# MODELING OF THE INFLUENCE TO DRIVERS' ROUTE CHOICE BEHAVIOR BY ACCURACY OF TRAVEL TIME INFORMATION

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**Abstract:** This paper observes the modeling method of the drivers' choice behavior, which represent the influence of accuracy of travel time information. Firstly, present situation of travel time information on inter-city expressways is described by the comparison of the transmitted travel time information and the estimated real travel time of drivers. It is considered that drivers' knowledge of accuracy of the offered information is based on the accuracy of the existing information systems. Secondly, modeling method to represent the relationship between the accuracy of provided information and the drivers' route choice behavior is observed. Disaggregate behavioral model which includes the Bayesian methodology is proposed to represent the change of drivers' knowledge of travel time distribution. This model is applied to the route choice behavior data based on stated preference survey. Based on the above analyses, the necessity to ensure the accuracy of travel time information is discussed.

## 1. INTRODUCTION

Nowadays, due to the progress of information and communication technologies, many types of traffic information systems are coming into practical use. It is expected that such information systems are influential in drivers' choice behaviors and they prevent the concentration of traffic volume to the specific routes or specific peak hours. For the road traffic managers, this is the most important effect to construct the various infrastructures that constitute the information systems.

It is considered that the accuracy of provided traffic information is influential in the effect of information systems, because it is influential in drivers' choice behaviors. It is generally believed that high quality information can change the choice behavior of many drivers and eventually result in the reduction of the peak volume. However, this cause-and-effect relationship is not yet well understood. Therefore, it is necessary to see how the accuracy of information can further influence this relationship.

This paper observes travel time information, which is one of the typical information to represent the existing situation of traffic congestion offered to the drivers. Travel time is one of the most important factors for the drivers to deciding their travel behaviors. Therefore, travel time information is one of the information systems that is well-received by many drivers in Japan.

Firstly, this paper observes the accuracy of present travel time information systems in Japan. It is considered that drivers' knowledge of accuracy of the offered information is based on current situation of accuracy of the provided information systems. In this section, the present situation of travel time information systems on inter-city expressways in Japan is described. Then, comparison of the transmitted travel time information and real travel time of drivers, which are estimated using vehicle detectors' data, identify its problems on the accuracy.

Secondly, modeling method to represent the relationship between the accuracy of provided information and the drivers' route choice behavior is observed. In this section, it is supposed that drivers evaluate traffic situations of the routes they use as travel time distributions. Therefore, their choice behaviors depend on their own knowledge of the travel time distributions. Disaggregate behavioral model which includes change of drivers' knowledge of travel time distribution is proposed. This model includes the Bayesian methodology to represent the change of drivers' knowledge of travel time distribution caused by the information. Then, this model is applied to the route choice behavior data based on stated preference survey to discuss the effectiveness of the model. Lastly, based on the above analyses, the necessity to ensure the accuracy of travel time information is discussed.

## 2. PRESENT SITUATION OF ACCURACY OF TRAVEL TIME INFORMATION IN JAPAN

### 2.1. Present Situation of Traffic Information Systems on Inter-City Expressways

Currently in Japan, several types of road traffic information are provided by road traffic managers on inter-city expressways, especially in areas having high traffic demands, like Tomei Expressway (between Tokyo and Nagoya), Meishin Expressway (between Nagoya and Kobe) and some other expressways near the Tokyo metropolitan area. Provided information includes existing situations of traffic congestion, traffic regulations, accidents, road constructions, weather situations and so on. These information are provided using on-board signs, radio broadcasts, telephones and information centers at service areas.

One of the very important and useful traffic informations for many drivers is travel time to the destination. This information provides the calculated travel time from existing position to some selected main interchanges ahead through the on-board signs. At present, transmitted travel time information on inter-city expressways is calculated using the method described below. Travel time calculated using this method is called "present travel time".

On the main line of inter-city expressways, vehicle detectors are installed at 1 or 2 kilometer-intervals. The detectors are used to measure traffic volume, average speed and time occupancy on each lane. Data are collected every 5 minutes. To calculate the travel time, firstly, the total road distance between the origin and destination is divided into several road sections in such a way that each section has a detector and they are divided at the midpoint to the position of next detector. Secondly, with this configuration, the average speed in the recent 5 minutes measured by the detector in the section is taken to be the average running speed of the vehicles for that road section. Travel time of each section is calculated by the dividing the length of the section by the average speed. Finally, the total travel time is simply the summation of travel time of all sections between the origin and destination.

