Evaluation of Toll on Doto Expressway by Considering Value of Safety

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Abstract: This study focused on Doto Expressway in Hokkaido, Japan which was opened between Obihiro and Sapporo in 2011. This study analyzed the toll from the viewpoints of both companies and users. Route choice model based on RP (Revealed Preference) data was established by binary logit model and the value of mental burden and comfort were calculated. Mode choice model based on TP (Transfer Price) data was established by nested logit model. From the viewpoint of companies, the toll was optimized by linear programing. Here, the objective functions which are maximized are *TR* (Total Revenue of three companies) and subtracting *NB* (Negative Benefit of Mental Burden) from *TR*. From the viewpoint of users, KLP (Kishi's Logit PSM) was applied to evaluate the toll and the value of safety.

Keywords: Mode Choice Modeling, Benefit Analysis, Value of Safety, Hokkaido

1. BACKGROUND AND OBJECTIVE

Doto Expressway in Hokkaido, Japan has been connected directly between Obihiro, one of the major cities of Hokkaido, and Sapporo, the capital city of Hokkaido, in November, 2011.

When people drive between Obihiro and Sapporo on general highway, they need to drive on Nissho Pass and Sekisho Jukai Road where the road conditions are quite severe such as steep slope and a lot of sharp curves. Doto Expressway allows people have safer drives because the road conditions are much better than that of Nissho Pass and Sekisho Jukai Road according to the website of Doto Expressway. In addition, two kinds of public transportations, limited express and intercity express bus, are operated between Obihiro and Sapporo. The competition among railway, intercity bus and Doto Expressway has become severer.

Meanwhile, in the past few years, toll policy of expressway has been changed many times in Japan, for example, upper limit 1000 yen ETC discount, free-toll social experiment and the cancelation of it, etc. According to the Questionnaire which The Hokkaido Shimbun Press.(2011) conducted just before the opening of new section, people said that they appreciate the value of safety, but the present toll, 4250 yen, is too expensive to select the expressway. If people do not use Doto Expressway because of the expensive toll, that means that the toll management has lost the effects of infrastructure. On the other hand, we need to take care that the cut of toll can affect the managements of other public transportation companies.

The objective of this study is to propose the desirable toll on Doto Expressway between Obihiro and Sapporo. Here, the value of safety on Doto Expressway is taken into consideration of analysis.

2. OUTLINE OF STUDY AREA

2.1 Locations of Study Area

Figure 1 shows the location of study area. As shown in the upper left map, Hokkaido is the north island of Japan. The upper right map shows the location of Obihiro City at the right balloon and Sapporo City at the left balloon. The lower map shows the locations of interchanges (IC) on Doto Expressway, Nissho Pass and Sekisho Jukai Road. The red line is the new section, the green line is Doto Expressway and the blue line is Hokkaido Expressway. Nissho Pass and Sekisho Jukai Road are portions of National highway Route 274 and they are known as steep and dangerous.

