# Verification of Combined RP/SP Route Choice Model Between Expressway and Ordinary Road With Social Experiment Data

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## 1. Introduction

Kumamoto City is the third biggest city in the Kyushu Island with population of 656,096 and the number of vehicles is around 289,000. Because of traffic congestion, traffic accidents and air pollution due to the exhaust gases, traffic becomes a big problem in Kumamoto City center. In order to solve this traffic problem, local government decided to convert ordinary road traffic to expressway, by expressway toll pricing policy. A route choice model based on discrete choice analysis between ordinary road and expressway was established. In the route choice analysis, between ordinary road and tolled expressway, RP and SP data are used together.

The main objectives of the study are; to provide the effective usage of expressway by toll pricing policy, to identify route choice behavior of freight and production companies separately, and to evaluate the Value of Time (VOT) for the efficiency of the combined model in linear and nonlinear approaches.

## 2. Route Choice Survey

Vehicles on business such as trucks are always on duty and cause more traffic problems than the private cars. Local government of Kumamoto Prefecture conducted a mailed route choice survey for freight and production companies to investigate the expressway toll policy for effective usage of expressway in the means of reducing ordinary road traffic in the city. This mailed survey was conducted from 25th of November to 5th of December, 2003. Totally 150 questionnaires were delivered to the companies within Kumamoto prefecture, 100 to freight and 50 to production companies. The response rates are 39% and 64%, respectively.

Each Questionnaire consists of three main parts; characteristics and general attitudes, revealed preference data and stated preference data.

In the first part, characteristics and general attitudes of the company were asked; as address, the number of employees and vehicles, the factors affect the route choice, etc.

Second part consists of Revealed Preference (RP) data. Study area is divided into 6 zones; the north areas in the direction of Tamana/Arao and Yamaga/Kikuchi; the east areas along Ozu/Aso and Mifune/Yabe; and the south area along Yatsushiro and Amakusa/Misumi. In this part respondents were asked to indicate on the map, usual route taken when going to the other zones within prefecture. Based on the mapped route, between company and client (origin-destination), attributes of route chosen and most appropriate alternative route as distance, travel time and toll were calculated. H11 national census of travel time in Japan roads is used to compute the travel times. A company from one zone will be asked to map routes when going to other three zones, thus, a maximum of three data can be derived from each respondent as RP data.

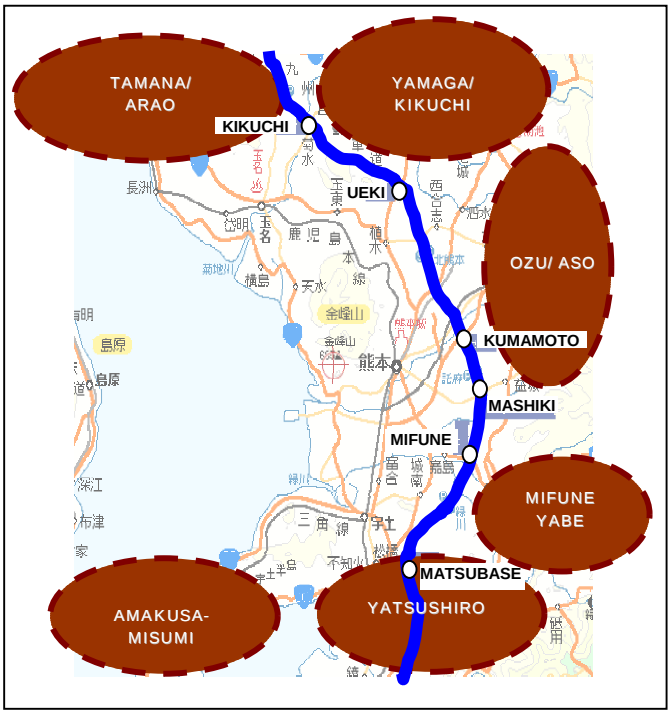


**Figure 0 Study area**

Third part is concerning about the stated preference (SP) data. SP questions are conducted to determine at what discount rate the respondent will convert to using expressway. SP questions are conducted to ordinary road users for each road chosen in RP data. A sample structure of the stated preference question is indicated in Figure 2. An ordinary route choice from one interchange to another will have corresponding stated preference questions for conversion.

