EFFECTS OF THE DIFFERENCE OF SP EXPERIMENTS AND TRANSPORTATION CIRCUMSTANCES ON TRANSFERABILITY OF SP-BASED MODE CHOICE MODELS
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abstract: This paper discusses effects of the difference of SP(Stated Preference) experiments and transportation circumstances on transferability of SP based mode choice models. Main findings are as followings. Firstly, the number of attributes or types of attributes used in SP experiment had significant effects upon the transferability of mode choice models. Secondly, spatial transferability of models estimated from SP data was scarcely affected by the different transportation circumstances. Finally, the update of alternative specific constants and additional update of scale produced a substantial improvement in the transferability of models. Future research will have to consider the market segments.

1. INTRODUCTION

Much research has been done on the stability of parameters of disaggregate travel demand models across space and time(Atherton & Ben-Akiva(1976), Koppleman & Wilmot(1982), Galbraith & Hensher(1982) and Polak & Meland(1994)). The reasons are as follows. Firstly, evidence of stable values of estimated parameters could prove a direct indication of model validity. Secondly, a model that is not stable over time is likely to produce inaccurate predictions. Finally, transferable models should allow for more cost-effective analysis of transport plans and policies. As traditionally estimation of travel demand models has relied on revealed preference(RP) data using the methods of discrete choice analysis, research on stability of parameters of disaggregate travel demand models has depended on travel demand models estimated from RP data. However, there has been an awakening interest in the use of stated preference(SP) data in transportation demand analysis. The theory and practice of SP which uses the respondent's expressed preferences to hypothetical situations has developed rapidly in transportation areas during past two decades.

However, at the same time as the advantages of SP are now generally appreciated, there is also a growing recognition among researchers that there remain many crucial aspects of existing SP techniques that are under-researched and poorly understood. This has motivated a growing critical interest in methodological aspects of SP. For example, some researchers on the reliability of SP data indicate that biases resulting from several reasons exist in SP data(Ben-Akiva, Morikawa & Shiroishi(1990)). It is clear that there are state-dependence and serial-correlation biases in SP data. In addition to these, some researches demonstrated the existence of significant task-order and fatigue effects in certain types of SP data(Bradley & Daly(1994)). However, the use of personal computers to collect SP data and the incorporation of SP data with RP data enhanced the reliability and applicability of SP data to transportation travel demand analysis to some degree(Bradley(1988), Ben-Akiva & Morikawa(1990)).

With a great growth of interest in SP research, interest of researchers was focused on the stability of SP-based preferences across space and time. To date, as far as we are aware, research on the stability of SP-based preferences have almost depended on temporal stability using longitudinal SP data. Temporal stability analysis is based on the assumption that 'true' preferences are stable over time. However, growing evidence from the analysis of longitudinal RP data as well as extensive evidence from research in other spheres of economic activity point to the fact that preferences can and do change over time. In respect to the analysis of SP data, some researchers indicate that the assumption that SP data are stable over time is rejected due to changing socio-economic circumstances as well as changing transportation circumstances(for example, Polak & Meland(1994)). On the other hand, only a few researches have been doing the spatial stability or transferability of SP-based preferences. In this context, the objective of this paper is to analyze the transferability of mode choice models estimated from SP data and to investigate the external validity of SP data over space. In particular, we focused on following points in analyzing the transferability of SP-based choice models.

1) effects of the number or type of attributes used in SP experiments on transferability of SP-based choice models
2) effects of different transportation circumstances on spatial transferability of SP-based choice models
3) transferability analysis with updating of constants and scale parameter

Surveys were carried out in three different areas with different transportation circumstances within Seoul city during 1993. Seoul city is facing serious traffic congestion. Now, newly planned subway lines are under construction to alleviate the traffic congestion. SP data were collected from each area to assess the respondent's preferences to the subway service to be newly introduced. The rest of this paper is organized as follows. In the next section, we explain characteristics of research areas which were selected for this research and present the design of SP experiments and survey method. Section 3 shows results of spatial transferability analysis for mode choice models estimated from SP data. In particular, we analyze not only effects of different SP experiments on transfer predictive accuracy but also effects of different transportation circumstances on spatial transferability. Also, we evaluate the spatial transfer predictive accuracy using models estimated with updated constants and scaling parameter. Lastly, we summarize the important findings of this research in Section 4.

