The simulation study of traffic information strategies using the computer for data collection on drivers' responses to ATIS

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Abstract

In this study, the process in which drivers make use of information was expressed by combining an information acquisition model with a route choice model. The relationship between drivers' use of traffic information and their route choice behavior was analyzed on the basis of stated preference data gathered through an intranet survey. Moreover, we propose the framework of simulation system for the investigation of ATIS performance under different information strategies on urban network. We examine the efficiency of the simulation system through the case study.

1 Introduction

Advances in the use of information technology in the transportation sector promise to bring about more and more efficient road transportation environment. In order to construct and implement more effective traveler information systems, it is essential to have reliable guidelines regarding the best way of using such systems. For instance, how should various types of information be utilized in order to satisfy drivers' requirements or to alleviate traffic congestion?

Against this backdrop, research into effective ways of providing information to drivers is proceeding from the standpoints of two major

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approaches. One approach deals with network analysis and the other approach focuses on traveler behavior analysis.

The primary objective of research being done from the perspective of traveler behavior analysis is to obtain fundamental knowledge about the principles at work in drivers' route choice under an environment in which traffic information is provided. This is accomplished by analyzing how drivers use information and its effect on their route choice behavior. A body of knowledge already exists concerning the relationship between methods of presenting information to drivers and differences in drivers' sensitivity to such information (Bonsall,1996, Hato et al, 1996). This knowledge is based on empirical data gathered with models that explicitly represent route choice behavior.

From the perspective of traffic network analysis, benchmark solutions have been advanced on the basis of assignment theory concerning the relationship between the extent of information diffusion and total travel time, among other aspects. With this approach, the route choice model employed must be simplified to a certain extent to obtain a unique solution. A simulation approach, on the other hand, allows the use of models that describe drivers' route choice behavior in greater detail under an environment with real-time traffic information. Based on the results of traveler behavior analyses, route choice models can be hypothesized for individual driver attributes. This approach thus makes it possible to analyze the relationship between changes in traffic network conditions and drivers' manifold reactions, something that is difficult to do with assignment models (Hato et al, 1995)

The principle of drivers' route choice in such research has been treated in terms of a simplistic, optimized decision-making rule in conventional assignment theory. This rule posits that "drivers who receive complete traffic information react immediately to changes in traffic conditions." However, it is now recognized that this idea is unrealistic when it comes to understanding the impact of advanced traveler information systems on driver behavior. A number of new conceptual frameworks have been proposed by Ben-Akiva et al. (1991), Polak and Jones (1993), Mahmassani and Jayakrishman (1991) and others concerning methods of analyzing how the provision of traffic information affects driver behavior. All of these frameworks recognize that is unrealistic to provide complete information on every possible route option available to drivers. Accordingly, the process by which drivers acquire and refer to traffic information needs to be made clear. The relationship between this process and actually observed driver behavior should be considered from the dual perspectives of driver behavior analysis and network analysis. This issue is especially important in situations where multiple traffic information sources are accessible through an advanced traveler information system and drivers must select from which source they want to receive information. In this study, the process in which drivers make use of information was expressed by an information acquisition model. The relationship between drivers' use of traffic information and their information acquisition behavior was analyzed on the basis of stated preference data gathered through an intranet survey. Moreover, we propose the framework of simulation

system for the investigation of ATIS performance under different information strategies on urban network. We examine the efficiency of the simulation system through the case study.

2. Computer Network Survey

Detailed data on drivers' reactions under a variety of travel scenarios are needed to analyze drivers' dynamic behavior in using real-time information. The use of questionnaire surveys to gather data on driver behavior offers the advantage of easy data collection. On the negative side, however, the questionnaire forms require drivers to recall their behavior afterwards, making it difficult to gather data with a one-to-one correspondence between the driving environment and drivers' reactions.

Computer-based research methods, typified by driving simulators, make it possible to measure subjects' reactions in a controlled test environment. For that reason, they can be expected to yield higher quality data than the SP approach involving the use of questionnaires. On the other hand, computer-based surveys have the drawback that it may be difficult to secure the desired sample size because of the time required to install the necessary equipment.

