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Development of a Latent Variable Model to Capture the Impact of Risk Aversion on Travelers' Switching Behavior

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Abstract

Advanced Traveler Information Systems (ATIS) are becoming increasingly available throughout the world. While the impact of the provided information on the switching behavior has been investigated in the past, an area of research that is less well understood relates to the effect of the travelers' risk aversion (or risk-seeking) in their travel behavior. The objective of this research is to examine the impact of information acquisition on travelers' switching travel behavior and to identify and quantify the role of attitudes and perceptions on switching behavior. A combined choice and latent variable model has been developed, in which the individual traveler's risk aversion has been modeled as a latent variable. The model has been estimated using data collected through travel diaries in the Puget Sound Region (PSRC) in 2000. As expected, travelers in general tend to maintain their habitual travel pattern. However, specific travel information –such as that regarding an incident or road closure– influences behavioral switches such as departure time change and route change.

Keywords: Advanced Traveler Information Systems (ATIS), Risk Attitudes, Integrated Choice and Latent Variable Model

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1 Introduction

The continuous growth of demand for road traffic increases the delays that road users face and negatively affects the overall transportation system performance. Traffic information provision may offer significant benefits in terms of improving the travel experience of individuals and overall system performance. However, the impact of traffic information on travelers' behavior is difficult to predict and may result in additional issues such as overreaction. Information acquisition may update travelers' perceptions of travel alternatives in two ways. First, it may increase travellers' awareness of alternatives by introducing them to the traveller or by explaining them and second, it may alter travellers' perception of the characteristics of travel alternatives. Eventually, travel information may, through the updating of perceptions, influence travellers' choice-behaviour (Chorus *et al.* 2006a). Bonsall (2004) discusses the nature and consequences of uncertainty in transport systems. The principal theories and models used to predict travellers' response to uncertainty are presented and a number of alternative modelling approaches (including random error components) are outlined.

The term ATIS has been used to describe a wide variety of services and systems with very different philosophy, scope, as well as operating characteristics. After many years of ATIS research, and many successful (and less successful) implementations, there is today a considerable amount of knowledge accumulated on the subject. Two thorough reviews on the subject (Lappin and Bottom 2003, and Chorus *et al.* 2006a) both agree on the fact that ATIS are a promising research direction. Chorus *et al.* (2006a) present a framework for a next-generation ATIS. Perhaps the biggest concern in the evaluation of ATIS is the difficulty associated with collecting high-quality, appropriate data sets, with the suitable parameters and size for their effective validation.

This paper presents a case study for the Puget Sound Region (PSRC), where the Regional Council has been running, since 1989, the longest continuous survey in the United States, regarding travel behavior. A supplement has added to the travel diaries, since 2000, asking individuals about the traveler information sources consulted on each trip and how the information was used. Traveler information sources, available in the region, encompass both conventional forms of information, such as radio traffic reports, as well as advanced traveler information systems, such as variable message signs (VMS) and web sites. In this paper, these data are used to model the impact of information acquisition on switching travel behavior (for more information regarding Puget Sound Regional Travel Survey, see Goulias *et al.* 2003). Besides the responses stated directly in the travel diaries, in this research latent variables capturing unobserved characteristics of the travelers are also modeled.

The remainder of this paper is organized as follows. Section two presents a brief review of the state-of-the-art of modeling ATIS impact on travelers' behavior. Section three presents a behavioral framework that incorporates the effect of information acquisition on the switching behavior of individuals from their usual travel pattern and the modeling methodology used. Section four presents the data used for the model development. Section five presents the model specification and estimation results and section six presents the conclusions.

2 State of the Art

Many researchers have studied the impact of advanced traveler information systems on travelers' decision-making behavior. A review of the state-of-the-art on modeling travelers' response to ATIS is presented in the remainder of this section. This review does not aim to be exhaustive, but instead strives to provide the necessary background, motivate and support the subsequent methodology and application. An exhaustive review of the literature on the assessment and prediction of drivers' response to information may be found in Lappin and Bottom (2003).

ATIS are likely to influence a variety of travel decisions (such as mode, route, and departure time), lifestyle decisions (location of residence, car ownership) and activity participation decisions (work, shopping) (Polydoropoulou and Ben-Akiva 1999). Toledo and Beinhaker (2006) evaluate the potential travel time-savings from Advanced Traveler Information Systems (ATIS) that provide drivers with travel time and routing information. A case study, using real-world data collected from a freeway network in Los Angeles, California, examines the potential travel time savings of ATIS as well as the implications on travel time variability and reliability and the sensitivity of the results to the accuracy of the information. Sources of information applicable to modeling the users' response to ATIS include (a) data from field experiments, travel surveys and diaries, and (b) data from simulators.

2.1 Travel Surveys, Diaries and Field Experiments

The most traditional method of obtaining travel data is through surveys and field experiments. Collected data may be either Revealed Preferences (RP) data or Stated Preferences (SP) data.

Abdel-Aty *et al.* (1997) studied commuters' route choice including the effect of traffic information. Two route choice models were estimated. The first model used five hypothetical binary choice sets collected in a computer-aided telephone interview. The results yielded important insights on the commuters' route choice in general, and the tradeoffs involved in the choice between a route which is longer but has reliable travel time versus another route which is shorter but has uncertain travel time. The model showed that both expected travel time and variation in travel time influence route choice. Commuters' attitudes toward several commute characteristics (e.g. distance and traffic safety) also influenced route choice, as well as socioeconomic factors, in particular gender. Receiving traffic information is found to have a significant effect in the model. Information might be used by commuters to reduce the degree of travel time uncertainty, and enables them to choose routes adaptively. The second model used data collected in a mail survey from three binary route choice stated preference scenarios customized according to each respondent's actual commute route and travel time. The results of the second model asserted the significance of travel time reliability on route choice, and showed clearly that ATIS has great potential in influencing commuters' route choice even when advising a route different from the habitual. Several other commute factors were found to affect the route choice, including freeway use and travel time. The correlation among error components in repeated measurement data was also addressed with individual-specific random error components in a binary logit model with normal mixing distribution.

Khattak and Khattak (1998) conducted mail surveys in the San Francisco and Chicago areas and asked respondents about the effects of en-route travel information on their trip-making decisions. About 16% of the respondents in San Francisco and

42% in Chicago had diverted within the past three months in response to their most recent unexpected traffic delay. It was found that automobile commuters' cognitive maps are influenced by duration of residence, personality, and location characteristics. In addition, travel time on both usual and alternate routes, reception of delay information via radio, and personality aspects are important attributes in drivers' en-route diversion behavior.

