – was found to be the most important factor influencing the reaction of drivers to VMS information. In fact, user's attitude and perception was also found to be the only significant variable convincing the commuters to alter their trip plans and change their destination and not only their route. These findings suggest that the City of Calgary needs to pay careful attention to the message content, as well as the quality and accuracy of the information, provided by VMS.

The results from this study show that commuters on Deerfoot Trail reacted in various ways to VMS and incident information suggesting a given-route. Obviously, diversion to the suggested route is not the optimal choice for all travellers or the overall system. In other words, if all drivers comply perfectly with the information provided by VMS by diverting to the suggested route, that latter route will quickly become the most congested path. Clearly, commuters on Deerfoot Trail are incorporating this learning component in their decision. This learning component is reflected in the survey results that suggest that information on major delays due to incidents or construction do influence travel decisions to some extent, yet a fair number of participants did not alter their trip as suggested by VMS. The net effect of the incident information was that 63.7% of the travel changed. The incident information was found to have greater impact on either diverting to the suggested route or to a route other than that suggested rather than on trip destination change. On the other hand, 36.7% of drivers experienced inertia and did not alter their routes. These results suggest that the City should conduct a dynamic traffic assignment to calculate how to spread traffic on the competing routes so that these routes are all in dynamic equilibrium. In addition, among the 63.7% of drivers who altered they route, 21.4% did divert to other than the suggested route. The reason behind this high rate of drivers diverting to rather than the suggested route could be attributed to either the lower perception of these drivers in VMS the information quality or simply to a high rate of familiar who exploit their knowledge in the network by diverting to other than the suggested routes that are supposed to be highly congested. More investigation is needed to understand the factors contributing to this high divergence to other than the suggested route.

One of the primary findings of this study was the impact of VMS message on changing not only the trip route but also trip plans. Our study shows that 4.2% of drivers changed destination in light of the en-route information provided by VMS.

In addition, the developed integrated discrete choice and latent variable model showed the existence of a significant positive correlation between radio traffic information and VMS displays. It was found that drivers who listen to radio traffic information are more likely to be compliant with VMS. Pre-trip information is also expected to result in greater change in trip planning. Despite the benefits of obtaining pre-trip travel information, only 21.6 % of respondents obtained information through the City of Calgary's traveller information website or TV prior to leaving for their commutes. There is apparently much room for improvement in obtaining pre-trip traffic information and, more importantly, using it. Our research clearly showed the interaction between VMS, radio information and route switching behaviour, including destination change. However, our survey did not provide the data necessary to examine the interaction between pre-trip information and trip plan changing behaviour. Drivers can react to pre-trip information by rescheduling or cancelling trips, changing modes of transportation or changing destination. These types of responses can play a more pronounced role in alleviating congestion before drivers are committed to routes that are experiencing high delays because of accidents. Future extension of this work should focus on examining the impact of pre-trip information on travellers' trip decisions and not only route choice. Furthermore, future research can also examine the day-to-day dynamics of driver's trip decisions in light of ATIS.

References

1. Bonsall P. and Parry T. (1991). Using an interactive route-choice simulator to investigate driver's compliance with route guidance advice. *Transportation Research Record,* vol. 1306, pp. 59–68.
2. Vaughn K., Reddy P., Abdel-Aty M., Kitamura, R. and Jovanis, P. (1995). Route choice and information use: Initial results simulation experiment. *Transportation Research Record*, vol. 1516, pp. 61–91.
3. Mahmassani H. and Hu T. (1997). Day-to-day evolution of network flows under real-time information and reactive signal control, *Transp. Research C*, vol. 5, no. 1, pp. 51–69, Feb. 1997.
4. Chatterjee K. and McDonald M. (2004). Effectiveness of using variable message signs to disseminate dynamic traffic information: evidence from field trials in European cities, *Transport Reviews,* 24, pp. 559–585.
5. Foo S. and Abdulhai B. (2006): Evaluating the Impacts of Changeable Message Signs on Traffic Diversion. Proceedings of the IEEE ITSC 2006 2006 IEEE Intelligent Transportation Systems Conference Toronto, Canada, September 17-20, 2006, pp. 891–896.
6. Caplice C. and Mahmassani H. S. (1992). Aspects of commuting behavior; preferred arrival time, use of information and switching propensity. Transportation Research, 26A, 409–418.
7. Tsirimpa A., Polydoropoulou A. and Antonio C. (2007). Development of a Mixed Multi-Nominal Logit Model to Capture the Impact of Information Systems on Travelers' Switching Behaviour. *Journal of Intelligent Transportation Systems: Technology, Planning and Operations*, vol. 11, no. 2, pp. 79–89.
8. Bonsall P. W. and Palmer, I. (1999). Route choice response to variable message signs: Factors affecting compliance, in: R. Emmerink and P. Nijkamp (Eds), Behavioural and Network Impacts of Driver Information Systems, pp. 181–214.
9. Khattak A., Koppelman F., and Schofer J. (1992). States Preferences for Investigating Commuter Diversion Propensity. 71st Annual Transportation Research Board Meeting, Washington, DC.