The travel time information calculated using this method is based on real-time traffic situation when data is first processed. However, due to the time lag between data processing and vehicles running on each section, the information received by the drivers is no longer real travel time of the drivers.

### 2.2. Estimation of the Average Real Travel Time for Drivers

Average real travel time for the drivers cannot be determined exactly, because the speed of each vehicle varies and measuring the speeds of all vehicles is too difficult. The data collected by vehicle detectors are aggregated data within 5 minutes. However, it is considered that average real travel times of drivers are different from the transmitted travel time information on the same district and departure time. Because there is a difference between the time that data of each section are collected for the information system and the actual time drivers pass each section.

To discuss the present situation of accuracy of the transmitted travel time information, it is necessary to estimate real travel time for the drivers. In this paper, the average real travel time is estimated using data measured by vehicle detectors. The method of estimation is described below.

Firstly, same as in the present method, the total road distance between the origin and destination is divided into sections with corresponding vehicle detectors. Secondly, the average running speed is determined. Instead of measuring and averaging the speeds in the recent 5 minutes, the speeds that must be measured and averaged are those after the vehicles have passed the upstream sections. Thirdly, again the same as in the present method, the time to pass each section is calculated by dividing the section length by average speed. Lastly, the total travel time is simply the summation of travel time of all sections between the origin and destination.

### 2.3. Summary of Surveying Data

The surveying data are collected by the vehicle detectors installed along the main line of Tomei Expressway. Survey district is between Tomei-Kawasaki interchange and Gotemba interchange, and survey dates are Aug. 12 and 16, 1995.

Tomei Expressway is an inter-city expressway connecting Tokyo and Nagoya. It is one of the expressways having the heaviest traffic volume in Japan. Heavy traffic congestion often occurs especially in the chosen survey district. One reason is that, since this district is inside the Tokyo metropolitan area, too much traffic uses this expressway. Another reason is that it is within a mountainous area such that it has many horizontal and vertical curves and tunnels.

During the survey dates, Aug. 12 and 16, 1995, heavy traffic congestion occurred in this district. These dates are just before and after the Buddhist Festival called "Obon". In Japan, many people living in Tokyo visit their hometown for this festival, therefore, heavy traffic congestion happens on the inter-city expressways yearly.

### 2.4. Comparison of the Informed Travel Time and the Estimated Real Travel Time

In this section, accuracy of the present travel time information on inter-city expressway are considered by comparing the "informed" travel time and "estimated" real travel time for drivers.

Fig.-1 shows the transitions of informed travel time and estimated real travel time of the drivers from Tomei-Kawasaki I.C. to Gotemba I.C. on Aug. 12. Informed travel time is calculated by the present method as shown in Section 2.1. In this figure, three types of real travel times for the drivers are estimated. One is the estimated travel time shown in Section 2.2. Another one is a travel time when driver uses the fastest lane at all sections. Third one is a travel time when driver uses the slowest lane at all sections. These travel times are named "estimated travel time", "fastest travel time" and "slowest travel time" respectively in this figure. The difference of these three travel times means the width of the distribution of real travel times for the drivers, which is caused by the drivers' lane choice behaviors.

Ordinary inter-city expressways have 2 or 3 lanes for one direction and running speed of the vehicles on each lane is obviously different. Therefore, difference of drivers' lane choice behaviors may cause the difference of the travel times by the individuals. Actual drivers on the inter-city expressways do not use the fastest or slowest lane along all over the district between the origin and destination. Therefore, it is considered that their real travel times distribute between the fastest and slowest travel times shown above.

Of course, each vehicle on the same lane is able to run at the different speed, especially in case of free flow. Then the difference of real travel times by the individuals is not only caused by their lane choice behavior. However, when traffic situation becomes congested, drivers must run under the influences of the other vehicles on the same lane. Therefore, it is considered that the vehicles run at the speed almost nearly to the average speed of the lane they use. Travel time information is efficient when traffic situation is congested, because the main purpose of its construction is traffic management to reduce the traffic jam. Then it is important to discuss accuracy of the information when traffic situation is congested. Therefore, it is suitable to consider that drivers' real travel times distribute between fastest travel time and slowest travel time shown in Fig.-1, to discuss the accuracy of information systems.

