AN EVALUATING METHOD ON EFFECTS OF DYNAMIC TRAFFIC INFORMATION

Toshio Yoshii
Associate Professor, Kochi University of Technology
Tosayamada, Kami-gun, Kochi, 782-8502, JAPAN
Tel: +81-887-57-2406, Fax: +81-887-57-2420, E-mail: yoshii@infra.kochi-tech.ac.jp

Masao Kuwahara
Professor, Institute of Industrial Science, University of Tokyo
4-6-1, Komaba, Meguro-Ku, Tokyo, 153-8505, JAPAN
Tel: +81-3-5452-6419, Fax: +81-3-5452-6420, E-mail: kuwahara@nishi.iis.u-tokyo.ac.jp

SUMMARY

This study proposes a realistic method to evaluate impacts of dynamic traffic information provision, and after we analyze the essence of impacts using a simple road network and a simple OD demand, the method is applied to a real urban expressway network using observed OD volumes. Although traffic information has been dynamically provided through VMS, on-board equipment, highway radio etc., the impacts on traffic have not been well evaluated by taking the daily OD demand fluctuation. We therefore propose a new evaluation method considering the OD demand fluctuation and show a possibility that the information provision may lead to total travel time increase. To examine this possibility, the method is then applied to the Tokyo Metropolitan Expressway network for one month. As a result, it is confirmed that dynamic traffic information provision would not be effective under regular traffic condition except at the beginning of a peak. However, the benefit arises in unusual traffic condition caused by incidents.

INTRODUCTION

One of the most expected effects of ATIS is the improvement of traffic condition by providing on-time traffic information. On the other hand, since there has been a negative opinion for the system[1)]. We should therefore understand the impacts through realistic experiments. Several studies have analyzed effects of dynamic route guidance on traffic. Moritsu *et al.*[2)] has analyzed the impacts of information simulating behavior of two types of drivers: guided drivers and unguided ones. A guided driver chooses the route, by which he can travel to his destination in 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.*[3] has developed a simulation model to investigate effects on the performance of a congested urban traffic under real-time in-vehicle information. 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.

Yoshii *et al.*[4] has analyzed effects of dynamic route guidance systems providing present or predicted information. They studied on actual road network with observed time-dependent OD volumes, and they 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.

These previous studies mostly analyze impacts of traffic information based upon fixed OD patterns and they estimate two cases, *with* and *without information*. They assumed that every driver chooses his route depend on its distance (or its free flow travel time) in case *without information*. This assumption must be non-realistic. On the other hand, in this study, two types of drivers are also considered in case *without information*, experienced drivers and inexperienced ones. Experienced drivers choose their route depend on their experience, which has been formed by daily traffic condition. We assume that they choose their route by averaged traffic condition. Now, under our assumption, if OD pattern is not changed and enough experienced drivers are existed, NO improvement would be observed by providing traffic information. Because, experienced drivers can choose their routes depend on on-time traffic condition that is equal to averaged traffic condition. Improvement can be generated under unusual traffic condition that is caused by difference of OD demand, incidents or others. The evaluation method of this study is more realistic than previous ones.

EVALUATION FRAMEWORK

Traffic condition both *with* and *without information* are produced by traffic simulation model. In this study, SOUND[5] (a Simulation model On Urban Networks with Dynamic route choice), which has been validated to reproduce various traffic condition reasonably well, is applied to an actual road network. Comparing these two results, we estimate the effects of Dynamic Traffic Information Provision.

Two Types of Models

There are two types of models for the case *with information* and *without information*.

<u>In Case *with Information*</u>
We consider the following two different types of drivers.

a. Fixed-Route Drivers
Drivers in this group do not change their routes regardless of travel times, and the fixed probabilities are calculated by the Logit assignment based on free flow link travel times. They will choose a next link to go at diverging point abiding by the diverging ratio determined by the assignment.

b. Guided Drivers (Route Choice Drivers 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 assigned by the Logit assignment based on on-time link travel times.

