A Basic Study on Trip Reservation Systems for Recreational Trips on Motorways

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ABSTRACT

This study quantitatively evaluates effects of trip reservation systems that manage motorway traffic demand on holidays based on a stated-preference survey. Traffic congestion analyzed in this study occurred at a bottleneck on an inbound inter-city motorway in the Tokyo Metropolitan area from 6:30 to 14:20 on a holiday in 1994. It was about twenty-one kilo-meters in the maximum length, and was estimated about forty-five minutes in the maximum travel time. In other words, the travel time was three times that of vehicles passing through the section at a speed of one hundred kilometers per hour. In this case, it is estimated that less than fifteen minute adjustment of the departure time of each traveler could level the traffic demand so that it would not exceed the bottleneck capacity.

There is an idea of trip reservation systems that adjust departure times of travelers on motorways in a similar way to train seat reservations. The revenue and expenditure of the system can be balanced by discounts on tolls for those who change their departure times and extras for others.

The preference of each traveler was surveyed by fifteen binary-choice questions that consisted of discounts/extras on tolls and changes in departure times. About 1,400 survey sheets were distributed at a service area of the motorway, and about twenty percent of which were mailed back. Parameters of an logit-model that includes socio-economic, trip and trip-reservation related attributes of travelers were identified based on the SP survey. The effect of the trip-reservation on the mitigation of the traffic congestion is to be quantitatively evaluated with the model.

INTORODUCTION

In Japan, very heavy traffic congestion of several ten kilo-meters in length occurs on trunk roads from four to five times a year mainly because people are likely to simultaneously take one-day or a-few-day holiday. It is not economically justified and hardly possible to increase road capacity in order to meet such peak traffic demand. The time fluctuations of traffic demand is rather to be leveled in order to decrease the imbalance between road capacity and traffic demand during the high-seasons.

This study quantitatively searches a possibility that trip reservation systems can dissolve or reduce holiday traffic congestion on rural-motorways, which connect urban areas with resorts, by leveling time-fluctuations of traffic demand.

Traffic demand is managed not to exceed road capacity by adjusting departure times of travelers on motorways in a similar way to train seat reservations. The revenue and expenditure of the systems can be balanced by discounts on tolls for those who change departure times and extras for others.

From hardware view points, the feasibility of this kind of systems seems to be increasing due to the recent advances in information-networks and road-to-vehicle communication technologies, especially electronic toll collection techniques. This study focuses on the balance of road capacity and traffic demand based on preferences of travelers who form traffic demand.

STATED-PREFERENCE SURVEY

A mail-back survey, where travelers were inquired their attributes, characteristics of trips, and preferences in supposed conditions of trip reservations, was conducted at Takasaka Service-Area of the in-bound Kanetsu Motorway that runs from north-west to the Tokyo Metropolitan Area.

Inquiries on Attributes of Travelers

Table 1 shows inquiries on attributes of travelers and characteristics of their trips asked in the survey.

Table 1. Inquiries on attributes of travelers and characteristics of their trips

Attributes of travelers	Characteristics of trips
Age of driver	Distance of trip
Sex of driver	Destination of trip
Driving frequency of driver	Entrance time to motorway
Occupancy of vehicle	Exit time from motorway
Way of deciding departure time of trip	One-day trip / Two or more-day trip
Tolerable delay in arrival	Purpose of trip
Preference in adjusting departure time	

Supposed Conditions of Trip Reservations

Table 2 shows two types of combinations of the supposed conditions of trip reservations. Type 1 consisted of binary-choices between discounts on tolls with adjusting departure times and extras with no adjustment. Type 2 consisted of binary-choices between a discount with adjustment of some minutes and another one with adjustment of different minutes.

Table 2. Types of combinations of conditions of trip reservations

	Combinations of conditions of trip reservations	
	Choice 1	Choice 2
Type-1	Discount on toll with adjusting departure time	Extra on toll with no adjustment
Type-2	Discount(1) on toll with adjusting departure time(a)	Discount(2) on toll with adjusting departure time(b)

Table 3 shows categories of discounts, extras and adjustments of departure times. As a result, twenty-seven binary-choices of Type-1 as well as nine of Type-2 were obtained, which formed into three patterns of survey sheets, each of which has fifteen inquiries.

Table 3. Categories of conditions of trip reservations

Items	Categories		
Discount	¥200	¥500	¥1,000
Extra	¥200	¥500	¥1,000
Adjustment time	15 min.	30 min.	60 min.

Results of SP Survey

The 1,389 survey sheets were distributed from 12:00 to 18:00 on November 4th in 1995, 348 sheets of which were mailed back. The 217 sheets that were mailed back from travelers whose purposes of trips had been recreational were chosen as effective samples, which were used for analyses below.

