A COMBINED RP/SP ROUTE CHOICE STUDY BETWEEN EXPRESSWAY AND ORDINARY ROADS BY USING ROUTE CHOICE SURVEY'S DATA*

By Yalcin ALVER** and Shoshi MIZOKAMI***

1. Introduction

This study investigates travel behaviors and route choice decisions of production and freight companies in Kumamoto Prefecture. Local Government of Kumamoto Prefecture decided to convert ordinary road traffic to expressway through toll pricing. For this aim, two social experiments were conducted to identify the effects of toll discounts on drivers' route choice decision. A route choice survey was conducted to freight and production companies prior to these social experiments. This paper depends on the data that was collected from the route choice survey.

Generally, route choice surveys are conducted to identify route choice decisions and travel attributes of drivers as Revealed Preference (RP) data. RP data are based on choices made under real situations. For example, actual route choice decision of a driver between origin and destination with information of attributes of each alternative route can be considered as RP data. Another type of data used in route choice analysis is Stated Preference (SP) data. Different from RP, SP data are used to improve alternative set by creating hypothetical scenarios. SP data are collected when alternatives are not yet present. RP data require higher costs due to large number of sample needed. However, collecting SP data can help to improve alternative set with low costs.

Combining RP and SP data to take advantage of prominent feature of each data type is another approach[1)2)]. This approach is currently applied in discrete choice analysis. In this study, both RP and SP data, which were collected from route choice survey, were used in the modeling approach. Modeling approach starts with a segmentation model. Then a route choice model was estimated with RP data. Afterwards, a convert model was estimated to identify the convert tendency of ordinary road users to expressway under discounted toll with SP data. Finally, both RP and SP data were combined in the same model. Combined model was estimated as linear and non-linear. Value of Time (VOT) was calculated in each step of the modeling to evaluate the models. VOT was calculated separately for freight and production companies and for different travel times in non-linear model.

In the second section, conducted surveys are discussed. Following section describes the modeling approach. In the fourth section, results of the models are discussed. Fifth section investigates evaluation of the results. Sixth section is conclusion.

2. Conducted Surveys

(1) Route choice survey

A mailed route choice survey was conducted to freight and production companies within Kumamoto Prefecture. The aim of the survey is to collect data for the future toll policy to convert traffic from ordinary road to expressway. In the survey, route choice decisions of freight and production companies were investigated under different discounted toll levels. A total of 150 questionnaires were delivered, 50 to production and 100 to freight companies. Finally, 32 of them from production and 39 from freight companies were collected. Survey was conducted from November 25th to December 5th of 2003. Questionnaires in the survey have three main parts; socioeconomic characteristics and general information about the company, revealed preference data, and stated preference data. The area was divided into six zones inside the prefecture under three directions; north, east and south.

---

* Keywords: Route choice model, Combined RP/SP model, VOT.

** Student Member of JSCE, Graduate School of Sci.&Tech., Kumamoto Univ., (2-39-1 Kurokami, Kumamoto 860-8555, Japan, TEL:81-96-342-3541-3441, FAX:81-96-342-3507, Email:030d9221@gsst.stud.kumamoto-u.ac.jp)

*** Member of JSCE, Dr. Eng., Dept. of Civil & Env. Eng., Kumamoto Univ., (2-39-1 Kurokami, Kumamoto 860-8555, Japan, TEL:81-96-342-3541-3441, FAX:81-96-342-3507, Email: smizo@gpo.kumamoto-u.ac.jp)

The zones and locations are shown in Figure 1.

a) Socioeconomic characteristics and general attitudes

This is the first part of the questionnaire. Number and types of vehicles and number of employee working in the company were asked to identify the socioeconomic characteristics of the company.

When the route choice decisions on daily business trips were investigated, it was found that the driver did 74% of the companies' route choice decision. When the companies who usually use ordinary roads were asked "why you do not use expressway instead of ordinary roads?", most of the production companies answered "using expressway does not shorten our travel time" with 45.5%. Most common answer for the same question for the freight companies was high expressway cost with 42.9%. When the three main directions were considered in the business trips of companies, it was identified that the biggest portion of the freight companies' trip was within the prefecture. Business trip directions of the companies are indicated in Figure 2.

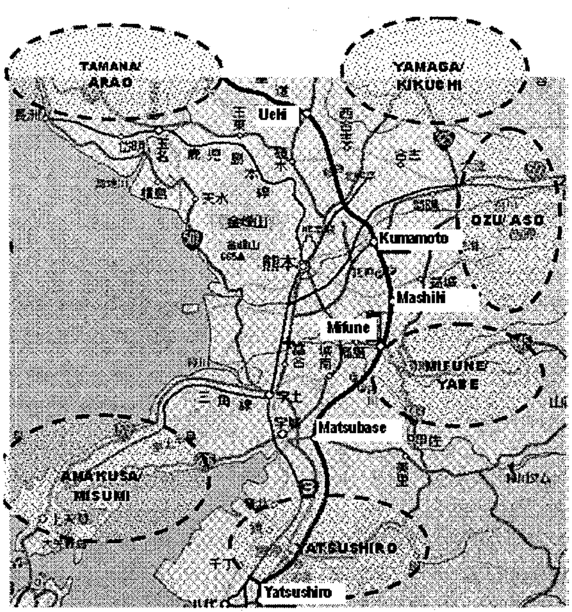

Figure 1. Study area and zones.