<u>In Case *without Information*</u>
We also consider the following two different types of drivers.

a. Non-experimental Drivers (Fixed-Route Drivers)
Same as the Fixed-Route Drivers above.

b. Experimental Drivers (Route Choice Drivers)
Drivers in this group choose their routes depending on travel times of each route on averaged traffic condition. They are assigned by the Logit assignment based on averaged link travel times. Here, averaged travel time is estimated using travel times, which are observed for many days.

SIMPLE NETWORK ANALYSIS

Network and Traffic Demand

<u>Network</u>
We use a simple study network as shown in Figure 1. There are one OD and two alternative routes A and B. Both routes have bottlenecks that capacities are defined as μ_a and μ_b respectively. Vertical queue is assumed in this network. Free flow travel times of via route A and B are T_a and T_b respectively.

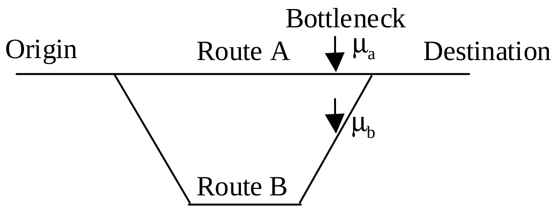

Fig. 1 Simple Network

<u>Traffic Demand</u>
Figure 2 shows assumed OD demand on study network. Traffic demand generates constantly (rate = q_0 [veh/h]) within the time interval from T_1 to T_2. These three conditions are assumed in this analysis as follows.

$$T_b > T_a \tag{1}$$

$$T_2 - T_1 >> T_d = T_b - T_a \tag{2}$$

$$\mu_a + \mu_b > q_0 > \mu_a \tag{3}$$

where
T_d : difference between travel time of via route A and route B

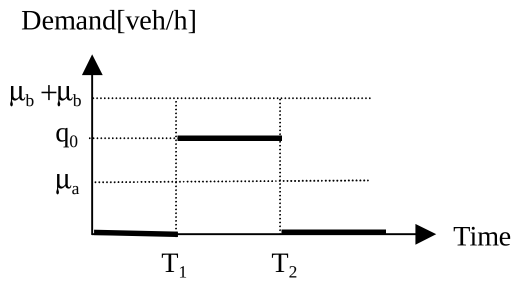

Fig. 2 Assumed Demand

Assumptions

In order to make the analysis essential we consider these two assumptions as follows;

a. All drivers belong to a group of Guided Drivers in case *with Information* and Experimental Drivers in case *without Information.*

b. OD demand is not changed. In other words, the fixed traffic condition is repeatedly appeared.

Traffic Assignment - *Daily Traffic Condition*

Under those assumptions, every driver is able to choose a minimum route by which he can arrive at destination with minimum travel time in both cases with and without information provision. Therefore, DUE (Dynamic User Equilibrium) condition would be achieved in both cases. Figure 3 shows cumulative numbers of vehicles generating at the Origin under DUE condition. At the beginning of the generating time interval (from T_1 to T_3), all drivers choose route A because of its free flow travel time. Because the demand rate is larger than bottleneck capacity (eqn.(3)), congestion queue will be appeared at the bottleneck on route A, and it grows constantly. Soon (time T_3) travel time of route A has become larger and reached to free flow travel time of route B. After that, some of drivers, which corresponded to the bottleneck capacity on route A (μ_a), choose route A and the others choose route B. Total of loss time (L_{UE}) is evaluated in eqn (4).

$$L_{UE} = T_d \cdot Q - \frac{1}{2} T_d^2 \cdot \frac{q_0 \cdot \mu_a}{q_0 - \mu_a} \qquad (4)$$