Fig. 1 shows ways of deciding departure times of trips, where thirty-three percent of the travelers commenced their trips just because their business prior to the trips had been completed.

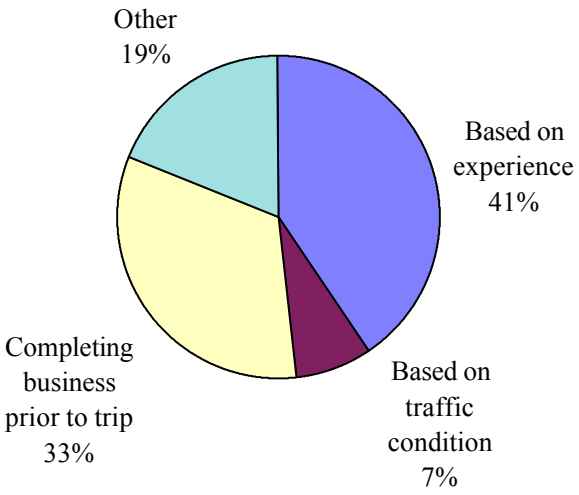


Fig.1. Ways of deciding departure times of trips

Fig. 2 shows the maximum permissible delays in arrivals, where forty-three percent of the travelers did not consider delays in their arrivals when they started.

These results may bring an expectation that most of holiday travelers going back home are very likely to accept adjustment of departure times in order to avoid traffic congestion. In reality, more than ninety percent of the travelers answered that they would accept the adjustment.

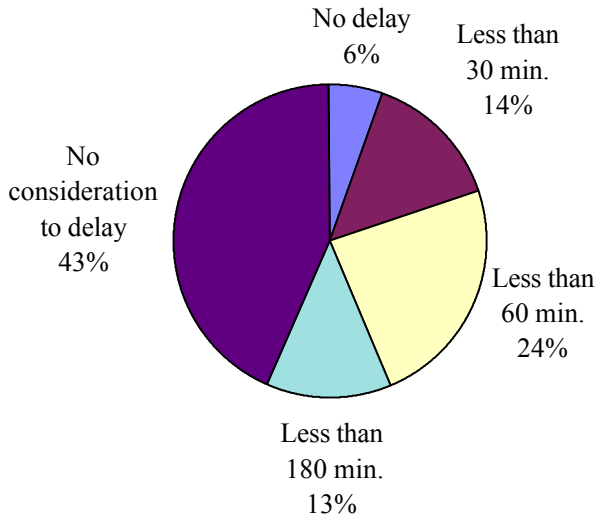


Fig. 2. Maximum permissible delays in arrivals

TRIP RESERVATION CHOICE MODEL

Table 4 shows the parameter values of a logit-type trip-reservation-choice-model that were identified based on the effective samples of the SP survey. It indicates that the shorter adjustments of departure times and the more discounts attract more participants in trip reservations. In addition, it should be noted that the parameter value of extras on tolls is about ten percent as large as that of discounts.

Table 4. Trip-Reservation-Choice-Model

Item	Category	Parameter Value		t-value
		Participate	Not participate	
Reservation Conditions	Discount[¥]	+0.001777		+6.64
	Adjustment[min.]	-0.027609		-6.58
	Extra[¥]		-0.001998	-7.25
Age of Traveler	Twenties	+0.120073		+0.54
	Thirties	+0.000968		+3.86
	Forties	+0.004451		+1.04
	Fifties or older	-0.000761		-3.04
Driving Frequency	Daily	+0.330795		+1.50
	1 or 2 days a week	-0.000621		-2.51
Trip Length	100km	-0.021384		-4.77
	100 200km	+0.000138		+0.58
	200km	+0.274173		+1.25
Hit Rate	76.7			
Likelihood Ratio	0.223			
No. of Samples	1953			

ANALISYS OF EFFECTS OF TRIP RESERVATION SYSTEMS

In order to analyze effects of the reservations, the trip-reservation-choice-model was applied to actually observed traffic congestion on the same section of the motorway as the SP survey was conducted. Table 5 shows the details of the congestion.

