Proving Tests for the Forward Obstacle Information Provision Service (ETC-ID System)

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ABSTRACT
The ETC-ID system is under consideration as a detection system for use in the forward obstacle information provision service, and proving tests were carried out to assess it. The ETC-ID system collects the ID of the onboard ETC (Electronic Toll Collection) device, and detects events on the basis of the information.

This paper is a report on the system configuration of the ETC-ID forward obstacle information provision service, as well as the system details and the results of the proving tests.

KEYWORDS
AHS (Advanced Cruise-Assist Highway Systems), ETC-ID, Expressway

BACKGROUND AND PURPOSE
Public experiments in Japan of the forward obstacle information provision service are currently being carried out on the Shinjuku-bound Sangubashi section of the Metropolitan Expressway. The forward obstacle information provision service detects situations such as a stopped vehicle or congestion on curves, etc., with poor visibility by means of a sensor, and gives warnings to approaching cars via an onboard screen or audible signal. Accidents on the Sangubashi section of the Metropolitan Expressway decreased 79% over the previous year as a result of implementation of the service, indicating that the service is extremely effective in reducing accidents. The forward obstacle information provision service on this stretch of the expressway utilizes an image sensor as the system for sensing forward traffic events, but various other systems are also considered possible.

At the same time, the ETC system for collecting tolls on toll roads is spreading; in total, a cumulative total of over 17 million onboard ETC devices have been shipped, and the ETC use rate for
metropolitan expressways is over 75%. As a way of using these widespread ETC onboard devices for sensing in the forward obstacle information provision service, a system is envisaged whereby the ID of the ETC device is collected by a DSRC (dedicated short range communication) device, and the status of vehicular passage along a given stretch of road is monitored. Existing image sensors are capable of detecting events with high precision, but cost restrictions limit the sites where they are set up to places where events occur frequently, such as accident black spots or stretches of road that are often congested; the ETC-ID system put forward in this paper may be expected to develop at low cost over a wide area.

**OUTLINE OF THE FORWARD OBSTACLE INFORMATION PROVISION SERVICE (ETC-ID SYSTEM)**

Under the forward obstacle information provision service (ETC-ID system), ID collection DSRC are situated at the start and the end of the target stretch of road in which events are to be detected. The ID collection DSRC at the start receives the ID from the ETC device of incoming cars; if this information is not then detected by the ID collection DSRC at the end within a certain criterion time, warning information is provided to approaching cars that traffic is not moving on this particular stretch of road because of congestion, stationary vehicles, etc. In this situation, the ID collected from the onboard ETC device is the anonymous LID (Link ID), an arbitrary ID generated from random numbers every time the onboard device is turned on, so the protection of personal information is ensured.

**CONFIGURATION OF PROVING TESTS**

Under the configuration of the forward obstacle information provision service (ETC-ID system), ETC-ID receiving DSRC1 and DSRC2 are situated at the start and the end, respectively, of the target stretch of road for event detection. The transit time estimated by the LID is used to detect events, and information is provided to vehicles following. In the event detected if vehicle does not pass DSRC2 within a defined period of time, the ID collected from the onboard ETC device is the anonymous LID (Link ID), an arbitrary ID generated from random numbers every time the onboard device is turned on, so the protection of personal information is ensured.
The stretch of road. The ETC-IDs received at the start and end of the target stretch are processed by a roadside ETC-ID processing unit, which judges whether or not an event has occurred. If an event is detected, warning information is provided to cars approaching the target stretch from an information-provision DSRC situated further up the road in the direction from which the traffic is coming. Also, in order to evaluate the effectiveness of the service, the onboard devices store vehicle behavior data such as location, speed, acceleration, etc., at fixed intervals. In order to evaluate the effectiveness of the service, this vehicle behavior data is up-linked using a vehicle data collection DSRC after the finish of the target stretch and processed by an evaluation device.

Algorithm for Determining Anomalies
The algorithm for determining anomalies is based on a transit time anomaly being determined when the time taken for a car that has passed ETC-ID collection DSRC1 (start) to pass ETC-ID collection DSRC2 (finish) is greater than the value for anomaly detection. The algorithm that is actually used has precautions to prevent data loss, etc. It judges an event to have occurred, and provides information to that effect, in the event that any one of the following four conditions are met.

- Two vehicles in succession do not pass DSRC2 (finish) with times less than the anomaly determination value.
- A vehicle does not pass DSRC2 (finish) with a time less than the anomaly determination value before the following vehicle passes DSRC1.
- A vehicle passes DSRC2 (finish) with a time greater than the time for anomaly detection, before the next vehicle exceeds the time for anomaly determination.
- A total of three vehicles within a fixed interval (one minute) do not pass DSRC2 (finish) with times less than the anomaly determination value.

