Impacts of the Accuracy of Traffic Information in Dynamic Route Guidance Systems

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ABSTRACT

In this study, we evaluate impacts of the accuracy of traffic information in dynamic route guidance. We focus on how the information quality (present or predicted information) and its accuracy influence on traffic condition in relation to the share of equipped vehicles. The recent developments in Intelligent Transport Systems are expected to bring the environment in which the dynamic traffic information and dynamic route guidance are frequently supplied to users. On the other hand, there have been negative opinions for the system: providing traffic information may sometimes make traffic condition worse because everyone would try to use routes recommended by the current information. We should, therefore, investigate how and to what extent route guidance systems (or more generally traffic information systems) can mitigate traffic condition. In addition to categorizing two type of information quality (present or predicted), predicted information is classified into three types with different level of accuracy (high, middle, low). The impacts of the information has been evaluated quantitatively by applying our dynamic traffic simulation model, SOUND[1], to the Tokyo Metropolitan Expressway network. As the result, it was confirmed that providing predicted information can improve traffic condition even if the information is not perfectly accurate and the improvement seems more when the share of equipped vehicle becomes higher.

1. INTRODUCTION

One of the most expected effect of ATIS is the improvement of traffic condition by providing traffic information. We should therefore understand the effect through realistic experiments. Yoshii et al. have analyzed effects of dynamic route guidance systems providing present or predicted information without prediction errors[2]. And they reported that traffic condition is improved more by providing the predicted information in most cases, especially when an unexpected accident occurs.

Whereas in reality, it is quite difficult to precisely predict future traffic condition.   In this study, we consider different accuracy levels in the predicted information and evaluate impacts of dynamic route guidance in relation to the share of equipped vehicles.   Another feature of this study is that the model is applied to a real network with observed time-dependent OD volumes so that the results of the analysis could practically more appeal.

2. SIMULATION MODEL

2.1 The Model Framework

As the model framework is written in reference[2], this chapter explains just the outline of   the model framework.   Let us first define present and predicted information, which this study uses. The present travel time of a route means the sum of present instantaneous link travel times along the route, while the predicted travel time is the actually experienced travel time obtained based on the future traffic condition estimated by the prediction logic mentioned below.

As shown in Fig.1, when the simulation starts at time 0, we first implement "Prediction of future traffic" to estimates future traffic condition up to one hour in advance.   In "Prediction of future traffic", we store future traffic condition by implementing the simulation assuming that everyone chooses a route based on the present link travel times. Then, we return to the main course of the simulation and progress the run for ΔT (5 minutes in Fig.1) by evaluating driver's routes based on the estimated future traffic condition above. Then, the simulation again bypasses to "Prediction of future traffic" in order to update future traffic condition and so on as shown in Fig.1.
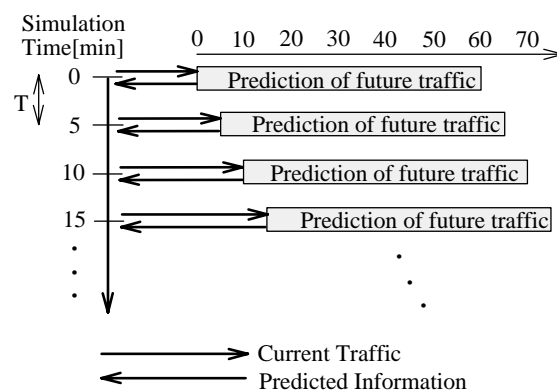

Fig.1 The Model Structure for Predicted Information

2.2 Route Choice Behavior

We consider the following two different types of drivers.

(1) *Fixed-Route Group*

Drivers in this group do not change routes regardless of travel times, and the fixed probabilities are calculated by the Logit assignment (with parameter   ) based on free flow link travel times at speed of 60 [km/h].   They will choose a next link to go at diverging point abiding by the diverging ratio determined by the assignment.

(2) *Route Choice Group*

Drivers in this group are respondent to traffic information from control center through car navigation equipment, which means they can access traffic condition of an entire network at any time. And they are assumed to choose the shortest routes to their destinations based on the information supplied.

2.3 The Accuracy of Predicted Information

In reality, predicted information may contain errors due to several factors as follows :
(a)   OD volumes may not be precisely estimated for the future prediction time period,
(b)   The simulation model may not be able to reproduce traffic condition perfectly,
(c)   Current traffic condition may not be exactly monitored,
(d)   Driver's route choice behavior may not be fully understood.

