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# A SENSITIVITY ANALYSIS ON VALUE OF INFORMATION FOR LOGIT TYPE OF ROUTE CHOICE *

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## 1. Introduction

Advanced Traveler Information Systems (ATIS) is one of components of Intelligent Transport Systems (ITS) which have increasingly important technologies available for the efficient transportation planning. It will provide advance information about the road conditions to the road users, which helps them make efficient and rational choices. The objective of this paper is to propose a methodology for estimating the economic benefits / value of Variable Message Signs (VMS) by using the logit model for route choice in mountainous areas. The concepts of option price have been adopted with respect to expected utility derived from Variable Message Signs (VMS), and broad sensitivity analyses have been worked out.

Most of the studies that deal with the estimation of benefits and economic evaluation of ITS use the reduction of travel time, vehicle operating costs and accidents as a measure of benefit, nevertheless this paper advocates that it is important and better to estimate benefits through the analysis of the *utility function* as explained below. The utility function is a measure of satisfaction of the user, the higher value of utility level is a higher level of satisfaction of the driver, and therefore the goal is to increase the utility level by the providing the information.

The change in utility level with and without provision of information is the key point to find the value of information; such value of information is given by the difference in expected maximum utilities in the case of logit modeling for route choice. We consider a constant absolute risk aversion (CARA) type of exponential utility function form and it is assumed that the driver behaves as risk avert and it consists of three variables, travel cost, travel time and accidents.

There are many papers that deal with the study of ATIS[1)-22)]. Some of them[1)-5)] use a stochastic equilibrium approach with demand and expected link travel costs. Other papers[6)-8)] use a deterministic queuing model to find the benefit of information by regression analysis[9), 10)]. In all of these papers there is a lack of concept of expected utility and the exact definition of value of information. Most of them consider only the reduction in expected travel cost as the benefit of information, except Kobayashi and Tatano[19)] wherein the concept of expected utility theory had considered. The use of expected utility is better than the use of expected travel cost because the former treats risk aversion behavior theoretically and consistently.

The focus of this article is on the following three points: a) the examination in the case that the utility function expresses risk aversion (base case), b) the inclusion of safety analysis, and c) sensitivity analysis on the base case. The closest research to this paper is that one made by Kobayashi and Tatano[19)], which is also based on the logit model and expected utility. However, in their investigation, they didn't consider the following three points: a) the examination in the case that the utility function expresses risk aversion (base case), b) the inclusion of safety analysis, and c) sensitivity analysis on the base case. The reasons why we have develop all this additional work in this paper is explained as follow: a) usually drivers behave as risk averts, instead of risk neutrals or risk lovers. Therefore to express risk aversion the utility function must have a concave shape. To express risk neutrality the utility function has a linear form (as assumed by Kobayashi and Tatano) and to express risk love it must have also a

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convex shape. b) We should take accidental losses into consideration because the benefit arising from the decrease in accidents might have been large. Moreover, the travel time is an exogenous variable in Kobayashi and Tatano's model, but this is an endogenous variable because drivers choose their speed freely with a trade-off to safety. Keeping the above view points the model have been developed in such a way that the travel time is treated as endogenously and also the safety factor is considered while developing the utility function. The model has been extended by incorporating the safety factor in the assessment of the benefits of VMS. This is done by the inclusion of the expected accident loss term into the utility function. This term is given by the multiplication of accident probability function and the average damage cost function. When we extend the model the travel time is incorporated as an endogenous variable, while in the first put analysis when we didn't consider the analysis of safety this variable was exogenous. c) Finally sensitivity analysis have been worked out to show, in what situations make the value of information more valuable and make a better project identification. We carry out sensitivity analysis for project identification and assess the change in value of information with respect to five factors: travel time in slippery condition, travel cost in route one, probability of state in slippery condition, value of time and parameter of driver's behavior. We show analytically and numerically that for most of the factors the value of information increases when every factor also increases.

## 2. Case to be studied

In order to understand the explanation of the model in a better way, we first describe a typical example of ATIS for two routes for a trip between two cities, Sendai and Yamagata in Japan shown in fig. 1. Suppose that drivers want to travel from Sendai to Yamagata and they start their trip on route 1.

