A MODAL SPLIT MODEL FOR INTER-REGIONAL TRAVELLERS ON HOLIDAYS WITH THE CONSIDERATION OF INTANGIBLE FACTORS

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Abstract: This study focuses on the demand of inter-regional travelers on holidays, where trains are expected to return the demand back from automobiles. Most trips on holidays are made with a personal purpose, hence the mode choice behavior on holidays is influenced by diverse personal factors named "intangible factors" in this study. To properly analyze mode choice behavior in the above context, it is necessary to convert such exogenous intangible factors into predetermined endogenous factors. This paper analyzes inter-regional travel demand on holidays by applying the disaggregate mode choice model incorporated with LISREL to include the effects of intangible factors and also examines issues related to the collection of pertinent data in order to perform the abovementioned analysis.

Key words: Inter-Regional Transportation, Modal Split on Holidays, Intangible Factors

1. INTRODUCTION

Japanese society is confronted with strict economic condition because of ever-increasing number of senior citizens and a decreasing birthrate[1) 2)] as shown in Figure 1. Inter-regional trip generation for the purpose of business is not expected to increase under such conditions. Statistics show that the number of Shinkansen passengers has decreased in the past several years because of the worsening economic climate brought about by the decreasing mortality rate and birth rate as shown in Figure 2. Since historical high economic growth has changed the general Japanese lifestyle and has diversified the general sense of values, the Japanese government has announced that structuring a well-balanced society is one important guiding principal in shaping transportation policies. Besides, the two-day-off-a-week system became widely popular in 1990s', the law on national holidays was amended in 2000 to make some of national holidays consecutive. Consequently, the Japanese people acquired more holidays and got more opportunities to have extended holidays than ever before.

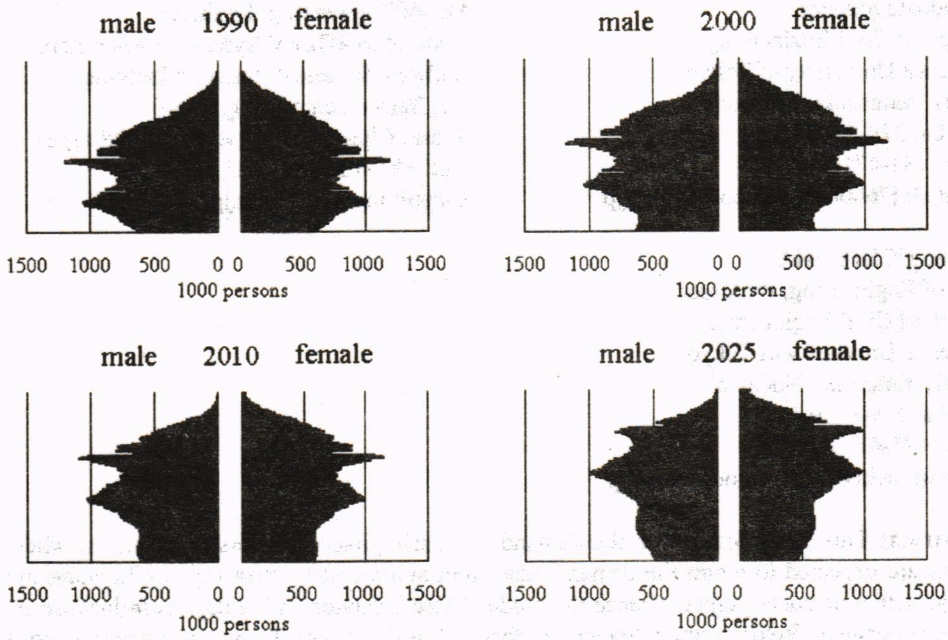

Figure 1. Population Pyramid in Japan from 1990 to 2025[2)]