Hato *et al.* (1999) conducted a survey targeting drivers traveling on the Tokyo Metropolitan Expressway network, where drivers can actually make use of traffic information from multiple sources when choosing their route. Information acquisition behavior seems to be influenced by the following latent variables: (1) drivers aggressiveness towards route choice matters, (2) drivers attitude towards warnings concerning traffic condition and (3) familiarity with the road network and ability to use traffic information efficiently, which are determined by individual's driving experience and individual characteristics.

Khattak *et al.* (1999) conducted telephone surveys in the San Francisco area and asked respondents about the effects of pre-trip travel information. The propensity to adjust pre-trip travel decisions based on travel information is highest for work trips, compared to a base of trips for school, shopping and other personal trips. Individuals who experience higher travel time uncertainty and reported occurrence of unexpected delays during the past month have a higher propensity for pre-trip decision changes in response to travel information. Non-commuters and radio listeners have a higher tendency to cancel their trips in response to information.

Dia (2002) conducted a survey with mail-back questionnaires that were distributed to peak-period automobile commuters traveling along a traffic corridor in Brisbane, in order to investigate the individual driver behavior under the influence of real traffic information. Decisions that were investigated included pre-trip response to unexpected congestion information, en-route response to unexpected congestion information, and willingness to change driving patterns. On average, respondents took an alternative route 3.5 times per month. Response to information seemed to be influenced significantly by the information type and the way that it is provided to the individuals.

Kyoung-Sik (2003) conducted a survey for morning commuters in Daegu (Korea) in order to investigate the effect of pre-trip information acquisition. A large portion of drivers change route (43%) or departure time in response to the acquired information. Drivers who have university degrees, professional or self-employed jobs, are more likely to change their route in response to pre-trip traffic information.

Mahmassani *et al.* (2003) conducted web-based stated preference experiments to study the impact of ATIS on travelers' decisions about a shopping trip. ATIS could be provided to the user at a pre-trip and en-route level. Discrete choice models were developed to examine all factors that make commuters change to an alternative destination or route. The fundamental difficulty in modelling this problem is due to the structure of the survey where the information provided and user choices are interdependent. The results indicated that gender, age, level of education and high income is not statistically significant in explaining either route or destination switching. Familiarity with the area, and number of frequent visits to a specific mall, are less related factors that influence the change of destination or road. On the other hand, provided information which concerns delays or traffic jams can make trip-makers to switch road. The model developed by Mahmassani *et al.* (2003) also accounts for heteroskedasticity and correlation between the decision states and trip dimensions. While the data suggests there is no difference in variances in the error terms, with respect to the first choice, correlation exists among the decision states and along the trip dimensions. The inclusion of such correlation significantly improves the model.

Bierlaire and Thémans (2005) present (a) a Mixed Multinomial Logit model with panel data to analyze the drivers' decisions when traffic information is provided during their trip through Radio Data System (RDS) or variable message signs (VMS) and (b) a Nested Logit model capturing the behavior of drivers when they are aware of traffic conditions before their trip. The models are estimated using data from a two-year national survey in Switzerland during which both Revealed Preferences (RP) and Stated Preferences (SP) data about choice decisions in terms of route and mode were collected. It was found that people who use the Internet to access traffic information and those who are aware of alternate routes have a propensity to switch routes.

Van de Horst and Ettema (2005) conducted an internet survey to study travel information acquisition and mode choice decisions. The results of the survey showed that younger travelers are more inclined to retrieve any kind of information than older travelers. Between 20% and 57% of the public transport travelers and 50% to 62% of the car travelers sought information about aspects of the competing mode. Many travelers make the choice to use the car deliberately and the availability of information appears to play an important role in the decision process of non-captive travelers.

Jou *et al.* (2005) interviewed freeway travelers from Taichung to Taiwan in order to study route-switching behavior. Real-time traffic information with guidance was preferable to freeway travelers, as was the quantitative type of real-time traffic information. The model results indicate that male travelers and travelers with a higher income would be more likely to switch to the best route, while elderly travelers would be less likely to switch due to habitual and risk-aversive effects.

Tsirimpa *et al.* (2007) developed a mixed Multinomial logit model to capture the impact of ATIS on travelers' switching behavior that accounts for correlation among observations from the same individuals in the data set. The model was applied in a data-set from the Puget Sound Region (PSRC). The estimated models show that travel pattern characteristics, the time of information acquisition (pre-trip vs. en-route), the source and the content of provided information significantly affect commuters' response to information.

Farag and Lyons (2008) studied the factors that influence the pre-trip use of public transport information services (via different media - Internet, phone, paper timetables, asking staff). A social-psychological perspective was adopted which takes habit, attitudes, anticipated emotions, and perceived behavioural control into account. The results showed that social-psychological factors are important determinants of travel information use, while external factors such as trip context could affect these determinants.

Zhang *et al.* (2008) examined the effect of real-time transit information on travellers'' behaviour and psychology, using the data of a campus transportation panel survey. Two fixed-effects models and five random-effects ordered probit models were estimated to sort out causal relations between information use and two behavioural and five psychological indicators respectively. The results showed that the use of real-time information significantly increased rider's feeling of security about riding bus after dark and boosted their overall satisfaction level.

Choocharukul (2008) studied the interrelationships among the likelihood of making route diversion, attitudinal variables, and several exogenous factors such as socioeconomic and travel characteristics of the motorists. A structural equation model was developed based on empirical data of road users in Bangkok. Modelling results indicate a direct relationship between stated route diversion and two of the attitudinal variables, i.e. VMS comprehension and perceived usefulness of VMS, while the awareness of VMS is not found to be a direct determinant for route diversion decision. Unlike past studies, none of the socioeconomic variables appeared to directly influence route diversion intentions.

Gan *et al.* (2008) conducted a quantitative assessment of the potential effects of Variable Message Signs (VMS) information, displaying travel times on both original and alternate routes, on drivers' en-route diversion behaviour. Based on a stated preference (SP) survey on freeway drivers in Shanghai urban area, three types of binary probit models were estimated. The results showed that the impact of VMS information varies significantly across the characteristics of driver, route and VMS message of travel time. Travel time saving and drivers' driving age serve as positive factors in drivers' diversion behaviour.

2.2 Simulators

A number of studies have focused on the use of travel simulators to obtain data, which indicates how drivers would behave under various scenarios of information provision.

