7TH WCTR
SYDNEY AUSTRALIA
1 9 9 5

TOPIC 15
TRAVEL CHOICE AND
DEMAND MODELLING

SIGNIFICANT FACTORS AFFECTING THE TEMPORAL VARIATION OF INDIVIDUALS' MODE CHOICE PREFERENCE

AKIMASA FUJIWARA
Graduate School for International Development and Cooperation
Hiroshima University:
Kagamiyama 1-4-1
Higashi-Hiroshima 739
JAPAN

YORIYASU SUGIE
Graduate School for International Development and Cooperation
Hiroshima University:
Kagamiyama 1-4-1
Higashi-Hiroshima 739
JAPAN

Abstract

The longitudinal casual relationship of individual's preference for the new transit system in Hiroshima were empirically examined with four-period SP panel data, by using LISREL models. It was shown that individual's SP is influenced by the actual and previous travel circumstances and experience of participation in the panel survey.

INTRODUCTION

Recently, there has been a growth of interest in panel analysis of travel behavior. The analysis is generally based on revealed preference panel data which consist of observations made repeatedly by the same respondents. It allows us to understand the fact that individuals' travel behavior is influenced by not only their current travel circumstances and constraints, but also the previous environment which they have experienced and the history of their behaviors (Kitamura, 1990). Conventional cross-sectional analysis cannot treat with such a temporally unstable travel behavior.

As individual travel behaviors are directly compared before and after introducing a certain transport policy, panel analysis is especially effective in evaluating its impact. In the case of supplying a new alternative or remarkable change in the levels of travel services, stated preference data can be used as a substitute for the observations of travel behaviors (ie. RP data) before introducing a policy. Thus, SP and RP panel data is often used in before-and-after studies. Many studies comparing individual SP with RP have been done during the past fifteen years in order to examine the reliability of SP data (eg. Couture and Dooley, 1981; Wardman, 1988).

Panel surveys collecting the same individual's SP responses at more than two points in time are effective in the following cases:

- Checking the variation of an individual's SP responses from different points in time;
- Investigating the temporal variation of effects of travel factors set up in SP experiments on an individual's SP; and
- Measuring taste variation by developing "individual choice model" based on SP data, as opposed to discrete choice models.

The first and second cases are highly related to the reliability of travel demand forecasting with SP data. If SP is variant over time, travel demand may be inaccurately predicted based on cross-sectional SP data. Individual preference for new alternatives where information levels may initially be poor and personal experience absent altogether, will change over time (Polak and Meland,1994). In order to predict travel demand accurately by considering temporal variation of SP, it is necessary to examine the longitudinal relationship between SP and causal factors with panel data obtained at as many survey periods as possible.

On the contrary, two practical problems will occur as the periods of panel survey increase. One of them is a "panel attrition" problem whereby some members of the panel will leave the survey. Another problem is called "attrition bias" which means that the panel attrition will lead to biases in the distribution of individual characteristics and stated preference. It is expected that the burden of participation in multi-period panel survey may cause fatigue and conditioning effects where SP responses are influenced by the behaviors and responses to earlier surveys. Thus, it is necessary to examine the biases in the results of the panel analysis based on these survey data.

This study aims to empirically investigate these two problems by employing linear structural equation models. Concerning the former problem, a longitudinal causal relationship of individual preference for travel mode was assumed in consideration of the effects of state dependence and serial correlation, in addition to those of travel factors set up in SP experiment and individual characteristics. With relation to the latter one, a cross-sectional causal relationship among three latent variables was assumed: individual preference, attitude for mode choice and experience in the panel survey. SP panel data for the New Transit System in Hiroshima was used in this study.

REVIEW OF EXISTING RESEARCH

Multi-period SP panel survey has received attention in many studies, especially the dynamic analysis of driver's behavior under providing trip information. For examples, the repeated laboratory experiments have been employed to investigate the driver's route choice behaviors

(Iida *et al.*, 1994) and to interpret the commuter's learning process of departure time decisions (Chang and Mahmassani, 1988). Temporal changes of SP were verified in these experiments.

Polak and Meland (1994) carried out a two-period SP panel survey one year before and after the introduction of the toll ring in Trondheim. They pointed out that SP-based tastes and preferences are variant over time and the variance is systematically related to changes in socio-economic and travel circumstances. In our previous analysis, by using discrete choice models based on three-period panel data, the temporal variation of SP was also significant (Fujiwara and Sugie,1995). The between-wave variation caused by temporal change in the biases inherent in SP panel data was not so small. However, those results based on SP data obtained from participants for all waves did not take panel attrition into account.

Panel attrition is highly related to panel survey methods, these being duration, interval, number of repetition, sampling method of the survey, contact with respondents between survey periods, and incentives to cooperate in the survey. Furthermore, the factors that influence panel participation are interviewers, household and individual characteristics of respondents, and their mobility (Hensher, 1987). In general, an additional sampling called "panel refreshment" is employed to recruit new respondents to maintain the size of the panel. The respondents who have different numbers or periods of participation in panel survey are included in the refreshed samples.

