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Route choice behavior of freeway travelers under real-time traffic information provision–application of the best route and the habitual route choice mechanisms

By
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The route choice behaviour on freeways between Taipei and Taichung in Taiwan under real-time traffic information provision is investigated. Two types of route choice mechanisms (the best-route and habitual-route) are analysed using ordered probit models to identify the major influences on freeway travellers’ route choice behaviour. The level of service associated with each route is defined as a generalized cost saving and specified non-linearly with a spline-like threshold inherent to travellers. The marginal (dis)utility thresholds in the ‘best’ and ‘habitual’ behaviour models are identified through a grid search assessed on overall goodness of fit. The findings from this study provide a better understanding of the effects of Advanced Traveller Information Systems on drivers’ route choice behaviour, and a useful reference when planning for the provision of real-time information for drivers.

**KEY WORDS:** Best route, habitual route, generalized cost savings, thresholds

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1. Introduction

Many studies have indicated that drivers’ route switching behavior could be influenced by the provision of real-time traffic information through Advanced Traveler Information Systems (ATIS) prior to their departure or while en route. With the provision of information to travelers, not only could travel time be reduced by driving on higher-service routes, but also the anxiety caused by recurrent and non-recurrent congestion could be reduced or mitigated. As a result, the quality of the transportation system could be greatly improved (Adler et al., 1999; Jou, 2001; Jou et al., 2004; Srinivasan and Krishnamurthy, 2004). The traffic impacts due to incidents could also be significantly alleviated if relevant traffic information ahead of drivers is provided in real time. (Emmerink et al., 1995a, 1996b; Al-Deek et al., 1998; Levinson, 2003). This may occur on freeway and tolled routes. The toll stations are evenly installed every 30 kilometers on the existing freeways, and travelers can enter and exit the freeways without being tolled. Electronic toll collection (ETC) is planned for introduction around 2010 as a way of eliminating local trips without being tolled, further adding to the performance of the network. The proposed toll regime under ETC (toll stations are installed at the entrances of freeways, i.e., entering ramps) will be charged on the exact distance traveled. Under these conditions drivers not only would consider travel times, but would take toll costs (calculated from ETC) into consideration when they choose routes on freeways, trading off routes on the basis of the generalized cost of travel.

A number of relevant studies, ranging from laboratory controlled experiments to field observations, show that drivers’ route choice decisions could be heavily influenced by the provision of real-time traffic information. Gender and age, and travel time have been shown to be the significant variables that affect travelers’ route choices (Benson, 1996; Abdel-Aty, 1997; Ramsay et al., 1997; Mahmassani and Jou, 1998; Chen et al., 1999; Hato, 1999; Mahmassani and Liu, 1999; Lai and Wong, 2000; Jou, 2001; Adler, 2001; Dia, 2002; Chatterjee, 2002; Srinivasan and Mahmassani, 2003; Jou et al., 2004; Jou et al., 2005). In addition, drivers also tend to be more sensitive to the perceived loss of delay (i.e., more prone to switch routes) in a situation where the actual delay is greater than the one shown on variable message signs (VMS) (Wardman, 1997).

While most research on route choice behavior has applied the best-route mechanism (in terms of travel time, travel monetary cost, or generalized travel cost), the habitual-route mechanism, has also been shown to be another important and realistic rule that could capture the effects of accumulated experiences on route choice behavior (Chen et al., 2001; Bogers et al., 2005; Zhiyong and Karthil, 2005). It is believed that some travelers are likely to travel by their habitual routes rather than on routes with the maximum utility. It was also shown that more incentive is needed to alter travelers’ habitual behavior since it is an inertia formed by previous experiences (Bamberg and Schmidt, 2003; Hendrickx, Jager, Steg, 2003).

The route choice behavior on freeways between Taipei and Taichung in Taiwan under real-time traffic information provision is investigated in this study. Two types of route choice mechanisms (the best-route and habitual-route) are analyzed by using ordered probit models to identify the influencing effects on freeway travelers’ route choice behavior. Generalized cost saving (GCS) is specified non-linearly with a spline-like threshold inherent to travelers. The marginal (dis)utility thresholds in the ‘best’ and ‘habitual’
behavior models are identified through a grid search assessed on overall goodness of fit. The findings from this study provide a better understanding of the effects of ATIS on drivers’ route choice behavior, and a useful reference when planning for the provision of real-time information for drivers in the presence of ETC.

The paper is structured as follows. The modeling theory and framework will be presented in Section 2. The characteristics of the data will be discussed in Section 3, followed by a presentation of model estimation results. The last section concludes the paper and recommends future research directions.

2. Methodology

An ordered probit model is used to investigate the effects of real time traffic information on freeway travelers’ route choice behavior. Two mechanisms that govern travelers’ route choice behavior, the best route and the habitual route, are defined with the incorporation of GCS thresholds. These two mechanisms are defined as follows:

1. the best route: the road with the least generalized cost in the vicinity of the study area (Fig. 1).

2. the habitual route: the road that the traveler had traveled on most frequently during the recent past. The habitual route of the respondent is identified from field surveys.