Mahmassani and Liu (1999) investigated departure time and route switching decisions made by commuters, in response to ATIS. The data was collected using a dynamic interactive travel simulator for laboratory studies of user response under real-time information. The experiment involved actual commuters who simultaneously interacted with each other within a simulated traffic corridor that consisted of alternative travel facilities with differing characteristics. In the pre-trip departure time switching decision, older commuters tended to tolerate greater schedule delay than younger ones. Also, female commuters exhibited a wider mean indifference band than male commuters for pre-trip departure time and route decisions as well as en-route path switching decision. The reliability of the real-time information is a significant variable that influences commuters' pre-trip departure time and route switching decisions as well as en-route path switching decisions. Travelers become more prone to switch routes when they perceive late arrival by following the current path than when they perceive early arrival by following the current path.

Abdel-Aty and Abdalla (2004) used a travel simulator (OTESP) to collect dynamic pre trip and en-route route choice data, in order to model the factors that affect drivers' compliance with a long-term pre trip advised route and drivers' usage of en route short-term traffic information. OTESP provided five different scenarios (levels) of traffic information to the subjects (pre trip information with and without advice, en-route information, keeping the pre trip information, with and without advice), besides the base-case of no traffic information, Each subject was required to choose his/her link-by-link route from a specified origin to a specified destination. A real network with historical congestion levels and weather conditions were used, and two models were developed. Generalized estimating equations (GEEs) with repeated observations and a binomial probit link function model were developed. The analysis showed that: (a) the pre trip advice has a good chance to be followed and is more beneficial compared with advice-free pre trip information and (b) the en-route short-term information provision increases the likelihood of making a positive link choice.

Chorus *et al.* (2006b) present a computer-based travel simulator for collecting data on the use of ATIS and their effects of travelers' decision making in a multimodal travel environment. The decision maker is presented with an abstract multimodal transport network, where knowledge levels are fully controlled for in terms of awareness of mode-route combinations as well as in terms of characteristics of known alternatives. Difference types of information provision with varying levels of reliability can be provided. The validation results suggest that the simulator succeeds in collecting data with a high validity on multimodal travel choice making under provision of advanced types of travel information.

Pan and Khattak (2008) explored the impacts of electronic traveler information on commercial and non-commercial users. By combining a behavioral model with a simulation tool, they studied whether traveler information can impact travel costs when (a) commercial truck percentages increase in traffic, (b) truck drivers divert to alternate routes in the same way as motorists do, and (c) when commercial trucks have relatively higher values of time. The analysis showed that by increasing the percentage of electronic traffic information dissemination in incident conditions, the network average travel time and total travel cost can be reduced up to 9%. The study also found that savings associated with electronic information are highly context dependent, i.e. they can be almost wiped out if drivers are able to observe traffic congestion.

Marchal and de Palma (2008) proposed a new method for measuring the impacts of non-recurrent congestion on travel costs by taking risk aversion into account. The traffic model used was based on the dynamic traffic simulations model METROPOLIS. Incidents were generated randomly by reducing the capacity of the network, while users could instantaneously adapt to the unexpected travel conditions or change their behavior via a day-to-day adjustment process. The main finding of this study is that the utility loss due to uncertainty is of the same order of magnitude as the total travel costs.

Han *et al.* (2008) investigated the effects of recommendation with different underlying control objectives on route choice under uncertainty via a computer experiment. The results indicated that when anticipating potential congestion, travelers use the provided recommendation as an indicator of the choices of other travelers as they conjecture the compliance rate to reduce the uncertainty when making decisions.
While actual results tend to vary among case studies, the information acquired by travelers (whether pre-trip or en-route) seems to play an important role on travelers switching behavior in almost all cases, especially when it involves traffic congestion and delays. In addition, the reliability and comprehension of the provided information is also crucial for ATIS usage and switch related decisions.

Travelers' socioeconomic characteristics are not always found significant (e.g. Mahmassani *et al.* 2003; Choocharukul 2008), but in the cases that they are, the most important are gender, age, education level and income. In most of the cases, young professional males with university degrees and high incomes are more inclined to retrieve traffic information than others.

In addition, minimizing travel time uncertainty seems to be one of the most important stimulants for ATIS usage, while the propensity of switching increases when travel time uncertainty is combined with reported delays from ATIS. According to Marchal and de Palma (2008), the utility loss due to uncertainty has the same order of magnitude with the total travel cost.

Moreover, past travel experiences as well as attitudes and perceptions were found to significantly affect commuters' behavior. Recent studies (e.g. Farag and Lyons 2008; Choocharukul 2008) showed that social and psychological factors affecting decisions and choices play an important role both in, ATIS usage and switching behavior, necessitating further research in this field. As analysed by Schwartz (2004) information gathering, quality and quantity of information, evaluation of alternatives, availability of alternatives, anchoring and frames, as well as comparisons of alternatives are notions to be taken into account when studying peoples' choices and decision making. Furthermore, it should be noted that most people tend to be risk averse when they are contemplating a choice between a certain small gain and an uncertain large one. Risk will be studied and modeled in detail in this research.

3 Methodological Framework

Travelers' response to traffic information consists of a series of actions and decisions occurring over time. Figure 1 describes the modeling framework of the switching from the habitual travel behavior of commuters in the presence of traveler information. The attributes that influence travelers' decision-making patterns can be broadly categorized into four groups. The first group consists of socio-economic characteristics, such as gender and age. The second group includes variables, which express habitual travel pattern, such as travel time, trip purpose and number of trips per day. The third group includes technology characteristics, such as access to the Internet, high-speed connections, and cellular phone ownership of the travelers. Finally the fourth group includes attitudes and perceptions, e.g. individual attitudes towards willingness to change travel patterns. It has been found that these are the main categories of independent variables that strongly affect travel decisions under the influence of ATIS (see for example Polydoropoulou *et al.* 1994; 1996; and Polydoropoulou and Ben-Akiva 1999).

Figure 1 presents the modeling framework of individual's switching behavior. In this figure ellipses represent variables that are not directly observable and therefore called latent variables. Rectangles represent observable variables, either explanatory or indicators of the latent variables.