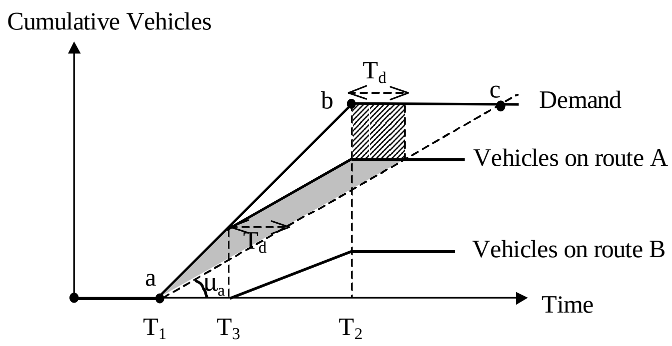

Fig. 3 Cumulative Vehicle Numbers in both Cases (under DUE Condition)

Evaluation

We consider that the OD demand has become smaller by a little volume. Constant generating rate becomes q ($q = q_0 - dq$). Total delays are different between the two cases. We now compare these two in order to evaluate an effect of traffic information.

<u>In Case *with Information*</u>

Even if OD demand is changed, DUE condition is also achieved in case *with information.* Cumulative numbers of vehicles generating at the Origin shown in figure 4. Total of loss time (L_{inf}) is calculated in eqn(5).

$$L_{\inf} = T_d \cdot Q - \frac{1}{2} T_d^2 \frac{q \cdot \mu_a}{q - \mu_a} \tag{5}$$

<u>In Case *without Information*</u>

All drivers cannot understand the change of traffic condition because he can receive no information. Therefore, every driver chooses his route based on the averaged traffic condition, which is achieved by cumulative numbers of generating vehicles shown in figure 3. Until time T_3, all drivers choose route A. After time T_3, the ratio of drivers who choose route A to those choose route B is not changed from that of daily traffic condition. Flow rates of both routes are lead by the simultaneous equations as follows.

$$\mu_a : q_0 - \mu_a = \mu_{1a} : \mu_{1b} \tag{6}$$

$$\mu_{1a} + \mu_{1b} = q_0 - dq = q \tag{7}$$

Total of loss time ($L_{no\text{-}inf}$) is calculated in eqn(8).

$$L_{no-\inf} = T_d \cdot Q + \frac{1}{2} T^2 \cdot \mu_a \left(\frac{q}{q_0} - 1 \right) - \frac{1}{2} T_d^2 \cdot \mu_a \left(\frac{q}{q_0} + \frac{q}{q_0 - \mu_a} \right) + \frac{1}{2} \mu_a \left(\frac{q}{q_0} (T + T_d) - T \right)^2 \tag{8}$$

<u>Effect of Dynamic Traffic Information Provision</u>

The difference between the value of L_{inf} and $L_{no\text{-}inf}$ is certainly the effects of dynamic traffic information provision itself. The effect of dynamic traffic information provision (E) is calculated in eqn(9). Differential value is positive as shown in eqn(11). Because there is no effect in case of daily traffic condition, we can get a conclusion as follows. If demand increases by a little volume, we can obtain benefit through providing information. On the other hand, if demand decreases, we suffer contrary effect. We prove that there is a possibility that information provision may lead to total travel time increase

$$E = L_{no-\inf} - L_{\inf} = \frac{1}{2} T^2 \cdot \mu_a \left(\frac{q}{q_0} - 1 \right) - \frac{1}{2} T_d^2 \cdot \mu_a \left\{ \left(\frac{q}{q_0} + \frac{q}{q_0 - \mu_a} \right) - \frac{q}{q - \mu_a} \right\} + \frac{1}{2} \mu_a \left(\frac{q}{q_0} (T + T_d) - T \right)^2 \tag{9}$$

$$\frac{dE}{dq} = \frac{1}{2} T^2 \cdot \mu_a \frac{1}{q_0} - \frac{1}{2} T_d^2 \cdot \mu_a \left\{ \frac{1}{q_0} + \frac{1}{q_0 - \mu_a} + \frac{\mu_a}{(q - \mu_a)^2} \right\} + \mu_a \frac{T + T_d}{q_0} \left\{ \frac{q}{q_0} (T + T_d) - T \right\} \tag{10}$$

$$\left. \frac{dE}{dq} \right|_{q=q_0} = \left\{ \frac{\mu_a}{q_0 - \mu_a} T_d + \frac{\mu_a}{2q_0} \left(T - \frac{\mu_a}{q_0 - \mu_a} T_d \right) \right\} \cdot \left(T - \frac{\mu_a}{q_0 - \mu_a} T_d \right) = \left\{ (T_3 - T_1) + \frac{\mu_a}{2q_0} (T_2 - T_3) \right\} (T_2 - T_3) > 0 \tag{11}$$

