Analysis of Stated Route Diversion Intentions Under Advanced Traveler Information Systems Using Latent Variable Modeling

SAMER M. MADANAT, C. Y. DAVID YANG, AND YING-MING YEN

One of the benefits of advanced traveler information systems (ATISs) is their ability to divert travelers to alternative routes during traffic incidents to alleviate congestion. ATISs may effectively convince travelers to divert to alternative routes by providing information that is considered useful. Therefore, it is important to identify the factors that explain drivers' route diversion behaviors to properly assist in the design and implementation of ATISs. An application of latent variable models to determine the factors that affect drivers' stated intentions to divert from their usual routes when faced with traffic congestion is described. Two latent variables were identified: drivers' attitudes toward route diversion and their perceptions of the reliability of information provided by radio traffic reports (RTRs) or changeable message signs (CMSs). These two latent variables were determined to be significant explanatory variables of route diversion intentions. Some drivers' travel and socioeconomic characteristics and the type of information provided by RTRs and CMSs were also found to be important explanatory variables.

Advanced traveler information systems (ATISs) are being developed to provide information that affects travel choices such as en route diversion, route selection, and departure time decisions. However, the benefits of ATISs are achieved only if the commuters respond to the information conveyed by ATISs in a positive manner. The study presented here discusses and identifies some of the relevant factors that influence drivers' stated diversion propensities.

A literature review of previous work in the area of modeling drivers' route diversion behaviors under conditions of real-time information presentation is presented first. Then, a description of the stated preference data used for the study is provided. The overall response patterns are then discussed. The core of the paper is the methodology used to estimate latent variables of travelers' attitudes toward route diversion and their perceptions of the reliabilities of radio traffic reports (RTRs) and changeable message signs (CMSs) and the discrete choice analysis used to identify the contributing factors that influence route diversion propensity. Finally, conclusions are presented.

LITERATURE REVIEW

Earlier studies found that prescriptive and descriptive traffic information encourages route diversion (*1–7*). Those studies also indicated that drivers expressed a higher propensity to divert their routes when they were experiencing increasing delays and congestion, when travel times and travel distances on drivers' preferred routes were longer, when congestion was caused by an unexpected incident rather than a recurring event, when trip direction was from home to work, and as their familiarity with the alternative routes increased. Finally, it was reported that young, male, and unmarried drivers are more likely to divert to alternative routes.

Khattak et al. (*8*) used a questionnaire survey of downtown Chicago commuters to study the factors that affect diversion from and return to regular routes. They used joint multinomial logit models to model drivers' choices among three alternatives: no diversion, diversion and no return, and diversion and return. They determined that drivers who were risk seekers, who stated a higher diversion preference, who were familiar with several routes, or who were making longer trips have higher diversion rates. Drivers who were making longer trips were also found to be more likely to return to the original route after a temporary diversion. On the other hand, commuters who were classified as risk seekers were less likely to return to their regular routes after diversion.

Khattak and colleagues (*9*) conducted a study in 1993 in the San Francisco Bay Area to identify variables that affect the diversion propensities of commuters. That study used a linear regression model to explore the effects of different types of information on route diversion. The study found that the diversion rate increases as the amount of travel information increases and that prescriptive information might be sufficient to achieve a high diversion rate. They also found that route diversion propensity depends on the presence of opportunities to divert, personality characteristics, and weather conditions.

Researchers at the University of California at Davis used bivariate probit models to determine the factors that influence the use of traffic information by commuters and their propensity to use alternative routes (*10*). They found that long-distance commuters, females, college graduates, or respondents who reported uncertainty in travel time as a major problem are more likely to use traffic information. Furthermore, they found that drivers with higher incomes and levels of education and who often use traffic information have a higher probability of using alternative routes. Those researchers also estimated negative binomial models of route-changing frequency and identified several influential factors: perceptions of the accuracy of traffic information and variations in traffic condition, travel time, and travel distance.

Jou and Mahmassani (*11*) used Poisson regression models to relate route, departure time, and joint switching frequencies to three

School of Civil Engineering, Purdue University, 1284 Civil Engineering Building, West Lafayette, Ind. 47907-1284.

factors: characteristics of the commuters, work environment, and traffic network. They found that commuters tend to change their departure times, routes, or both more frequently in the morning than in the evening. Furthermore, they showed that route and departure time decisions are interdependent on each other. Finally, they found that all three factors mentioned earlier are important determinants of the departure time and route-switching behavior.