The selected model specification is a standard linear-in-the-parameters specification, used in the vast majority of such models. The actual choice of variables is limited by data availability and postulated based on a priori expectations. The model specification has been refined based on statistical tests on estimation results of alternative considered models. The integrated model consists of two parts: a discrete

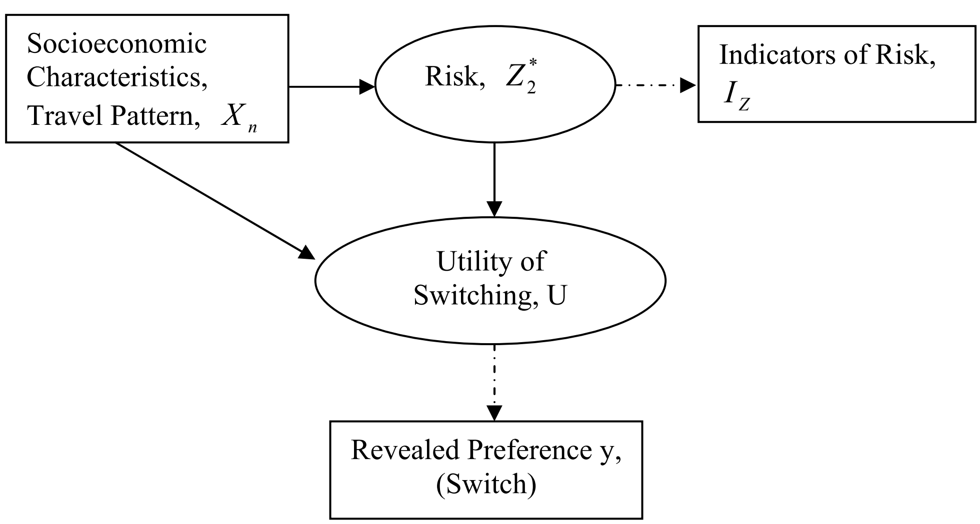

Figure 1. Modeling Framework for Switching with Latent Attributes

choice model and a latent variable model.

The notation for the switching model is:

X	Explanatory variables (stated), such as characteristics of individuals
Z^*	Latent (Unobserved) Variable, attitude towards risk
y	Choice indicators, 1 if Not Change, 0 Otherwise
I	Indicators of Latent Variables
α, β, λ	Vectors of Unknown parameters
$\omega, \varepsilon, \upsilon$	Random disturbance terms
Σ, σ	Covariance of random disturbance terms
φ	Standard normal probability density function
Φ	Standard normal cumulative distribution function

The switching model with latent attribute comprises structural and measurement equations. A more detailed description of these classes of models can be found in Walker (2001).

Structural equations

For the latent variable model, we need the distribution of the latent variables given the observed variables, $f_1(Z_n^* \mid X_n; \lambda, \Sigma_\omega)$.

$$Z_n^* = X_n\lambda + \omega_n, \quad \omega_n \sim N(0, \Sigma_\omega \quad diagonal) \tag{1}$$

For the choice model, we need the distribution of the utilities, $f_2(U_n \mid X_n, Z_n^*; \beta, \Sigma_\varepsilon)$.

$$U_{in} = X_{in}\beta_1 + Z_n^*\beta_2 + \varepsilon_{in} \quad and \quad \varepsilon_{in} \sim N(0,1) \tag{2}$$

Note that the latent variable of risk aversion is specified only in the utility of switching route.

Measurement equations

For the latent variable model, we need the distribution of the indicators conditional on the values of the latent variables, $f_3(I_n \mid X_n, Z_n^*; \alpha, \Sigma_u)$.

$$I_{rn} = Z_n^*\alpha_r + \upsilon_{rn}, \quad r = 1,2,3 \quad and \quad u_{rn} \sim N(0, \Sigma_u \quad diagonal) \tag{3}$$

These measurement equations (one equation for each indicator, i.e. each survey question) relate the indicator variables I (left hand side) with the latent variables and individual characteristics (right-hand-side).

No constants are included in the measurement equations since I_{rn} is in deviation form.

For the Choice Model we express the choice as a function of the utilities.

$$y_{in} = \begin{cases} 1, if \quad U_{in} \geq U_{jn}, for \quad j = 1,2,3 \\ 0, otherwise \end{cases} \tag{4}$$

The covariances of the error terms in the latent variable structural and measurement model are constrained to be equal to zero (denoted by the Σ diagonal notation).

Likelihood Function

Maximum likelihood techniques can be used to estimate the unknown parameters. The likelihood function for the integrated model presented above can be written as:

$$f_4(y_n, I_n \mid X_n; \alpha, \beta, \lambda, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_\omega) =$$

$$\int_{Z^*} P(y_n \mid X_n, Z^*; \beta, \Sigma_\varepsilon) f_3(I_n \mid X_n, Z^*; \alpha, \Sigma_\upsilon) f_1(Z_n^* \mid X_n; \lambda, \Sigma_\omega) dZ^* \tag{5}$$

The first term of the integrand corresponds to the choice model, the second term to the measurement equation from the latent variable model and the third term to the structural equation of the latent variable model. The joint probability of the y_n, I_n, and Z_n^*, is integrated over the vector of latent construct Z_n^*, because the latent variable is only known to its distribution.

4 Data Collection and Descriptive Statistics

Since 1989 the Puget Sound Regional Council (PSRC) has been gathering information about household travel patterns using a panel survey design. Every one or two years, the members of a random sample -approximately 2000 households- have been asked to complete a 48-hours travel diary, recording the details of their trips. Since 2000, a supplement was added to the travel diaries collecting data about the information sources consulted on each trip and how the information was used.

The Puget Sound Transportation Panel data have also been analyzed by Lappin (2000), Lappin and Pierce (2003), Ma and Goulias (1997) and Goulias *et al.* (2003). Lappin and Pierce (2003) studied the awareness and use of travel information sources by Seattle region highway and transit commuters in 2000 as well as their attitudes pertaining to the use of information. Furthermore, they highlighted how awareness, use, and attitudes have evolved since 1997. Goulias *et al.* (2003) used data from the first 9 waves of the survey and conducted latent class cluster analysis. The results of the analysis showed that no major longitudinal shifts occur. However, the most important finding is a general temporal shift to travel patterns of more traveling-alone trips and less traveling with others. Tsirimpa *et al.* (2007) estimated binary and mixed logit models capturing the impact of traffic information to traveler switching behavior using the same dataset.

In this paper, the data gathered by the 2000 survey are used to examine the impact of information acquisition on travel behavior. A total of 2,848 individuals participated in the research, less than half (1,191) of which completed the entire questionnaires related to the socio-economic characteristics and the individuals' attitudes and perceptions. From those 1,191 individuals, who completed the entire questionnaire and its supplement, 234 were considered in the analysis and model estimation of this paper: those that commute at least three days per week and have acquired travel information for their trips (total number of trips generated from those 234: 408 trips).

Table 1 summarizes some key statistics of the total sample and the sample that was considered in this research, showing that these key statistics do not change considerably for the smaller sample. The average age of the sample is 46 years and more than fifty percent are male. More than two thirds of the respondents have internet access at work or school (68.4%), at home (76%), or use a cellular or digital phone (71.6%).

On the recorded trips (408 trips), where individuals used some form of traveler information, traditional information sources (such as TV, phone, and radio) were the most frequently used (88.2%), while almost one tenth (9.3%) obtained the information through the Internet. Internet was preferred mainly by males in their 40´s that have little flexibility in their schedules.

