Field operational tests of Smartway in Japan

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A B S T R A C T

Efforts are underway in Japan to promote “Smartway” next-generation roadways, which provide a variety of services through the use of advanced ITS technologies. In recent years, the National Institute for Land and Infrastructure Management (NILIM), part of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), has conducted public–private joint research on next-generation road services using ITS technologies. Field operational tests (FOTs) of services including forward obstacle information provision and merging assistance using 5.8 GHz dedicated short range communication (DSRC) were conducted on the Tokyo Metropolitan Expressway through FY2007. In FY2008–2009, FOTs were conducted in three major metropolitan areas—Tokyo, Nagoya, and Kii Hanshin (Kyoto, Osaka, and Kobe)—to promote future deployment nationwide. These included tests of information provision services to alert drivers to forward obstacles hidden beyond the crest of an incline and prevent excessive speed on sharp curves. This paper presents an overview of these FOTs conducted by NILIM in recent years and their results.

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1. Introduction

In Japan, traffic accidents caused 4914 fatalities in 2009, and have been decreasing from year to year. The number of total accidents and injuries, however, remains high, at about 740,000 accidents and 910,000 injuries. Reducing the number of accidents, therefore, remains an urgent issue. The adoption of intelligent transport systems (ITS) offers one effective solution for improving safety.

Most conventional traffic accident countermeasures can be categorized as one of three types: advance measures such as road improvements and traffic safety education; measures that have an effect during or immediately after accidents such as legal requirements for fastening seat belts or installing airbags; and measures after the fact such as improving emergency information and improving emergency medical treatment. However, countermeasures targeting the moments immediately prior to accidents have not been fully applied until now.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has undertaken research and development of Advanced Cruise-assist Highway Systems (AHS) that use cooperative vehicle–infrastructure systems (5.8 GHz DSRC) to communicate in real-time between vehicles (on-board units) and roadside sensors or beacons. This paper outlines the field operational tests (FOTs) conducted by NILIM in recent years and briefly presents the results.

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2. Outline of FOTs

2.1. Outline of FOTs through FY2007

The following is an outline of FOTs conducted through FY2007. The tests were performed on the Metropolitan Expressway and covered “forward obstacle information provision” and “merging assistance” services.

The “forward obstacle information provision” service uses sensors installed on the roadside to detect stopped or slow-moving vehicles on sharp curves with poor visibility, then uses a road–vehicle communication system to relay this information to drivers [1]. The purpose of this service is to prevent sharp braking and rear-end collisions. This service can be classified into two types according to the method of detecting stopped or slow-moving vehicles. In the image processing sensor method shown in Fig. 1(a), stopped or slow-moving vehicles on the road ahead are detected using infrared or visible image processing sensors installed on the roadside. On the other hand, in the ETC-ID method shown in Fig. 1(b), stopped or slow-moving vehicles are detected by matching ETC-ID collected from DSRC beacons installed at the beginning and end of a given road section to identify vehicles that take a long time to pass through. This system has been installed at Sangubashi Curve, Shinjuku Curve, and Akasaka Tunnel. The “merging assistance” service shown in Fig. 2 uses sensors installed on the roadside at merging sections of expressways to detect merging vehicles, and provides information about the presence of merging vehicles to vehicles in the main lane [2]. This system has been installed at Tanimachi Junction and Higashi–Ikebukuro Ramp.

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2.2. Outline of FOTs in FY2008

Based on the results of FOTs up to FY2007, in FY2008 FOTs were conducted in the two metropolitan areas of Tokyo and Keihanshin (Kyoto, Osaka, and Kobe) as well as in as other areas to promote the deployment of Smartway nationwide.

2.2.1. FOTs in Tokyo [3]

The FOTs of the “forward obstacle information provision” service in Tokyo were conducted on the Rinkai–Fukutoshin off-ramp on the Tokyo Metropolitan Expressway’s Bay Shore Line and on a street at the end of the off-ramp. A crest vertical curve on the off-ramp approaching the intersection reduces the visibility of vehicles stopped at the intersection for a red light. Approaching vehicles, therefore, are at a high risk of rear-end collisions.

As shown in Fig. 3, an image sensor was installed near the intersection to observe stopped vehicles, and DSRC was installed at the beginning of the uphill incline to provide information to drivers.

When the image sensor detects a vehicle stopped at the intersection, the system provides information such as alarm sounds, voice warnings or simple images through on-board ITS units to alert approaching drivers of the forward vehicle. Two types of information are provided: “Watch for stopped traffic, be careful of rear-end collisions” if a stopped vehicle is waiting for a signal change, and “Intersection ahead” if there is no such vehicle.