Adler et al. (*12*) used an in-laboratory interactive microcomputer simulation to collect data for the study of en route behavior under ATISs. They estimated a structural equation model for modeling the en route behaviors of drivers. In addition, they identified four latent factors that affect diversion and information acquisition by drivers and investigated the interrelationships between these decisions. They viewed these latent factors as arousal and motivation concepts that would lead drivers to divert their routes or acquire information.

To pursue a deeper understanding of travelers' route diversion behaviors, the study presented in this paper further explores the determinants that affect drivers' decisions regarding route diversion. Like other researchers, the richness of stated preference data, specifically, rating data, has been exploited. Moreover, this study incorporated stated preference data into a structural equation model of route diversion behavior and allowed the latent factors representing drivers' perceptions of the reliability of traffic information and attitudes toward compliance with traffic advisories to be captured.

DESCRIPTION OF SURVEY AND DATA SET

Factors that may influence drivers' willingness to divert from a regular route were summarized by Khattak et al. (*7,8*):

1. Characteristics of congestion such as length and cause of the delay;
2. Source of delay information such as radio traffic reports, CMSs, or personal observation of congestion;
3. Attributes of delay information received such as accuracy and reliability;
4. Attributes of regular and alternative routes such as travel time and safety;
5. Attributes of commuters such as socioeconomic characteristics and personality;
6. Trip characteristics such as trip origin and destination; and
7. Situational factors such as time pressure, time of the day (i.e., daylight hours or nighttime hours), and weather conditions.

Based on these factors, a questionnaire survey was designed to collect the necessary stated preference (SP) data. The relevant parts of the questionnaire were organized as follows. First, the respondents were asked about the characteristics of their commute trip. Then, the respondents were asked a series of questions concerning their attitudes toward route diversion and perceptions of the reliability of traffic information provided by RTRs and CMSs. A five-point Likert scale ranging from "strongly agree" to "strongly disagree" was used as the response format for these questions on attitudes and perceptions. Next, hypothetical situations were presented to the respondents to explore drivers' stated diversion propensities. The responses for these hypothetical questions were simple binary choices, that is, either "yes" or "no." Finally, the socioeconomic characteristics of the respondents were recorded.

The data for the study were collected through a phone survey of households in the northwestern part of Indiana that included Lake County, Porter County, and La Porte County. The respondents who participated in the phone survey were randomly selected from telephone directories. These respondents were first asked if they were frequent users of the Borman Expressway. A total of 491 valid observations were collected through the telephone survey.

The Borman Expressway is a section of I-94 that stretches from the county line of Indiana's Lake County and Porter County to the state line of Illinois and Indiana. Besides the Borman Expressway, three other east–west routes are located in the study area. These east–west routes include the I-90 Toll Road, US-12, and US-20. The Borman Expressway is one of the most heavily congested freeways in the Midwest and is characterized by very high truck traffic: about 30 percent of daytime traffic consists of commercial trucks.

Since SP data were used in the study to evaluate drivers' stated diversion propensities, a general understanding of the strengths and weaknesses of SP data is important. According to Ben-Akiva et al. (*13*), the advantages of SP data are that

1. They can educe preferences on new (nonexisting) alternatives;
2. Attributes are prespecified and error free;
3. Multicollinearity among attributes can be avoided; and
4. Attributes that are not easily quantified, such as safety and comfort, can be incorporated.

However, one major drawback of SP data causes this type of data not to be widely used in model estimation: the reliability of the elicited information under hypothetical scenarios and its consistency with actual market behavior (*13*). The reliability of SP data has two different aspects: validity and stability. Discrepancies between stated and actual behavior may exist because of policy or justification biases, and this is referred to as a lack of validity. Lack of stability relates to the magnitude of random errors in SP data (*14*). In one case reported in the literature, Wardman (*15*) found that the residual standard deviation of an SP choice model differed from that associated with a reveal preference (RP) model by 20 percent. However, Wardman also indicated that the 20 percent difference would not lead to critical differences between RP and SP choice probabilities. Nevertheless, caution should be taken whenever SP data are used.

SP data were used in the present study because the focus of the research is to investigate the latent variables that influence drivers' route diversion propensities. This type of information can only be obtained by asking some hypothetical questions by the SP approach.