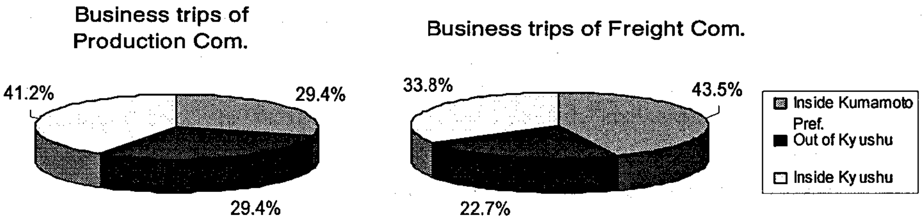

Figure 2. Business trip directions of companies.

Companies were asked to rank five factors which effects route choice decision from first important to fifth important. These factors are; travel time, travel cost, wider roads, less pedestrian, and reliability of travel time. Companies ranked the factors from five to one. Five means the most important and one means the least important. Total points for each factor are indicated in Figure 3. Travel time was the most important factor for both companies. In addition, reliability of time is the second important factor for the production companies; however, it was cost for freight companies.

b) Revealed preference data

Second part of the questionnaire was designed to collect RP data. Respondents were asked to indicate the route on the map while traveling to other three zones inside the prefecture. Each company was asked for three different routes. As an example, a company located at Yatsushiro area was asked to indicate the routes when traveling to Tamana/Arao, Yamaga/Kikuchi and Ozu/Aso areas. Based on the indicated route on the map, attributes of route chosen and most appropriate alternative route were considered for each trip. For example, if ordinary road was chosen, an alternative route, which uses expressway, was created and travel attributes as distance, travel time and toll were calculated. Distances were calculated on the map and travel times were calculated with the help of H11 national census of travel time in Japan roads.

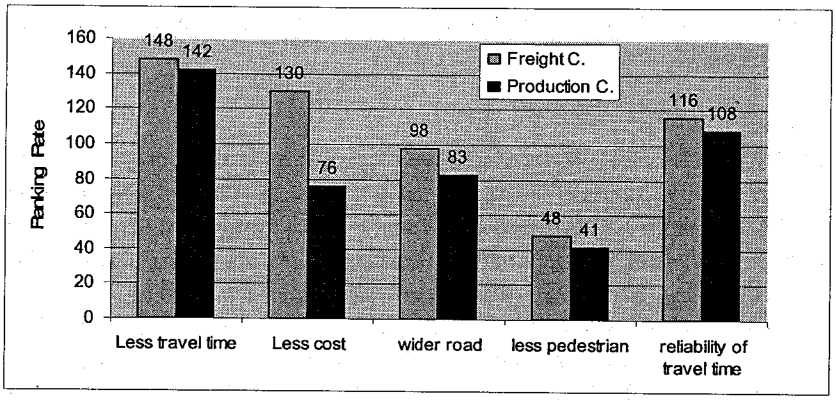

Figure 3. Factors which effect drivers' route choice decisions.

c) Stated preference data

Third part of the questionnaire was prepared for SP questions. These questions were asked to determine at what discount rate the respondent would convert to expressway from ordinary road. For each route indicated in the map in the RP questions, an SP scenario was prepared for the respondent to identify his willingness to pay for expressway toll.

As an example, a company located in Yatsushiro area and traveling to Yamaga/Kikuchi area probably uses the expressway between Ueki and Matsubase ICs. SP questions for this direction are indicated in Figure 4. First, the travel time of ordinary road and alternative expressway was shown to the respondent. Then, a bidding of discount rate that would attract the respondent to convert followed. According to the first question, follow up bids were asked. Finally, debriefing question on eliciting reason for the respondent who did not want to convert under given discount rates was added along with the minimum acceptable discount rate of respondent for conversion.

EXPRESSWAY TOLL QUESTIONS

From Ueki Interchange to Matsubase Interchange

Ordinary Road	Off-peak	About 1.0 hour
	Peak	About 1.5 hours
Expressway		About 30 minutes

If the toll will be decreased **30 percent**, will you convert to using expressway? (¥1150 - **¥800**)
1. Yes
2. No

(1. Yes →) How about if the toll will be decreased **20 percent**, will you convert to using expressway? (¥1150 - **¥900**)
1. Yes (Finish) 2. No (Finish)

(2. No →) How about if the toll will be decreased **50 percent**, will you convert to using expressway? (¥1150 - **¥600**)
1. Yes (Finish) 2. No

(2. No →) What is the reason why you don't want to convert to expressway?
1. The cost should be reduced as much as possible
2. Time savings benefits is very minimal
3. Others, specify (   )

At what toll level will you convert to use expressway?
1. (   ) % discount 2. Toll free

Figure 4. Stated preference questions.

