An Analysis of the Uncertainty of Perceived Travel Time of Drivers Considering the Route Navigation and Traffic Information

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Abstract **– In this research, route choice behaviors of drivers using route navigation and information systems are analyzed. Discrete choice models which include the uncertainty of perceived travel times of drivers are constructed. Furthermore, the effects of route navigation and information systems to the traffic conditions on hypothetical urban road network are estimated with the combinatorial optimization problem of the navigated routes. The optimization problem is solved by using genetic algorithms in this research.**

I. INTRODUCTION

Today, many types of traffic information systems for road traffic are coming into practical use. Such information systems are expected to influent to drivers' route choice behaviors, departure time choice behaviors, and so on. They might prevent traffic congestion on the road network caused by the concentration of traffic flow to the specific links and the specific peak hours. For the road traffic administrators, this might be the most important incentive to construct the various infrastructures that constitute the traffic information systems.

One of the very useful traffic information systems for many drivers is route navigation system through the in-vehicle computer and display systems. Route navigation systems can estimate the most useful route for the drivers using a certain optimization algorithm and indicate the route and information within the map on the display. Route navigation systems with real-time traffic information are rapidly coming into wide use in Japan, which is called vehicle information and communication systems. Therefore, many drivers can perform route choice behaviors comfortably based on real-time traffic information by using route navigation and information systems.

However, it is pointed out in existing researches that traffic condition on whole road network might be worse if too much drivers using route navigation systems are guided into the same routes which estimated by the same algorithm [1][2]. It is since too much vehicles might concentrate into the specific links on the road network.

Therefore, route choice behaviors of the drivers using route navigation and information systems are focused in this research. The main aim of this research is to analyzing and modeling the route choice behaviors of drivers using route navigation systems and to estimate the influences of traffic information to their route choice behaviors. Discrete choice model which includes the uncertainty of perceived travel times of drivers is constructed. Furthermore, the effects of route navigation and information systems are estimated on the hypothetical urban road network within the combinatorial optimization problem of the navigated routes. The optimization problem of the navigated routes is solved by using genetic algorithms in this research.

II. PERCEIVED TRAVEL TIMES OF DRIVERS

A. Summary of the Data

The data used in this research are based on the stated preference survey about the perceived travel times and route choice behaviors under the hypothetical route navigation and information systems. The questionnaire survey is performed into the students of Ritsumeikan University in December 2002.

In the questionnaire survey, perceived travel times and route choice behaviors based on the hypothetical traffic information which indicated on the displays of in-vehicle navigation and information systems are asked. The provided information consists of the ordinary shortest route based on the ordinary traffic conditions, and the real-time shortest route based on the real-time traffic conditions. It is supposed that drivers might choose their route from these two alternatives. Drivers can recognize several types of information on both routes from the indicated map such as total distance, number of right and left turns, road classification (e.g. national road, main prefecture road, general prefecture road, etc.), and so on.

Also, route choice behaviors of drivers are asked if two routes are indicated on the hypothetical route navigation systems. Three types of navigation systems are assumed; 1) Only route indications are provided; 2) Route indications and distances of both routes are provided; 3) Route indications, distances, and travel times of both routes are provided.

Figure 1: Sample of the Questionnaire Survey

B. Modeling of the Perceived Travel Times of Drivers

Based on the above-mentioned data, regression models are constructed in order to represent the relationship between perceived travel times of drivers, provided information and route characteristics. The route characteristics consist of distance, number of right and left turns, and road classification as shown above.

It is assumed that the perceived travel times of drivers are represented as triangle fuzzy numbers to represent the uncertainty of recognition of drivers for travel times. The relationships between provided information and the median, left spread, and right spread of fuzzy perceived travel times of drivers are assumed to be a linear regression model respectively. The estimation results of the regression parameters to represent the median of perceived travel time are shown in Table 1.