Departing from Sendai, drivers without information will face two situations when they arrive to the intersection between routes 1 and 2: to continue the trip through route 1 or to divert to route 2. It is assumed that before arriving to the intersection a "variable message sign" (VMS) is showing the state of route 1: "slippery" or "normal condition", due to snow or heavy rain. Let's suppose the driver is able to estimate exactly the travel times and travel costs to arrive into Yamagata using route 1 or route 2 if the road condition is known.

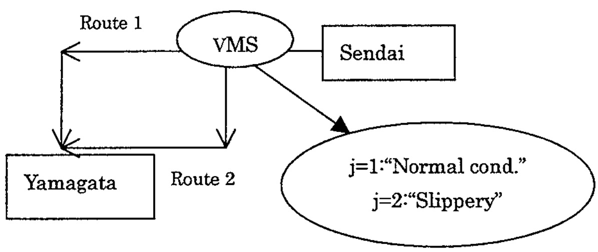


**Fig. 1 Example of ATIS for a trip between 2 cities**

It is assumed the following conditions:

The travel time on route 1 in slippery condition is greater than the travel time on route 2 ($TT_{12} > TT_2$);

The travel time on route 2 is greater than the travel time on route 1 in normal condition ($TT_2 > TT_{11}$);

The travel cost in route 1 is same for either normal or slippery. ($TC_{11}=TC_{12}$)

Therefore, in order to save time, the driver with information has two choices: in the case that the route 1 is slippery he is going to use route 2, which provides a less travel time. Otherwise he is going to use route 1. Therefore the information provided to the driver is useful because it will make him/her to select the route with less travel time and increase his/her utility level.

## 3. Route choice and value of information.- Basic modeling

### (1) Assumptions

We assume that a driver might choose between two routes under two states of the world: "normal condition" and "slippery condition" for route 1, while normal condition constantly for route 2. It is supposed that every combination of route and condition (i,j) gives him/her a different utility level depending on the situation of every route. Adopting the expected utility theory[20], the expected utilities EU without information "using route 1" and "using route 2" are respectively defined as:

$$EU_{11}^{WO} = EU_{12}^{WO} \equiv EU_{1}^{WO} = \pi U_{11} + (1-\pi) U_{12} \quad (3.1), \qquad EU_{21}^{WO} = EU_{22}^{WO} \equiv EU_{2}^{WO} = U_2 \quad (3.2)$$

where $EU_{ij}^{k}$ = Expected utility level of route i under the state j with the situation k on information supply, i=1,2; and j=1: normal condition, j=2 slippery, $U_{ij}$=Utility level when choosing route i under state j, $\pi$ = Occurrence probability of state 1. Note that for without information case (k=WO) the expected utility for route 1 is the identical over the state (i.e. $EU_{11}^{WO} = EU_{12}^{WO}$) because the driver does not know the actual situations in advance. Notice also that the expected utility on route 1 is simply the weighted sum of the utilities in each state of the world, where the weights are given by the probabilities $\pi$ shown by eq.(3.1). If one of the states is certain, so that $\pi = 1$, then $U_{11}$ is the utility of using route 1 in normal condition in state 1. Similarly, if $\pi = 0$, $U_{12}$ is the utility of using route 1 in slippery condition in state 2. Thus eq.(3.1) represents the average utility or the expected utility of the pattern of situation 1 and 2, $U_{11}$ and $U_{12}$. The expected utility in eq. 3.2. is directly equal to utility in route 2 because this route is analyzed under a status of road in normal condition only. The use of expected utility is reasonable because in the case of uncertainty the fact that, outcomes of random choice are what will be in normal or slippery condition means that ultimately only one of the outcomes is actually going to occur; either using route one in normal condition or using route one in slippery condition.

We assume that the state of route is unknown for the case "without information". The value of probability for the case "without information" will be between 0 and 1. "With information" we assume that the driver knows the state of the road with certainty.