A binary variable named as "convert" was formed by using SP data for each route chosen by companies. This variable is set to one, if the respondent is willing to convert at a certain discount rate and zero, if the respondent does not want to convert to expressway.

(2) Social experiments

Two route choice experiments were conducted on Kyushu Expressway. In this study, these experiments are called as social experiments. These experiments are very valuable to evaluate the situation before the actual policy implementation. Verification of the estimated models was done by these experiments. However, these results are not discussed in this paper. A comparison between traffic volume and estimated results is discussed in further sections. Comparison of actual data with estimated ones will be discussed in detail in future studies.

During the experiments, expressway toll was discounted 50% approximately for one month to identify the conversion characteristics of drivers from ordinary road to expressway. First experiment was conducted from November 1st to December 25th of 2004 between Ueki IC and Matsubase IC. Five ICs (37.8 km) were covered in the first experiment. Second experiment was conducted from February 7th to March 4th of 2005. One more IC was added to the previous and totally six ICs were covered from Ueki IC to Yatsuhiro IC, 56.2 km. Traffic on both expressway and alternative ordinary roads were monitored before and during the experiments. Thus, the effect of discounted expressway toll was observed on traffic volume. Questionnaire surveys were conducted to different groups of individuals such as; expressway users, freight and production companies, bus drivers, commuters, and people living along the alternative ordinary roads.

3. Modeling Approach

Discrete choice analysis of road users' route preference between expressway and ordinary road options is an effective method. In this analysis, observed choices based on alternative attributes and road users' inherent socioeconomic characteristics were considered. In most cases, RP data are used in route choice analysis and SP choices in hypothetical situations can respond to improving alternative set. This study aimed to combine RP data, as the actual route choice decisions, and SP data, as the willingness to pay for the expressway toll, in the estimation with discrete choice models.

Discrete choice models assume that an entity n chooses among routes i, based on his utility level, U_{in}, which is a function of deterministic component, i.e. level of service (LOS) variables, socioeconomic (SE) variables, and random term e_{in} representing omitted model elements due to the survey limitations;

$$U_{in} = \alpha_i + \beta LOS_{in} + \gamma SE_n + \varepsilon_{in} \tag{1}$$

Where, U_{in} is utility function, α_i is constant, β and γ are parameter vectors to be estimated. Considering choices between two alternatives; ordinary road (OR) and expressway (EW), the probability that a respondent n will choose expressway can be denoted by:

$$P(U_{EW,n} > U_{OR,n}) = \frac{\exp(V_{EW,n})}{\exp(V_{EW,n} + V_{OR,n})} \tag{2}$$

In Eq. (2) $V_{EW,n}$ and $V_{OR,n}$ are indirect utility functions for expressway and ordinary road, respectively. Using maximum likelihood estimation, parameter vectors β and γ can be estimated. Furthermore, other indicators such as VOT, or the ratio specifications of the travel time and travel cost parameters can be computed[3)].

In the route choice survey, totally, 71 companies responded the questionnaires. Each company was asked for three different directions, but some of them answered less. After eliminating the useless data, finally, 102 routes were used in the estimation. Modeling approach in this study has four steps: (1) Segmentation model, (2) Route choice model with RP data, (3) Conversion model with SP data, (4) Combined RP/SP route choice model. The structure of the model is shown in Figure 5 and numbers of the data used in the models are indicated in parenthesis. In adopting the structure indicated in Figure 5, we have considered three points. First, a segmentation model was estimated to separate the respondents whose route choice decision was fixed to ordinary road and could not be changed by discounted toll. Second, we wanted to estimate models by using RP and SP data separately to evaluate the results, especially, VOT. Third, we combined RP and SP data to estimate a more efficient model.

(1) Segmentation Model

Modeling was started with estimating a segmentation model. All collected routes were used to estimate segmentation model. Data was divided into two groups; ordinary road captive and choice. Respondents who always want to use ordinary road, even if expressway is free of charge, are collected under captive group. Choice group is made of both ordinary road users who want to convert under certain discount rate and expressway users themselves. The aim of the model is to divide the data into captive and choice groups and to identify the differences between these groups. Data of choice group was used in the next steps of modeling.

