EVALUATION OF LONG-TERM EFFECTS FOR DRIVING SAFETY SUPPORT SERVICE USING VEHICLE-INFRASTRUCTURE COOPERATIVE ITS

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ABSTRACT
As urban expressways were built in limited space, they sometimes have structure with sharp curves and so on. Concentration of traffic in urban environment often causes congestions on urban expressways as well. Consequently, traffic accidents such as overshooting by approaching blind curves at excessive speed, or collision accidents at the congestion tail are often trigged. National Institute for Land and Infrastructure Management (of the Ministry of Land, Infrastructure, Transport and Tourism of Japan) has been researching and developing on vehicle-infrastructure cooperative ITS using V2I communication, and developed new onboard unit (OBU) called ETC2.0 in 2015. This OBU enables alerting drivers in one second after receiving driving safety support information. This research explains the background of development of driving safety support information using ETC2.0, and then, reports evaluation of continuous effects of the service.

Keywords: C-ITS, ETC2.0, Driving Safety Support, Road Safety

1 INTRODUCTION
As urban expressways were built in limited space, they sometimes have structure with sharp curves and so on. Concentration of traffic in urban environment often causes congestions on urban expressways as well. Consequently, traffic accidents such as overshooting by approaching blind curves at excessive speed, or collision accidents at the congestion tail are often trigged.

National Institute for Land and Infrastructure Management (NILIM) has been researching and developing the Advanced Cruise-Assist Highway Systems (AHS) since 1996. AHS improves the effectiveness of information provision by providing necessary information to the driver at a necessary timing. And with the cooperation of Metropolitan Expressway Company Limited, NILIM carried out the experiment of "the Providing Forward Obstacle Information Service (PFOIS)" at the Sangu-bashi curve of Metropolitan Expressway route 4. In addition, we conducted experiments on "the Preventing Curve Entry Risk Service (PCERS)" at Kumano-cho curve of route 5 from 2011 to 2014 and verified the effectiveness of the service.

In 2014, based on these results, MLIT deployed the concept of a new Electronic Toll Collection (ETC) OBU. That enables avoidance of traffic congestion, driving safety support, and electronic fee collection by vehicle-infrastructure cooperative ITS using V2I communication. And in 2015, MLIT developed OBUs called "ETC2.0". ETC2.0 OBU can warn the driver within 1 second after receiving driving safety support information. In the nationwide deployment of ETC2.0 DSSS (driving safety support service), it is necessary to grasp the effect comprehensively and focus on the necessary part.

In this research, the authors review the effectiveness verification result of PFOIS in AHS research and development (R&D), the results of long-term effect verification by the Field Operation Test (FOT) of PCERS and the monitor survey of the ETC2.0 OBU. Then, it summarizes the features of the ETC2.0 DSSS and report on the results of evaluating the continuity of the effect and the effectiveness of service at multiple locations.

2 FEATURES OF THE ETC2.0 OBU
The features and advantages of ETC2.0 are explained below.
2.1 Introduction of DSRC
ETC2.0 uses the active DSRC (Dedicated Short Range Communications) in the 5.8 GHz band. High-speed, high-capacity communications enable to provide information for supporting safe driving, and wide-area traffic congestion information for over approximately 1.000 km to be provided. Two-way communications also allows probe data, such as driving history data and behavioral history data, to be collected from vehicles. Driving history data and behavioral history data contain positional information collected through onboard GNSS positioning functions. The 5.8 GHz active DSRC was certified by the international ISO 14906 standard in 1998. Also, the frequency band recommended for Electronic Fee Collection systems was also certified as an international standard in accordance with the ITU (International Telecommunication Union) recommendation in 2000.

2.2 Security Guaranteed and Privacy Protected
ETC2.0 is able to guarantee security and to protect privacy ETC2.0 uses an IC card with an IC chip with built-in CPU, and this enables two-way authorization and the encryption of recorded data with DSRC Security Platform (DSRC-SPF).