Some correcting methodologies for the attrition bias in model building have been developed (Kitamura and Bovy, 1987; Hensher, 1987). For instance, a weighting method for attrition was developed to the choice-based panel sample (Kitamura *et al*, 1993; Pendyala *et al*, 1993). The reciprocal of the probability that respondents successively participate in the following wave was introduced as a weight for each sample in the log-likelihood function. The effectiveness of this method was verified on two-period panel data, but was unknown on panel data obtained at more than two points in time. Pendyala and Kitamura (1995) applied this method to the panel including refreshed samples. As the authors mentioned, this procedure is more complicated to apply in the case that "returners" exists, those being respondents who had previously left the panel. In order to confirm the applicability of these methods, the analysis of longitudinal causal relationship will be made using SP data in this study.

OUTLINE OF SP PANEL DATA

SP Experiment

The New Transit System (NTS) in Hiroshima opened in August 1994, in an effort to relieve the traffic congestion caused by commuters from the north-western residential areas to the city center. Panel surveys that asked work and school travelers aged fifteen years or over to state their preference for the NTS under a hypothetical condition were carried out at five different points in time for seven years. The first wave was initially administered to a random sample of about 500 households in 1987. The following four waves, done in 1988, 90, 93 and 94, examined the temporal variation of individual preference for the NTS as the project progressed. As these waves were all done in November, excluding the last one, the seasonal effect in SP responses was avoided. The last one was accomplished a month before the opening in July 1994. RP survey was also done with the same respondents three months after the opening.

The four-period panel data except the second wave will be used in this analysis, because many respondents dropped out at that wave due to the difference of sampling method. A more complete description of this SP panel survey is given in Fujiwara and Sugie (1995).

Ranking among three travel modes: car, bus and the NTS was employed to present the respondents' preference in SP experiments. As shown in Table 1, eleven travel factors were used in four SP experiments. Three different levels were determined by travel mode for all travel factors by considering the observed levels at each wave. The means of three levels are indicated in the same table for reference. According to the temporal change of the actual travel service and the progress of the NTS project, these levels set up in the SP experiments varied among four waves. The fare for bus was set to a fixed level at wave 1. The congestion in vehicle for the NTS was set up at all waves besides wave 1. The access cost by bus to the nearest NTS stations was taken for waves 4 and 5. Twenty-seven sets of tri-modal options were generated by combining different levels of these travel factors, using a fractional factorial design.

As previously mentioned, about 500 households were randomly selected from the residential area along the NTS line at wave 1. The households who had taken part in the previous surveys from the third wave onwards in contrast with the first wave, were chosen to fill in the questionnaires. A brief report that outlined the results of a prior survey was distributed with a letter of request a few days before the day respondents were asked to fill in the questionnaires. Incentives for their cooperation in the surveys were handed out at waves 4 and 5.

Table 1 Levels of travel factors set up in SP experiment at each wave

Travel factor	Wave1	Wave3	Wave4	Wave5
Car				
In-vehicle time (min.)	62.5	75.0	60.0	63.3
Parking cost (yen)	200	200	200	200
Bus				
In-vehicle time (min.)	47.5	62.5	55.0	53.3
Fare (yen)	----	440	494	494
Waiting time (min.)	9.8	3.3	3.3	3.3
New Transit System				
In-vehicle time (min.)	23.5	22.5	26.7	26.7
Fare (yen)	430	490	494	410
Access time (min.)	11.7	9.0	9.0	9.0
Access cost (yen)	----	----	107	100
Waiting time (min.)	3.3	3.3	3.7	3.7
Congestion in vehicle*)	----	0.3	0.3	0.3

*=1: if possible to have a seat, =0: otherwise.

Panel attrition

Respondents who continuously cooperated in the panel at both earlier and later waves are named "stayers". "Dropouts" means the respondents who participated in the previous wave, but could not be reached in a later one, due to one of the following reasons:

- the respondent could not be contacted by his/her moving;
- the respondent was not a work/school traveler aged 15 years or over by this time;
- the respondent's socio-demographic characteristics did not match with his/her previous data (their names were not reported); and
- the respondent refused to respond to the survey.

"Refreshments" means the respondents newly selected to compensate for the dropouts. These respondents are further divided into two groups: initial participants at that time, and respondents who have previously participated in the survey. The latter ones are called "returners".

The panel attrition and refreshment at each wave are outlined in Figure 1. The numerical values in this figure indicate the numbers of the respondents by four types of participation; stayers, dropouts, refreshments and returners, at each wave. For example, the stayers from wave 1 to 3 count 281 individuals and the number of dropouts who left the survey during those two periods is 228. The number of the refreshments is 207 at wave 4, and includes 32 returners.

As a result of panel refreshment, the numbers of all samples at each wave totaled 509, 595, 568 and 546. These sample sizes are adequate to statistically analyze. It is found that the ratio of stayers in all samples increases from wave 1 to 5, in opposition to the ratio of dropouts which declines. The number of refreshments also gradually decreases. The number of stayers through the four waves is 128. The number of respondents in the SP panel survey for all four waves totals 2,218.

The temporal variation of SP responses is shown in Figure 2. The proportion of responses when the NTS was ranked as the best mode (ie. NTS share) has a tendency to decrease with time for both all samples and stayers through all four waves. The NTS shares at waves 4 and 5 are lower than those at waves 1 and 3. It is found that SP responses are not stable over time. The shares of stayers through four waves are slightly higher as compared with those of all samples.

