An Evaluation of Effects of Dynamic Route Guidance on an Urban Expressway Network

Toshio Yoshii [1)]
Hirokazu Akahane [2)]
Masao Kuwahara [1)]

[1)] Institute of Industrial Science, University of Tokyo
7-22-1 Roppongi, Minato-ku Tokyo 106, Japan
Tel 03-3402-6231, Fax 03-3401-6286, e-mail yoshii@ozak.iis.u-tokyo.ac.jp
[2)] Department of Civil Engineering, Chiba Institute of Technology
2-17-1 Tsudanuma, Narashino, Chiba 275, Japan

ABSTRACT

This study evaluates impacts of dynamic route guidance by applying our traffic simulation model, SOUND, to the Tokyo Metropolitan Expressway network. The focus is placed on how the information quality (present or predicted information) and a share of equipped vehicles of navigation systems influence on traffic condition. Proposing several scenarios with different compositions of driver types and with/without an accident, we examine the impacts qualitatively. In most cases of this study, the predicted information improves traffic condition more than the present one, especially in a case with an accident unexpectedly occurred.

1. INTRODUCTION

The recent developments in Intelligent Transport Systems are expected to bring the environment in which the dynamic traffic information and route guidance are frequently supplied to users. On the other hand, since there has been a negative opinion for the system [1]. For instance, due to providing traffic information, traffic condition might sometimes get worse than one without the information, since 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 congestion.

In this study, we focus on how the information quality (present or predicted information) and a share of equipped vehicles of navigation systems influence on traffic condition. We use the dynamic traffic simulation model, SOUND (a Simulation model On Urban Networks with Dynamic route choice), which has been validated to

reproduce various traffic conditions reasonably well [2]. The model is here applied to the Tokyo Metropolitan Expressway network to examine impacts of traffic information.

Several studies have analysed effects of dynamic route guidance on traffic. Moritsu *et al.* have analysed the impacts of information simulating behavior of two types of drivers: guided and unguided drivers [3]. A guided driver chooses a route of the shortest travel time based on the current traffic condition, whereas an unguided driver chooses a fixed route. They report that the negative effect appears, when over 70% of drivers are guided and that the positive impact may also be reduced by the communication delay.

Mahmassani *et al.* have developed a simulation model to investigate effects on the performance of a congested urban traffic under real-time in-vehicle information [4]. The study reports that the optimal condition is achieved when a driver switches his current path only if the improvement in remaining travel time exceeds some threshold level of about 20% of the remaining trip time.

These previous studies mostly analyse impacts of traffic information based upon present conditions. On the other hand, we here analyse both present as well as predicted traffic information, since we expect to provide traffic information which tells predicted future traffic condition. Another unique feature of this study is that the model is applied to a real network with observed time-dependent OD volumes so that the results derived from the study could practically more appeal.

2. SIMULATION MODEL

2.1. The model Framework

In this study, there are two types of models for the present information and the predicted information. 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 considered to approximate the actually experienced travel time and is obtained based on the future traffic condition estimated by the prediction logic mentioned later.

(1) The model for ***present*** information

Fig.1 shows the model for the present travel time that consists of two modules: the vehicle simulation and the route choice modules. The vehicle simulation module moves discrete vehicles forward at every scanning interval of Δt (=3 seconds) based on a simple car-following model along routes determined by the route choice module, and updates present link travel times whenever vehicles leave links. On the other hand, the route choice module evaluates every driver's route at a regular interval of ΔT (= 5 minutes) based on present link travel times estimated by the vehicle simulation module. These two modules are repeatedly implemented to reproduce dynamic evolution of traffic flow on a network. The detailed description of the model is written in reference [2].

