

Introduction of Honda Driving Support System – Field Operation Test (FOT) with Road Infrastructure Systems (Driving Safety Support System: DSSS) –

Yuriko INO* Tomo FUJIMAKI* Nobuyoshi ASANUMA*

ABSTRACT

Honda has been taking part in the Driving Safety Support System (DSSS) of the Universal Traffic Management Society of Japan (UTMS Society). Based on an analysis of traffic collisions, Honda has engaged in the two issues below by developing an operation test vehicle and promoting research.

- Dealing with conditions where the counterpart vehicle is not readily visible (due to structures, trucks, buses, or other such shielding obstructions)
- Dealing with motorcycles as vulnerable parties in traffic

The research has involved the application of road infrastructure technology (use of information from sensors installed at the roadside) and effect verification on public roadways. The results indicate that this approach can be expected to effectively reduce collisions.

1. Introduction

The traffic collision situation in Japan continues to be treated as a major issue for society. It was in this context that the government announced the “New IT Reform Strategy” in January 2006 that called for traffic collision deaths to be reduced to 5000 or fewer by the end of 2012, with the goal of making Japan’s road traffic the safest in the world. Under such premise, the ministries and agencies concerned have collaborated with private sector enterprises on a Driving Safety Support System that makes use of IT. This system is to be constructed, subjected to operation tests and effect verification, and evaluated quantitatively for its contribution to collision reduction. Under the supervision of the National Police Agency, the UTMS Society has promoted research on the Driving Safety Support System incorporating road-to-vehicle communications technology. Field operation tests have been conducted in four prefectures (Tochigi, Aichi, Kanagawa, and Hiroshima)^{(1), (2)}.

Honda conducted field operation tests (FOT) in Utsunomiya City, Tochigi Prefecture, in FY2007. These were particularly concerned with formulating system specifications to enhance the visibility of motorcycles.

Honda’s research sought to make the system compatible with actual vehicles, and aimed for practical application.

This paper will introduce background information on the traffic collision situation and describe the system configuration and road-to-vehicle communication technology. It will also describe the public demonstration that was conducted and the course of evaluation of the system’s effectiveness in traffic collision reduction.

Joint field test is planned to take place in Tokyo in FY2008, under the auspices of the Cabinet Secretariat. This operation testing is slated to take place with the collaboration of the National Police Agency, the Ministry of Internal Affairs and Communications, the Ministry of Economy, Trade and Industry, the Ministry of Land, Infrastructure and Transport, and private enterprise.

2. Background

As indicated by the composition of traffic collisions by type based on traffic collision statistics (ITARDA)(Fig. 1), the greatest number of fatal collisions between vehicles occur as crossing incidents, at 17%, while rear-end incidents are the type with the greatest number of collisions resulting in either injury or death, at 32%. Left-

* Automobile R&D Center

turn collisions, right-turn and straight collisions (incidents involving a vehicle making a right turn and a vehicle proceeding straight), and other such intersection system collisions are also numerous. Figure 2 shows the composition of traffic collisions between passenger cars and collisions in which the damaged party is a motorcycle. The most numerous type in both fatal collisions and collisions resulting in injury or death is the crossing collision. This type, together with the left-turn, right-turn collisions, makes up 60% or more of the total. Figure 3 shows the human factors involved in right-turn collisions by counterpart vehicle. In collisions where the counterpart vehicle is a motorcycle, the human factors of “no confirmation of safety” and “less confirmation of safety”

were found to account for 80% of the total. In other words, delay in recognition by the drivers of passenger cars was the main causal factor. It can be inferred that the motorcycle riders on the damaged side also showed some “inadequacy of prediction” or other mistakes in judgment.

It can be inferred from collision background of this kind that providing each of the two sides, both passenger cars and motorcycles, with information about the presence of the other could inhibit the occurrence of delays in recognition. This appears likely to help prevent such collisions before they can happen.

The delay in recognition on the part of the passenger car drivers that is a cause of these collisions may occur

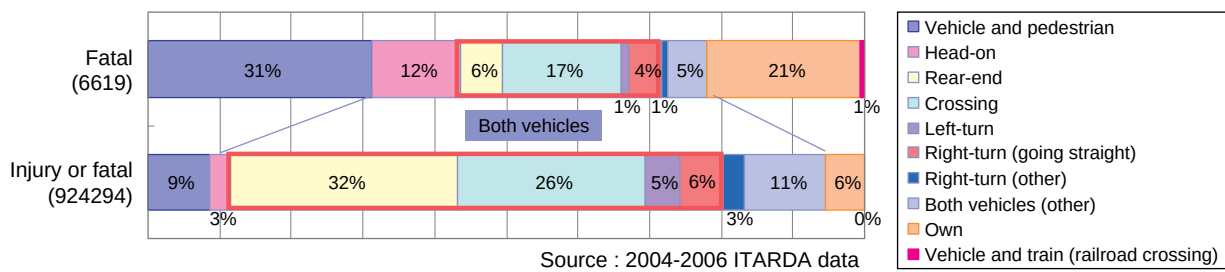


Fig. 1 Traffic collision occurrence rate classified by collision type

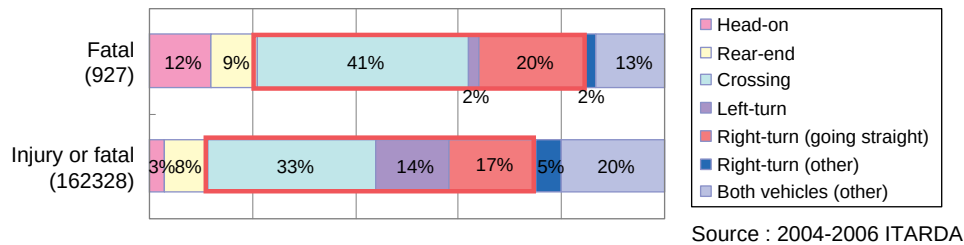


Fig. 2 Traffic collision occurrence rate classified by collision type (vehicle and motorcycle)