Another important part of the questionnaire captures the impact of information on the respondents' trips, the content of the information that they received, and the primary benefit that they were seeking when they made a change to their trip. One third of the travelers consulted traffic information prior to departure (33.3%), almost half (46.1%) en-route, and one fifth (20.6%) both pre-trip and en-route. The most common reasons for seeking assistance include anticipation of traffic congestion (61%), need to be sure of arriving on time (22.3%) and wanting to reach the destination as soon as possible (6.5%).

More than a third of the respondents that used information systems on their trips made some changes in their trip (34.1%). Out of those who did change some aspect of their trip, 11.8% change departure time and 22.3% made small or major route changes. Women, in their mid 40's tend to change their usual travel pattern in response to information, easier than men of the same age. Departure time changes are only possible when the information is received prior to the start of the trip.

One third of the respondents reported that the information that led them to change route involved an incident along their route (30.8%), while 11% changed departure time due to this information. In addition, 22.9% of the respondents changed departure time, after being informed that some part of their usual route was closed.

Furthermore, the majority of the respondents who changed their trip in response to traffic information (60.4%) indicated the reduction of travel time as the primary motivation for this decision. It is worth noting that more than half of the commuters (63.2%) face an unexpected delay at least twice a week on their route.

Table 1: Comparison of the Total Sample to the Considered Sample

	Total Sample	**Considered Sample**
# of observations	**1,191**	**234**
Average Age	50	46
Gender (male)	53%	57.8%
Cellular Phone	71.5%	71.6%
Internet Access at Work/School	63.1%	68.4%
Internet Access at Home	71.3%	76%

Table 2. Reason for Consulting Information

Reasons (Travellers could choose up to 3)	Percentage
Anticipated traffic congestion	61.0%
I wanted to get to my destination as fast as possible	6.5%
Other	3.8%
I wanted to be sure I would arrive on time at my destination	22.3%
For schedules / directions	2.5%
I could see congestion on my route	1.6%
I had heard about an incident and wanted to know more about it	0.9%
The weather was bad	0.7%
My ferry was late	0.5%
I was late	0.5%
My bus was late	0.2%

The respondents also replied to six questions that can be used to infer their attitude toward inertia or willingness to change their travel patterns. Table 3 presents the statements that reflect the attitude of the commuters towards willingness to change travel behavior. In a sense, one can argue that those who are less reluctant to change are more "risk-prone", while those that show a higher inertia, or in other words would need a significant utility advantage in order to change, and are more "risk-averse". A ten-point scaling ranking from Strongly Disagree to Strongly Agree or from Not Important to Extremely Important was used to indicate the level of agreement or the level of importance of these statements. A correlation matrix of the six indicator statements is presented in Table 4. It becomes apparent that some of the statements are correlated and therefore they should not be all used together in the model formulation.

Table 4 presents the correlations of the above indicators.

Table 3. Statements indicating individuals' risk attitudes

Risk Prone Indicators	Mean	Std. Deviation
I don't like to have plan ahead	3.41	2.772
It's important that other people are able to contact me	5.43	3.189
I prefer to find my own way rather than ask for information	4.43	2.887
I worry a lot about being late	6.00	2.721
I don't like to take risks with new products	4.46	2.435
When I need information I like to be able to ask for it	5.04	2.645

Table 4. Correlation of Risk Attitude Indicators

		I don't like to have plan ahead	It's important that other people are able to contact me	I prefer to find my own way rather than ask for information	I worry a lot about being late	I don't like to take risks with new products	When I need information I like to be able to ask for it
I don't like to have plan ahead	Pearson Correlation	1	-0.048	0.115*	0.172**	0.072	-0.019
	Sig. (2-tailed)		0.330	0.020	0.000	0.145	0.701
It's important that other people are able to contact me	Pearson Correlation	-0.048	1	-0.080	0.063	-0.052	-0.004
	Sig. (2-tailed)	0.330		0.106	0.203	0.297	0.938
I prefer to find my own way rather than ask for information	Pearson Correlation	0.115*	-0.080	1	-0.172**	0.085	-0.149**
	Sig. (2-tailed)	0.020	0.106		0.000	0.085	0.002
I worry a lot about being late	Pearson Correlation	0.172**	0.063	-0.172**	1	0.009	-0.042
	Sig. (2-tailed)	0.000	0.203	0.000		0.858	0.398
I don't like to take risks with new products	Pearson Correlation	0.072	-0.052	0.085	0.009	1	0.179**
	Sig. (2-tailed)	0.145	0.297	0.085	0.858		0.000
When I need information I like to be able to ask for it	Pearson Correlation	-0.019	-0.004	-0.149**	-0.042	0.179**	1
	Sig. (2-tailed)	0.701	0.938	0.002	0.398	0.000	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

5 Model Specification and Estimation Results

This section presents the model estimation results. The integrated choice and latent model that has been specified in Section 3 has been estimated using the software package ICVL (Denis Bolduc). The integrated choice and latent model consists of the choice model with the risk aversion variable and the latent variable model (one structural equation and 3 measurement equations). The presented model was selected on the basis of statistical goodness-of-fit (likelihood ratio tests, estimated coefficient significance t-tests, the rho-square (ρ^2) as well as parsimony.

The utilities of the Logit Model specific to individual are:

$$U_{NOC,n} = X_{NOC,n}\beta + \nu_{NOC,n} \text{ (Utility of No Change)} \quad (6a)$$

$$U_{CDT,n} = a_{CDT} + X_{CDT,n}\beta + \nu_{CDT,n} \text{ (Utility of Departure Time Change)} \quad (6b)$$

$$U_{RC,n} = a_{RC} + X_{RC,n}\beta + Z^{*}_{RC,n}\beta + \nu_{RC,n} \text{ (Utility of Route Change)} \quad (6c)$$

The vector X contains variables that are associated with fixed parameters included in the column β with components β_k, k = 1,…, K. The coefficients α represent the alternative specific constants of each alternative (defined for two of the three alternatives, while the remaining alternative serves as the base case).

Table 5 presents the specification of the alternative utility functions. Table 6 presents the estimation model results (coefficients and t-statistics) for the combined discrete and latent variable model and the MNL model.

In the estimated model the independent variables that were found significant are: (1) the type (pre-trip or en-route), source (Internet), content of information provided, primary benefit for seeking information and the reason for consulting information; (2) usual travel pattern characteristics, such as congestion and travel mode on the habitual route and (3) the latent variable of risk aversion.