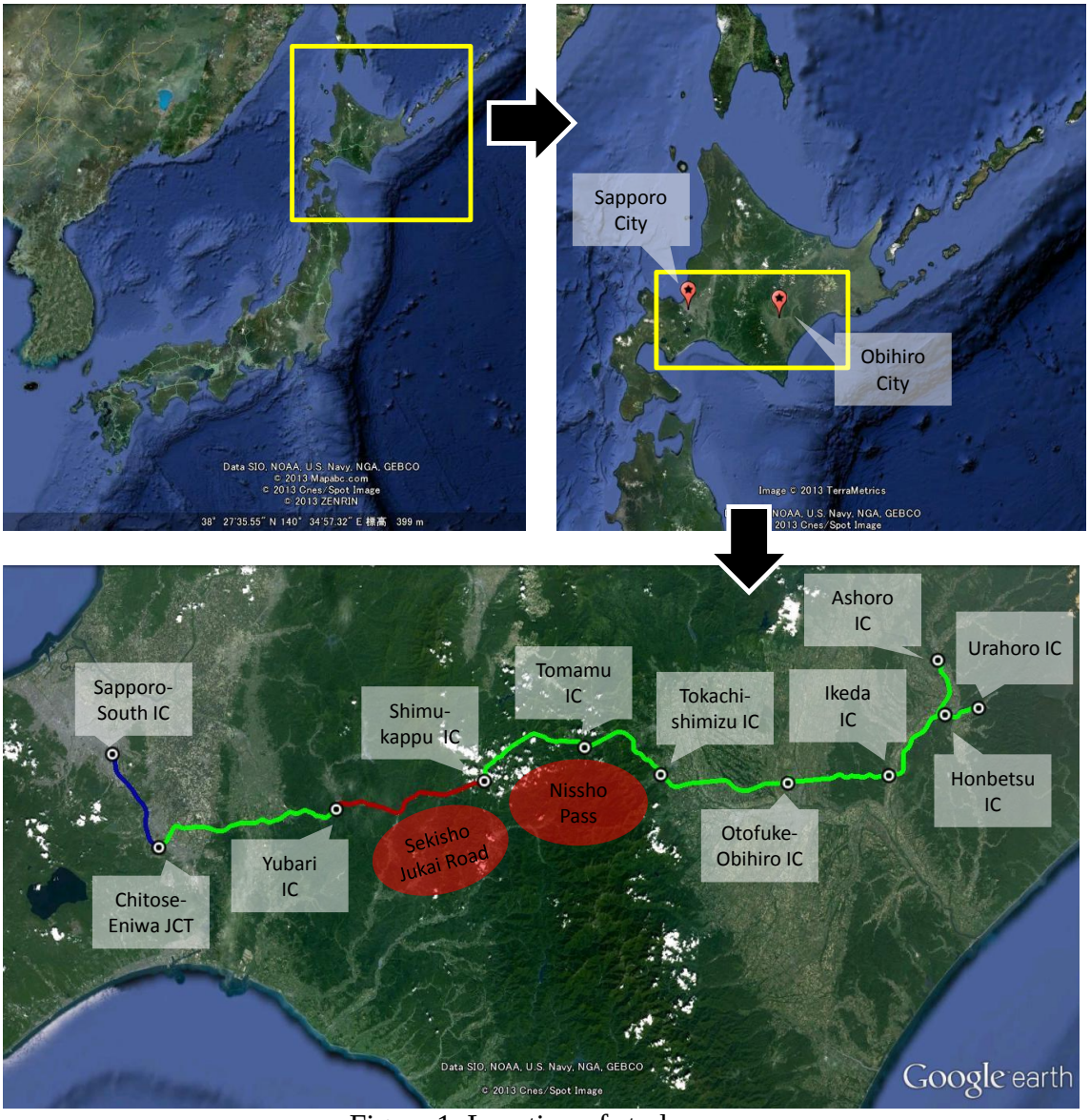

Figure 1. Location of study area

2.2 History of Extension on Doto Expressway

Table 1 shows the history of extension on Doto expressway with the distance of extended section and travel time between Obihiro and Sapporo. The travel time via National highway

Route 274 is 4:18, however, that via Doto Expressway is shortened to three hours.

Table 1. History of extension on Doto Expressway

Year	Date	Extended section	Distance of extended section	Travel time between Obihiro and Sapporo
1995	Oct. 3	Tokachi-shimizu IC to Ikeda IC	50.3	3:50
1999	Oct. 7	Chitose-Eniwa JCT to Yubari IC	42.1	—
2003	Jun. 8	Ikeda IC to Ashoro IC and Honbetsu IC	32.1	—
2007	Oct. 21	Tokachi-shimizu IC to Tomamu IC	20.9	3:39
2009	Oct. 7	Tomamu IC to Shimukappu IC	26.2	3:29
2009	Nov. 21	Honbetsu IC to Urahoro IC	8.0	—
2011	Oct. 29	Shimukappu IC to Yubari IC	34.5	3:01

− Distance: [km]

− Travel time via National highway Route 274 is 4:18.

2.3 Public Transportations

Table 2 shows the summary of limited express, “JR Sekisho Line”, and intercity bus, “Potato Liner”. The railway is faster than the intercity bus by one hour, however, the fare of intercity bus is as half as that of railway. The number of passengers of railway is approximately 20 times as large as that of intercity bus in 2010 which is before the opening.

Table 2. Summary of limited express and intercity bus

	Limitted Express JR Sekisho Line	Intercity bus Potato Liner
Travel time	2:12	3:30 (4:00)
Fare of round trip	14,040 yen	6,930 yen
Services	12 round trips	10 round trips (7 round trips)
Number of Passengers per year in 2010	1.69 million	87.3 thousand

− In parentheses : the value before the opening of the section between Shimukappu IC and Yubari IC

After the opening of the new section, the intercity bus company shortened the travel time and increased the number of services. On the other hand, the railway company proposed new discounts of fares. According to the Hokkaido Shimbun Press. (2012), the intercity bus increased the number of passengers by 40 % and Doto Expressway increased the traffic volume by 50%, on the other hand, railway company decreased the number of passengers by 8%.

3. LITERATURE REVIEW

We have conducted several studies on Doto Expressway and Nissho Pass focusing on the safety. Kishi (2010) quantified the amount of mental burden by proposing Index of Mental Burden for Driving (IMB), which was determined based on the relation between the drivers’ mental burden and road structures such as curve, gradient and width, and evaluated the value of safety by KLP (Kishi’s Logit PSM). The survey was conducted just after the section

between Toakchi-shimizu IC and Tomamu IC was opened in 2007. However, the relation between mental burden and route choice and the relation between Doto Expressway and mode choice between Obihiro and Sapporo were not discussed.

As for the evaluation of expressway, the conventional studies usually focus on the value of shortening travel time. However, several studies focus on the value of safety or comfort in the route choice model.

Okutani *et al* (2008) built up disaggregate multinomial logit model by adopting the drivability rank, which they determined based on the road structures such as design speed, gradient and width, as the explanatory variable. However, they noted that the result was peculiar to their study area.

Morisugi *et al* (2001) and Morisugi *et al* (2003) measured the benefit of Variable Message Signs, which provides the road conditions such as slippery or normal, on mountainous areas. They calculated the benefit as the difference of generalized cost based on the route choice model.

4. DATA COLLECTION

This study conducted questionnaire survey in November 2011, which was just after the opening of the section between Shimukappu IC and Yubari IC.