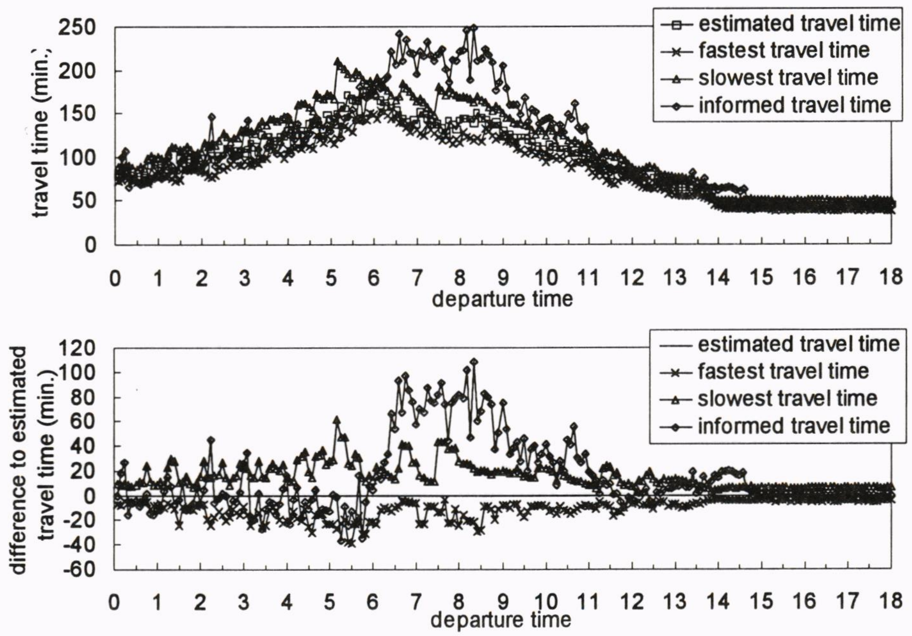
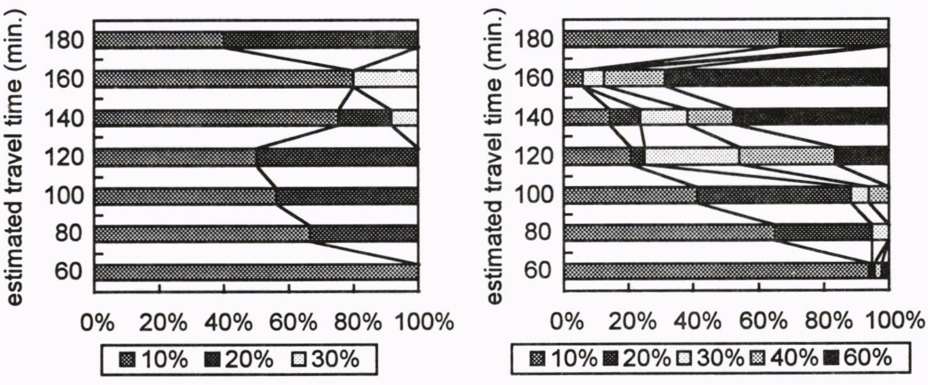



Fig.-1 Transition of informed travel time, estimated travel time and the fastest and slowest travel times




(a) the case that informed travel time is shorter than estimated travel time

(b) the case that informed travel time is longer than estimated travel time

Fig.-2 Ratio of the differences of the informed travel time to estimated travel time

Fig.-2 shows the ratio of the difference of the informed travel time to estimated travel time. One is in the case that informed travel time is shorter than estimated travel time and another one is in the case that informed travel time is longer than estimated travel time.

These figures show that informed travel time and estimated real travel time are different when traffic situation is congested. It is known that the difference between informed travel time and estimated travel time may become more than 30 or 40 % and it depends on the traffic situation. Informed travel time is shorter than estimated travel time when congestion is becoming heavier, and longer when congestion is becoming shorter. It is known that this difference is larger than the difference between fastest or slowest travel time and estimated travel time.

Such situation of accuracy of the existing travel time information systems may influence drivers' knowledge of accuracy of the information systems. It is considered that drivers' knowledge of the error level of the existing information systems is more than 30 or 40 % of the real travel time, in case of heavy traffic congestion. Therefore, it is necessary to discuss whether the current method is sufficient or not to influence drivers' choice behavior, as a method of traffic demand management.

