

Introduction of the Honda ASV-2, an Advanced Cruise-assist Highway System Test Vehicle (Passenger car)

Hiroshi MASHIMO* Yoshimi FURUKAWA* Nobuyoshi ASANUMA*
Tomoyuki FUKUMARU* Hideki KASEYAMA*

ABSTRACT

The Advanced Safety Vehicle phase 2 (ASV-2) proposed by the Road Transport Bureau, Ministry of Land, Infrastructure and Transport (formerly the Ministry of Transport) includes driver assistance services composed of 7 services or 8 systems that coordinate between the vehicle and the road infrastructure. The authors participated in proving tests that evaluated the basic functions of these driver assistance services. The following results were obtained:

- With respect to the “validity of road infrastructure functions,” the services were verified to be effective in response to driver assistance conditions.
- With respect to “driver acceptance,” we had braking driver assistance tests with haptic warning by brake actuation, and it was verified to be effective in reducing driver’s emergency response time.

1. Introduction

The Advanced Safety Vehicle phase 2 (ASV^{*1-2}) development program was proposed by the Road Transport Bureau, Ministry of Land, Infrastructure and Transportation (formerly the Ministry of Transportation). It was implemented as a 5-year project beginning in fiscal 1996 with the participation of 13 domestic Japanese automobile manufacturers.⁽¹⁾

During this same period, the Road Bureau, Ministry of Land, Infrastructure and Transportation (formerly the Ministry of Construction) proposed the Advanced Cruise-assist Highway System (AHS^{*2}) and established the Advanced Cruise-Assist Highway System Research Association (AHSRA) to develop systems that coordinate between the vehicle and the infrastructure. As part of this effort, studies⁽²⁾ were conducted on the principal user services with the goal of reducing the amount of human loss and the number of fatalities resulting from accidents by a cumulative 90% or more.

In 2000, the National Institute for Land and Infrastructure Management (formerly the Public Works Research Institute) conducted the ASV/AHS Joint Proving Tests to evaluate the basic functions of the Smart Cruise Systems. The purpose of these systems is to coordinate the ASV-2 vehicle and the road-infrastructure to help prevent traffic accidents and reduce damages that occur during accidents. The objective of the tests was to evaluate the validity of the infrastructure and also driver acceptance by evaluating the basic system functions.

The Smart Cruise Systems that function through the cooperation of the vehicle and the infrastructure are able to provide drivers with information that is difficult for an autonomous system to detect. This includes short-range information on intersections with complex shapes, environments affected by dead angles, and so on, and long-range information on slippery road surface conditions due to snow and ice. It is therefore expected that these systems will reduce the impact of accidents that occur because of a lack of such information.

*Tochigi R&D Center

- *1 ASV: Advanced Safety Vehicle promoted by the Road Transport Bureau, Ministry of Land, Infrastructure and Transportation
- *2 AHS: Advanced Cruise-assist Highway System under the jurisdiction of the Road Bureau, Ministry of Land, Infrastructure and Transportation

Table 1 Services of joint proving test

No.	Service System	Participation
1	Forward Obstacle Collision Prevention Support System	Yes
2	Curve Overshooting Prevention Support System	No
3	Lane Departure Prevention Support System	No
4-1	Intersection Stopping Support System	Yes
4-2	Crossing Collision Prevention Advisory System	Yes
5	Right Turn Collision Prevention Advisory System	Yes
6	Crossing Pedestrian Collision Prevention Advisory System	Yes
7	Road Surface Information System for ACC etc.	No



Fig. 1 Honda ASV/AHS

2. Overview of Services

The proving tests were conducted on the 7 services and 8 systems intended to help prevent traffic accidents and reduce damages that occur during accidents. Of these, the tests for the services and systems that Honda participated in are shown in Table 1.

The proving tests for road-to-vehicle cooperation involved the following:

- The road-infrastructure detected obstacles (fallen cargo, vehicles, pedestrians) and road surface information (slipperiness due to rain, snow, etc.) in poor-visibility road environments where it is difficult for the vehicle's sensor to detect such information.
- That detected information was transmitted to the vehicle by road-to-vehicle communication and used for information, warnings to the driver, and vehicle control.

Fig. 1 shows the test vehicle built for this project.

2.1 Systems to Reduce Damage by Prompting the Vehicle to Stop

2.1.1 Forward obstacle collision prevention support system

Aim: The objective of this system is to reduce accidents involving collisions with obstacles on roads with poor forward visibility.

Function: The system receives information from the road-infrastructure about such obstacles as fallen cargo and

vehicles stopped due to traffic congestion in locations with poor forward visibility. The system calculates the distance from the subject car to the obstacle and when it judges that the driver maintains the velocity which may result in a collision, it provides the driver with voice guidance and visual displays urging caution and warnings prompting the driver to respond appropriately.

Target roads: Expressways, ordinary roads

Assistance level: Information, warning

2.1.2 Intersection stopping support system

Aim: The objective of this system is to reduce accidents caused by failure to stop at intersections without a traffic signal where stopping is required because of driver inattention and so on.