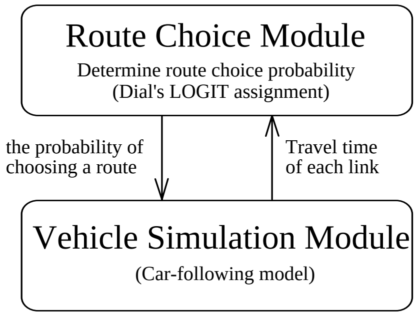

Fig.1 The Model for Present Information

(2) The model for ***predicted*** information

Although, for predicted information, the general model structure is the same as above, the difference is found only in provision of the predicted travel times. As shown in Fig.2, 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. "Prediction of future traffic" means the computation of the model for present information; that is, everyone is assumed to choose a route based on the present travel times in this prediction. Then we determine driver's routes based on the estimated future traffic condition above, and execute the computation for ΔT time interval. This process is repeated at every ΔT. Therefore, for predicted information, the simulation bypasses to the model for present information every ΔT interval so as to estimate future condition.

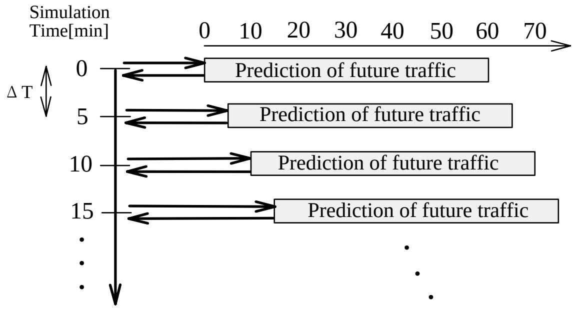

Fig.2 The Model Structure for Predicted Information

2.2. Travel Time Information

In the simulation model for predicted information, at every ΔT, future traffic condition is produced up to one hour in advance. And the average link travel time of each link is updated for every 5 minutes during the one-hour time period. Then, predicted travel times of routes are calculated along the routes as the sum of predicted link travel times at times when a vehicle will enter the links. For example, suppose the simple network shown in Fig.3. Table 1 shows the average travel time of each link for every 5 minutes. In this case, a vehicle at node A will arrive at node B 8 minutes later because current travel time of link a is 8 minutes. And it will arrive at node C 12 minutes later as travel time of link b at time the vehicle arriving at node B (8 minutes later than current time) is 4 minutes. In this way, the predicted travel time is evaluated along a route. On the other hand, the present travel time of a route is obtained by simply summing up present link travel times on the route.

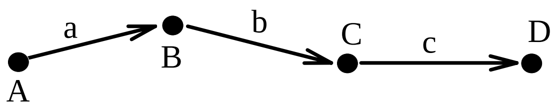

Fig.3 Simple Network

Table 1 Link Travel Time of Each Link for Every 5min.

[min.]	Link a	Link b	Link c
15~20	10	8	12
10~15	8	5	10
5~10	7	4	8
0~5	8	3	8

2.3. Route Choice Behavior

We consider the following three 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 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) ***VMS*** Group (Route Choice Group based on Variable Message Signs)

Drivers in this group are respondent to traffic information but they do not have vehicle navigation equipment. They are assumed to have experiences to drive on a network and have knowledge of average travel times of all links under regular condition (with no accident). They can get information covering only a limited area through VMS (Variable Message Signs). The information updates a part of average travel times at regular condition. They are assumed to choose the travel time minimum routes to their destinations, therefore, based on the above partially update travel times.

The rule of determining a section which VMS displays is in accordance with the logic employed by the Metropolitan Expressway Public Corporation. Roughly speaking, the section is selected depending upon the degree of congestion and the share of the traffic volume related to the congestion. In case of providing predicted information, the selection is based on predicted traffic condition at 30 minutes later than current time.

(3) ***Navigation*** Group (Route Choice Group using Vehicle Navigation Systems)

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

Fig.4 shows the difference in covered areas by the information between VMS and Navigation Groups. The horizontal axis shows a route and each section represents a link, while the vertical axis shows the future traffic condition accessible either through VMS or vehicle equipment. When the present information is provided, only traffic condition on the horizontal axis are updated by it. But, VMS Group can get the information until the head of the queue on the route according to the logic how to select the displayed section mentioned above. On the other hand, when the predicted information is provided, since Navigation Group can get all the information up to one hour in advance, they renew the all of the time-space plane of the link travel times shown in Fig.4. While VMS Group can update a part of the plane that is up to a head of the nearest queue at 30 minutes later time and hence displayed on VMS.