In summary: "without information": $0 < \pi < 1$; and "with information": $\pi = 1 \ or \ 0$. Therefore, the expected utilities with information are:

$$EU_{11}^{W} = U_{11} \quad (3.3), \qquad EU_{12}^{W} = U_{12} \quad (3.4)$$

Thus we can assume that the impact of information supply is the reduction of uncertainty.

### (2) Route choice and utility function

We assume that the utility function has an exponential form eq.(3.5) to analyze a risk aversion behavior of drivers and is consists of two variables: travel cost and travel time. The decrease in travel cost or travel time represents an increase in utility level.

$$U_{ij} = -\exp(\alpha TC_{ij} + \beta TT_{ij}) \quad (3.5)$$

where $TC_{ij}$ = Travel cost of i,j (yen/trip); $TT_{ij}$ = Travel time of i,j (min/trip); $\alpha$ , $\beta > 0$ are parameters of utility function. We assume $U_2$ is also same form as eq.(3.5) in spite of the nonexistence of uncertainty. This is constant absolute risk aversion (CARA) type of utility function[21]. It is also possible to assume constant relative risk aversion (CRRA) type of utility function. However, because the difference of risk premium is not so large among drivers in transportation and for the simplicity of numerical simulation, we adopt absolute risk aversion type of utility function.

$P_{ij}^{k}$ , the probability of route choice of (k, i, j), is formulated by the logit model using the expected utility as follows:

$$P_{ij}^{k} = \exp(\theta EU_{ij}^{k}) / \sum \exp(\theta EU_{ij}^{k}) \tag{3.6}$$

where $\theta$ is a positive scale parameter which expresses variance of choice randomness.

It is assumed that the driver will select the route that gives him/her the highest expected utility. Therefore for a higher expected utility in route one the driver will tend to select route one and for a higher expected utility in route two the driver will tend to select route two. In summary it is assumed that the driver will select the route that gives him/her the highest expected utility with a value of probability of choice calculated with eq.(3.6). It is noted that in this paper we treat only two routes. However, even if there are $n$ routes that link a starting point and a destination, the framework of this model is easily expanded. Thus, this model is flexible for generalization.

## 4. Benefit estimation

### (1) The definition of benefit of information supply

We define the expected maximum utility (MEU) corresponding to the given values of levels of services for all choice of one trip as the log-sum function derived in the logit model[22]:

$$MEU^{k}(TC_{ij}, TT_{ij}) = A\frac{1}{\theta}\ln\sum_{i=1,2}\exp(\theta EU_{ij}^{k}) + (1-A)\frac{1}{\theta}\ln\sum_{i=1,2}\exp(\theta EU_{ij}^{k}) \tag{4.1}$$

where: k=W (with information) or WO (without information); A= Share of days of winter season over a year

Finally the value of information (VI) under uncertainty in terms of expected maximum utility is the difference in the levels of expected maximum utilities with and without information: $VI = MEU^{W} - MEU^{WO}$. In order to obtain the value of information in monetary term we use the concept of "option price (OP)" applied to one trip with two routes. Then OP represents the value of information per one trip and we define it as the decrease in transport price level of all routes under the situation "without information" which sustains the expected maximum utility level with the situation "with information"[23], expressed as follows:

$$MEU^{WO}(TC_{ij} - OP, TT_{ij}) = MEU^{W}(TC_{ij}, TT_{ij}) \tag{4.2}$$

### (2) Numerical results

This section shows a numerical estimation based on fig.1. The distance for route 1 is 55 km and for route 2 is 60 km. The travel cost per trip for route 1 is 550 yen/trip and 600 yen/trip for route 2. We set the probability of road condition $\pi = 0.6$ for normal on route 1. We have to estimate the parameters $\alpha$ and $\beta$ of eq. (3.5) in order to evaluate the value of information numerically. We use the data obtained by Akoshima[14] which is based on a stated preference methodology and a pair questionnaire to know the driver's predicted travel time and travel cost. The result is shown in bottom line of table 1. We estimated the parameters for the utility function by applying calibration to the logit model with traffic volume in 1997 so that the outcomes of the model fit Akoshima's data. The results are shown in Table 1.