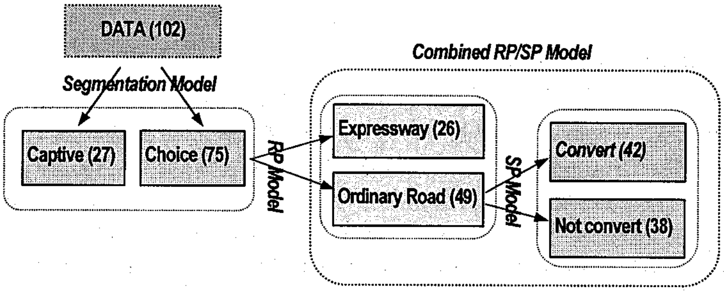

Figure 5. Steps of the modeling approach.

In the model, two utility functions were considered for expressway and ordinary road users. Captive group is defined as the ordinary road users whose convert variable is zero (defined in the SP data) and choice group includes all other users. Both utility functions for expressway and ordinary road alternatives are as follows:

$$V_{ord} = \beta_1((act + egt)/onet) + \beta_2 t + \beta_3(10 * dis) + \gamma_1 d \quad (3)$$

$$V_{\exp} = \alpha + \beta_2 t + \beta_3(c + 10 * dis) + \gamma_2 e \quad (4)$$

Where V_{ord} and V_{exp} are the indirect utility functions, a is the constant, $\beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2$, are the parameters estimated. t is travel time, *dis* is trip distance, c is expressway toll, d is company dummy variable and e is number of employee working in the company. Travel cost was considered as expressway toll plus gas cost (10 ¥/km).

In some cases, if the companies' and clients' locations are far from the ICs and expressway has been chosen as an alternative, the portion of the time that will be spent on the expressway will be short in the total travel time. Thus, they can not get the benefit of using expressway in total travel time. For this reason, another time variable was added to the utility function. Travel time for expressway was divided into three parts; from origin to access IC (act), between IC pair on the expressway (onet) and from egress IC to destination (egt).

(2) Route choice model with RP data

RP model was estimated to investigate the route choice decisions of companies by binary logit model. Different from the segmentation model, in the RP model, only companies in the choice group were used. Captive group was not included in the model, because, they were ordinary road users under any circumstances. This estimation was done by using RP data from route choice survey. In the utility function, travel time, travel cost (actual expressway toll), company dummy variable and number of employee were considered. Route choice model with RP data estimated 26 expressway users and 49 ordinary road users.

(3) Conversion model with SP data

This model was estimated to identify the number of ordinary road users who would convert to expressway and their conversion characteristics under different discount levels. In the conversion model 80 data was considered. There were only 49 ordinary road users. However, due to the responses to SP questions, a respondent could have two SP data. For instance, a company answered "no" to the first question of the SP scenario (30% discount) and agreed to convert under 50% discount was considered as two SP data. The companies who wanted to convert with more than 50% discount but not toll free option were considered as one SP data (not convert under 50% discount). The model estimated 42 users would convert to expressway and 38 users would not. Not all the drivers want to convert, because, some of the companies' route do not match with the expressway's route or some has strict budget constrains. In the conversion model with SP data; travel time, travel cost as discounted toll, company dummy variable and number of employee were considered same as route choice model with RP data.

(4) Combined RP/SP route choice model

After using RP and SP data separately in different models, the last step of the modeling approach is combining both data types in the same route choice model. Combining RP and SP data has some advantages to estimate better models. However, it has some difficulties because of the different nature of two data sets. Usually RP errors are related to the attributes of the choices (independent variables), whereas SP errors are related to the answers collected from the respondents from the questionnaires. Thus, it can be assumed that prediction and estimation errors are same in RP data, but this can not be assumed as same in SP data[3]. The main problem in combining RP and SP data is the different nature of their errors. Ben Akiva and Morikawa[1] developed a framework for combining the two types of data considering differences in nature of errors. Differences in the errors of RP and SP data can be denoted as a function of their variance ($\sigma^2_{RP}, \sigma^2_{SP}$).

$$\sigma^2_{RP} = \mu^2 \sigma^2_{SP} \tag{5}$$

Where, μ represents scale factor. The utility functions for both RP and SP data are as follows:

$$U^{RP}_{in} = \alpha^{RP}_i + \beta^{RP} LOS^{RP} + \gamma^{RP} SE + \varepsilon^{RP}_{in} \tag{6}$$

$$U^{SP}_{in} = \alpha^{SP}_i + \beta^{SP} LOS^{SP} + \gamma^{SP} SE + \varepsilon^{SP}_{in} \tag{7}$$

In both utility functions for RP and SP data, LOS variables are different and SE variables are same.

Two estimation methods have been proposed to deal with the non-linearity problem in the maximization of the joint likelihood problem since some of the parameters have to be multiplied by scale factor μ.. First one is the sequential estimation method proposed by Ben Akiva and Morikawa and the second one is a simultaneous estimation method proposed by Bradley and Daly[2]. For the purpose of this study, estimation was done with simultaneous estimation method.