[*]Key words: Toll policy, Social experiment, Route choice model, Combined RP/SP

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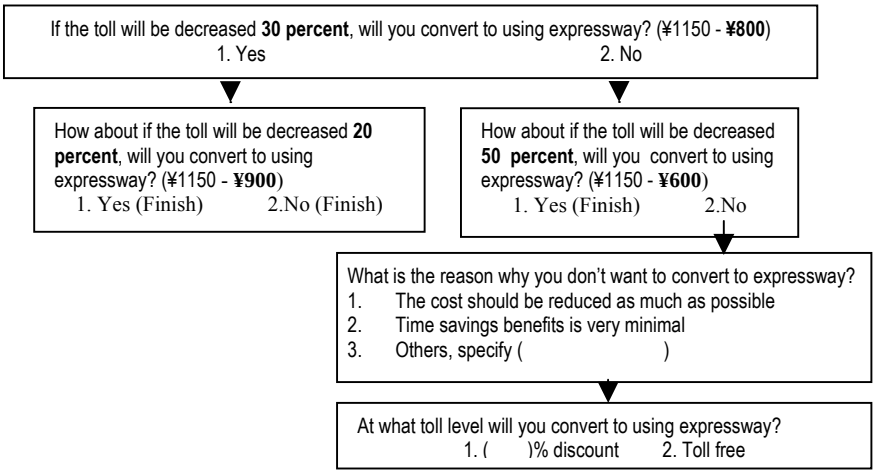


**Figure 2 Stated preference scenario**

## 3. Social Experiment

Social experiment (SE) was in the second part of the survey calendar. This experiment helped us to get actual data during the discounted toll and we could verify the model and see how discount rate works. Social experiment was conducted from November, 1st to December, 25th of 2004 between Ueki interchange (IC) and Matsubase IC. 50% discounted toll was applied to the expressway between 5 IC couples from Ueki IC to Matsubase IC. Experiment comprises all kinds of vehicles for 24 hours during the experiment. Toll program was changed to count the discounted toll. Everybody could join the experiment; questionnaires were delivered at the off interchange and collected by mail. During the SE, traffic counts were done and traffic volumes between IC couples are identified. Increase rates in the traffic volume between IC couples, compared to one month before the SE, are shown for all vehicles and trucks in Figure 3.

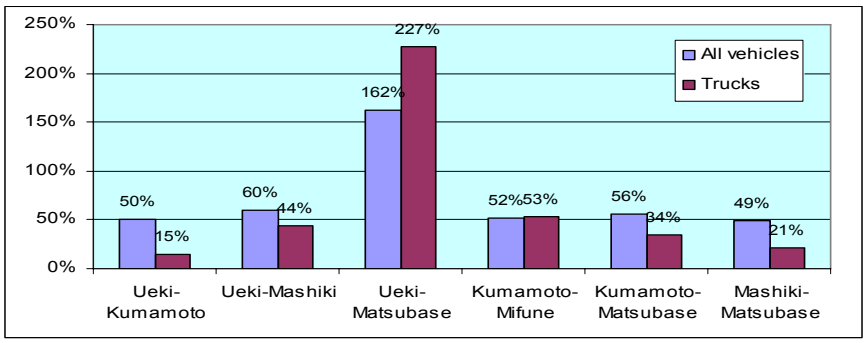


**Figure 3 Increase in traffic volume between IC couples for all vehicles and trucks**

## 4. Modeling Methodology and Results

Modeling approach has four steps in this study as indicated in Figure 4. Number of the data is written in the parenthesis for each. First segmentation model is estimated by using 102 data from freight and production companies, and data is divided into ordinary road captive and choice groups. RP route choice model is estimated by using the choice group which includes ordinary road and expressway users. SP convert model is established to clarify the convert behaviors of respondent and finally combined RP/SP model is estimated by using both RP and SP data.