The generalized cost for each route is calculated as:

\[ GC_k = \theta T_k^i + \psi_k^i \]

Where \( \theta \) is the value of travel time savings (VTTS), set at NT$1.66/min (MOTC, 1996), \( T_k^i \) is the travel time in minutes, and \( \psi_k^i \) is the ETC charges on route \( k \) and time \( t \).

2.1 The best route model (B_model)

We define \( GC_{cr} \) as the generalized cost of the current route and \( GC_{br} \) as the generalized cost of the best route under real-time traffic information provision. The generalized cost saving based on the best route can then be defined as \( GCS_{br} = GC_{cr} - GC_{br} \) (where \( GC_{cr} \) is greater than or equal to \( GC_{br} \)). The best route model can be defined as Eq. (1) in an ordered probit framework.

\[
y^* = \alpha Z_i + \beta X_i + \gamma_1 GCS_1 + \gamma_2 GCS_2 + \epsilon_i, \quad \text{and} \quad y_i = \begin{cases} 0, & \text{if} \quad -\infty < y^* \leq \mu_0, \\ 1, & \text{if} \quad \mu_0 < y^* \leq \mu_1, \\ 2, & \text{if} \quad \mu_1 < y^* \leq \mu_2, \\ 3, & \text{if} \quad \mu_2 < y^* \leq \infty \end{cases}
\]

(1)
Where \( y_i \) represents the number of times that traveler \( i \) travels the best route from Taichung to Taipei in Taiwan, i.e., there are at most four occasions in which an individual can travel the best route (please refer to Fig. 1). The values of \( y_i \) are defined to vary from 0 to 3 \((0,1,2,3)\). For identification, \( \mu_0 = 0 \), hence, only \( \mu_1 \) and \( \mu_2 \) are estimated (Greene, 2002). \( Z_i \) is a vector of socio-economic characteristics of traveler \( i \); \( X_i \) is a vector of travel characteristics; \( \alpha_1, \beta_1, \gamma_{11}, \gamma_{12} \) are the parameters to be estimated; and \( \epsilon_i \) is the error term normally distributed as \( \mathcal{N}(0,1) \). \( GCS_1 \) and \( GCS_2 \) in Eq. (1) are defined as Eqs. (2) and (3).

\[
GCS_1 = \begin{cases} 
GCS_{br} - \text{threshold}_{br}, & \text{if } GCS_{br} \geq \text{threshold}_{br} \\
0, & \text{otherwise}
\end{cases} \tag{2}
\]

\[
GCS_2 = \begin{cases} 
\text{threshold}_{br} - GCS_{br}, & \text{if } GCS_{br} < \text{threshold}_{br} \\
0, & \text{otherwise}
\end{cases} \tag{3}
\]

where \( \text{threshold}_{br} \) represents the threshold of a traveler’s \( GCS_{br} \) for the best route. Theoretically, the traveler would tend to choose the best route as his/her \( GCS_{br} \) increases, all other things being equal. In reality there exists one threshold of \( GCS_{br} \) for the traveler and they would be likely to choose the best route when their \( GCS_{br} \) is greater than this threshold; conversely, the traveler would tend to stay with their current route when the \( GCS_{br} \) is smaller than this threshold. There are many reasons for such a choice outcome, linked to transaction costs in searching to acquire information and comparing, perceptual differences and effort.

### 2.2 The habitual route model

An habitual route is defined as the route that the traveler travels most frequently in the recent past. \( GC_{hr} \) represents the generalized cost of the habitual route. The magnitude of the relationship between \( GC_{cr} \) and \( GC_{hr} \) is not positive, unlike the best route model.

Two situations can be further defined: (A) \( GC_{cr} \geq GC_{hr} \); (B) \( GC_{cr} < GC_{hr} \). These two situations are discussed as follows.

(A) the habitual route model A (H_model_A): if the generalized cost of the current route is greater than the habitual route \( (GC_{cr} \geq GC_{hr}) \), then we define the generalized cost saving of the habitual route as \( GCS_{hr} = GC_{cr} - GC_{hr} \). The habitual route model A can be defined as Eq. (4) in an ordered probit framework.
\[ y^* = \alpha J_i + \beta X_i + \gamma_{21} GCS_3 + \gamma_{22} GCS_4 + \delta J_i \]  

(4)

where \( Z_i \) and \( X_i \) are defined as Eq. (1), \( \alpha J, \beta X, \gamma_{21}, \gamma_{22} \) are the parameters to be estimated and \( \delta J_i \) is the error term normally distributed as \( N(0,1) \). \( GCS_3 \) and \( GCS_4 \) in Eq. (4) are defined as Eqs. (5) and (6).

\[ GCS_3 = \begin{cases} 
GCS_{hr} - \text{threshold}_{hr}, & \text{if } GCS_{hr} \geq \text{threshold}_{hr} \\
0, & \text{otherwise} 
\end{cases} \]  

(5)

\[ GCS_4 = \begin{cases} 
\text{threshold}_{hr} - GCS_{hr}, & \text{if } GCS_{hr} < \text{threshold}_{hr} \\
0, & \text{otherwise} 
\end{cases} \]  

(6)

where \( \text{threshold}_{hr} \) represents the threshold of a traveler’s \( GCS_{hr} \) under the habitual route mechanism. Theoretically, the traveler would tend to choose the habitual route as his/her \( GCS_{hr} \) increases. Given that in reality there exists one threshold of \( GCS_{hr} \) for the traveler, they would likely choose the habitual route when \( GCS_{hr} \) is greater than this threshold, all other things being equal; but tend to stay on the current route when \( GCS_{hr} \) is smaller than this threshold, for the same reasons given above for the best model.

