AN ANALYSIS OF THE EFFECT OF INFORMATION SERVICE ON GAP CHOICE AT MERGING SECTION

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SUMMARY

The AHS system at merging sections to achieve safer, more comfortable and more efficient traffic flow is expected in Japan. The objective of this study is to consider appropriate information service at stop-and-go merging section. A simple field experiment using hands-free cellular phone is proposed. Several microscopic analyses through the experiment indicate that it is important to give information which is consistent to driver's decision criterion, and information reduces the possibility of dangerous merging.

INTRODUCTION

Japanese government has started the field experiments of AHS system that is composed of 7 user services as first phase of AHS implementation in 2002. The major objective of these user services is to reduce fatalities and the injured by traffic accidents. This is because these services will be applied to intersections and curves with many accidents. Merging sections are considered to be quite dangerous as well as intersections and curves because vehicle maneuvers are so complicated. However, any user services of AHS are proposed at merging sections in first phase because the number of accidents is lower than that at intersections or curves.

It is obvious that drivers at merging sections are exposed to dangers caused by maneuver of surrounded vehicles or road structure condition. It is considered that drivers always pay "high level" attention so that they are not caught up into accident. This fact suggests that there may be some huge economical losses although few accidents occur at merging sections. Another problem is the difficulty in improving road facilities themselves at many merging sections in Japan to achieve safer and more efficient traffic flow condition because of spatial and financial restrictions. Some AHS functions should be proposed to increase the traffic volume and decrease traffic accidents. Standing on these viewpoints, the user service of AHS at merging section should be implemented.

The concept of AHS systems proposed in Japan is divided into 3 levels, information, control and automation. The automation is not considered as technologies in near future, and information and control functions are now focused on coming technologies. Several technologies of control already introduced such as lane detection system or passive gap control are based on autonomous rules. These are considered to be easily applicable because any process that forecast the maneuver of surrounding vehicles do not need. In other words, there is fewer responsibility of AHS system even if driver is caught up into accident in the condition of use of such services. On the contrary, the precognitive technologies that utilize the road environment data detected by censors on not only vehicles but also roadside facilities and forecast the maneuver of surrounding vehicles seem to have much difficulty in implementing under present traffic laws. This is why information based AHS services are quite important and applicable in general. Needless to say, such services should be sought at merging sections because the forecast of maneuver of surrounding vehicles seem to be more difficult compared with any road sections.

A previous study by Shimizu *et al* only shows the effect of information services on the driving behavior at merging sections of urban expressway (at which drivers are not requested to stop once) in Tokyo based on simple field experiment (1). Besides, advantages and disadvantages of several information contents at merging sections of urban expressway are considered in successive study (2). More applications at various sections with various design, operation and demand conditions are needed to propose comprehensive user services.

This study deals the information service at merging section at which drivers are requested to stop once, confirm the condition of main through traffic, and go into chosen gap (we call "stop-and-go" merging section). The analyses are based on simple field experiment conducted at the merging section of Japanese national trunk road with heavy traffic flow in suburban area of Tokyo metropolitan area. The necessary conditions of information service at stop-and-go merging sections with general viewpoints are considered firstly. The explanation of field experiment is mentioned secondary. Several analyses of the characteristics of gap choice under experimental information service are conducted, and several basic recommendations for future deployment are also given finally.

NECESSARY CONDITION OF INFORMATION SERVICE

Assumption of Gap Choice

Many studies on gap choice behavior by gap acceptance model and critical gap model have been conducted previously. Recent research by Brilon *et al* reviewed the formulation and estimation method of several important critical gap models at unsignalized intersection previously proposed by different researchers(3). Tian *et al* also tried to measure critical gap at two-way stop-controlled intersections(4). Related with these techniques, Harwood *et al* developed sight distance model based on gap acceptance to reflect the intersection design parameters(5). However, these models based on field observation cannot be clarified why driver choose the gap, or under what mechanism driver chooses the gap. This means that we cannot forecast the effect of safety programs (e.g. design improvement, ITS supports) on gap choice behavior in advance. In addition, driver's attributes and waiting condition cannot be considered in previous gap acceptance models because models are described by aggregated viewpoint. Pollatschek *et al* proposed more advanced and microscopic gap acceptance model



Figure 1 Outline of gap choice at merging section

which takes account into the individual preference for the risk and compares risk of smaller gap and time saved when driver choose it (6). However, the effect of safety programs also cannot be analyzed by this model. In this study, we presume to decompose chosen gap time into several time components. If we specify the factors (e.g. flow rate, road design parameters, individual attribute, etc.) of average and variation of each time component and specify the relation between safety program and change of factors, we can forecast the effect in advance.

Here we explain the basic idea of decomposition of chosen gap. It is reasonable to consider that driver waiting at merging section searches his/her desirable gap in order. Figure 1 shows the outline of gap choice in this study. We assume that every driver knows his/her own merging time required T_e^* sensibly. We also assume that driver decides whether he/she chooses the side gap or not comparing cognitive side gap time T_e and T_e^* .