2.3 Supports Complex Payment Systems
ETC2.0 also enables introducing a system to support complex payment systems. This allows a large number of road operators, not only in Japan but also worldwide, to operate and manage toll roads. As it employs the nationally unified standards, ETC2.0 is able to support many different types of payment systems: various types of payment systems, including uniform tolls and distance-based tolls, currently in operation.

2.4 Use of the Two-Piece System
ETC2.0 uses a two-piece system that supports multiple users. Vehicle information is stored in onboard units and personal information is stored on IC cards, enabling to separate the vehicle owner and the toll payer. This allows people other than the owners of the vehicle, such as car rentals, to pay EFC tolls via the onboard unit. The cards inserted will also be incorporated with different transportation cards to expand the potential of the services available in the future.

3 EVALUATION OF THE PROVIDING FORWARD OBSTACLE INFORMATION SERVICE (PFOIS)
This chapter reviews past research on the evaluation of PFOIS, which is one of DS, and evaluate the service by complementing with some recent research. Specifically, NILIM conducted preliminary verification by the Driving Simulator (DS) in AHS R&D, evaluation of the social experiments at the Sangu-bashi curve of Metropolitan Expressway route 4, and evaluations in the questionnaire survey to the drivers.

3.1 Basic concept of PFOIS
The basic concept of PFOIS in AHS R&D is as follows. PFOIS is a service which provides information on detected events such as traffic congestion and stopped vehicles to the driver by image sensors installed on the roadside. In considering the service in 1998, the authors verified using DS. As a result of measuring the reaction time of the information provision and the danger avoidance behavior, it was found that the driver could avoid a 90% collision accident if it could find the obstacle ahead about 4 seconds ago. In addition, the driver recognizes the warning by OBUs with a probability of 90%, and the recognition rate is higher than 50% of VMS (Variable Message Signs). Through these preliminary verifications, the authors confirmed the effectiveness against human errors (judgment delay, misjudgement, operation error), which is a factor of 95% of the accident, and decided to conduct the social experiments on public roads.

Next, NILIM decided the specifications necessary for system design. The time required for recognition and risk avoidance behavior was adopted 5 seconds. Next, the contents of the information provision decided to display the situation at the end of the curve as a simplified Figure and to ring the attention sound “Beep”. Also, as a result of investigating commercially available IVI (In Vehicle Information) OBUs, the time for information processing and display was 4.6 seconds at the maximum; therefore it set 5 seconds as information processing and display time. (In ETC2.0 OBU, this information processing and display time set one second.) Lastly, from the results of FOT, the deceleration set 2m/s² that can be safely stopped.

Using the above design criteria, NILIM calculated the idle running distance until displaying on OBUs after receiving information from RSUs, the idle running distance until the driver recognizes it, and braking distance from system design speed, and decided the installation position of RSUs.

3.2 Outline of the social experiment of the Sangu-bashi curve
The Sangu-bashi curve is the sharp curve with a curvature radius of 88 m. Due to the sound insulation wall inside the curve, it is difficult for the driver to grasp the situation before the curve when there is a congestion tail, a stopped vehicle, and a low speed vehicle. For this reason, collision accidents and sudden braking occurred frequently at
the congestion tails. During the period from March to May 2005, we conducted the social experiments which utilize the emergency interrupt information provision function of 3 media IVI compatible car navigation system to provide information on forward obstacles to the general driver by screen and voice as shown in Figure 1.

![Figure 1 PFOIS of the Sangu-bashi curve](image)

**3.3 Review of preliminary verification results by DS**

In October 2004, prior to the social experiments, we conducted a preliminary verification in an environment similar to the Sangu-bashi curve using DS of Keio University. We set the system design speed to 80 km/h, and provided information at 234 m before the curve section. The 29 research participants (Male 20, Female 9) were experienced users of IVI OBUs from 21 to 67 years old who often used the Metropolitan Expressway. Figure 2 shows an example of the driving operation of the subject. The driver visually recognizes the information after providing the information, and then releases the accelerator. Furthermore, after viewing the stopped vehicle again, it stops before the preceding vehicle by stepping on the brake. Also, in response to changes in the presence or absence of information provision, although the driver does not perform braking operation during normal driving, but, at the time of information provision, 56% participants put a brake on and 93% of people take safe action such as decelerating and braking.