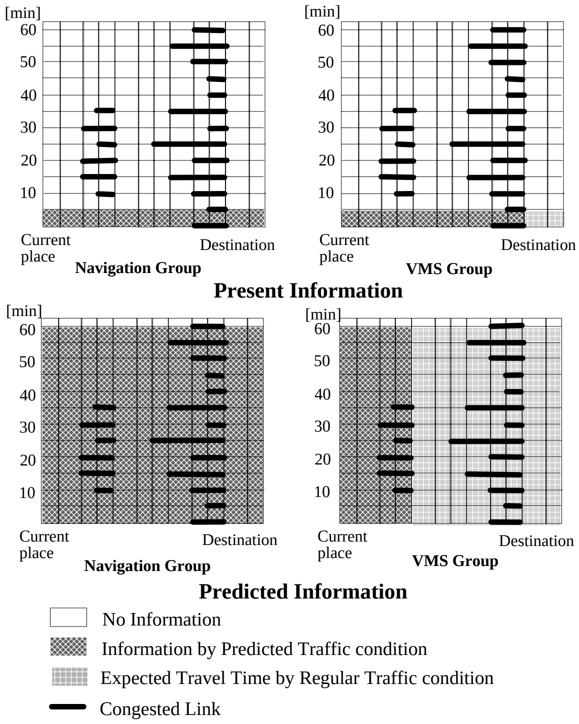

Fig.4 Covered Areas by Information

3. APPLICATIONS TO TOKYO METROPOLITAN EXPRESSWAY

3.1. Network and Traffic Demand

Table 2 and Fig.5 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 created. During the simulation period from 4 am. to 11 am., about 350 thousands vehicle trips are generated.

Table 2 Network and Traffic Demand in this study

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

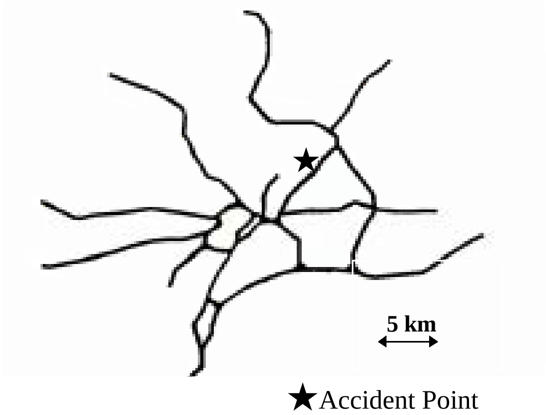

Fig.5 Tokyo Metropolitan Expressway Network

3.2. Scenarios

The applications are made according to three scenarios below.

Scenario 1
In order to simplify the situation, the VMS Group is eliminated. Then, we change the share of Fixed Route Group and Navigation group to evaluate effects of information at various different components of drivers responding traffic information.

Scenario 2
It is reported by another research survey that about a half of drivers traveling the expressway are respondent to traffic information and the remaining do not change their routes[5]. Thus, the share of Fixed Route Group is set at 50% and effects of information is evaluated at various shares of other two groups of VMS and Navigation Group. In this scenario, impacts can be evaluated due to diffusion of vehicle navigation systems under the current situation of 50% Fixed Route Group.

Scenario 3
In the near future, it is expected that information will be more accurate and easily acquired by drivers, then the share of drivers responding information would increase and that of Fixed Route Group would decrease. For this reason, the share of Fixed Route Group is set at 20% and effects of various shares of other two groups are examined.

In each scenario, two situations of with and without an accident at the location marked in Fig.5 are simulated. Since many OD pairs have several alternative routes, substantial amount of vehicles are expected to switch routes due to congestion caused by the accident. For all the scenarios, traffic capacity at the accident site is reduced for one hour period from 7 to 8 am., and the reduced capacity value is assumed to be exactly known in the simulation.

3.3. Application Results

(1) Improvement of Traffic Condition by Present and Predicted Information

Fig. 6 shows the average travel time per trip by the share of Navigation Group in scenario 1. Since the average travel time per trip gets extremely large when the share is less than 50%, the figure describes only a portion with greater than 50% share of Navigation Group. From the figure, traffic condition seems to be improved more by predicted information than present information regardless of the share of Navigation Group. Especially, when traffic condition changes drastically due to the accident, predicted information largely improve the condition compared to present information.