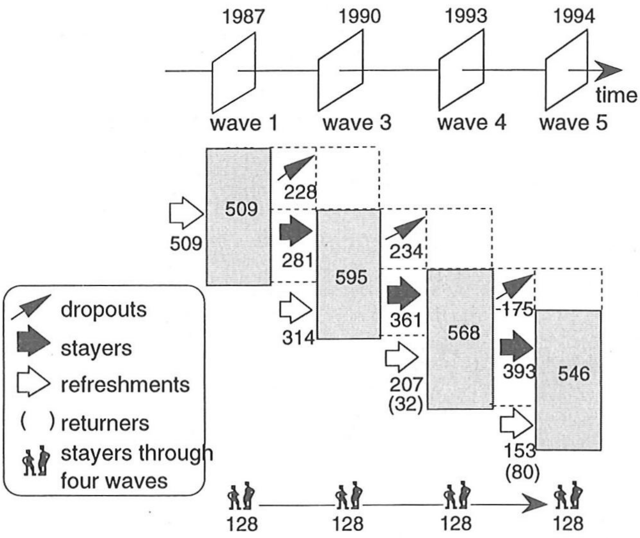

Figure 1 Numbers of stayers, dropouts, refreshments and returners at each wave

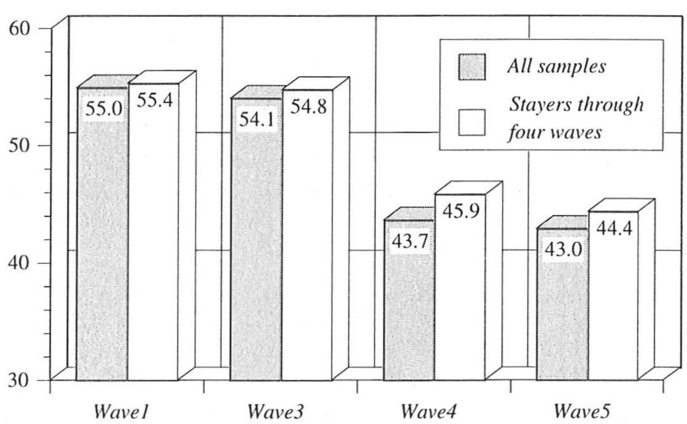

Figure 2 Temporal variation of NTS shares stated by stayers through four waves and all samples

LONGITUDINAL CAUSAL RELATIONSHIP OF MODE CHOICE PREFERENCE

Assumption of causal relationship

First of all, we consider a cross-sectional causal relationship of mode choice preference at a wave t. It is assumed that an individual's preference for the NTS measured as ranking SP data is affected by two sets of variables. One is a set of level-of-service variables set up in the SP experiment. Another is a latent variable that represents the individual's attitude for actual mode including choice inertia and travel constraints. Because this variable cannot be directly observed, the actual travel mode (ie. RP) is employed as a substitute indicator for this one. The attitude is then also caused by individual socio-economic characteristics. The effect of the omitted variables from the SP experiment, the effect of unfamiliarity for SP questions, the fatigue effect by replicated surveys and some biases inherent in SP data are considered as random errors here.

In a longitudinal causal relationship as shown in Figure 3, the current preference for NTS at wave t is influenced by the past preferences and attitudes for actual mode in addition to the effects supposed in a cross-sectional structure. These effects are known as state dependence. When the effects of omitted variables and SP biases exist in common at multiple waves, the random error at each wave will serially correlate with each other. In recent techniques of model building, it is possible to estimate discrete choice models considering state dependence and serial correlation (Morikawa 1994). However, one expects it to be more complicated within the context of multi-period and multi-modal choice behaviors.

Linear structural equation models

Linear structural equation models have been used in the study of macroeconomics policy formation, studies of antecedents and consequences of drug use, consumer behavior, and many other phenomena. Just as many studies exit in transport research. For examples, Golob (1989) investigated the effects of household income and car ownership on trip generation. Morikawa and Sasaki (1994) described the individual decision-making process by using this model and combined it with discrete choice model. Pendyala (1994) investigated the effect of structural heterogeneity in causal relationship on properties of model estimates.

The full model is defined by the following three equations:

Structural Equation Model: $$\eta = \mathbf{B}\eta + \Gamma\xi + \zeta \quad (1)$$

Measurement Model for y: $$y = \Lambda_y \eta + \varepsilon \quad (2)$$

Measurement Model for x: $$x = \Lambda_x \xi + \delta \quad (3)$$

where

η = vecter of latent endogenous variables (i.e. attitude and preference in Fig.3);

ξ = vecter of latent exogenous variables;

$\mathbf{B}$ = matrix of structural coefficients;

Γ = matrix of structural coefficients;

ζ = random vecter of residuals;

y = vecter of observed endogenous variables (i.e. SP and actual mode);

x = vecter of observed exogenous variables (i.e. level - of - services and socio - economic characteristics);

Λ_y = matrix of measurement coefficients on endogenous variable side;