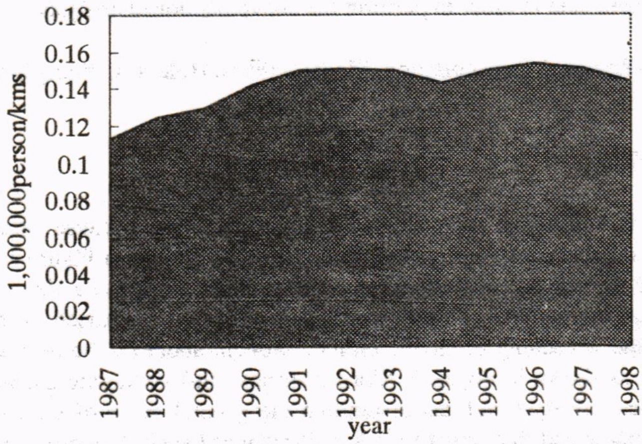

Figure 2. Density of Passengers on Shinkansen Lines

To date, the Japanese railways, which operate inter-regional express trains running on Shinkansen lines and ordinary lines are facing strict competition from other modes such as airplanes, automobiles and expressway buses in all categories of trip distance. Over the past few decades, automobiles had been getting the upper hand particularly in both the short- (between approx. 100kms up to approx. 300kms) and the middle (between approx. 300kms up to approx. 500kms) distance trips. The reason for this is increased car-ownership rates and the general expansion and improvement of the expressway network. From the point of view of environmental conservation along the roads, where traffic congestion is often observed on holidays, and promoting reduced polluted gas emissions, it is necessary to put in place a policy that will promote a modal shift from automobiles to public transportation on holidays.

It is recognized that efficient analysis methods and robust estimation models are necessary for the effective planning of services and enforcement. It is likewise recognized that the analyses and estimation models should be based on a good set of data. The current database used in most analyses related to inter-regional transportation planning in Japan comes from the Inter-Regional Net Flow Survey Data. The data is based on a nation wide trip survey conducted in 1990 and 1995. The data, however, was sampled from passengers on a weekday, and hence is not appropriate for the extraction of characteristics related to holiday trips. *M. Muto, H.Uchiyama*[3)] showed that diversified personal factors except for Level of Service (LOS) such as travel time and fare are effective parameters in modeling mode choice behavior on holidays. In this study, these personal factors are called intangible factors. Since these intangible factors are not included in the Inter-Regional Net Flow Survey database, it will be difficult to analyze and estimate the demand on holidays without additional data gathering exercises.

This study tries to explain the intuitively answered intangible variables with objectively observed variables such as trip attributes by applying the LISREL model. It also aims to introduce some proxy variables representing intangible factors estimated in the LISREL into a disaggregate modal split model in order to consider exogenous intangible factors quantitatively when the calibrated model is applied to a future estimation. The model system will imply what kind of data should be collected in future nation-wide surveys to improve the model calibration process with regard to inter-regional travel demand on holidays.

2. QUESTIONNAIRE SURVEY

2.1. Concept of the Survey

In the past decade, the importance of holiday trips both in inner regions and inter-regions has been recognized gradually in Japan, and several studies and academic discussions are available e.g. *K. Nishii, T. Morikawa et al.*[4)]*, 1999*. Some of the authors analyzed the modal split between inter-regional railways and automobiles on holidays to discuss the future directions of service plans on railways[3)]. Table 1 shows the estimated mode choice models in a previous study of *M.Muto, H.Uchiyama*[3)]

In model 1, only the time and fare are introduced as explanatory variables. The model is not efficient to represent the mode choice behavior on holidays. In model 2, the responses to some intangible factors are directly substituted as explanatory variables. This model reveals that introduction of these intangible factors has a great effect on the mode choice. For future estimation, it is necessary to represent these exogenous factors with some objectively predetermined exogenous ones. In this study, a pilot questionnaire survey regarding mode choice behavior between inter-regional express trains and automobiles on holidays was conducted to identify the relationship between the subjective intangible factors with objectively observed variables.