The target of questionnaire survey was the people who have traveled between Obihiro and Sapporo. Accordingly, the questionnaires were distributed at four different places relating to the travel between Obihiro and Sapporo: JR Obihiro Station, Obihiro Bus Terminal, Shimukappu PA(Parking Area) on Doto expressway and Roadside Station Hidaka. Besides, the questionnaires were distributed to the residents in Obihiro area, such as Obihiro City, Otofuke Town and Makubetsu Town.

We distributed total 1660 questionnaires and took back 656 valid questionnaires. This study analyzes the data collected by the questionnaire survey in the following chapters.

Table 3. Outline of questionnaire survey

Target	People who have traveled between Obihiro and Sapporo
Place	JRObihiro Station, Obihiro Bus Terminal, Doto Expressway Shimukappu PA, Roadside Station Hidaka, Residential area (Obihiro, Otofuke, Makubetsu)
Date	November 11-12 and 19 , 2011
Method	Distributing by hand and collecting by mail
Distributed questionnaires	1660
Collected questionnaires	656 (Collected rate 39.5%)

5. ROUTE CHOICE MODELING BASED ON RP DATA

5.1 Modeling

Route choice model is established to estimate the value of mental burden and comfort based on the past situation. Binary logit model is applied to describe route choice behavior between Obihiro and Sapporo. The alternatives of route are the general highway (National highway Route 274) and the expressway (Doto Expressway) as shown in Figure 2.

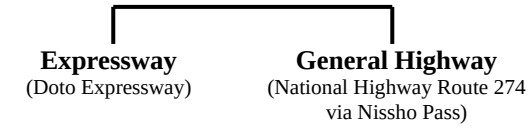

Figure 2. Tree structure of alternatives

5.2 Data

RP (Revealed Preference) data which is the actual data in the past is used for modeling. RP data, which route the driver selected, is obtained at 4 past periods: before the toll-free social experiment, during the upper limit 1000 yen discount, during the toll-free social experiment and after the toll-free social experiment. Table 4 shows the travel time and toll which are used in this modeling.

Table 4. Variables of travel time and toll

		Travel time	Toll
Expressway	Before free-toll social experiment	3:39	3,100
	During upper limit 1000 yen ETC discount	3:29	With ETC 1,000 Without ETC 3,100
	During free-toll social experiment		0
	After Free toll experiment		3,750
General Highway		4:18	0

− Toll [yen]

− Upper limit 1000 yen discount started (Mar.28, 2009-Jun.19, 2011), Shimukappu IC-Tomamu IC was opened (Oct.7, 2009), Toll-free social experiment (Jun.28, 2010-Jun.19, 2011).

5.3 Specification of Utility Function

Utility function of using expressway and general highway are specified by equation (1) and (2). The travel time and travel cost are considered as the explanatory variables. In addition, the dummy variables which express mental burden or comfort are used.

$$V_{epw}=b_1C_{epw}+b_2T_{epw}+b_3M2_{epw}+b_5 \quad (1)$$

$$V_{gen}=b_1C_{gen}+b_2T_{gen}+b_4M1_{gen} \quad (2)$$

where,

V_i	: deterministic term of utility function of mode i,
epw	: expressway,
gen	: general highway,
C_i	: cost of mode i [100 yen],
T_i	: time of mode i [minutes],
$M1_{gen}$	: dummy variable of mental burden on Nissho Pass,
$M2_{epw}$	: dummy variable of comfort on Doto Expressway,
b_1, b_2, b_3, b_4	: parameters, and
b_5	: constant of expressway.

Here, dummy variable of mental burden *M1* and dummy variable of comfort *M2* are defined as follows.

$M1_i$: if driver feel mental burden while driving route i, $M1_i$ is equal to 1.

$M2_i$: if driver does not feel mental burden while driving route i, $M2_i$ is equal to 1.

5.4 Estimation of Parameters

The parameters are estimated based on maximum likelihood estimation by using free statistical software R version 2.14.1.

The parameters indicate reasonable signs and t-values of those parameters are large enough which means that they are significant. Besides, both the likelihood ratio and the hitting rate are large enough. Therefore, this model is considered to be statistically valid

Table 5. Result of estimated parameters

	b1 Travel cost	b2 Travel time	b3 Dummy variable of comfort on Doto Expressway	b4 Dummy variable of mental burden on Nissho Pass	b5 Constant of expressway
parameters	-0.0700	-0.0690	0.913	-1.256	-1.758
t values	-8.38 ***	-3.67 ***	5.00 ***	-4.79 ***	-1.84 .
Samples			213		
Likelihood ratio			0.359		
Hitting rate			78.5%		

− Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

5.5 Considerations of Result

5.5.1 High time value

First discussion is that the time value calculated from this model is quite high compared with general value provided by MLIT of Japan government (Ministry of Land, Infrastructure, Transport and Tourism). One of the reasons is the difference of calculation method and assumptions between MLIT (2008) and this study.

Firstly, MLIT calculates the time value based on the concept of opportunity cost by inputting labor cost, depreciation cost of vehicle, etc. Secondly, the time value of MLIT includes both inner-city trip and intercity trip, however, this study deals with only intercity trip, of which time value obviously become higher than that of inner-city. Thirdly, MLIT assumes the number of passengers as 1.22 for business trip and 1.30 for non-business trip. However, the number of passengers in this modeling is 1.86, thus the time value in this study should also be larger than that of MLIT.