**Table 1. Numerical results of benefit of VMS**

| Analysis | Probability in normal condition | Probabil in Slippery cond. | Benefit of information (yen/trip) | Annual benefit (million yen) | Annual cost (million yen) | Benefit-Cost ratio |
|---|---|---|---|---|---|---|
| Without safety | 0.6 | 0.4 | 65.8 | 93 | 48 | 1.9 |

Note for without safety Parameters: $\alpha$ =0.0054 (2.6*), $\beta$ =0.0331 (3.2*), $\theta$ =0.05 (2.1*),
Traffic vol.=22,700 veh/day; Days of snow season per year =50. Maximum likelihood ratio=0.8
(* t-statistic value).

The value of information is 65.8 yen/trip which was obtained by applying eq.(4.2) with reference to eq.(3.1)-(3.5) and (4.1). This value looks reasonable and might be similar to a toll fee. In order to obtain the annual benefit we assumed a fixed traffic volume of 22,700 trip/day according to the census 1997 and 50 days of snow season per year. In this case, the annual benefit is 93 (=65.8×22,700×50) million yen/year. The annual cost is estimated based on actual devices located on the route that is 48 million yen/year. Then the benefit-cost ratio is 1.9.

## 5. Sensitivity analysis on parameters

We applied sensitivity analysis to know how the value of information (VI) changes with respect to five factors: travel time in slippery condition, probability of state in slippery condition, parameter of driver's behavior, travel cost in route 1, and value of time. One of rational of sensitivity analysis is to facilitate to identify a good project with values of parameters that give a higher IV, which can be known only by sensitivity analysis. For every factor numerical and analytical analysis was carried out. Some results of the numerical analysis are shown in figs 2, 3 and 4.

We show the development for $TT_{12}$ as a stereotype of analytical analysis for every factor as follow. In order to find the sensitivity to change in $TT_{12}$ we apply total differentiation to the expected maximum utility with and without information for the two variables: *option price* (which represents the *value of information)* and *travel time in route 1 in slippery condition* for eq. (4.2). This is represented by the following expression:

$$\frac{\partial MEU^{wo}}{\partial TT_{12}} dTT_{12} + \frac{\partial MEU^{wo}}{\partial OP} dOP = \frac{\partial MEU^{w}}{\partial TT_{12}} dTT_{12} \tag{5.1}$$

Solving for OP with respect to travel time:

$$\frac{dOP}{dTT_{12}} = \left( \frac{\partial MEU^{w}}{\partial TT_{12}} - \frac{\partial MEU^{wo}}{\partial TT_{12}} \right) \Big/ \left( \frac{\partial MEU^{wo}}{\partial OP} \right) \tag{5.2}$$

After calculating every term independently the result is $dOP/dTT_{12} > 0$. This shows that the longer travel time in slippery condition, the higher the value of information $OP$.

Table 2 shows the summary of analytical results of sensitivity with respect to every factor. We conclude that the value of information increases when the travel time in route 1 in slippery condition also increases as can be seen in fig. 2. The elasticity for $TT_{12}$, is 2.5, which indicates that this variable is very sensitive. In fig. 3 the relation between value of information and value of time is presented. VI increases when the value of time increases and the elasticity is 1.3, which indicates that this variable is not so sensitive. Fig. 4 shows that VI increases when the probability of state in slippery condition also increases. The elasticity is 1.2, describing the variable as not so sensitive.