Details of Information Provision
If an event is detected, information is provided via an onboard device to the car navigation system display of the approaching cars. Information is provided as shown in Figure 4 by a warning beep, a warning voice, and an image.
OUTLINE OF PROVING TESTS

The proving tests for the forward obstacle information provision service (ETC-ID system) were carried out at Akasaka Tunnel (in-bound lanes) and the Sangubashi section (in-bound lanes) along the Metropolitan Expressway No. 4 Shinjuku Line.

Proving Test at Akasaka Tunnel

Akasaka Tunnel is a tunnel of approximately 600m, with a gentle curve to the right. As the tunnel is frequently congested, the tunnel itself and the stretch of road near the tunnel entrance are areas of frequent rear-end collisions.

ETC-ID collection DSRCs were set up, one at the tunnel entrance and one at the tunnel exit, and a DSRC for providing information to approaching vehicles was situated before the entrance to the tunnel. Also, a DSRC was situated some distance after the tunnel to collect vehicle behavior data in order to verify the effectiveness of the service.

The purpose of the test at Akasaka Tunnel was to verify the effectiveness and the functional capacity of the system through vehicle behavior data and a driver survey.

The location for setting up the information provision DSRC was determined according to the following formula:

\[ L = \frac{a}{2} + \frac{v^2}{2a} + \frac{v^2}{2a} \times \frac{a}{2} \]

where 
- \( L \) = deceleration and stopping distance
- \( a \) = deceleration = 2.0m/s²
- \( T_c \) = onboard device processing time = 1s (Time taken from receipt of signal to display on navigation system is 1s)
- \( T \) = information provision and reaction time = 5s (Information recognition time [2s] + information assessment time [from 2.0 to 2.5s] ~ 5s)
- \( V \) = vehicle velocity = 60km/h (speed limit around Akasaka Tunnel) + 30km/h = 90km/h

from this, \( L = 306m \)
A post approximately 280m from the mouth of the tunnel was selected for installation of the DSRC, as this was an existing post in the region of 306 meters upstream of the tunnel entrance to which the DSRC could be installed.

**Proving Test Along the Sangubashi Section**

A public test of a forward obstacle information provision service using an image sensor is currently being carried out along the Sangubashi section. A sensing system using ETC-ID was set up at the Sangubashi section, and compared to the image sensor system. The purpose of the proving test along the Sangubashi section was to verify the functional capacity of the ETC-ID system by carrying out a comparison of the event detection results of the ETC-ID system with those of the image sensor system.

**EVALUATION ITEMS**

The evaluation items given in Table 1 were verified and evaluated under the proving test for the forward obstacle information provision service (ETC-ID system).

![Figure 6. Proving Test System Along the Sangubashi Section](image)

<table>
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<th>Verification Item</th>
<th>Verification Method</th>
<th>Verification Site</th>
<th>Details of Verification and Evaluation</th>
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<td>Verification of service effectiveness through vehicle behavior</td>
<td>Survey</td>
<td>Sangubashi Section</td>
<td>Comparison of speeds over target stretch when information is provided and when it is not provided</td>
</tr>
<tr>
<td>Verification of service effectiveness through drivers' subjective views</td>
<td>Survey</td>
<td>Sangubashi Section</td>
<td>Verification by survey of whether information is effective in avoiding accidents</td>
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<tr>
<td>Verification of service acceptability (negative check)</td>
<td>Survey</td>
<td>Sangubashi Section</td>
<td>Confirmation from vehicle behavior data that there was no sudden braking, etc., after receipt of information</td>
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<tr>
<td>Verification of anomaly detection / false detection</td>
<td>Survey</td>
<td>Sangubashi Section</td>
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<td>Verification of driver receptivity to timing of information provision</td>
<td>Survey</td>
<td>Sangubashi Section</td>
<td>Verification by survey of acceptability to drivers of timing of information provision</td>
</tr>
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</table>
RESULTS OF PROVING TESTS

Verification of Service Effectiveness Through Vehicle Behavior
System verification of the effectiveness of the forward obstacle information provision service (ETC-ID system) through vehicle behavior was carried out by evaluating the difference in speeds at the entrance to Akasaka Tunnel between the case where information was provided to drivers (service provided) and where information was not provided (no service).

The average speed at the entrance to the tunnel when the service was provided was found to be 3km/h slower than when the service was not provided; it was thus possible to confirm the effectiveness of the information provision service.

Verification of Service Effectiveness Through Driver’s Subjective Views
For the validation of the service through the subjective opinions of drivers, a survey into whether the service contributed to safe driving was conducted among subjects who had experienced the service.