10. Mannering F., Kim S., Barfield W. and Ng L. (1994). Statistical analysis of commuters' route, mode and departure time flexibility. *Transportation Research C*, vol. 2, no. 1, pp. 35–47.
11. Wardman M., Bonsall P. W. and Shires J. D. (1997). Driver Response to Variable Message Signs: A Stated Preference Investigation. *Transportation Research Part C*, vol. 5, pp. 389–405.
12. Peeta S. and Ramos J.L. Jr. (2006). Driver Response to Variable Message Signs-Based Traffic Information. IEE Proc. Intelligent Transportation Systems, vol. 153, no.1.
13. Emmerink R. H. M, Nijkamp P., Rietveld P. and Van Ommeren J. N. (1996). Variable message signs and radio traffic information: An integrated empirical analysis of drivers' route choice behaviour. *Transportation Research Part A: Policy and Practice*, vol. 30, Iss. 2, March 1996, pp. 135–153.
14. Abdel-Aty M. and Fathy Abdalla M. (2006). Examination of Multiple Mode/Route-Choice Paradigms Under ATIS. IEEE Transactions on Intelligent Transportation Systems, Vol. 7, No. 3, September 2006.
15. Khattak A., Polydoropoulou A. and Ben-Akiva M. (1996). Modeling revealed and stated en-route travel response to advanced traveler information systems. *Transportation Research Record* 1537, pp. 46–54.
16. Peirce S. and Lappin J., (2004). Why don't more people use advanced traveller information? Evidence from the Seattle area. Report presented at the 83rd Meeting of the Transportation Research Board, Washington, DC, USA.
17. Chen P.S., Srinivasan K. K., and Mahmassani, H. S. (1999). Effect of information quality on compliance behavior of commuters under real-time traffic information. *Transportation Research Record* 1676, pp. 53–60.
18. Ben-Elia E., Erev I. and Shiftan Y. (2008). The combined effect of information and experience on drivers' route-choice behavior. Transportation vol. 35, no2, pp. 165-177.
19. Madanat S., Yang D., and Yen A. (1995). Analysis of Stated Route Diversion Intentions Using Latent Variable Modeling. *Transportation Research Record* 1485, Transportation Research Board, National Research Council.
20. Feng C.M. and Kuo Y.W. (2007). Comparative Analysis of Stated En-Route Switching Behavior Under Various Information Scenarios, International Conference on Wireless

Communications, Networking and Mobile Computing 2007 (WiCom 2007), 21-25 Sept. 2007, pp. 6150–6153.

21. Ben-Akiva M. and Lerman S. (1985). Discrete Choice Analysis. MIT Press.
22. Train K. (2002). Discrete Choice Method with Simulation. Cambridge University Press.
23. Walker J. (2001). Extended Discrete Choice Models: Integrated Framework, Flexible Error Structures and Latent Variables. PhD thesis, MIT.
24. Aptech Systems (2008). GAUSS User's Manual. Maple Valley, CA.
25. Habib K.M.N., Kattan L., and Islam T. (2009). Model of personal attitude towards transit service quality. Forthcoming in Journal of Advanced Transportation.