Table 1: Estimation Results of Perceived Travel Time Model

	No Information	Travel Time Information	Congestion Length Information
Travel Time Information [min.]	-	1.021 (10.43)	-
Congestion Length Information [km]	-	-	0.7320 (5.459)
Total Distance [km]	1.740 (6.641)	-	1.413 (5.432)
Distance of National Road [km]	-	-0.2138 (-2.541)	-
National Road Dummy	-13.43 (-3.648)	-	-9.410 (-2.913)
R^2	0.3961	0.7567	0.5764
Sample Number	119	139	106

III. Modeling of Route Choice Behaviors

A. Summary of the Modeling

In this section, discrete choice models are constructed to analyzing the route choice behaviors of drivers when route navigation and information are provided. It is supposed that the provided information is transposed into the perceived travel time in each driver's knowledge, in order to compare the traffic conditions on multiple routes. Furthermore, in order to represent the uncertainty of perceived travel times of drivers, they are represented as triangle fuzzy numbers.

Route choice behaviors of drivers are represented by constructing discrete choice models including explanation variables based on fuzzy perceived travel times. Therefore, it is necessary to compare the fuzzy perceived travel times on both routes to construct the discrete choice model. In existing researches, "possibility measure method" is required for the analyses of the route choice behaviors. It is summarized as shown in Figure 2 [3].

At first, the fuzzy target G is defined as a measure of driver's satisfaction for the travel time of the objective origin-destination pair. Then, the possibility measure

$Pos(R \le G)$ is determined for the explanation variables of discrete choice model. It is defined as a possibility that the driver's fuzzy perceived travel time R is equal to or less than the fuzzy target G of the origin-destination pair. If the membership functions of fuzzy numbers R and G are determined as $\mu_R(u)$ and $\mu_G(v)$ respectively, the possibility measure $Pos(R \le G)$ is represented as a following.

$$Pos(R \le G) = \sup_{u \ge v}\{\min(\mu_R(u), \mu_G(v))\} \tag{1}$$

On the other hand, another possibility measure $Pos(R < G)$ is also defined. It is defined as a possibility that the driver's fuzzy perceived travel time R is less than the fuzzy target G of the origin-destination pair. If the membership functions of fuzzy numbers R and G are determined as $\mu_R(u)$ and $\mu_G(v)$ respectively, it is represented as a following.

$$Pos(R < G) = \sup_{u}\left[\inf_{u > v}\{\min(1-\mu_R(u), \mu_G(v))\}\right] \tag{2}$$

In this research, it is assumed that all of the drivers are having the common fuzzy target for each route and origin-destination pair.

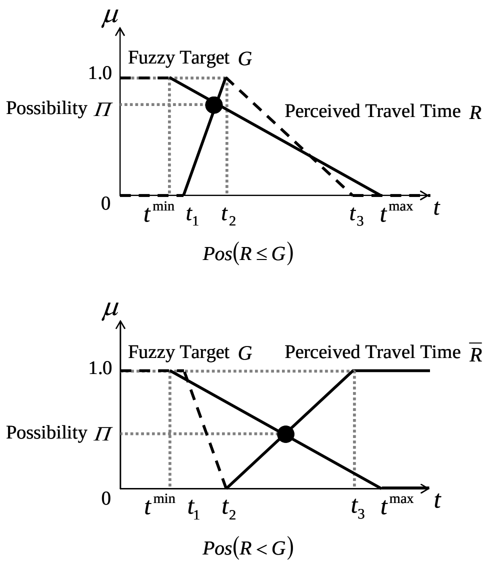

Figure 2: Definition of the Possibility Measures

It is considered that the possibility measure $Pos(R \le G)$ means the driver's optimistic recognition for the uncertainty of perceived travel times. It is a measure of the risk preference behavior of drivers, since it is defined by the left spread of the fuzzy perceived travel time R and the fuzzy target G. On the other hand, it is considered that the possibility measure $Pos(R < G)$ means the driver's pessimistic recognition for the uncertainty of perceived travel times. It is a measure of the risk avoidance behavior of drivers, since it is defined by the right spread of the fuzzy perceived travel time R and the fuzzy target G.

B. Estimation Results of the Model Parameters

Based on the above-mentioned assumptions, route choice models of the drivers using route navigation and information systems are constructed. As explanation variables, two possibility measures, distance and number of right and left turns on both routes are installed in the model.