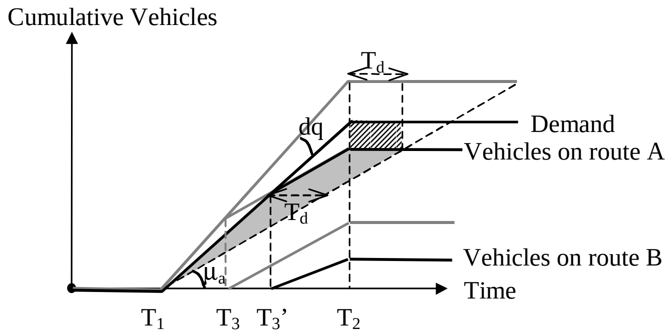

Fig. 4 Cumulative Vehicle Numbers in Case *with Information*

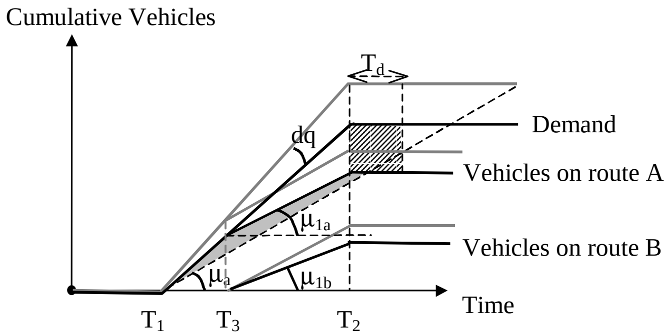

Fig. 5 Cumulative Vehicle Numbers in Case *without Information*

APPLICATION RESULTS

Study Network and Demand

Network and Demand

Figure 6 shows 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. During the simulation period from 4 a.m. to 11 a.m., about 350 thousands vehicle trips are generated. Traffic jam is appeared from 7 a.m. and peak time is from 7 to 10 a.m. Hourly OD volumes of actual 30 days on October 1990 are prepared and input to the simulation model. Totally, 60 results of traffic condition are produced in this study. October 18 is a special day on which OD demand survey was carried out. We can get much data on that day such as time-dependent OD volumes, traffic volumes and vehicle velocities at every link. Therefore, we regard the traffic condition of October 18 as averaged traffic condition by which Experimental Drivers choose their routes.

Ratio of Each Type of Drivers

We use the ratio of each type of drivers as shown in table 1. From the local survey[6] of driver's route choice behavior, about 50% of drivers choose their routes depending on real-time traffic condition. Oguchi and Hatou *et al.*[7),8)] report as follows. Although it is influenced by difference of distance between two alternative routes whether drivers choose their route using real-time information or not, approximately from 50 to 80 % of drivers use real-time information.

Table 1　Ratio of Each Type of Drivers

	with Information	*without Information*
Fixed-Route (Non-Experimental)	50%	50%
Route Choice (Experimental)	50%	50%

Table 2　Improvement in Averaged Total Travel Time

	with Information (veh*h)	*without Information* (veh*h)	Improvement (%)
Weekdays(21days)	193,014	193,210	0.10
Holidays(9days)	170,928	173,593	1.53

Table 3　Averaged Travel Time of 20 Sections (Weekdays)

	Averaged Travel Time[min.]		Number of Sections(in 420 sections)	
Time	*with Information*	*without Information*	*Improved*	*Contrary*
6:00-6:30	11.8	11.8	34	50
6:30-7:00	13.5	13.4	133	97
7:00-7:30	20.7	20.7	145	80
7:30-8:00	17.2	17.1	189	161
8:00-8:30	18.1	18.1	165	164
8:30-9:00	20.2	20.1	184	185
9:00-9:30	21.9	20.7	160	226
9:30-10:00	25.3	23.2	158	221