## 3. MODELING CONCEPT OF THE DRIVERS' ROUTE CHOICE BEHAVIOR BY ACCURACY OF THE INFORMATION

From the viewpoint of road traffic managers, providing road traffic information is one of the methods of traffic demand management. With the aim to flatten-out the peak distribution of traffic volume, it is necessary to influence drivers' behaviors, for examples,

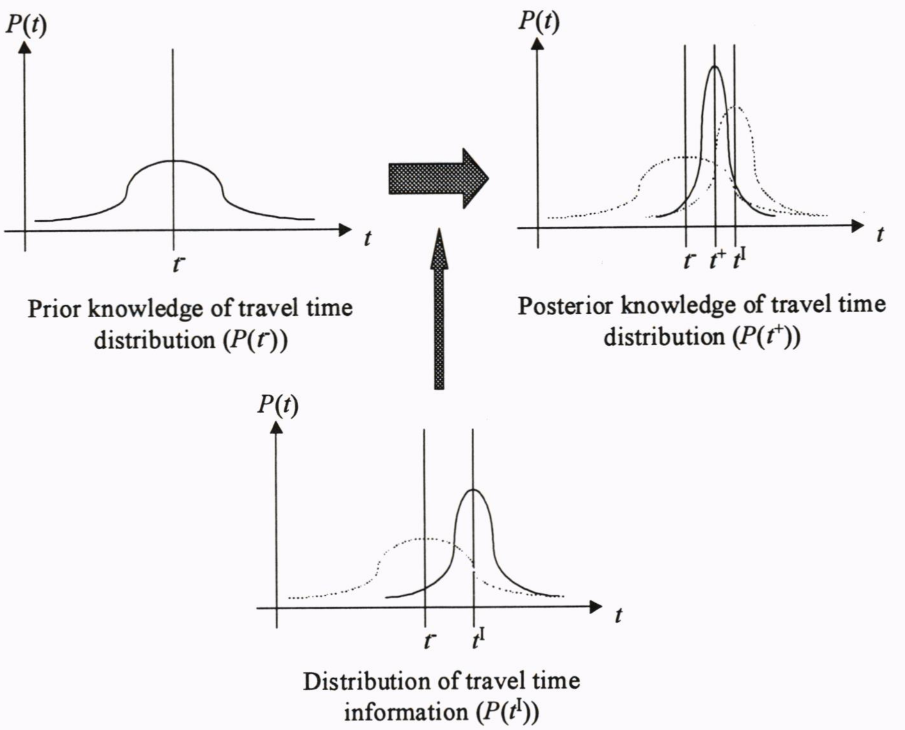



Fig.-3 Concept of change of the drivers' knowledge of travel time distribution caused by provided information route choice or departure time choice. In this section, drivers' route choice behavior is observed for the formulation of the behavioral model. The modeling method to represent the relationship between the accuracy of provided information and the drivers' choice behavior is observed.

Now we suppose that drivers evaluate traffic situations of the routes they use as travel time distributions. Drivers' route choice behavior depends on their own knowledge of travel time distribution and it may changes caused by the travel time information they get before departure and/or on the way. The concept of change of the drivers' knowledge of travel time distribution caused by the information is represented as Fig.-3.

This figure shows that drivers' knowledge of travel time distribution changes caused by the travel time information. Posterior distribution of travel time depends on both of the prior distribution and the provided information. The width variables (e.g. standard deviation) of the distribution of travel time information are understood as drivers' knowledge to accuracy of the provided information system. It is considered that drivers' knowledge depend on the real accuracy of the information system. If accuracy of the information system is high quality, the width of the distribution becomes small, and if accuracy of the information system is low quality, the width of the distribution becomes large.

In this paper, disaggregate behavioral model is proposed to represent drivers' route choice behavior. This model includes drivers' knowledge of the travel time distribution of each route and it can change caused by the provided information.

## 4. SUMMARY OF STATED PREFERENCE DATA

### 4.1. Summary of the Questionnaire Survey

The data used for the estimation of model parameters are based on the home-based questionnaire survey, which is done at the residential areas in Yokohama and Kawasaki City in Dec. 1992. In this survey, the drivers' route choice behaviors under the hypothetical travel time information are focused. Number of the examinees is 210 persons. Almost all (94 %) examinees are owners of private vehicles, and 42 % of examinees drive frequently more than four days in one week. 185 samples data can be used for the estimation of the model parameters on the following sections.

In this survey, drivers' route choice behavior from their own house to the central area of Tokyo is highlighted. Trip distances are almost 20 to 25 kilometers. Three routes are shown as alternatives. "Route 1" includes Tomei Expressway and Tokyo Metropolitan Expressway, "Route 2" includes Tokyo Metropolitan Expressway and "Route 3" consists of ordinary road only. The main districts of these three routes consist of inter-city expressway, urban expressway and high-quality national roads. Then vehicles are able to run at high speeds in case of free flow. However, these routes have high traffic demands and heavy traffic congestion happens many times.

### 4.2. Setting of the Hypothetical Travel Time Information to the Drivers and Its Accuracy

Firstly, drivers' ordinary route choices and their knowledge of the travel times are asked. Three types of drivers' own knowledge of the ordinary travel times are asked, for each of three routes above. One is an ordinary travel time, another one is the shortest travel time and third one is the longest travel time. These three values are used for the estimation of the prior knowledge of travel time distribution of the drivers.