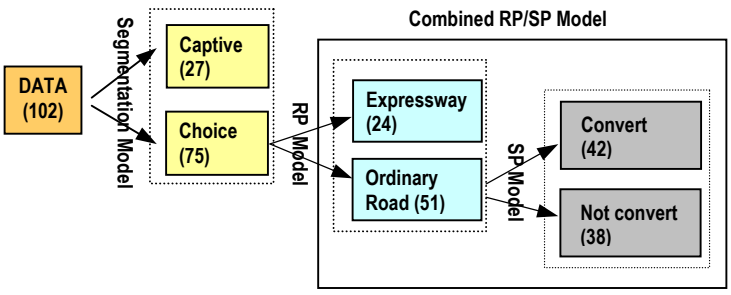


**Figure 4 Structure of the model**

(1) Segmentation Model

This model is used to divide the data into two groups; ordinary road captive and choice. Choice group consists of ordinary road users who do not want to convert to expressway even if the toll is free and choice group includes both expressway users and ordinary road users who evaluate converting to expressway with discount.

If the portion of access time and egress time in the total travel time is big respondents likely to be ordinary road captive, and freight companies are more likely to be in the captive group. The results of the segmentation model are shown in Table 1.

**Table 1 Segmentation model results**

| Variable | Estimate | t-statistic |
|---|---|---|
| Constant | 3.9274 | 3.51 |
| (Accesstime+EgressTime)/On-Exp. Time | 0.0574 | 1.98 |
| Travel time | -0.0114 | -1.00 |
| Cost (Expressway toll+Gas) | -0.0004 | -1.14 |
| Company dummy (Freight=1, Production=0) | 2.6213 | 2.45 |
| Number of Employees | -0.0013 | -1.78 |
| *Number of Samples* | 102 | |
| *Log Likelihood* | -49.96 | |
| *Hit Ratio* | 0.76 | |
| $\rho^2$ | 0.29 | |

(2) RP and SP Models

Binary logit model is used in the estimation procedure of RP and SP models. RP model is established to estimate the route choice of choice group as the captive group declared not to use ordinary road even if the toll is free. SP model is a convert model for the ordinary road users to evaluate the conversion from ordinary road to expressway by toll pricing policy under different discount levels.

RP and SP results show that freight companies more likely to choose expressway than ordinary road. Travel time and cost are the most significant variables in both models. From $\rho^2$ value RP model is more consistent than SP model. Result of both RP and SP models are shown in Table 2.

(3) Combined RP/SP model

Combined model uses RP and SP data in the same model. In combining RP and SP data, one of the most important factors to consider is the differences in the nature of the stochastic part of the utility function. In RP data, errors are due to attributes. On the other hand, SP errors are related to how the respondents made choices. Ben Akiva and Morikawa (1990) developed a framework to combine two types of data. RP and SP data errors can be denoted as a function of their variance.

$$\sigma_{RP}^2 = \mu^2 \sigma_{SP}^2$$

A nested logit type structure was established to estimate the combined RP/SP model. The structure of the combined RP/SP model is indicated in Figure 5, as many other models evaluated in the estimation procedure.

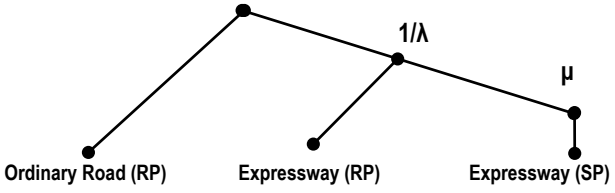


**Figure 5 Combined RP/SP model structure**

Nest parameter (1/λ) is introduced to the model because of the correlation between expressway RP and expressway SP, both use same time variables as data. Combined RP/SP model is estimated as linear, and then to estimate the VOT for freight and production companies separately a nonlinear model is introduced. Nonlinear model helps to see the change in VOT with time by using some travel attributes (Morikawa et.all., 2002). In the nonlinear model, company type is introduced as a dummy variable over the time in the utility function.

In both linear and nonlinear combined models $\rho^2$ values are around 0.36. In combined RP/SP models, all variables are significant and t-statistics of these models are high compared to those of the RP and SP models, separately. t-statistics of new introduced values as μ, *λ,* and C (company dummy variable) is high.