There is a difference in the error scale. In order to solve this problem in the model structure, an artificial tree structure was used. In the nested model structures indicated in Figure 6, three roots were considered. Expressway (RP) represents the expressway users who have used expressway before the discount. Expressway (SP) users are the ones who were ordinary road users during the route choice survey and wanted to use expressway under discounted toll. Ordinary road (RP) users are ordinary road users who do not want to convert with 50% discounted toll.

Three model structures were considered as indicated in Figure 6. Model structure 1 is the first approach to the estimation. It was estimated as a multinomial logit structure, but it failed to estimate logical parameters. Then, second model structure was estimated by separating ordinary road (RP) to a nest with the nest parameter ($1/\lambda$). In this case, estimation results showed that nest parameter was not logical and estimation was not significant. Model structure 3 is the most significant and logical one in the developed structures when the estimation results are considered. The value of (1-λ) is an indicator of the unobserved attributes. When results of the third model are considered, (λ) is close to zero. Thus, there is a strong correlation between the nests. In the model structure 3, nest parameter ($1/\lambda$) was introduced due to the correlation between expressway (RP) and expressway (SP), while both utilities used same time variables. Nest parameter ($1/\lambda$) is restricted to be between zero and one. In addition, scale parameter (μ) was introduced for SP alternatives of expressway. Note that for SP alternatives, it does not emerge directly from the root or branch, but from a particular nest with scale parameter (μ)[6]. If the value of μ is greater than one, it means that the SP data has less variability in explanatory variable than the RP data, and vice versa.

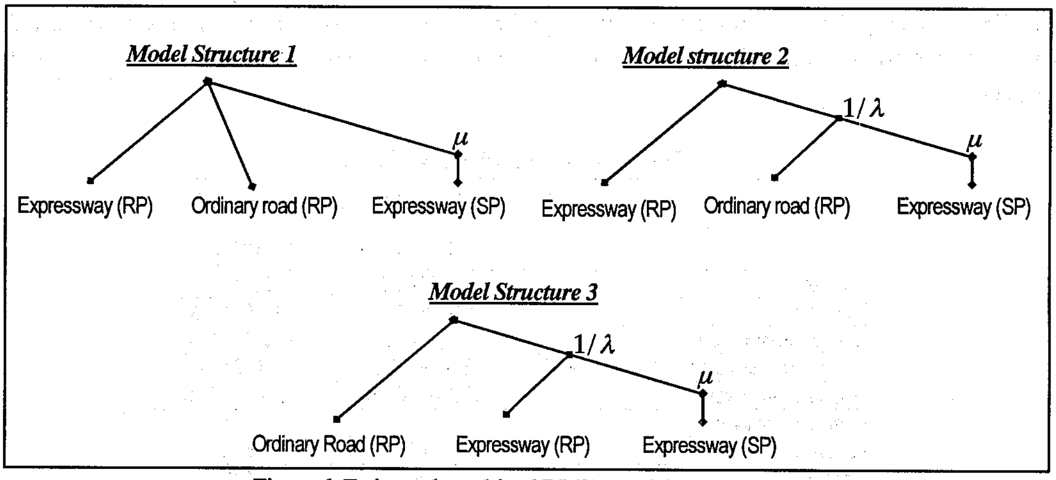

Figure 6. Estimated combined RP/SP model structures.

4. Results of the Models

(1) Results of segmentation model

A total of 102 data were used in the estimation of segmentation model and six variables were considered. The estimation results are indicated in Table 1. As discussed, different from travel time, another time variable was added to the model by dividing travel time into three parts. It can be seen from the results that [(act+egt)/onet] is more significant than travel time in the estimation. If the access time and egress time are too long, drivers do not want to use expressway, because they can not get the time saving benefit of expressway for a long time and there is a toll. Thus, if the portion of access time and egress time in the total travel time is big, respondents are likely to be in ordinary road captive group. Distance between the company location and access IC is very important in route choice decision.

Table 1. Results of segmentation model.

Variable	Estimate	t-statistic
Constant	3.9306	3.50
(act+egti)/onet	0.0579	1.99
Travel time	-0.0136	-1.03
Cost (expressway toll+gas)	-0.0005	-1.13
Company dummy (freight=1, production=0)	2.6077	2.44
Number of employee	-0.0013	-1.79
Number of samples	102	
Log Likelihood	-49.98	
Hit ratio	0.77	
ρ^2	0.29	

Company dummy variable is the most significant variable in the model. Freight companies are more likely to be in ordinary road captive group because their business depends on the delivery costs of the products. Therefore, they do not want to use expressway if the toll is expensive.

(2) Results of route choice model with RP data and conversion model with SP data

Binary logit model was used in the estimation procedure of both route choice models with RP data and conversion model with SP data. In the route choice model with RP data, considered alternatives were expressway and ordinary road. In the SP conversion model, considered alternatives for ordinary road users were convert to expressway and not convert to expressway under discounted toll conditions. In both models, five variables were considered.