Then, hypothetical travel time information is provided to the drivers for each route, and their route choice behaviors under the information are asked. The values of travel time information are indicated at random, of course independently to the drivers' prior knowledge of travel times. These travel times are set inside the range between the shortest travel time and the longest travel time, which are estimated by the trip distance, road structure and so on.

In the questionnaire sheets, the hypothetical travel time information is represented as "A min. ± B min.". "A" means average travel time and "B" means error to the average time. The width of error to the average travel time is defined as the accuracy of travel time information in this study.

## 5. ROUTE CHOICE MODEL CONSIDERING THE DRIVERS' RELIABILITY TO THE INFORMATION

### 5.1. Modeling of Change of Drivers' Knowledge of Average Travel Time

At first, we will consider disaggregate logit model with utility function that includes the drivers' reliability parameters to the information. In this model, to represent drivers' route choice behavior, the utility functions of each route before and after providing the information are defined as followings.

- before providing information :

$$V^- = \beta \cdot t^- + h(x) \tag{1}$$

- after providing information :

$$V^+ = \beta \cdot \left\{ \rho \cdot t^I + (1-\rho) \cdot t^- \right\} + h(x) \tag{2}$$

where $t^-$ is drivers' knowledge to ordinary travel time before providing information and $t^I$ is informed travel time. Distribution of the variable $t^-$ depends on the distribution of real travel time of the route and it is considered to be different by the individuals based on their own characteristics. Distribution of the variable $t^I$ is also influenced by the real travel time distribution. However, it is appropriate to suppose that these two variables are independent each other, because informed travel times on the questionnaire survey are indicated independently to the drivers' knowledge of the travel time.

Parameter $\rho$ means the drivers' reliability to the travel time information. If parameter $\rho$ is 0, drivers choose route based on their own knowledge only, and if parameter $\rho$ is 1, drivers choose route based on informed travel time only. Therefore, if estimated parameter $\rho$ is larger, it can be considered that drivers' choice behavior is more influenced by the transmitted travel time information. It is considered that this parameter is different owing to the accuracy of travel time information.

### 5.2. Estimation of the Route Choice Model Based on Stated Preference Survey

In this section, the parameters of the route choice model proposed in Section 5.1 are estimated using stated preference data shown in Section 4. Table-1 shows the result of estimation of parameters of the route choice model. In this model, drivers' reliability to the travel time information is assumed different in four steps owing to the accuracy of the travel time information.

From this estimation result, it is known that drivers' reliability to the travel time information is in the high levels for the case wherein the ratio of error is lower than 20 % of average travel time, but reliability become low for the case wherein the ratio of error is larger than 20 %. Therefore, it is considered that travel time information should be kept accurate with error lower than 20 % to influence the drivers' choice behavior. Moreover, this result shows that the drivers' reliability to the information becomes highest in case that the error level is 15 to 20 %, not in case it is less than 10 %.

Table-1 Result of estimation of the route choice model

| | parameters | t-value |
|---|---|---|
| drivers' reliability to the information | | |
| (case 1 : error is less than 10 %) | 0.8851 | (7.559) |
| (case 2 : error is 10 % to 15 %) | 0.7315 | (6.106) |
| (case 3 : error is 15 % to 20 %) | 0.9217 | (6.662) |
| (case 4 : error is more than 20 %) | 0.4271 | (1.081) |
| travel time (min.) | -0.09170 | (-8.374) |
| income dummy (route 1) * | 1.098 | (4.844) |
| distance to interchange dummy (route 1) ** | -0.7432 | (-2.520) |
| constant (before information, route 1) | -1.794 | (-6.009) |
| constant (before information, route 2) | -2.756 | (-8.036) |
| constant (after information, route 1) | -1.294 | (-4.457) |
| constant (after information, route 2) | -2.046 | (-7.060) |
| initial likelihood | -317.4 | |
| last likelihood | -255.6 | |
| likelihood ratio | 0.1864 | |
| hit ratio | 67.78 | |
| number of samples | 180 | |

* : 1 if annual income is more than 10 million yen, 0 otherwise.
** : 1 if distance to the nearest interchange is more than 6 km, 0 otherwise.

Comparing this result to the Section 2, it is learned that the present situation of accuracy of travel time information is not enough to influence drivers' choice behavior. The necessity to ensure the accuracy of travel time information should be highlighted.