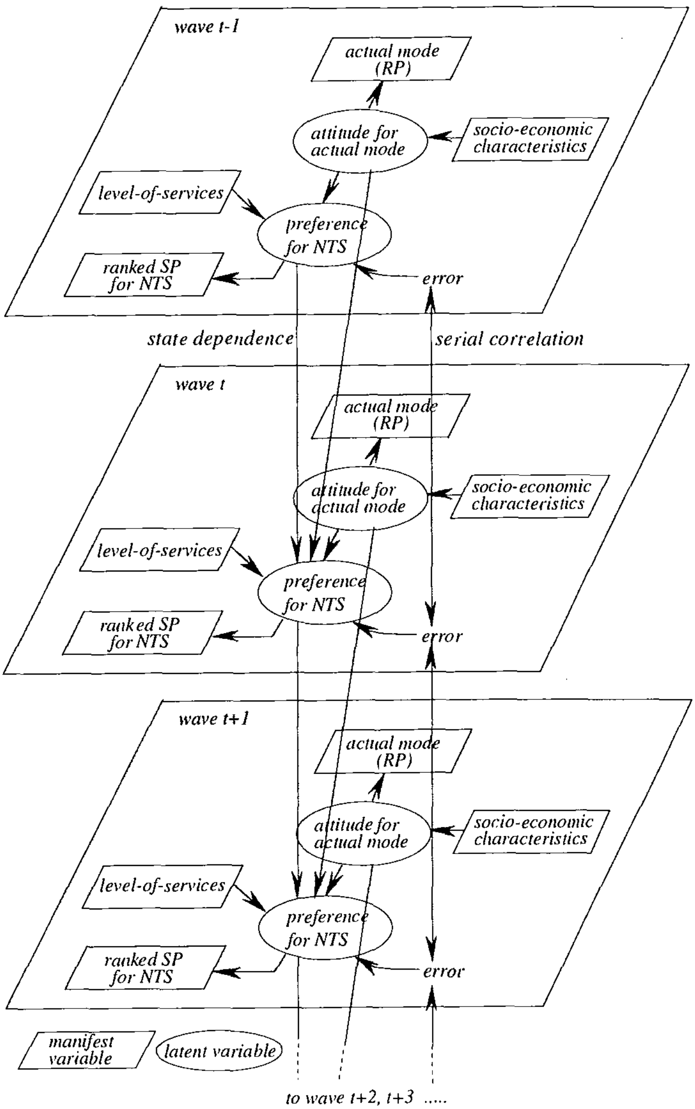

Figure 3 Assumed longitudinal causal relationship of preference for NTS

Λ_x = matrix of measurement coefficients on exogenous variable side;

ε = vecter of measurement errors on endogenous variable side; and

δ = vecter of measurement errors on exogenous variable side.

Let Φ, Ψ, Θ_ε and Θ_δ be the covariance matrices of ξ, ζ, ε and δ, respectively. Then it follows that the covariance matrix Σ of the model is

$$\Sigma = \begin{pmatrix} \Lambda_y(\mathbf{I}-\mathbf{B})^{-1}(\Gamma\Phi\Gamma' + \Psi)(\mathbf{I}-\mathbf{B})^{-1} + \Theta_\varepsilon & \Lambda_y(\mathbf{I}-\mathbf{B})^{-1}\Gamma\Phi\Lambda'_x \\ \Lambda_x\Phi\Gamma'(\mathbf{I}-\mathbf{B})^{-1}\Lambda'_y & \Lambda_x\Phi\Lambda'_x + \Theta_\delta \end{pmatrix} \tag{4}$$

The parameters are estimated to fit Σ to the covariance matrix of raw data. Some kinds of programming software for the parameter estimation are generally provided, for examples, LISREL, LISCOMP and CALIS. LISREL for SPSS was used in this analysis (Joreskog and Sorbom 1989).

Estimation of LISREL models based on longitudinal causal relationship

The linear structural equation models were estimated based on a longitudinal causal relationship as shown in Figure 3. The simplified relationship was sought through trial and error by using data from 128 stayers for all four waves. As a result, a quite simple causal relationship at wave t was decided as shown in Figure 4. The manifest (observed) exogenous variables consist of four level-of-service variables x_k^t (k=1,...,4): travel time and cost differences between the NTS and car, and the NTS and bus. The latent variable of attitude for actual mode ξ_5^t is indicated as an actual mode dummy variable x_5^t (=1, if respondent's actual mode is car at wave t; =0, otherwise). Since the exogenous variables of the stayers' socio-economic characteristics (eg. sex and car license) are fixed levels between some sequential two waves, they cannot be included in this model.

The paths from the previous attitude to current preference which indicates state dependence of preference for the NTS in Figure 3 were eliminated to simplify the causal relationship. The state dependence between the previous and current preferences and the serial correlation of error terms were included in this structure. As there existed continuous variables (ie. travel time and cost), a dummy variable (ie. actual mode) and an ordinal variable (ie. SP for the NTS), PRELIS, a preprocessor for LISREL, was used to compute correlation coefficient matrix as input data. Weighted Least Square was employed to estimate the LISREL models here.

The result of model estimation is shown in Table 2. Three SP responses were obtained from a respondent by repetitive questions under the different hypothetical conditions, excluding wave 2, in which four responses were collected. The first three SP responses were used at wave 3 to make the replication effect identical with the other waves. We have 81 (=3^4) combinations of SP responses from all of 128 stayers through four waves. The number of samples used in LISREL models, therefore, is 8,343 eliminating non-responses from 10,368 (=81*128).

As the adjusted goodness-of-fit index (AGFI) of this model is high, but the root mean squared residual (RMR) is low, the model can adequately describe the causal relationship assumed in Figure 4. The coefficient of determination (ie. total R^2) of the model is not low. This implies that several linear relationships in this model are strong. The squared multiple correlations of the structural equations at each wave are 0.278, 0.284, 0.185 and 0.091 for wave 1, 3, 4 and 5, respectively. These indices demonstrate that the error variances in the equations at waves 4 and 5 are larger than ones at waves 1 and 3. This implies the fatigue effect of multi-period panel survey.