(B) the habitual route model B (H_model_B): if the generalized cost of the habitual route is greater than the current route \((GC_{hr} < GC_{cr})\), then we define the generalized cost saving of the current route as \( GC_{cr} = GC_{hr} - GC_{cr} \). The habitual route model B can be defined as Equation (7) in an ordered probit framework.

\[ y^* = \alpha J_i + \beta X_i + \gamma_{31} GCS_5 + \gamma_{32} GCS_6 + \eta_i \]  

(7)

where \( \alpha J, \beta X, \gamma_{31}, \gamma_{32} \) are parameters to be estimated and \( \eta_i \) is the error term normally distributed with \( N(0,1) \). \( GCS_5 \) and \( GCS_6 \) in Eq. (7) are defined as Eqs. (8) and (9).

\[ GCS_5 = \begin{cases} 
GCS_{cr} - \text{threshold}_{cr}, & \text{if } GCS_{cr} \geq \text{threshold}_{cr} \\
0, & \text{otherwise} 
\end{cases} \]  

(8)

\[ GCS_6 = \begin{cases} 
\text{threshold}_{cr} - GCS_{cr}, & \text{if } GCS_{cr} < \text{threshold}_{cr} \\
0, & \text{otherwise} 
\end{cases} \]  

(9)

where \( \text{threshold}_{cr} \) represents the threshold of a traveler’s \( GCS_{cr} \) on the current route. Theoretically, the traveler would tend to choose the current route when \( GCS_{cr} \) increases. However in reality there exists one threshold of \( GCS_{cr} \) with the traveler most likely to choose the current route when \( GCS_{cr} \) is greater than this threshold, other other things held constant; and conversely, they would tend to stay on the habitual route when \( GCS_{cr} \) is smaller than this threshold.
In all three models, the threshold is identified through a grid search method over a range from 0 to 60, selecting the best fit level based on overall goodness-of-fit and asymptotically efficient parameter estimate.

### 2.3 Ordered probit models

Eqs. (1), (4) and (7) can be modeled in an ordered probit form as Eqs. (10) - (13).

\[
p(y_i = 0) = F\left(-\beta'X_i\right) \quad (10)
\]

\[
p(y_i = 1) = \left\{ F\left(\mu_i - \beta'X_i\right) - F\left(-\beta'X_i\right) \right\} \quad (11)
\]

\[
p(y_i = 2) = \left\{ F\left(\mu_i - \beta'X_i\right) - F\left(\mu_i - \beta'X_i\right) \right\} \quad (12)
\]

\[
p(y_i = 3) = \{1 - F\left(\mu_i - \beta'X_i\right)\} \quad (13)
\]

Estimation results of ordered probit models provide estimates of the thresholds (\(\mu\)). A test can be performed to investigate the appropriateness of the ordered probit models specified herein. The thresholds (\(\mu\)) are assumed to be normally distributed with means, variances and covariances, estimated from the models. The difference of two consecutive stochastic variables (thresholds) \(\mu_j - \mu_{j-1}\) can be defined as follows.

\[
\mu_j - \mu_{j-1} \sim N(\mu^*_j - \mu^*_{j-1}, \sigma^2_j - \sigma^2_{j-1} + 2\sigma^*_j, \sigma^*_{j,j-1}) \quad (14)
\]

where an asterisk denotes an estimated value, \(\sigma^2\) denotes a variance and \(\sigma_{j,k}\) denotes the covariance between \(\mu_j\) and \(\mu_k\). Using the approximation, the probability when the ordering is appropriate is \(P(\mu_j - \mu_{j-1} \leq 0)\). The ordering in terms of thresholds (\(\mu\)) is appropriate if the probability is small. Otherwise, the applicability of ordered models can be questioned.

### 3. Data collection and analysis

To evaluate the effectiveness of the model framework, stated preference data for route switching behavior in response to the provision of real-time traffic information of freeway travelers from Taichung to Taiwan was obtained. Socio-economic and trip characteristics collected in the survey, were augmented by hypothetical trip scenarios to identify travelers’ route choice behavior under real-time traffic information. The study area and survey methodology are presented in Section 3.1, followed by the stated preference experiment and analysis of survey data in Sections 3.2-3.5.
3.1 Study area and survey methodology

In the study area, the freeways from Taichung to Taipei were segregated into four segments, as shown in Fig. 1. There are six decision points (Taichung area, A-E) where drivers have the opportunity to choose an alternative route. However, there are only four decision points (or switching points indicated in Figure 1) used in the experimental design. The numbers next to each route in Figure 1 represent the length in kilometers. There are two freeways, Freeway No.2 (②) and Freeway No.4 (④), connecting Freeway No.1 (①) and Freeway No.3(③).

