AN ANALYSIS OF DRIVER’S BEHAVIOR AT MERGING SECTION ON TOKYO METROPOLITAN EXPRESSWAY WITH THE VIEWPOINT OF MIXTURE AHS SYSTEM

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SUMMARY

The objective of the study is to analyze the vehicle behaviour at the merging section of the MEX through the detailed driver’s driving data with the viewpoint of “Mixture AHS System”. We conducted the survey of traffic flow at merging section that consists of two different viewpoint surveys with old geometric standard in the MEX using the vehicle with equipment to obtain driver’s behaviours data and vehicle’s behaviours in detail. We analyze analyze the time-series processes of driving operations and vehicle behaviours for vehicles at merging section and discuss the future direction of development of Mixture AHS System.

INTRODUCTION

In Japan, some trials to develop AHS (Advanced and cruise-assist Highway System) system have demonstrated for several years and AHS system is classified as a key concept of safety driving systems in the latest “Japanese ITS System Architecture (SA)” (1) published in late 1999. In first phase, Japanese AHS system will be introduced with 7 major services that can reduce the number of traffic accident. There are lesser accidents related to merging traffic in Japan. This is because the AHS service for merging behaviour has lesser priorities to be developed. However, it is considered that the importance of AHS services at merging section is explained by not only safety achievement but also effective operation. Several definitions of vehicle-infrastructure interactive information systems and functions for merging traffic was introduced with the viewpoint of safety in the SA, but successive efforts in order to guide traffic flow at merging section smoothly will be necessary.

In Tokyo Metropolitan area, the Metropolitan Expressway (MEX) Network is provided with about 260km length, on which over one million vehicles use annually. This was firstly constructed in late 1960s and gradually extended up to now. The geometric condition at first phase of the MEX was designed by older geometric design standard, and safety and capacity level at the geometric discontinuous sites such as merging section were reduced by recent improvement of vehicle performance. The introduction of several AHS functions to such sites
is now expected under the condition that any construction for the facility improvement cannot be done because of space constraint.

We should consider the “Mixture System” to introduce the AHS system into the MEX because there will be difficulty in constructing the exclusive lane along the network under the budget and space constraint in metropolitan area. This indicates the importance of the study about not only the driver’s behaviour with AHS but also that without AHS. The objective of the study is to analyze the vehicle behaviour at the merging section of the MEX through the detailed driver’s driving data with the viewpoint of “Mixture AHS System”.

In this paper, we first show the definitions of the “Mixture AHS System” at merging section of urban expressway to make clear what AHS function should be critical for driver’s behaviour. Secondary, we show some results of driving behaviour survey at merging section in the MEX. Finally, we discuss the future direction for the development of AHS System at merging section considering the results from survey.

MIXTURE AHS SYSTEM AT MERGING SECTION OF URBAN EXPRESSWAY

In general, the development stage for Japanese AHS System is conceptualised with 3 different stages as shown in Figure 1. At first phase called AHS-i system, some information system about other vehicles’ existence/movement will be deployed to help drivers drive safety and smooth, or to guide appropriate driving behaviour. At AHS-c stage, some direct assistance and operation functions will be deployed to avoid accident and to make traffic flow smoother. Final stage is called AHS-a System in which vehicles are operated fully/partly automated.

AHS-a System will requires the exclusive lane which is impossible to constructed in urban expressway. In this study, we do not focus AHS-a system for the time being because it will be very difficult to consider automated vehicle operation for mixed traffic on non-exclusive lanes. On the other hand, we consider that AHS-i and -c systems will be quite feasible for urban expressway networks with mixed traffic condition. We may call these functions as “Mixture AHS System”. Table 1 shows the list of AHS functions at merging section considered in this study.

Especially in the MEX, AHS-i functions are very important because many merging sections do not provide sufficient acceleration lane to merge and we can finally identify the traffic situation at merging section just before reaching acceleration lane. AHS-i System will be considered as effective system to achieve smoother merging behaviour.

DRIVING BEHAVIOUR SURVEY AT MERGING SECTION IN THE MEX

We conducted the survey of traffic flow at merging section with old geometric standard in the MEX on October 25 and 26, 1999 at Higashi-Ikebukuro onramp in the MEX. The focused onramp only has 60m length of accelerating lane in spite of long length approach way, and a merging vehicle can run on approach way at the same speed as through traffic. The driver in merging vehicle cannot confirm the condition of through traffic just before accelerating lane because of roadside wall.
This survey is consists of two different view-point survey, one is “Video Taking Survey” which can obtain the traffic flow data without any driver’s information and another is “In-vehicle Survey” which can obtain the detailed driver’s behaviour data with data from surrounding vehicles. This paper will mainly focus on the latter survey. The latter survey is consists of “Survey for Merging Behaviour” and “Survey for Through Traffic” using the vehicle with equipment to obtain driver’s behaviours data such as acceleration and breaking and vehicle’s behaviours data such as speed and front gap length for every 0.1 second, and video system to record the driver’s body and surrounding vehicles. Several drivers drove through the focused section repeatedly in the survey and we obtain 12 cases for “Merging Behaviour” and 18 cases for “Though Traffic”.