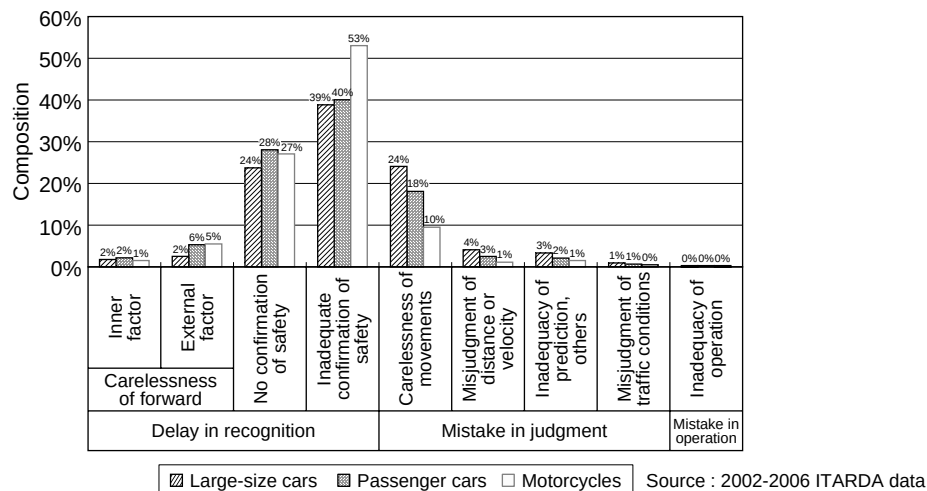


Fig. 3 Human factors in right-turn collision

because of the factors below⁽³⁾.

- (1) The motorcycle profile is so small that the driver misjudges the distance from the motorcycle and the vehicles' approach velocity.
- (2) The motorcycle profile is so small that it is buried among surrounding vehicles and background, and the driver overlooks it.

Implementation of measures that address these causal factors can be expected to enable detection of motorcycles so that fewer misjudgments of vehicle distances and approach velocity are likely to occur.

The Honda DSSS was formulated in light of the above collision background information, allowing it to differentiate the system from the DSSSs in other regions. Honda accordingly implemented a rear-end collision avoidance system as well as left-turn and right-turn collision avoidance systems that provide information about the presence of approaching motorcycles.

3. System Construction

A road-to-vehicle communication system that coordinates the use of infrared beacons and dedicated short range communication (DSRC) was built.

3.1. Road-to-Vehicle Communication System

Figure 4 shows a diagram of the system configuration. Figure 5 shows the FOT vehicles.

3.1.1. Roadside processing

An imaging sensor is used to detect the presence of vehicles in the coverage area. Motorcycles and passenger

cars are differentiated, and that information is transmitted to the DSSS central unit, together with position and vehicle velocity information. The vehicle information is passed through the DSSS central unit and transmitted from the DSRC roadside unit to vehicle DSRC antennas at 100 msec intervals. At the same time, information on the current status of traffic signals acquired in real time from the traffic signals is also transmitted.

The infrared beacon roadside unit is used to transmit relevant vehicle lane information to passing vehicles equipped with infrared beacon receivers.

3.1.2. On-board unit

The on-board unit receives the vehicle lane information sent from the infrared beacon roadside unit. Using that information, the on-board unit performs location position estimation. The information received from the DSRC roadside unit together with the vehicle's own status



Fig. 5 Honda DSSS FOT cars

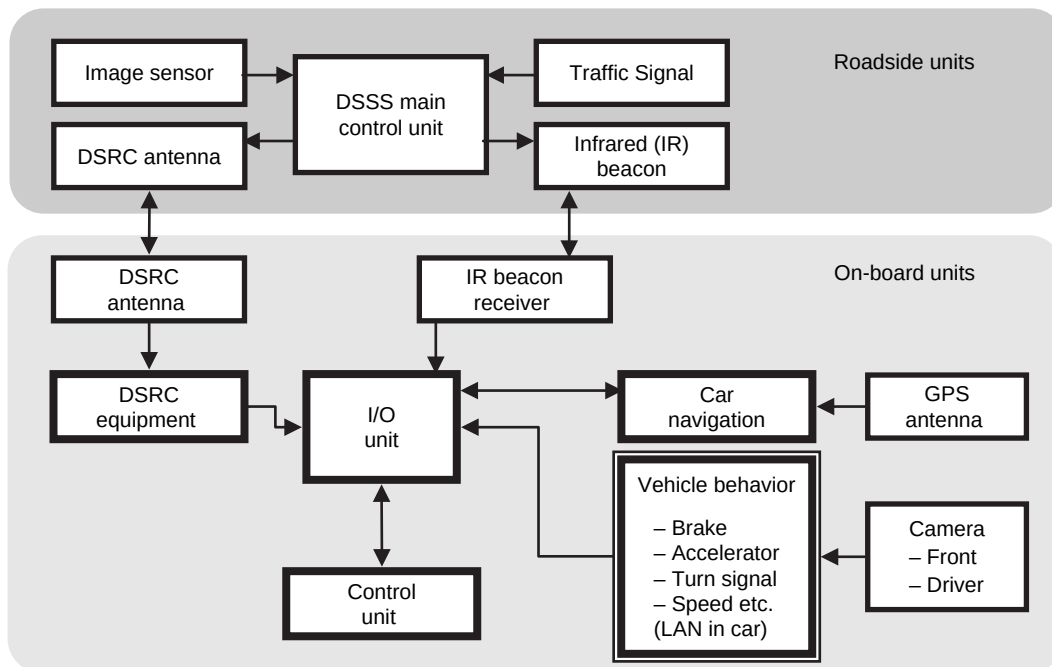


Fig. 4 System configuration

information is then used to judge the likelihood of a collision. The system provides the driver with information on the presence of a counterpart vehicle only when traffic signal current status information indicates a green light.

