Introduction

The National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure and Transport conducted proving tests of the Advanced Cruise-assist Highway System in FY2002 and 2003. This paper reports on the results of the field operational tests conducted on the Sangubashi section of the Shinjuku Line of Metropolitan Expressway No. 4, with a particular focus on the effectiveness of AHS. The tests demonstrated that in addition to being effective in reducing the number of accidents, AHS can be expected to reduce the incidence or the severity of dangerous driving situations which do not result in accidents, and is therefore a service with clear social benefits.

Proving Tests and Test System

Figure 1 shows the flow of AHS research. First, we analysed traffic accident data to make priority where should be installed the AHS system, with the highest proportion of fatalities, casualties and financial losses occurred as a result of accidents. Next, to proceed with the realization of these services, we defined system requirements; visual and infrared sensors were selected to function as road condition detection sensors and visual and laser radar sensors were selected to function as road surface condition detection sensors. Dedicated Short Range Communications (DSRC) was selected for road-to-vehicle communication. Therefore a feasible system was constructed.

This system was installed on the NILIM test course and on seven sections of actual roads, and evaluations were carried out using real vehicles.
Proving tests evaluated the AHS on single road, as shown in Fig. 2. With this system, an infrastructure gathers and provides information to support safer driving.

(1) Support system for provision of information on stationary and slow-moving vehicles ahead
This system enables early braking when there are forward obstacles which are difficult to see (stationary vehicles, rearmost congestion), reducing the danger of collision and contributing to peace of mind in driving.

(2) Support system for prevention of overshooting on curve
This system warns the drivers that they are driving too fast to realize a sharp curve ahead, enabling them to enter the curve at a safe speed.

Dangerous Situations on Highways
The types of accidents occurring on highway curves can be broadly divided into two; rear-end collisions with stationary vehicles ahead and single-vehicle accidents, such as collisions with a side wall, etc. AHS is aimed at reducing the number of the accidents such as collisions with stationary or slow-moving vehicles or the congestion around the curve where the driver cannot see and collisions with side walls caused by entering the curve too fast and departure from the lane.

It is known that where accidents occur, dangerous driving situations (sudden braking, etc.) also often occur. Table 1 shows a breakdown of these other dangerous situations.

It has been difficult to collect every vehicle data, although it is important for developing safety measures to analyze into data concerning the status of these dangerous situations and the number of times they occur on curve sections.

From this field operational test on Sangubashi section, we could clarify the status of these dangerous situations by way of analyzing the data obtained from sensors.

<table>
<thead>
<tr>
<th>Accident</th>
<th>Related to rear-end collisions with stationary vehicles ahead</th>
<th>Related to single-vehicle accidents (Collision with side wall, etc.)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Rear-end collisions with stationary vehicles / rearmost congestion Collision with side wall when swerving to avoid obstacle ahead</td>
<td>Single-vehicle accidents (Collision with side wall, overturning, etc.)</td>
</tr>
<tr>
<td>Danger ous behavior (Close call)</td>
<td>Sudden braking swerving</td>
<td>Sudden braking deviation from the lane</td>
</tr>
</tbody>
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Table 1 Dangerous situations on expressway curves
Status of Dangerous Driving Situations on Sangubashi Section

This section will discuss dangerous situations on highway curves, with results from Sangubashi curve experiment. Because of space restrictions of urban highways, curved sections are frequent on these roads. Traffic safety measures have been put in place, such as signboards to provide drivers with information of congestion, but accidents on the 270 curved sections (approximately 10% of the total length) of Japan’s metropolitan expressways (radius of curvature of 200m or less) account for approximately 20% (approximately 3,000/year) of all traffic accidents, resulting in estimated losses of 7 billion yen per year.

As Figure 3 shows, there is a sharp left curve of a radius of curvature of 88m on the Sangubashi section. In FY2002, 140 accidents occurred on this curve.