Another reason is that the effect of shortening time is large especially on the opening of section in mountainous area. In the data set, the time variable changes in accordance with the opening of section. Accordingly, the effect of time, which is equal to parameter, becomes larger.

5.5.2 Negative sign of constant

Second discussion is that the constant of expressway is negative. This seems that people select general highway if all the conditions are same. In reality, the travel time, however, is obviously different between using expressway and general highway and people recognize it.

Besides, the structure of utility function also causes this problem. As mentioned above, the effect of shortening time is large in this model. Here, the utility function of general highway also has a term of time, although the time variable of general highway does not vary. Thus, the constant of expressway works to adjust and turns into negative. This is confirmed by building model which uses the variable of shortened time instead of travel time. The result

shows that the constant turns into positive and the other parameters are same.

5.6 Conversion of Value of Mental Burden and Value of Comfort

Each variable can be converted into money by dividing by parameter of cost. This study names the amount of mental burden converted into money "Value of mental burden" and the amount of comfort converted into money "Value of comfort", and calculates them by equation (3) and (4).

$$Value\ of\ mental\ burden = \frac{parameter\ of\ mental\ burden}{parameter\ of\ cost \cdot (-1)} \quad (3)$$

$$Value\ of\ comfort = \frac{parameter\ of\ comfort}{parameter\ of\ cost \cdot (-1)} \quad (4)$$

As a result, the value of mental burden on Nissho Pass is calculated as -1795 yen and the value of comfort on Doto Expressway is calculated as 1304 yen. Therefore, the difference between these two values, 3099 yen, is equivalent to the total value that the drivers appreciate when avoiding steep Nissho Pass and selecting the safer Doto Expressway. The key point is that these values are calculated from RP data which indicates the actual behavior but not from the direct way such as willingness to pay.

6. MODE CHOICE MODELING BASED ON TP DATA

6.1 Modeling

Mode choice model is established to estimate the modal shares based on the situation after the opening of new section. Nested logit model is applied to describe mode choice behavior between Obihiro and Sapporo. There are three alternatives of modes: railway, intercity bus and private car. In addition, there are two alternatives of route for people who select private car: expressway and general highway. The nest structure is composed of two layers as shown in Figure 3. The upper level layer describes the mode choice and the lower level layer following private car describes the route choice. The scale parameter of lower level is standardized as 1.0.

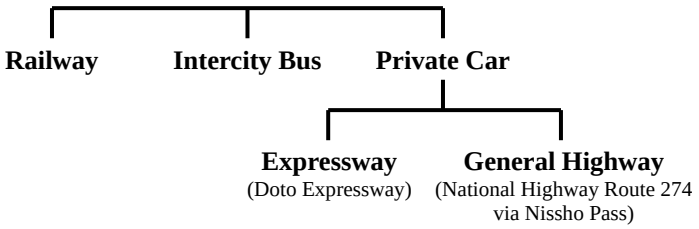

Figure 3. Nest structure of alternatives

Besides, the samples are divided into three segment based on which mode they usually choose. They are named as railway segment, intercity bus segment and private car segment. The mode choice models are built in each segment respectively.

6.2 Data

The questionnaire showed the travel time of each mode after the opening of new section and

asked the respondents Transfer Price (TP), in which price they change mode choice from the mode they usually use to another mode. TP data is a kind of SP (Stated Preference) data and can be used in mode choice model (Bonsall, 1985; Kitamura and Morikawa, 2002). The questions of TP assume two types of scenarios in the questionnaire. One is the case that the mode which they usually use raises its fare or toll and another is the case that the mode which they usually do not use cuts its fare or toll.

The discrete choice model requires choice data in accordance with the conditions. Thus, this study converts TP data into choice data as following procedures. This seems the opposite flow to the modeling which uses the orthogonal array.

First, levels are given to a variable corresponding to each scenario and the other variables are fixed as shown in Table 6.

Table 6. TP data and level

Segment	Scenario	Travel cost			level
		Railway	Intercity bus	Expressway	
Railway segment	(1) If the fare of railway is raised	level	3600	4250	7000 to 10000 (by 1000)
	(2) If the fare of intercity bus is cut	6200	level	4250	3000 to 1500 (by 500)
	(3) If the toll of expressway is cut	6200	3600	level	3500 to 0 (by 500)
Intercity bus segment	(1) If the fare of intercity bus is raised	6200	level	4250	4000 to 6000 (by 500)
	(2) If the fare of railway is cut	level	3600	4250	5000 to 3000 (by 500)
	(3) If the toll of expressway is cut	6200	3600	level	3500 to 0 (by 500)
Private car segment	(1) The border of toll of expressway	6200	3600	level	0 to 6000 (by 500)
	(2) If the fare of intercity bus is cut	6200	level	4250	3000 to 1500 (by 500)
	(3) If the fare of railway is cut	level	3600	4250	5000 to 3000 (by 500)

− Travel cost and level : [yen]

Afterwards, choice data is determined by comparing the level and TP data as follows.

a) Scenario in which fare or toll is raised

$$\begin{cases} \text{If } TP_{up}(i) > level_k \text{ then } \delta_k(i)=1 \\ \text{If } TP_{up}(i) \le level_k \text{ then } \delta_k(i)=0,\ \delta_k(j)=1 \end{cases} \quad (5)$$

b) Scenario in which fare or toll is cut

$$\begin{cases} \text{If } TP_{down}(j) < level_k \text{ then } \delta_k(i)=1 \\ \text{If } TP_{down}(j) \ge level_k \text{ then } \delta_k(i)=0,\ \delta_k(j)=1 \end{cases} \quad (6)$$

where,

$level_k$: k th level of price,
$\delta_k(i)$, $\delta_k(j)$: choice data under $level_k$,
$TP_{up}(i)$: transfer price not to select mode i in scenario that fare or toll is raised, and
$TP_{down}(j)$: transfer price to select mode j in scenario that fare or toll is cut.