The parameter estimates of the paths from level-of-services to preference all have correct signs except travel time (NTS-bus) γ_{12}^4 at wave 4, and also have significant t-values except three parameters γ_{13}^3, γ_{11}^5 and γ_{12}^5. Furthermore, the parameters γ_{15}^t of the path from attitude for actual mode ξ_5^t to preference for NTS η_1^t have higher t-values. Those findings reveal that individual preferences for the NTS are influenced by not only travel factors set up in SP experiments but also the individual's actual travel circumstances.

All parameters of state dependence $\beta_1^{t-1,t}$ also present significant t-values. Individual preference for the NTS is affected by previous travel factors and circumstances in addition to the actual ones. This effect between waves 4 and 5, which have only a year interval, is fairly large in comparison to that between the other waves of three year intervals. The significance of state dependence relates to the interval between waves.

The covariances of errors between two waves (ie. 1-3, 3-4 and 4-5 waves) are 0.051, 0.089 and -0.352, so that the correlation coefficients can be calculated as 0.07, 0.12 and -0.41, respectively. The serial correlations of errors between two sequential waves are not significant.

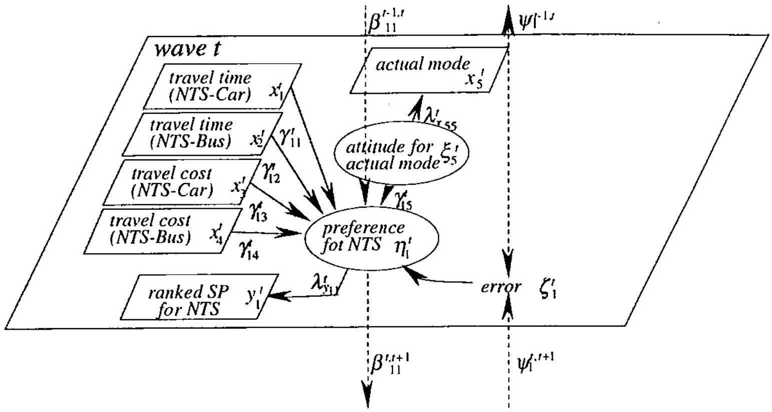

Figure 4 Simplified longitudinal causal relationship of preference for NTS

Table 2 Estimation of longitudinal LISREL model

	t=1		t=3		t=4		t=5	
Path	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
SP $\lambda^t_{y_{11}}$	1.000	----	1.000	----	1.000	----	1.000	----
Actual mode λ^t_{x55}	1.000	----	1.000	----	1.000	----	1.000	----
Level-of-services γ^t_{11}	-0.115	(-6.91)	-0.236	(-10.8)	-0.075	(-5.87)	-0.023	(-1.59)
γ^t_{12}	-0.054	(-4.02)	-0.050	(-3.23)	0.104	(7.40)	-0.023	(-1.47)
γ^t_{13}	-0.111	(-6.63)	-0.028	(-1.92)	-0.049	(-3.94)	-0.047	(-3.14)
γ^t_{14}	-0.084	(-6.18)	-0.233	(-14.4)	-0.083	(-6.72)	-0.105	(-7.90)
Attitude γ^t_{15}	-0.483	(-61.4)	-0.132	(-5.03)	-0.185	(-16.9)	-0.231	(-15.4)
State dependence $\beta^{t-1,t}_{l}$	-----	-----	0.254	(4.83)	0.238	(10.2)	0.604	(14.0)
Serial correlation $\psi^{t-1,t}_{l}$	-----	----	0.051	(1.17)	0.089	(3.55)	-0.352	(-8.12)
Error variance ζ^t_l	0.722	(39.1)	0.716	(32.9)	0.815	(45.3)	0.909	(23.0)
R^2 at wave t	0.278		0.284		0.185		0.091	
Total R^2	0.502							
AGFI	0.990							
RMR	0.029							
No.of sample	8343							

CROSS-SECTIONAL CAUSAL RELATIONSHIP OF MODE CHOICE PREFERENCE

Relationship between mode choice preference and experience of participation in survey

The panel data obtained from 128 stayers through four waves was used in the previous section. The sample size was small when compared with the total 2,218 participants in all waves. The panel refreshment was therefore requested to keep the panel sample representative of the original sample. In this section, a cross-sectional causal relationship among individuals' preference for NTS, attitude for actual mode and experience of participation in the panel survey, will be analyzed using all samples including the refreshments.

The respondents are divided into thirteen segments by their numbers of participation. The numbers of respondents in these segments are shown in Table 3. The numbers of the respondents who took part in only one wave decline by degrees from wave 1 to 5. The respondents who experienced all five waves count 32, which correspond to only 6% of all samples at wave 5.

As can be seen in Table 4, the percentage of male respondents in this segmentation (ie. 84.4%) is highest in all segments at wave 5. The percentages of each segment gradually increase in proportion to the number of participation. Since the subjects of the SP panel survey are commuters and students, the male respondents who consist mainly of full-time workers may be easier to stay in the panel. The segment of the respondents who cooperate only once indicates a low share at each wave. Thus, the shares of male respondents are variant among samples who have different numbers of participation. However, as a result of panel refreshment, the male proportion in all samples is stable over time.