The (negative) sign of the values of the estimated alternative specific constants (corresponding to changing departure time and changing route) show that, ceteris paribus, there is inertia towards no change. This is an intuitive finding that essentially confirms that there is a perceived penalty associated with switching from the habitual travel pattern. In other words, there is a threshold, above which a change becomes attractive. The relative magnitude of the estimated constants suggests that travelers are more reluctant to change route than departure time.

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Table 5. Specification Table of the Choice Model

	α_{01}	α_{02}	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9
Utility of No Change	0	0	1 if Information Source is Internet	0	0	0	0	0	0	0	0
Utility of Change Departure Time	1	0	0	1 if Consult Travel Information Prior to Departure	1 if Reason for consulting information was: *I wanted to be sure I would arrive on time*	0	0	0	0	0	0
Utility of Change	0	1	0	0	0	1 if Usual Travel Pattern: *At least twice a week there is an unexpected delay on my route*	1 if Information provided was: *There was an incident on my route such as a car accident or overturned truck*	1 if Information provided was: *Some part of my route was closed or out of service for repairs or construction*	1 if Primary benefit for seeking information was: *Reduced trip time*	1 if Travel Mode Used: *Car*	Risk Aversion

The positive value of the estimated coefficient associated with the access to information (specific to the change of departure time) indicates that travelers are more likely to change departure time when they receive information. The significance of the internet, as the source of information in no changing alternative, is consistent with the findings of Bierlaire and Thémans (2005) and Tsirimpa *et al.* (2007), who also identified the effect of internet as an information source in individuals' route switching behavior.

Individuals that consulted information because they wanted to be sure they would arrive on time have a higher tendency towards changing their departure time. In addition, those who acquired information having as primary benefit the reduction of travel time are more prone to change route.

Drivers who face unexpected congestion at least twice a week are more prone to change route in response to traffic information. This is captured by the positive sign of the related binary variable associated with the route change alternative.

Information types have been linked in the developed model with route change alternative. These have been coded in the model as zero/one dummy variables. The provision of information increases the propensity of the travelers to switch from their habitual travel pattern, as expected. The travelers' propensity towards a route change is increased when there is information on an incident or a road closure on the habitual route.

The presence of the risk aversion latent variable is significant. The higher the risk aversion, the higher the likelihood of not switching route in response to information.

The structural equation of the latent variable model suggests that males are more likely to avoid taking risks than females, which is a finding that needs more research since most literature so far suggest that men are more risky than women. Age was also found a significant factor, with travelers of age 35–55 being less prone towards risk than younger travelers.

The coefficients of the three indicators of the measurement equation (1) I worry a lot about being late; (2) I don't like to have a plan ahead; and (3) I prefer to find my own way rather than ask for information, were found significant as expected.

The model estimation results can be summarized in the following statements:

- There is an inertia associated with the no change alternative
- The occurrence of unexpected congestion on the usual route at least twice a week increase the propensity of the drivers to change their habitual route
- Access to travel information (pre-trip), increase the propensity of the travellers' to change departure time
- Individuals who don't like taking risks are less likely to switch route
- The internet as information medium, as well as the content of the provided information (incident on the habitual route) and the reason for consulting information has a positive effect in the propensity towards route change.

The significance of the content of the information provided on travellers' switching behaviour is consistent with the findings of Dia (2002) and Mahmassani *et al.* (2003). In their studies they have identified that, when the content of information involves travel time delays, the probability of (small or major) route changes increases. Kyoung-Sik (2003) also found that the content of pre-trip information motivates people to change departure time.

Table 6. Model Estimation Results

	MNL with Latent Variable		MNL	
CHOICE MODEL				
Explanatory Variables	**Coef.**	**(*t*-stat)**	**Coef.**	**(*t*-stat)**
Constant (specific to Change Departure Time)	-2.55	(-8.94)	-2.56	(-9.19)
Constant (specific to Change Route)	-4.87	(-6.30)	-4.30	(-8.13)
Information Source: Internet (specific to No Change)	-1.01	(-2.23)	-0.93	(-2.07)
Consult Travel Information Prior to Departure (specific to Change Departure Time)	1.12	(2.76)	1.14	(2.88)
Reason for consulting information: *I wanted to be sure I would arrive on time* (specific to Change Departure Time)	2.44	(4.92)	0.67	(1.68)
Usual Travel Pattern: *At least twice a week there is an unexpected delay on my route* (specific to Change Route)	1.36	(2.97)	1.15	(3.09)
Information provided: *There was an incident on my route such as a car accident or overturned truck* (specific to Change Route)	0.60	(1.45)	2.48	(5.41)
Information provided: *Some part of my route was closed or out of service for repairs or construction* (specific to Change Route)	1.86	(2.54)	1.78	(3.18)
Primary benefit for seeking information: *Reduced trip time* (specific to Change Route)	3.14	(6.19)	2.71	(7.41)
Travel Mode: *Car* (specific to Change Route)	1.66	(3.24)	1.54	(3.71)
Z_1^* Risk Aversion (specific to Change Route)	-0.91	(-2.77)		
Initial Log-Likelihood	-448.23		-448.23	
Final Log-Likelihood	-259.93		-261.56	
ρ^2	0.42		0.41	
LATENT VARIABLE MODEL				
Structural Model for Z_1^* Risk Aversion				
Gender (male dummy)	0.77	(3.47)		
Age: 35-55 years	-0.52	(-3.04)		
Age: > 56	0.24	(0.94)		
ρ^2 of Structural Equation	0.17			
Measurement Model				
λ_1 I worry a lot about being late	1.34	(4.13)		
λ_2 I don't like to have a plan ahead	0.61	(3.17)		
λ_3 I prefer to find my own way rather than ask for information	-0.72	(-3.28)		
σ_1 I worry a lot about being late	2.28	(11.43)		
σ_2 I don't like to have a plan ahead	2.68	(20.25)		
σ_3 I prefer to find my own way rather than ask for information	2.77	(18.48)		

A discussion on the meaning of the terms risk averse and risk seeking is useful in the understanding of these results, as they may have more than one interpretation in the literature (e.g., Cohen *et al.* 1987; Lopes 1984). According to Katsikopoulos *et al.* (2002), at the behavioral level most interpretations refer to the pattern of choices that a participant makes when presented with an option having one certain outcome and an option or options having an equal (or almost equal) expected value but more than one possible outcome. Usually, a decision maker who chooses the certain option more often is termed risk averse, and a decision maker is risk seeking if he or she chooses the certain option less often. In the context of route choice in the presence of traffic information, a driver could be termed as risk averse if, among travel time distributions that have equal expectations, he or she more often chooses the route with the smaller variability. Conversely, a driver is termed risk seeking if, among travel time distributions that have equal expectations, he or she more often chooses the route with the larger variability.