6.3 Specification of Utility Function

Utility function of using railway, intercity express bus, expressway and general highway are specified by equation (7) to (10). The travel cost per person is used as the explanatory variable. Here, the travel cost of private car, that of expressway and general highway, are divided by the number of passengers in order to be converted to the cost per person. Besides, the parameters of travel cost, *b1*, *b2* and *b3*, are separated by transportation modes because people should feel different degree of effects on the change of travel cost corresponding to the modes.

Though the travel time was considered to be introduced, t-value was not statistically significant according to the estimation of parameters. One of the main reasons is that the modeling uses TP data which lets respondents focus on travel cost in mode choice. Another reason may be that OD is fixed and the travel times of each mode do not change in this situation. As a result, the effect of travel time is contained in the constants of each mode.

$$V_{rail}=b_1 C_{rail}+b_4 \quad (7)$$
$$V_{bus}=b_2 C_{bus}+b_5 \quad (8)$$
$$V_{epw}=b_3 C_{epw}/np+b_6 \quad (9)$$
$$V_{gen}=b_3 C_{gen}/np \quad (10)$$

where,

V_i	: deterministic term of utility function,
rail	: railway,
bus	: intercity bus,
epw	: expressway,
gen	: general highway,
C_i	: travel cost of mode *i* [100yen],
np	: number of passengers in a party,
b_1, b_2, b_3	: parameters,
b_4	: constant of railway,
b_5	: constant of intercity bus, and
b_6	: constant of expressway.

6.4 Estimation of Parameters

The parameters are estimated based on maximum likelihood estimation by using free statistical software R version 2.14.1.

The parameters indicate reasonable signs and t-values of those parameters are large enough which means that they are significant. The scale parameters are less than 1.0, which is the condition the nested logit model must satisfy. Besides, both the likelihood ratio and the hitting rate are large enough. Therefore, this model is considered to be statistically valid.

Table 7. Results of estimated parameters

	Railway segment		Intercity bus segment		Private car segment	
	parameters	t values	parameters	t values	parameters	t values
Travel cost per person						
b1 Travel cost of railway	-0.092	-5.20 ***	-0.220	-5.12 ***	-0.526	-5.39 ***
b2 Travel cost of intercity bus	-0.394	-5.34 ***	-0.178	-4.89 ***	-0.944	-5.40 ***
b3 Travel cost of private car	-0.108	-5.59 ***	-0.108	-5.66 ***	-0.099	-32.61 ***
Constant						
b4 Constant of railway	8.62	7.80 ***	12.4	5.70 ***	18.8	4.90 ***
b5 Constant of intercity bus	14.52	6.69 ***	7.50	5.89 ***	21.2	4.96 ***
b6 Constant of expressway	6.10	10.48 ***	4.41	8.59 ***	2.43	27.58 ***
Scale parameter μ	0.723	5.46 ***	0.863	5.32 ***	0.361	5.52 ***
Average of passengers	1.61		1.51		1.23	
Samples	136		39		262	
Likelihood ratio	0.290		0.319		0.448	
Hitting rate	62.1%		62.5%		71.9%	

− Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

7. RELATION BETWEEN TOLL AND TRANSPORTATION SYSTEM

7.1 Indices

This study defines three indices: modal share, revenue, total revenue and negative benefit of mental burden. Here, in order to describe transportation system of traveling between Obihiro and Sapporo, these indices do not include either the amount of Kushiro Area, which is located in the east of Obihiro, or the amount of large-size vehicle.

a) modal share: S, SS and $\overline{SS}$

The modal share after some conditions are changed is calculated as shown in equation (11) and (12). SS is described in units of people and $\overline{SS}$ is described in units of party or vehicle.

$$SS_i = \sum_k S_k \, P_k(i) \tag{11}$$

$$\overline{SS}_i = \sum_k S_k \, P_k(i)/np_k \tag{12}$$

where,

S_i : present modal share of mode i,
SS_i : modal share of mode i after some condition are changed [people],
$\overline{SS}_i$: modal share of mode i after some condition are changed [party] or [vehicle],
$P_k(i)$: choice probability of mode i in segment k, and
np_k : number of passengers in a party in segment k.