Function: The system receives information from the road-infrastructure about an intersection ahead that does not have a traffic signal but where stopping is required. The system urges caution about the approaching intersection with advance information in the form of voice guidance. The system further calculates the distance to the stopping point from that information and the subject vehicle's velocity, and if it judges that the vehicle will not be able to stop before the stop line, it provides warnings prompting the driver to stop.

Target roads: Intersections without a traffic signal where stopping is required

Assistance level: Information, warning

2.2 Systems for Reducing Damage by Controlling

Vehicle Static Starts

2.2.1 Crossing collision prevention advisory system

Aim: The objective of this system is to reduce accidents at intersections without a traffic signal where stopping is required caused by improper movement into the intersection from a static start because of driver inattention, poor visibility, and so on.

Function: After the vehicle comes to a stop at the intersection stop line, the system receives information from the road-infrastructure about vehicles that will cross the intersection on the road that has the right-of-way. The system provides a warning to the driver with voice guidance and display messages urging caution.

Target roads: Intersections without a traffic signal where stopping is required

Assistance level: Information

2.2.2 Right turn (cross traffic) collision prevention advisory system

Aim: The objective of this system is to reduce accidents involving collisions with oncoming vehicles caused by driver miscalculation or poor visibility while turning right (in Japan, left in the U.S.) across traffic at an intersection with a signal.

Function: After the vehicle comes to a stop at the intersection stop line, the system receives information from the road-infrastructure about vehicles that will cross the intersection on the road that has the right-of-way. The system provides a warning to the driver with voice guidance and visual displays urging caution.

Target road: Intersections with traffic signal

Assistance level: Information

2.2.3 Crossing pedestrian collision prevention advisory system

Aim: The objective of this system is to reduce accidents with pedestrians in crosswalks caused by improper driving resulting from driver inattention, poor visibility, and so on.

Function: The system receives information from the road-infrastructure about pedestrians on the crosswalk ahead. Based on that information and the vehicle's current condition, the system provides a warning to the driver with voice guidance and visual displays urging caution.

Target road: Intersection

Assistance level: Information

3. Overview of Road-to-Vehicle Cooperation System Operation

An overview of system operation will be given using the Forward Obstacle Collision Prevention Support System as an example.

- (1) Sensors installed on the road constantly monitor the road surface and obstacles on the road.
- (2) The test vehicle recognizes the type of service being offered by passing the control detection marker that marks the location where the service begins. An overview of this operation is shown in Fig. 2.
- (3) The test vehicle is successively sent the latest information on obstacles (the presence or absence of obstacles, the distance to obstacles, the road surface condition, etc.) by road-to-vehicle communication until it passes the control detection marker that marks the location where the service ends.

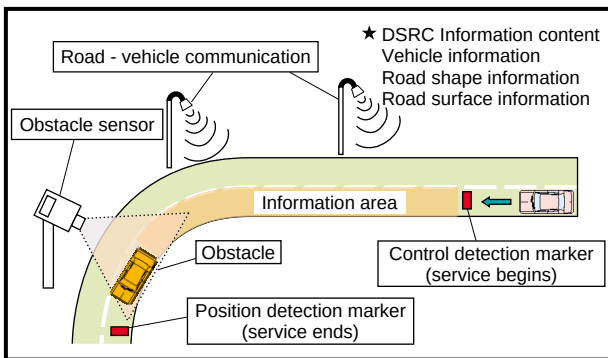


Fig. 2 Example of forward obstacle collision prevention support system (service begins)

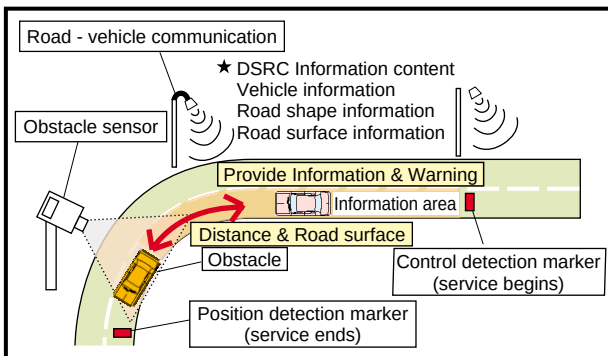


Fig.3 Example of forward obstacle collision prevention support system (information & warning)

- (4) The test vehicle uses the distance to obstacles and the road surface condition to provide information on obstacles to the driver at an appropriate timing. When the driver does not stop or take other action with respect to the information provided, the system gives a warning. An overview of this operation is shown in Fig. 3.

4. System Configuration

4.1 Road-infrastructure System

The following facilities were installed on the road for the National Institute for Land and Infrastructure Management proving tests:

4.1.1 Control detection markers

These markers were installed where the Smart Cruise Services begin and end. They provide location information on lanes and so on in connection with the services.

- Information content: Road number, number of lanes, lane number, corresponding beacon number
- Radio mode: Active Modulated Radio Wave Type
- Radio frequency: 13.56 MHz

4.1.2 Road condition detection sensors

These sensors detect vehicles and other obstacles on the road and pedestrians on crosswalks and provide information about their position.