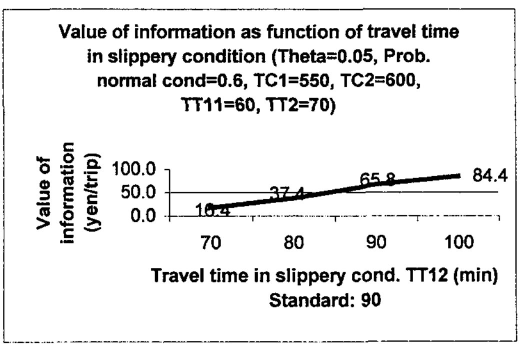


Fig. 2 VI and $TT_{12}$

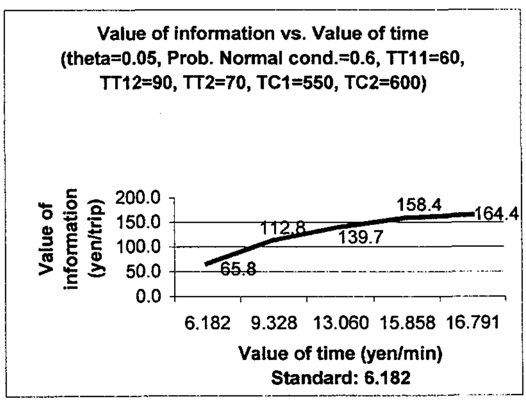


Fig. 3 VI and value of time

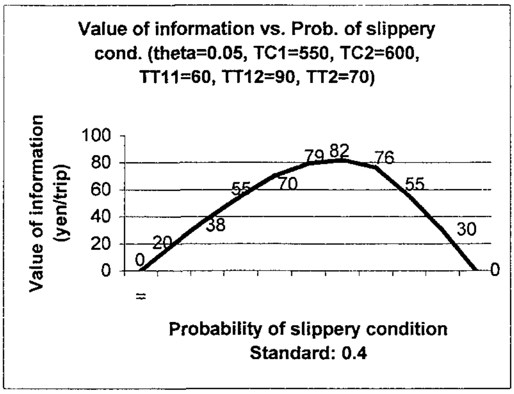


**Fig. 4 VI and probability of state in slippery condition**

**Table 2. Summary of analytical results of sensitivity**

| Factor | Tendency | Avarage elaticity |
|---|---|---|
| Travel time in slippery condition $TT_{12}$ | (+) | 2.5 |
| Probability of state in slipperry condition $\pi_2$ | (+) when probability is small and (-) when probability is large | - |
| Value of time $\frac{\beta}{\alpha}$ | (+) | 1.3 |
| Prarameter of driver's behavior $\theta$ | (+) | 0.2 |
| Travel cost in route 1 | (+) when TC is small and (-) when TC is large | - |

Table 2 summarizes the analytical results of sensitivity which shows that most contributing factor to IV is the travel time in slippery condition.

## 6. Benefit of information including of safety

### (1) Extension of the model

In order to estimate the benefit of information considering safety, we add a third term that represents the expected level of damage brought by accident in the conditional expected utility function $EU_S$ with respect to safety given the level of $TC_{ij}$ and $TT_{ij}$. It is expressed by the multiplication of probability of accident times the average damage cost. It is assumed that both probability of accident and average damage cost functions depend on the speed of trip V with the condition of road j (j=1 (normal condition) or 2 (slippery)):

$$EU_{Sij}^{WO} = EU_{Sij}^{W} \equiv EU_{Sij}^{k} = -\exp\left\{\alpha TC_{ij} + \beta TT_{ij} + \gamma\left[P_{ij}(V)DAM_{ij}(V)\right]\right\} \quad (6.1)$$

where: P=Probability of accident; DAM= Average damage cost (yen); $\gamma$ = Parameter of expected accident loss. Notice that eq.(6.1) assumes that the conditional expected utility is identical over the situation of information supply (i.e. $EU_{Sij}^{WO} = EU_{Sij}^{W}$). Though theoretically it should be defined based on the unconditional expected utility theorem, we can justify the eq.(6.1) by adding some assumptions. The derivation of eq.(6.1) is shown in Appendix. Utilizing eq.(6.1), unconditional EU is expressed as

$$EU_{ij}^{WO} = \pi EU_{Si1}^{WO} + (1-\pi)EU_{Si2}^{WO} \quad (6.2a), \qquad EU_{ij}^{W} = EU_{Sij}^{W} \quad (6.2b)$$

If we express the speed as the ratio of length by travel time, then we can obtain the maximum utility by the differentiating of conditional expected utility (6.1) with respect to travel time:

$$\partial EU_{Sij}^{k} / \partial TT_{ij} = 0 \quad (6.3)$$

We assume that the accident probability function $P_{ij}(V)$ and the average damage cost function $DAM_{ij}(V)$ are increasing and convex with respect to speed $V$ because it is reasonable to assume that the increase of speed represents a higher probability of having an accident and consequently a higher average damage cost, see figs. 5 and 6. For these functions we don't have data, therefore, we specify the functions as shown in eqs.(6.4). The parameters in eqs.(6.4) are assumed to be a=0.00002675, b=1.8, c=0.000681, d=1.2, e=1838, f=0.9, g=14197, h=0.5 and the functions are graphically shown in figs. 5 and 6.