The face to face (pencil and paper) interviews were conducted at freeway rest stations along the study area in a two-week period around the Chinese New Year holidays in 2004. The locations of interviews were distributed between Freeway No.1 and Freeway No.3. A total of 557 valid questionnaires were returned (in total 562 samples), a response rate of 99.11%. The interviewers explained the objective and the various questions to the respondents.

Fig. 1 The study area and route switching points
3.2 The stated preference experiment

There are four types of real time traffic information provided to the travelers in this study. They are: (1) qualitative information, (2) qualitative with guidance, (3) quantitative and (4) quantitative with guidance. In the experimental design, the total sample was divided into four groups, with each individual provided with four types of real traffic information at the switching points (as shown in Table 1). For example, the individuals in group one were provided qualitative information at switching point 1, qualitative with guidance information at switching point 2, quantitative information at switching point 3 and quantitative with guidance at switching point 4.

Table 1: Scenarios of real time traffic information provision at different switching points for different groups

<table>
<thead>
<tr>
<th>Switching points</th>
<th>Group one</th>
<th>Group two</th>
<th>Group three</th>
<th>Group four</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Taichung area)</td>
<td>Qualitative</td>
<td>quantitative/guidance</td>
<td>quantitative information</td>
<td>qualitative/guidance</td>
</tr>
<tr>
<td>2 (A and B)</td>
<td>qualitative/guidance</td>
<td>Qualitative</td>
<td>qualitative/guidance</td>
<td>quantitative</td>
</tr>
<tr>
<td>3 (C)</td>
<td>Quantitative</td>
<td>qualitative/guidance</td>
<td>qualitative</td>
<td>quantitative information</td>
</tr>
<tr>
<td>4 (D and E)</td>
<td>quantitative/guidance</td>
<td>Quantitative</td>
<td>qualitative/guidance</td>
<td>qualitative</td>
</tr>
</tbody>
</table>

In this experimental design, the individuals who had the same trips before are required to answer one questionnaire, and the sequential of types of information, provided at switching points, depends on which group they are randomly classified into (see Table 1 above, and an example of showcards in Appendix A). There are four attributes included in this experiment: the prediction error of traffic information, travel speed (time), travel cost and the guidance instruction, described as follows.

1. Prediction error of travel time, measured as:

Prediction error of travel time on route i
\[ \text{Prediction error of travel time on route i} = \frac{\text{travel time provided by VMS on route i-actual travel time on route i}}{\text{actual travel time on route i}} \times 100\% \]

There are six levels of this attribute, +30%, +20%, +10%, 0%, -10% and -20%. For example, 0% means there is no prediction error of VMS. It shall be noted that this attribute was only provided at switching points 2, 3, and 4 since we only provide the information after their travel on the previous route.

2. Travel speed has three levels: high, medium and low. Table 2 shows the respective levels on different Freeways (for qualitative and quantitative information). The calculation of travel time converted from travel speed is described in Appendix B.

3. Travel cost is measured by the actual distance traveled by each individual. The calculation of travel cost is described in Appendix C.
Table 2: Levels of speeds on different Freeways (qualitative and quantitative)

<table>
<thead>
<tr>
<th>Attribute levels</th>
<th>Freeway No.1</th>
<th>Freeway No.2</th>
<th>Freeway No.3</th>
<th>Freeway No.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>high smooth</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>90</td>
</tr>
<tr>
<td>medium normal</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>50</td>
</tr>
<tr>
<td>low congested</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

4. Guidance instruction has three levels: switch, recommend to switch and strongly recommend to switch. The main criterion to use for guidance is travel time, since travel distance lacks adequate variance. It also shall be noted that “switch” is provided when the levels of travel time of both routes are in the same category (such as low, low). “Recommend to switch” is provided when the levels of travel time of both routes are (high, medium) or (medium, low), and “strongly recommend to switch” is provided when the levels of travel time of both routes are (high, low).

This design specification gives $6 \times 3^2 \times 1 = 54$ scenarios in addition to the scenarios in guidance instruction for both routes (current and alternative) at each switching point. We randomly select one scenario for the traveler according to the sequence of Table 1.

### 3.3 Socio-economic characteristics

Table 3 summarises the socio-economic profile of the respondents. Most are male (85%) and the majority (40%) are between 31 and 40 years, followed by those between 18 and 30 (33%), with an average age of 35 years. 62% of the respondents are married. A large portion (27%) of the respondents are workmen (labourers) followed by commerce and service related industries (24% and 21%, respectively). The education level is mainly college and university (60%), followed by senior high school (31%). The average monthly personal income is mostly NT$ 40-60 thousand. Twenty percent of the respondents have a household income in the range NT$ 80-100 thousand, but most respondents are above NT$ 100 thousand. The average number of cars per household is 1.7 vehicles, averaging 0.9 vehicles per person, with an average household size of 4.5 persons.

