EXPERIMENTAL ANALYSIS AND MODELING OF ROUTE CHOICE WITH THE REVEALED AND STATED PREFERENCE DATA

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Abstract: The paper used a two-step survey with the revealed and stated preferential parameters. The experiment recorded the drivers' pre-trip route choice behavior at 12 zones of Taipei. A logic model formulation was also adopted to form sequential route choice behavior. The results indicate that drivers update their knowledge of the system on a weekly circular basis and take routine driving routes in some range of routine departure hours. The calibration of departure hour concordance model indicates the two best alternations are dynamic 10 minutes and 30 minutes. The calibration of route choice concordance model indicates the best alternation is the routine route.

1. INTRODUCTION

The route choice process in the real traffic environment is very complex and there is little experimental evidence of how drivers process information and select their route (1). Therefore, it was decided to analyze route choice behavior under the revealed and stated preferential parameters. The factor of utmost importance to any analysis of driver behavior influenced by an advanced traveler information system (ATIS) is a measure of the information accuracy. Certainly the future success or failure of ATIS will highly depend on the accuracy as well as the quality of advice that can be consistently delivered to the drivers (2).

An experiment was performed by using a two-step survey to collect route choice data with the revealed and stated preferential parameters which was then under the influence of traffic condition in Taipei Urban Area.. The experiment recorded the drivers' pre-trip route choice behavior at 12 zones of Taipei. The analysis of variance was carried out on those data to find out the interrelationship among the different variables in an attempt to develop an understanding of which factors have significant influence on route choice behavior and learning. A logic model formulation was also adopted to form sequential route choice behavior. It was assumed that drivers would have updated their knowledge of the system according to their previous experiences; therefore an information updating function was specified and incorporated into the model.

2. DESCRIPTION OF ROUTE CHOICE EXPERIMENT

An experiment was performed by using a two-step survey to investigate drivers' learning and pre-trip route choice behavior under the influence of traffic in Taipei Urban Area. In the first stage important variables were collected in an attempt to develop an understanding of which factors have significant influence on route choice behavior and then in the second stage those for routine trip were collected and developed.

The survey began with presenting a set of instructions to the subjects, explaining how the procedure operated before the subjects started working on the questionnaire. The subjects were shown with examples of the fastest and the slowest possible traveling time on each of the routes, and some of them must repeat the questionnaire about 30 days in a row. The subjects were instructed that their main tasks were to minimize their overall traveling time by deciding when and when not to follow the advice provided by any traffic information system. The subjects' route choice behavior is approximated in Figure 1. Based on the data an investigation was made on the factors that influenced drivers' route choices and the factor analysis method was then applied to find out which eigen-value was equal to 1, and varimax rotation method was adopted to orthogonal rotation which got the factors loading. By the interrelation of above procedure was got and named the key influential factors which are:

a) Road geometric: means slope, curve, parking disturbance, and so forth.
b) Information provision: means the frequency of information provision, speed limit, etc.
c) Left turn: the major influential elements include the number of left turn, the number of lane intersection, etc.
d) Overpass facilities: the major influential elements include number of subway or sky overpass, railway cross, etc.
e) Travel speed: major influential elements include traveling time and speed.
f) Travel distance: means travel distance only.
g) Traffic signal: means the number of traffic signal and speed limit.
h) Safety: means situation of roadside, accident frequency, etc.
i) Complication of Flow: means complication of flow only.
j) Crowd along Way: means crowd along way only.

The experiment on the pattern of drivers' route and departure hour was to investigate drivers' dynamic learning procedure. The dynamic procedures are presented in Figure 2. There are six feasible types but only type (e) suits Taipei urban area.