Table 1. Mode Choice Models in the Previous Study[3)]

	Variables	Model 1	Model 2
Common Variables	Travel time (hour)	-0.25 (-3.88)	-0.25 (-2.51)
	Fare (¥10,000)	-0.44 (-4.52)	-0.29 (-2.16)
Intangible Factors	Accuracy of time schedule (dummy)	***	2.30 (2.18)
	Safety (dummy)	***	2.48 (2.28)
	Easiness of loading baggage (dummy)	***	-3.08 (-5.26)
	Mobility (dummy)	***	-2.74 (-5.63)
	Railway constant	-0.31 (-1.62)	0.86 (2.63)
$\bar{\rho}$		0.070	0.611
Hit ratio (%)		68.0 (204/300)	90.3 (271/300)
Value of time (¥/min.)		93	140

( ) : t-value

2.2. Contents of Questionnaire

In order to identify the relationship between subjective and objective ones, the questionnaire was designed to consider the followings:

(1) To weigh the magnitude of importance on each intangible factor.
(2) To grasp trip and socio economic attributes which are expected to explain intangible factors as much as possible.

The contents in this questionnaire are shown in Table 2. The examinee is requested to answer 7 ranked (+1~+7) categorized magnitude of importance for each intangible factor.

Table 2. Contents of the Questionnaire

Experience of trips on holidays	**Trip attributes**
	season, itinerary, origin and destination
	other candidates of destination, departure time
	type and number of traveler, fare, trip purpose, who pays
	Transportation mode
	access, egress mode
	line haul mode and its traveling section
	use of discount fare (only for train users)
	use of parcel delivery service (only for train users)
	share of driving time (only for automobile users)
	type and number of automobiles (only for automobile users)
	Magnitude of importance on intangible factors (10 items)
	ability of reaching rapidly
	enjoyability of moving itself
	selectability of time schedule
	accuracy of time schedule
	familiarity
	easiness of loading baggage
	safety and security
	discount fare available
	economical cost such as paying one's share
	mobility
	Other reasons of mode choice behavior (24 reasons)
	mode captive or not
	single mode available
	possibility of meeting traffic jam etc.
Socio-economic Attributes	sex, rank of age, occupation
	driving license, car ownership

2.3. Conduct of Questionnaire Survey

A pilot questionnaire survey was conducted in Tokyo Metropolitan Area (TMA) shown in Figure 3. Sampled trips are limited to short and middle distance levels from TMA, where heavy competition between trains and automobiles is generally observed. The questionnaires were distributed to the mailboxes of the target residents in 50 representative districts in TMA The respondents were asked to fill up the questionnaire and return it through the postal service. The survey was conducted in November 2000 distributing a total number of 5000 questionnaires of which 633 were returned. Some samples, which were judged as a captive and single mode choice, were further excluded bringing the final sample size to 302.