Surveys conducted over the Internet have attracted interest in recent years as a way of simultaneously resolving the data quality problem of the questionnaire approach and the sample size problem of computer-based survey methods. Targeted at people who are connected to computer networks, Internet surveys are designed to secure a sufficient sample size and to obtain more detailed data on subjects by running an interactive survey program.

The features of surveys carried out over computer networks are summarized in Table 1 in comparison with conventional survey methods. Traffic simulators and the like can be used in conjunction with animation software to create a test environment that closely simulates the real world (point 4). The first through the third points are effective in surveys intended to evaluate traffic policy, such as traffic demand management (TDM) and the provision of traffic information, quickly and in detail, from the standpoints of survey efficiency and the collection of more accurate data.

Table 1: Features of a computer network survey.

1.	Sending responses over a network shortens the time required to collect data.
2.	Use of a common gateway interface (CGI) allows the test conditions to be controlled according to the participants' responses.
3.	Participants can be recruited more efficiently by using e-mail.
4.	Use of animation software creates a more realistic test environment.

It is envisaged that further penetration of Internet use at home will make it possible to conduct household-based travel behavior surveys via the Internet in

the future. At the present time, however, the rate of Internet diffusion among ordinary households in Japan is still low, and use of the Internet is limited to certain segments of the population. Accordingly, substituting an Internet-based survey for a house call-based one might skewer the representativeness of the population. The spread of computer networks in offices, on the other hand, is gradually making it possible to conduct surveys of travel behavior among employees at business locations using their company's intranet.

In this study, therefore, it was decided to conduct a survey via a certain company's intranet in the Oppama area of Kanagawa Prefecture where a number of companies are located. The companies in this area have poor access to railway transportation, so many employees commute to work by car, giving rise to traffic congestion during morning and evening commuting hours. The survey focused on the trip home from the office, and traffic information was provided to employees before they left the office and in their vehicles on the way home (Figure. 1). We assumed that subjects can get the information about two routes, both of which have a single lane in each direction. The main route is a riverside road meeting Route 16 at Uchikawa Bridge. The speed of free flow on this road averages 40 km/h. Another route runs along the main route and joins to it. The speed of free flow here averages 30 km/h. Although the length of the link between Hirakata Bridge and Uchikawa Bridge is only about one kilometer, travel time on peak hours amounts to more than 20 minutes. Through the intranet survey, data was collected on drivers' use of information and their route choice behavior.

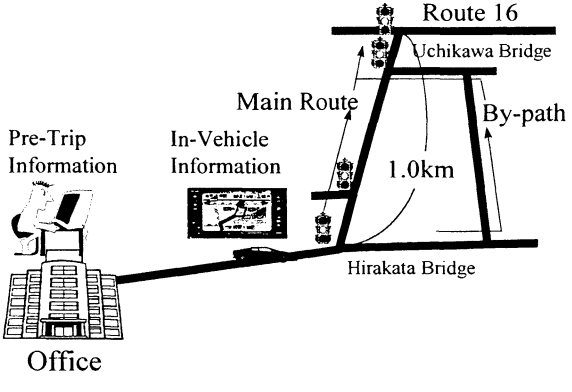


Figure 1: Network corridor in Oppama area.

It should be noted that the rate of personal computer penetration at the company where the survey was conducted is one machine per employee. Employees use e-mail and scheduling management software in carrying out their daily work. Consequently, the survey participants did not show any resistance to being recruited by e-mail or to using a Web browser on their intranet to take part in the survey.

3. Overview of Survey

Participants were sent an e-mail message containing a URL address. By clicking on that address they were able to access a Web server where the survey program was installed. They then downloaded the program to their own client machines using a Web browser and the survey began at that point (Figure 2). The participants were asked certain questions under the assumption that they were working in their office at a certain time during the day. The questions pertained to their willingness to access traffic information depending on the price and accuracy of the information, their desire to use traffic information, the time they intend to leave the office and their route choice to reach home. The traffic information presented to them was determined on the basis of traffic conditions calculated by the traffic network simulation model. Then, based on the expected time they gave for leaving the office, animation software was used to present a scenario in which it was assumed the participants had actually left the office and were driving home through the Oppama district. The participants responded concerning their use of information while following in the scenario; their awareness of congestion and intended route choice.