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1 US$ is approximately 34.97 NT$
Table 3: Descriptive profile of socioeconomic characteristics (percentages in parentheses)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>471(85.2)</th>
<th>Education</th>
<th>Senior high</th>
<th>172(31.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>86(15.6)</td>
<td>University</td>
<td>334(60.4)</td>
<td>51(9.2)</td>
</tr>
<tr>
<td>Age</td>
<td>18-30</td>
<td>183(33.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>223(40.3)</td>
<td>Personal income</td>
<td>62(11.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>41-50</td>
<td>110(19.9)</td>
<td>(NT$ 10,000)</td>
<td>185(33.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>51-60</td>
<td>36(6.5)</td>
<td>dollars per</td>
<td>191(34.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Above 60</td>
<td>5(0.9)</td>
<td>month</td>
<td>63(11.4)</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>346(62.6)</td>
<td>8-10</td>
<td></td>
<td>31(5.6)</td>
<td></td>
</tr>
<tr>
<td>Occupation</td>
<td>Government employee</td>
<td>67(12.1)</td>
<td></td>
<td>Above 10</td>
<td>25(4.5)</td>
</tr>
<tr>
<td></td>
<td>Student</td>
<td>28(5.1)</td>
<td>Household</td>
<td>Below 2</td>
<td>3(0.5)</td>
</tr>
<tr>
<td></td>
<td>Commerce</td>
<td>132(23.9)</td>
<td>income</td>
<td>2-4</td>
<td>30(5.4)</td>
</tr>
<tr>
<td></td>
<td>Worker</td>
<td>151(27.3)</td>
<td>(NT$ 10,000)</td>
<td>4-6</td>
<td>91(16.5)</td>
</tr>
<tr>
<td></td>
<td>Service</td>
<td>118(21.3)</td>
<td>dollars per</td>
<td>6-8</td>
<td>109(19.7)</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>61(11)</td>
<td>month</td>
<td>8-10</td>
<td>112(20.3)</td>
</tr>
<tr>
<td>Ave. household car ownership</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave. person car ownership</td>
<td>0.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave. household size</td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave. members under 18</td>
<td>0.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samples</td>
<td>553(100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4 Travel characteristics

Table 4 shows the trip characteristics of the sample. 42% of the trips were mainly work related (either commuting or traveling as part of work), and 34% of the trips were leisure. In an actual trip, most drivers (82%) obtained real-time traffic information through traffic condition broadcast, followed by Variable Message Signs (18%). The low use level of VMS may be due to real-time traffic information not being sufficiently effective in Taiwan, neither the information is accurate nor relevant to traffic conditions. 47% of the drivers occasionally acquire real-time traffic information themselves, including drivers who obtained the real-time traffic information by themselves, either before or during their trips. On average, drivers travel on the freeways (including No. 1-4) 6.04 times per month.
Table 4: Descriptions of travel characteristics of respondents on freeways
(we asked “usually” situation instead of a recent trip) (percentages in parentheses)

<table>
<thead>
<tr>
<th>Items</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trip purpose</strong></td>
<td></td>
</tr>
<tr>
<td>Work-related</td>
<td>236(42.7)</td>
</tr>
<tr>
<td>Return home</td>
<td>67(12.1)</td>
</tr>
<tr>
<td>Leisure</td>
<td>190(34.4)</td>
</tr>
<tr>
<td>Visiting friends or relatives</td>
<td>47(8.5)</td>
</tr>
<tr>
<td>Shopping</td>
<td>8(1.4)</td>
</tr>
<tr>
<td>Others</td>
<td>9(1.6)</td>
</tr>
<tr>
<td><strong>Ways you actually access real time traffic information</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>53(9.6)</td>
</tr>
<tr>
<td>VMS</td>
<td>102(18.4)</td>
</tr>
<tr>
<td>Radio</td>
<td>457(82.6)</td>
</tr>
<tr>
<td>Internet</td>
<td>68(12.3)</td>
</tr>
<tr>
<td>Telephone</td>
<td>25(4.5)</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>11(2)</td>
</tr>
<tr>
<td>Others</td>
<td>14(2.5)</td>
</tr>
<tr>
<td><strong>Frequencies of accessing real time traffic information</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>54(9.8)</td>
</tr>
<tr>
<td>Once in a while</td>
<td>259(46.8)</td>
</tr>
<tr>
<td>Very frequent</td>
<td>123(22.2)</td>
</tr>
<tr>
<td>Every time</td>
<td>121(21.9)</td>
</tr>
<tr>
<td><strong>Average frequency of using freeways per month</strong></td>
<td>6.04</td>
</tr>
</tbody>
</table>