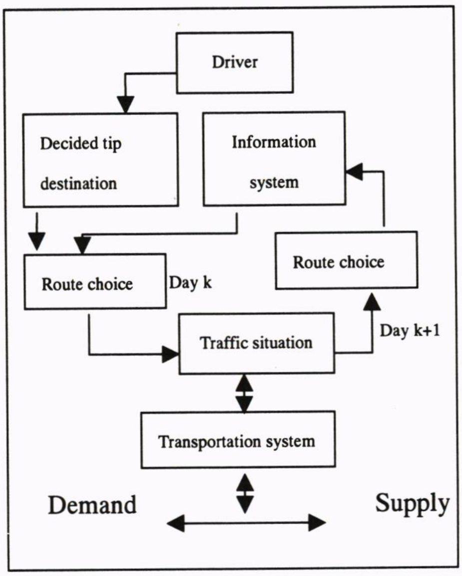
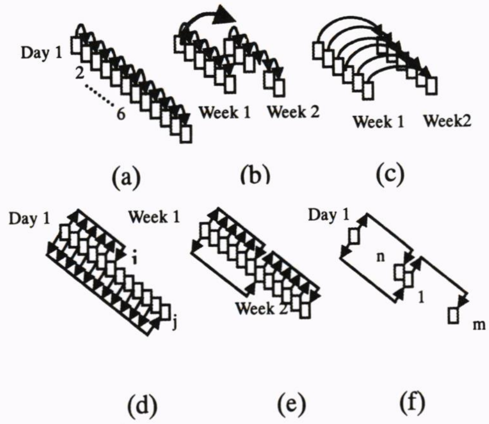


FIGURE 1 Drivers' route choice model



(a) Day by day dynamic procedure

(b) Day by day dynamic procedure upon last week

(c) Week day dynamic procedure

(d) Some day dynamic procedure

(e) Recycle some day dynamic procedure

(f) Recycle interval some day dynamic procedure

Figure 2 Drivers' feasible dynamic pattern

3. INVESTIGATION OF BEHAVIORAL RELATIONSHIP By ANALYSIS OF VARIANCE

Analysis of variance (ANOVA) models were used for studying the relationship between a dependent variable and one or more independent variables for experimental and observation data. The correlation between drivers' decision with total traveling time and maximum accepted delay is presented in Table 1 and Table 2. Most of the drivers' route diversion was made in accordance with the traffic situation. Only the 17.8% of drivers whose traveling time was within 30-40 minutes kept the same route. The 85% of drivers changed the route when ran into delay time more than 40 minutes. We can plot the change rate of drivers' departure hour in the scale of range between present trip with previous trip. The results presented in Figure 3. The change rate of drivers' departure hour in the scale of range between present trip with mode of trip is presented in Figure 4 and Figure 5. Most of drivers changed departure hour on Monday because the traffic was always blocked up at most of roads in Taipei urban area. Almost everyone changes the departure hour in a weekly cycle.

TABLE 1 Correlation of Drivers' Travel Time

Drivers' Decision / Travel Time	Change the route	Diverted Depend upon the Traffic	Keep the Same route
≦10min	0.01	- 0.01	0.08
10-20min	- 0.19	0.74	0.30
20-30min	0.26	0.36	0.06
30-40min	- 0.34	0.60	0.51
40-50min	0.01	0.01	0.20
50-60min	0.49	- 0.49	-0.24
≧60min	0.32	- 0.26	-0.09

TABLE 2 Correlation of Maximum Accepted Delay

Drivers' Decision / Maximum Accepted Delay	Change the Route	Diverted Depend upon the Traffic	Keep the Same route
≦10min	- 0.45	0.91	0.32
10-20min	- 0.52	0.78	0.44
20-30min	0.27	- 0.41	0.15
30-40min	0.51	- 0.50	- 0.15
40-50min	0.53	- 0.45	- 0.29
50-60min	0.54	- 0.46	- 0.37
≧60min	0.56	- 0.23	- 0.25

The rate of drivers' route change is presented in Figure 6. Most of drivers adjusted route on Monday. The pattern of route choice became stable gradually from Monday to Saturday.