## 6. MODELING OF THE DRIVERS' ROUTE CHOICE BEHAVIOR USING BAYESIAN METHODOLOGY

### 6.1. Summary of "Bayes' Theorem"

Bayesian methodology is one of the methods to forecast the variable $\theta$, which is uncertain for decision-maker, using some information $x$ about that variable. The characteristic of this methodology is to express the uncertainty of the variable as a subjective probability distribution of the decision-maker. He estimates an uncertain variable $\theta$ by using his all knowledge on decision-making situation, and recognizes it as a subjective probability distribution. The subjective probability distribution can change following to getting additional information. The probability distribution before he gets information is called "prior distribution" and the probability distribution after he gets information is called "posterior distribution".

The mathematical framework of this methodology is represented as followings.

(1) The prior distribution of uncertain variable $\theta$ is supposed by each decision-maker. The uncertainty is considered as a subjective probability distribution and it is represented as $p(\theta)$.

(2) It is supposed that the information $x$, which is offered to the decision-maker, is distributed as a probability function $p(x|\theta)$ around the actual value of variable $\theta$. This distribution $p(x|\theta)$ is understood as a "likelihood" of the information $x$ to the actual value of variable $\theta$.

(3) The posterior distribution is a subjective probability distribution of the variable $\theta$ under the condition that decision-maker gets information $x$. Using the formula of the conditional probability,

$$p(\theta, x) = p(\theta \mid x) \cdot p(x) \\ = p(x \mid \theta) \cdot p(\theta) \tag{3}$$

the posterior distribution $p(\theta|x)$ is represented as following,

$$p(\theta \mid x) = \frac{p(\theta, x)}{p(x)} \\ = \frac{p(\theta) \cdot p(\theta \mid x)}{\int_{\Theta} p(\theta, x) d\theta} \\ = \frac{p(\theta) \cdot p(\theta \mid x)}{\int_{\Theta} p(\theta) \cdot p(\theta \mid x) d\theta} \quad (\theta \in \Theta) \tag{4}$$

where $\Theta$ is a parameter space of variable $\theta$.

This formula (Eq.-4) is called "Bayes' theorem". It can be expressed simply as following, in other words.

$$\textit{Posterior Distribution} \propto \textit{Likelihood} \times \textit{Prior Distribution} \tag{5}$$

The important characteristic of this formula is that both of "prior distribution" and "posterior distribution" are subjective probability distributions of the decision-maker. Furthermore, "likelihood" is also subjective distribution of the decision-maker. Of course, they are different by individuals. Therefore, even if offered actual information is same distribution, posterior distributions of the drivers should be different distributions by individuals.

### 6.2. Representation of Change of the Drivers' Knowledge of Travel Time Distribution Using Bayes' Theorem

In this section, Bayesian methodology is used to represent change of drivers' knowledge of travel time distribution. Using the Bayes' theorem, drivers' knowledge of travel time distribution after providing information is proportional to the product of the drivers' knowledge of travel time distribution before providing information and the distribution of provided travel time information. It is considered that accuracy of the provided information is represented as a standard deviation of the subjective distribution of the information. Therefore, drivers' knowledge of travel time distribution after providing information is obviously influenced by accuracy of the provided information.

In this paper, it is supposed that drivers' knowledge of travel time distribution before providing information ("prior distribution") is normal distribution. Providing travel time information ("likelihood") is also supposed to be normal distribution. Based on these supposing, drivers' knowledge of travel times distribution after providing information ("posterior distribution") becomes also normal distribution. In this case, expected value and standard deviation of the posterior distribution is expressed as followings, using those variables of the prior distribution and likelihood.

- expected value of posterior distribution :

$$\mu^{+} = \frac{\mu^{-} \cdot \sigma^{I2} + \mu^{I} \cdot \sigma^{-2}}{\sigma^{-2} + \sigma^{I2}} \tag{6}$$

- standard deviation of posterior distribution :

$$\sigma^{+} = \sqrt{\frac{\sigma^{-2} \cdot \sigma^{I2}}{\sigma^{-2} + \sigma^{I2}}} \tag{7}$$

where $\mu^-$ and $\sigma^-$ are expected value and standard deviation of the "prior distribution", and $\mu^l$ and $\sigma^l$ are those of the "likelihood". $\mu^+$ and $\sigma^+$ are expected value and standard deviation of the "posterior distribution".

### 6.3. Estimation of the Route Choice Model Using Bayes' Theorem

In this section, disaggregate behavioral model which includes change of the drivers' knowledge of travel time distribution based on the Bayes' theorem is proposed.