OVERVIEW OF RESULTS

This section summarizes the results obtained from the telephone survey. It should be emphasized that the results presented in this section only describe the relative importance of various factors in determining a tendency toward diversion but do not give any absolute patterns of diversion.

Most respondents (87.6 percent) stated that they would divert to an alternative route when the Borman Expressway is congested. Almost 68 percent of respondents who participated in the study indicated that they cannot tolerate more than 15 min of traffic delay. More respondents stated that they would divert to an alternative route to avoid traffic delay and congestion during daylight hours instead of nighttime hours and during good weather conditions instead of bad weather conditions. It was also found that approximately the same number of respondents stated that they would divert to an alternative route to avoid traffic delay and congestion whether they are driving from home to work or from work to home. Such a result might indicate that the time pressure factor is not very significant to these respondents.

Drivers' attitudes toward route diversion and perceptions of the reliability of the information provided by RTRs and CMSs were identified through a series of questions that required the responses to be given on a five-point Likert scale. Table 1 reports the distributions of responses along with the statements used in the survey.

Most respondents stated that they have positive attitudes toward route diversion by answering agree or strongly agree to the first three statements (Table 1). Respondents were also asked about their perceptions of RTRs and CMSs in terms of information attributes (relevance, reliability, and accuracy) as shown in Statements 4 to 7 of Table 1. More than half of the respondents rated RTRs and CMSs better than average on these three information attributes by stating that they agree or strongly agree on Statements 4 to 6 and disagree or strongly disagree on Statement 7. This indicates that traffic information disseminated through current information sources is perceived positively by regular users of the Borman Expressway. It is important to point out that a high percentage of participants have positive attitudes toward diversion and good perception of RTRs and CMSs, as indicated in Table 1. This is because the respondents sampled in the study are frequent users of the Borman Expressway and are familiar with the highway network of the area. Finally, it is noteworthy that Statement 7 is designed as an opposite of Statement 5 to check the validities of the responses given by survey participants.

Respondents were then presented with five hypothetical scenarios and were asked whether they would divert to an alternative route from the Borman Expressway. The scenarios were characterized by different types of information conveyed. The results and the hypothetical scenarios are presented in Table 2.

The diversion rate is lowest when the information provided is qualitative (Table 2); such a result is expected since this type of information does not provide additional details compared with what was available to the drivers when they first found out about the congestion. Table 2 also indicates that the diversion rate increased as the amount of information provided increased. This suggests that some commuters might be restrained from diverting their routes because of not having enough information about their alternative route at present. Finally, the largest stated propensity to divert the route was obtained when RTRs and CMSs provided prescriptive information. Such a finding is also expected, because prescriptive information implies that the alternative route is the best option. These high diversion rates provide a good indication that drivers are responsive to the information given by RTRs and CMSs under incident conditions. Once again, the percentages of respondents who indicated a preference for route diversion during traffic congestion reported in Table 2 are relatively high because these respondents are frequent users of the Borman Expressway.

Finally, some socioeconomic characteristics of the 491 respondents who participated in the survey are summarized in Table 3. According to Table 3 the majority of people who participated in the study range in age from 20 to 65 years (91.8 percent). Such results are reasonable because most people in these age groups are working people.

TABLE 1 Distributions (Percent) of Responses to Questions on Attitudes and Perceptions

Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. For my typical trip using the Borman Expressway, I am familiar with at least one other alternative route besides the Borman Expressway.	4.3	4.1	0.4	36.8	54.4
2. I often change my planned route while driving.	12.2	26.9	3.7	29.9	27.3
3. I am willing to divert to alternative routes to avoid traffic delays/congestion.	1.8	3.5	2.0	37.9	54.8
4. I frequently listen to radio traffic reports (RTR) or take notice of changeable message signs (CMS).	7.5	19.6	2.9	40.3	29.7
5. RTR or CMS usually provide information useful to me.	6.9	11.0	5.9	49.3	26.9
6. I often change my route in response to RTR or CMS.	9.4	28.5	4.9	36.4	20.8
7. RTR or CMS do not provide any relevant information.	30.7	51.1	6.9	8.2	3.1

TABLE 2 Route Diversion Behavior in Response to Five Hypothetical Scenario Questions