3.2. Equipment Specifications

Specifications of the equipment used in this system are as shown below.

(1) Infrared beacon

- Communication method: Near-infrared communication
- Wavelength: 850 ± 50 nm
- Transfer speed: Downlink 1024 kbps, uplink 64 kbps
- Communication range: Approximately 3.7 m longitudinally, 3.5 m laterally

(2) DSRC

- Carrier frequency: 5.8 GHz
- Transfer speed: 1024 kbps or 4096 kbps
- Modulation method: QPSK
- Communication cycle: 100 msec

For the imaging sensor, the system employs a sensor developed using spatio-temporal Markov Random Field (MRF) model technology⁽⁴⁾. A spatio-temporal MRF model enables stable, high precision tracking of a moving object to be conducted,

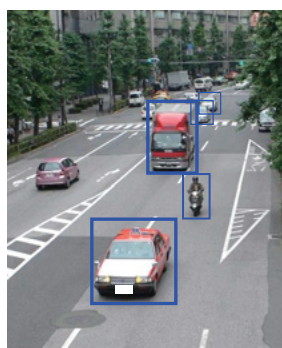


Fig. 6 Image of sensing by MRF model

independent of the type of object, its orientation, movement, or overlap (occlusion). It can also differentiate motorcycles from passenger cars. Figure 6 shows an image of sensing by this method. Rectangular frames indicate that a vehicle is recognized as individual.

3.3. Rear-end Collision Avoidance System

3.3.1. System overview

Figure 7 shows a rear-end collision avoidance system on a road with reduced visibility. The system uses infrastructure equipment to transmit information on the presence of low-speed vehicles and help prevent collisions.

Installation location: Crests and curved locations with reduced visibility

Goal: To help prevent traffic collisions caused by careless driving (compensate for deviations in recognition and judgment)

The rear-end collision avoidance system uses the imaging sensor installed on the roadside to detect the rear end of traffic congestion. Information on the presence or absence of traffic congestion is then transmitted through the DSSS central unit and the infrared beacon to the on-board unit. When the rear end of traffic congestion is present, the system cautions the driver by means of the car navigation display screen and voice announcements. The voice announcement alerts the driver with the words, "Traffic congestion ahead, watch out for rear-end collisions."

3.3.2. System installation conditions

Installation location L_1 (m) for the infrared beacon in the rear-end collision avoidance system is the road distance from the infrared beacon to the rear end of the traffic congestion. This is calculated by Eq. (1).

$$L_1 = V^2/2\alpha + (T_p + T_d) V \quad (1)$$

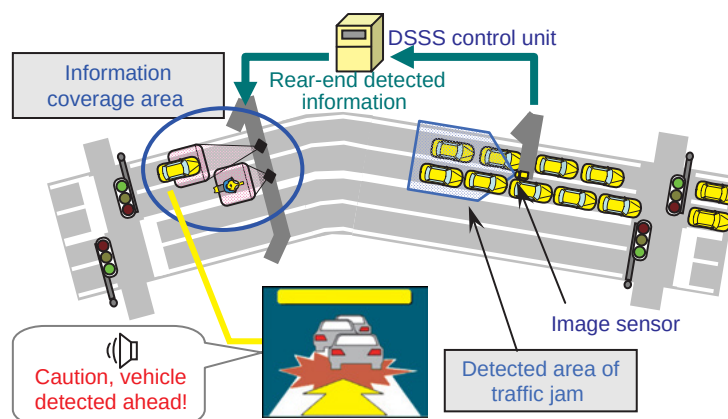


Fig. 7 Rear-end collision avoidance information service

The parameters shown below are preconditions for the function of this system.

- Vehicle velocity V : 13.9 m/s (50 km/h)
- Deceleration α : 0.3 G (G: Acceleration of gravity, 1.0 G=9.8 m/s²)
- Processing time for infrastructure equipment and on-board unit T_p : 2.0 sec
- Driver reaction time T_d : 2.0 sec

3.4. Left-turn Collision Avoidance System and Right-turn Collision Avoidance System

3.4.1. Overview of Left-turn Collision Avoidance System

Figure 8 shows a left-turn collision avoidance system in an intersection with a traffic signal. It helps prevent

collisions by transmitting vehicle information to vehicles making left turns where traffic coming from behind (blind spot) is difficult to see.

Installation location: Outside (roadside) lane at intersections where vehicles approaching from the rear are not readily visible

Goal: Help prevent driving collisions by providing blind spot information (compensate for presence of motorcycle)

Figure 9 shows the flow of logic in the left-turn collision avoidance system. An imaging sensor installed roadside detects a motorcycle approaching from behind, and information on the presence of the motorcycle is transmitted to the on-board unit through the DSSS central

