Development of a choice model in consideration of the contingent factor of SP data
-Contextual influences and the cognitive boundaries of attributes-

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1. Introduction

Choice responses from hypothetical stimuli are categorized into stated preference (SP) because analysts assumed respondents choose an alternative according to preferences. The stated preference was originally introduced by Arrow (1953) and getting popular in late 1980's (Bates, 1988). The most prevailing and useful method to analyze SP data is discrete choice models such as Logit model (Ben-Akiva and Lerman, 1986) based on the utility maximizing theory in microeconomics. This powerful and easy tool made it convenient for transportation analysts to use SP method in demand forecasting. Especially, SP model is applicable to non-existing alternatives. Those models relate stated choice responses with proposed conditions via weight parameters. These parameters are estimated plausibly to explain the choice data. The weight parameters of attributes consequentially show tastes of individuals. Moreover, the analysts can control the co-linearity between attributes. Thus SP model can give analyst more efficient parameter, while RP model sometimes fails to get efficient parameters even in the important attributes in mode choice such as travel time and travel cost. However, reliability and stability of the parameters has been controversial because SP data is not based on actual behavior on real market. The future behaviors may not be consistent with the stated choices. Especially, when the purpose of stated choice survey is for improvement of transportation facility, respondents tend to overestimate own intention. This kind of bias in stated choice is called as policy control bias. This kind of bias was often discussing in CVM method (Kahneman and Knetsch, 1992), too. The purpose of this study is to reduce this kind of bias, modeling the decision-making processes using stable indicators. Consequentially, the prediction power will be improved.

Attitude is another psychometric data that measure the taste of individual. In the travel behavior analysis, evaluations of an alternative and importance ratings of attributes are generally used as attitudinal variables. These kinds of data were used in travel behavior analysis, before SP became popular (Recker and Golob, 1976; Louviere, 1979; Koppelman and Patrica, 1981). Attitudes are mainly used in marketing and psychological researches. Those researches have tested the stability and reliability of attitudes. Importance rating of an attribute as attitudinal variable measures the taste of individual, while a weight parameter for the same attribute means the taste against the attribute. Therefore, we thought these measure the same latent factor in the different ways. This means supplemental use of attitudinal data in stated preference model will give analysts richer information of decision-making process. This research focused on this point and apply these data to decision making modeling as measurement information.

2. Validation of Stated Choice Data

Greene and Srinivasan (1978) discussed the reliability of SP data on conjoint analysis and indicated four sources of error. Those are inaccuracies in the preference judgments, validity of constructed stimuli, errors in the estimation procedure, and time instability. From the view of survey design, there are a lot of researches to improve the reliability of SP data (e.g. Green and Srinivasan (1978), Louviere (1988)). For example, computer based interview improves the validity of stimuli, since it can change the range of attributes instantly (Bradly and Daly, 1994). Combining multiple data source such as RP-SP improves reliability of utility parameters (Morikawa, 1994; Swait, Louviere and Williams, 1994). The relaxation of assumptions of error term is one of the effective methods to remove unessential constraint (Louviere, Hensher and Swait, 2000).

Combining revealed preference (RP) and stated preference assumed that SP and RP data had measured preference in a different way. Based on this assumption, Morikawa (1989) proposed a method of combining RP data with SP data to identify parameters in utility functions clearly. This method needs the proportional relation of utility parameter in SP and RP data. This implies that core structure of utility function is the same inside RP and SP. Several researches tested the hypothesis and showed that it was impossible to reject the hypothesis using inter-city mode choice data (Morikawa, 1989; Ben-Akiva and Morikawa, 1990; Deighton et al., 1994). However, utility parameters in the RP model have sometimes unexpected signs. Those parameters are sometimes not significant even in important attributes. In this case, the hypothesis will be rejected. Leisure trips, which are influenced by many latent factors such as heterogeneity, are difficult to keep this hypothesis.