3.5 Route choice analysis (the experiment results)

The routes chosen by each traveler before and after the provision of real time traffic information in the SP experiment are shown in Table 5, which shows that prior to the provision of real-time traffic information the majority of travelers habitually chose Freeway No. 1, whereas there was a significant shift of travelers to Freeway No. 3 (with the exception of Freeway No. 4) after the provision of real-time information. It shall be noted that “before” means a traveler’s habitual routes, and “after” means the routes that the traveler chooses after the provision of real time traffic information. Moreover, a more equal distribution of the traffic volumes on the two freeways was observed. Therefore this shows that effective real-time traffic information can enhance the efficiency of roads in the network and enhance the quality of transportation. It was also observed that, as travelers get closer to the end of their trip (segment 4), less route switching occurred. This indicates that the indifference bands for route switching enlarge as travelers get closer to their destination and where greater motivation (more savings in the generalized travel cost) is needed to induce route switching. This also shows that in the absence of traffic incidences it may be more effective to provide real-time traffic information on the first half of the route, as shown in Table 5.
The chosen routes of travelers after the provision of real-time traffic information are shown in Table 6. The habitual route is defined as the most often used route taken by a traveler obtained from the survey. More than half of the travelers chose the best route. This shows that with traffic information, travelers tended to be willing to comply with the information. Fewer travelers switch to the best route while more stay on the habitual one on segment 4 due to habitual preferences.

The consistency of chosen routes and the best routes (the habitual routes) of travelers after the provision of real-time traffic information is summarized in Table 7. This consistency is defined as

\( \frac{1 - \frac{\text{travel time of best (habitual) routes}}{\text{travel time of chosen routes}}} \times 100\% \), i.e., the chosen routes are more likely to be the best (habitual) routes as the consistency value reduces in magnitude. The results indicate that under the best route mechanism, travelers are more likely to choose the best routes; while under the habitual route mechanism, travelers are more likely to stay on the habitual routes on segment 4 due to habitual preferences.
4. Model Estimation Results

As described in Section 2, three models, the best route model (B_model), the habitual route model A (H_model_A), and the habitual route B (H_model_B), are estimated and the results are presented in the following subsections.

4.1 The best route model (B_model)

The estimation results of B_model are presented in Table 8. It can be shown that the models with thresholds in the range of 10-30 outperform other models in terms of log-likelihood values and t-statistics. The model with threshold 10 has the best goodness-of-fit ($\rho^2 = 0.3824$). The positive coefficients of variables in the Table imply the tendency of choosing the best routes. The estimation results suggest that male drivers are more likely to choose the best routes; and the higher the level of car ownership, the more likely she/he would stay on their current routes (not necessarily the best routes), possibly because of a higher amount of travel experience delivering an acceptable level of service. However, when a household has more than 2 cars and the monthly income greater than 60 thousand NT dollars, the drivers are more likely to choose the best routes. This indicates that the effects of the value placed on time savings are greater than the travel experience, suggesting that the provision of real time traffic information would have a significant influence on travelers with higher values of time savings (for example, the trip purpose of commerce).
Table 8: The estimation results of the best route model (B_model)
(t statistics in parentheses)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Constant</td>
<td>1.342(3.96)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.261(1.78)</td>
</tr>
<tr>
<td>Individual car ownership</td>
<td>0.725(2.29)</td>
</tr>
<tr>
<td>Individual car ownership&gt;2 and monthly income&gt;60 thousands NT dollars</td>
<td>0.294(2.07)</td>
</tr>
<tr>
<td>Travel time ratio</td>
<td>2.260(2.59)</td>
</tr>
<tr>
<td>Travel time ratio (segment 1)</td>
<td>0.578(1.93)</td>
</tr>
<tr>
<td>Travel time ratio (segments 1+2)</td>
<td></td>
</tr>
<tr>
<td>Travel time ratio (segment 4)</td>
<td></td>
</tr>
<tr>
<td>Frequency of freeway usage per week &gt;4 and very frequently access to real time traffic information</td>
<td>-0.194(-1.39)</td>
</tr>
<tr>
<td>Gain</td>
<td>0.016(1.34)</td>
</tr>
<tr>
<td>Loss</td>
<td>-0.013(-1.82)</td>
</tr>
<tr>
<td>GCS1</td>
<td>0.091(2.99)</td>
</tr>
<tr>
<td>GCS2</td>
<td>-2.791(-18.59)</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>2.188(23.43)</td>
</tr>
<tr>
<td>$\mu_2$</td>
<td>3.572(33.35)</td>
</tr>
<tr>
<td>Test on ($\mu_2 - \mu_1$)</td>
<td>$P &lt; 0.10$</td>
</tr>
<tr>
<td>$LL(0)$</td>
<td>-703.154</td>
</tr>
<tr>
<td>$LL(\beta)$</td>
<td>-434.277</td>
</tr>
<tr>
<td>$\rho^2$</td>
<td>0.3824</td>
</tr>
<tr>
<td>Observations</td>
<td>553</td>
</tr>
</tbody>
</table>

For the travel characteristics, the higher the travel time ratio of the first 50% of the trip length, the more likely that drivers would choose the best routes. The travel time ratio is defined as the travel time on the current routes divided by the time on the best routes. This route preference is not the case in the final segment, which could be the result of travelers’ adherence to the habitual routes at the end of their journey (also refer to habitual route in Table 6). The evidence supports the provision of real time traffic information in the first half of a journey (please refer to Table 6). On the other hand, the drivers with frequent freeway usage per week (i.e. >4 trips) and very frequent access to real time traffic information, are not likely to choose the best routes. That is, they are likely to stay on their preferred routes, partly through habit and partly because real time traffic information provided in Taiwan is currently not sufficient.