Scenario	Respondent Who Indicated a Preference for Route Diversion (%)
Qualitative Information	
1. Congestion is reported by RTR or CMS but no information is conveyed concerning expected delay time or possible alternative routes.	59.7
Quantitative Information	
2. Congestion is reported by RTR or CMS and information is given regarding the expected delay time, but no information regarding alternative routes is conveyed.	71.3
3. Congestion is reported by RTR or CMS and the information conveyed includes the expected delay time and specific instruction on the direction of your best alternative route.	86.8
4. Congestion is reported by RTR or CMS and the information conveyed includes the expected delay time, specific instruction on the direction of your best alternative route, and travel time on your best alternative route.	90.8
Prescriptive Information	
5. Congestion is reported, and RTR or CMS urges you to take your best alternative route.	94.1

LATENT VARIABLE MODELING

Latent variable models have been used in the social and behavioral sciences for many years. Recently, researchers from other disciplines such as economics and transportation have also used the concepts of latent variables. Ben-Akiva et al. proposed an analytical framework for incorporating psychometric data in the modeling of travel decisions (*13*). Figure 1 presents the framework used in the present study. In Figure 1 latent variables are those terms inside the ellipses, whereas the measurable (manifest) variables are inside the rectangles. According to Figure 1 drivers' preferences are influenced by two major components: (a) manifest variables that include socioeconomic characteristics and traffic information and (b) latent variables that include attitudes and perceptions. Since attitudes and perceptions cannot be measured directly, attitudinal indicators and perceptual indicators (i.e., Statements 1 to 7 from Table 1) were used to measure drivers' attitudes and perceptions. The present study used the framework in Figure 1 to identify the latent variables that influence drivers' route diversion intentions. First, the methodology used for the analysis of latent variables will be presented. Then, the results of the analysis are described.

TABLE 3 Socioeconomic Characteristic Distributions of Respondents

Classification of Socioeconomic Characteristics	Distribution (%)
Age Groups	
Less than 20 years old	2.1
20 ~ 29 years old	24.6
30 ~ 39 years old	28.5
40 ~ 49 years old	21.8
50 ~ 65 years old	16.9
Greater than 65 years old	6.1
Marital Status	
Single	38.3
Married	61.7
Gender	
Male	56.2
Female	43.8

Methodology

The analysis of latent variables for the present study was accomplished by using the LISREL model. The LISREL model consists of two parts: structural equations and measurement equations.

Structural equations specify the relationships between the latent variables. For the purpose of the present study the structural equation specifies the relationship between the unobservable factors that influence route diversion propensity. According to Everitt (*16*) a structural equation that relates two types of latent variables, dependent and explanatory, can be expressed as

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (1)$$

where

$\eta' = [\eta_1, \ldots, \eta_m]$, a vector of dependent latent variables,
$\xi' = [\xi_1, \ldots, \xi_n]$, a vector of explanatory latent variables,
$\zeta' = [\zeta_1, \ldots, \zeta_m]$, a vector of residuals representing both errors in equations and random disturbance terms,
B = the matrix that contains regression weights for predicting η's from other η's, and
Γ = the matrix that contains regression weights for predicting η's from ξ's.

The direct causal effects of η variables on other η variables are represented by the elements of B; hence, the diagonal elements of B are

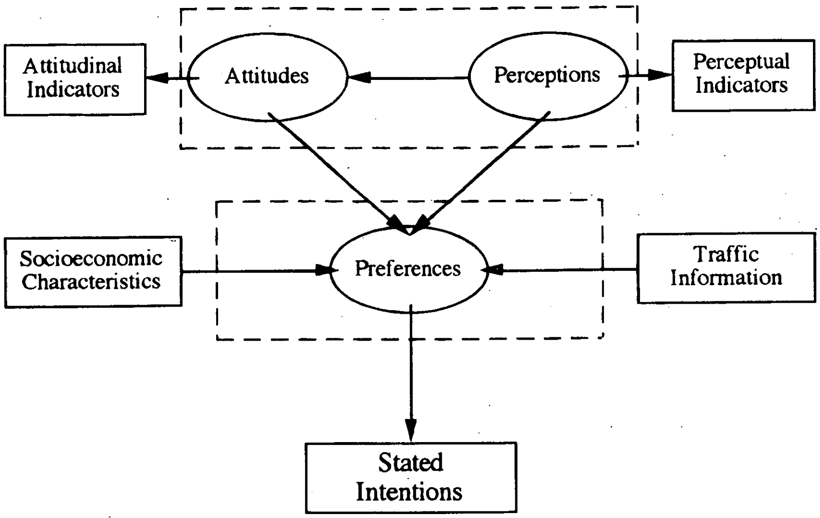

FIGURE 1 Framework for analysis of drivers' stated route diversion intentions.

zero. Similarly, the elements of Γ represent the direct causal effects of ξ variables on η variables. ζ and ξ are assumed to be uncorrelated.