Another method to validate SP parameter is to consider the structure of random term. Brownstone and Train (2003) showed mixed logit model that has flexible error structure than that of ordinary logit model assuming I.I.D. Gunbell distribution. If instability of SP model is caused by a few sources, and if we can know the source of error and its structural effect to choice responses clearly, we will be able to describe its error structure in a model. These models can include some sources of errors explicitly and validate the utility parameters.

3. Attitude and Attitudinal Indicators

In behavioral psychology, attitude is regarded as a main factor that influences behaviors (Fishbein, 1975). There are several definitions of attitude, however that can be summarized as "a person's overall evaluation of a concept". In marketing research, attitude is also important factor to comprehend the consumer behavior (Olson, 1998). Psychologists and marketing researchers studied attitudes in detail how attitudes affect behavior and when attitudes change (e.g. Eagly and Chaiken, 1993). The basic statistical analyzing method with a concept of attitude is developed by Fishbein-Ajazen model (Ajzen and Fishbein, 1980). This model is called Reasoned Action model. Several extended model, such as the Multiple Attributes Model, are also developed.

When applying these kinds of statistical models to analyzing behaviors, the stability of attitudes is concerned with the adequacy of prediction. Sivack and Crano (1982) showed deep interest in an object increased the stiffness of relationship between attitude and behavior. Snyder and Kendziersky (1982) investigated the stability of attitude. They concluded if a given behavior is embedded in a context of availability of an attitude corresponding to behavior, and a given attitude is embedded in a knowledge about the relevance of an attitude for consecutive behavior, the relation of attitude and behavior will be difficult to observe. Snyder (1982) found that those who is influenced by situational conditions would yield a low consistency. Zanna and Olson (1982) and Zanna, Olson and Fazio (1980) said that attitudes based on direct behavioral experiences are more predictive of a later behavior than attitudes based on indirect or non-behavioral experiences. As stated in this section, attitude is stable over time, under several conditions. Consequently, this study uses importance ratings of attributes for mode choice as attitudinal indicators based on practical experience as supplements of stated choices. In the next chapter, we are going to show the methodologies combining those attitudinal indicators with stated choices. The methodologies are based on behavioral hypothesis.

4. Behavioral Hypothesis of Attitudinal Indicator and Its Modeling

Here, we show a hypothesis between the attitudinal indicators (importance ratings) and the stated choices. We also show the modeling methodology in this chapter.

The hypothesis we test in this paper is below.

"attitudes relate to the involvement of attributes and to cognition of attributes"

This hypothesis means that the importance ratings measure the involvement in attributes. An attribute is more important for one who is involved with the attribute. Some past researches found that the design of the questionnaire and the context of SP experiments tend to have influence on stated choices. Besides that, respondents tend to answer the questionnaire considered not all the attributes but a few important attributes (Ortuzar and Rodriguez, 2000). Decision-makers attempt to simplify problems because of saving their calculation resources. Sometimes the choice situation is too complex to choose instantly. One method to simplify the choice problem is to judge one attribute similar, if the attribute of two alternatives is alike (Rubinstein, 1988). Consequently, decision-maker can reduce the number of elements to consider. Next, we translate this hypothesis into mathematical formula. To simplify the notation, suffix *n* for an individual is omitted.

Here are the properties of similarity relation on the set $I = [0,1]$. The notation of similarity is "~". This was quoted from the Rubinstein's (1988) definition.

1) reflexivity: For all $a \in I, a \sim a$
2) Symmetry: For all $a, b \in I, if\ a \sim b, then\ b \sim a$
3) Continuity: The graph of the relation ~ is closed in $I \times I$
4) Betweenness: $if\ a \leq b \leq c \leq d\ and\ a \sim d, then\ b \sim c$
5) Nondegeneracy: $0 \sim 1$, and for all $0 < a < 1$, there are b and c so that $b < a < c$ and $a \sim b$ and $a \sim c$. For $a = 1$, there is $b < a$ so that $a \sim b$.
6) Responsiveness: denote by a^* and a_* the largest and the smallest elements in the set that are similar to a. The a^* and a_* are strictly increasing functions (in a) at any point at which they obtain a value different from 0 or 1.