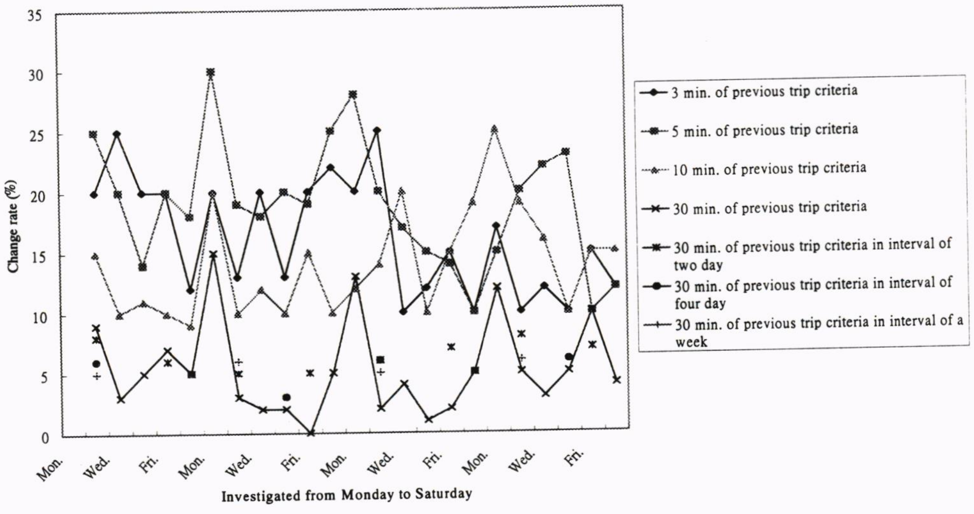


Figure 3 Departure time change rate (previous trip criteria)

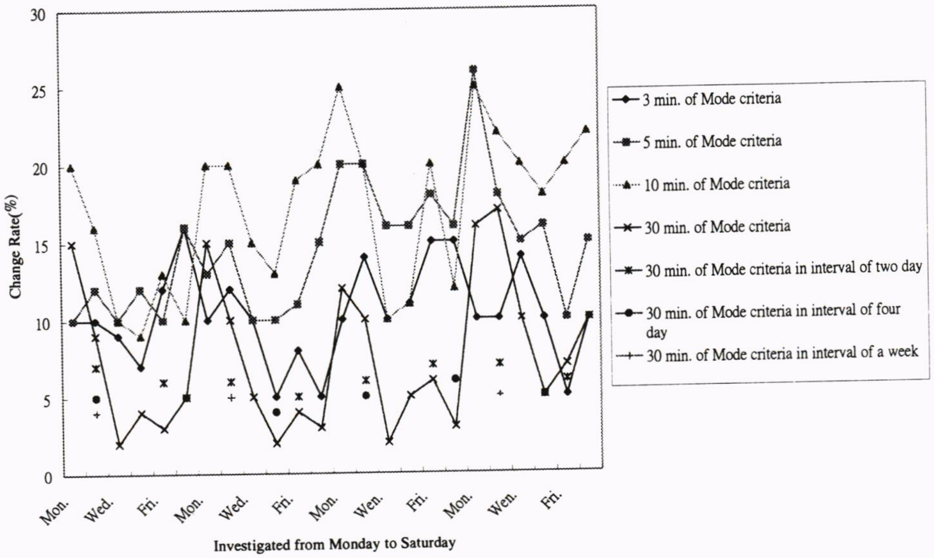


Figure 4 Departure time change rate (scale of mode)