2. CHARACTERISTICS OF SURVEY

2.1 Research Area

There are serious traffic congestion problems in Seoul. In order to relieve the traffic congestion, new subway services are under construction in Seoul. We chose three areas to analyze the spatial transferability of mode choice models estimated from SP data. One area(Area C) is already under operation, whereas, in other areas(Area A and B) new subway services are to be provided(Figure 1). The existing subway line is a circular line passing through the CBD(Central Business District) area. The new subway line will link the east areas with the west areas as well as pass through the CBD area. So, we can analyze the effects of different transportation circumstances by considering three areas. In addition, area A is similar to area C in that both areas have almost the same social composition and housing type. On the other hand, area B is different from area A and C. Our research shows almost the same results. For example, the share of respondents living in the apartment was 60% in area A, 46% in area B, and 66% in area C, the share of male was 72% in area A, 61% in area B and 70% in area C, and the share of above 40 in age was 35% in area A, 19% in area B, and 32% in area C. These results show that area A and area C have almost the same social composition and housing type. Data collected from three areas makes it possible to investigate spatial transferability analysis for mode choice models based on SP data. Comparing mode choice models estimated from the data set collected from one area with those from another area, in addition, we could find effects of transportation circumstances on the transferability of SP-based choice models.

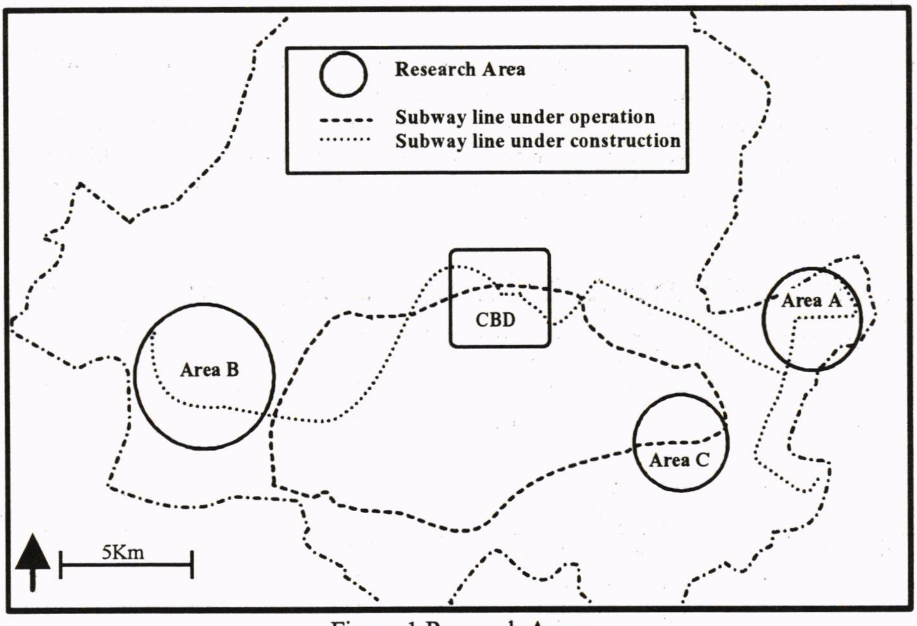

Figure 1 Research Areas

2.2 Survey Method

It is very important that the level-of-service of alternative attributes in a SP experiment should be set to realistic transportation services which respondents are facing. Because it makes the respondents understand the problem well and could reduce bias resulting from bad service-level setting. For this reason, we conducted preliminary surveys to decide the realistic service-level of attributes.

For simplicity we decided to consider four exogenous attributes: in-vehicle travel time(IVT), travel cost(COS), access time(ACT) and congestion(CON). Here, IVT and COS are common attributes, whereas ACT and CON are bus and subway specific attributes. We made a $L_{27}(3^{13})$ factorial design. Particularly, it is interesting to note that the congestion factor was included in this SP experiment. As a variable for congestion which respondents feel at peak time is almost the same, it is unreasonable to use congestion data obtained from actual market. In addition, it is not easy to measure the congestion rate in actual market. However, SP approach uses hypothetical congestion and makes it possible to incorporate congestion into the mode choice model. In order to have respondents perceive the congestion condition, we used pictures that showed and explained congestion condition according to congestion rates, 100%, 150% and above 200%. Respondents consider level-of-service of attributes including congestion and rank from the most preferred mode to the worst preferred mode. Ranking-based data were obtained from respondents. Five pairs of options were presented to each individual and five SP data can be collected from each individual. Attributes and level-of-service of attributes for experimental design are shown in table 1.