Estimation results of the model parameters are shown in Table 2. In the case of route navigation only, both of the possibility measures and number of right and left turns are having significant influence to the route choice behaviors, although total distance is not so much influential.

Moreover, compared the three models, the following points are recognized. If travel time information is provided, only possibility measures based on the perceived travel times are significant. However, in other two cases, total distance or number of right and left turns is also becoming significant. That is, if travel times are not informed for the drivers clearly, other factors are also taken into consideration of the drivers in their route choice behaviors. However, if travel time information is provided clearly, route choice behaviors of drivers are performed almost only in consideration with the perceived travel times of the drivers.

Table 2: Estimation Results of Route Choice Model

	Route Navigation Only	Route Navigation and Distance	Route Navigation, Distance and Travel Time
Possibility Measure $Pos(R \le G)$	12.32 (9.879)	14.75 (8.435)	15.93 (17.55)
Possibility Measure $Pos(R < G)$	13.98 (10.35)	15.43 (9.867)	20.59 (24.65)
Total Distance [km]	-3.987 (-1.321)	-8.549 (-4.651)	-
Number of Right and Left Turns	-0.534 (-5.486)	-	-0.142 (-0.751)
Likelihood Ratio	0.431	0.365	0.498
Hit ratio	0.745	0.804	0.811
Sample Number	145	168	132

IV. Effects of Route Navigation on Urban Network

A. Hypothetical Urban Road Network

In this section, the effects of route navigation and information systems to the traffic conditions are estimated with the optimization problem of combination of the navigated routes on the hypothetical urban road network.

For the following analyses, a hypothetical road network which consists of 25 nodes, 80 links, and 9 centroids is assumed as shown in Figure 3. There are two types of links in the network; one is the two-lane national roads (C = 4,000 [veh/h]) and another one is the one-lane ordinary roads (C = 2,000 [veh/h]). Traffic demand between each origin-destination pair is assumed to be 2,000 [veh/h] respectively.

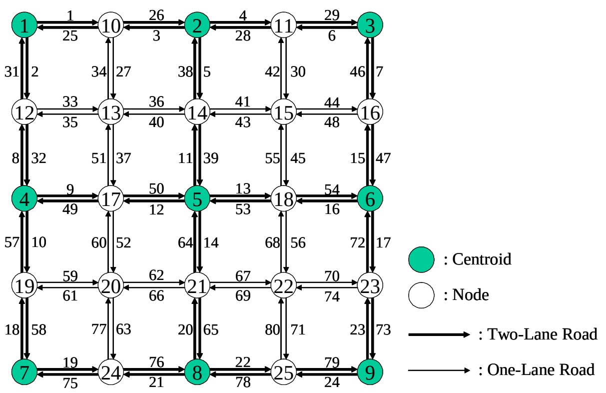

Figure 3: Objective Road Network

There are two types of vehicles on the road network. One is "guided vehicles" which having in-vehicle navigation systems and another one is "unguided vehicles" which do not having in-vehicle navigation systems. For guided vehicles, route navigation according to real-time traffic condition is performed, and it is assumed that drivers might choose their route according to the above route choice model. For unguided vehicles, it is assumed that drivers choose ordinary route since they cannot acquire the real-time traffic information. Specifically, it is estimated by the stochastic user equilibrium based on the above-mentioned traffic demand.

B. Combinatorial Problem of the Navigated Routes

In this research, several cases that a traffic obstacle exists on the above-mentioned road network are considered. Specifically, it is assumed that one lane is blockaded on the link that the traffic obstacle exists and that the traffic capacity of the link decreases from 4,000 [veh/h] to 2,000 [veh/h]. Two cases of the position of traffic obstacle in the network are assumed. One is "Link No.10" which is located at the perimeter of network and another one is "Link No.53" which is located at the center of network. In such cases, there are several routes whose travel times are shorter than the travel time of the ordinary shortest route for some origin-destination pairs. Therefore, information of the several routes might be provided into the drivers of guided vehicles, and drivers might choose their route based on the provided information.

Moreover, the optimization problem of combination of the navigated routes according to the traffic conditions on whole road network is considered. The purpose of traffic administrator is assumed as the minimization of total travel time of vehicles in whole road network. Based on the purpose, traffic administrator shall examine the optimal combinatorial problem of the navigated routes for guided vehicles of many origin-destination pairs.