Table 5. Analyzed traffic congestion

Date and time of occurrence	From 7:10 to 13:50, December 8th , 1994
Position of bottleneck	39.40 kilo-post of the inbound line of the Kanetsu Motorway
Maximum length reported	22.1 kilometers
Bottleneck capacity	3,900 vehicles/hour/3lanes
Traffic density in congested flow	107 vehicles/kilometer/3lanes
Traffic density in free flow	45 vehicles/kilometer/3lanes
Maximum delay due to congestion	21 minutes
Total delay due to congestion	4,500 vehicle-hours

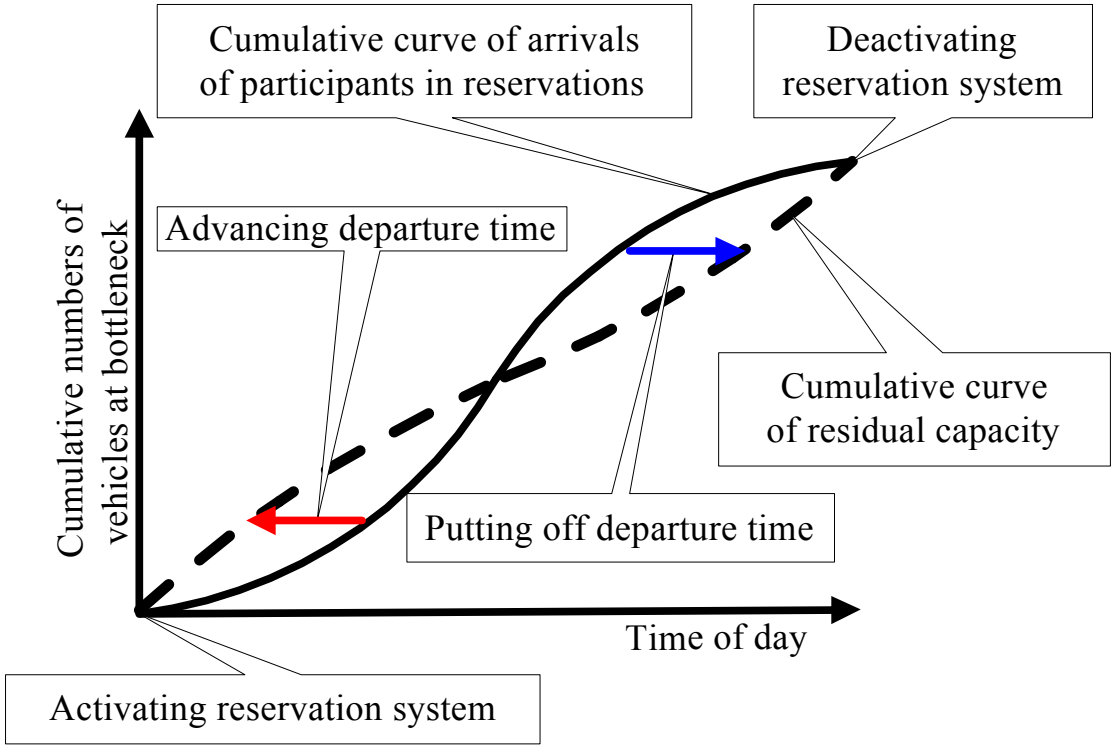


Fig. 3. Concept of adjusting departure time

Fig. 3 shows a concept of adjusting departure times, where horizontal and vertical axes individually indicate time of day and cumulative numbers of vehicles that pass a bottleneck. In the figure, adjustments of departure times where the traffic demand balances with the bottleneck capacity are equivalent to distances along the horizontal axis between a

cumulative curve of participants in reservations and one of the residual bottleneck capacity which is the bottleneck capacity minus the traffic demand with no reservations. The adjustments can take negative values, which means departure times are advanced, as well as positive values. The maximum adjustments of departure times for all participation ratios in reservations were optimized in a way of minimizing them.

Fig. 4 shows the optimized maximum adjustments. It was found that the maximum adjustment had to be at least fifteen minutes even when the participation ratio reached ninety percent. However, the fifteen minute adjustment is shorter than the maximum delay that reached twenty-one minutes due to the congestion because departure times are not only put off but also advanced.

According to the analyses, if the maximum adjustment is fifteen minutes, traffic congestion cannot be fully eliminated due to the low participation ratio. If the maximum adjustment is thirty minutes, traffic congestion does not occur except for the combinations where both of the discount and extra are one hundred yen. Moreover, there is no congestion if the maximum adjustment is forty-five or sixty minutes even with the small discounts and extras.

