IMPACTS ON TRAFFIC CONGESTION BY SWITCHING ROUTES AND SHIFTING DEPARTURE TIME OF TRIPS

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SUMMARY

This study evaluates the possibilities of traffic improvement by spatial and temporal demand spreading. It is understood that some vehicles can reduce his travel time and improve traffic condition by changing his route and departure time so as to avoid traffic jam. However, it is not clear to what extent such a demand spreading can improve traffic condition. Therefore, we investigate the effects of demand spreading by quantitative analysis using actual road network and actual traffic. In the evaluation method, starting from the current traffic condition as an initial, some trips are shifted to other alternative route or other departure time to reduce total travel time. In an application to a part of Tokyo, we understand that shifting departure times is far effective to reduce traffic congestion than switching routes, and the short degree of shifting time is enough to eliminate heavy traffic congestion.

INTRODUCTION

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. Vehicle dispersion achieved from such an environment must be expected to improve traffic condition. However, 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(1). Moritsu *et al.*(2) reported that the negative effect appears, when over 70% of drivers are guided, and Yoshii *et al.*(3) reported that even if the information is not perfectly accurate, predicted information seems to improve traffic condition when the share of guided vehicle becomes higher. Mahmassani *et al.*(4) have developed a simulation model to investigate effects on the performance of a congested urban traffic under real-time in-vehicle information. Using this simulation, they implement assignment including driver’s choice of departure time, and they reported that peak spreading, which is achieved by shifting vehicles’ departure time, may hold considerably more potential to reduce travel times in some situations.

Though these studies have analyzed effects of dynamic route guidance under the assumption every driver choose his route to minimize his utility, it has been not cleared how much improvement every drivers choose his route to minimize total traffic condition. In this study, we investigate to what extent we can reduce traffic condition in relation to the ratio of switching vehicles and to the length of time shifted.

NETWORK ANALYSIS

EVALUATION FLAMEWORK

Network

The network used in this study is the South-West area of Tokyo, shown in Fig.1. The network consists of 623 links and 249 nodes, and 72 origin and 69 destination nodes. At first, trips are loaded by using a simulation model, SOUND(5). As Origin-Destination volumes are required by simulation, we set an O-D pattern estimated from actual traffic counts on a weekday in June 1994, by implementing the estimating method proposed by Oneyama *et al.*(6). Study time is from 6 a.m. to noon, which includes a morning peak period.

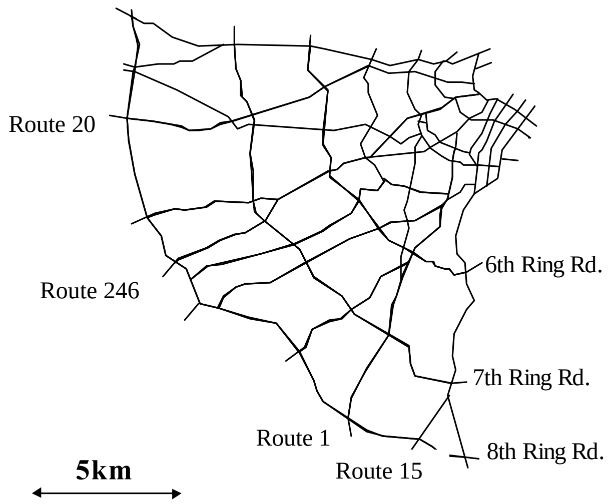

Fig.1 Study Network (South-West Area of Tokyo)

Method of Evaluation

Route Switch

Though each O-D pairs has many routes in this network, we assumed five alternative routes for each O-D pairs which are shortest distance route, 2nd, 3rd, 4th and 5th shortest one from origin to destination. After trips are loaded, the route of each trip (=individual vehicle trip) is switched to other alternative route, when the change reduces total travel time or when the change reduces the vehicle’s own travel time. In this method, departure times are not shifted. And it must be careful this method doesn’t have certification to get unique answer, but answer depends on the order of vehicles shifted.

In this study, after we numbered every vehicle, each vehicle is shifted in this fixed numerical order. In this sense, our method can not evaluate exactly, but it can be enough to get essentials of this kind of matter.