 T_{e}^{*} is expressed by combining 3 time factors in this study as follows,

$$T_e^* = T_d + T_o + T_m \tag{1}$$

where T_d is time for decision, T_o is time for operation (decreased gap time when speed of merging vehicle reaches up to same speed of vehicle in through traffic) and T_m is margin time. T_d varies with individual condition (e.g. fatigue, health), road design parameters, individual attributes (e.g. experience) and random effect. T_o varies with vehicle performance, road design parameters, individual attributes and random effect. T_m varies with individual condition, individual attributes (e.g. personality), flow condition (e.g. demand, waiting time) climatic conditions (e.g. rain, snow) and random effect. It is assumed that T_o is largest value with about 4 seconds, and T_d and T_m are about 1 second if chosen gap is 6 seconds.

 T_e varies with road design parameters, individual condition and attributes, attributes of approaching vehicle (color, truck) and random effect.

Motivation of Information Service

It is easily understandable that vehicles of through traffic have priority than merging vehicles at stop-and-go merging sections. This indicates that vehicles of through traffic never have

incentive to reduce their driving speed and give front gap to merging vehicle waiting at stop line. It is considered that no information service for through traffic is effective in this case.

The motivation to introduce information service at stop-and-go merging section is that service makes driver choose appropriate gap to achieve safer, more comfortable and more effective traffic flow. It is considered that safe is most important of there because the difference between speed of merging vehicle and vehicle in through traffic is quite huge, and demand of merging direction is largely smaller than demand of through traffic.

Two major roles of information service should be focused. One is the reduction of the variation of T_e , another is the reduction of T_d . In other words, desirable function of information service is the reduction of possibility of traffic accident by assisting decision processes.

Contents of Information Service

Previous study considers 3 types of contents, present based information, future based information and behavioral recommendation(1). Present based information has less responsibility in the case of accident than rest 2 types, however the valuable of information becomes quite low at stop-and-go merging sections where can see the condition of through traffic. Future based information is more effective at the timing when merging driver cannot see the condition of through traffic. Behavioral recommendation is most responsible despite the valuable of information is highest.

3 types of device for information service is considered, fixed signal, fixed Variable Message Sign (VMS) and in-vehicle unit with monitor and voice guidance. Every driver can use the service through signal and VMS, however these devices cannot give any information considering individual gap choice criteria. Besides, driver cannot understand easily for whom information displayed is given. On the contrary, contents and timing are easily controllable through in-vehicle unit. 2 types of information phrase for present based and future based information are considered, existence and variable (e.g. speed, gap distance, gap time) of approaching vehicle in through traffic. Existence information seems to be meaningless at stop-and-go merging sections where can see the condition of through traffic, while phrase tends to make T_d larger in the case of variable information although it makes the variation of T_a small.

The information service of behavioral recommendation through in-vehicle unit is sought in this study taken into account the consideration above. In this service, T_d may be typically small if driver can rely on it. It is needless to say that the phrase should be very short.

EXPERIMENT OF INFORMAION SERVICE

Outline of the Experiment

Table 1 shows the outline of the experiment. The site is exit and entrance ramp at national trunk road with 2 lanes suburban area of Tokyo Metropolitan area (Figure 2). Driver is

Table 1 Outline of the experiment	
Date	Dec. 5,6,17,18, 2001
Site	Aobadai ramp in Yokohama city on National Road No. 246
Contents	Merging without information
	Merging with information (2 types)
Obtained Data	Video image of marging section
	Video image of driver's operation
	Video image of surrounding environment
Driver	6 (all male and student)

Table 1 Outline of the experiment



Figure 2 Photo image of merging section surveyed

prohibited to change his/her lane before merging section, this is why give-way behavior by through traffic cannot be considered. Demand of through traffic and merging traffic are both high level. Number of rear-end collision type accidents by first and second waiting vehicles is very large at merging lane. Second waiting vehicle can also see the traffic condition of through traffic and there is some possibility that driver in first waiting vehicle gives up to choose side gap while driver in second vehicle believes first vehicle will choose it and start the acceleration. This case will be avoided if appropriate information is given for both drivers.

6 young male drivers attended the experiment for 4 days in late 2001 and total 99 gap choice data with and without information are obtained. Data of eye's movement (front, side mirror, glance at direction of right side rear) and foot's movement (break pedal, acceleration pedal) are obtained by several video cameras fixed in survey vehicles. Speed and position of survey vehicle are also obtained by several video cameras focusing merging section from different angles. Figure 3 shows the example of time series relation among driver's operation (foot's position, eye's direction), vehicle's movement (speed, position) and information status. Every data are coded every 0.2 second.