The data used for the estimation are shown in Section 4. In this questionnaire survey, drivers' knowledge of travel times on each route is expressed as "ordinary travel time", "shortest travel time" and "longest travel time". Drivers' knowledge of travel time distribution is supposed to be normal distribution, using these three values, as followings. "Ordinary travel time" is the expected value of the distribution, and the difference between "shortest travel time" and "longest travel time" is 3 times of the standard deviation of the distribution. Furthermore, the distribution of likelihood is also supposed to be normal distribution. For the travel time information represented as "A min. ± B min.", it is supposed that "A" is the expected value and that "B" is 1.5 times of the standard deviation.

Table-2 shows the estimation results of the parameters of route choice behavioral models. In this table, both models are disaggregate logit models which include expected value and standard deviation of drivers' subjective travel time distribution as explanation variables. In "Bayes model", Bayes' theorem is used to represent change of drivers' knowledge of travel time distribution, therefore, the explanation variables are supposed to be changed as shown in Eq.-6 and Eq.-7 when drivers get travel time information. In "non-Bayes model", these variables are supposed to be same with provided travel time information.

Table-2 Results of estimation of the route choice model

| | Bayes model | | non-Bayes model | |
|---|---|---|---|---|
| | parameters | t-value | parameters | t-value |
| expected value of travel time (min.) | -0.07460 | (-4.217) | -0.06098 | (-4.307) |
| standard deviation of travel time (min.) | -0.4490 | (-2.910) | -0.1985 | (-3.084) |
| income dummy (route 1) * | 0.9864 | (2.746) | 1.178 | (3.165) |
| distance to interchange dummy (route 1) ** | -0.9637 | (-2.106) | -0.9250 | (-2.082) |
| constant (route 1) | -1.110 | (-2.791) | -0.9134 | (-2.547) |
| constant (route 2) | -2.065 | (-6.380) | -1.902 | (-6.116) |
| initial likelihood | -163.8 | | -163.8 | |
| last likelihood | -134.1 | | -131.9 | |
| likelihood ratio | 0.1815 | | 0.1945 | |
| hit ratio | 67.22 | | 68.88 | |
| number of samples | 180 | | 180 | |

* : 1 if annual income is more than 10 million yen, 0 otherwise.
** : 1 if distance to the nearest interchange is more than 6 km, 0 otherwise.

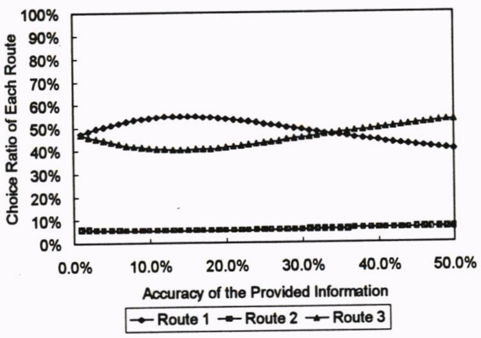
From these estimation results, it is known that likelihood ratio and hit ratio, which indicate the goodness of fit of the proposed models, are almost same values in both models. Non-Bayes model has a fitting a little better than Bayes model. Comparing the estimated parameters, the parameter of standard deviation of drivers' subjective travel time distribution in Bayes model is larger than that in non-Bayes model. This result shows that the Bayes model represents more sensitively the influence of accuracy of the provided travel time information. Therefore, it is known that using Bayes' theorem to represent change of the drivers' knowledge of travel time distribution is efficient to represent their route choice behaviors, especially to represent the influence of accuracy of the provided information.

### 6.4. Sensitivity Analyses of the Influences of Accuracy of the Information to the Route Choice Behavior of Drivers

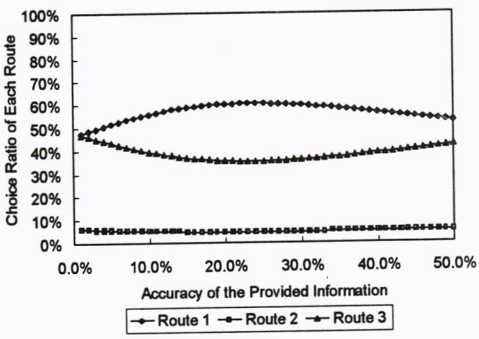
In this section, the influence of accuracy of the travel time information to route choice behavior of the drivers is analyzed using route choice model shown above.