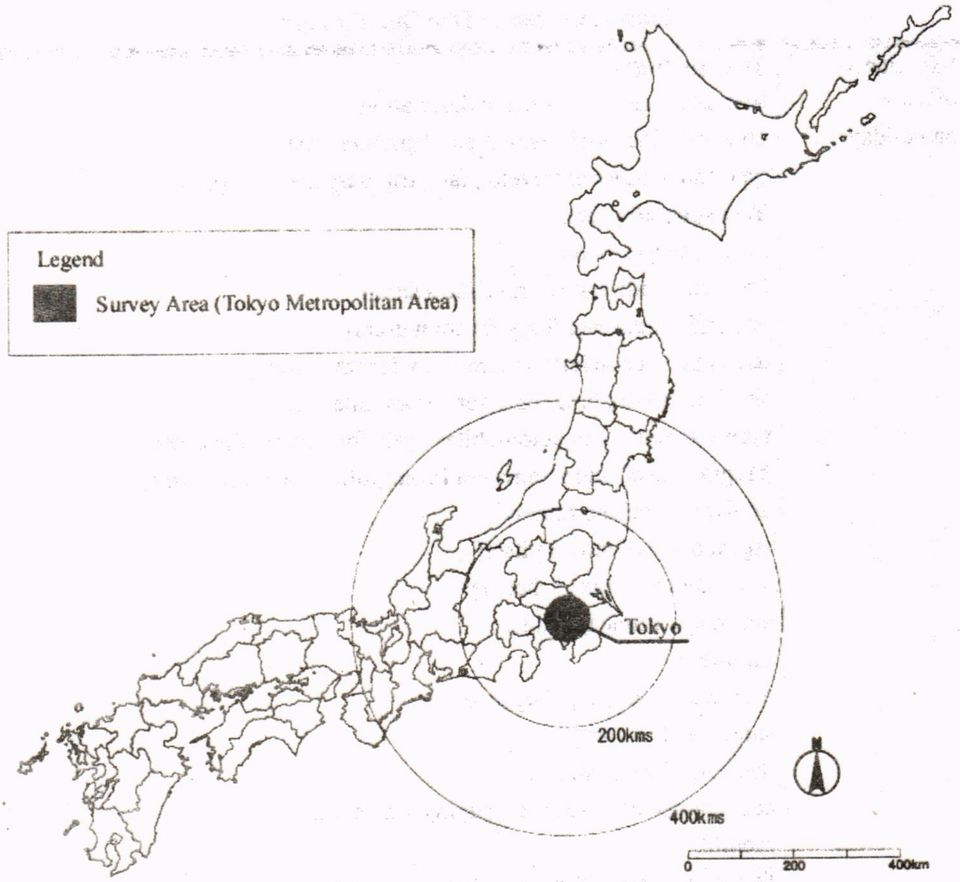

Figure 3. The Survey Area in this Study

3. INITIAL FINDINGS

The relative magnitude of importance of the 10 intangible factors was calculated per sample. This exercise confirms the characteristics and the tendency of mode choice behavior on holidays. Figure 4 shows the mean values of the relative magnitude of importance of each intangible factor across the whole 302 samples.

Figure 4 shows that railway users place weight particularly on "ability of reaching rapidly", "accuracy of time schedule" and "safety and security" while automobile users give more importance to "easiness of loading baggage" and "mobility". Figure 4 brings out some typical characteristics which can be attached each mode, and highlights the differences between railway users and automobile users with regard to the magnitude of importance of the different intangible factors vis-à-vis mode choice. "Enjoyability of moving itself", "selectability of time schedule" and "familiarity" are common intangible factors because these are important regardless of the mode choice.