Measurement equations specify how the latent variables relate to the observed (manifest) variables. Two sets of observed variables correspond to the two types of latent variables mentioned earlier: $y' = [y_1, \ldots, y_q]$ and $x' = [x_1, \ldots, x_p]$. The y variables are regarded as the indicators for η, the dependent latent variables. The indicators of the explanatory latent variables, ξ, are the x variables. Hence, the measurement part of the LISREL model that relates the manifest and latent variables can be written as

$$y = \Lambda_y \eta + \epsilon \tag{2}$$

and

$$x = \Lambda_x \xi + \delta \tag{3}$$

where

Λ_y = the matrix that contains regression weights of y on η, $(q \times m)$,
Λ_x = the matrix that contains regression weights of x on ξ, $(p \times n)$, and
ϵ and δ = vectors of error terms corresponding to y and x, respectively.

The methodology discussed in this section is used to analyze the data and identify the relevant latent variables. It is important to keep in mind that the LISREL model assumes that the manifest variables are independent of one another given the values of the latent variables. This assumption is termed *conditional independence*, and it implies that the observed relationships between the manifest variables are produced by the latent variables.

Discussion of Results and Results of LISREL Model

Survey participants' responses from the seven questions on attitudes and perceptions presented in Table 1 were used to identify the latent variables. It was hypothesized that the latent aspects of drivers' route diversion propensities can be represented by two latent factors: (a) drivers' attitudes toward route diversion (denoted η_1) and (b) drivers' perceptions of the reliability of traffic information (denoted η_2). Hence, the structural equation can be expressed as

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0 & \beta_{12} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} \tag{4}$$

where

$\eta' = [\eta_1, \eta_2]$, the vector of dependent latent variables,
$\zeta' = [\zeta_1, \zeta_2]$, the vector of residuals, and
β_{12} = the direct effect of η_2 on η_1.

The measurement equation for the present study has seven indicators for the two latent variables that were identified. These seven indicators correspond exactly to the seven statements described in Table 1; thus, the first indicator (denoted y_1) corresponds to Statement 1, the second indicator (denoted y_2) corresponds to Statement 2, and so forth. The measurement equation is expressed as

$$\begin{vmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \end{vmatrix} = \begin{vmatrix} \lambda_{11} & 0 \\ 1 & 0 \\ \lambda_{31} & 0 \\ \lambda_{41} & \lambda_{42} \\ 0 & 1 \\ \lambda_{61} & \lambda_{62} \\ 0 & \lambda_{72} \end{vmatrix} \begin{vmatrix} \eta_1 \\ \eta_2 \end{vmatrix} + \begin{vmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ \epsilon_5 \\ \epsilon_6 \\ \epsilon_7 \end{vmatrix} \tag{5}$$

where

$y_1, \ldots, y_7$ = indicators for η_1 and η_2,
$\lambda_{11}, \ldots, \lambda_{72}$ = regression weights of the indicators on η_1 and η_2, and
$\epsilon_1, \ldots, \epsilon_7$ = error terms.

In the Λ_y matrix from Equation 5, λ_{21} and λ_{52} have been set equal to 1 to normalize the scale of η_1 and η_2. Also noted from Equation 5, several elements of the Λ_y matrix were set equal to zero to denote that some indicators do not load onto a particular latent variable. For example, λ_{12} equal to zero means that the first indicator (i.e., Statement 1, For my typical trip using the Borman Expressway, I am familiar with at least one other alternative route besides the Borman Expressway) is not an indicator of a driver's perceptions of information reliability (i.e., η_2). It is also evident from Equation 5 that the fourth indicator (i.e., Statement 4) and the sixth indicator (i.e., Statement 6) extend over both latent variables, and thus, these two indicators were loaded on both η_1 and η_2. This overlap implies that these indicators are related to both latent variables, which is established by the results presented in Table 4.