Here, the present modal shares are estimated as follows. Table 8 shows the conditions and the result of estimation.

$$S_{rail} = N_{rail} \cdot \omega_{rail} \tag{13}$$

$$S_{bus} = N_{bus} \tag{14}$$
$$S_{epw} = N_{epw} \cdot \omega_{car} \cdot (1-\gamma_{epw}) \cdot \alpha \tag{15}$$
$$S_{gen} = N_{gen} \cdot \omega_{car} \cdot (1-\gamma_{gen}) \cdot \alpha \tag{16}$$

where,

N_i : present number of passenger of mode *i* or traffic volume of route *i* per year (Oct. to Nov. 2010),
ω_i : ratio of trip between Obihiro and Sapporo to the sum of that between Obihiro and Sapporo and that of between Kushiro and Sapporo of mode *i*,
γ_i : ratio of large-size vehicle on route *i*, and
α : average of passengers in a vehicle.

Table 8. Calculation conditions and present modal share

		N	λ	α	ω	S
Private car	Doto Expressway	3.093	0.416	1.32	0.726	1.951
	National Highway Route 274	0.530	0.575			
Railway	JR Sekisho Line	1.705	—	—	0.637	1.086
Intercity bus	Potato Liner	0.090	—	—	—	0.090

- N : [million people per year] or [million vehicles per year]
- S : [million people per year]
- Source of λ and α : Road Traffic Census (2010)
- Source of ω : Inter-Regional Travel Survey (2005)

b) Revenue: *R* and Total Revenue: *TR*

Revenue of railway company, intercity bus company and expressway company are calculated by equation (17) to (19).

$$R_{rail} = SS_{rail}\ C_{rail} \tag{17}$$
$$R_{bus} = SS_{bus}\ C_{bus} \tag{18}$$
$$R_{epw} = \overline{SS}_{epw}\ C1_{epw} \tag{19}$$

where,

R_i : revenue of company of mode i [yen],
$C1_{epw}$: toll [yen/vehicle], and
C_i : fare of mode i [yen/person].

The total revenue of these three companies, *TR*, is calculated by equation (20).

$$TR = R_{rail} + R_{bus} + R_{epw} \tag{20}$$

c) Negative Benefit of Mental Burden: *NB*

This study regards it as a social loss that people choose to drive on Nissho Pass and feel mental burden. Thus, this study converts the negative effect which is caused by feeling mental burden into money and names it as "Negative Benefit of Mental Burden". This index is calculated by equation (21). Here, the unit benefit of mental burden applies 1795 yen which is calculated in route choice model based on RP data.

$$NB = \overline{\overline{SS}}_{gen}\ UB \tag{21}$$

where,

NB	: negative benefit of mental burden [yen],and
UB	: unit benefit of mental burden [=1795 yen/vehicle].

7.2 Optimization of Toll by Linear Programing

Linear programing is applied to obtain the toll which maximizes the below two objective functions. The objective functions are based on *TR* instead of R_i in order to prevent the cut of toll from affecting other companies' revenue too much. Indeed, railway and bus companies had criticized that the toll-free social experiment would decrease their revenue.

$$Objective\ function = \begin{cases} 1)\ \text{TR} \\ 2)\ \text{TR-NB} \end{cases} \tag{22}$$

Figure 4 illustrates the flow of optimization. Here, the fare of railway and intercity bus are fixed as the present fares. Accordingly, C_{rail} is 6200 yen and C_{bus} is 3600yen.

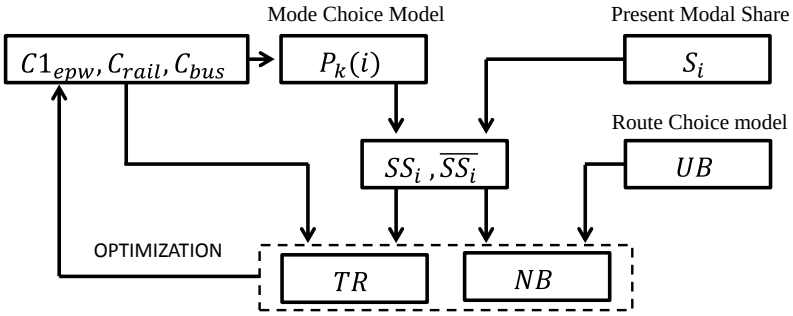

Figure 4. Flow of optimization of toll

Table 9 shows the result of optimization of the toll and the indices.

Table 9. Result of optimization of toll

	Toll	SS: Modal Share				R: Revenue			TR	NB	TR-NB
		Railway	Intercity bus	Express way	General Highway	Railway	Intercity bus	Express way			
Present	4250	24.0%	6.7%	25.1%	44.1%	4.66	0.75	2.50	7.92	2.02	5.90
Maximization of TR	3925	23.1%	6.5%	29.6%	40.9%	4.48	0.73	2.73	7.94	1.87	6.07
Maximization of TR-NB	3101	20.5%	5.7%	42.4%	31.4%	3.97	0.64	3.11	7.73	1.43	6.30

- Toll: [yen]
- R, TR, NB and TR-NB: [billion yen]

The optimized toll is 3925 yen in the case that *TR* is maximized. In that case, however, not a few people are still forced to drive on Nissho Pass. Therefore, it is necessary to cut the toll more so as to decrease the number of people who drive on Nissho Pass and let them to choose Doto Expressway. Accordingly, the second objective function subtracts *NB* from *TR* and the optimized toll is decreased to 3101 yen. The difference of the optimized toll between two objective functions is 825 yen.