Time Shift

We evaluate the effects of shifting vehicle's departure time. After trips are loaded in the same way above, departure time of each trips are shifted to 15 minutes before when the change reduces total travel time and its own travel time is reduced, provided that routes are not switched in this method. The answer of this method is also depending on the order of vehicles shifted.

RESULTS AND DISCUSSION

We evaluate the effects of improvement of traffic condition by route switch and by time shift in this chapter. Switching policies are determined as these 3 condition as follows;

Route switch A: trips are switched if total travel time is reduced

Route switch B: trips are switched if travel time of switched trip of its own is reduced

Time shift :departure times of each trip are shifted to 15 minutes before when total travel time and its own travel time is reduced, and maximum shifted time of each trips is set as 30 minutes.

Initial traffic condition, which is regarded as actual traffic condition, is shown in Table.1. Total loss time is calculated by taking difference between free flow travel time and actual travel time. The average speed of 15km/h is used as free flow speed.

Table.1 Traffic Condition before Switching

	Total	Average
Trips	247,000 veh	
Travel distance	2,100,856 veh•km	8.5 km/veh
Travel time	160,626 veh•hour	39 min/veh
Loss time	35,948 veh•hour	8.8 min/veh

The result is shown in Fig.2 and 3. Fig.2 shows the number of trips switched to other alternative route and Fig.3 shows the reduction percentage of total loss time in each case. There is not so much difference between three cases in Fig.2. Less than 15% of trips change their routes (or departure time) in each cases. On the other hand, the effect of improvement of traffic condition is much different among 3 cases in Fig.3. In the result of switching Routes under the policy A, total loss time becomes half of actual one. In this case, however, there is not a little number of switched trips which travel times are increased by switching their route. Fig.4 shows the saving travel time of switched trips. Negative change of travel time is equivalent as saving travel time. This figure shows that about 30% of switched trips increase their travel time caused by their change. It is very difficult to guide drivers to change their route in spite of increasing their travel time in real world. On the other hand, in case of switching policy B, route switch being done only when travel times of switched cars are reduced, it is much more realistic than switching policy A. But the improvement in loss time is only less than 5%. Comparing these two results, we confirm that shifting departure time of trips has a potential that can achieve great improvement of traffic condition. In case of evaluation under time shift policy, reduction ratio of loss time becomes more than 70%, and it asks each driver to shift their departure time only 21.4 minutes in average.

