ABSTRACT

In Japan, although conventional preventive measures of accidents and pre-crash measures of accidents have been deployed intensively, the accident number is so far still at a high level. The authors have been developing AHS measures which prevent accidents through cooperation between roadside equipments and on-board units for providing information to drivers in real time. A social testing of a forward obstacle information provision service was conducted. The system decreased dangerous situations such as close calls, and reduced accidents such as rear-end collision or side wall collisions. This paper reports the result of the social testing.

INTRODUCTION

Although the number of fatalities from traffic accidents has been on the decline in recent years, the number of traffic accidents remains at a high level. Therefore, effective measures for reducing traffic accidents need to be realized as soon as possible. In its research into new traffic safety measures for preventing accidents by providing information, warnings, and operation support immediately prior to potential accidents, the ITS R&D Division of NILIM has focused on the fact that 75% of all accidents are due to human errors immediately before the accident, such as late recognition, bad judgment and mistakes in vehicle operation.

The effectiveness of services that use information boards and on-board devices to provide such information as the presence of obstacles in front of the vehicle has been verified on actual roads and in simulators. This has shown that while 50% of drivers take hazard avoidance actions, such as braking, in response to the information provided by the information boards, 90% of drivers take hazard avoidance actions in response to information provided by on-board devices. This shows that services actually using the on-board devices envisioned for AHS can be expected to make a real reduction in accidents and continue to be effective accident prevention measures.

In fiscal 2003, previously prepared test vehicles were used to conduct verification testing. This testing showed that a large number of rear-end collisions and side wall impact collisions were occurring due to the sudden appearance of dangers, such as the back of traffic jams or stopped vehicles, in road curves where they could not be seen in advance by the driver. The testing also confirmed that it is possible to provide information to car navigation systems using dedicated short range communication (DSRC), and that this can be expected to reduce accidents by providing information immediately before the driver encounters the danger. It shows that it has become possible to scientifically identify dangerous behavior, the hazard level of potential accidents, and the effectiveness of countermeasures by using sensors.

Based on the results from this verification testing, during the period from March to May 2005, information regarding obstacles in front of vehicles was provided to drivers from the general population who use commercially available and widespread car navigation systems that support 3 Media VICS, to conduct a social test of the ability of forward obstacle collision prevention support services that reduce rear-end collisions, side wall impact collisions, and dangerous situations such as close calls. This paper reports the results of this testing.

NECESSITY AND POSSIBILITY OF COOPERATIVE VEHICLE-HIGHWAY SERVICES

NECESSITY OF SERVICES

Nationwide there are 470 locations in the urban expressways in Japan where curves have a radius of 200m or less. Accidents occur at a rate of 2.6 times the average in such sharp curves (Fig. 1). Further, the loss due to damage from these accidents is estimated to be 10 billion annually. In particular, 21% of curves where accidents occur frequently (6% of total length) are concentrated in the Metropolitan Expressway (Fig. 2).

Most of the accidents are due to driver action immediately before the accident, such as late recognition and errors in judgment (Fig. 3). For this reason, notifying drivers in advance of road conditions ahead of them is important for reducing accidents. To meet this need, development has been progressing on systems that detect obstacles in front of the vehicle
using sensors installed in the vehicle and other means. These systems are increasing driving safety in regards to obstacles in front of the vehicle, but in sharp curves (radius of 250m or less) it is difficult for the vehicles alone to detect such obstacles (Fig. 4).

Considering the above, measures to prevent accidents in sharp curves, where it is difficult for the driver to see and for the on-board sensors to detect the situation ahead of the vehicle, are urgently needed. Therefore, a means for providing information on obstacles ahead of the vehicle from the road to the vehicle is an indispensable part of such measures.

POSSIBILITY OF SERVICES

The Metropolitan Expressway No.4 Shinjuku Route Sangubashi Section has a sharp curve with a radius of 88m where 181 accidents occurred during fiscal 2003. In fiscal 2003, the test vehicles were used to conduct actual road tests in the Sangubashi Section and the following is the result of the tests.1)

- The number of accidents that actually occur (30/month) exceeds the number reported to the Metropolitan Expressway Public Corporation control room (12/month) (Fig.6).
- Thirty percent of the accidents (11/month) are caused by stopped or slowed vehicles in front of the vehicle that the driver cannot see, and most of these are secondary accidents caused by vehicles stopped suddenly by accidents (Fig.6).
- An AHS image processing sensor was used to quantitatively assess for the first time the overall state of hazardous driving and it was found that in connection with 1 accident there were approximately 80 cases of rapid speed reduction deemed to be close calls.
- Of the 11 accidents caused by obstructions in front of the vehicles, it was found that in 10 cases information immediately prior to the accident could have been provided to drivers had an AHS image processing sensor detected stopped or slowed vehicles in front of them and had their vehicles been equipped with devices for receiving this information.
- The developed AHS image processing sensor was able to detect stopped vehicles with a 96% or greater accuracy.