The results of this survey show that nearly 80% of the subjects who experienced the service evaluated it as useful for safe driving.

Furthermore, those who responded that the service was useful gave such reasons as, “Because I was informed in advance that the tunnel was congested or there were stopped/slow vehicles, I was able to prepare for the situation,” and “I decelerated in advance with time to spare, so I was able to avoid a rear-end collision or sudden braking.” It is thus considered that the ability of drivers to prepare themselves in advance as a result of information provision is an effective contribution to safe driving.

Verification of service acceptability
To verify the acceptability of the service, a negative check was conducted into such items as whether dangerous behavior occurred as a result of the service provision. The negative check was carried out by assessing vehicle behavior data for whether there was behavior such as sudden deceleration, and by assessing the survey of subjects for dangerous behavior.

In the assessment of vehicle behavior data, it was found that the maximum deceleration of subjects was from braking during the 10-second period immediately after receiving information, but no dangerous behavior such as sudden braking was found.

In the survey of subjects, in answer to the question regarding how subjects felt after receiving the information, no one responded negatively that they had been surprised by the information and had felt rushed.
Verification of Anomalous Event Detection Rate

Verification of the rate of detection of anomalous events by the ETC-ID system was carried out by comparing the log data of the ETC-ID system with that of the image sensor system, and by checking events that occurred via the images on the image sensor. Over the experimental period (approx. two weeks), the detection of anomalous events by the ETC-ID system was 100%, and it was confirmed that the ETC-ID system is capable of detecting the same anomalous events such as naturally occurring congestion or accidents, etc. that are detected by the image sensor. However, there were cases in which despite there being no anomalous event such as natural congestion, congestion due to accident, traffic restrictions, etc., the ETC-ID detected an anomalous event. The main cause of these false detections was identified as the failure of DSRC2 to collect ETC-ID information. Anomaly detection by the ETC-ID system depends on the ETC-ID information collected by DSRC1 also being reliably collected by DSRC2. However, there are cases in which DSRC2 is unable to collect ETC-IDs due to the effects of phasing and other radio wave interference, and shadowing, in which the ETC-ID of a vehicle hidden by a larger vehicle, etc., cannot be collected. Furthermore, there is also believed to be a possibility that the ETC-IDs of vehicles not forming part of the experiment, such as vehicles in the oncoming lanes, were collected by DSRC1.

Based on these findings, there is a need for improvements in the future to the anomaly judgment logic, and these are currently being implemented.

Table 2. Experimental Results of ETC-ID System Anomalous Event Detection Rate

<table>
<thead>
<tr>
<th>Anomalous Event</th>
<th>Number Detected by ETC-ID System (A)*</th>
<th>Number Detected by Image Sensor System (B)</th>
<th>Anomalous Event Detection Rate (A) / (B) × 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Events</td>
<td>50</td>
<td>50</td>
<td>100%</td>
</tr>
<tr>
<td>A) Natural congestion</td>
<td>35</td>
<td>35</td>
<td>100%</td>
</tr>
<tr>
<td>B) Congestion due to accident</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>C) Congestion due to traffic restrictions</td>
<td>14</td>
<td>14</td>
<td>100%</td>
</tr>
</tbody>
</table>

* The number of events detected by the image sensor system that the ETC-ID system detected. In addition to this, there were false detections of abnormal events by the ETC-ID system when no abnormal events had actually occurred.
Verification of Driver Receptivity to Timing of Information Provision

For the verification of driver receptivity to the timing of information provision, a survey was conducted into whether the timing of the information provision by the onboard device was appropriate or not. Although approximately 15% of the subjects responded that the information was “rather late,” no one responded that it was “late,” and approximately 75% of the subjects responded that it was “appropriate”; it is thus possible to evaluate that there was no problem with the timing of the information provision. From this, it may be regarded that the DSRCs were situated in an appropriate position.

**Figure 9. Verification of Acceptability to Drivers of Timing of Information Provision: Survey Results**

**CONCLUSIONS AND FUTURE WORK**

An assessment was carried out of a sensing system using ETC-ID through the proving test of the forward obstacle information provision service (ETC-ID system). It was found that the ETC-ID system was capable of detecting the same anomalous events as those an image sensor system detects, and from the vehicle behavior data and the survey it was found that the ETC-ID service is both effective and acceptable. However, as false detections occurred when there had been no event, there is a need for improvements to the anomaly detection algorithm, and these are currently being implemented.

Based on the evaluation results of the current proving test, improvements will be made to the ETC-ID system, while at the same time various types of infrastructure development are being planned in order to apply the system to other areas.