Examining the results in Table 4, Indicators 1, 2, and 3 (i.e., λ_{11}, λ_{21}, and λ_{31}, respectively) can be classified as attitudinal indicators since these three indicators show a significant relationship to η_1, drivers' attitudes toward route diversion: they have high coefficients and *t*-statistic values. Similarly, indicators 4, 5, 6, and 7 (i.e., λ_{42}, λ_{52}, λ_{62}, and λ_{72}, respectively) were classified as perceptual indicators because they have high coefficients related to η_2, drivers' perceptions of information reliability. Furthermore, Indicators 4 and 6 also have a noticeable relationship to η_1, as discussed earlier.

The element of matrix B, β_{12}, represents the direct causal effects of η_2 on η_1. Therefore, a positive β_{12} value indicates that a driver who has a good perception of traffic information provided by RTRs and CMSs is likely to have a positive attitude toward route diversion. Such a finding is reasonable and expected. Also shown in Table 4 is the chi-square value for the null hypothesis that the predicted covariance matrix of the *y* variables is equal to the observed covariance matrix of the *y* variables. This statistic equals 15.93, which is less than the 95th percentile of the chi-square distribution with 11 degrees of freedom, 19.68. This suggests that the LISREL model used here does provide an adequate fit for the data.

Finally, the estimated values of the two latent variables, known as factor scores, were obtained by using the LISREL model. Every observation collected for the study has its corresponding factor scores, or $\eta_{1,i}$ and $\eta_{2,i}$, where i is equal to 1, . . . , 491. These factor scores are used in the following section to determine the factors that influence drivers' stated route diversion propensities by using discrete choice models.

TABLE 4 Estimation Results for LISREL Model

Parameter	Estimated Coefficient	t-Statistic
β_{12}	0.3143	4.6004
λ_{11}	0.6570	7.3781
λ_{31}	0.4604	6.4173
λ_{41}	0.1123	1.7397
λ_{42}	0.8832	14.7491
λ_{61}	0.3521	5.1483
λ_{62}	0.6950	12.0282
λ_{72}	-0.6512	-14.3891
Summary Statistics:		
No. of Observations = 491		
Degree of Freedom = 11		
Chi-Square Value = 15.93		

BINARY CHOICE MODEL

Methodology

The five hypothetical scenario questions (Table 2) in the survey that were presented to the respondents to explore drivers' stated diversion propensities required simple binary responses of yes or no. Since the choice set in this situation contains exactly two choices, binary choice modeling is the appropriate analysis tool to be used. For the purpose of the present study a binary logit model is used.

The model can be represented by the following equation:

$$U = \alpha p + \beta q + \gamma\eta + \nu$$

$$U^* = \begin{cases} 1 \text{ if } U \geq 0 \\ 0 \text{ otherwise} \end{cases} \tag{6}$$

where

U = unobserved variable representing a respondent's propensity to divert,
U^* = observed choice (1 if the respondent diverts to an alternative route and 0 otherwise);
p = vector of dummy variables that represents various types of information provided to drivers, in this case, the five hypothetical scenarios described in Table 2;
α = coefficient vector corresponding to p;
q = vector of manifest variables that influence choices, which includes the travel and socioeconomic characteristics of respondents;
β = coefficient vector corresponding to q;
η = vector of latent variables that influence route diversion decision, in this case, values of $\eta_{1,i}$ and $\eta_{2,i}$ obtained from the LISREL model;
γ = coefficient vector corresponding to η; and
ν = error term.

The αp portion of Equation 6 can be rewritten as

$$\alpha p = \alpha_0 + \alpha_1 p_1 + \alpha_2 p_2 + \alpha_3 p_3 + \alpha_4 p_4 \tag{7}$$

where

α_0 = alternative specific constant,
p_1 to p_4 = dummy variables corresponding to Scenarios 2 to 5 in Table 2, respectively, and
α_1 to α_4 = coefficient vector corresponding to p_1 to p_4, respectively.

To better explore the effects of different types of information and other factors on commuters' stated route diversion intentions, respondents' stated preferences to the five hypothetical scenarios described in Table 2 were pooled to produce a data set of 2,455 observations.