Summary of SP survey was presented in table 2. Surveys carried out in 1993 focused on commuters only and adopted an interview method with respondents working in CBD area for the data collection. A total sample size was 615(205 from Area A, 171 from Area B and 239 from Area C).

We divided SP questionnaires into two types and designed different SP experiments respectively. X type deals with In-vehicle time(IVH), travel cost(COS) and access time(ACT) which are considered as important exogenous variables in mode choice. At the same time, Y type involves congestion rate to public transport as well as variables included in X type(Table 3). This makes it possible to assess effects of different SP experiments on transferability of SP-based choice models.

Table 1 Attributes and Level-of-services for the ranking experimental design

Choice set	Attributes	Level 1	Level 2	Level 3
Car	In vehicle time(min.)	50	60	70
	Travel cost (won)	800	1300	1800
Bus	In vehicle time(min.)	50	60	70
	travel cost(won)	250	300	350
	Access time(min.)	4	7	10
	Congestion(%)	100	150	above 200
Subway	In vehicle time(min.)	30	40	50
	travel cost(won)	400	500	600
	Access time(min.)	5	10	15
	Congestion(%)	100	150	above 200

800 won = 1 US$

Table 2 Summary of SP survey

Survey period	1993.8.10～8.20
Respondents	Only Commuters
Research Area	Areas where subway line is under construction(Area A and B) Area where subway line is under operation(Area C)
Survey Method	Interview with respondents in their company (if necessary, explanation was added)
Sample size	615(205 from Area A, 171 from Area B and 239 from Area C)

Table 3 Type of attributes used in different SP experiments

	Type X			Type Y		
Variables	bus	subway	car	bus	subway	car
In-Vehicle Time(IVT)	O	O	O	O	O	O
travel COSt(COS)	O	O	O	O	O	O
ACcess Time(ACT)	O	O	—	O	O	—
CONgestion(CON)	—	—	—	O	O	—

Table 4 Estimation results for type X

Variable	Area A	Area B	Area C
IVT	-0.0587(6.02)	-0.0595(5.67)	-0.0585(5.67)
COS	-0.0016(5.67)	-0.0015(5.18)	-0.0016(5.18)
ACT	-0.0993(4.57)	-0.1067(4.37)	-0.1103(4.37)
Car dummy	0.3811(1.19)	0.7321(2.07)	0.5343(2.07)
Bus dummy	-1.0920(5.61)	-0.5133(2.43)	-0.8692(2.43)
$L(\hat{\beta})$	-439.8	-371.4	-584.9
Percent correctly predicted	59.39	53.11	53.73
Rho-squared bar	0.1913	0.1242	0.1642
No. of samples	495	386	637

t-statistics in parentheses

Table 5 Estimation results for type Y

Variable	Area A	Area B	Area C
IVT	-0.0253(2.77)	-0.0367(3.90)	-0.0504(5.27)
COS	-0.0016(5.92)	-0.0015(6.07)	-0.0014(5.77)
ACT	-0.0676(3.21)	-0.0368(1.64)	-0.0643(2.94)
CON	-0.0157(8.17)	-0.0112(5.68)	-0.0119(6.12)
Car dummy	-1.9580(4.35)	-0.0706(0.16)	-0.7024(1.60)
Bus dummy	-1.3740(6.55)	-0.9397(4.47)	-1.4890(6.75)
$L(\hat{\beta})$	-450.7	-431.1	-429.6
Percent correctly predicted	58.74	56.58	57.75
Rho-squared bar	0.1940	0.1755	0.2421
No. of samples	509	456	516

t-statistics in parentheses

3. TRANSFERABILITY OF MODE CHOICE MODEL ESTIMATED USING SP DATA

3.1 Estimation Results for Mode Choice Models

We estimated the mode choice models for type X and type Y, respectively. Table 4 and table 5 show results estimating the multinomial logit model(MNL) specification with the data set for type X and type Y, respectively. Models estimated from SP data set for type X have correct signs and significant difference for all variables. Models estimated from SP data set for type Y also have correct signs and significant difference for all variables except

Car dummy variable in area B. We judged that these models are adequate for analyzing the transferability of SP-based choice models. Next, we will examine the spatial transferability using these base models.