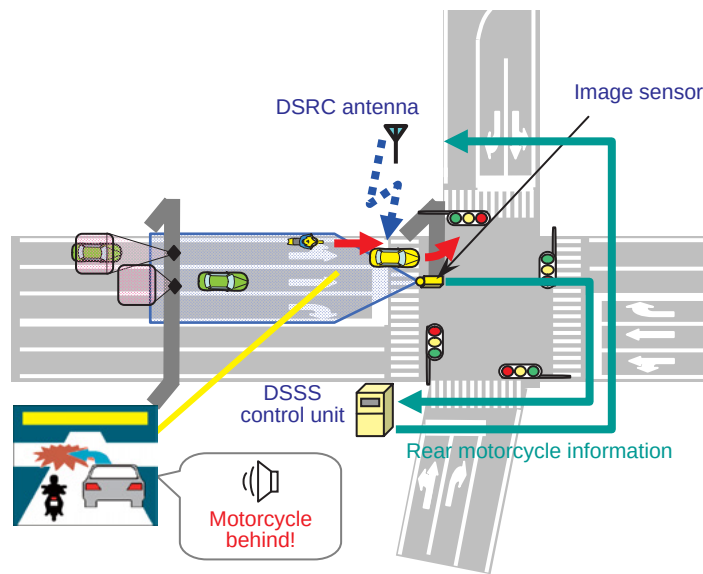


Fig. 8 Left-turn collision avoidance information service

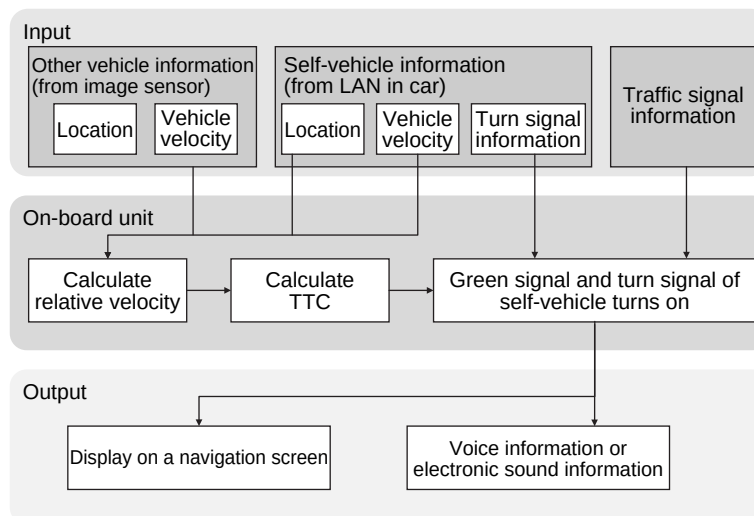


Fig. 9 Algorithm for determination (left-turn and right-turn collision)

unit and DSRC. Vehicle lane information is sent by the infrared beacon and used for location position estimation. The on-board unit computes the time to collision (TTC) using the transmitted information on the counterpart vehicle, together with information on the vehicle's own position and velocity acquired from the on-board LAN. The system cautions the driver using the navigation display screen and voice announcements when traffic signal current status information indicates a green light and the vehicle's own left turn signal is activated. The voice announcement alerts the driver with the words, "There is a motorcycle. Watch out when making a left turn."

3.4.2. Overview of right-turn collision avoidance system

Figure 10 shows the right-turn collision avoidance system in an intersection with a traffic signal. It helps prevent collisions by transmitting information to vehicles making right turns about oncoming vehicles in difficult to see locations.

Installation location: Right-turn lanes in intersections where oncoming vehicles proceeding straight are not readily visible

Goal: Help prevent driving collisions resulting from miscalculation (compensate for misperception of motorcycle velocity and distance)

The same road processing as the left-turn collision avoidance system (3.4.1.) is performed in the right-turn collision avoidance system (Fig. 9). The on-board unit computes the TTC using the transmitted information on the counterpart vehicle, together with information on the vehicle's own position and velocity acquired from the on-board LAN. The system cautions the driver using the navigation display screen, an electronic tone, and voice

announcements when traffic signal current status information indicates a green light and the vehicle's own right turn signal is activated. When the oncoming vehicle is a passenger car, the system uses a combination of the navigation display screen and an electronic beep tone to alert the driver. When the counterpart vehicle is a motorcycle, the system prompts for additional caution using a combination of the navigation display screen and the voice announcement, "Watch out for the oncoming vehicle."

3.4.3. System installation conditions

Installation location L_2 (m) for the infrared beacon in the left-turn collision avoidance system is the road distance from the infrared beacon to the location where collision involvement is predicted. Installation location L_3 (m) for the infrared beacon in the right-turn collision avoidance system is the road distance from the infrared beacon to the center of the intersection (right turn wait line). Both L_2 and L_3 are calculated by Eq. (2).

$$L_2, L_3 = V^2/2\alpha + ((T_p + T_d) + V_i/\alpha - V/\alpha) V \quad (2)$$

The parameters shown below are preconditions for the function of this system.

- Vehicle velocity V : 11.1 m/s (40 km/h) in left turns, 13.9 m/s (50 km/h) in right turns
- Vehicle velocity allowing left turn or right turn V_i : 8.3 m/s (30 km/h) in left turns, 5.6 m/s (20 km/h) in right turns
- Deceleration α : 0.3 G
- Processing time for infrastructure equipment and on-board unit T_p : 2.0 sec
- Driver reaction time T_d : 2.0 sec

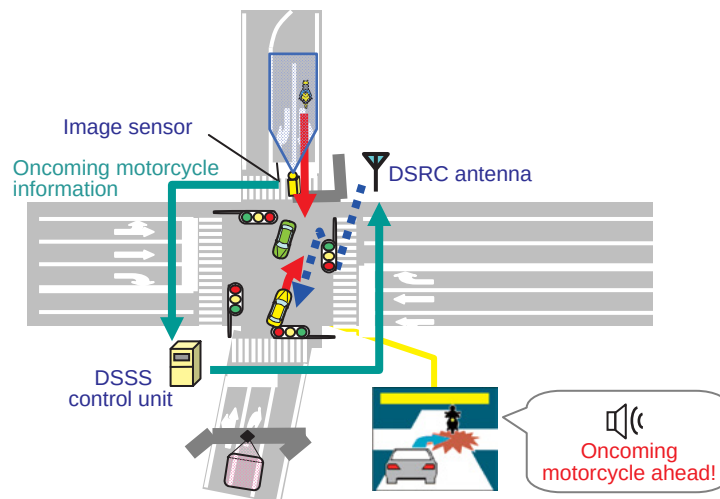


Fig. 10 Right-turn collision avoidance information service

4. Field Operation Test

4.1. Overview

Honda commenced field operation tests in September 2007, and held a public demonstration in November 2007. In addition, system effectiveness in collision reduction will be evaluated by the end of 2008.