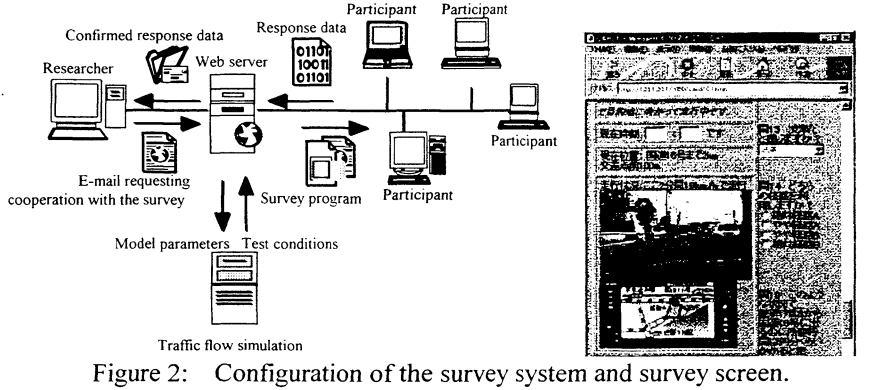


Figure 2: Configuration of the survey system and survey screen.

The responses were initially stored in memory on each participant's client machine and were then sent to the Web server at the conclusion of the scenario. The server first checked the data and then forwarded the data again to the researcher's client machine. This procedure made it possible to execute on the intranet all the tasks involved in the survey, including distribution of the survey forms, execution of the survey, collection of the survey forms, data entry and confirmation of the responses.

Table 2 summarizes the survey results. The time required to conduct the same survey by mail-back questionnaires is also given for comparative purposes. The details of the surveys were not entirely identical. Compared with the use of conventional questionnaire forms, the intranet survey greatly reduced the time required for distributing survey forms and entering and checking response data.

Moreover, the number of valid responses was also larger. This is attributed to the fact that the program incorporated a check function which caught any missing responses during the course of the survey.

Table 2: Comparison of survey times.

Survey method	Distribution of survey forms	Collection of data	Data entry and checking	Valid response rate	Sample size
Questionnaire survey	2day	8day	1day	76%	86
Intranet survey	0.1h	3day	0h	100%	83

Note: (1) The survey was designed to investigate drivers' reaction to the presentation of traffic information and route choice behavior.
(2) The questionnaire survey contained 9 items.
(3) The intranet survey contained 38 items.

4. The Information Acquisition Model

4.1 Model formulation

Previous analyses concerning the effects of providing drivers with traffic information have often treated the process in which such information is used by varying the ratios of information users and non-users as externally generated variables. The present study assumes that drivers actively access traffic information, given the availability of diverse information services. It is assumed that drivers' behavior in using information will vary according to such factors as the price of information services and their accessibility. In this case, from the standpoint of analyzing effects produced by network improvements, it is necessary to have a model that explicitly explains drivers' active behavior in acquiring information. It is also essential to understand the principles underlying drivers' behavior in using information in order to provide information services that actually meet their needs. This section proposes an information acquisition model that take into account the process in which commuters use information in the office before departure and enroute in their vehicles.

Consider the question of whether a driver should acquire and use certain traffic information. The information acquisition model presented here assumes that a driver uses that information only when the utility of acquiring the information, expressed as a continuous latent variable U, exceeds a certain threshold S_I. The probability that a driver will acquire the information $P_I(a|a=1)$ can be expressed with the following equation(1)- (3):

$$P_I(a|a=1) = \Pr[U_I \geq S_I] \tag{1}$$

$$U_I = \sum_M \alpha_{mI} serv_{mI} + \sum_N \beta_n trip_n + \sum_O \gamma_o soc_o + \varepsilon_u \tag{2}$$