3.2 Test of Model Parameter for Equality

First of all, we will conduct the test for equality of coefficients and check whether individual coefficients among three models can be transferable. For this, we will use the t statistic that is used for evaluating the differences among individual coefficients (Ortuzar, Achondo, & Espinosa(1986)):

$$t = \frac{|\theta_{ak} - \theta_{bk}|}{\sqrt{(\theta_{ak} / t_{ak})^2 + (\theta_{bk} / t_{bk})^2}} \tag{1}$$

where,

θ_k = the coefficient of the kth attribute

θ_{ak} = the estimate of θ_k from data set of area A

θ_{bk} = the estimate of θ_k from data set of area B

t_{ak}, t_{bk} = t-statistics of coefficients

If t value is less than 1.96, the null hypothesis that both coefficients are equal cannot be rejected at the 95% level. Table 6 and table 7 show values of the t statistic for the models. The statistical tests suggest that the null hypothesis of equality of coefficients cannot be rejected for the model for type X as well as the model for type Y. These results imply that all parameters of models for type Y as well as type X are stable over space regardless of transportation circumstances, that respondents' preferences with respect to level-of-service variables are almost same even though transportation circumstances are different. These results are very encouraging and seem to favor the hypothesis of spatial stability. However, we should also check disaggregate transferability measures for more accurate analysis.

Table 6 Tests for equality of coefficients for type X

Variable	Comparison area A and area B	Comparison area A and area C
IVT	0.05	0.01
COS	0.18	0.25
ACT	0.23	0.38

* indicates significant difference at the 5% level

Table 7 Tests for equality of coefficients for type Y

Variable	Comparison area A and area B	Comparison area A and area C
IVT	0.87	1.89
COS	0.14	0.56
ACT	0.99	0.11
CON	1.62	1.37

* indicates significant difference at the 5% level

3.3 Disaggregate Transferability Measures

Based on the mode choice model estimated from SP data of type X and the mode choice model estimated from SP data of type Y, we investigated the spatial transferability. There are some methods to evaluate the transferability of choice models(Koppelman & Wilmot(1982)). This paper used following measures to evaluate the transferability of SP-based choice models: METS(Model Equality Test Statistic) and TTS(Transferability Test Statistics). METS and TTS are defined as follows.

$$TTS = -2\left(L_a(\theta_b) - L_a(\theta_a)\right) \tag{2}$$

where,

$L_a(\theta_b)$ = The log likelihood that the data observed in context A were generated by the model estimated in context B

$L_a(\theta_a)$ = The log likelihood at convergence of a model estimated in context A

$$METS = -2\left(L_{a+b}(\theta_{a+b}) - L_a(\theta_a) - L_b(\theta_b)\right) \tag{3}$$

where,

$L_{a+b}(\theta_{a+b})$ = The log likelihood at convergence of a model estimated in context A and B

These transfer indices will be applied to compare area A with area C as well as area A with area B. Table 8 shows results of TTS and METS for type X and table 9 shows results of TTS and METS for type Y. The important findings obtained from these results are as follows.

Firstly, the number and type of alternative attributes used in SP experiment have significant effects upon the spatial transferability of SP-based choice models. As shown in Table 8, in the case of type X there are no significant differences in not only between area A and B but also between area A and C. Although only TTS in comparison of area A and B reject that SP-based choice models are spatially transferable in between area A and B, the difference, if being compared with $\chi^2_{0.05;4} = 9.49$, is not great. On the other hand, in the case of type Y null hypothesis that SP-based mode choice models are spatially transferable is rejected at the 5% level. This result indicates that the number or the type of alternative attributes have a great effects upon the respondent's response and effects from different SP experiments directly appear in values of TTS and METS. In particular, it is thought that respondent could not understand the SP questionnaire well, for congestion variable used in type Y is qualitative data. In conclusion, it is obvious that the number of attributes or the type of attributes used in an SP experiment have a great effect upon the transferability of SP-based mode choice models, and that SP experiment which was designed for respondent to understand it easily could enhance the spatial transferability of SP-based mode choice models.

Secondly, regarding only values of TTS and METS for type X shown in table 8, we can say with fair certainty that the spatial transferability is scarcely affected by the difference of transportation circumstances in our research. There is no significant differences between results comparing area A and B and results comparing area A and C, though theoretically values of TTS and METS for results comparing area A and B should be much lower than those for results comparing area A and C. Therefore, it seems reasonable to suppose that difference of transportation circumstances has little effect upon the spatial transferability for models estimated from SP data.