Estimation Results for Binary Logit Model

The results of the estimation obtained by using the binary logit model are presented in Table 5. The estimated coefficient for the constant term is negative according to the results presented in Table

TABLE 5 Estimation Results for Binary Logit Model

Variable Name	Estimated Coefficient	t-Statistic
constant	-3.5599	-7.5442
dummy 1	0.7454	4.5482
dummy 2	2.1209	10.6283
dummy 3	2.6841	11.9990
dummy 4	3.3055	12.7843
time	-0.5640	-7.7865
age	0.1925	1.2133
marital status	-0.1684	-1.1779
attitude	0.5426	8.8990
perception	0.8142	14.0592
Summary Statistics:		
No. of Observations = 2455		
L(O) = -1701.7		
L(B) = -789.39		
Rho-Square = 0.536		

5. This indicates that drivers will not likely divert to alternative routes when only qualitative information (i.e., Scenario 1 in Table 2) is provided by RTRs and CMSs. Route diversion rates of drivers will increase as the information provided by RTRs and CMSs changes to quantitative information (i.e., Scenarios 2, 3, and 4 in Table 2) and the amount of information provided contains increasingly more detail, especially relating to the alternative routes. Such a conclusion is inferred on the basis of estimated coefficients of the variables Dummy 1, Dummy 2, and Dummy 3 since they correspond to Scenarios 2, 3, and 4, in Table 2, respectively. The values of the estimated coefficients for these three variables increase from Dummy 1 through Dummy 3. The variable Dummy 4 indicates prescriptive information (i.e., Scenario 5 in Table 2); it has the highest value of all dummy variables. Thus, the route diversion rate increases even further when prescriptive information is provided. All of these variables are statistically significant; thus, these variables play an important role in explaining drivers' route diversion behaviors.

The time variable indicates the total delay time a driver can tolerate before considering using an alternative route. The estimated coefficients for the time variable in Table 4 have negative values, which means that the longer the delay a driver can tolerate, the more likely he or she is not to divert to alternative routes. Such a finding is expected.

The variable age represents the ages of the respondents who participated in the phone survey. According to the results given in Table 5, it can be concluded that young drivers are more likely to divert their routes. Even though the value of the *t*-statistic for this variable is relatively low, this variable was kept in the final model because it has been recognized as an important determinant of route diversion behavior, and the finding here is consistent with the result reported by other researchers. The estimated coefficient of the variable marital status is negative; therefore, it can be inferred that single drivers are more likely to divert to alternative routes to avoid traffic congestion. Other researchers reported a similar finding on the effects of marital status on route diversion. The *t*-statistic for this variable is also relatively low.

The variables attitude and perception are the latent variables identified earlier by using the LISREL model. The variable attitude characterizes drivers' attitudes toward route diversion. According to the estimated coefficient listed in Table 5, commuters are more likely to divert their routes to avoid traffic delays and congestion when they have positive attitudes toward route diversion. The variable perception captures drivers' perceptions of the reliability of traffic information provided by RTRs and CMSs. The estimated coefficient for this variable is positive as well; thus, drivers who have good perceptions of RTRs and CMSs would more likely follow the recommendations provided. It should be noted that the *t*-statistic values reported in Table 5 for these two variables are overstated because the predicted values of the latent variables were used as explanatory variables (*17*).

Finally, it is recognized that the estimation results presented in Table 5 may be inconsistent because a sequential estimation approach instead of a joint estimation of the LISREL model and the discrete choice model was used for this model system. The sequential estimation approach results in inconsistent parameter estimates, given that the discrete choice model is a nonlinear model (*10*). Despite this potential inconsistency, the major contribution of the present study should be recognized. It identified two latent variables that are very important in determining drivers' route diversion behaviors. As shown in the estimation results of the binary logit model, the addition of latent variables provided a better understanding of drivers' decision-making process in regard to route diversion.

CONCLUSION

The effects of drivers' travel and socioeconomic characteristics, attitudes toward route diversion, perceptions of the reliability of traffic information provided, and the types of information provided by RTRs and CMSs on their willingness to divert their routes were investigated.

The results indicated that drivers who have low tolerances toward traffic delays, have positive attitudes toward route diversion, and perceive RTRs and CMSs to be reliable sources of information are more likely to divert from their usual routes in cases of traffic incidents. In addition, various types of information conveyed through RTRs and CMSs greatly influence drivers' route diversion intentions. Drivers' willingness to divert their routes increased as the amount of information provided by RTRs and CMSs became increasingly more elaborate. It was found that drivers are most likely to divert their routes when elaborate quantitative information (i.e., Scenario 4 in Table 2) or prescriptive information (i.e., Scenario 5 in Table 2) is conveyed through RTRs and CMSs. These results are consistent with findings reported by other researchers.