4.1.1. Public demonstration

The participating companies jointly held a public demonstration of the Honda DSSS using road-to-vehicle communication on public roads in Utsunomiya City, Tochigi Prefecture from November 5th to 7th. The public demonstration covered the rear-end, left-turn and right-turn collision avoidance systems (Fig. 11). Dedicated on-board units were installed on FOT vehicles, and people were allowed to take test rides to experience the system. An exhibition of equipment, panel displays explaining the system, a driving simulator, and other displays were also held in conjunction with the demonstration (Fig. 12).

The event had a total of 278 visitors over a three-day period. Practically all of the visitors were able to experience a test drive.

4.1.2. Criteria for evaluation of effectiveness

It was decided to evaluate through the FOT the effect



Fig. 11 Situation of right-turn collision avoidance information service



Fig. 12 Exhibition site

of caution by the system on driver awareness, collision avoidance operation, or other driving behavior. For the left-turn collision avoidance system, the evaluation considered the effect on detection of a motorcycle approaching from the rear, and on involvement avoidance behavior. For the right-turn collision avoidance system, it considered the effect on detection of an oncoming vehicle and on collision avoidance behavior. For the rear-end collision avoidance system, it considered the effect on detection of traffic congestion ahead, and on deceleration behavior.

In order to evaluate effectiveness with regard to these various types of driving behavior, discernible indicators in each driving behavior are determined. Then the resulting effects on the indicator in cases when the system provided caution and cases when it did not are compared and verified.

Examples of indicators are shown below.

- The location where brakes or accelerator pedal (accelerator pedal release) are operated with respect to the objective position⁽⁵⁾
- Vehicle velocity change
- Differential time in right and left turns

Figure 13 shows the vehicle velocity change that takes place with left-turn collision avoidance. As a result of caution by the system for approaching motorcycle from behind, collision avoidance behavior such as deceleration occurs earlier. This indicates that an extra margin of time is available in the collision avoidance operation.

For the present testing, an evaluation was made using three FOT vehicles and six test subjects before going on to full-scale operation. The following section introduces the left-turn collision system using an example of results from previous verification testing.

4.2. Field Operation Test Results

4.2.1. Evaluations of the test drive

A questionnaire survey concerning the test ride experience was administered over the three-day period and 258 responses (approximately 93% of the total number of

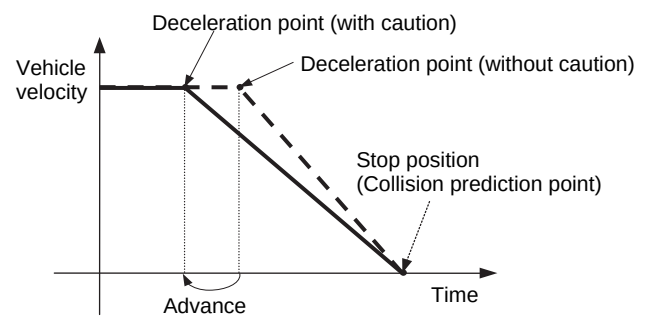


Fig. 13 Vehicle velocity change (left-turn collision avoidance system)

event visitors) were obtained. Figure 14 shows that the number of respondents who said they understood the left-turn collision avoidance system “well” or “somewhat” amounted to 100%. This indicates that even ordinary members of the public, without any prior knowledge of the system, were able to gain some understanding of it. About the necessity for a left-turn collision avoidance system, respondents who found that a system is “needed” or “needed depending on location” amounted to 99% of the total. Similar results were obtained regarding rear-end collision prevention and the right-turn collision avoidance system. Responses to the exhibition content were also favorable.

The above results show that the systems were viewed positively, not only by the people concerned but also by members of the public at large. The findings also confirm that there are people who look forward to widespread use of such systems in the future. These results provided data points that will be considered during future work to optimize the systems.

4.2.2. Left-turn collision avoidance system

(1) Conceptual approach of evaluation of system effectiveness

The intersection where testing of the left-turn collision avoidance system took place has large numbers of motorcycles passing through during the morning commuter period. Drivers who make left turns at the intersection must always watch out for the movement of motorcycles approaching from behind and motorcycles traveling to their left. If drivers delay in noticing a motorcycle approaching from behind them because of inadequate confirmation of safety or inattention, then they may involve the motorcycle in a collision during their left turn. Alternatively, they may experience a close call, for example if they notice the motorcycle just before their left turn and abruptly stop the turn.

Under these kinds of circumstances, drivers are likely to notice motorcycles sooner if they are informed in advance that a motorcycle is present before they make their left turn. Then they will have a greater margin of time for their involvement avoidance operation.

(2) Evaluation items

The driving actions taken by drivers making left turns at this intersection are assumed to be as in the following.

- Drivers decelerate to the target vehicle velocity before starting their left turn. At the left turn start location they conduct a steering operation and make their left turn.