Table 5 summarizes the NTS shares broken down by numbers of participation in the panel survey. The segment of stayers in all past waves indicates the highest NTS shares of all others at each wave. The share differences between these stayers and all samples are statistically corroborated by t-test at each wave. As shown in Table 6, the differences at waves 3 and 4 are significant at the 5% confidence level. This means that an individual's mode choice preference is significantly related with their numbers of participation.

Estimation of LISREL models based on cross-sectional causal relationship

The cross-sectional relationship among three latent variables: individual's preference for NTS, attitude for actual mode, and experience of participation in the panel, was specified by LISREL models. As can be seen in Figure 5, a simple causal relationship at each wave was assumed based on Figure 3. The state dependence and serial correlation were, of course, not considered. SP responses from all samples at each wave were used to estimate the models. The numbers of samples were identical with the numbers of respondents times the numbers of repetitive SP questions at each wave, eliminating non-responses.

The latent endogenous variable of attitude for actual mode η_2^t is caused by two manifest variables of sex x_5^t (=1, if male) and car license x_6^t (=1, if holder), and is measured as a manifest indicator of actual mode y_2^t (=1, if car user). Then the latent variable of individual's experience of participation in the panel η_3^t is measured as the number of participation y_3^t.

These two latent variables have effects on the latent variables of preference for the NTS η_1^t. The attitude η_2^t also causes the experience of participation η_3^t. By introducing the experience variables in the model, the effect of the attrition bias on the other parameters can be eliminated.

Table 3 Numbers of respondents by numbers of participation at each wave

No.of participation	Wave1	Wave3	Wave4	Wave5
1	509	221	171	73
2	-----	322	141	154
3	-----	52	218	110
4	-----	-----	38	177
5	-----	-----	-----	32
All samples	509	595	568	546

Table 4 Percentages of male by numbers of participation at each wave

No.of participation	Wave1	Wave3	Wave4	Wave5
1	69.9	57.0	46.2	54.8
2	-----	73.3	55.3	53.9
3	-----	84.6	75.7	59.1
4	-----	-----	84.2	74.6
5	-----	-----	-----	84.4
All samples	69.6	68.2	62.3	63.6

Table 5 NTS shares by numbers of participation at each wave

No.of participation	Wave1	Wave3	Wave4	Wave5
1	52.2	52.7	49.9	49.0
2	-----	55.1	41.4	41.8
3	-----	63.2	41.6	44.0
4	-----	-----	64.0	43.3
5	-----	-----	-----	52.7
All samples	52.2	55.0	45.5	44.4

Table 6 T-test for differences of NTS shares between segmented and all samples at each wave

No.of participation	Wave1	Wave3	Wave4	Wave5
1	n.a.	1.09	1.69	1.25
2	-----	0.01	1.48	0.93
3	-----	2.25*	1.70	0.13
4	-----	-----	3.78*	0.43
5	-----	-----	-----	1.56

*=significant at 5% level

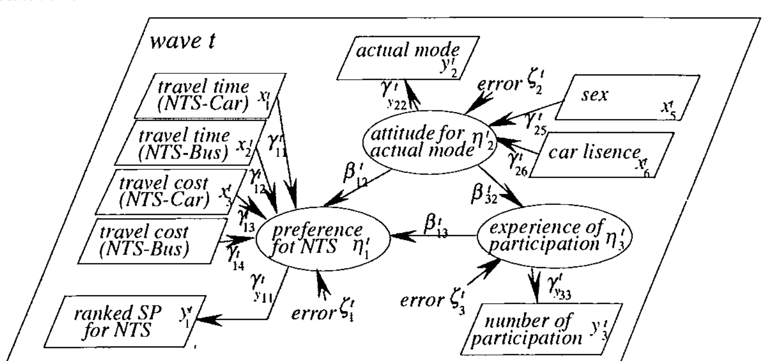

Figure 5 Cross-sectional causal relationship of preference for NTS with effect of experience of participation

The estimation results of LISREL models at waves 3, 4 and 5 are shown in Table 7. Since all respondents participated in the panel for the first time, the model cannot be estimated at wave 1. The coefficients of determination (total R^2) correspond to 0.862, 0.792 and 0.762 for waves 3, 4 and 5, respectively. These high values mean that the linear relationships assumed in models are very strong at these three waves. Judging from AGFI and RMR, it is found that those models have high explanatory powers.