Route choice model results show that freight companies are more likely to choose expressway rather than ordinary road. Thus, company dummy variable is the most significant variable in route choice model with RP data. On the other hand, in convert model with SP data it is not significant, because most of the ordinary road users are freight companies.

Table 2. Results of RP and SP models.

Variable	RP Model	SP Model
	Estimate (t-statistic)	Estimate (t-statistic)
Constant	-1.6147 (-1.63)	-0.9614 (-0.91)
Travel time	-0.0225 (-1.53)	-0.0256 (-1.34)
Cost (expressway toll)	-0.0008 (-1.21)	-0.0012 (-1.94)
Company dummy (freight=1, production=0)	3.2619 (4.28)	0.4023 (0.47)
Number of employee	-0.0005 (-0.65)	-0.0004 (-0.29)
Number of samples	75	80
Log Likelihood	-31.09	-53.24
Hit ratio	0.80	0.80
ρ^2	0.40	0.04

(3) Results of combined RP/SP models

Combined RP/SP model was estimated in two steps by using two different utility functions. In the second step, a treatment of time variable was proposed. Thus, the utility function became a non-linear function of travel time. In consequence, first estimated combined RP/SP model will be called as linear and the second one as non-linear models.

Two main reasons were considered in the estimation of non-linear model. First, it is reported that VOT can change by travel time[4]. To identify the relation between VOT and travel time, non-linear model is needed. The other reason is, non-linear model allows us to estimate VOT for freight and production companies separately. In the non-linear model, a treatment of travel time was assumed as indicated in Eq. (9) and company type was introduced as a dummy variable in formulation of δ_n. The indirect utility for linear and non-linear models can be seen in Eq. (8) and Eq. (9), respectively.

$$V_{in} = \alpha + \beta_1 t_{in} + \beta_2 c_{in} + \gamma_1 e_{in} + \gamma_2 d_{in} \tag{8}$$

$$V_{in} = \alpha + \beta_1 t_{in}^{\delta_n} + \beta_2 c_{in} + \gamma_1 e_{in} + \gamma_2 d_{in} \tag{9}$$

In Eq.(8) and (9); α (constant), β_1, β_2, γ_1 and γ_2 are the parameters to be estimated. LOS variables are travel time (t_{in}) and expressway toll as cost (c_{in}). SE variables are number of employee (e_{in}) and company dummy variable (d_{in}). Formulation of δ_n is as follows:

$$\delta_n = \frac{\eta \exp(\xi z_n)}{1 + \exp(\xi z_n)} \tag{10}$$

where, η is the parameter that we decide, ξ is parameter to be estimated and z_n is company dummy variable; one for freight companies and zero for production companies. In non-linear estimation, VOT is not constant and changes with time. η is used in the formulation of δ_n and therefore results can change by different η values.

Results of the estimated models are shown in Table 3 for both models. In the linear model, seven variables were considered. Non-linear model includes nine variables with the addition of two variables to linear model. In both models t-statistic of variables are high compared to those of RP and SP models, separately. Scale parameter μ is very significant. In linear model, all variables are more significant than those of non-linear model, but ρ^2 is higher in non-linear model.

Company dummy variable was introduced in the formulation of δ_n. As indicated in Eq. (10), η was assigned 1.3 because most significant model was estimated with this value.

Table 3. Results of combined RP/SP route choice models.

Variable	RP/SP (linear)	RP/SP (non-linear)
	Estimate (t-statistic)	Estimate (t-statistic)
Constant	1.3091 (2.67)	2.2572 (2.16)
Travel time	-0.0305 (-3.28)	-0.4297 (-2.10)
Cost (expressway toll)	-0.0014 (-2.97)	-0.0018 (-2.49)
Company dummy (freight=1, production=0)	1.2605 (2.96)	1.9482 (2.24)
Number of employee	0.0030 (1.93)	0.0038 (1.42)
λ	0.0925 (0.50)	0.1779 (0.61)
μ	0.9339 (14.93)	0.9024 (12.35)
η (assigned value)		1.3
ξ		-0.3514 (-1.49)
Number of samples	91	91
Log Likelihood	-63.34	-60.11
ρ^2	0.37	0.40

5. Evaluation of Results

(1) Value of time

The value of time for vehicles has been evaluated for more than 40 years, since it was noted to be an important part of economic analysis in transport planning[5]. Many researchers in both engineering and economics fields investigate VOT in transportation. The value of travel time is probably the most important parameter in a social benefit-cost analysis and marginal cost pricing in the transport sector. To evaluate the alternative transportation projects, VOT is used.

In this study, VOT was estimated to evaluate the models and identify the actual values for freight and production companies. VOT was calculated in each RP, SP and combined RP/SP models. Basically, VOT is defined as the change in travel time with the utility level kept constant. The formulation of VOT for linear model is denoted as (β_1/β_2).