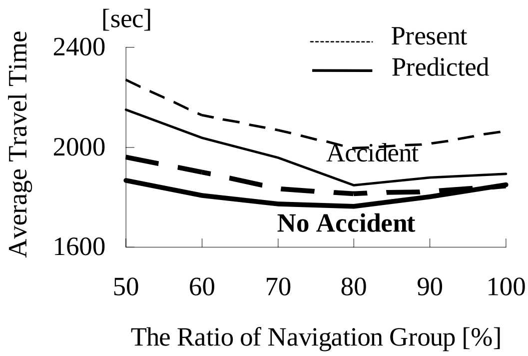

Fig.6 Changes in Traffic Condition depending on the Share of Navigation Group (scenario 1)

(2) Traffic Condition depending on Share of Navigation Group

Figure 6 says that, with the share of Navigation Group of more than 80%, traffic condition gets worse with higher share even if the predicted information is provided. When the present information is given, this worse traffic condition is considered to be brought by the concentration of vehicles to routes with currently shorter travel times. However, this tendency is observed even with the predicted information, although the concentration would not as much as the situation with the present information.

The main reason for this worse traffic condition would be due to the predicted information which cannot exactly estimate future condition. Especially, when the share of Navigation Group is 100%, the average travel time with the predicted information and present one are almost the same in the case of no accident. Since, in this study, the travel time is predicted assuming that drivers choose routes based on current traffic condition, the gap between the predicted and the actual traffic condition may become large with the very high share of Navigation Group. Another reason would be found from the fact that the user equilibrium condition is not generally the optimal condition for the system as a whole. In other words, some portion of drivers must be forced to choose routes not giving the shortest travel times for them in the system optimal condition. In this case study, the above condition seems to be established when the share of Navigation Group is more or less 80%.

(3) Areas covered by Traffic Information

In scenario 2 and 3, keeping the share of Fixed-Route Group 50% and 20% respectively, we change the shares of VMS Group who can get traffic information of a limited part of a network and Navigation Group who can get information of an entire network. Figures 7 and 8 respectively show the result without and with the accident.

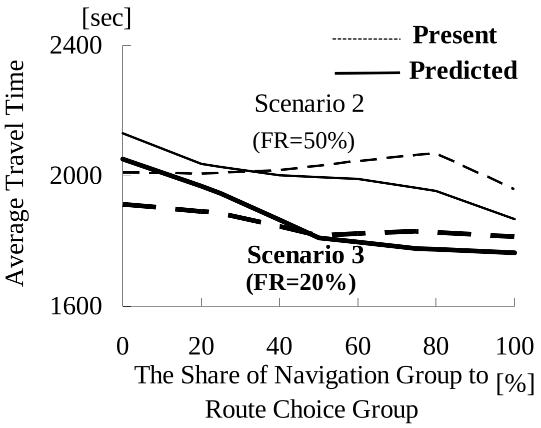

Fig.7 Changes in Traffic Condition depending on Information Sources (without the accident)

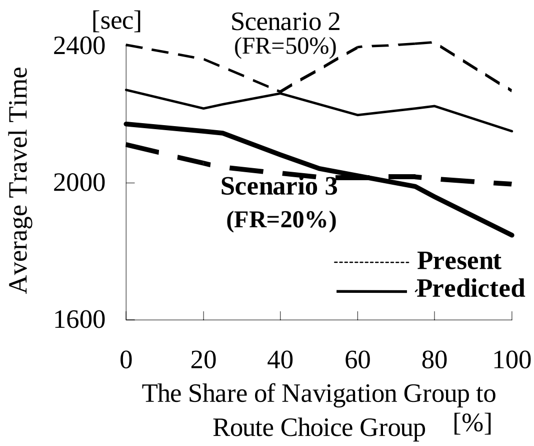

Fig.8 Changes in Traffic Condition depending on Information Sources (with the accident)

In both scenarios, the traffic condition is improved as the share of Navigation Group increases. Traffic condition with the predicted information becomes clearly improved compared to the condition with the present information, when the share of Navigation Group out of drivers utilizing information exceeds a certain level. This boundary level is higher as the share of Fixed-Route Group decreases and in a case with the accident.