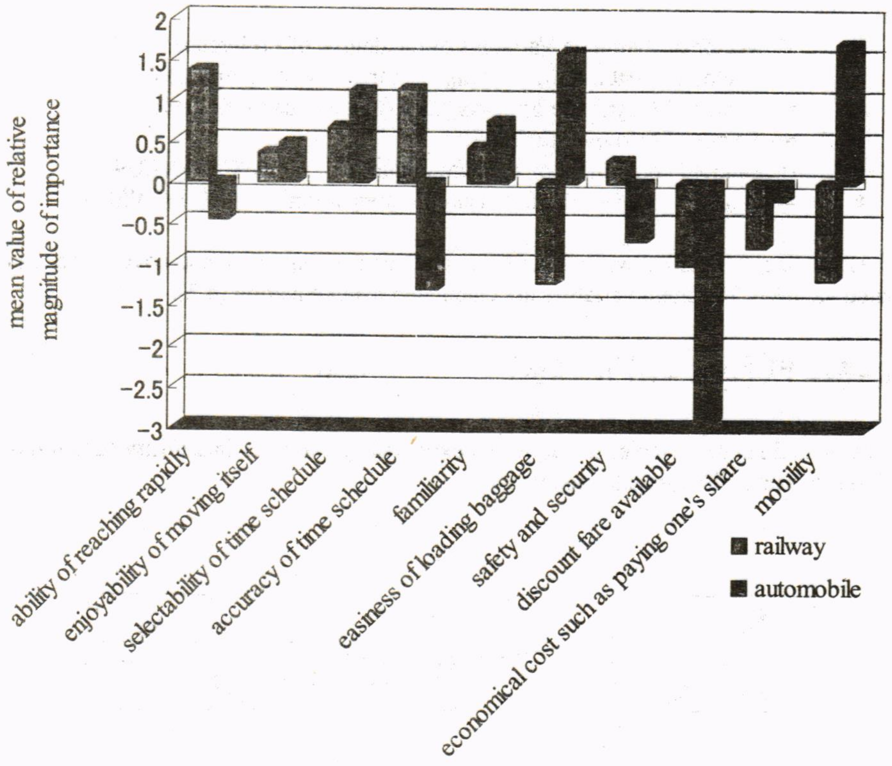

Figure 4. Mean Value of Relative Magnitude of Importance

4. MODAL SPLIT MODEL

4.1. Model System

Some attempts to analyze choice behavior considering personal factors have been made since the disaggregate modeling system appeared[5]. The method of estimating a disaggregate model with indirectly determined latent variables was proposed by *T. Morikawa et al.*[6) 7)].

First, it is necessary to identify the relationship between subjectively observed magnitude of importance, synthetic variables named Synthetic Variables of the degree of Preference for Railways or Automobiles (SVPR, SVPA) and some attributes by calibrating the Multiple Indicator Multiple Cause (MIMIC) model, a kind of Linear Structural Relationship (LISREL) model as shown in Figure 5.

A MIMIC model is composed of a structural equation (4.1) and a measurement equation (4.2) formulated as follow:

$$\mathbf{w} = \mathbf{B}\mathbf{s} + \zeta \tag{4.1}$$

$$\mathbf{y} = \Lambda \mathbf{w} + \varepsilon \tag{4.2}$$

where

$\mathbf{w}$	=	vector of Synthetic Variables of the degree of Preference
$\mathbf{s}$	=	vector of attributes identifying $\mathbf{w}$ in the structural equation
$\mathbf{y}$	=	vector of magnitude of importance of each intangible factor
$\mathbf{B}, \Lambda$	=	vector of unknown parameters
ζ	=	random component of structural equation $A/W\ MVN(0, \Psi)$
ε	=	random component of measurement equation $A/W\ MVN(0, \Theta)$

After estimating all unknown parameters and computing variance-covariance matrix, estimated values of the latent variables are calculated using equation (4.3).

$$\hat{\mathbf{w}} = \hat{\mathbf{B}}\mathbf{s} + \hat{\Psi}\hat{\Lambda}'\left(\hat{\Lambda}\hat{\Psi}\hat{\Lambda}' + \hat{\Theta}\right)^{-1}\left(\mathbf{y} - \hat{\Lambda}\hat{\mathbf{B}}\mathbf{s}\right) \tag{4.3}$$

These estimated latent variables are added as explanatory variables in a utility function of the model to estimate a disaggregate model.

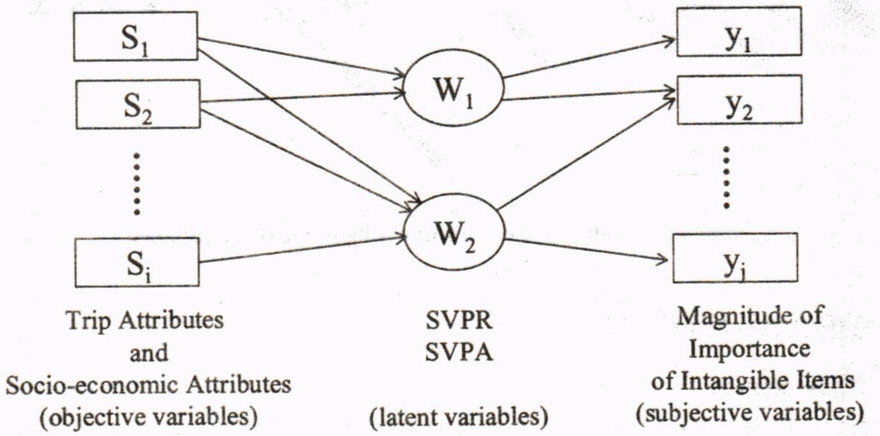

Figure 5. Path diagram for the MIMIC Model in this Study

4.2. Mimic Model

The path diagram of the calibrated MIMIC model is shown in Figure 6. Table 3 and 4 show the estimated standard regression weight. The collected magnitude of importance may be represented discretely as categorical data in a vector $\mathbf{y}$. But theoretically, the assumption that the categorical data is a continuous standard distribution may lead to better result. Experimentally however, it can be shown that over 5 categorical data can be used as a continuous quantity[8]. Therefore, in this study, magnitude of importance of each intangible factor is inputted "as is" in a vector y.