**Table 2 RP, SP and combined RP/SP model results**

| Variables | RP Model | SP Model | RP/SP linear | RP/SP Nonlinear |
|---|---|---|---|---|
| | Estimate (t-stat.) | Estimate (t-stat.) | Estimate (t-stat.) | Estimate (t-stat.) |
| Constant (α) | -1.6147 (-1.63) | -0.9614 (-0.91) | 1.3091 (2.67) | 1.0724 (1.48) |
| Travel Time ($\beta_1$) | -0.0225 (-1.53) | -0.0256 (-1.34) | -0.0305 (-3.28) | -0.0082 (-1.75) |
| Cost (Exp.way toll)($\beta_2$) | -0.0008 (-1.21) | -0.0012 (-1.94) | -0.0014 (-2.97) | -0.0009 (-1.79) |
| Com.(Freight=1, Production=0)($\beta_3$) | 3.2619 (4.28) | 0.4023 (0.47) | 1.2605 (2.96) | 1.2863 (1.38) |
| Number of Emp. ($\beta_4$) | -0.0005 (-0.65) | -0.0004 (-0.29) | 0.0030 (1.93) | 0.0025 (0.99) |
| λ | | | 0.0925 (0.50) | 0.1670 (0.60) |
| μ | | | 0.9339 (14.93) | 0.9204 (8.44) |
| C (Com. Dummy varb.) | | | | -0.4067 (-2.2) |
| Number of Samples | 75 | 80 | 91 | 91 |
| Log Likelihood | -31.09 | -53.24 | -63.34 | -64.4 |
| $\rho^2$ | 0.4 | 0.04 | 0.37 | 0.36 |
| VOT (¥/min) | 27.86 | 21.92 | 21.52 | |
| $\gamma_n$ | | | | 1.08* 1.35** |
| VOT (30) (¥/min) | 27.86 | 21.92 | 21.52 | 13.61* 42.76** |
| VOT (60) (¥/min) | 27.86 | 21.92 | 21.52 | 14.38* 54.50** |

Note: $V = \alpha + \beta_1 t_{in}^{\gamma_n} + \beta_2 c_{in} + \beta_3 x_1 + \beta_4 x_2$, $\gamma_n = \frac{\eta * \exp(CZ_n)}{1 + \exp(CZ_n)}$, *freight company, **production company

## 5. Conclusions

The modeling is completed in four steps and finally linear and nonlinear combined RP/SP models are estimated. Variables are more significant in combined RP/SP models compared to RP and SP models. Nonlinear model is introduced for a detailed estimation for VOT thus VOT for freight and production companies are estimated separately. Increase rates between IC couples are indicated in Figure 6. The actual increase rate, in 50 % discount is calculated from the observations; one month before and during the SE. Increase rates for linear and nonlinear models are estimated with the combined RP/SP models. The verification of the combined model between Ueki IC and Matsubase IC is very poor, because these two IC are the borders of the discounted area and transit drivers used expressway a lot to take the benefit of discounted toll. In the verification, estimated traffic volumes are more reliable in nonlinear approach. Estimation can be improved by introducing new attributes to the nonlinear model for more significant results.

VOT estimated for all models are shown in Table 2. VOT for production companies is higher than freight companies because production companies are mostly expressway users. Estimated VOT rates are low, when they are compared with the rates used in Japan. As a reference, VOT for private cars is established around 50 ¥/min in Japan.

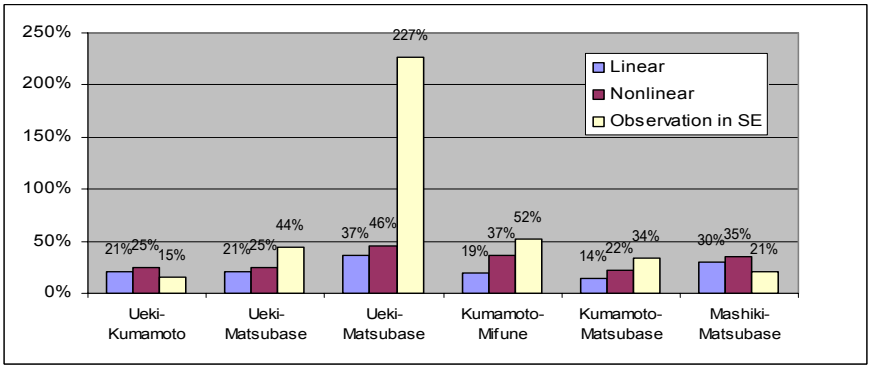


**Figure 6 Traffic volume increase rates between interchanges**

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