The provision of real-time traffic information may reduce the anxiety due to uncertainty in traffic conditions. To test for this, the variables $Gain$ and $Loss$ are introduced to capture travelers’ perception of the accuracy of the real-time traffic information. When the real-time traffic information is over-estimated on the best routes (the forecasted travel times longer than the actual travel times), travelers would have the feeling of “Gain” (the forecasted travel times-the actual travel times>0). Otherwise, travelers would have the feeling of “Loss” (the actual travel times-the forecasted travel times>0). The results show
that both attributes Gain and Loss have significant effects on route choice. The effect of “Gain” is more than “Loss”, which implies that on average travelers they are not willing to bear the loss due to underestimation, implying that they tend to be more risk-adverse. Therefore, they would tend to choose the best route to travel when the real-time traffic information is overestimated.

4.2 The habitual route model A (H_model_A)

The estimation results of H_model_A \((GC_p \geq GC_h)\) are given in Table 9. It shall be noted that the positive coefficient implies the tendency of choosing the habitual routes. The models with thresholds in the range of 30-40 outperform other models in terms of log-likelihood values and t-statistics \((\rho^2 = 0.3146-0.3665)\). The estimation results in Table 9 indicate that married drivers are more likely to choose the habitual routes, possibly because of their life pattern is more routine even under the provision of real time traffic information. In addition, when the number of cars per household is greater than 2 and the frequency of freeway usage per week is greater than 4 trips, the drivers are less likely to choose their habitual routes. This may appear in part to be due to their rich driving experiences and their familiarity with other alternative routes.

The results of a positive coefficient on the travel time ratio show that the higher the travel time ratio, the more likely the drivers would choose the habitual routes. The travel time ratio is defined as the travel time on the current routes divided by the one on the habitual routes. However, the negative sign on the travel time ratio (segment 1) indicates that drivers have a higher tendency of staying away from their habitual routes in the beginning of their journey. Again, the results suggests that real time traffic information should be provided in the beginning of a journey (refer to the results shown in Table 6).
The results also suggest that both attributes Gain and Loss are significant. Therefore, drivers would tend to choose the habitual routes to travel when the real-time traffic information is overestimated on habitual routes. GCS3 indicates that when GCS is greater than the thresholds, the drivers are more likely to choose the habitual routes. Otherwise, they would stay on the current routes or preferred routes. The threshold test results ($P < 0.10$) justify the application of ordered probit models.

### 4.3 The habitual route model B (H_model_B)

The estimation results of H_model_B ($GC_{cr} < GC_{hr}$) are listed in Table 10. The positive coefficients imply the tendency of choosing the current routes. The models with all thresholds are marginally statistically significant ($\rho^2$ is less than 0.2), and the one with threshold 50 is the best among all models. The larger threshold is probably due to the drivers’ inertia effects. That is, although the travel cost of habitual routes is higher, the drivers still prefer to stay on their habitual routes (not choose current route). The thresholds of habitual route models are higher than the ones of the best route models.
The estimation results in Table 10 indicate that highly educated drivers are more likely to choose the current routes. Drivers in households with more cars have, the less likely they would stay on their current routes. The car ownership effect needs to be further investigated. The drivers with higher frequency of freeway usage per week are less likely to choose their habitual routes, possibly due to their rich driving experiences and their familiarity with other alternative routes.

The results of a negative coefficient of travel time ratio show that the higher the travel time ratio (defined in Section 4.2), the more likely the drivers would choose the habitual routes. The results of the travel time ratio (segment 1) indicate the drivers are likely to stay on the current routes (instead of habitual routes) in the very beginning of their trips. However, segments 3 and 4 indicate that drivers tend to choose their habitual routes when approaching the end of the journey.

The attribute Gain is significant so that the drivers would tend to choose the current routes to travel when the real-time traffic information on current routes is overestimated. When GCS is greater than the thresholds, the drivers are more likely to choose the current routes. Otherwise, they would stay on the habitual routes. The threshold test results ($P < 0.10$) justify the application of ordered probit models.
5. Conclusions

This study investigated the route choice behavior on freeways between Taipei and Taichung in Taiwan under real-time traffic information provision. Two types of route choice mechanisms, the best-route and the habitual-route, were analyzed by using the ordered probit modeling framework. The thresholds of generalized cost savings (GCS) for different models were further determined in terms of the models’ goodness of fit. The estimation results from the models indicated that the thresholds were 10 for the best route model, and 30-50 for the habitual route models. The results confirm that the thresholds for changing the inertia behavior of drivers should be substantially larger than the ones for choosing the best routes. Moreover, the drivers were more likely to choose either the best or the habitual routes once the generalized cost savings were greater than threshold values. The results of the travel time ratio on segments one and two indicated that drivers had a higher tendency of staying away from either their best or habitual routes in the beginning of their journey, indicating a better time to provide real-time traffic information is in the beginning of journey. Nevertheless, due to the inertia effects, drivers were adherent to their habitual routes in the end of their journey. Finally, Gain and Loss were two important perception variables inherent to drivers and would have different influences on route choice behavior.