On the other hand, when we evaluate the impacts through the model, the errors (a), (b) and (c) are not included, since the simulated traffic condition by the model is considered as the real traffic condition.   Thus, for the more realistic evaluation of traffic information systems, we should add error terms to the predicted information.

Since drivers in Route Choice Group respond to predicted travel time in their route choices, the error term should be added to travel times.   There are two ways to put error terms to travel times:

Method 1   Adding the error term to each link travel time, or
Method 2   Adding the error term to each route travel time.

In Method 1, there is a problem that if the number of links along a route increases, the error term becomes less dominant.   For example, suppose that travel time of link a , $\widehat{t_a}$, consists of constant term of t_a and its error term is ε_a following the Normal distribution, $N(0, (\alpha \cdot t_a)^2)$:

$$\widehat{t}_a = t_a + \varepsilon_a . \tag{1}$$

Then, travel time of route p composed of n links, $\widehat{T}_p$, is

$$\widehat{T}_p = \Sigma_a \widehat{t}_a = \Sigma_a t_a + \Sigma_a \varepsilon_a = T_p + \varepsilon_p \tag{2}$$
$$\varepsilon_p \sim N(0,(\alpha \cdot \sqrt{\Sigma_a t_a^2})^2).$$

Therefore, this ratio of standard deviation of the error term to the constant time on route p is smaller

than one at link a approximately by a factor of $1/\sqrt{n}$:

$$(\alpha \cdot t_a)/t_a \;=\; \alpha \;>\; (\alpha \cdot \sqrt{\Sigma_a t_a{}^2})/T_p. \approx \;\; \alpha/\sqrt{n} \tag{3}$$

On the other hand, in case of Method 2, instead of avoiding the problem as above, another problem occurs in route travel time.   Suppose there are two routes of almost the same travel times but they share some portion of the routes as shown in Fig.2.   We cannot add the error term independently because their routes are partially overlapped each other.   In general, however to add appropriate error term considering this kind of shared portion is not systematically easy.
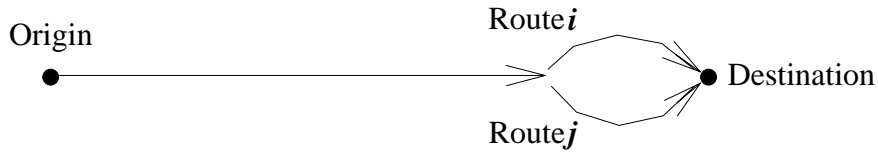

Fig.2 Example Network

Therefore, this study employs the following method, which is a slight modification of Method 1. For route p, its travel time is defined

$$\hat{T}_p \;=\; T_p + \varepsilon_p \;=\; T_p + (\Sigma_a \hat{t}_a - \Sigma_a t_a)\cdot(\Sigma_a t_a / \sqrt{\Sigma_a t_a{}^2}) \tag{4}$$

so that $\sqrt{Var(\varepsilon_p)}\,/T_p$ is equal to α, which is shown as below:

$$Var\{(\Sigma_a \hat{t}_a - \Sigma_a t_a)\cdot(\Sigma_a t_a / \sqrt{\Sigma_a t_a{}^2})\} = \{(\Sigma_a t_a)^2/(\Sigma_a t_a{}^2)\}\cdot Var(\varepsilon_p)$$
$$= \{(\Sigma_a t_a)^2/(\Sigma_a t_a{}^2)\}\cdot \alpha^2 \cdot(\Sigma_a t_a{}^2)$$
$$= (\alpha\, T_p)^2$$

However, there is still a problem that the additive law is not warranted; that is, for route p consisting of link a and b, $\hat{T}_p \neq \hat{t}_a + \hat{t}_b$ as illustrated in an example below.
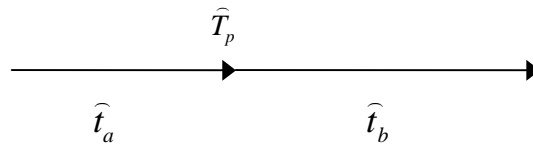