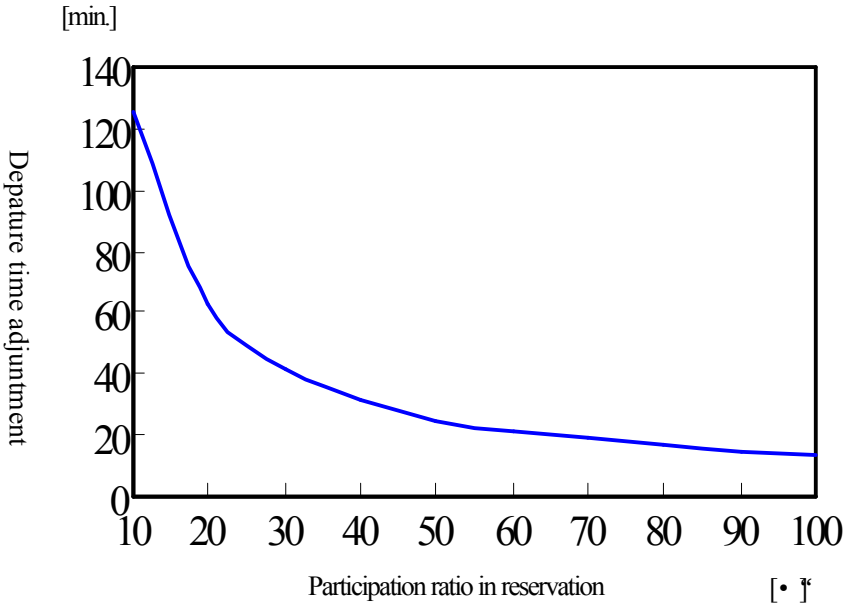
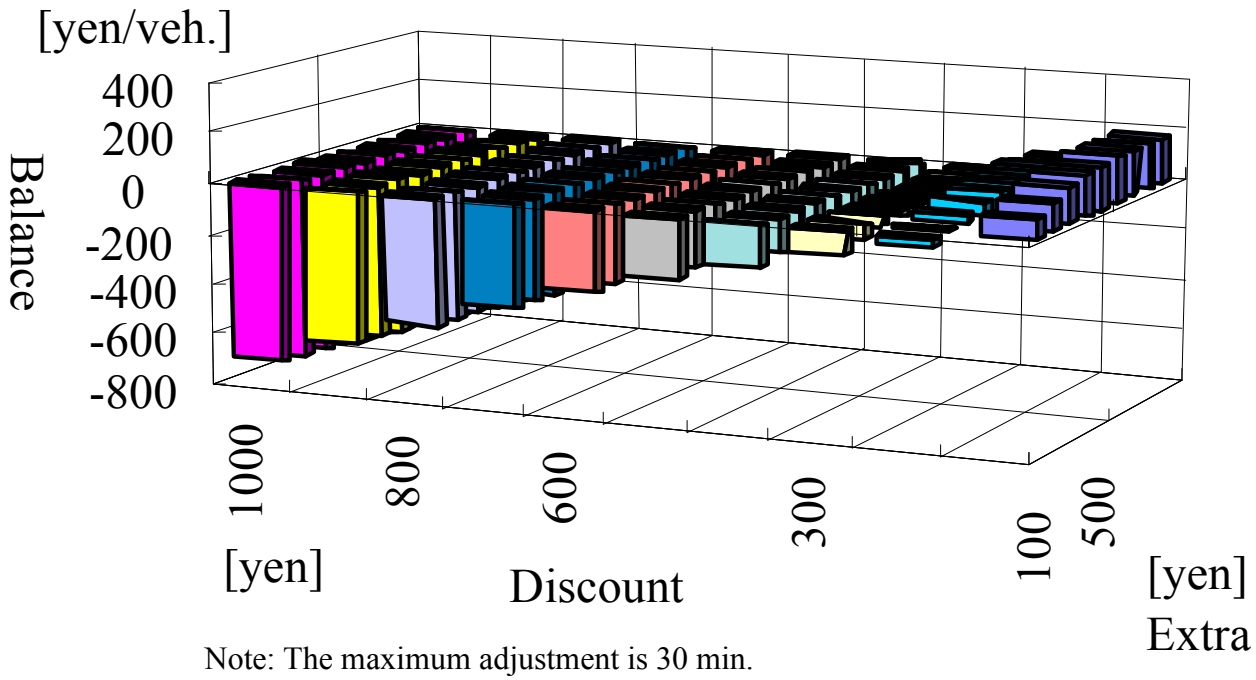


Fig. 4. Participation ratio versus departure time adjustment

Fig. 5 shows the revenue and the expenditure per vehicle for the combinations of discounts and extras where no congestion occurs with the maximum adjustment is thirty minutes. According to the figure, extras have to be increased as the discounts are decreased, together with which the balance turns from the black to the red. Just before turning from the black to the red, both of the discount and the extra are two hundred yen, which result in the surplus of eight yen per vehicle.



Note: The maximum adjustment is 30 min.

Fig. 5. Reservation conditions versus balance

CONCLUSION

An trip-reservation-choice-model was identified based on an SP survey. The effects of trip reservation systems on relieving holiday traffic congestion on a rural motorway were quantitatively evaluated through the use of the behavioral logit model. As a result, the trip-reservation systems seems to be promising. However, validity tests are to be increased.

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