$$P_{i1}=aV^{b}\ \text{(6.4a)},\quad P_{i2}=cV^{d}\ \text{(6.4b)},\quad DAM_{i1}=eV^{f}\ \text{(6.4c)},\quad DAM_{i2}=gV^{h}\ \text{(6.4d)}$$

where: $P_{i1}$ = Prob. of accident in normal cond., $P_{i2}$ = Prob. of accident in slippery cond., $DAM_{i1}$ = Average damage cost in normal cond., $DAM_{i2}$ = Average damage cost in slippery cond., a,b,c,d,e,f,g,h= parameters of accident prob. and damage cost functions in both different conditions.

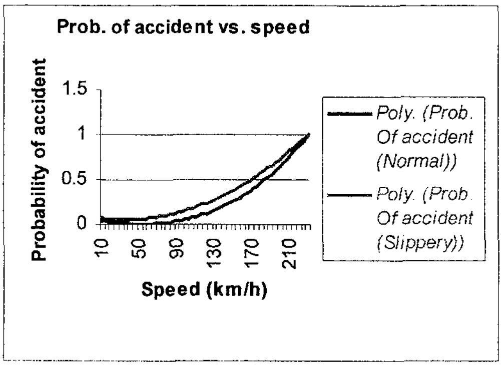


**Fig. 5 Prob. of accident vs. speed**

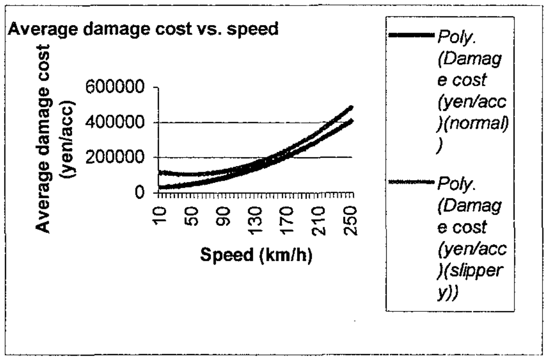


**Fig. 6 Average damage cost vs. speed**

The assumption of this kind of behavior is based on a stated preference methodology in which experienced drivers have an intuitively feeling that with a higher speed there is a higher probability of accident. One of the objectives in this paper is to show the methodology for including the analysis of safety for VMS rather than the practicality of obtaining data. We believe that for further research might be possible to elaborate a questionnaire and try to obtain more consistent data in order to run simulations and compare among the results.

Given the $EU^{k}_{Sij}$, $P_{ij}$ and $DAM_{ij}$ shown in eq.(6.1) and eq.(6.4), we assume that drivers take a speed or travel time to maximize $EU^{k}_{Sij}$ by eq.(6.3). Then the resulting $T_{ij}$, $P_{ij}$ and $P_{ij}$ are expressed as

$$T_{i1}=\sqrt[b+f+1]{\frac{ae\gamma L^{b+f}(b+f)}{\beta}}\ \text{(6.5a)},\qquad T_{i2}=\sqrt[d+h+1]{\frac{cg\gamma L^{d+h}(d+h)}{\beta}}\ \text{(6.5b)},$$

$$P_{i1}=aeL^{b+f}\ \text{(6.6a)},\qquad P_{i2}=cgL^{d+h}\ \text{(6.6b)},$$

$$DAM_{i1}=\left[\sqrt[b+f+1]{\frac{ae\gamma L^{b+f}(b+f)}{\beta}}\right]^{-b-f}\ \text{(6.7a)},\qquad DAM_{i2}=\left[\sqrt[d+h+1]{\frac{cg\gamma L^{d+h}(d+h)}{\beta}}\right]^{-d-h}\ \text{(6.7b)}$$