One of the definitions of similarity for one attribute that satisfies these aspects above is derived from a quotient on the attributes of two alternatives.

$$X_{ik} \sim X_{jk},\ if\ \frac{1}{\delta_k} < \frac{X_{ik}}{X_{jk}} < \delta_k\ \ j \neq k \tag{1}$$

δ_k : a threshold value of similarity on attribute *k*, which should be lager than 1

Now, we are going to apply the definition of similarity into random utility model. The random utility model is denoted below.

$$U_i = \sum_k \alpha_k X_{ik} + \varepsilon_i \tag{2}$$

U_i : random utility of alternative *i*
α_k : unknown parameter for *k*th explanatory variable
X_{ik} : *k*th explanatory variable of alternative *i*

Similarity means that an individual regards an attribute of different alternatives as identical value. In random utility model scheme, forcing a utility parameter into 0 becomes the same as the similarity. Thus, equation (3) has the same meaning with equation (1).

$$\alpha_k = 0 \quad if \ \frac{1}{\delta_k} < \frac{X_{ik}}{X_{jk}} < \delta_k \ j \neq i \tag{3}$$

To keep the condition that δ_k is larger than 0, we define δ_k as an exponential function.

$$\delta_k = 1 + \exp(\theta_k) \tag{4}$$

θ_k : an unknown parameter

Therefore, a utility parameter varies discontinuously. Latent class model (e.g. Kamakura et. al, 1996) is useful to model this kind of variation of utility parameter. In this vein, we redefine the utility function in latent class mode scheme. However, this definition makes the choosing probability of alternative *i* discontinuous with the threshold value. This discontinuity is undesirable on estimation of random utility model. Considering this aspect, the definition of similarity is modified as described below. A random term is added to δ_k. Besides that, equation (3) assumes the threshold deterministic. Equation (5) also makes this assumption relax.

$$\alpha_{nk} = 0 \quad if \ \frac{1}{1+\exp(\theta_k + \xi)} < \frac{X_{nik}}{X_{njk}} < 1 + \exp(\theta_k + \xi) \ j \neq i \tag{5}$$

ξ : an error term

By defining the distribution of random term, the probability of $\alpha_{nk} = 0$ can be defined.

$$P(\alpha_k = 0) = P\left(\frac{X_{ik}}{X_{jk}} < \frac{1}{1+\exp(\theta_k + \xi)} \ or \ 1+\exp(\theta_k + \xi) < \frac{X_{ik}}{X_{jk}} \right) \tag{6}$$

This can be read as membership of latent class model with two latent classes.

$$P(s_1) = P(\alpha_{k|s} = 0)$$
$$P(s_2) = P(\alpha_{k|s} \neq 0)$$

Assuming that attitudes (importance ratings) affect the thresholds is quite natural, because unimportant attribute tends to be ignored. According to this assumption, we write measurement equations of attitudes as equation (7). Note in equation (7) that to simplify the notation, we focused on only one attribute.

$$y = \begin{cases} 1 \; if \theta_k + \xi \geq \mu \\ 0 \; if \theta_k + \xi < \mu \end{cases} \tag{7}$$

y: an attitudinal indicator

Introducing the same assumption of equation (3) into equation (7), we can define the probability observing indicator y.

$$P(y_g) = \{P(y=1)\}^{y_g}\{1-P(y=1)\}^{1-y_g} \tag{8}$$

We can finally deduce the joint probability of stated choice and attitudinal indicator.

$$P(i,y) = \int_w \left[\sum_s \left\{ \frac{\exp(V_{i|s})}{\sum_j \exp(V_{j|s})} \cdot P(s) \right\} \times \left[\{P(y=1)\}^{y_g}\{1-P(y \neq 1)\}^{1-y_g} \right] \times f(\theta) \right] d\theta \tag{9}$$

This definition is a kind of semi-lexicographic strategy (Kurauchi and Morikawa, 2001). Using an attitudinal indicator as measurement of utility parameter would improve stability and predictability of the model.