![Figure 2 Example of driver operation after information provision](image)

**3.4 Review of effect evaluation on changes in vehicle behavior**

We confirmed the effect of improving curve entry at high speed and dangerous sudden braking, because the frequency of sudden deceleration occurrence and the curve entry speed have been changed by the PFOIS at the Sangu-bashi curve. In the evaluation result based on the detection data using the image processing sensor, the frequency of
sudden deceleration occurrence decreased by 12%, the frequency of curve entry at high speed decreased by 14%, and
the vehicle behavior changed to the safe side. (Table 1) In particular, at the time of 2005, the mixing ratio of 3-media
IVI compliant OBUs was about 10%, but service effectiveness was 12% to 14%. This result seems to be due to the fact
that when the serviced vehicle decelerates, the following vehicle also decelerates earlier.

Table 1: Effect on sudden deceleration, approach speed

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number of effective samples</th>
<th>Frequency of sudden deceleration occurrence of 0.5 G or more</th>
<th>Frequency of curve entry at high speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>① No service (28 days of from Oct. to Nov. in 2003)</td>
<td>10,344</td>
<td>18.1%</td>
<td>4.9%</td>
</tr>
<tr>
<td>② IVI service only (28 days of from Mar. to Apr. in 2005)</td>
<td>13,181</td>
<td>15.9%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Effectiveness (①-②) / ①</td>
<td>-</td>
<td>Decreased by 12%</td>
<td>Decreased by 14%</td>
</tr>
</tbody>
</table>

3.5 Traffic Accident Reduction Effect

3.5.1 Review of short-term accident reduction effect
In the comparison of the numbers of accidents before and after the social experiments, traffic accidents caused
by forward obstacles decreased from 33 to 7 per year after service started. However, PFOIS is one of comprehensive
accident measures. Road managers have installed VMS in 2003, and colorization of thin layer pavement in 2005.

3.5.2 Review of long-term accident reduction effect
Figure 3 shows the changes in the long-term accident of the Sangu-bashi curve. In order to compare the effect
of 3 media IVI compliant OBUs, it shows the data until 2011 when new ITS-spot service is started. By continuing
comprehensive traffic safety measures, the number of accidents is maintained at less than half of the peak year. The
effects of the thin-layer color pavement and multi-function pavement change by the deterioration of the road surface,
and there are variations in the number of accidents in relation to these effects complicatedly. However, the number of
accidents (secondary accident involved in the forward accident, collision accidents at the preceding vehicle) targeted by
the PFOIS has been reduced to about 10 or less per year.

3.6 Subjective assessment of driver
In the social experiments, we collected opinions from 259 experimental monitors by questionnaire and evaluate
their satisfaction level. In addition, we collected opinions from the general drivers on the Internet etc. by questionnaire
and got responses 296 cases including the above 29 research participants. Focusing on the answer to the question "Was
it useful for safe driving if you receive information?" and their reasons, 26.2% of the monitors answered "useful" for
PFOIS, 27.3% answered "somewhat useful", and in total 53.5% answered that it was useful. The reason was that 102
people were able to prepare in advance, 66 people were able to slow down in advance. On the other hand, there were
opinions that information provision was not useful at the time of the experience. Analyzing the reasons, 86 people
(32%) experienced congested traffic in front of the curve, therefore they answered that the information was unnecessary.
NILIM has conducted FOT of PCERS which used V2I communication at the sharp curve in urban expressway such as Metropolitan Expressway, Hanshin Expressway, and Nagoya Expressway. In this section, we evaluate the effect of PCERS which is one of DSSS.

This study estimated the evaluation effect on the driving test course in 2002, public road tests at the Kumano-cho curve in 2011, and analysis before and after measures was carried out. In FY 2014, we conducted the same FOT as in 2011 and evaluated the continuous effect.