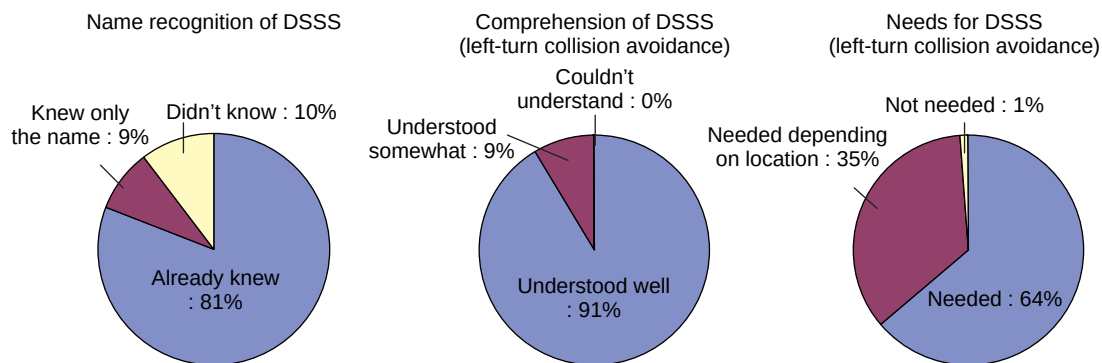


Fig. 14 Questionnaire results

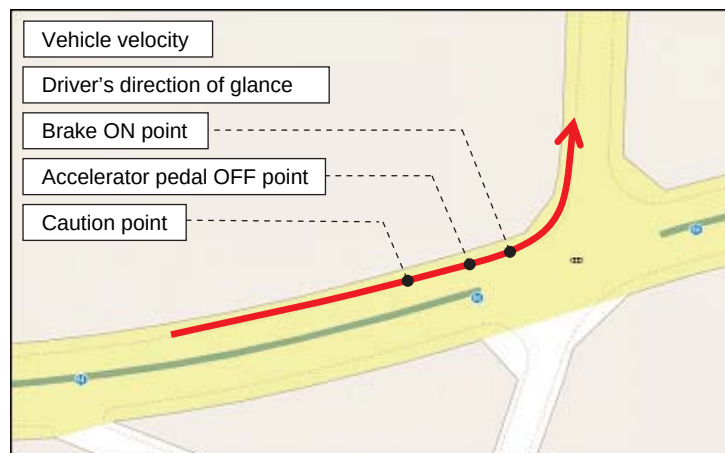


Fig. 15 Evaluation items (left-turn collision)

- When there is a motorcycle approaching from behind, they closely observe its movement up to the point where they begin their left turn, to determine whether safety is maintained.
- When drivers determine that a motorcycle will be passing on their left, they engage in involvement avoidance operation. In other words, they decelerate to a vehicle velocity that will enable them to stop before their left turn start location (the location where collision involvement is predicted).

The evaluation items are vehicle velocity, driver's direction of glance, caution point, brake ON point, and accelerator pedal OFF point (Fig. 15). Verification is

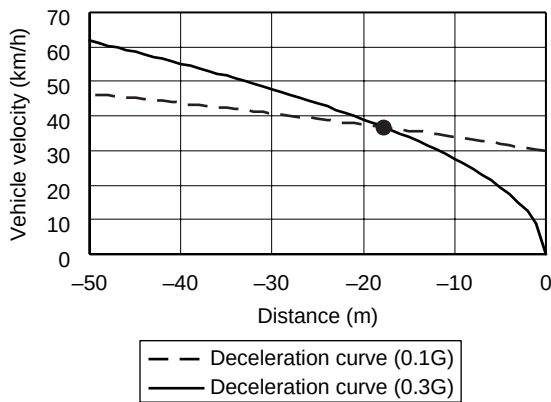


Fig. 16 Deceleration curve (0.1 G, 0.3 G)

made of the system's effects on driving actions.

The following standards were determined for evaluation of driving action: the standard vehicle velocity for starting a left turn at the intersection to be 30 km/h, the deceleration to the standard vehicle velocity due to release of the accelerator pedal to be 0.1 G, and the deceleration due to braking to be 0.3 G. Those deceleration curves (standard velocity curves), which plot velocity versus distance to starting point of each left turn, are shown in Fig. 16.

Distance and velocity at accelerator pedal OFF point were compared to 0.1-G standard velocity curve in order to evaluate the timing of accelerator pedal OFF point. If the accelerator pedal release data are plotted under the standard velocity curve, this would indicate that release of the accelerator pedal occurs earlier. Conversely, if the data are plotted above, this would indicate a delay.

Furthermore, vehicle velocity at the distance before beginning the left turn was compared to 0.3-G standard velocity curve in order to evaluate whether involvement avoidance operation occurred in time. If the vehicle velocity data are plotted below the 0.3-G deceleration curve, this would indicate that the involvement avoidance operation occurs with a margin of time. If the data are plotted above the curve, this would mean that the avoidance takes place with no extra margin of time. The intersection of the two deceleration curves signifies the cutoff point of distance and velocity for quitting the left