Company dummy variable was introduced in the formulation of δ_n. Thus, VOT could be estimated for freight and production companies, separately. In addition, non-linear estimation makes it possible to identify the VOT curve with travel time. The formulation for VOT in non-linear model is indicated in Eq.(11).

$$VOT = \frac{\beta_1 \delta_n t_{in}^{\delta_n - 1}}{\beta_2} \tag{11}$$

Different from linear model, in non-linear estimation VOT is not constant and changes with time. Different η values were assigned in the estimation and most significant model from the view point of ρ^2 is presented in the results in Table 3. Due to the assigned value for η, VOT can change with a decreasing, increasing or constant function with travel time. Calculated values for VOT in each estimated model are indicated in Table 4. In non-linear model, VOT values are estimated for 30 and 60 minutes, as an example. Estimated VOT for production companies is higher than VOT for freight companies in non-linear model. This is why production companies use expressway more.

Table 4. Calculated VOTs in each model.

	RP model	SP model	RP/SP (linear)	RP/SP (non-linear)
VOT (30 min.) (¥/min)	27.86	21.92	21.52	26.80 freight 47.65 production
VOT (60 min.) (¥/min)				19.44 freight 37.99 production

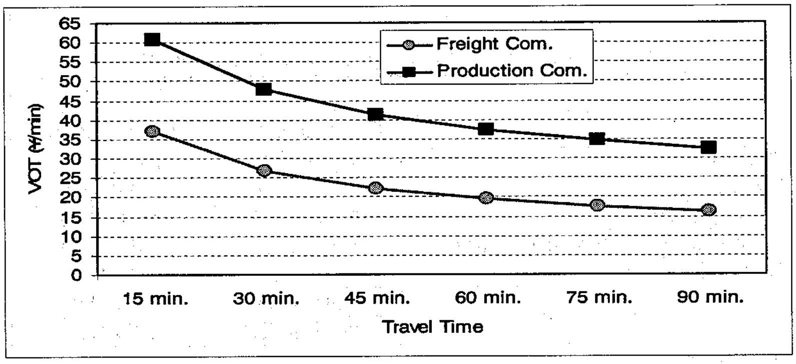

Figure 7. VOT curves for company types in combined non-linear model.

In the estimation, δ_n values are both smaller than one; 0.65 for freight companies and 0.54 for production companies. Generally, VOT is assumed to be constant with the change in travel time. It has been reported that VOT follows an increasing function by total travel time[4]. However, in our study, VOT was estimated as a decreasing function by using the data from route choice survey. In our estimation, both RP and SP data were used. Thus, combining two types of data effects the estimation for VOT. Figure 7 shows relation between VOT and travel time for both company types. VOT become smaller for longer travel times. Results show that shorter trips cost more than longer trips to considered companies inside the prefecture.

Estimated VOTs are low when they are compared with the values that are used in assessing benefit of travel time saving in Japan roads. The values used in Japan are indicated in Table 5. Our values were calculated with the actual route choice surveys in Kumamoto Prefecture for freight and production companies. Our values seem more appropriate when they are compared with other surveys' results.

Table 5. VOT used in Japan Roads.

	Private cars	Small trucks	Big trucks
VOT (¥/min)	56	90	111

(2) Aggregated based comparison

The effects of discounted toll in different groups of expressway users were compared based on two social experiments. Social experiments give us a great chance to verify estimated models. However, there will be a difference in the demand calculated from social experiments and real demand of non-experimental conditions. Thus, it is important to remember experimental demand can not represent the final demand 100% after the policy implementation. Traffic counts were conducted between IC couples, one month before and during the social experiments. Thus, the increase rates of traffic on expressway were calculated for different types of vehicles by discounted toll. For this comparison, increase rates for trucks were considered same as the vehicles that freight and production companies use.

In order to verify the models, increase rates were estimated for linear and nonlinear combined RP/SP models. All these results are indicated in Figure 8. In the verification, estimated demand from linear and nonlinear models do not match very well with those of social experiment one and two between all IC pairs. The reasons of the gap between the estimated results and results of experiments are:

- Estimated models consider route choice decisions of freight and production companies. However, results of social experiments do not have such restriction. In the comparison, only vehicle types are same with estimated models.
- As discussed in the paper, route choice decisions of freight and production companies are different from each other. Thus, to estimate all traffic demand on the expressway after policy implementation (discount on expressway toll), it is necessary to collect data from all actual and possible expressway user groups.
- Estimated models consider the trips inside the prefecture. However, presented results of social experiments include transit users with a high percentage. Thus, transit users affect experimental demands between IC pairs.

These results are discussed here to give an idea about the increase rates of traffic volumes to the reader. Comparing disaggregated data from route choice survey and aggregated data from social experiments is not an appropriate way of verifying the estimated models. Appropriate verification can be done by using data collected from freight and production companies during the social experiments. Estimated model results will be compared with these data and discussed in future studies.