### 4.1 Service overview

PCERS is the service which provides the driving safety support information from RSUs to OBUs before sharp curve. This information is selected by the event judgment device based on the vehicle speed per lane, the type of vehicle, and the road surface condition collected from roadside sensors. The purposes of this service are to prompt the drivers:

- To adequately slow down to enter the curve
- To get ready for early braking action

However, curve entrance risk information is not as urgent as information on forward obstacles, it is expected that driver's reaction is not so sensitive. We guess that increasing effect of the driver's preparation, such as deceleration and placing a foot on the brake.

### 4.2 Test at the test driving course

In June 2002, when testing the effectiveness of the service on the test driving course during the AHS R&D, it was observed that the speed at entering a curve decreases when it called attention. The test purpose on the driving test course is "the drivers decelerate earlier before entering the curve and enter the curve at a safety speed". We set the target safety speed according to the radius of curvature, and studied whether the speed can be reduced by the service. 30 participants (Male 10, Female 10, Elderly people 10) drove 2 curves which the curvature radius of 80m and 220m on the driving test course at NILIM. Table 2 shows the comparing results of the curve entry average speed with or without service. It became clear that the curve entry speed was reduced to the target safety speed plus about 10 km/h when it called attention.

<table>
<thead>
<tr>
<th>The curvature radius</th>
<th>Entry speed</th>
<th>No service average</th>
<th>Service average</th>
<th>Target safety speed</th>
<th>Providing point</th>
</tr>
</thead>
<tbody>
<tr>
<td>80m</td>
<td>90km/h</td>
<td>64km/h</td>
<td>60km/h</td>
<td>50km/h</td>
<td>Before 233m</td>
</tr>
<tr>
<td>220m</td>
<td>120km/h</td>
<td>100km/h</td>
<td>85km/h</td>
<td>80km/h</td>
<td>Before 320m</td>
</tr>
</tbody>
</table>

### 4.3 FOT at the Kumano-cho Curve

#### 4.3.1 Outline of the Kumano-cho Curve

The Kumano-cho curve is one of the accident frequent occurrence areas by heavy vehicles on the Metropolitan Expressway. It is a right-hand curve with a curvature radius of 88 m, and the average daily traffic volume in 2014 is about 43,000. Characteristics of the curve area are multi-layered structure due to restrictions of the space, the structure at the curve point is difficult to see because the viewing distance is obstructed by the side walls and a strut. In addition, speed tends to be faster because near side of the curve is a long straight section. In August 2008, a large tank truck caused a rollover accident, and forced traffic restrictions for a long time.

#### 4.3.2 Outline of PCERS at the Kumano-cho Curve

PCERS installed in the Kumano-cho curve is the system using ETC2.0 to provide the information on dangerous curve for drivers. It uses the voice message function of ETC2.0. The speed which can drive the curve safely differs depending on the vehicle type (large vehicles / small vehicles) and road surface condition (dry, wet, frozen). At the Kumano-cho Curve, we set the threshold speed as shown in Table 3 from the side slipping friction coefficient defined by Government Order on Road Design Standards.

<table>
<thead>
<tr>
<th>Road surface condition</th>
<th>Small vehicles</th>
<th>Large vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target speed</td>
<td>Threshold speed</td>
</tr>
<tr>
<td>Drying</td>
<td>75km/h</td>
<td>90km/h</td>
</tr>
<tr>
<td>Wetting</td>
<td>65km/h</td>
<td>80km/h</td>
</tr>
<tr>
<td>Freezing</td>
<td>45km/h</td>
<td>45km/h</td>
</tr>
</tbody>
</table>
Figure 4 shows the system outline. The roadside sensor installed at 7.7 kp senses the type and speed of vehicles entering the curve. If the risk exceeding the threshold speed at that point is high, ITS spot at 7.83kp provides the voice message "Caution your speed! Next curve is accident frequent occurrence area". Even when it does not exceed the threshold speed in order to improve safety, it provides the voice message "Next curve is accident frequent occurrence area".