References


Ministry of Transportation and Communication, 1996. The report on travelers’ value of travel time in Taiwan area.


Appendix A: An example set of showcards for the choice experiment
Route choice behavior of freeway travelers under real-time traffic information provision—application of the best route and the habitual route choice mechanisms
Jou, Hensher & Chen

Stated Choice Experiment
switching point 1

Ignoring the access time of local streets to freeways, and the VMS information shows:

Take ① to interchange A: "SMOOTH", NT 17
Take ② to interchange B: "SMOOTH", NT 18

Which route would you take?

Stated Choice Experiment
switching point 2

You are approaching interchange A, and the VMS information shows:

Take ① to interchange C: "NORMAL", NT$ 86
Take ② to interchange D: "SMOOTH", NT$ 102
Recommend to switch to ①!

Which route would you take?
If your actual travel time on previous route you just took is longer than the VMS provided about 30%, and you are approaching interchange C, and the VMS information shows:

Take 1 to interchange E: speed (travel time) “100 KPH (28.6 mins)”, NTS 63
Take 3 to interchange D: speed (travel time) “110 KPH (25.4 mins)”, NTS 56
Which route would you take?

If your actual travel time on previous route you just took is longer than the VMS provided about 30%, and you are approaching interchange E, and the VMS information shows:

Take 1 to Muxia: speed (travel time) “70 KPH (28.3 mins)”, NTS 44
Take 2 to Yuanshan: speed (travel time) “100 KPH (24.2 mins)”, NTS 53
Recommend to switch to 4!
Which route would you take?

To Taipei
Route choice behavior of freeway travelers under real-time traffic information provision—application of the best route and the habitual route choice mechanisms
Jou, Hensher & Chen
Appendix B: Calculation of travel time and travel cost

(1) travel time: can be calculated by dividing the length of a specific route by the speed of that route. The lengths of routes are shown in Figure 1. The speeds of routes can be obtained by the following procedures:

a. the speed limits of each Freeway (as shown in the following table);

<table>
<thead>
<tr>
<th>Freeways</th>
<th>No. 1</th>
<th>No. 3</th>
<th>No. 2</th>
<th>No.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit (KPH)</td>
<td>100</td>
<td>100 and 110</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>

b. three speed levels were defined in this experiment (as shown in the following table). For the three levels of qualitative speed information, i.e., smooth, normal, and congested, we converted the qualitative speeds into numbers based on the individuals' perceived speeds (provided by the individuals) with respect to the qualitative one (see Appendix C). Also, if the route including two freeways (such as, travel on Freeway No. 1 first, then switch to Freeway No.2), then the speed is calculated proportionally to the length of each Freeway.

<table>
<thead>
<tr>
<th>Attribute levels</th>
<th>qualitative</th>
<th>Freeway No.1</th>
<th>Freeway No.2</th>
<th>Freeway No.3</th>
<th>Freeway No.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>smooth</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>90</td>
</tr>
<tr>
<td>medium</td>
<td>normal</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>50</td>
</tr>
<tr>
<td>low</td>
<td>congested</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

(2) travel cost: the toll per km is 1.32 $NT【MOTC, 2003】，therefore the travel cost can be obtained by multiplying the travel distance by this number.
Appendix C: Individuals’ perceived speeds with respect to the qualitative attribute

(1.) Please indicate your perceived speeds regarding the following three speed levels under the speed limits provided belowed.

<table>
<thead>
<tr>
<th>Freeways</th>
<th>Speed levels</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways No. 1 &amp; No. 2 (Speed limit 100 KPH)</td>
<td>smooth</td>
<td>normal</td>
<td>congested</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KPH</td>
<td>KPH</td>
<td>KPH</td>
<td></td>
</tr>
</tbody>
</table>

(2.) Please indicate your perceived speeds regarding the following three speed levels under the speed limits provided belowed.

<table>
<thead>
<tr>
<th>Freeways</th>
<th>Speed levels</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways No. 3 (Speed limit 110 KPH)</td>
<td>smooth</td>
<td>Normal</td>
<td>congested</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KPH</td>
<td>KPH</td>
<td>KPH</td>
<td></td>
</tr>
</tbody>
</table>

(3.) Please indicate your perceived speeds regarding the following three speed levels under the speed limits provided belowed.

<table>
<thead>
<tr>
<th>Freeways</th>
<th>Speed levels</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeways No. 4 (Speed limit 90 KPH)</td>
<td>smooth</td>
<td>Normal</td>
<td>congested</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KPH</td>
<td>KPH</td>
<td>KPH</td>
<td></td>
</tr>
</tbody>
</table>