Fig.3 Violation of the Additive Law

3. APPLICATIONS TO TOKYO METROPOLITAN EXPRESSWAY

3.1. Network and Traffic Demand

Table 1 and Figure 4 show the outline of the Tokyo Metropolitan Expressway network used in this study. The network is approximately 240 km in length with about 800 links and 800 nodes, and a star mark in the figure denotes the location of an accident we creates. During the simulation period from 4 am. to 11 am., about 350 thousands vehicle trips are generated.
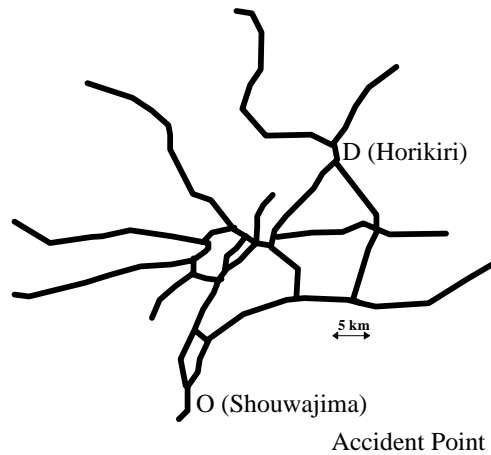
3.2 The Ratio of Drivers belongs to Route Choice Group

We change the share of Fixed Route Group and Route Choice Group to evaluate effects of information at various different components of drivers responding traffic information.

Fig.4 Tokyo Metropolitan Expressway Network

Table 1   Network and Traffic Demand

Length in km	240
No. of Links	800
No. of Nodes	800
No. of Trips (4 am. - 11 am.)	350,000

3.3 Information Quality

Four types of information with different quality are defined as follows :

(a)present information,
(b)predicted information without any error,
(c)predicted information with error whose standard deviation is 10% of travel time ($\alpha=0.1$),
(d)predicted information with error whose standard deviation is 20% of travel time ($\alpha=0.2$).

For information types (c) and (d), since we have to add the error term according to the Normal distribution, we run the simulation several times and take an average of these results to evaluate impacts on traffic condition.

3.4 Application Result

Fig.5 shows the average travel time per trip within the simulation time (from 4 a.m. to 11 a.m.) by the share of Route Choice Group. Since the average travel time per trip gets extremely large when the share is less than 50%, the figure describes only a portion with the share greater than 50%.
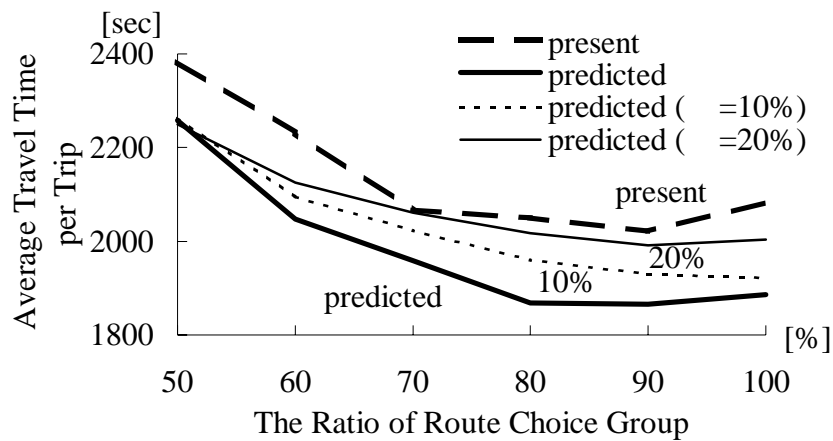
Fig.5 Changes in Traffic Condition depending on the Share of Route Choice Group

From the figure, we remark the following points :

(1) Traffic condition seems to be improved more with predicted information than with present information regardless of the share of Navigation Group, even if the information is not strictly accurate.

(2) The gap between the cases with predicted information and predicted information with error becomes large as the share of Route Choice Group increases except for the case of 100%.

(3) In both cases with present and predicted information without error, when the share of Route Choice Group is more than 80-90%, traffic condition gets worse as the share increases. On the other hand, if there are some errors in predicted information, this tendency is not apparent.

The following section explains each points in more detailed manner.

(1) Table2 shows average travel times under provision of predicted information with and without error as well as present information for the 80% share of Route Choice Group. The travel time is averaged over 20 calculations for the case providing erroneous predicted information ($\alpha=0.1$). From the table, traffic condition seems to be more improved by predicted information even with error than by present information.