$$S_I = \theta_I + \varepsilon_s \tag{3}$$

where $trip_n$ is a variable concerning travel conditions, including travel purpose and degree of congestion enroute; β_n is a parameter of their effect; $serv_{ml}$ is a variable concerning the information service l such as its accuracy, price and accessibility and α_{ml} is a parameter of their effect; soc_o is a variable concerning individual driver attributes such as gender and age and γ_o is a parameter of their effect; and ε_u and ε_s are the error terms. Assuming that the error term ε_u and ε_s have a Gumbel distribution, the probability that a driver will acquire the information can be expressed with the following logit model:

$$P_l(a|a=1) = \frac{\exp(V_l)}{\{\exp(V_l) + \exp(\theta_l)\}} \tag{4}$$

where V_l is the determiner of the expected utility of acquiring the information and θ_l is the threshold as to whether a driver will acquire the information.

4.2 Model estimation results

The estimation results obtained for equation (4) are given in Table 3.

Table 3: Model estimation results.

Information Acquisition Model	Office(pre trip)	in-Vehicle(enroute)
Information accuracy	-0.07 (-1.12)	-0.03 (-0.47)
Information service fee	-0.08 (-3.28 **)	-0.06 (-2.82 *)
Ease of operation	-0.01 (-0.02)	-0.18 (-1.75)
Access speed	0.01 (1.07)	0.00 (0.24)
Travel purpose	1.48 (1.69)	2.03 (2.07 *)
Congestion awareness level		0.38 (1.72)
Gender (female=1)	-1.28 (-1.31)	-2.51 (-2.33 *)
Age	-0.05 (-0.55)	-0.09 (-0.85)
Driving experience	-0.26 (1.31)	-0.95 (-0.56)
θ_l	3.50 (0.79)	3.39 (0.71)
Sample population	83	83
Initial likelihood	56.84	56.84
Final likelihood	44.11	45.18
Rho bar squared	0.213	0.190

Note

1) Figures in parentheses are t-values. *: Significant at 5% leve. **: Significant at 1% level.
2)Information service fee: Charge in yen per access.
3) Ease of operation: Number of buttons that must be manipulated to obtain information.
4)Access speed: Time required to display information.
5) Travel purpose: With a time constraint = 1; dummy variable of 0 without.
6) Congestion awareness level: (50-Vc)^0.580*Tc*0.194, Vc: Congested traffic speed. Tc: Duration of congested traffic speed.
7) Driving experience: Dummy variable of 1 if the participant does not drive to work every day

We estimated information acquisition models for pre-trip information and in-vehicle information. Looking at the parameter values estimated for the information acquisition models, the information service fee shows a large t-value. This indicates that the fee charged for accessing information had a large influence as a determining factor of whether drivers used information both in the office and en-route in their vehicles. As for the variables concerning travel, information acquisition behavior in the vehicle indicates a strong necessity for acquiring information in the case of trips under time constraints and which include the travel purpose as a significant parameter. Congestion disutility was defined here as a congestion awareness level, and a logit-type congestion judgment model was estimated using the method proposed by Hato (1995). The parameter of the congestion awareness level, defined in terms of the congested traffic speed V_c and duration of the congested traffic speed T_c, shows a positive value. This indicates that drivers were more likely to use traffic information as their awareness of congestion increased.

5. Simulation experiments

When evaluating the effects of ATIS through a simulation, the model must describe the dynamic interaction among drivers' route choices, network performance and information. The model framework used in this study represent these interaction. Simulation systems consist of four sub-models: network-flow model, route-choice model, information acquisition model and information model (Figure 3).

The overall simulation flow in this model system is as follows: The information model calculates travel time information using the time of individual vehicles' passing at each nodes that have already been predicted by the network-flow model. In route choice model, the probability of a driver choosing a particular route is calculated using a discrete choice model in which available traffic information is an exogenous variable. The in-flow volume at the node turning into the link is calculated using the driver route choice model. Moreover, driver model predicts individual vehicles' movements (stop/go and accelerate/decelerate) based on signal timing and the headway predicted by the traffic model and driver network flow model can accurately analyze changes in traffic conditions under ATIS.