Table 7 Estimation of cross-sectional LISREL models

	t=3		t=4		t=5	
Path	Parameter	t-values	Parameter	t-values	Parameter	t-values
SP $\lambda^t_{y_{11}}$	1.000	----	1.000	----	1.000	----
Actual mode $\lambda^t_{y_{22}}$	1.000	----	1.000	----	1.000	----
No. of participation $\lambda^t_{y_{33}}$	1.000	----	1.000	----	1.000	----
Level-of-services γ^t_{11}	-0.142	(-3.26)	-0.101	(-2.23)	-0.056	(-1.71)
γ^t_{12}	-0.245	(-6.85)	-0.072	(-2.09)	-0.105	(-2.81)
γ^t_{13}	-0.208	(-6.69)	-0.159	(-5.07)	-0.187	(-4.72)
γ^t_{14}	-0.293	(-26.6)	-0.146	(-4.02)	-0.209	(-21.5)
SE characteristics γ^t_{25}	0.046	(0.76)	0.185	(3.14)	0.053	(2.39)
γ^t_{26}	0.812	(14.2)	0.696	(12.9)	0.769	(10.7)
Latent variable β^t_{12}	-0.046	(-1.45)	-0.097	(-2.65)	-0.114	(-2.84)
β^t_{13}	0.116	(3.89)	0.065	(2.07)	0.083	(1.84)
β^t_{32}	0.427	(12.9)	0.461	(12.0)	0.435	(10.9)
Error variance ζ^t_1	0.776	(18.1)	0.911	(22.0)	0.870	(20.0)
ζ^t_2	0.294	(6.17)	0.343	(6.39)	0.359	(6.03)
ζ^t_3	1.150	(24.0)	1.163	(20.4)	1.120	(20.0)
Total R^2	0.862		0.792		0.762	
AGFI	0.994		0.990		0.994	
RMR	0.069		0.046		0.055	
No.of samples	2192		1605		1455	

All parameters of the paths (ie. γ^t_{11} , γ^t_{12}, γ^t_{13} and γ^t_{14}) from four level-of-service variables to the latent variable of preference have correct signs, and their t-values are significant at the 5% confidence level excluding the path γ^5_{11} from travel time (NTS-car) at wave 5. The t-values of the paths from socio-economic characteristics to attitude for actual mode are also statistically significant except γ^3_{25}.

The parameters of relationship between the latent variables are significant at 5 % levels except β^3_{12} and β^5_{13}. These parameters indicate that an individual's preference for NTS becomes lower as attitude for actual mode grows higher, but that it becomes higher as experience of participation increases. This result demonstrates that an individual's experience is an important causal factor of preference for NTS in addition to level-of-services and his/her attitude for actual mode.

The t-test for the equality of these parameters was made between two sequential waves. The results are shown in Table 8. The hypotheses were rejected in the case of γ^t_{12}, γ^t_{14} and γ^t_{25}. This leads to the conclusion that the causal relationship between the differences of travel time and cost of NTS and bus and preference for NTS is not temporally stable over those three years. With regard to latent variables, the hypothesis of the equality of parameters was accepted. This suggests that the effects of an individual's attitude for actual mode and experience of participation in the panel on preference for NTS are stable over time.

Table 8 T-test for the differences of the path parameters between two sequential waves

Path	t=3 and 4	t=4 and 5
Level-of-services γ^t_{11}	0.63	0.82
γ^t_{12}	3.42*	0.64
γ^t_{13}	1.08	0.55
γ^t_{14}	3.38*	1.75
SE characteristics γ^t_{25}	1.61	2.17*
γ^t_{26}	1.45	0.80
Latent variable β^t_{12}	1.01	0.31
β^t_{13}	1.14	0.32
β^t_{32}	0.64	0.47

*=significant at 5% level

In order to examine the temporal variation of the effects on individuals' mode choice preference, the total effects of the observed exogenous variables x^t and the latent endogenous variables η^t on ranked SP for NTS y^t_l were calculated by the following equations:

$$x^t \rightarrow y^t_l \;:\; \Lambda^t_y(\mathrm{I}-\mathrm{B}^t)^{-1}\Gamma \tag{5}$$

$$\eta^t \rightarrow y^t_l \;:\; \Lambda^t_y(\mathrm{I}-\mathrm{B}^t)^{-1} \tag{6}$$

As shown in Figure 5, concerning the observed exogenous variables, the total effects of the level-of-service variables (ie. travel time and cost) are higher than those of socio-economic characteristics (ie. sex and car license). Specifically, the effects of x^3_2 and x^3_4 at wave 3 are higher than those at waves 4 and 5. Concerning the endogenous variables, the total effect of attitude for actual mode η^3_2 on ranked SP for NTS at wave 3 is almost zero, but those at waves 4 and 5 have negative values. These results imply that the temporal variation of SP over four waves as shown in Figure 2 is caused by both travel factors for the NTS and bus, and attitude for actual mode.

CONCLUSIONS

In order to investigate the significant factors affecting the temporal variation of SP data, two hypothetical causal relationships in terms of individual preference for the NTS in Hiroshima were empirically examined, using LISREL models.

The longitudinal causal relationship with state dependence and serial correlation between error terms in the equations was analyzed based on the four-period SP panel data. The results of the model estimation demonstrated that individual mode choice preference was significantly affected by the level-of-services set up in the SP experiment and attitude for actual mode. The effect of state dependence was significant in the longitudinal causal relationship. It is believed that the SP variation over time is caused by actual and previous travel circumstances.