Also, when the share of Navigation Group is zero, traffic condition with the predicted information sometimes gets worse than one with the present information. Fig. 9 shows a variation of distances to the head of a queue shown on the variable message sign from the diverging point at which the variable message sign is installed. From the figure, we see that the area shown on the variable message sign with the predicted information is quite different from one with the present information. Because of this difference in the area shown on the sign, sometimes traffic condition with the predicted information, which often shows more narrow area than one by present information, happens to be worse. In reality, this situation would not likely occur, since drivers can see the approximate traffic condition of a wider area from graphic information signs which have been installed on the network in addition to variable message signs.

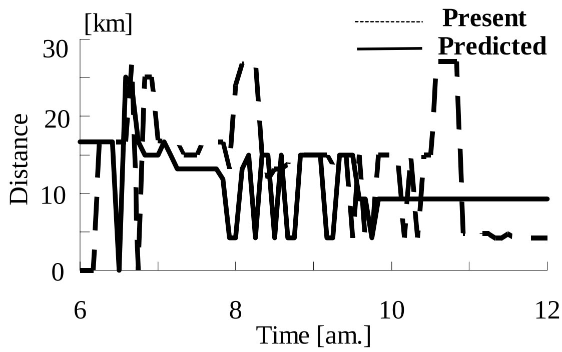

Fig.9 Variations of Distances to the Head of a Queue from the VMS Location

4. SUMMARY AND FUTURE SCOPE

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

1. It is confirmed that, in most situations, traffic condition is more improved by providing the predicted information than the present information.

2. Especially, the above improvement becomes significant when an unexpected accident occurs. Also, traffic condition gets better as the share of drivers utilizing information increases.
3. Since the predicted information cannot exactly estimate future condition, and the user equilibrium condition is not generally optimal for the system as a whole, traffic condition sometimes gets worse as the share of Navigation Group increases even if the predicted information is provided, especially with the rate more than 80%.
4. Compared to traffic information through variable message signs covering a part of the network, information through navigation equipment covering a wider area improve traffic condition more.
5. When traffic information of only a part of the network is given, traffic condition with the predicted information may sometimes get worse than one with the present information. Hence, it is important to select one or two proper areas shown on a variable message signs, which can provide only a limited number of messages at once.

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 accuracy of information affects traffic condition. For instance, the OD volumes have no errors in this simulation model, and thus the predicted information seems more accurate than one in the real situation, if the same prediction logic is employed. Furthermore, if the bi-directional communication system were common, the amount of information acquired from vehicles traveling on a network could be substantially more and the predicted information could be more accurate.
3. Effects of graphic information boards should be analysed, since drivers can roughly recognize traffic condition of a wider area than one covered by VMS.
4. Although the route choice behavior of a driver is a base of modelling, there are still enough rooms to be studied.

ACKNOWLEDGMENT

We would like express our sincere thanks to Dr. Morita, vice director of Engineering Department as well as members in Planning and Traffic Control Divisions, Metropolitan Expressway Public Corporation, who kindly provided traffic data for the research.

REFERENCES

[1] Arnott, R. et al., "Does Providing Information to Driver Reduce Traffic Congestion ? ", *Transpn. Res.* Vol.25A , No.5, pp.309-318 , 1991.
[2] Yoshii, T. et al., "Development of Traffic Network Simulation Model for Oversaturated Traffic Flow on Urban Expressways", *Traffic Engineering* Vol.30, No.1, pp.33-41,1995.
[3] Moritsu, H. et al., "Analysis of Traffic Network Flow by Adapting Route Guidance", *proceedings of Infrastructure Planning*, Vol.9, pp.37-44, 1991.
[4] Mahmassani, H. S. & Jayakrishnan, R., "System Performance and User Response under real-time information in a congested traffic corridor", *Transpn. Res.* Vol.25A, No.5, pp.293-307,1991.
[5] Center for Tokyo Metropolitan expressway Technology, "The Report of Basic Research about Traffic Engineering and Traffic Economy in Tokyo Metropolitan Expressway", pp.275-287,1993.2.