These studies both showed the need for providing cooperative vehicle-highway services as soon as possible and that doing so is technologically feasible.

Further, there have been no previous examples of using image processing to analyze the behavior of each individual vehicle to quantitatively assess accident situations, so this is expected to be utilized for before and after evaluation of traffic accident countermeasures and other applications in the future.
PROVIDING INFORMATION THROUGH COOPERATIVE VEHICLE-HIGHWAY SYSTEMS

SOCIAL TESTING OF COOPERATIVE VEHICLE-HIGHWAY SERVICES

During the period from March 1 to May 31, 2005, currently widespread car navigation systems that support 3-Media VICS were utilized to conduct social testing of providing safe driving support information to general vehicles. The social testing locations and service overview are given in Figs. 7 and 8.

The service provided this time displayed on the car navigation system screen with simple illustrations of the rear-end traffic congestion and included the message “Warning, traffic congestion ahead” for all stopped vehicles, slowed vehicles, and traffic congestion detected in front of the vehicle by the AHS image processing sensor. A scene of information being provided to an actual car navigation system is shown in Fig. 8.
PRIOR VERIFICATION

The information was provided to general drivers using simple illustrations via the widely utilized VICS. Prior verification of the following items using a driving simulator and actual vehicle testing on a test course was conducted as a negative check in preparation for providing the safety information using simple illustrations.

- Movement of the line of sight in regards to the information
  The movement of the line of sight to the on-board device display monitor was about 1 second and was confirmed to be of a degree that it does not affect driving.
- Understanding of information contents
  It was confirmed that the drivers could understand the provided information without trouble.
- Actions taken after the information was received
  It was confirmed that reception of the information by the drivers resulted in some sort of driving action by the driver, such as greater care or gradually reducing speed.
- Driving behavior after reception of the information
  When speed was reduced before the stopped or slowed vehicle could be seen, it was confirmed that drivers did not engage in hazardous behavior, such as sudden speed reduction.

The following was confirmed from these results.

- It is possible to provide cooperative vehicle-highway services using widely employed car navigation systems that support 3-media VICS to support safe driving, and that using simple illustrations to provide information is more easily noticed and understood by the driver compared to using roadside signs and displays.
- Providing information using car navigation systems that support 3-media VICS had no negative impact understanding, actions taken after information reception, or driving behavior.

RESULTS OF SOCIAL TESTING

A comparison of the number of accidents that occur before and after implementation of the services could be used to measure the effect of the implementation, but this would require the gathering of accident data over a long period of time. Rather, the authors propose using AHS image processing sensors that can analyze the behavior of each individual vehicle as a method for evaluating the results of traffic safety measures in a short period of time. The actual road testing analysis conducted in 2003 showed that for each rear-end accident there occurred what was deemed to be nearly 80 close calls, such as sudden speed reduction.

The authors conducted further evaluations, such as gathering of driver opinions, based on the measurement and comparison of the frequency of rapid speed reduction and speed when entering curves of vehicles in curve sections when there is an obstacle in front of them by utilizing the AHS image processing sensor detection data.

FUNDAMENTAL ANALYSIS RESULTS

For the social testing conducted from March to May, a comparison was made of the number of accidents that occurred on the Metropolitan Expressway No.4 Shinjuku Route during the past fiscal year (Fig.9).

Compared to 2004, there was a tendency during 2005 for the number of accidents to slightly increase in sharp curves in the Metropolitan Expressway No.4 Shinjuku Route and similar curves in other locations, but the number occurring in the Sangubashi curve drastically declined during 2005. This showed the effectiveness of

Note 1: For 2003 and 2004, the number of cases is based on MEX data (main line)
Note 2: Similar sharp curves cover accidents that occurred on curve sections with radius of 200 m or less.

Fig.9 State of accident occurrence on the No.4 Shinjuku Route including the Sangubashi Curve on drivers in terms of sight checking actions, driver
the social testing of the services and other traffic safety measures conducted for the Sangubashi curve.

The daily traffic quantity of the Metropolitan Expressway No.4 Shinjuku Route Sangubashi section (inbound) where the social testing was conducted is approximately 47,000 vehicles; making it a heavily traveled section. For this reason, it is subject to chronic traffic jams during the morning and evening rush hours. Providing these services allowed the authors to examine the vehicles driving in this section. This examination showed that approximately 10% of all vehicles traveling through this section are equipped with car navigation systems supporting 3-media VICS, which are able to receive the services.

EVALUATING EFFECTIVENESS BY OBSERVING TRAFFIC FLOW

The AHS image processing sensor detection data was used to measure the frequency of sudden speed reduction of vehicles in the curve section and the speed with which the vehicles entered the curve when there was an obstacle in front of the vehicle (Table 1).