5. Empirical Study

5.1 Descriptions of Data Used

The survey was conducted in 1992 to measure demands for introducing of high-speed ferry to Tokyo Bay. The samples were randomly selected from tourists near the ferry terminal. This survey consists of three parts. One is questionnaire about attributes of the trip. The others are intention of using new ferry, and importance ratings of the attributes of the ferry. The intentions of using new ferry were asked on six profiles, which consist of travel cost and frequency as shown in **Table 1**. Travel time was neglected because it was impossible to vary actual travel time of new ferry. As see in **Table 1**, this data had possibility to be biased because the travel time did not appear in the profile of new ferry. The answers of the survey were converted to choice data between actual mode and the new ferry. The importance ratings of attributes were asked in binary choice format. The format is choice from two alternatives "important" or "not important", which are asked about each eight attributes shown in **Table 2**. The number of effective samples is 210.

We used one of these importance ratings as an attitudinal indicator. All the respondents are expected to have enough experiences of using transportation alternatives. Consequently, they have substantial attitudes for the attribute importance.

5.2 Estimation Results and Discussion

Before inspection of the estimation result of proposed model, we show the estimation result of ordinary Logit model. This is easier way to compare the efficiency of our proposed model. **Table 3** show the estimation result of ordinary Logit model based on random utility. Both the individual attributes and constant are in the utility function of new ferry. Consequently, if an explanatory variable has positive sign, it means that the attribute increases the utility of new ferry. The result may look good, however, the value of time calculated from the result in **Table 4** was 84 yen/min (=0.7 $/min). That is too expensive than the average of other reports. The overestimated time value will cause over-prediction of ferry demand. There are several ways to use attitudinal indicator such as importance ratings. The most naive method is to incorporate attitudinal indicators as explanatory variable into utility function. The estimated result of this model is shown in **Table 4**. To simplify the understanding of the effect of the attitudinal indicator, we use only one attitudinal indicator. We use “importance of less travel time” as an representative attitudinal indicator. This model is a kind of Reasoned Action Model, which was mentioned in chapter 3. The estimated parameter of attitudinal indicator is not significant. Therefore, importance rating for travel time has no direct effect to the stated choice. The parameter is not different significantly from the parameter of the model without attitudinal indicator shown in **Table 3**. These results imply that this type of usage of attitudinal indicator is impropriety. The value of time calculated from the result in **Table 4** was not so different from that by **Table 3**.

The estimated parameters of the proposed model to the actual data are shown in **Table 5**. The fixed parameter is only “travel time” reflecting the attitudinal indicators “importance of less travel time". This model is estimated using common variables in **Table 4**. That is, the same input information to construct the model. In this model, time attribute is judged as similar, if the quotient of presented time and actual time is within the thresholds. The estimate of D is nearly equal to zero. Thus, T is 2. That is, respondents judge the time as similar, if the travel time presented in SP experiment is between double and half of actual travel time, although this is extreme of threshold. The value of time is 48 yen/min (=0.4 $/min) in the latent class 2. This is usual value of time in Japan. Latent class 1 has no value of travel time. This shows that respondents expected that the time is not so different from current situation and they were interested only in the travel cost.