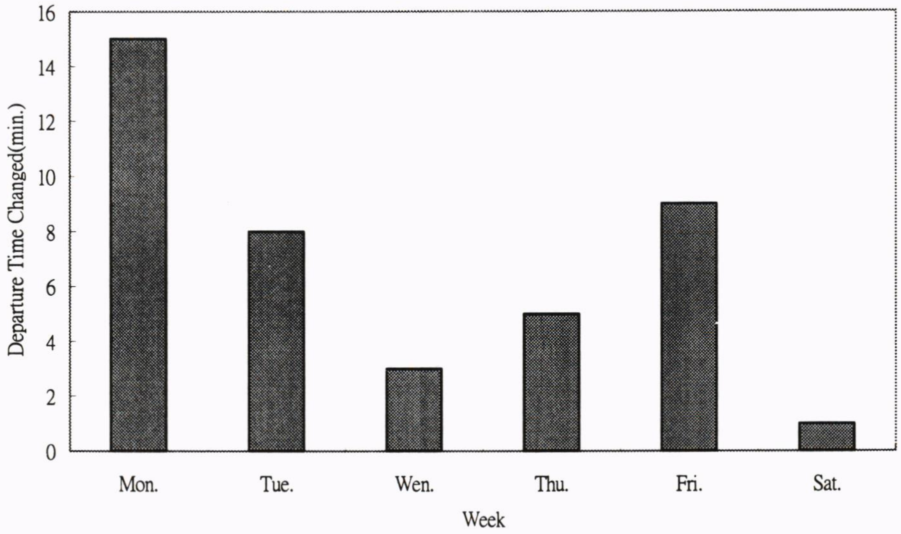


Figure 5 Average departure time changed in one week

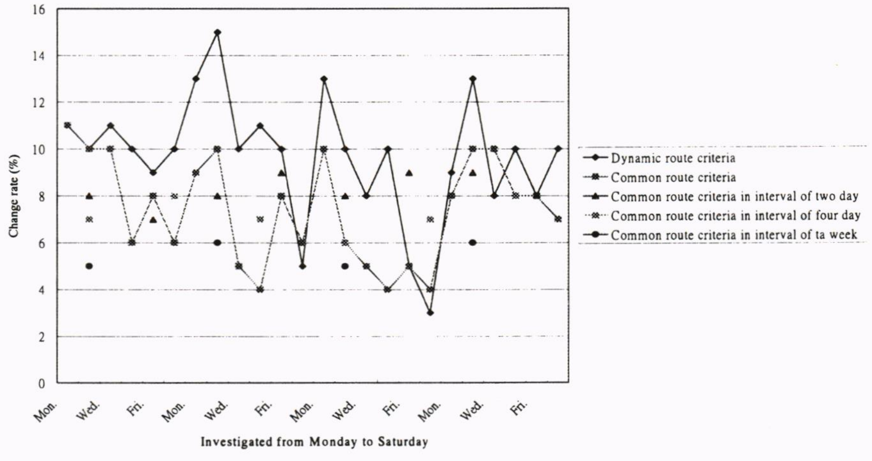


Figure 6 Drivers' route change rate

4. CONCORDANCE MODEL

The goal of this research is to develop models of route choice under the influence of daily traffic and to capture and incorporate into these models the effects of drivers' learning abilities. The first step in this process is to develop a basic understanding of the factors that influence drivers' route choices and of how the presence of traffic systems will affect drivers' route choice decisions over the time.

The first step in the data analysis was to investigate the interrelationship among the various variables in an attempt to develop an understanding of which factors significantly influence route choice behavior and learning. Ten variables of significant interest were selected from the data set for analysis as index. The influential index of route choice behavior included road geometric, traffic information, travel speed, travel instance, and safety. The influential index of departure hour included travel experience, traffic situation, route diversion, climate, and other stop demands. Each influential index can be presented as fuzzy number with the form in equation (1).

$$I_s = \frac{1}{N}\left[\begin{array}{l} n_{s_1}\left(0,0,\frac{1}{2(L-1)},\frac{1}{L-1}\right) + n_{s_2}\left(\frac{0}{L-1},\frac{1}{2(L-1)},\frac{3}{2(L-1)},\frac{2}{L-1}\right) + \cdots \\ + n_{s_k}\left(\frac{K-2}{L-1},\frac{2K-3}{2(L-1)},\frac{2K-1}{2(L-1)},\frac{K}{L-1}\right) + \cdots + n_{s_L}\left(\frac{L-2}{L-1},\frac{2L-3}{2(L-1)},1,1\right)\end{array}\right] \quad (1)$$