The variable "out of line haul time on railway" is equivalent to the summation of AC, EG, and transfer time in case of using trains. GFI is Goodness of Fit Index of the estimated model, and AGFI is Adjusted GFI.

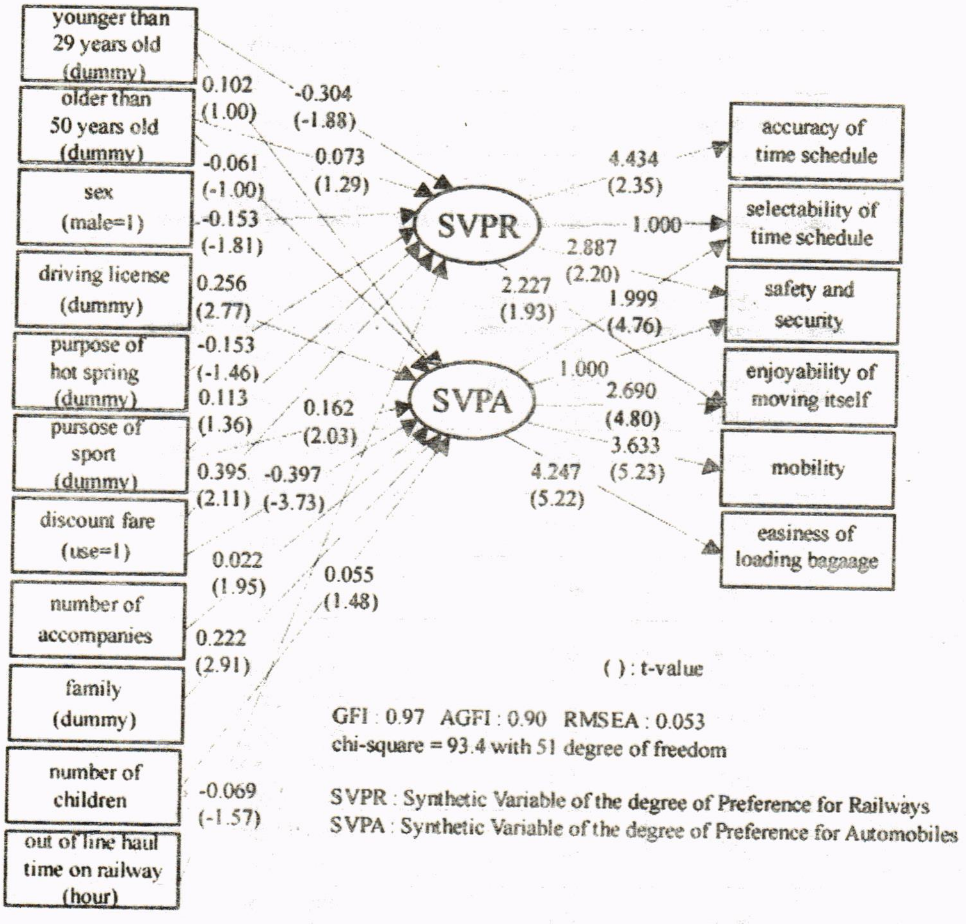

Figure 6. The Path Diagram of the MIMIC Model

From the fitness shown by GFI, AGFI and chi-square, the model shows the relationship between objectively observed attributes, intuitively answered factors and intervening synthetic variables, the SVPR and the SVPA. With regards to the measurement equation, "accuracy of time schedule" and "safety and security" have particularly heavier weights to the SVPR. By contrast, "easiness of loading baggage" and "mobility" have heavier weights to the SVPA. These correspond to typical characteristics of preference components with respect to each mode in this model.