In the case of models estimated from SP data of type Y, however, null hypothesis that models from SP data are transferable spatially cannot be accepted. It is thought that there are several reasons for the rejection of spatial transferability with respect to SP data of type Y: for example, prominence hypothesis, difference in response to congestion across market segments(as shown in table 7, values of t statistic for CON variable is higher and less stable. This indicates that response to congestion may be diverse across market segment), bias included in SP data such as state-dependence and serial-correlation and so on. In addition to these reasons, difference of contexts among three areas should be considered. When transferring a model to a new context it is clearly necessary to update the mode-specific constants and scale. It would manage to reproduce the aggregate shares of each alternative in a new context. Next, for this reason, we will examine the spatial transferability with updating of constants and scale.

Table 8 Results of TTS and METS for type X

	TTS	METS
Comparison area A and B	10.6*	4.6
Comparison area A and C	0.16	3.4

* indicates significant difference at the 5% level

Table 9 Results of TTS and METS for type Y

	TTS	METS
Comparison area A and B	53.8*	18.4*
Comparison area A and C	83.6*	22.2*

* indicates significant difference at the 5% level

3.4 Transferability Analyzing with Updating of Constants and Scale

We investigate the transferability of models estimated from SP data with updating of constants and scale. The method to update constants and scale is presented below.

$$P_{in} = \frac{e^{\alpha(\theta x_{in})+\beta_i}}{\sum_j e^{\alpha(\theta x_{jn})+\beta_j}} \qquad (4)$$

where

P_{in} = the probability of individual n choosing alternative i

α = Scaling Parameter to adjust the parameters

θ = vectors unknown parameters

x_{in} = Vectors of explanatory variables of Alternative i for Individuals n

β_i = Vectors of Adjusted constants

Updated constants and the scaling parameter were reproduced and estimation results are shown in table 10. Again, we conducted transferability analysis using TTS and METS, as conducted in section 3.3, and evaluated the transferability of models estimated with updated constants and scaling parameter. Results are given in table 11. These values indicate that the updating of alternative specific constants and additional update of scale produce a substantial improvement in the transferability of models. However, Models estimated from SP data of type Y are not transferable among three different areas, even if transferability of models with updated constants and scaling parameter has improved substantially. In order to conduct more accurate transferability analysis, as mentioned earlier, market segmentation and elimination of bias included in SP data should be considered. We cannot say whether models estimated from SP data of type Y are transferable spatially, without considering the market segmentation bias included in SP data and so on. This may be topics for future research.

Table 10 Estimation results with Updating of constants and scaling parameter

	Comparison area A and area B	Comparison area A and area C
Scale Parameter(α)	0.7309(7.8)	0.8189(9.0)
IVT	-0.0185	-0.0207
COS	-0.0012	-0.00131
ACT	-0.0490	-0.0554
CON	-0.0115	-0.0129
Car dummy	-0.7145	-1.2090
Bus dummy	-1.1360	-1.9430

t-statistics in parentheses

Table 11 Results of TTS and METS of reproduced model for type Y

	TTS	METS
Comparison area A and area B	26.4*	9.6
Comparison area A and area C	35.6*	12.4*

* indicates significant difference at the 5% level

4. CONCLUSION

This paper focused on three points and found out findings like following.

- The number of attributes or the sort of attributes to be used in SP experiment had significant effects upon the transferability of mode choice models estimated from SP data. These results implicate that SP experiment, which was designed for a respondent to easily understand, could improve the transferable accuracy and enhance validity of SP data.
- We found out that the spatial transferability of models estimated from SP data was scarcely affected by the different transportation circumstances in our research. With respect to tests of a model parameter for equality, there was no significant difference among three different areas. In addition, transferability measures showed that there was no significant difference between models estimated from SP data of type X. It is thought that the spatial transferability of SP-based mode choice models is much greatly influenced by the number or the sort of alternative attributes used in SP experiment than by difference of transportation circumstances.
- The update of alternative specific constants and additional update of scale produced a substantial improvement in the transferability of models estimated from SP data of type Y.

Finally, we present some topics for future research.

Null hypothesis that models estimated from SP data are transferable spatially cannot accepted for models for type Y. The reason for this seems to be that the preference or taste is diverse across market segments, and that biases are included in SP data. For this reason, we should use a market segmentation approach to conduct more accurate analysis and classify respondents into small groups within which preferences for transportation services are homogenous. In addition to this approach, we should also eliminate biases included in SP data and evaluate the spatial transferability. In the next step of this research, we will consider market segmentation.

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