Katsikopoulos *et al.* (2000) found that risk attitude in route choice is influenced by whether the route choice scenario is classified as belonging to the domain of gains or to the domain of losses. Katsikopoulos *et al.* (2000) proposed a simple model that described risk attitude reversals quite well. This model represents a realistic break from the tradition of choice models that assume humans have the capacity for complex transformations of all probabilities and values involved (e.g. Tversky and Kahneman 1981, 1992). In an extension of the work of Katsikopoulos *et al.* (2000), Katsikopoulos *et al.* (2002) assumed that drivers exhibit bounded rationality (Simon 1957). That is, a simple heuristic is used to process probabilistic travel time information (see also Gigerenzer and Goldstein 1996). Specifically, a driver is assumed to heuristically estimate a probabilistic travel time as simply a point inside the given range. Katsikopoulos *et al.* (2002) found that diversion frequency among alternative routes with fixed expectation e smaller than the reference travel time c was decreasing in the range of the alternative route r. Also, diversion frequency was increasing in r when expectation e was larger than the reference travel time c. This finding is consistent with risk attitude reversals for other choices (Tversky and Kahneman 1981).

More recently, Casas and Kwan (2007) investigated the final choice of people's decision-making process when faced with unexpected events during the commute trip in the presence of real-time information collected using a travel simulator. Results show that people are willing to experiment with other alternatives if provided the information to support their choice, i.e. they are not inherently risk-averse. The above conclusions of the presented model in this paper are consistent with this finding.

6 Conclusions

In the presented research, RP data from a 2-day diary survey have been used. In the survey, individuals provided information about the traveller information sources consulted on each trip, as well as how the obtained information influenced their usual travel behaviour. Since multiple information sources are actually available in the Puget Sound area, the results obtained demonstrate the actual choices of individuals in an information-rich environment.

A joint choice and latent variable model that explicitly captures the attitude of travellers' towards travel pattern switching has been developed and may be used to realistically predict travellers' switching patterns with regards to departure time change and route change. As expected, travelers in general tend to maintain their habitual travel pattern. However, specific travel information - such as incident or road closure – influences behavioural switches such as departure time change and route change.

In terms of better-informed travel decisions and more efficient use of transportation infrastructure, Advanced Traveler Information Systems (ATIS) offer an appealing alternative. The information provided by ATIS in a constantly changing environment helps individuals to readjust their travel decisions, make more informed and conscious travel decisions and reduce travel time and stress. The majority of the respondents, who changed their trip in response to travel information, reported that the main reason for making that change was to reduce travel time (60.4%). As the results indicate, the biggest impact of traffic information is reflected in route changes, reducing the peak and most likely causing a re-distribution of travel demand, thus helping reduce air pollution and congestion.

While the PSRC data set may well be the richest available to transportation researchers, it still has limitations. For example, the descriptive statistics of the analysed diaries indicate that respondents used some form of information system (internet, television, radio, or other) only for 4.1% of their total trips, while the use of traveller information systems is mostly made during the trip (46.1%). It is believed that with a larger data set, i.e. a higher number of observations receiving traffic information, richer models could be estimated. For example, additional parameters might enter the model specification, or some nesting structures might emerge.

The estimated model should therefore be seen in the context of the available data. Generally speaking, the value of the ρ^2 of the structural equation (0.17) is rather low. Further research should aim at extending the presented methodological framework with additional variables and structures that would capture the underlying processes more accurately and would provide better fit. An interesting candidate direction for analysis of the travellers'' behaviour could be found in the field of psychological foundations from behavioural theory (e.g. based on the works by Tversky and Kahneman 1981, 1992) for items such as character development, stress and anxiety, as well as risk behavior and trade-offs for better choices (Kahneman and Tversky (2000), Rabin and Thaler (2001), and Schwartz (2004).

One consideration relates to the extent at which the presented model may be useful to practitioners. While currently the software to estimate such models may not be widely available to practitioners, it is very likely that in a few years it will become more accessible. Research in this area could then be used as a basis for the practitioners to adopt this more powerful type of models and integrate them into their arsenal. As has been illustrated from the model estimation results, the presented methodology outperforms the simpler MNL model that is widely used by practitioners today.

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References

Abdel-Aty, M. and Abdalla, M. F., 2004. Modeling drivers' diversion from normal routes under ATIS using generalized estimating equations and binomial probit link function. Transportation, 31(3), 327-348.

Abdel-Aty, M., Kitamura R. and Jovanis P., 1997. Using stated preference data for studying the effect of advanced traffic information on drivers' route choice. Transportation Research Part C, 5(1), 39-50.

Bierlaire, M. and Thémans, M., 2005. Development of Swiss models for transportation demand prediction in response to real-time traffic information. Proceedings of the 5th Swiss Transport Research Conference, Monte Verita/Ascona, Switzerland.

Bonsall, P., 2004. Traveller Behavior: Decision-Making in an Unpredictable World, Journal of Intelligent Transportation Systems. 8(1), 45-60.

Casas, I., and Kwan, M. P., 2007. The Impact of Real-Time Information on Choices During the Commute Trip: Evidence from a Travel Simulator. Growth and Change, 38(4), 523–543.

Choocharukul, K., 2008. Effects of Attitudes and Socioeconomic and Travel Characteristics on Stated Route Diversion: Structural Equation Modeling Approach of Road Users in Bangkok. Transportation Research Record: Journal of the Transportation Research Board, 2048, 35-42.

Chorus, G. C., Molin, J. E. E. and Van Wee, B., 2006a. Use and effects of advanced traveller information services (ATIS): A review of the literature. Transport Reviews, 26(2), 127–149.

Chorus, C. G., Molin, J. E. E., Arentze, T. A., Hoogendoorn, S. P., Timmermans, H. J. P. and Van Wee, G. P., 2006b. Observing the making of travel choices under uncertainty and information: validation of travel simulator. Paper presented at the 85th Annual Meeting of the Transportation Research Board, Washington, DC.

Cohen, M., Jaffray, J.-Y and Said, T., 1987. Experimental comparison of individual behavior under risk and under uncertainty for gains and losses. Organizational Behavior and Human Decision Processes, 39(1), 1-22.

Dia, H., 2002. An agent-based approach to modelling driver route choice behaviour under the influence of real-time information. Transportation Research Part C, 10(5), 331-349.

Ettema, D. and van der Horst, R., 2005. Use of travel information and effects on mode choice for recreational trips. Proceedings of the 84nd Annual Meeting of the Transport Research Board, Washington DC.

Farag S. and Lyons, G., 2008. What Affects Use of Pretrip Public Transport Information? Empirical Results of a Qualitative Study. Transportation Research Record, 2069, 85-92.