Table 3. Estimated Parameters on Measurement Equation

SVPR (latent variable)	SVPA (latent variable)	Magnitude of importance of intangible factor (subjective variable)
standard regression weight		
0.871	***	accuracy of time schedule
0.205	0.514	selectablility of time schedule
0.657	0.285	safety and security
0.465	0.704	enjoyability of moving itself
***	0.771	mobility
***	0.907	easiness of loading baggage

Table 4. Estimated Parameters on Structural Equation

SVPR (latent variable)	SVPA (latent variable)	Attribute (objective variable)
standard regression weight		
-0.220	0.059	younger than 29 years old (dummy)
0.092	-0.061	older than 50 years old (dummy)
-0.180	***	sex (male=1)
***	0.174	driving license (dummy)
-0.113	***	purpose of hot spring (dummy)
0.101	0.115	purpose of sport (dummy)
0.363	-0.291	discount fare (use=1)
***	0.117	number of accompanies
***	0.208	family (dummy)
***	0.096	number of children
-0.126	***	out of line haul time on railway (hour)

The structural equation shows the influent weights of each attribute to the SVPR and the SVPA. The sign of each parameter is consistent with their intuitive effects. For example, whether the traveler uses any kind of discount fare or not has greater effect on both the SVPR and the SVPA. This implies that the availability of discount fare may be considered to be one of the important elements for railway users.

For future estimation, the SVPR and the SVPA must be predicted indirectly using only the structural equations for each sample. In the MIMIC model, the values predicted using only the structural equations may be considered relatively insignificant. To improve it, it is proposed that the samples be divided into groups having similar preference using market segmentation[7]. This however, will necessitate the use of a larger sample size.

4.3. Disaggregate Modal Split Model

Disaggregate modal split models between trains and automobiles were also calibrated, the results of which are shown in Table 5. In the case of traveling with a family, the fare is equivalent to the summation of the individual family members[3].

Table 5. Estimated Parameters on Modal Split Models

	Variables	Normal Logit Model	Model with SVPR &SVPA
Common Variables	Travel time (hour)	-0.39 (-3.36)	-0.45 (-2.12)
	Fare (¥10,000)	-0.59 (-3.70)	-0.53 (-1.99)
Intangible Factors	SVPR	* * *	6.21 (7.23)
	SVPA	* * *	-5.40 (-7.64)
	Railway constant	-0.61 (-2.41)	0.92 (1.42)
$\bar{\rho}$		0.124	0.684
Hit ratio (%)		64.9 (196/302)	90.7 (274/302)
Value of time (¥/min.)		112	144

( ) : t-value

Although, both time and fare, most often used explanatory variables in mode choice modeling have significant t-values, the goodness-of-fit shown by the likelihood ratio is insignificant in the Normal Logit Model. As for the model with the SVPR and the SVPA, the goodness-of-fit is improved by the introduction of the synthetic variables. This suggests that the magnitude of importance of some intangible factors has profound effect on mode choice behavior on holidays than conventionally used variables. The introduction of the SVPR and the SVPA therefore greatly helps to explain mode choice behavior on holidays.

Comparing the above result to that of the models shown in Table 1[3)], it can be observed that the change in the value of the parameters and the t-values between with and without intangible factors exhibit similar tendencies. This indicates considering magnitude of importance produce a stable and efficient way of estimating modal split models for inter-regional holiday trips.

5. CONCLUSION

This study demonstrates the significance of treating exogenous intangible factors as predetermined endogenous synthetic variables in the mode choice behavior of inter-regional trips on holidays. The correspondence of the factors was established by applying the LISREL model. The estimated mode choice model reveals the SVPR and the SVPA have a profound effect on the mode choice behavior. In addition, the mode choice model with consideration of magnitude of importance of some intangible factors is stable and efficient.

This study also reveals the some issue regarding the survey of the inter-regional trips on holidays. It shows that it is necessary to collect a larger number of samples to represent intangible personal factors.

Finally, this paper concludes that:

(1) Treating the magnitude of importance of some intangible factors as predetermined endogenous variables is important and stable for estimating a mode choice model for inter-regional holiday trips.
(2) It is necessary to conduct this kind of survey in large nation-wide scale, which shall help to analyze and estimate the demand as to inter-regional trips on holidays.

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