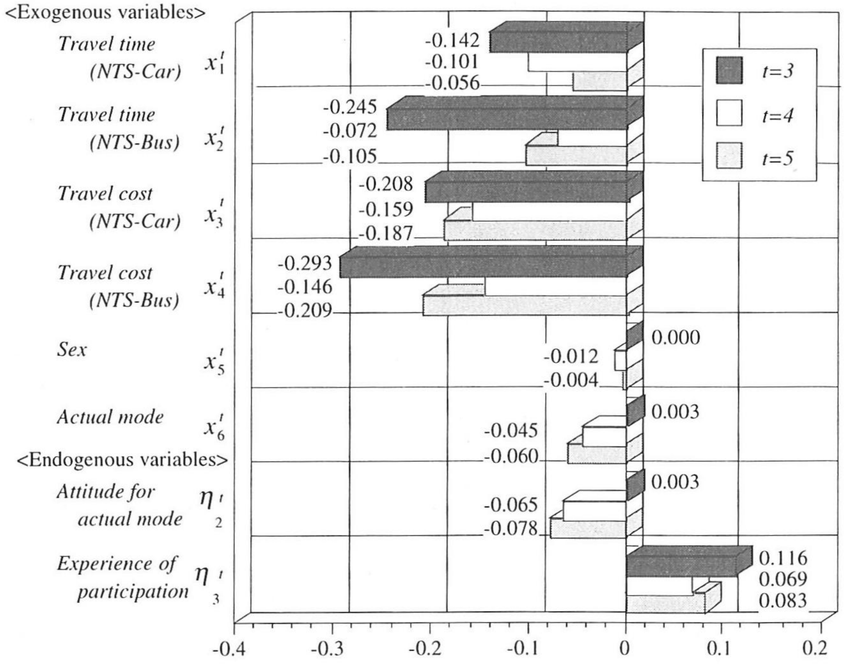

Figure 6 Total effects of exogenous and endogenous variables on ranked SP for NTS

The cross-sectional causal relationships among individual's mode choice preference, attitude for actual mode and experience of participation in the panel were explored based on the panel data including the new samples obtained by panel refreshment. It was found that the effect of an individual's experience of participation in the panel on the preference was an important determinant in addition to his/her travel circumstances. This leads to the finding that the attrition bias is likely variant over time in the case of multi-period panel data. From the results of the LISREL model, it is concluded that the differences of SP responses between the first two waves and the latter ones are caused by the travel factors for the NTS and bus, and attitude for actual mode.

These causal relationships are expected to be useful in developing dynamic mode choice models which consider the temporal variation of SP responses. Fortunately, as we have collected RP data after the opening of NTS from the same panel samples in this study, the external validity of the dynamic models will be examined in further work.

REFERENCES

Couture, M.R. and T. Dooley (1981) Analyzing traveler attitudes to resolve intended and actual use of a new transit service, *Transportation Research Record* , 794, 27-33.

Chang, G.L. and H.S. Mahmassani (1988) Travel time prediction and departure time adjustment behavior dynamics in a congested traffic system, *Transportation Research*, 22B(3), 217-232.

Fujiwara, A. and Y. Sugie (1995) Temporal stability of stated preference data, In: *Understanding Travel Behaviour in an Era of Change* (P.R. Stopher and M. Lee-Grosselin, eds.), Pergamon Press, Oxford (in press).

Golob, T. (1989) The causal influences of income and car ownership on trip generation by mode, *Journal of Transport Economics and Policy*, 23(2), 141-162.

Hensher, D.A. (1987) Issues in the pre-analysis of panel data, *Transportation Research*, 21A(4/5), 265-285.

Iida, Y., N. Uno and T. Yamada (1994) Experimental analysis approach to analyze dynamic route choice behavior of driver with travel time information, *Proceedings of Vehicle Navigation and Information Systems Conference*, Yokohama, Japan, August 31-September 2, 1994, 377-382.

Joreskog, K.G. and D. Sorbom (1986) *LISREL VII User's Reference Guide*, Scientific Software.

Kitamura, R. and P.H.L. Bovy (1987) Analysis of attrition biases and trip reporting errors for panel data, *Transportation Research*, 21A(4/5), 287-302.

Kitamura, R. (1990) Panel analysis in transportation planning: An overview, *Transportation Research*, 24A(6), 405-415.

Kitamura, R., R.M. Pendyala and K.G. Goulias (1993) Weighting methods for choice-based panels with correlated attrition and initial choice, In: *Transportation and Traffic Theory* (C. Daganzo, ed.), pp.275-294, Elsevier Science Publishers B.V., North Holland, Amsterdam.

Morikawa, T. (1994) Correcting state dependence and serial correlation in the RP/SP combined estimation method, *Transportation*, 21, 153-165.

Morikawa, T. and K. Sasaki (1994) Discrete choice models with latent variables using subjective data, *Paper presented at the 7th International Conference on Travel Behaviour*, Valle Nevado, Santiago, Chile, June, 1994, 13-16.

Pendyala, R.M., K.G. Goulias, R. Kitamura and E. Murakami (1993) Development of weights for a choice-based panel sample with attrition, *Transportation Research*, 27A(6), 477-492.

Pendyala, R.M. (1994) Causal analysis in travel behavior research: A cautionary note, *Paper presented at the 7th International Conference on Travel Behaviour*, Valle Nevado, Santiago, Chile, June, 1994, 127-138.

Pendyala, R.M. and R. Kitamura (1995) Weighting methods for choice based panel with attrition, In: *Panels for Transportation Planning* (T .Golob et al. eds), Kluwer Academic Publishers (in press).

Polak, J. and S. Meland (1994) Evidence on the temporal stability and inter-temporal properties of stated preference data, *Proceedings of 22nd PTRC Summer Annual Meeting*, University of Warwick, England, 12-16, September, 1994, 315-326.

Wardman, M. (1988) A comparison of revealed preference and stated preference models of travel behavior, *Journal of Transport Economics and Policy*, 22(1), 71-92.