Gan, H. C., Ye, H. and Gao, W. S., 2008. Drivers' En-Route Diversion under the Influence of Variable Message Sign Information: An Empirical Analysis. Proceedings of the Transportation Research Board Annual Meeting, Washington DC.

Gigerenzer, G., and Goldstein, D. G., 1996. Reasoning the fast and frugal way: Models of bounded rationality. Psychological Review, 103(4), 650-669.

Goulias, C., Kilgren N. and Kim, T., 2003. A decade of longitudinal travel behavior observation in the Puget sound region: sample composition, summary statistics, and a selection of first order findings. Proceedings of the 10th International Conference on Travel Behaviour Research, Moving Through Nets: The Physical and Social Dimensions of Travel, Lucerne, August 10-14.

Han, Q., Timmermans, H., Dellaert, B. G. C. and van Raaij, F., 2008. Route Choice Under Uncertainty: Effects of Recommendation. Transportation Research Record, 2082, 72-80.

Hato, E., Taniguchi, M., Sugie, Y., Kuwahara, M. and Morita, H., 1999. Incorporating an information acquisition process into a route choice model with multiple information sources. Transportation Research Part C, 7(2), 109-129.

Jou, R., Lam, S., Liu, Y. and Chen, K., 2005. Route switching behaviour on freeways with the provision of different types of real-time traffic information. Transportation Research Part A, 39(5), 445-461.

Kahneman, D. and Tversky, A., 2000. Choices, Values and Frames. New York, Cambridge University Press.

Katsikopoulos, K. V., Duse-Anthony, Y., Fisher, D. L., and Duffy, S. A., 2000. The framing of drivers' route choices when travel time information is provided under varying degrees of cognitive load. Human Factors, 42(3), 470-481.

Katsikopoulos, K. V., Duse-Anthony, Y. Fisher, D. L. and Duffy, S. A., 2002. Risk attitude reversals in drivers' route choice when range of travel time information is provided. Human Factors, 44(3), 466-473.

Khattak, J. A. and Khattak, A. J., 1998. A comperative analysis of spatial knowledge and en route diversion behavior in Chicago and San Fransisco: Implications for advanced traveler information systems. Transportation Research Record, 1621, 27-35.

Khattak, J. A., Yim, Y. and Stalker, L., 1999. Does travel information influence commuter and non-commuter behavior? Results from the San Fransisco bay area TravInfo project. Transportation Research Record, 1694, 48-58.

Kyoung-Sik, K., 2003. Role of information sources in driver switching decision. EC Workshop on Behavioural Responses to ITS, Eindhoven, The Netherlands.

Lappin, J., 2000. Advanced Traveler Information Service (ATIS): Who are ATIS Customers? Report for Federal Highway Administration, U.S. Department of Transportation.

Lappin, J. and Bottom, J., 2003. Understanding and Predicting Traveler Response to Information: A Literature Review. Technical Report No.: FHWA-JPO-04-014, US Department of Transportation

Lappin, J. and Pierce, S., 2003. Evolving awareness, use, and opinions of Seattle region commuters concerning traveller information: Findings from the Puget Sound Transportation Panel Survey, 1997 and 2000. Proceedings of the 82nd Annual Meeting of the Transport Research Board, Washington DC.

Lopes, L. L., 1984. Risk and distributional inequality. Journal of Experimental Psychology: Human Perception and Performance, 10(4), 465-485.

Ma, J. and Goulias, K.G., 1997. A dynamic analysis of activity and travel patterns using data from the Puget Sound transportation panel. Transportation, 24(1), 1-23.

Mahmassani, H., Huynh, N., Srinivasan, K. and Kraan, M., 2003. Trip maker choice behavior for shopping trips under real-time information: model formulation and results of stated-preference internet-based interactive experiments. Journal of Retailing and Consumer Service, 10(6), 311-321(11).

Mahmassani, H. and Liu, Y., 1999. Dynamics of commuting decision behavior under advanced traveler information systems, Transportation Research Part C, 7(2-3), 91-107.

Marchal, F. and De Palma, A., 2008. Measurement of Uncertainty Costs with Dynamic Traffic Simulations. Proceedings of the Transportation Research Board Annual Meeting, Washington DC.

Polydoropoulou, A. and Ben-Akiva, M., 1999. The effect of advanced traveler information systems (ATIS) on travelers behaviour. In Emmerink R.and Nijkamp, P. (Ed.) Behavioural and Network Impacts of Driver Information Systems.

Polydoropoulou, A., Ben-Akiva, M. and Kaysi I., 1994. Revealed preference models of the influence of traffic information on drivers route choice behavior, Transportation Research Record, 1453.

Polydoropoulou, A., Ben-Akiva, M., Khattak, A. and Lauprete, G., 1996. Modeling revealed and stated en-route travel response to ATIS. Transportation Research Record, 1537, 38-45.

Rabin, M., and Thaler, R. 2001. Anomalies Risk Aversion. Journal of Economic Perspectives, 15(1), Winter 2001.

Simon, H. A., 1957. Models of man. New York: Wiley.

Schwartz, B., 2004. The Paradox of Choice. Why more is less. Herper Perennial 2004.
Toledo, T. and Beinhaker, R., 2006. Evaluation of the Potential Benefits of Advanced Traveler Information Systems. Journal of Intelligent Transportation Systems, 10(4), 173-183.
Tsirimpa, A., Polydoropoulou, A., and Antoniou, C., 2007. Development of a Mixed MNL Model to Capture the Impact of Information Systems on Travelers' Switching Behavior. Journal of Intelligent Transportation Systems, 11(2), 1-11.
Tversky, A., and Kahneman, D., 1981. The framing of decisions and the psychology of choice. Science, 211(4481), 453-458.
Tversky, A., and Kahneman, D., 1992. Advances in prospect theory: Cumulative representation of uncertainty. Journal of Risk and Uncertainty, 5(4), 297-323.
Van der Horst, R. S. N. and Ettema, D. (2005) Use of travel information and effects on mode choice for recreational trips. Paper presented at the 84th Meeting of the Transportation Research Board, Washington, DC, USA.
Walker, J. L., 2001. Extended Discrete Choice Models: Integrated Framework, Flexible Error Structures, and Latent Variables. Ph.D. Dissertation, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology.
Xiaohong Pan and Khattak, A. J., 2008. Evaluating Traveler Information Impacts on Commercial and Non-Commercial Users. Transportation Research Record, 2086, 56-63.
Zhang, F., Shen, Q. and Clifton, K., 2008. An examination of Traveler Responses to Real-time Bus Arrival Information Using Panel Data. Transportation Research Record, 2086, 56-63, 2082, 107-115.