Where I_s : fuzzy number of the s - th index

n_{s_k} : k - th evaluate scale numbers of the s - th index

N : *sum of* n_{s_k}

L : *the numbers evaluate scale*

K : *evaluate scale*

The alternation of the route and departure hour could be presented with evaluate scale of 5 degrees ranging from very like, like, ordinary, dislike, very dislike. Establishment of fuzzy number is presented in the equation (2). And in consequence if there are two fuzzy relations of P(X,Y) and Q(X,Z), the composition of these two relations is denoted by R(X,Z) = P(X,Y) ∘ Q(Y,Z) , and this operation is defined by

$$u_{P \circ Q}(x,z) = \max_{y \in Y} \min \left[u_P(x,y),\, u_Q(y,z)\right]$$

$$\text{for all } x \in X, z \in Z.$$

Following above we get the concordance matrix and discordance matrix. The drivers could have different index weight which affected behavior of route choice and departure model structure of change behavior is presented by equation (3).

$$J_t = \frac{1}{M}\left[\begin{array}{l} n_{t_1}\left(0,0,\frac{1}{2(L-1)},\frac{1}{L-1}\right) + n_{t_2}\left(\frac{0}{L-1},\frac{1}{2(L-1)},\frac{3}{2(L-1)},\frac{2}{L-1}\right) + \cdots \\ + n_{t_k}\left(\frac{K-2}{L-1},\frac{2K-3}{2(L-1)},\frac{2K-1}{2(L-1)},\frac{K}{L-1}\right) + \cdots + n_{t_L}\left(\frac{L-2}{L-1},\frac{2L-3}{2(L-1)},1,1\right) \end{array}\right] \quad (2)$$

where J_t : *fuzzy number of t – th route or departure time*
n_{t_k} : *the numbers of k – th word scale in t – th route or departure time alternatio n*
M : *sum of* n_{t_k}

$$\Pr(\text{switching}) = \Pr(TD_{it} > GU_{it} \text{ or } TD_{it} < BU_{it}) \quad (3)$$

Where TD_{it} is the weight of index

GU_{it} and BU_{it} is threshold value of concordance and discordance

According to the differentiated analysis output which the important factors affecting the decision of departure hour, included were the number of changed departure hour, standard error of traveling time, traveling time saved by adjusting departure hour, and the frequency of successful traveling time saved with the adjustment of departure hour. The concordance model of departure hour is presented in equation (4). And the calibration of departure hour concordance model is presented in Table 3 in which departure hour concordance model evaluates four type of dynamic change rate in 3 minutes, 5 minutes, 10 minutes, 30 minutes, and indicates the two best alternations are dynamic 10 minutes and 30 minutes. From the t-value of the model, the numbers of changed departure hour and numbers of travel time saved by adjusted departure hour influenced of information play more important role in the model. Because the coefficient is negative which intend more of the numbers of changed departure hour and numbers of travel time saved by adjusted departure hour influenced of information, the range of departure hour concordance will be narrow, the driver will often change departure hour. The factor of route choice decision includes the number of changed route, standard error of traveling time, traveling time saved by adjusting route choice, and the frequency of successful traveling time saved with the adjustment of route choice. The concordance model of route choice is presented in equation (5) and calibration of route choice concordance model is presented in Table 4 which concludes that the best alternation is the routine route. From the t-value of the model, the variables of upper all play more important role in the model. Because the coefficient is negative which intend more of the number of changed route, standard error of traveling time, traveling time saved by adjusting route choice, and the frequency of successful traveling time saved with the adjustment of route choice, the range of route choice concordance will be narrow, the driver will often change the route.

$$\begin{aligned} TD_{it} = {} & \delta_{it} * a_1 + (1-\delta_{it}) * a_2 + \\ & \delta_{it} * a_3 * PEL_{it-1} + (1-\delta_{it}) * a_4 * PEL_{it-1} + \\ & \delta_{it} * a_5 * TRA_{it-1} + (1-\delta_{it}) * a_6 * TRA_{it-1} + \\ & \delta_{it} * a_7 * EFC_{it-1} + (1-\delta_{it}) * a_8 * EFC_{it-1} + \\ & \delta_{it} * a_9 * INF_{it-1} + (1-\delta_{it}) * a_{10} * INF_{it-1} \; + \; \varepsilon_{it}^{D} \end{aligned} \tag{4}$$

$$\delta_{it} = \begin{cases} 1, if\,(TD_{it} - GU_{it}) < 0 \;\; or \;\; (TD_{it} - BU_{it}) > 0 \\ 0, otherwise \end{cases}$$