8. KLP (KISHI'S LOGIT PSM) ON DOTO EXPRESSWAY

8.1 Summary of KLP

KLP (Kishi's Logit PSM) is a kind of marketing research method and completely different from economic approach such as demand-supply relation. Thus, KLP can analyze how the users feel, for example, they choose expressway but feel expensive.

PSM (Price sensitivity Measurement) is a method to measure consumers' perceptions to a price. PSM asks respondents prices at four different levels: "reasonable", "expensive", "too expensive to be willing to buy", and "too cheap to be willing to buy" as shown in Figure 5.

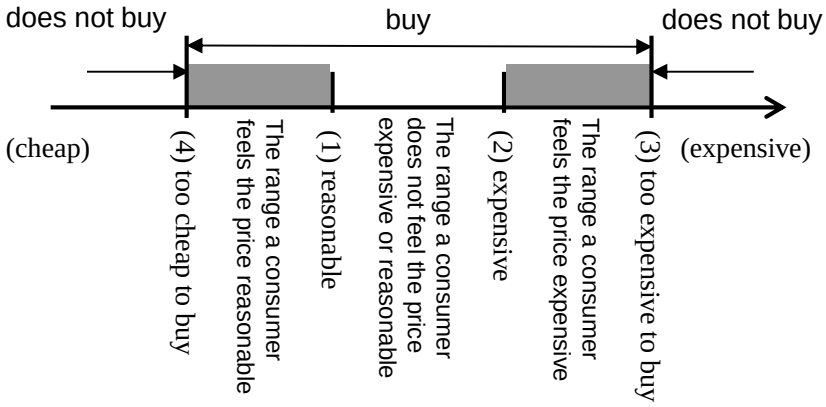

Figure 5. Four prices of PSM

KLP improves PSM by applying logit regression to the relative cumulative frequencies as shown in Figure 6. Consequently, KLP gives four indicators: "Minimum Price", "Maximum Price", "Standard Price" and "Reasonable Price".

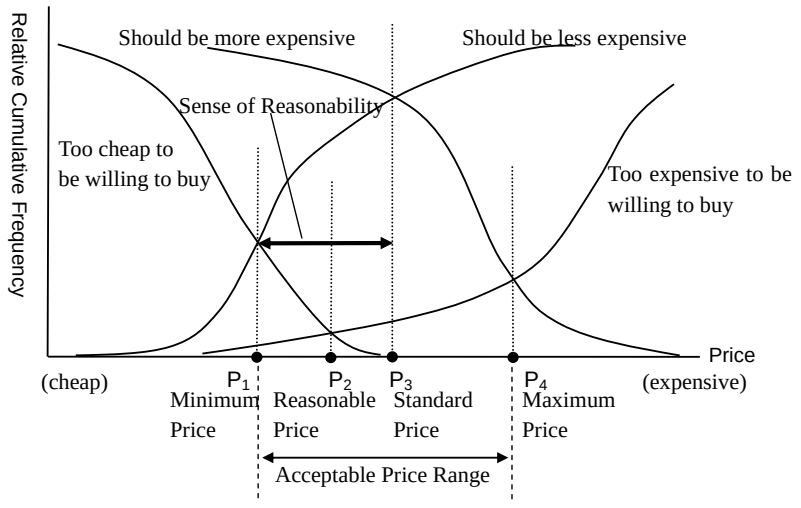

Figure 6. Logit regression of KLP

8.2 Type of Questionnaires

The questionnaire has three types of questionnaires on KLP. Type 1 asks the evaluation of toll between Obihiro and Sapporo, type 2 asks the evaluation of the value of safety between Obihiro and Sapporo, and type 3 asks the evaluation of the value of safety between

Tokachi-shimizu IC and Yubari IC where the road condition is the most severe between Obihiro and Sapporo. Type 2 and type 3 ask the respondents to answer on the assumption that they pay the toll for the value of safety which allow them to avoid from Nissho Pass and drive safely.

Besides, the questionnaire excluded the question of KLP which asks the price they feel "too cheap to be willing to use", because it is not appropriate to the toll of expressway. Consequently, out of four indicators of KLP, Maximum price and Standard price can be obtained.

8.3 Result of KLP

Table 10 shows the result of KLP analysis.

Table 10. Result of KLP analysis

	Type 1 **Toll** **Obihiro-Sapporo**	Type 2 **Value of Safety** **Obihiro-Sapporo**	Type 3 **Value of Safety** **Tokachishimizu-Yubari**
Maximum Price	3874	4288	3052
Standard Price	2881	3186	2292
Samples	202	156	177

− Maxmum Price and Standard Price : [yen]

First, regarding to the toll between Obihiro and Sapporo, the standard price is 2881 yen and the maximum price is 3874 yen. The present toll, 4250 yen, is higher than the maximum price. Thus, KLP analysis indicates that people are not satisfied with the present toll.

Second, regarding to the value of safety between Obihiro and Sapporo, the standard price is 3186 yen and the maximum price is 4288 yen. These are higher than the KLP analysis to the toll between Obihiro and Sapporo. This means that people appreciate the value of safety on Doto Expressway, however, they hesitate to choose Doto Expressway because of the expensive toll. There is a gap between recognized value of safety and acceptable price for selection.