**ANALYSIS OF DRIVING BEHAVIOUR AT FOCUSED MERGING SECTION**

**Classification of Merging Type**

Table 2 shows the classification of merging type in this study. We classify according to the relation between the gap that exists besides the merging vehicle just coming to accelerating lane on the main lane and the gap into which merging vehicle finally enters. We also introduce another criterion whether merging vehicle affects the behaviour of following vehicle or not. Overtaking type was not obtained from the survey because there was no congestion.

**Analysis of Time-space Diagrams**

Firstly, we make “Time-space Diagram” of the survey vehicle that contains surrounding vehicles on main line using data from merging behaviour survey to analyze the basic merging processes. Figure 2 shows one example of time-space diagram of “Stopping and Watching through” type. This expresses that merging vehicle encounters the successive gaps on main lane into which it cannot enter safely and is forced to stop on accelerating lane and is finally able to merge because some vehicle approaching merging section gives-way to another main lane. Less-experienced driver drives in this case and he tends to break and stop in other cases. These results suggest the necessity of AHS system to assist smooth merging behaviour

**Analysis of Driver’s Behaviour**

Secondary, we analyze the time-series processes of driving operations and vehicle behaviours for both merging vehicle and main lane vehicle. Figure 3.1 and 3.2 indicate the difference between well-experienced driver and less-experienced driver in “Independent” merging type. Well-experienced driver tends to run in approach way at higher speed and it only takes about one second that he checks the existence of approaching vehicles in main lane, decides to merge and treads on accelerating pedal. The other side, less-experienced driver tends to tread on breaking pedal and in takes over 3 seconds to behave in the same manner as written above. In the case of “Watching Through” merging type, less-experienced driver treads on breaking pedal faster than well-experienced driver, and this causes earlier reduction of driving speed at acceleration lane.

In the “Survey for Through Traffic”, driving speed is reduced at merging section in all cases. Especially, drivers tend to relax accelerating pedal before merging section in case that no leading vehicle and merging vehicle exist. In other cases, drivers reduce the speed by reacting
the reduction of gap ahead. Figure 4 shows the phenomenon that merging vehicle enters into former narrow gap and shock wave occur to the following vehicles. This should be avoided in terms of safety and capacity control using effective AHS functions.

Discussion - in Terms of Effective Mixture AHS System

The result written above will be extended as follows in terms of the relation to effectiveness of Mixture AHS System:

1) The analysis indicates that there is a possibility to assist the smoother merging behaviour if driver can recognize the traffic flow of main lane in advance. This can be achieved by introducing simple AHS-i System and ramp metering system and should be confirmed through field studies.

2) The driving assistance function at merging section in the Japanese ITS-SA defines that only merging vehicle should be controlled, but vehicles on main lanes also should be controlled in the situation that penetration rate of AHS-assisted vehicles becomes higher. The analysis indicates that less-experienced driver will not be able to merge smoothly because average gap length will be shorten by increase of AHS-assisted vehicles.

CONCLUSIONS AND VIEW OF FURTHER STUDY

In this paper, we first confirm the importance of AHS System for mixed traffic at merging section of urban expressway. The survey about driving and vehicle behaviour in detail at one merging section of the MEX was conducted in order to understand appropriate functions of Mixture AHS System. We analyse the relation between merging behaviour and the level of driving experience and give a few suggestions to the deployment of Mixture AHS System.

The final purpose of this study will be extended to making behavioural simulation system of merging section to evaluate the improvement of some indices of traffic performance measure by introducing AHS functions. We cannot obtain any parameter of behavioural models under the introduction of AHS System directly and should assume these parameters from present driving data. The analysis of this study will partly help us assume appropriate parameters.

Acknowledgement

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References

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<th>Sort</th>
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<td>Sign</td>
<td>Merging Traffic</td>
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**Table 1 List of ITS functions at merging section of urban expressway**

**Table 2 Classification of merging type**

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<thead>
<tr>
<th>Merging Type</th>
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<tr>
<td>Independent</td>
<td>NO (no impact)</td>
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<td>Stopping and</td>
<td>Deceleration, Give-way, NO</td>
</tr>
<tr>
<td>Watching through</td>
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**Figure 1 Deployment concept of Japanese AHS System**
Figure 2. Time-space diagram (Less-experienced driver)

Figure 3.1. Time-series data of driving operation and vehicle behaviour (Less-experienced)

Figure 3.2. Time-series data of driving operation and vehicle behaviour (Well-experienced)
Figure 4: Time-series data of driving operation and vehicle behaviour (Less-experienced)