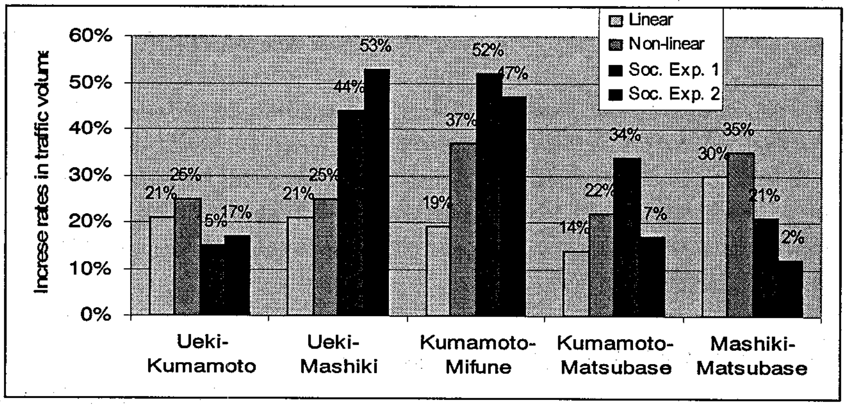

Figure 8. Comparison of increase rates of traffic volume during social experiments with estimated results.

6. Conclusion

This paper investigates a route choice study between expressway and ordinary road. Expressway toll was chosen as the key factor to attract the drivers to convert to use expressway more. Estimation was done in four steps: segmentation model, route choice model with RP data, conversion model with SP data and combined RP/SP models. Finally, linear and non-linear combined RP/SP models were estimated. Non-linear model was introduced to calculate the VOT separately for freight and production companies and to identify the VOT curve with travel time.

Estimated variables are more significant in combined RP/SP models than those of RP and SP models. Estimated values for linear model are higher than those of other models. In RP, SP and linear combined models VOT is constant. It is calculated around 28 ¥/min in RP model and 22 ¥/min in both SP and linear combined models.

VOT was estimated as a function of total travel time in non-linear model. It is reported that VOT follows an increasing curve by increasing travel time, but, in our study, in non-linear model, VOT follows a decreasing curve with increasing travel time for freight and production companies. Researchers who calculated VOT as an increasing curve used SP data only, but, in our study, we used both SP and RP data from the route choice surveys. Estimated values are higher in production companies than freight companies are. Production companies are mostly expressway users and their travel cost is high because of expressway toll.

Expressway toll policy will help to reduce the traffic in Kumamoto City. Definitely, toll policy is not enough to solve the traffic problem in city center, but, if we consider high expressway tolls in Japan, it will help more than it is expected.

References

1) Ben Akiva, M. and Morikawa, T.: Estimation of travel demand models from multiple data sources, Proceedings of the 11th International Symposium on Transportation and Traffic Theory, Yokohama, Japan, July, 1990.
2) Bradley, M. A. and Daly, A. J.: Estimation of logit choice models using mixed stated-preference and revealed-preference information. Understanding Travel Behavior in an Era of Change, eds. P. Stopher and M. Lee-Gosselin, Elsevier science, Oxford, 1997
3) Bates, J.: Measuring travel time values with a discrete choice model: A note, The Economic Journal, 97, pp.493-498, 1987.
4) Morikawa, T. Jiang, M. Sobue, S. and Kurauchi, S.: Empirical Analysis of the value of travel time using SP data, Infrastructure Planning Review, JSCE, Vol. 9, No. 3, pp. 513-520, 2002.
5) Bruzelius, N.: The Value of Travel Time: theory and measurement, Croom Helm, London, 1979.
6) Ortuzar, JDD. and Iacobelli, A.: Mixed Modeling of Interurban Trips by coach and Train, Transportation Research A, Vol. 32, No. 5, pp. 345-357, 1998.

A combined RP/SP Route Choice Study between Expressway and Ordinary Roads by using Route Choice Survey's Data*

by Yalcin ALVER** • Shoshi MIZOKAMI***

In order to solve the traffic congestion problem, it is decided to convert some of the traffic from ordinary road to expressway with discounted toll. A route choice survey was conducted to freight and production companies to collect two different types of data; Revealed Preference (RP) and Stated Preference (SP). Estimation was done in four steps; segmentation model, a route choice model with RP data and a convert model with SP data. Finally, RP and SP data were combined in linear and non-linear models. It is identified that VOT follows a decreasing curve by increasing travel time.

RP／SPデータを結合した高速道路と一般街路の経路選択モデル

by Yalcin ALVER** ・ 溝上 章志***

本研究は，高速道路有効利活用社会実験の実施前に行われた運送会社や事業者に対する高速道路への経路転換に関する意識調査データと経路選択行動データをもとに，RP/SP結合経路選択モデルを構築したものである．このRP/SP結合モデルは，RPやSPだけのモデルよりも適合性が高いこと，業種によって時間価値は異なること，所要時間ともに増加するとされていた時間価値は，逆に所要時間の増加とともに低減することなどが実証的に明らかになった．