Fig.-4 shows the differences of the choice ratios of each route caused by the accuracy of the proposed travel time information based on the "Bayes model" shown in Table-2. Drivers' knowledge of ordinary travel time of each route is fixed to 40 minutes. Travel time information is provided for the all routes and indicated travel times are "30 min." for the route 1 and "40 min." for the route 2 and 3. Therefore, if the choice ratio of route 1 is increased, it is considered that drivers' behaviors are largely influenced by the provided information. Income dummy and distance to interchange dummy are fixed to the average numbers of all drivers.

The differences of Fig.(a) and Fig.(b) show the influence of the drivers' perception of the standard deviation of travel time distribution before providing information. Fig.(a) shows the case that the drivers' perception of the standard deviation of travel time is 10 minutes. Fig.(b) shows the case that the drivers' perception of the standard deviation of travel time is 15 minutes.

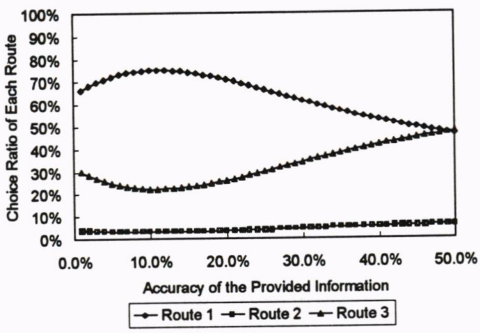



(a) the case that the standard deviation of travel time perception is 10 min.

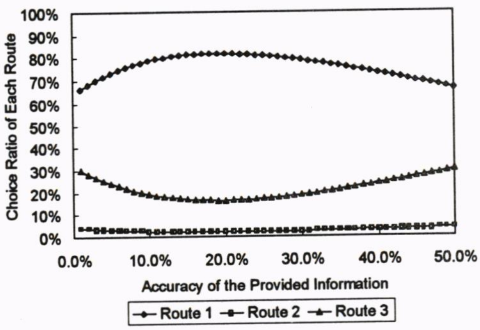



(b) the case that the standard deviation of travel time perception is 15 min.

Fig.-4 Differences of the choice ratio of each route by the accuracy of the proposed travel time information (1)




(a) the case that the standard deviation of travel time perception is 10 min.




(b) the case that the standard deviation of travel time perception is 15 min.

Fig.-5 Differences of the choice ratio of each route by the accuracy of the proposed travel time information (2)

Fig.-5 shows the results of the same analyses in case that the indicated travel times are "30 min." for the route 1 and "50 min." for the route 2 and 3. Drivers' knowledge of ordinary travel time of each route and its standard deviation before providing information is set as same as the case of Fig.-4.

From these figures, it is known that drivers' route choice ratio is cause by the accuracy of the provided information. In addition, it is caused by the drivers' own knowledge of travel times and their standard deviations. Moreover, it is known that too accurate information (error level is too small) will not increase the choice ratio of the route 1, which is the route that the information indicates travel time is shorter than other routes. This result accords with the result in Section 5.2, which shows the drivers' reliability to the information becomes highest in case that the error level is 15 to 20 %, not in case it is less than 10 %.

## 7. CONCLUSION

In this paper, the relationship between the accuracy of travel time information and the drivers' route choice behavior is observed.

Firstly, present situation of accuracy of travel time information on inter-city expressways is investigated. Supposing that such actual situation of accuracy causes drivers' knowledge of accuracy of the information, the accuracy of present travel time information is not in enough quality to influence drivers' route choice behavior, when traffic situation is heavy congested. Therefore, the necessity to ensure the accuracy of travel time information should be highlighted.

Secondly, modeling method of the relationship between accuracy of travel time information and drivers' route choice behavior is established. One is disaggregate behavioral model that includes the parameter to represent the drivers' reliability to the information. Another one is disaggregate behavioral model that includes the representation of change of the drivers' knowledge of travel time distribution using Bayes' theorem. These models are applied to the stated preference data of route choice behavior.

The results of the estimation of the model parameters show that the proposed choice model represents more sensitively the influence of accuracy of the provided travel time information. Therefore, it is known that using Bayes' theorem is efficient to represent change of the drivers' knowledge of travel time distribution on route choice behaviors, especially to represent the influence of accuracy of the provided information. Moreover, throughout the sensitivity analyses, it is known that too accurate information will not increase the choice ratio of the route that the information indicates travel time is shorter than other routes.

In this paper, all of the subjective distributions of travel times are supposed to be normal distributions. However, it is considered that drivers' actual knowledge of travel time distribution is not only in normal distribution but also in other various types of distribution. Therefore, in future study, it is necessary to discuss the influence of the difference of travel time distribution by individuals to the choice behavior. Furthermore, it is necessary to discuss the method to identify the distribution of drivers' knowledge of travel time.

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