$$\begin{aligned} RD_{it} = {} & \delta_{it} * a_1 + (1-\delta_{it}) * a_2 + \\ & \delta_{it} * a_3 * PER_{it-1} + (1-\delta_{it}) * a_4 * PER_{it-1} + \\ & \delta_{it} * a_5 * TRA_{it-1} + (1-\delta_{it}) * a_6 * TRA_{it-1} + \\ & \delta_{it} * a_7 * EFC_{it-1} + (1-\delta_{it}) * a_8 * EFC_{it-1} + \\ & \delta_{it} * a_9 * INF_{it-1} + (1-\delta_{it}) * a_{10} * INF_{it-1} \; + \; \varepsilon_{it}^{D} \end{aligned} \tag{5}$$

$$\delta_{it} = \begin{cases} 1, if\,(TD_{it} - GU_{it}) < 0 \;\; or \;\; (TD_{it} - BU_{it}) > 0 \\ 0, otherwise \end{cases}$$

TABLE 3 Calibration of departure hour concordance model

Variable	Model 1	Model 2	Model 3	Model 4
Constant	20.11 (1.02)	20.34 (1.37)	24.55 (4.34)	24.33 (4.25)
Numbers of changed departure hour	-0.235 (-1.1)	-0.456 (-1.54)	-0.934 (-2.93)	-0.812 (-2.87)
Standard error of travel time	-0.042 (-0.70)	-0.045 (-0.99)	-0.038 (-1.55)	-0.065 (-1.34)
Saved time just adjusted departure hour	-0.345 (-1.86)	-0.115 (-0.73)	-0.103 (-0.67)	-0.089 (-1.11)
Numbers of travel time saved by adjusted departure time influenced of information	-0.356 (-1.03)	-0.398 (-1.22)	-0.892 (3.44)	-0.734 (2.45)
$L(\hat{\beta})$	-32.56	-40.31	-50.66	-44.27
L(0)	-43.25	-47.57	-64.56	-49.23
ρ^2	0.029	0.156	0.256	0.245
$\bar{\rho}^2$	0.015	0.121	0.236	0.221
N	223	223	223	223

* ( ) intent the t-value

TABLE 4 Calibration of route choice concordance model

Variable	Dynamic route choice index model	Routine route index model
Constant	22.56 (3.14)	26.52 (3.87)
Numbers of changed route	-2.365 (-3.24)	-2.416 (-3.35)
Standard error of travel time	0.142 (-2.18)	0.104 (-2.49)
Saved time just adjusted route choice	-0.312 (-2.86)	-0.245 (-2.97)
Numbers of travel time saved by adjusted route choice influenced of information	-0.315 (-3.09)	-0.329 (-3.22)
$L(\hat{\beta})$	-22.16	-40.31
L(0)	-63.75	-67.83
ρ^2	0.798	0.823
$\bar{\rho}^2$	0.692	0.734
N	223	223

* ( ) intent the t-value

5. SUMARY AND CONCLUSIONS

Previous research by the authors(1) has shown that a basic understanding of drivers' route choice behavior is necessary to develop predictive models of drivers' en route diversion choice. The analysis of these experimental data resulted in the discovery of some interesting relationships. It was assumed that drivers update their knowledge of the system on the basis of their previous experiences; therefore an information updating function was specified and incorporated into the model. The results indicate that drivers update their knowledge of the system on a weekly circular basis and take routine driving route in some range of routine departure hours. The important factor affecting the decision of departure hour includes the number of changed departure hour, standard error of traveling time, traveling time saved by adjusting departure hour, and the frequency of successful traveling time saved with the adjustment of departure hour. The calibration of departure hour concordance model indicates the two best alternations are dynamic 10 minutes and 30 minutes. The important factor affecting the decision of route choice includes the number of changed route, standard error of traveling time, traveling time saved by adjusting route choice, and the frequency of successful traveling time saved with the adjustment of route choice. The calibration of route choice concordance model indicates the best alternation is the routine route.

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