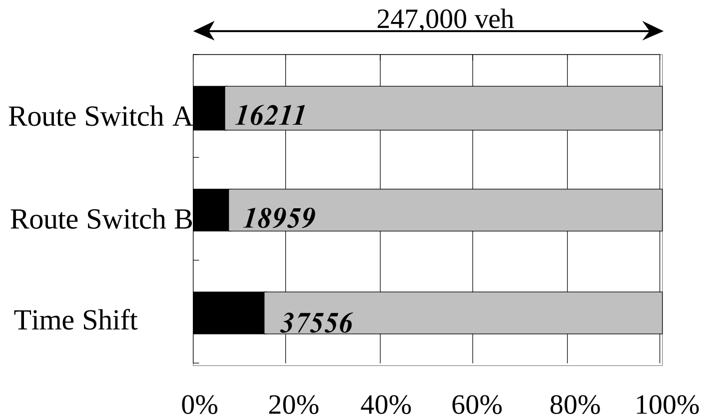

Fig.2 Number of Switched Trips

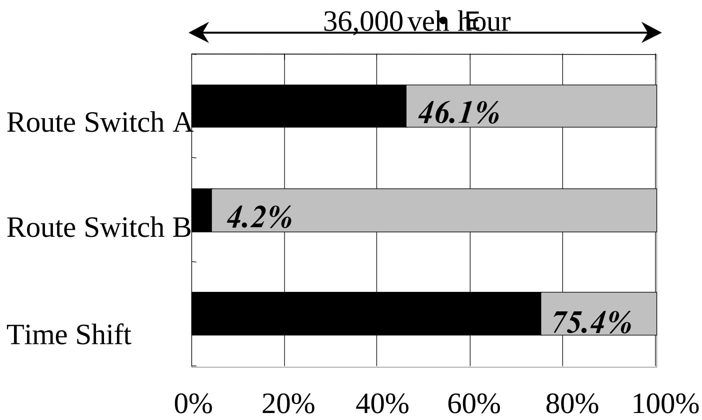

Fig.3 Improvement of Traffic Congestion in Loss Time

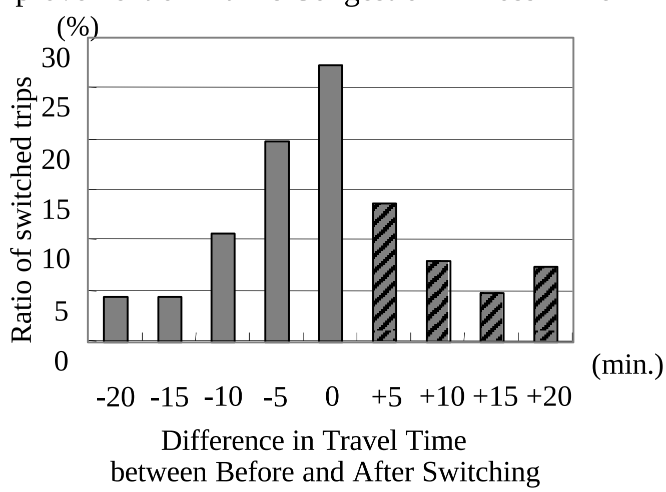

Fig.4 Travel Time Difference between Before and After Switching

Fig.5 shows initial traffic situation and situation of 3 cases at 9 o'clock. Black lines stand for heavy congestion section in average speed of less than 7.5km/h and gray line stand for congestion from 7.5 to 15km/h. This figure indicates that policy of time shift is more effective to reduce traffic congestion than switching policy, and shifting departure time of trips eliminates almost all traffic congestion.

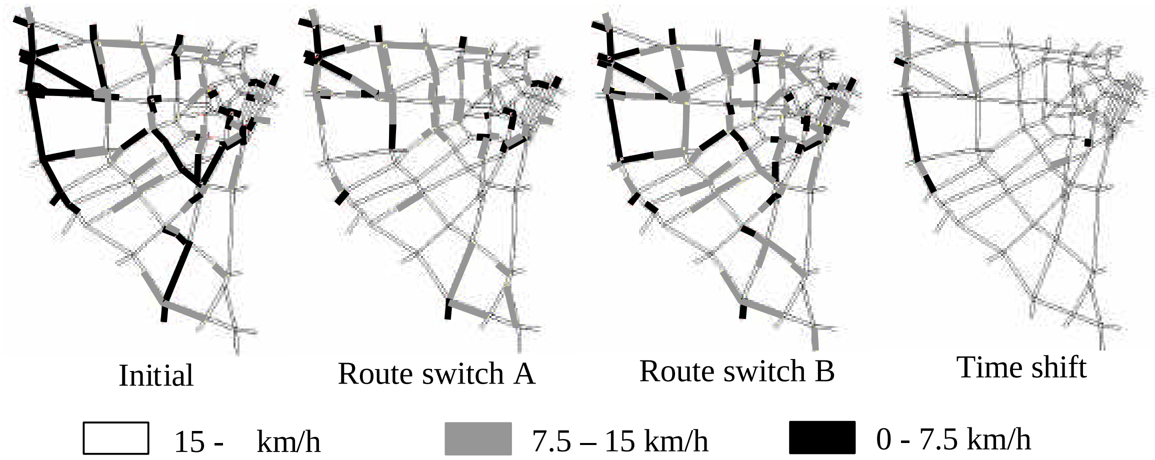

Fig.5 Comparison of Traffic Condition at 9 a.m.

ONE BOTTLENECK ANALYYSIS

EVALUATION FLAMEWORK

We evaluate the effects of time shift in more detail using a network with only one bottleneck in this chapter. We considered point queue at the bottleneck to estimate loss time. Departure time of each trip is shifted to 15 minutes before when the change reduces total travel time. The area used in this study is the section with 11.6 km length from Ichikawa tollgate to Kasai JCT in Tokyo Metropolitan Expressway. Evaluation uses traffic data from 3.a.m to noon on a weekday in November 1990.