where $L$ is the length of road. Substituting eq.(6.5), (6.6) and (6.7) into eq.(6.1) we obtain the maximized conditional expected utility functions shown as eq.(6.8):

$$EU^{k}_{Si1}=-\exp\left\{\alpha TC_{i1}+\beta\left[\sqrt[b+f+1]{\frac{ae\gamma L^{b+f}(b+f)}{\beta}}\right]+\gamma aeL^{b+f}\left[\sqrt[b+f+1]{\frac{ae\gamma L^{b+f}(b+f)}{\beta}}\right]^{-b-f}\right\}\qquad \text{(6.8a)}$$

$$EU^{k}_{Si2}=-\exp\left\{\alpha TC_{i2}+\beta\left[\sqrt[d+h+1]{\frac{cg\gamma L^{d+h}(d+h)}{\beta}}\right]+\gamma cgL^{d+h}\left[\sqrt[d+h+1]{\frac{cg\gamma L^{d+h}(d+h)}{\beta}}\right]^{-d-h}\right\}\qquad \text{(6.8b)}$$

We find $\alpha$, $\beta$, and $\gamma$ through calibration and we use the previous procedure to estimate the value of information. The results are shown in table 3. It is noted that this methodology is general when we consider some other effect of information, for example traffic congestion.

### (2) Numerical results

We present the results of benefit of information including safety in table 3. The value of information per trip increases from 65.8 to 71.5 (8.7% increase). Because, first is inclusion of safety term, second is the change in values of parameters, especially $\beta$ from 0.0331 to 0.12. The annual benefit is 101 million yen and the benefit-cost ratio is 2.1. We conclude that the benefit of information increases a little bit when we extend the model considering safety. For the case of analysis of safety, travel time is incorporated in the model as an endogenous variable, while in the first analysis it was an exogenous variable by taking into account safety.

**Table 3. Numerical results of benefit of VMS considering safety**

| Analysis | Probability in normal condition | Probabil in Slippery cond. | Benefit of information (yen/trip) | Annual benefit (million yen) | Annual cost (million yen) | Benefit-Cost ratio |
|---|---|---|---|---|---|---|
| With safety | 0.6 | 0.4 | 71.5 | 101 | 48 | 2.1 |
| Without safety | 0.6 | 0.4 | 65.8 | 93 | 48 | 1.9 |

Note for with safety Parameters: $\alpha$ =0.00512 (2.4*), $\beta$ =0.12 (2.9*), $\gamma$ =0.00005 (2.2*), $\theta$ =0.05 (2.1*), a=0.00002675, b=1.8, c=0.000681, d=1.2, e=1838, f=0.9, g=14197, h=0.5;
Traffic vol.=22,700 veh/day; Days of snow season per year =50. Maximum likelihood ratio=0.4 (* t-statistic value).

## 7. Conclusions

Following the paper of Kobayashi and Tatano[19] and enhancing their research, here we focus on the treatment of non-neutral preferences towards risks (i.e. development of the model with an exponential utility function), assessment of sensitivity analysis, inclusion of safety analysis, and finally the development of a simple methodology to estimate the benefits of information for the condition of roads given by Variable Message Signs (VMS).

We showed with a numerical example that this methodology is practical and can be applied to ATIS projects. We extended the model including safety analysis and showed that the benefits of VMS increase when the driver receives the information about the condition of the route. We conclude that for both simulations the results might be reasonable and that this VMS are a feasible project.

Sensitivity analysis was carried out with respect to various factors aiming that such information helps to find good and efficient projects. For all factors we developed analytical and numerical analysis and the main conclusions are as follow: a) The value of information increases when the status of the surface gets worst in terms of slippery conditions (i.e. when the travel time in slippery condition increases). b) Confirming our intuition, we showed that the value of information increases when the worth of time and probability of slippery condition also increases.