As for the traffic condition in the wide-area network, the uncharged traffic information service provided by FM multi-radio communication have been considered. On the other hand, the traffic information provision utilizing cellular phone in considered for the detailed route information on each of the road networks. In our country, the traffic information has been provided free of charge via roadside information board and FM multi-radio on the main road network. Recently, however, some traffic information providers launched the pay service using cellular phone. Under this current status, we must examine

how this pay traffic information influence the congestion improvement on the road network as a whole.

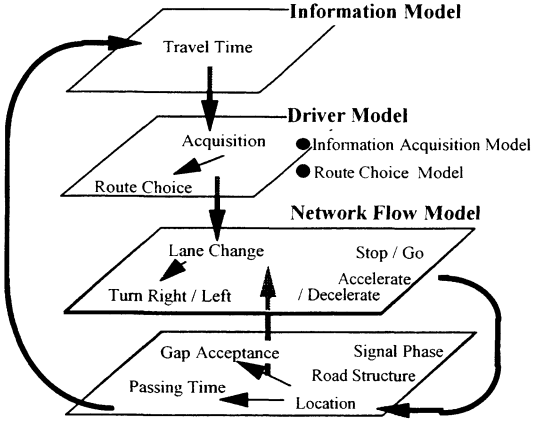


Figure 3: Model framework.

We conducted simulation study for real-world road network, based on the data collected through the intranet survey on information acquisition and route choice behavior when the information cost some fee, and analyzed the effect in reducing congestion on network. The simulation was set up to examine the changes of traffic condition by varying the information fee at the range of free to 50 yen per access, on the targeted road network for three hours from 17:00 to 20:00 in the evening. The average travel time of vehicles passed on a specific network and the average information-accessed rate when each service fee is charged are shown in Figure 4

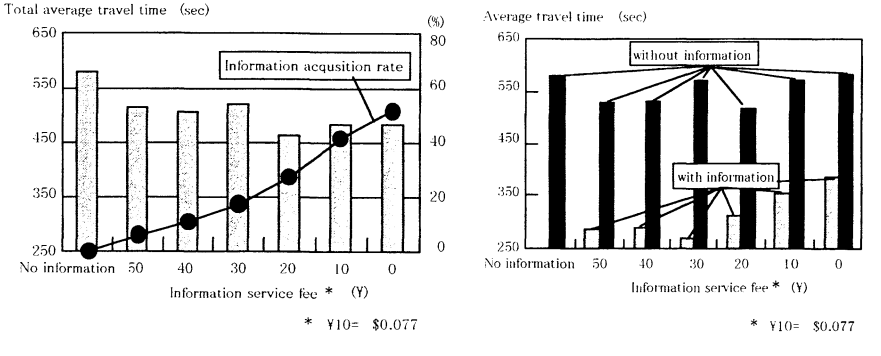


Figure 4: Simulation results.

The figure indicates that the lower the service fee is charged, the higher the access rate becomes; thus causing the network's total average travel time to be shortened. The case with free information provision is expected to reduce it's travel time by approximately 20 %, compared to the vehicle with no information at all. Next, when the access fee is below 30 yen, the travel time of information-accessed drivers becomes longer as the access fee comes close to free. On the other hand, the travel times of drivers without information indicate no certain tendency. The travel time difference between the driver with and without information on the network becomes the least when the access fee is set free. This result shows that the time saving effect with obtained information may decrease when the access fee is minimized.

6. Conclusion

This intranet survey was conducted on an experimental basis and the sample size was also limited. Nonetheless, considering the ongoing diffusion of computer networks in offices and the improved survey efficiency obtained, it can be regarded as a practical survey methodology. Also, in this study, we examined the information provision scenario of which the one reflecting the behavior-model parameter assumed by the result of intranet survey into the simulated behavior model. Furthermore, the traffic flow changes by providing certain information was included in the SP survey, thus enables to examine more realistically with the use of intranet survey as an experiment condition. In future work, the practical utility of this survey method and the structure of the information acquisition model will be re-examined using larger sample sizes. In addition, it is planned to incorporate this method in a simulation model as a survey execution tool.

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