TRAFFIC CONDITION

Initial traffic condition, which is equal to actual condition, is shown in Table.2 and Fig.6. Loss time is calculated by taking difference between free flow travel time and actual travel time. Free flow travel time is calculated by using 40km/h as free flow speed. Fig.6 is Time-Space figure, which vertical line stands for time and horizontal line stands for distance. Two arrows in the figure indicate typical movement of trips departing at each time. From this figure, we can see the extension of the congestion from Kasai JCT during 4 hours (from 6 to 10 a.m.).

Table.2 Traffic Condition before Time Shift

Trips	32,652 veh
Free flow travel time(40km/h) Congested travel time(maximum)	14 min. 40 min.
Loss time	1,912 veh•hour
Distance of congestion queue(maximum)	7 km

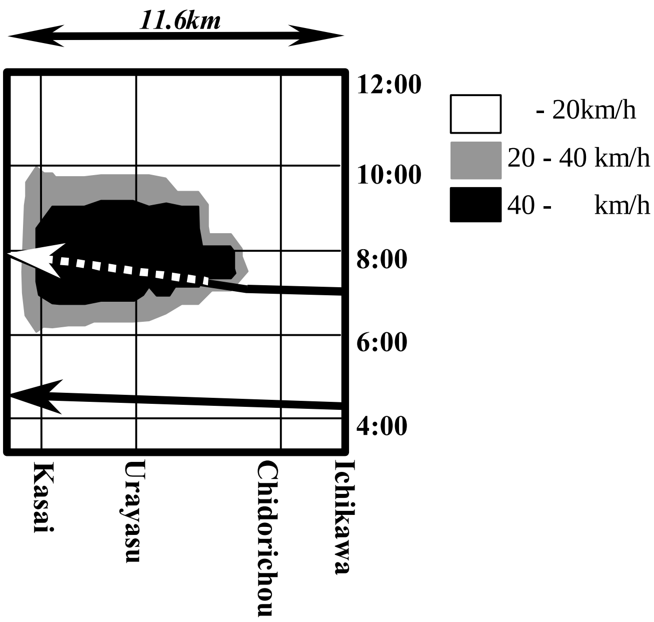

Fig.6 Actual Traffic Condition

RESULTS AND **D**ISCUSSION

As a result of shifting departure time of trips, loss time becomes to zero with 30 minutes shift in maximum and 16.2 minutes in average, shown in Table.3. This result shows that only 25% of total trips shift their departure time to 16 minutes before, this congestion from Kasai JCT is perfectly eliminated.

Table.3 Effects of Time Shifting

Shifted trips	7,421 veh (25% of total trips)
Maximum shifting time	30 min.
Average shifting time	16.2 min.
Loss time	0 veh • hour

Fig.7 stands for the relationship between the required number of trips to eliminate the congestion and the average or maximum shifting time when departure time can be shifted to both before and after the time. If the number of shifting vehicles is fewer and fewer, longer time have to be shifted to eliminate the congestion. We are required to shift at least 1,518 trips (5% in total) with 84 minutes in average and 120 minutes in maximum shifting time. On the other hand, if 14,000 trips (43% in total) can be shifted, only 7.5 minutes of shifting in average and 15 minutes in maximum are enough to eliminate the congestion. However it is really difficult to shift too many trips or shift the departure time more than 1 hour.

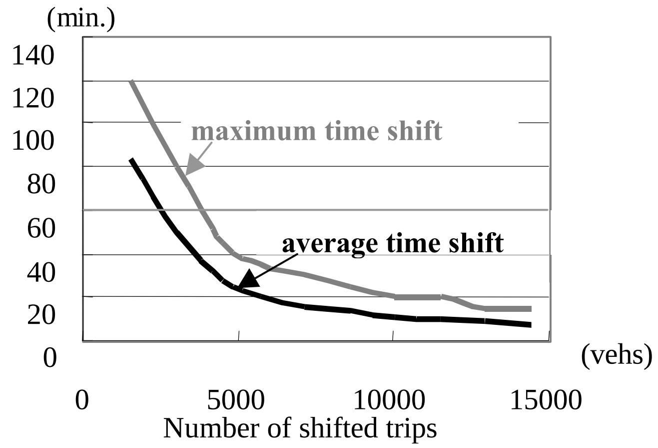

Fig.7 Shifted Time and the Number of Shifted Vehicle

Table.4 Effects of Time Shifting (ratio of shifting is maximum 30%)