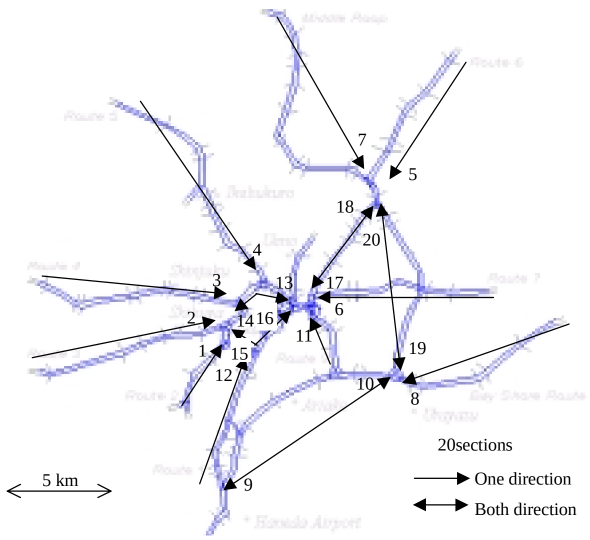

Fig.6　Tokyo Metropolitan Expressway Network

Evaluation Results

<u>Effect of Information Provision in Total Travel Time</u>

Table 2 shows the improvement of averaged total travel time.　From these results, it is confirmed that benefit is not obtained on weekdays, because traffic condition is similar to averaged traffic condition. On the other hand, benefit is obtained on holidays, because traffic condition is different from that of averaged traffic condition.　From these results, we understand that effect of traffic information provision arises in unusual traffic condition.　Unusual traffic condition appears caused by difference of OD demand, some of incidents or others.

Effect of Information Provision at each Time Interval

Table 3 shows averaged travel time of 20 sections at each time interval within 21 weekdays, which location is shown in figure 6. Total number of 420 values, 20 sections multiplied by 21 days, are averaged in this table. The total numbers of improved sections, which travel time is reduced by traffic information provision, and that of contrary sections, which travel time is increased, are also shown in the table. From this figure, we can find that improvement must be observed around 7 a.m. but contrary effect is surely observed after 9 a.m. There is a little capacity for detoured traffic at the time when congestion jam starts, but almost no capacity is existed after congestion jam has grown up. Such a result must be obtained because this reason. We confirm that we can expect improvement by traffic information provision under the network that has some spare capacity, but there is little possibility of improvement under a heavily congested network.

FUTURE SCOPE

Evaluation results are strongly effected by (a) Driver's route choice behavior, (b) Network configuration and (c) OD patterns. Some of future research topics would be:

(a) Although the route choice behavior of a driver with dynamic information is a base of modeling, there is still enough room to be studied on the human factor.

(b) This result is only one of case study. Some theoretical network analyses in addition to the simulation study are required to support the results above.

(c) We should determine how we consider the daily OD demand fluctuation.

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) Moritsu, H. *et al.*, "Analysis of Traffic Network Flow by Adapting Route Guidance", proceedings of Infrastructure Planning, Vol.9, pp.37-44, 1991. (*in Japanese*)

3) 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.

4) Yoshii, T. *et al.*, " Impacts of the Accuracy of Traffic Information in Dynamic Route Guidance Systems ", The Third Annual World Congress on Intelligent Transport Systems '96 Orlando, CD-ROM, 1996.

5) 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. (*in Japanese*)

6) 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. (*in Japanese*)

7) Oguchi, T. *et al.*, "Survey on the Actual Phenomenon about Route Choice in Tokyo Metropolitan Expressway", Traffic Engineering Vol.30, No.1, pp.33-41, 1995. (*in Japanese*)

8) Hatou, E. *et al.*, "Route Choice Model Considering Driver's Information Acquisition and Reference Behavior under Multiple Traffic Information", Journal of Infrastructure Planning and Management No.597, IV-40, pp.99-111, 1998. (*in Japanese*)