**Figure 4 Outline of PCERS at the Kumano-cho Curve**

4.4 Review of FOT Outline in FY2011 and Evaluation results

4.4.1 FOT Outline

4.4.1.1 FOT Term
We conducted dried condition test from February to March in 2011, and wet condition test from January to February.

4.4.1.2 Vehicles used in FOT
We used 4t long trucks full of cargo, because we assumed large vehicles full of cargo and the highest risk in driving this curve. In addition, the test vehicles were equipped with speaking type OBU so that voice message of PCERS was provided.

4.4.1.3 Test drivers
We selected drivers from 20s to 60s (many in the 30s and 40s) who drive large vehicles on a daily basis. Most test drivers have a high frequency of driving on Metropolitan Expressway, because they drive large vehicles on a daily basis. 40 people (dry condition: 20, wet condition: 20) test drivers drove every 3 times with service or no service.

4.4.1.4 Driving method
We conducted the FOT on test drivers without giving previous knowledge such as test purpose, evaluation area etc. Test drivers were not instructed such as lanes and speed when driving. FOT was conducted when traffic flow was free flow.

4.4.1.5 Evaluation items
We checked the "Deceleration level" from the information provision point to the curve entrance, "Change of Deceleration behavior" such as accelerator OFF or brake operation, and "Subjective assessment of the drivers".

4.4.2 Evaluation Results

4.4.2.1 Analysis of observational data
Deceleration level from the information provision point to the curve entrance did not appear as so clearly. However, there were some improvement effects. Deceleration level was larger for information provided, increased 0.9 km/h during drying condition, and increased 0.2 km/h on wet condition. As a result, the curve entry speed was 60.9 km/h with providing information for the target speed (large vehicles 65 km/h) when the road surface was dry, 62.9 km/h without providing information. When the road surface was wet, the curve entry speed was 54.0 km/h with providing information for the target speed (50 km/h) and 56.7 km/h for without providing information.

Focusing on the change in the deceleration behavior during drying (Figure 5), the point where deceleration behavior starts after receiving information provision moved to the upstream side. It was the same trend when wet.
4.4.2.2 Subjective evaluation results of drivers

80% of drivers felt "I felt that trying to pay attention" as a result of receiving the information when road surface was both at dry and wet. Drivers who felt that "trying to slow down" were 80% when it was during drying, and 70% when it was wet. Drivers who answered that the service was useful were 90% when it was during drying, and 80% when it was wet.

4.4.2.3 Occurrence of driver's dangerous behavior (Negative check)

There were not driver's dangerous behaviors such as sudden deceleration caused by information provision.

4.5 Review of FOT Outline in FY2014 and Evaluation results

4.5.1 FOT Outline

FOT conducted from November 2014 to January 2015 basically carried out the same contents as in 2011. However, test drivers were 25 people and they drove every three times with and without providing information (basically dry conditions, included some wet it). In addition, test drivers were different than in 2011. As an added research, we conducted the image analysis using a camera installed in a roadside building overlooking the Kumano-cho curve. The data which collected was used to confirm the "effect on surrounding vehicles" of the test vehicles.

4.5.2 Evaluation Results

4.5.2.1 Analysis of observational data

The deceleration due to the information provision point to the curve entrance was not observed so much, similar to FY2011. It was also the same trend that deceleration level was larger with providing information. Deceleration level increased by 1.4 km/h when dry, and increased 0.6 km/h when wet. As the results, the curve entry speed was 55.4 km/h (the target speed of large vehicles: 65km/h) with information provision and 55.3 km/h without information when road surface was dry. When road surface was wet, it was 51.2 km/h (the target speed: 50km/h) with information provision and 49.9 km/h without information.

Focusing on the change in the deceleration behavior during drying (Figure 6), the start point of deceleration behavior increased right after the information provision point by providing information. On the contrary, it decreased before and after the curve entrance. This result was the same trend when it was also wet. The improvement effect was appeared remarkable than FY2011.
4.5.2.2 Subjective evaluation results of drivers

32% of the drivers felt that they were "prepared to their best" about the preparation at the time of entering the curve without information provision, and increased to 84% when it provided. Furthermore, 20% of the drivers felt that "they were able to drive very safely" without information provision, and increased to 68% when it provided.

