A MICROSCOPIC ANALYSIS OF TRAFFIC CONFLICT CAUSED BY LANE-CHANGING VEHICLE AT WEAVING SECTION

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1 INTRODUCTION

Improving road traffic safety is a worldwide political issue to be relieved urgently. In Japan, the road traffic accidents kill around ten thousand persons every year. A recent statistics suggests that about 75% of accidents are caused mainly by some kind of human error. Accordingly, there is a great possibility that preventing human error in driving behavior might lead to reducing the number of traffic accidents. A lot of researchers and engineers expect that automation of driving tasks might prevent human error and enhance the road traffic safety drastically. Based on such expectations, Advanced cruise-assist Highway System (AHS) has been developed for the last decade in Japan. AHS is regarded as a sub system of Intelligent Transportation System (ITS). The hardware aspects of AHS are composed of sensors installed into roadway, communication devices connecting vehicle with roadway, and in-vehicle sensors and computers. AHS is expected to bring about well-coordinated relationship between vehicle, driver and roadway.

In order to make effective plans or strategies of comprehensive traffic safety measures including the application of AHS, it is important to evaluate objectively the risk of traffic accidents. It is difficult for us to evaluate the effects of traffic safety measures in terms of change in number of traffic accident in the studied section, because the traffic accident itself is a kind of rare event that may be well-explained by a series of Poisson distribution. Therefore, this study applies a kind of traffic conflict techniques for making the objective evaluation on traffic safety. The microscopic data on vehicular movements required for the analysis are extracted from video data on traffic flow using the image processing technique. Especially, the risk of vehicle collision at a weaving section is evaluated on the basis of the observable conflicts caused mainly by the mandatory lane-changes. In addition, as the initial research stage for developing a microscopic traffic simulation, this study analyzes the speed adjustment processes of a lane-changing vehicle and its surroundings.
2 Weaving Section Studied

Figure 1 shows a schematic chart of weaving section to be studied. The studied weaving section is located in the eastern suburb of Kyoto City and on the borderline between Kyoto and Shiga Prefectures. Also the weaving section is regarded as one of the important places for road transportation, because at the weaving section shown in figure 1 two major national highways, National Highway 1 and National Highway 161 merge. This study uses the video recordings of traffic flow from 15:00 to 16:00 on May 25 1999.

![Figure 1 Studied Weaving Section](image)

The observed hourly traffic volumes of National Highway 1 and 161 are 942 and 1096 respectively. The vehicles traveling from National Highway 161 to CBD of Kyoto city, of which number is 128, are required to make lane-change in this weaving section of which length is only 150 meters. In other words, the lane-changes done by the vehicles from National Highway 161 to CBD of Kyoto city are regarded as mandatory lane-changes. It is not so difficult for us to imagine that these mandatory lane-changes often cause the conflicts between vehicles. This study concentrates on the analyses of these mandatory lane-changes and the related conflicts.

This study has developed a computerized tool to trace vehicle movement from the digital video images of traffic flow. The tool provides us with the data of vehicle location in every 0.5 seconds on the real field coordinates. The data of vehicle location can be converted into vehicle speed and acceleration easily. In addition, the time headway between vehicles can be measured by the tool.

3 Analyses of Traffic Conflict Caused by Lane-change

Figure 2 indicates the typical situation of vehicle lane-change to be studied in this study. This study focuses on the lane-change behavior of vehicles traveling from National Highway 161 to Sanjo Street shown in figure 1. In order to evaluate the danger of traffic accident, the microscopic vehicle
behaviors are analyzed from the viewpoint of traffic conflict. Though some research works have suggested that there is only medium correlation between the number of traffic accidents and the traffic conflicts, this study adopts the methodology to evaluate the number of traffic conflicts and their severity due to the difficulty in observing the traffic accident itself. This study uses two indices to evaluate the conflicts: 1) TTC (Time to Collision, Hayward (1972)) and 2) PICUD (Potential Index for Collision with Urgent Deceleration).

![Figure 2 Lane Changing Vehicle and its Surrounding Vehicles](image)

TTC index has been widely used and represents the time remained until the following vehicle collides with the tail of vehicle in front under the assumption that the speed and direction of the vehicles do not change. PICUD is an index to evaluate the possibility that two consecutive vehicles might collide assuming that the leading vehicle applies its emergency brake. PICUD is defined as the distance between the two vehicles considered when they completely stop (Figure 3).