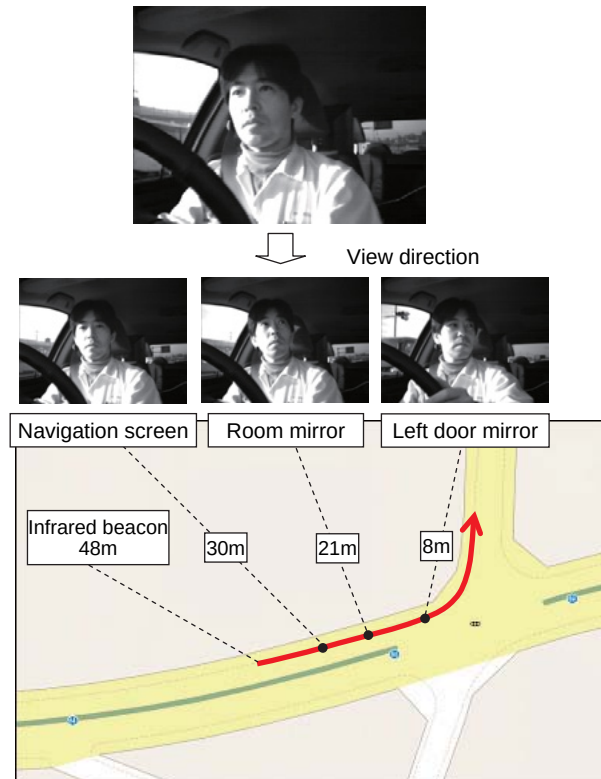
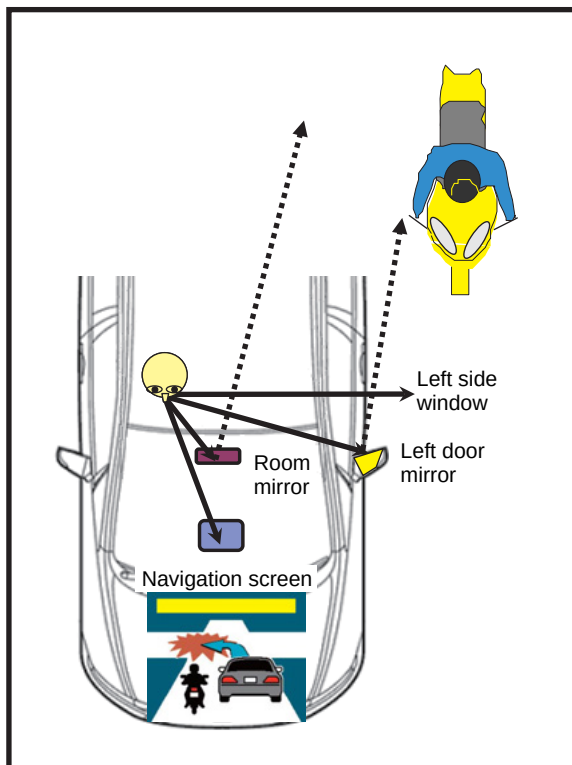


Fig. 17 Analysis of driver's view direction

turn and switching over to involvement avoidance operation. The standard distance for starting avoidance operation was determined to be -18 m, and the standard velocity to be 37 km/h. In this experiment, measured velocities were compared to the standard velocity at the standard distance for starting point of avoidance operation, in order to determine whether involvement avoidance operation is performed in time.

Actions taken to confirm safety with regard to a motorcycle approaching from behind can be determined from the direction in which the driver is looking. For example, when the driver looks in the direction of the room mirror or the left door mirror, this would mean that the driver is exercising caution with regard to a

motorcycle approaching from behind, and is closely observing the motorcycle's movement (Fig. 17).

(3) Test results

The test subject results on the test course are as indicated below.

Figure 18(a) shows the OFF point at which the accelerator pedal is released when there is a motorcycle approaching from behind before beginning the left turn. This plots the measured data when the accelerator pedal is released for the two cases in which system caution is and is not provided. The solid line in this graph indicates the standard velocity curve in 0.1-G.

Figure 18(b) shows accumulated components of distance difference between the standard velocity curve

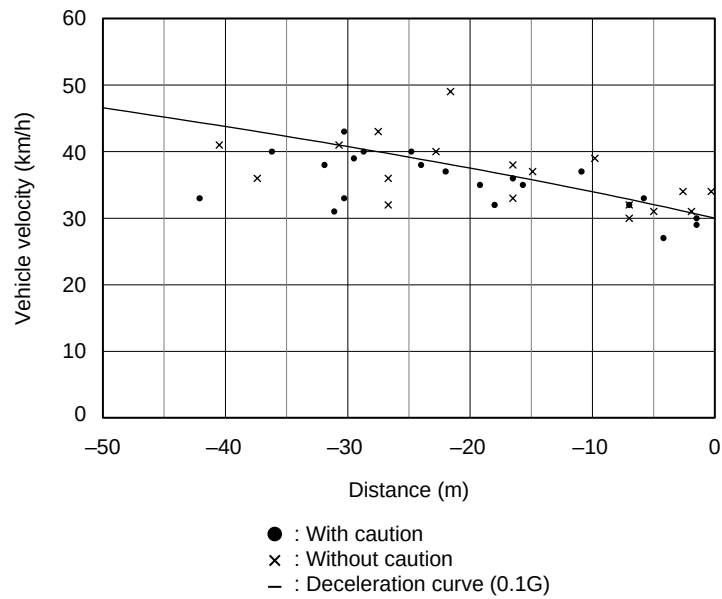


Fig. 18 (a) Accelerator pedal OFF point

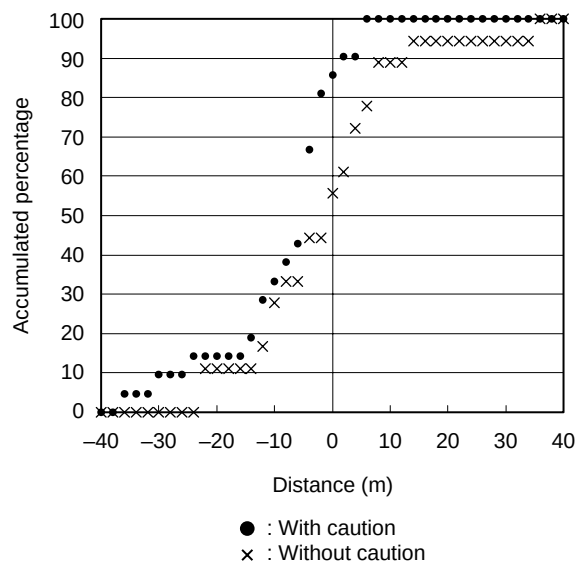


Fig. 18 (b) Accumulated percentage of accelerator pedal OFF point

and the OFF point at which the accelerator pedal is released. The distance on the standard velocity curve was set as a standard (0 m). If the distance difference on the lateral axis is negative, this would indicate that the timing of accelerator pedal OFF is earlier than the standard, and if positive, this would indicate the timing is later.