The following procedure is performed to define and solve the optimization problem for road traffic administrator. Firstly, three alternative routes are selected for each origin-destination pair. These routes are the first shortest route, the second shortest route, and the third shortest route of the origin-destination pair. Then, traffic administrator might select a route from the three alternatives as the navigated route for providing to drivers. At that time, traffic administrator selects the optimal combination of the routes for all origin-destination pairs to minimize the total travel time on whole road network. In this research, genetic algorithms are applied for solving efficiently the combinatorial optimization problem of navigated routes of all origin-destination pairs.

C. Effect of Optimal Combination of the Navigated Routes

Figure 4 and Figure 5 show the total travel times on whole road network based on the route navigation with the optimal combination of the navigated routes for all origin-destination pairs.

From these figures, it is known that it is possible to decrease total travel time on whole road network if traffic administrator provides the traffic information with suitable combination of the navigated routes appropriately, comparing with the case that the real-time shortest routes are provided for all guided vehicles. It turns out that it is possible to prevent to increase total travel time caused by the concentration of vehicles on the specific links when diffusion ratio of navigation systems is increasing. It is known that traffic flow on the link which the traffic obstacle exists might decrease of course. It means that most of guided vehicles have avoided traffic congestion on the link which the traffic obstacle exists and that their behaviors have influenced into the traffic condition on the other links.

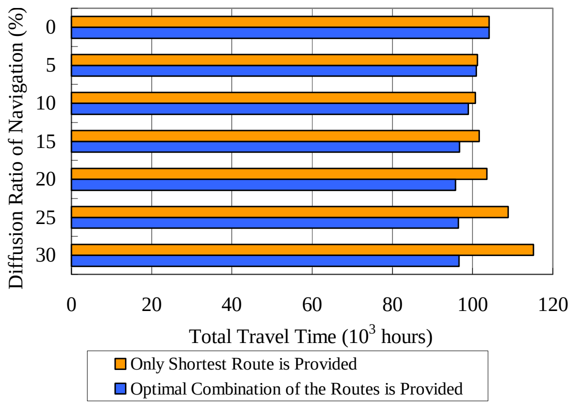

Figure 4: Total Travel Times on Whole Road Network (Traffic Obstacle on Link No.10)

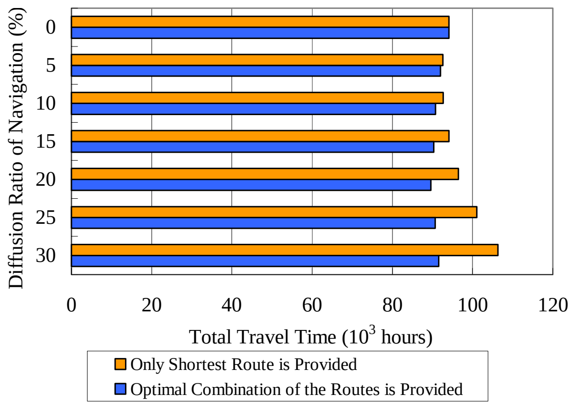

Figure 5: Total Travel Times on Whole Road Network (Traffic Obstacle on Link No.53)

V. Concluding Remarks

Throughout the above analyses, the following conclusions are pointed out. Firstly, if travel time information is provided, route choice behaviors of drivers are performed almost only in consideration of perceived travel times. However, if travel time information is not provided, other factors are taken into consideration of the drivers in their route choice behaviors. Secondly, throughout the evaluation procedure of the effects of traffic information, it turned out that it is possible to prevent the much concentration of traffic flow to the specific links, if the traffic administrator provides the suitable combination of the traffic information for the drivers.

The following points are mentioned as future works. Firstly, it is considered that drivers can be classified into several groups having the different behavioral characteristics in actual. Therefore, it is necessary to analyze the characteristics of drivers and to evaluate the influence of traffic information for each group which having the different characteristics. Secondly, it is necessary to examine the generality of the results with the various cases of road networks, such as types and scales of road networks, traffic demand patterns, and so on.

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