Third, regarding to the value of safety between Tokachi-shimizu IC and Yubari IC, the standard price is 2292 yen and the maximum price is 3052 yen. The distance of this section is 47% of that of whole section (between Obihiro and Sapporo), however, the value of safety of this section occupies 71% of that of whole section. That is because the road condition of this section is the most severe as mentioned above.

8.4 Comparison with the Value of Safety Obtained From RP Data

The value of safety on Doto Expressway has been obtained also in route choice model based on RP data and it is calculated as 3099 yen. This is quite close to the standard price of the value of safety of the whole section and the maximum price of the value of safety between Tokachi-shimizu IC and Yubari IC. This result indicates the consistency between KLP analysis and actual choice behavior.

9. CONCLUSION

9.1 Evaluation of the Toll of Doto Expressway

This study analyzed the toll of Doto Expressway from the viewpoint of both companies and users and obtained four values as shown in Table 11 and Figure 7.

Table 11. Summary of analysis of toll

Analysis		Toll
Present		4250
Optimization	TR	3925
	TR-NB	3101
KLP	Maxmum Price	3874
	Standard Price	2881

− Toll: [yen]

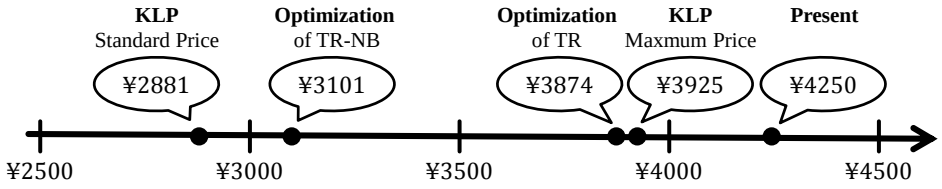

Figure 7. Summary of analysis of toll (number line)

The analysis from company side optimized the toll to maximize the *TR* and *TR-NB* based on mode choice model. The optimized toll is 3925 yen when the total revenue of three companies is maximized, however, when Negative Benefit of Mental Burden is subtracted from the total revenue, the optimized toll is decreased to 3101 yen.
The analysis from users side measured the price sensitivity by KLP. The standard price, which is well-balanced price, is 2881 yen and the maximum price, which is the upper limit to be accepted, is 3874 yen.

Referring to the optimized toll which maximizes *TR-NB*, 3101 yen, and the standard price of KLP, 2881yen, this study concludes that the toll of Doto Expressway between Obihiro and Sapporo should be 3000 yen. In that case, the reduction effect of negative benefit of mental burden is estimated as 640 million yen per year.

However, this amount includes only the travel between Obihiro and Sapporo excluding large-size vehicle and the travel between Kushiro and Sapporo. Consequently, the reduction effect can increase by roughly 3 to 4 times.

9.2 Other Achievements of This Study

In addition to the evaluation of the toll as mentioned above, this study achieved the following points.

1) In the route choice model, this study introduced the variable which indicated the mental burden and comfort as dummy variable. Furthermore, this study converted them into money.
2) This study proposed the new index, “Negative Benefit of Mental Burden”, which focused on the importance of the value of safety for drivers. The unit cost of this index was determined as 1795 yen per vehicle based on the result of route choice model but not direct way such as willingness to pay.

3) KLP analysis evaluated the public opinion that the toll is high although the value of safety is important quantitatively.
4) This study demonstrated the consistency between KLP analysis and the actual choice behavior.

REFERENCES

Doto Expressway- East Nippon Expressway Company Limited (http://www.e-nexco.co.jp/dotodo/) Accessed Feb. 12th, 2013

Questionnaire on opening of Doto Expressway. Oct. 29th ,2011. *The Hokkaido Shimbun Press.*, Hokkaido, Japan

Increasing the use of Doto Expressway. Oct. 27th ,2012. *The Hokkaido Shimbun Press.*, Hokkaido, Japan

Bonsall, P. (1985) Transfer price data- Its definition, collection and use. *New Survey Method in Transport*, VNU Press, 257-271.

Kitamura, R. Morikawa, T. (2002) Modeling Travel Behavior. Gihodo Shuppan Co., Ltd., Tokyo, Japan.

Kishi, K., Sato, K. (2010) Drivers' mental burden minimizing effects of the opening the expressway in mountainous area. *12th World Conference on Transport Research Society*.

Okutani, T., Hashimoto, H. (2008) Analysis concerning evaluation of road network in which it paid attention to drivability. *Proceedings of Infrastructure Planning of Japan Society of Civil Engineers*, CD-ROM, 37, 215. (in Japanese)

Morisugi, H., Hayashiyama, Y., Saito, M., Akoshima, M. (2001) Benefit evaluation of roads information service on winter mountain passes. *Proceedings of Infrastructure Planning of Japan Society of Civil Engineers*, 24, 205-208. (in Japanese)

Morisugi, H., Alarcon, E., Kishi, A., Kono, T.. (2003) A sensitivity analysis on value of information for logit type of route choice. *Infrastructure Planning Review of Japan Society of Civil Engineers*, 20, 913-922.

Ministry of Land, Infrastructure, Transport and Tourism. (2008) The procedure of calculation of unit of time value and travel cost (in Japanese) (http://www.mlit.go.jp/road/ir/ir-council/hyouka-syuhou/4pdf/s1.pdf) Accessed Jul. 10th, 2013