	Before time shift	Maximum 15 min.	Maximum 30 min.
Shifted trips	32,652 veh(total)	2,084 veh	3,094 veh
Loss time for congestion (ratio of reduction)	1,912 veh•hour	951 veh•hour (50.3 %)	343 veh•hour (82.1 %)
Average shifting time		15.0 min.	23.7 min.

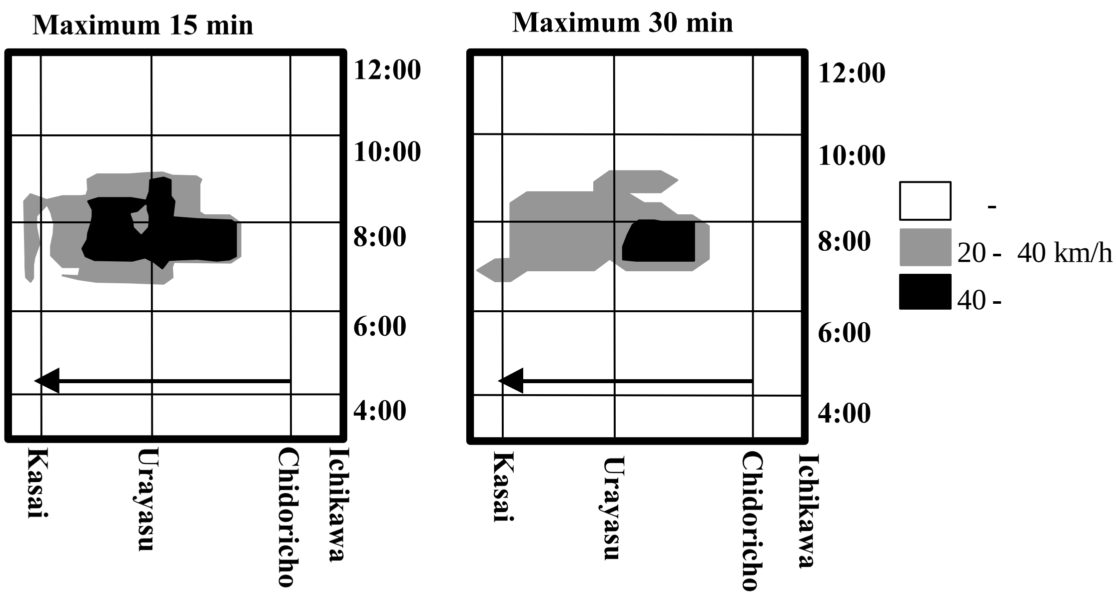

Fig.8 Traffic Condition after Shifting

Then we evaluate the effects of time shift on condition that shifting rate of trips in every hour is limited to maximum 30%, and maximum shifting time of departure time is limited to 15 minutes and 30 minutes. The results are shown in Table.4 and Fig.8. The loss time is reduced to 50% even if maximum shifting time is 15 minutes, and we can see much improvement of traffic congestion in both case compared with the traffic situation before shifting shown in Fig.6.

CONCLUSION

We confirm these results as follows. Shifting departure time of trips can eliminate traffic congestion with not so much time shift. For the congestion from Kasai JCT in Tokyo Metropolitan Expressway, only 15 minutes of time shifting is enough to eliminate the congestion. On the other hand, though switching route of trips can reduce travel time, it has not always been able to eliminate traffic congestion. In the analysis of the South-West area of Tokyo, switching route of trips can reduce only 40% of the loss time, but if 15% of total trips shift their departure time by 20 minutes in average, about 80% of the loss time disappears.

The evaluation framework in this study provides new knowledge that small shift of departure time has a potential which can achieve great improvement of traffic condition. However, it has still not been understood how to achieve such an improved condition by feasible traffic control. We should propose a new traffic control method by which traffic condition can be approached to such an improved condition.

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