Outline of Information System in the Experiment

We use hands-free cellular phones for primitive information system at focused merging section like in Figure 4. The operator stands at control line and detects the existence of vehicles in detection area and gives information phrase through cellular phone based on very simple algorithm below while survey vehicle runs in merging lane. If more than one vehicle runs in detection area, the operator speaks "stop" (operator speaks nothing in first two days).





Figure 3 Example of time series data of driver's operation and vehicle movement



Figure 4 Concept of information service using hands-free cellular phone

If no vehicle runs there, he/she speaks "go". The length of detection area is set in 80m (the gap into which 50% of vehicles enter by the observation) and 100m (85%).

ANALYSIS OF THE EFFECT OF INFORMATION SERVICE

Microscopic Analysis

Some considerations are given through the microscopic analyses using time series data of driver's operation and vehicle's movement like Figure 3 in this section.



Figure 5 Difference of driver's operation between with and without information



Figure 6 Example of hesitation by "stop" information

Figure 5 shows one good example of the difference of driving operation between withinformation and without-information by same driver. These cases are considered that traffic conditions are almost same and driver expects that he can choose side gap. "Go" information is given in this case. It takes 3.2 second to start accelerating after the confirmation of through traffic in the case of without-information, while it is reduced to 1.4 second in the case of withinformation. This indicates that there is some possibility to reduce T_d by information in case driver's expectation is same as recommendation.



Figure 7 Example of hesitation by "stop" information

Figure 6 shows one bad example of hesitation by "stop" information. Driver once tries to stop after listening "stop" information although he expects that he can choose side gap at this time. He recognizes approaching vehicle as slow heavy truck and finally choose side gap against the information. Figure 7 shows another example. The operator gives "go" information because there is enough gap aside, however he hesitates to start. He suddenly listens "stop" information just after he determines to start and hesitates again. This results in the rapid speed reduction by following vehicle in through traffic. We cannot observe these cases in first two days because we never gave "stop" information. These cases are observed when the length of detection area is 100m. Most drivers tend to confuse "stop" information in the case length of detection area is 100m because they can choose shorter gap than 100m. This suggests that setting the length of detection area much longer than driver's critical gap length should be avoided.

Relation between Merging Rate and Information

Figure 8 shows the merging rate by side gap time in the case of with-information and withoutinformation. The distribution of with-information in case the length of detection area is 80m is almost same as the distribution of without-information. While chosen side gap time tends to be larger and all gaps with 4 to 5 seconds are not chosen in case the length of detection area is 100m. These facts indicate that driver's decision criterion and recommendation are consistent in case of 80m, and on the contrary, these are inconsistent in case of 100m as already described before. In concrete, driver tends to hesitate to choose side gap with 4 to 5 seconds that is chosen usually, or he dares to comply with the information. The time for decision may be possibly larger in former case.



Figure 8 Effect of information on merging rate for side gap time



Figure 9 Relation between merging acceleration and chosen side gap time

Relation between Driver's Confidence and Information

It may be possible to assume that information strengthens the driver's confidence of the side gap condition although there are little difference between the case of without-information and 80m detection area of with-information in terms of distribution of merging rate. We substitute driver's confidence for the variation of merging acceleration. In concrete, we assume that the driver feels more confident for information if the variation of acceleration is smaller. Figure 9 shows the relation between side gap time chosen and merging acceleration. The variation of merging acceleration of with-information is a little bit smaller than that of without-information. Whether this relation is significant or not should be confirmed though additional experiment.

Relation between Safety and Information

Figure 10 is attached the equivalent line of danger (in case that gap length with following vehicle with 60km/h speed is less than 20m if vehicle is accelerated in same merging acceleration up to same speed as following vehicle) to figure 9. The plot placed between the origin and the equivalent line is dangerous case in this definition. We can realize that many



Figure 10 Effect of information on safety condition

plots of without-information case are located in "dangerous area" compared with that of withinformation case. This suggests that information may assist safer merging and reduce the possibility of traffic accident.

Discussion

It is difficult to wholly conclude the future direction of development of information service at stop-and-go merging section in this study because the samples obtained in the experiment are limited. However, several suggestions below are clearly presented.

- (1)Behavioral recommendation has less possibility to make driver's decision confuse if "stop" information is avoided.
- (2)Information should be consistent to usual driver's gap choice criterion because T_d can be reduced.
- (3)It is unclear by this study that information increases driver's confidence and leads to stable driving operation.
- (4)It is possible that information reduces the possibility of dangerous merging if driver relies on the system and willing to comply with it.

CONCLUSIONS

This study considers the information service at stop-and-go merging section to achieve safer, more comfortable and more efficient traffic flow. Behavioral recommendation type of information service through in-vehicle unit is recommended in the consideration of the necessary condition. A simple field experiment method using hands-free cellular phone is proposed. Through several quantitative analyses, we understand that it is important to give information which is consistent to driver's decision criterion, and information reduces the possibility of dangerous merging.

For further study, above all, increase of sample (number of runs, number of drivers) and survey site is quite important to settle our experimental results. Besides, the trial development of information system is indispensable.

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