On the other hand, 26% felt troublesomeness by providing information. The reason was "because they already recognized the dangers of the Kumano-cho curve."

4.5.2.3 Occurrence of driver's dangerous behavior (Negative check)

There were not driver's dangerous behaviors such as sudden deceleration caused by information provision.

4.5.2.4 Impact assessment on surrounding vehicles

We confirmed the brake operation position of the surrounding vehicle group using the images taken from the roadside building overlooking the Kumano-cho curve when with information provision and without it. Because we guessed that they might be impacted by the test vehicles which received information. We defined surrounding vehicle group as following vehicles in the same lane of the test vehicle, or following vehicles which vehicle spacing time was within 5 second.

Figure 7 shows that the brake starting position of the vehicle group at the road surface drying shifts to the upstream side when there is information provision. Furthermore, the brake operation immediately before the curve entrance was decreased. In addition, no adverse effect such as sudden deceleration of surrounding vehicles has occurred.
4.5.3 Evaluation of each test drivers

Focusing on each 25 test driver, we analyzed the situation of spreading effects for surrounding vehicle group when test drivers perceived information, decided, and operated. The situations were defined at the following 5 levels. Occurrence situation of level 1 and level 2 was confirmed by the questionnaire survey, and level 3 was checked by the video camera which is able to record the brake operation. Level 4 was checked by the data of drive recorder, and level 5 was analyzed by the images taken from the roadside building.

Test drivers who recognized information (level 1) were 94%, and subjects who changed the psychological actions such as preparation for curves (level 2) were 81%. Drivers who caused a change to make a deceleration action early (Level 3) were 50%, and subjects who changed behavior of the vehicle such as an increase in deceleration level were 38%. Finally, test drivers who impacted braking operation earlier for surrounding vehicles (Level 5) were 19%.

4.5.4 Evaluation on changes in driving behavior

We analyzed specifically changes in driving behavior after information provision. Even in the PCERS, the drivers turned off the accelerator after recognized the information, operated the brake action, and the curve entry speed was slowed down (Figure 8). This result is the same trend as the situation of the driving operation after providing the forward obstacle information analyzed by the DS in Figure 2 above.

5 EVALUATION OF DSSS BY USER MONITORING SURVEY

In order to evaluate long-term DSSS, NILIM conducted the analysis of long-term monitoring survey from FY2011 to FY2014 for ETC2.0 OBU users. ETC2.0 OBU is provided information of 6 types about DSSS. These are congestion tail information, construction / regulation / obstacle information, accident frequent occurrence area information (sharp curves, continuous curves, frequent accident area such as downhill), weather information, image information (road surface condition information, etc.), and emergency information (earthquake of seismic intensity 5 or more, fire disaster, etc.). We analyze the change over time of the user monitoring evaluation about these DSSS.

5.1 Survey summary

NILIM has conducted continuously the questionnaire survey to evaluate effects of ETC2.0 service for nationwide users driving expressway from FY 2011. We lent the ETC2.0 OBUs for about 700 users, and have confirmed usage situation of it. Table 4 shows the summary of survey. Previous studies based on this survey show that the service was evaluated helpful highly by users. In this paper, we consider the tendency of subjective evaluation about information provision of accident frequent occurrence area for long-term users. It was based on the questionnaire survey result in FY 2014 which is the 4th year from the start of use.
Table 4: Summary of users’ survey

<table>
<thead>
<tr>
<th>Survey term</th>
<th>April in 2011 ~ March in 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire survey date / Number of responses</td>
<td>Number of responses: 504 (Survey target: 603, Response rate: 83.6%)</td>
</tr>
<tr>
<td>1) November in 2011 (Conducted September, also January the following year)</td>
<td>Number of responses: 467 (Survey target: 587, Response rate: 79.6%)</td>
</tr>
<tr>
<td>2) November in 2012</td>
<td>Number of responses: 419 (Survey target: 561, Response rate: 74.7%)</td>
</tr>
<tr>
<td>3) December in 2013</td>
<td>Number of responses: 344 (Survey target: 344, Response rate: 61.2%)</td>
</tr>
</tbody>
</table>