The findings from the present study could be used to form useful policy guidelines in developing ATISs. For example, ATISs can effectively influence drivers' route diversion decisions by providing detailed descriptions of alternative routes on the network or by conveying quantitative rather than qualitative information.

ACKNOWLEDGMENTS

The research was partly supported by Hughes Aircraft Co. through a research grant to Purdue University. The authors benefited from the comments of three anonymous reviewers.

REFERENCES

1. Heathington, K., R. Worrall, and G. Hoff. Attitudes and Behavior of Drivers Regarding Route Diversion. In *Highway Research Record 363*, HRB, National Research Council, Washington, D.C., 1971, pp. 18–23.
2. Huchingson, R. D., and C. Dudek. Delay, Time Saved, and Travel Time Information for Freeway Traffic Management. In *Transportation Research Record 722*, TRB, National Research Council, Washington, D.C., 1979, pp. 36–39.
3. Dudek, C., R. Huchingson, and R. Brackett. Studies of Highway Advisory Radio Messages for Route Diversion. In *Transportation Research Record 904*, TRB, National Research Council, Washington, D.C., 1983, pp. 4–9.
4. Mannering, F. L. Poisson Analysis of Commuter Flexibility in Changing Routes and Departure Times. *Transportation Research*, Part B, Vol. 23B, 1989, pp. 53–60.
5. Mahmassani, H. S., C. Caplice, and C. Walton. Characteristics of Urban Commuter Behavior: Switching Propensity and Use of Information. In *Transportation Research Record 1285*, TRB, National Research Council, Washington, D.C., 1990, pp. 57–69.
6. Allen, R. W., D. Ziedman, T. J. Rosenthal, A. C. Stein, J. F. Torres, and A. Halati. Laboratory Assessment of Driver Route Diversion in Response to In-Vehicle Navigation and Motorist Information Systems. In *Transportation Research Record 1306*, TRB, National Research Council, Washington, D.C., 1991, pp. 82–91.
7. Khattak, A. J., F. S. Koppelman, and J. L. Schofer. Stated Preferences for Investigating Commuters' Diversion Propensity. *Transportation*, Vol. 20, No. 2, 1993, pp. 107–127.
8. Khattak, A. J., J. L. Schofer, and F. S. Koppelman. Commuters' Enroute Diversion and Return Decisions: Analysis and Implications for Advanced Traveler Information Systems. *Transportation Research*, Part A, Vol. 27A, No. 2, 1993, pp. 101–111.
9. Khattak, A. J., A. Kanafani, and E. Le Colletter. Stated and Reported Route Diversion Behavior: Implications on the Benefits of ATIS. Presented at 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
10. Abdel-Aty, M. A., K. M. Vaughn, R. Kitamura, P. P. Jovanis, and F. L. Mannering. Models of Commuters' Information Use and Route Choice: Initial Results Based on a Southern California Commuter Route Choice Survey. Presented at 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
11. Jou, R. C., and H. S. Mahmassani. Comparability and Transferability of Commuter Behavior Characteristics Between Cities: Departure Time and Switching Decision. Presented at 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
12. Adler, J. L., T. F. Golob, and M. G. McNally. A Structural Model with Discrete Choice Variables for Predicting Enroute Behavior Under ATIS. Presented at 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
13. Ben-Akiva, M., T. Morikawa, and F. Shiroishi. Reliability of Stated Preference Techniques. *Proc., 5th World Conference on Transportation Research*, Yokohama, Japan, 1989.
14. Ben-Akiva, M., and T. Morikawa. Estimation of Travel Demand Models from Multiple Data Sources. *Proc., 11th International Symposium on Transportation and Traffic Theory*, Yokohama, Japan, 1990.
15. Wardman, M. Stated Preference Methods and Travel Demand Forecasting: An Examination of the Scale Factor Problem. *Transportation Research,* Part A, Vol. 25A, Nos. 2/3, 1991, pp. 79–89.
16. Everitt, B. S. *An Introduction to Latent Variable Models.* Monographs on Statistics and Applied Probability. Chapman & Hall, New York, 1984.
17. Ben-Akiva, M., and S. R. Lerman. *Discrete Choice Analysis: Theory and Application to Travel Demand.* MIT Press, Cambridge, Mass., 1985.

Publication of this paper sponsored by Committee on User Information Systems.