Table 2   Average Travel Time

Predicted Information (α =10%)	[sec]
Average Travel Time	1936
Standard Deviation	53
Min. Travel Time	1850
Max. Travel Time	2025
Predicted Information (no error)	
Average Travel Time	1868
Present Information	
Average Travel Time	2050

(2) Fig.6 shows how much time Route Choice Group saves compared to Fixed Route Group in cases of 50% and 80% share of Route Choice Group under provision of predicted information with random error ($\alpha=0.1$) for trips from Shouwajima to Horikiri. From this figure, the advantage of Route Choice Group in travel times with 80% share of Route Choice Group is smaller than one with

50% share; that is, this advantage seems smaller as the share increases, and this tendency has been confirmed in all cases with other type of information.　This advantage would be caused by the difference of travel time between the shortest route and the other alternative routes.　When the share of Route Choice Group is large, the travel time difference among alternative routes would be smaller, since travel times on alternative routes could be more equalized by the majority of Route Choice Group.　Thus, if predicted information has some errors, Route Choice Group may have larger chance not to choose the shortest route and consequently their advantage may be smaller compared with Fixed Route Group.　On the contrary, if the share is small which means travel time difference among alternative routes is large, Route Choice Group could successfully choose the shortest route even with erroneous predicted information.
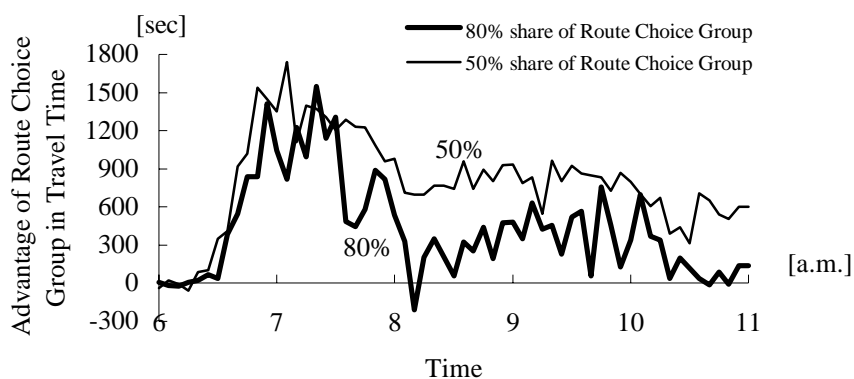

Fig.6 Advantage of Route choice Group ($\alpha=0.1$

As the share of route Choice Group increases, the advantage is smaller, and there are some time intervals with very little advantage, for example from 8 a.m. in Fig.6.　Then, it seems that there is few effect of route guidance when the share of Route Choice group increases; however, as the average travel time would be shorter than one for lower share, the utility of users belonging to Route Choice Group is not reduced by the larger share of Route Choice Group.

(3) Figure 5 says that, with the share of Navigation Group of more than 80-90%, traffic condition gets worse even if the predicted information is provided.　When the present information is given, this tendency would be brought by the concentration of vehicles to the shortest route.　However, this tendency is observed even with the predicted information, although the concentration is not as much as the situation with the present information.　The main reasons for this worth traffic condition would be:

　1. The predicted information which cannot be the exact estimate of future traffic condition.
　2. The user equilibrium condition does not generally bring the optimal condition for the system as a whole.　In other words, some portion of drivers must be forced to choose the second or third shortest routes for them in the system optimal condition.　In this case study, the above condition seems to be established when the share of Route Choice Group is more or less 80%.

On the other hand, in the case of providing predicted information with error, even if all drivers belong to Route Choice Group, some of them may choose the second or third shortest routes because of the error term.　Therefore, lines of　=10 and 20% look monotone decreasing in the share.

4. SUMMARY AND FUTURE SCOPE

This study analyses impacts of the quality of information on traffic condition.　The major remarks are summarized as follows :

1. It is confirmed that traffic condition is more improved by providing the predicted information than the present information, even if the information is not strictly accurate.
2. Since the gap between the cases providing predicted information and predicted information with error becomes large with high share of Route Choice Group, the accuracy of predicted information is more important as the share of Route Choice Group increases.
3. In the case of providing predicted information with error, the higher share of Route Choice Group can achieve more improvement.

Some of future research topics would be :

1. Some theoretical analyses in addition to the simulation study are required to support the above results obtained here, since those obtained through some case studies using the Metropolitan Expressway network may not be generally concluded.
2. We should examine how the several error factors influence the accuracy of information.
3. Although the route choice behavior of a driver with dynamic information is a base of modeling, there are still enough rooms to be studied on the human factor.

ACKNOWLEDGMENT

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