This graph indicates that the timing for accelerator pedal release when no caution is provided is earlier than the standard timing in less than 60% of cases. When caution is provided, however, accelerator pedal release comes earlier than the standard timing in more than 80% of cases. This shows that the caution provided by the system tends to make deceleration behavior occur earlier.

Figure 19 shows accumulated components of velocity difference from the standard velocity (37 km/h) at the

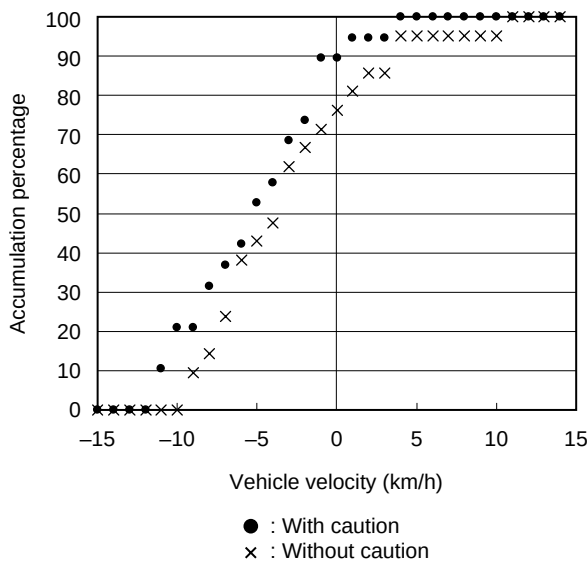


Fig. 19 Distribution of speed

standard distance for starting avoidance operation (18 m before beginning the left turn). If the velocity difference on the lateral axis is negative, this would indicate that the velocity is lower than the standard, and if positive, this would indicate the velocity is higher.

This graph indicates that the velocity when no caution is provided is lower than the standard velocity in less than 80% of cases. When caution is provided, however, the rate of such cases increased to almost 90%. This shows that the vehicle velocity when caution is provided by the system is lower than when not provided.

Figure 20 is a graph showing the distribution of the driver's direction of view before beginning the left turn. It indicates the number of times the driver checks for safety with respect to a motorcycle to the rear by looking at the room mirror or left door mirror. When system caution is not provided, the driver will look next at the room mirror and left door mirror an increasing number of times at a point about 15-25 m before beginning the left turn. When system caution is provided, the driver is looking at the car navigation screen after system caution at a point about 20-50 m before beginning the left turn, checking the caution displayed on the screen. An increasing number of times, the driver will look next at the room mirror and left door mirror at a point about 25-40 m before beginning the left turn.

This shows that the driver starts checking for safety with respect to a motorcycle to the rear by looking at the room mirror or left door mirror at an earlier point, when system caution is provided.

The above results confirm that the left-turn collision avoidance system has the effect of prompting drivers to check for safety with regard to a motorcycle approaching from behind, may cause deceleration behavior to occur earlier, and increases the margin of time available for involvement in avoidance operation.

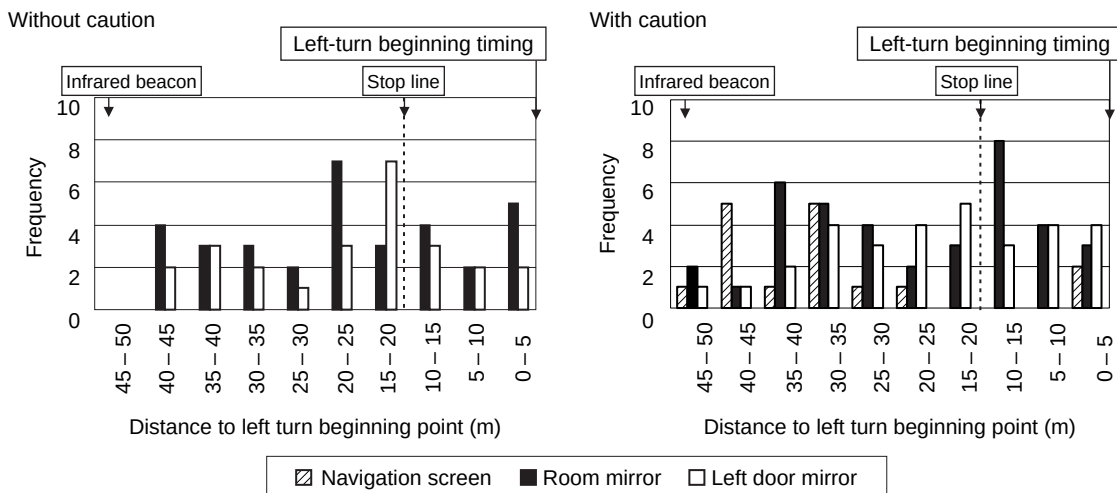


Fig. 20 Distribution of driver's direction of view

5. Conclusions

The results from Honda DSSS field operation tests are as follows.

- (1) Systems for rear-end, left-turn and right-turn collision avoidance were built on the basis of collision analysis results.
- (2) These driving support systems were provided by the coordination of continuous communications through infrared beacons and DSRC.
- (3) Test subject verification was performed under complex traffic conditions of public roads.
- (4) System effectiveness was verified by the verification.

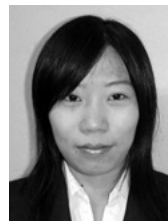
It was determined from the above results that the systems could be expected to be effective in traffic collision reduction.

In this paper, the results from previous verification tests were introduced for the left-turn collision avoidance system. For the future, testing of commuter vehicles will be conducted over the long term, and system effectiveness will be confirmed, including the rear-end and right-turn collision avoidance systems.

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■ Author ■



Yuriko INO



Tomo FUJIMAKI



Nobuyoshi ASANUMA