Fig. 4 presents a comparison of approach speed with and without the service at the point where drivers are able to see forward stopped vehicles for the first time. Approach speed decreases markedly in cases where the service is provided.

2.2.2. FOTs in the Keihanshin Area [4]

The Keihanshin area FOTs of the “forward obstacle information provision” service were conducted on the No. 14 Matsubara Line’s Miyake Curve. This sharp curve with radius of 160 m is a frequent site of wall collisions due to excess speed. To prevent such accidents, existing technologies were used to implement a service that not only

![Diagram of Forward Obstacle Information Provision](image-url)
provides drivers with information about forward road congestion but also alerts drivers when they exceed a safe speed. Information is provided to drivers in two steps. First, information is provided to vehicles when their speed exceeds a predetermined safe speed. Second, information is provided if the vehicle maintains high speed even after receiving the first information. This service applied the ETC-ID method to measure the speed of moving vehicles as shown in Fig. 5. The threshold value for providing information varied with pavement conditions (wet or dry), making it possible to provide more effective and less confusing information to drivers.

Fig. 6 presents the observed cumulative distribution for estimated vehicle arrival time at the starting point of the curve from the moment of first deceleration. The estimated arrival time is calculated by dividing the distance between the point where the vehicle began to decelerate and the start of the curve by the speed of the vehicle when it began to decelerate. Longer estimated arrival times mean that the vehicle's approach speed was low or that the vehicle began to decelerate earlier. As shown in Fig. 6, almost all of the cumulative curves for the with-service cases are located on the right side, indicating that drivers tended to decelerate earlier than in the without-service case.

2.3. Outline of FOTs in FY2009

The 2009 FOTs were conducted at three locations: one in the Keihanshin Area and two in the Nagoya Area. Services provided in these FOTs were customized for each area in accordance with road structure, traffic conditions, and accident occurrence.
2.3.1. FOTs in the Keihanshin Area

The Keihanshin area FOTs were conducted near the Yanagihara interchange on the Hanshin Expressway’s No. 3 Kobe Line (inbound), where many accidents occur due to multiple factors such as the series of curves beyond the interchange and merging vehicles from the Yanagihara on-ramp.

Tests of two services were conducted. The first is “forward obstacle information provision,” which provides information to drivers about forward obstacles and congestion beyond curves. The second is “merging assistance,” which provides vehicles in the main lane with information on the existence of merging vehicles from the Yanagihara on-ramp. While merging assistance was also tested in 2007, this FOT was different in that the merging lane was located to the right of the Yanagihara on-ramp.

DSRC antennas and variable message signs (VMS) were installed on the roadside before the merging section of the Yanagihara on-ramp. Image sensors were used to detect vehicles stopped due to congestion and vehicle sensors were used to detect merging vehicles. The system alerted drivers of vehicles that were equipped with on-board ITS units using warning sounds, images, or voice messages transmitted through a road–vehicle communication system from the DSRC antennas to the on-board ITS units. In addition, a VMS board was used to provide information to drivers of vehicles without on-board ITS units.

2.3.2. FOTs in the Nagoya Area

Nagoya area FOTs were conducted at two locations: the Meido-cho Junction on No. 6 Kiyosu Line and the Higashikataha–Minami Curve on the Inner Circular Route of the Nagoya Expressway.

The Meido-cho Junction has a sharp curve with radius of 90 m. This creates a serious risk of wall collisions by vehicles entering the curve at high speed and, due to poor visibility, rear-end collisions with vehicles at the tail end of congestion beyond the curve. In order to alleviate congestion and prevent collisions at the junction, two DSRC antennas were installed before the curve to provide information through a road–vehicle communication system. The first was installed about 1 km before the curve to provide information on forward congestion. Since there is an off-ramp about 300 m before the curve, drivers can select whether to continue on or leave the expressway to avoid the congestion. The second one was installed about 300 m before the curve to inform drivers of rear-end collision risk at the tail end of congestion by alerting them if there was congestion ahead. In addition, it also warned drivers moving at high speed to slow down even if there was no congestion. This information was provided through on-board ITS units using warning sounds, visual information, or voice messages.

In the Higashikataha–Minami Curve section, a VMS already in place before the curve provided information on congestion ahead using ultrasonic vehicle detectors. At the same location, a DSRC antenna was installed to more effectively provide more advanced information to drivers of vehicles equipped with on-board ITS units, notifying them of the risk of rear-end collision or slippage given traffic condition and road surface conditions as detected by existing sensors.

3. Summary

This paper presented an outline of field operational tests conducted from 2007 to 2009, as well as some of the test results. In the future, we will confirm the effectiveness of information provision and confirm that it does not cause negative driver reactions such as sudden deceleration or abrupt steering, and try to deploy Smartway as a fully operational system.

References