A test AHS system was placed on this section to enable verification of the effectiveness of the AHS. Figure 4 shows the locations of the sensors and the DSRC antennas. Infrared image sensors were installed in this test.
1) Details of accident analysis (Dangerous driving situations)

Table 2 shows the number of accidents which occurred on the curve during the test period. The detected records of the sensors were analyzed, the data shows the following points:
(1) During the test period (4 weeks), approximately 30 accidents occurred.
(2) The accidents break down by type as follows: 1 collision with the tail-end of a traffic jam, 4 rear-end collisions with a stationary vehicle that had been involved in an accident, 6 collisions with the side wall as a result of attempting to avoid a rear-end collision and 19 collisions with the side wall as a result of entering the curve too fast.
(3) 12 of the accidents were reported, but there were 18 further accidents, some of which were extremely minor, which were not reported. We can catch “hidden” accidents which will not appear in statistics. 7 of the 26 collisions with the side wall resulted from drivers avoiding collisions with the tail-ends of traffic jams or vehicles in front which were stationary as a result of accidents. The rate of accidents resulting from forward obstacles was thus confirmed to be around three times higher than that of the official accident statistics.

Figure 5 shows the distribution of speeds at the time when the vehicles involved in this 30 accidents entered the curve, as recorded by the sensors. Although the speed limit for the Sangubashi curve is 50km/h, it is clear that most of them attempted to enter the curve at higher speed than limited and caused the accidents.

![Figure 5 Distribution of speed on entering curve of vehicles involved in accidents](image-url)
2) Analysis of sudden braking
We analyzed sudden braking occurring on the section. As no standard definition of sudden braking exists, on this study we defined sudden braking as braking at an average of 0.5G or more per second.
Table 3 shows the maximum deceleration on the curved section of vehicles which entered the curve at 40km/h and over. These data were collected by the sensors. On average, 20,302 vehicles entered the curve at speeds of 40km/h and over per day. The data indicate 782 vehicles (3.9%) per day braked suddenly to avoid collision with a forward obstacle or overshooting.

(1) When there is a forward obstacle
The average maximum deceleration is 0.34G, which is higher than the figure of 0.2G without forward obstacle. In addition, 29 of the 196 vehicles (15%) that entered the curve at 40km/h and over and encountered a forward obstacle braked suddenly.

(2) When there is no forward obstacle
Even when there is no forward obstacle, 753 of the 20,106 vehicles (3.7%) per day entered the curve at 40km/h and over.
It is difficult for drivers to imagine that they will encounter a forward obstacle on a highway. When they meet this situation, with an extremely high proportion, they braked suddenly.

Predicted Effect of Provision of Information on Curved Sections
These Sangubashi tests were conducted only with particular vehicles able to receive particular information. There are also signboards for other vehicles, and some of the vehicles could be equipped with OBU to receive information. From these tests, we found that the AHS service provides the vehicles with information just before they arrived sites in 10 out of 11 cases of accidents.
Figure 6 shows a graph of the trajectory over time of a vehicle as recorded by the sensors. This vehicle collided with the side wall as a result of avoiding the rearmost congestion. The figure shows that as this vehicle passed the antenna, the AHS did detect the presence of a stationary vehicle on the curve, which means the AHS is able to provide information on this forward obstacle in advance.
Table 4 shows what kind of information the AHS provided when 11 vehicles which caused accidents passed the antenna. We found that if the vehicles had possessed receiving equipment, 10 would have received information on the existence of a forward obstacle. It would have been impossible to provide information to one vehicle, but it was determined that this problem could be solved through modifications to the system, such as positioning a separate antenna immediately before the curve.
The AHS established at Sangubashi was able to provide warnings and information about the situation ahead in the majority of cases in which the congestion or a stationary vehicle would cause sudden braking. In addition, it was able to give warnings just before curved section to drivers who pass at high speed without knowing the presence of a curve or how sharp it was. The trials showed that the system may also be effective in reducing the incidence of sudden braking which do not result in accidents.

Conclusion

Sensors were set up on sections of functioning roads to enable proving tests of the AHS under real traffic conditions. The test of Sangubashi section is one of these trials. By the way of analyzing the sensor data, it enables to understand the status of accidents. This indicates that AHS also could be practical to know dangerous areas from data.

The trials were carried out using only particular vehicles able to receive particular information, but because the system was able to provide information immediately in advance to vehicles involved in accidents and to vehicles braked suddenly, the service can be predicted to be effective.

References