The results of this showed that providing a service to inform drivers ahead of time of obstacles in front of them using car navigation systems that support 3-media VICS reduced behavior deemed to be close calls, such as sudden speed reduction in the curve section and entering the curve at high speed, was reduced by 12% to 14%. It was further shown that combining this with information boards to provide information reduced close call behavior by 15% to 47%. This proved that the expected effect of the system (information boards 50%, on-board devices 90%), which was found by the verification using driving simulators in the past, was reasonable.

Of the vehicles that passed through the test section, 10% were equipped with car navigation systems that support 3-media VICS, so further improvements in the effect can be expected if car navigation systems that support 3-media VICS come into greater use in the future.

SATISFACTION EVALUATION

As part of the social testing, general drivers were recruited as test monitors in advance and asked to fill out a questionnaire regarding their opinions of when they were traveling through the curve section, and the results from this were used to evaluate satisfaction. There were 259 people who served as test monitors. The Internet and other means were also used to collect the opinions of general drivers, which together with the questionnaires from the test monitors, allowed the authors to obtain replies from a total of 296 people who had experienced receiving the provided information.

The results of this survey showed that drivers generally accepted the service and reacted as expected by being

Table 1 Comparison before and after the implementation of the service using sensor data analysis

<table>
<thead>
<tr>
<th>Classification</th>
<th>When there is traffic congestion or a stopped or slowed vehicle ahead in the curve</th>
<th>Valid number of samples of vehicles entered at 30 km/h or faster (vehicles/28 days)</th>
<th>Frequency of sudden speed reduction behavior</th>
<th>Frequency of entering curve at high speed (vehicles entering at a speed of 60 km/h or more)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Before service implementation 28 days during October to November 2003</td>
<td>10,344</td>
<td>30.2 vehicles /100 vehicles</td>
<td>18.1 vehicles /100 vehicles</td>
<td>4.9 vehicles /100 vehicles</td>
</tr>
<tr>
<td>(2) VICS service 28 days during March to April 2005</td>
<td>13,181</td>
<td>27.4 vehicles /100 vehicles</td>
<td>15.9 vehicles /100 vehicles</td>
<td>4.2 vehicles /100 vehicles</td>
</tr>
<tr>
<td>Effect ((1) → (2))</td>
<td>9% decrease</td>
<td>12% decrease</td>
<td>14% decrease</td>
<td></td>
</tr>
<tr>
<td>(3) VICS + Information board 28 days from April to May 2005</td>
<td>11,409</td>
<td>27.1 vehicles /100 vehicles</td>
<td>15.4 vehicles /100 vehicles</td>
<td>2.6 vehicles /100 vehicles</td>
</tr>
<tr>
<td>Effect ((1) → (3))</td>
<td>10% decrease</td>
<td>15% decrease</td>
<td>47% decrease</td>
<td></td>
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</table>
more careful and slowing down when they received the information. In addition, there were no occurrences of dangerous actions, such as drivers being surprised by the information and overreacting. There were some people; however, who felt that being provided with the information was not helpful. Analyzing the reason for this showed that traffic had already become congested before the curve section, so the information was not needed. To maintain the effect of providing safety information, it is important that the required information be provided when necessary, so this is an issue that requires further improvement in the future.

A questionnaire survey of the test monitors was also conducted throughout the social testing period (3 months) and used to conduct a comprehensive evaluation on the service (Fig. 10). This showed that 85% of the test monitors thought the service was effective, and 90% of them desired that the service be continued in the Sangubashi curve, so it was concluded that the service was highly evaluated.

CONCLUSION

The results of social testing on the forward obstacle collision prevention support service using car navigation systems that support 3-media VICS confirmed that although only 10% of the vehicles traveling through the test section were equipped with car navigation systems that support 3-media VICS, providing the information made vehicle behavior safer and that the service was accepted by general drivers and thus demonstrated the possibility of using this service as new traffic safety measure.

It was clearly shown; however, that to maintain the effectiveness of the service it must be improved to provide the required information when necessary. Further, it was also shown that using AHS image processing sensors was effective in analyzing vehicle behavior deemed to be close calls and thus ITS can be used as a effective method for analyzing and evaluating traffic safety measures.

Long-term social testing of the service was started again in September 2005 after incorporating input from general drivers, and this testing is still underway (as of June 2006). The authors plan to assess the year-round sustainability of the effect based on the results of this long-term social testing.

In addition, in January 2006, the target of “Reducing the number of traffic fatalities and traffic accidents by realizing Cooperative Driving Safety Support Systems that cooperate with traffic infrastructure” was set as part of the “New IT Reform Strategy” (Director-General of the IT Strategic Headquarters: the Prime Minister). We think the results of this research will contribute to achieving this target, and we will continue research and development to achieve AHS to reduce the number of traffic accidents in the future.

REFERENCES