Content of the questionnaire
- Driving situation (driving record, driving cycle, cycle of using expressway)
- Recognizability, utilization experience, and helpful level of ETC2.0 service

5.2 Subjective evaluation results about DSSS
5.2.1 Recognizability and utilization experience of the service

Figure 9 shows that about 70% over of respondents recognize the service about congestion tail information, accident frequent occurrence area information and construction / regulation / obstacle information. About half of respondents have an experience with receiving information. There are few people with experience in using about weather information, image information (road surface condition information, etc.), and emergency information. Because these provision information area is limited and occurrence frequency is low.

5.2.2 Helpful level of the service

Next, Figure 10 shows the result of evaluating whether or not the users who received information felt helpful about this service. About 80% to 90% of responses say "It's very helpful" and "It's helpful" about each services excluding emergency information.

We defined the respondents of using expressway "almost every day" "2 to 3 times a week" "at least once a week" as high-frequency users, the respondents of using expressway "2 to 3 times per month" "1 times or less" as low-frequency users. Furthermore, Figure 11 shows that compared the trend of answers. As a result, there was no great difference between high-frequency users and low-frequency users. It was confirmed that high-frequency users who have relatively many experiences receiving the services even were helpful.

Figure 12 shows the reasons why the service was helpful about congestion tail information, accident frequent occurrence area information, and construction / regulation / obstacle information by users who have utilization experience. A high percentage of the three services are shown as answering that "safety driving was possible by knowing information in advance".

![Figure 9 Recognizability and usage experience of the service](image-url)
Congestion tail information (N=160)

Accident frequent occurrence area information (N=147)

Construction / regulation / obstacle information (N=156)

Weather information (N=69)

Image information (N=38)

Emergency information (N=17)

Figure 10 Helpful level of the service

Figure 11 Helpful level of the service (By frequency of expressway use)

Figure 12 Reasons why the service was helpful (Multiple answers)
5.2.3 Behavior change by the service

Figure 13 shows that about 90% of users answered "taken the actions to drive safely" in receive to the information. Therefore, it shows that the information contributes to raising motivation of safety driving.

![Behavior change by getting information](image)

6 CONCLUSIONS

As an evaluation of the ETC2.0 DSSS, we focused on PFOIS and PCERS on the Metropolitan Expressway. In addition, we reviewed analysis so far, and conducted evaluation of long-term effect with a new investigation.

As a result, PFOIS provides information that the driver feels the danger level strongly, so clear effects have appeared at each stage of information recognition, judgment and operation. In addition, effects such as decrease in sudden deceleration and approach speed, reduction in accidents, etc. were shown, and the situation was confirmed in which the driver felt usefulness.

On the other hand, PCERS is a service in which direct dangers are hard to convey to drivers, and the rate of deceleration did not change so much in the experiments of FY2011 and FY2014. However, from the driver's behavior and questionnaire survey, we confirmed that the driver was able to prepare for the curve after recognizing the information, and the deceleration behavior will be accelerated.

Moreover, when comparing the DS experiment result of PFOIS and the Kumano-cho curve experiment result of PCERS, although installation locations and the support contents to the driver are different services, it was confirmed that the driver perceived the information after providing the information from RSU, and the driver perform the brake operation in response to the information. Therefore, it became clear that both services are effective countermeasures for causing driver's safety behavior.

From the above, the ETC2.0 DSSS can be expected to have a long-term effect. It is also considered to be an effective service that expected to deploy to the curve section where problems similar to the Sangu-bashi curve and the Kumano-cho curve. Furthermore, since ETC2.0 DSSS captures information in a range invisible to vehicle sensors via V2I communication, it is considered that enables to apply to cooperative automated driving expected to be realized in the future.

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