![Figure 3 Estimation Method for PICUD](image)
In the case where the leading vehicle is faster than the following vehicle, TTC index cannot be estimated in a finite number. This is a practical weak point of TTC index. It is found that the average speed of the second lane from left-end is higher than that of the first lane. Thereby, it is difficult to estimate TTC index between lane changing vehicle (a) and leading vehicle on target (the second) lane (b) shown in figure 2 in a finite number. However, the situation where the distance between two subsequent vehicles is very short should be regarded as a dangerous situation, even if the leading vehicle travels a little faster than the following vehicle. Under such a situation, there is a high possibility that lane changing vehicle might have a rear-end collision, if the leading vehicle applies an emergency braking. PICUD is regarded as the index to evaluate the potential danger of rear-end collision. Estimation of PICUD requires two predetermined parameters: 1) reaction time of vehicle and 2) deceleration rate of vehicle. In this study, it is assumed that the vehicle deceleration rate is 3.3(m/sec^2) and the reaction time is 1.0 second.

Figure 4 represents an example of computing TTC and PICUD for a following vehicle on the target lane against a lane-changing vehicle in front. The difference in speed between the lane-changing vehicle and the following vehicle on the target lane is fairly small, and their distance is also small. This is the suitable example to show the characteristics of PICUD compared with TTC. It can be found that the value of TTC fluctuates against time and varies from 5.5 seconds to infinity. In this case, PICUD continues to take the negative values and suggests that the following vehicle on the target lane can hardly avoid colliding with the lane-changing vehicle in front, if the lane-changing vehicle applies the emergency brake. There is a possibility that PICUD is more suitable than TTC for evaluating the danger of collision of the consecutive vehicles with similar speeds.
Table 1 Danger of Vehicle Collision for Studied Weaving Section Based on PICUD

<table>
<thead>
<tr>
<th>Type of Collision</th>
<th>Collision might occur.</th>
<th>Collision might not occur.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Changing Vehicle with Leading Vehicle on Target Lane</td>
<td>19 (31%)</td>
<td>43 (69%)</td>
<td>62 (100%)</td>
</tr>
<tr>
<td>Following Vehicle on Target Lane with Lane Changing Vehicle</td>
<td>28 (67%)</td>
<td>14 (33%)</td>
<td>42 (100%)</td>
</tr>
</tbody>
</table>

Table 1 shows two types of the danger of vehicle collision: 1) the collision of the lane-changing vehicle with the leading vehicle on the target lane and 2) the collision of the following vehicle on the target lane with the lane-changing vehicle. Judging from the computed PICUD, one third of the mandatory lane changes might lead to colliding with the leading vehicle on the target lane, if the leading vehicle suddenly makes intensive deceleration. However, two thirds of the mandatory lane changes might cause the collision of the following vehicle on the target lane with the lane-changing vehicle, in the case of sudden and intensive deceleration of the lane-changing vehicle.

In addition to the conflict analysis, this study conducts a microscopic analysis of the relation between applying brake, and both the relative speed and the time headway from the following vehicle on the target lane to the lane-changing vehicle. This relation analyzed here suggests that maneuvering vehicles by drivers including the usage of brake might be strongly influenced by their attitudes toward the risk of vehicle collision, especially under the so-called ‘medium’ dangerous traffic situation.

4 SPEED ADJUSTMENT MODEL

One of the crucial factors to relieve the potential danger of rear-end collision is to synchronize the behavior of lane-changing vehicle with that of the following vehicle on target lane. In order to analyze the effects of automation of driving tasks on the safety in lane changing behavior, this study attempts to make two types of the speed adjustment models: 1) the speed adjustment model of the lane-changing vehicle, and 2) the speed adjustment model of the following vehicle on target lane. The former model includes the relative speed to the leading vehicle on the target lane and the time headways to both the leading and following vehicles on the target lane as the explanatory variables. The explanatory variables of the latter model are the relative speed and the time headway to the lane-changing vehicle in front. There is a possibility that drivers might tend to recognize these explanatory variables in linguistic manners, like ‘very large relative speed’ or ‘short time headway’. Accordingly, this study applies the Fuzzy Inference System for developing the speed adjustment
model mentioned above. Due to the limitation of the space, the detail of the models will be presented at the conference.

5 CONCLUDING REMARKS

The basic findings in this study are as follows.
1) Judging from the proposed index for traffic conflict, PICUD, there is a strong possibility that the following vehicles on the target lane might be smashed into the lane-changing vehicles in front, if the lane-changing vehicles face the situation where they should apply the emergency brakes.
2) Maneuvering vehicles by drivers including the usage of brake might be strongly influenced by their attitudes toward the risk of vehicle collision, especially under the so-called ‘medium’ dangerous traffic situation. Considering the driver's attitude toward risk explicitly might lead to drastic improvement of the speed adjustment model.

REFERENCES