Finally we describe some advantages and disadvantages of the model:

1. It is a model, which is easy to use, due calculations can be performed in spreadsheet software and a statistical package available in the market.
2. The model is based on a strong theoretical basis, wherein microeconomics and discrete choice analysis were used to understand the consumer behavior.
3. We think that the model is useful for the estimation of economic benefits not only in the field of transportation, bus also in other fields like investment science (e.g. stocks, bonds, etc.); construction of facilities under risk analysis (e.g. dams, bridges, etc.); and environmental projects (e.g. parks, rivers, etc.).
4. The disadvantage of this model is when we consider safety in lack of consistent data. We believe that from a practical point of view it is very hard to obtain the probability of accident and the average damage cost as a function of speed, nevertheless we showed a methodology that includes the analysis of safety in order to find the

economic benefits of VMS and we think that further research should be carried out with more consistent data to compare the results.

**Appendix**

If we assume that the level of damage is discrete, that is, we assume only two states: one is accident and another is non-accident, the conditional expected utility function with respect to safety is expressed as

$$\begin{aligned} EU_{Sij}^{k} &= \left(1-P_{ij}(V)\right)\left[-\exp\left(\alpha TC_{ij}+\beta TT_{ij}\right)\right]+P_{ij}(V)\left[-\exp\left(\alpha TC_{ij}+\beta TT_{ij}+\gamma DAM_{ij}(V)\right)\right] \\ &= -\exp\left(\alpha TC_{ij}+\beta TT_{ij}\right)\left[1-P_{ij}(V)+P_{ij}(V)\exp\gamma DAM_{ij}(V)\right] \end{aligned}, \quad \text{(A.1)}$$

where $P_{ij}(V)$ is probability of accident. If we apply Taylor expansion around 0 up to the first order to $\exp\gamma DAM_{ij}(V)$, it becomes $1+\gamma DAM_{ij}(V)$. As a result, eq.(A.1) is written as

$$EU_{Sij}^{k} = -\exp\left(\alpha TC_{ij}+\beta TT_{ij}\right)\left[1+\gamma P_{ij}(V)DAM_{ij}(V)\right]. \quad \text{(A.2)}$$

Now this time reversibly applying Taylor expansion around 0 up to the first order to $\left[1+\gamma P_{ij}(V)DAM_{ij}(V)\right]$, it becomes $\exp\left[\gamma P_{ij}(V)DAM_{ij}(V)\right]$. As a result, eq.(A.2) is written as

$$EU_{Sij}^{k} = -\exp\left\{\alpha TC_{ij}+\beta TT_{ij}+\gamma\left[P_{ij}(V)DAM_{ij}(V)\right]\right\} \quad \text{(A.3)}$$

which is identical to eq.(6.1).

It is noted that we utilize Taylor expansion around 0 up to the first order. That is, we assume that the marginal utility with respect to safety is not so large. This is equivalent to the assumption of linearity of utility with respect to safety, which is the contradiction what we explicitly introduced as the risk premium of generalized const (by eq.(3.5)). It means that we ignore risk premium for safety.

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**A sensitivity analysis on value of information for logit type of route choice** *

By Hisa Morisugi **, Enrique Alarcon***, Akio Kishi**** and Tatsuhito Kono*****

We present a methodology for estimating the benefit of Variable Message Signs (VMS) projects, one of the components of ATIS. Using the logit model, the expected utility theorem and the option price concept, we develop a simple methodology to estimate the benefits of the provision of information. Furthermore, we extend the model in order to calculate the benefit of information considering safety and sensitivity analysis is carried out for determining the changes of value of information with respect to different variables and functional forms.
***Key Words* : *ATIS, Benefits of VMS, Value of information, Sensitivity analysis, Expected utility***

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**ロジット型ルート選択行動モデルにおける交通情報便益計測に関する感度分析** *

森杉壽芳**・アラルコン　エンリケ***・岸昭雄****・河野達仁*****

本研究では，ATIS（高度旅行情報提供システム）の一つであるVMS（Variable Message Signs, 可変表示機）プロジェクトの便益計測について検討を行う．具体的には，ドライバーの経路選択行動を期待効用理論およびロジットモデルを用いて表し，オプション価値によって便益を計測する簡便な方法を提案する．さらに，所要時間や時間価値に関する便益の比較静学分析および感度分析を行っている．また，所要時間を内生化した行動モデルを構築し，情報提供による安全性向上の便益計測手法を提案している．

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