6. Conclusion

This study proposed a methodology that integrates attitudinal indicators and stated choice. This modeling scheme is to acquire plausible utility parameter and predictive power. The cue of this approach is that we got evident over-estimated value of time by naïve SP model. Then we tried to incorporate attitudinal indicator into RUM (random utility model) to get plausible value of time, because the contextual effect of the survey is expected to influence attitudinal indicator. The proposed methodology in this paper has focused on the similarity of attribute because some research reported that respondents tend to omit some attributes according to their attitudes. As a result, we got plausible value of time. Other than the proposed method, we have estimated several models such as "a-priori segmentation by attitudinal indicators", "latent-class-model in which the membership of each class consists of attitudinal indicators". But, those did not show appropriate value of time.

This study is one of a methodology that reinforces the prediction accuracy of stated preference model. We think that the data we used in this study was contextually affected. In this case, our model is effective. For a data that is dominated by other contingency, our model will not correct the parameters. Thus, we concluded that analysts should identify the cause that affects the utility parameter and apply appropriate model to the data.

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TABLES

Table 1 An Outline of SP Experiments

Condition of New Ferry	Travel Cost per Person (Yen)	Frequency (Per Hour)
Case 1	3,000	3
Case 2	4,000	3
Case 3	2,500	3
Case 4	5,000	4
Case 5	3,500	4
Case 6	4,000	2

Table 2 Importance Ratings for Mode Choice

Attribute of the Mode	Importance in Mode Choice	
Less Congestion in the Vehicle or Coach	Important	Not Important
Less Transfer	Important	Not Important
Better Riding Comfort	Important	Not Important
Easier when with Luggage	Important	Not Important
Less Noise while the Trip	Important	Not Important
Less Expensive	Important	Not Important
Less Travel Time	Important	Not Important
Better Reliability on Arrival Time	Important	Not Important

Table 3 Estimation results of ordinary Logit model

Variable	Estimates	T-statistics
New ferry Constant	-1.71	-5.43
Travel Cost per person	-1.44	-6.33
Line-haul travel time	-1.21	-5.19
Frequency of new ferry	1.43	9.29
Female dummy	0.274	1.35
Age under 20 dummy	-0.677	-3.24
Age over 50 dummy	0.248	1.00
Business trip dummy	-0.574	-2.17
Leisure trip dummy	-0.483	-2.05
Sports activity dummy	0.447	2.19
Sample size	818	$\bar{\rho}^2 = 0.235$

(Grey cells: insignificant at 5% hazard)

Table 4 Estimation result of the model with attitudinal indicator as an explanatory variable

Variable	Estimates	T-statistics
New ferry Constant	-1.55	-4.82
Travel Cost per person (10000 yen)	-1.50	-6.07
Line-haul travel time (100 min)	-1.18	-4.92
Frequency of new ferry	1.43	9.30
Female dummy	0.255	1.18
Age under 20 dummy	-0.733	-3.20
Age over 50 dummy	0.254	1.08
Business trip dummy	-0.608	-2.19
Leisure trip dummy	-0.466	-1.91
Sports activity dummy	0.498	2.25
Less travel time	-0.262	-1.25
Number of Observation	818	$\bar{\rho}^2 = 0.235$

(Grey cells: insignificant at 5% hazard)

Table 5 Estimation result of proposed model

Variable names	Latent Class 1		Latent Class 2	
New ferry constant	-12.1 (-3.7)			
Travel Cost per person (10000 yen)	-2.58	(-3.0)	-7.33	(-2.8)
Line-haul travel time (100 min)	0*		-3.54	(-2.7)
Frequency of new ferry	6.90	(4.0)	27.0	(3.9)
Female dummy	0.710 (1.1)			
Age under 20 dummy	-1.63 (-2.2)			
Age over 50 dummy	0.441 (0.6)			
Business trip dummy	-2.51 (-2.4)			
Leisure activity dummy	-1.45 (-2.3)			
Sports activity dummy	0.568 (0.9)			
ϑ	-0.0215 (-0.3)			
φ	0.695 (9.4)			
Number of observations	818			
Goodness of fit indicator	$\bar{\rho}^2 = 0.502$			

(Grey cells: insignificant at 5% hazard) *Fixed parameter