Information content: Obstacle type, position, and velocity of obstacle movement

4.1.3 Road surface condition detection sensors

These sensors classify the road surface condition in the service provision area into 5 categories: dry, wet, water-covered, snow-covered, and icy. It then provides this information to the vehicles.

4.1.4 Road-to-Vehicle communication system

This system transmits information detected by the roadside infrastructure to cruising vehicles.

- Radio mode: Dedicated Short Range Communication (DSRC)
- Radio frequency: 5.8 GHz band

4.2 Test Vehicle On-board Systems

The on-board configuration of the system that integrates the 5 Smart Cruise Systems subjected to functional testing in the proving tests is shown in Fig. 4. A block diagram of the system is shown in Fig. 5.

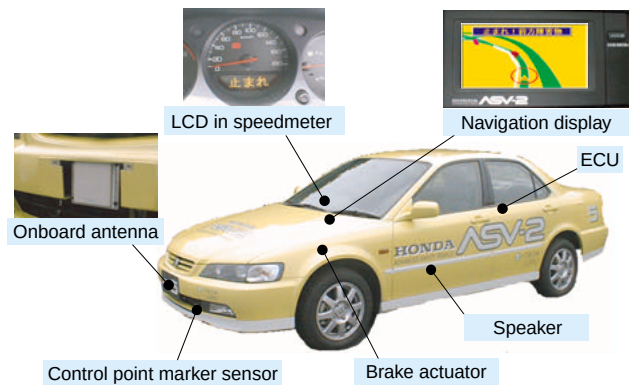


Fig. 4 Configuration of ASV/AHS

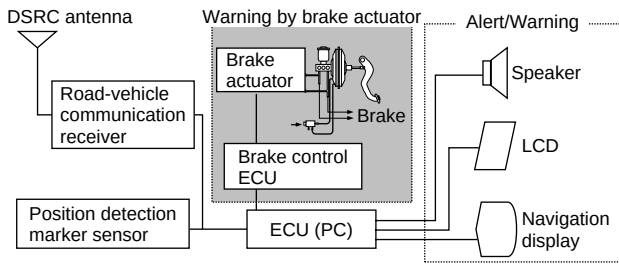


Fig. 5 Block diagram of the ASV/AHS

5. Features of the Test Vehicle Systems

5.1 High Accuracy Map Matching Navigation System

The road-to-vehicle cooperative system uses the control detection marker as the control point for distance in the service area. The on-board control detection marker sensor determines the control point according to the timing of the information received from the control detection marker when the vehicle passes by the control detection marker on the road. This method causes the distance control point to be displaced along the axis of movement because the timing for receiving the information is delayed due to the affects of vehicle velocity. The ASV/AHS Test Vehicle implemented the following processes to resolve this distance control point displacement.

- (1) A digital map was created for navigation with control detection marker information added as node information.
- (2) The vehicle position was determined using the digital map and control detection marker, map matching with the road configuration, and the Global Positioning System (GPS).
- (3) Data on the location of obstacles sent by the roadside infrastructure was mapped onto the digital map.
- (4) The information or warning timing was determined from the relative position of the subject vehicle and the obstacle on the digital map and the velocity of the subject vehicle.

As a result, it became possible to create a system in which the error in the distance to an obstacle consists only of the cumulative error in vehicle distance, thus enabling provision of highly accurate information or warnings to the driver. Fig. 6 presents an overview of the vehicle map matching for the AVS/AHS system.

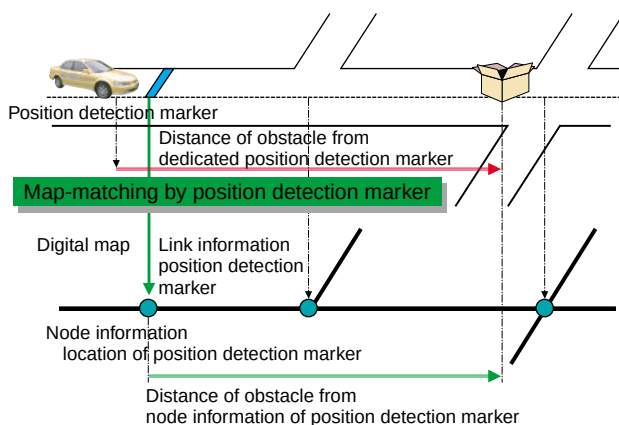


Fig. 6 Map-matching for the ASV/AHS

5.2 Haptic Warning by Brake Actuation

Appropriate information about potential dangers must be provided to drivers earlier in order to help prevent accidents from occurring. It has been reported⁽³⁾ that using the sense of touch provides a faster driver response time than using either the sense of sight (visual display) or hearing (voice guidance) as have been conventionally used. Therefore, a system for haptic warning by brake actuation was installed in the vehicle and its function was verified. The haptic warning by brake actuation system is a system for warning the driver by applying brief, intermittent deceleration G-force along the axis of movement.

6. Validity of the Road-Infrastructure

The validity of the road-infrastructure was confirmed⁽⁴⁾⁽⁵⁾ to be effective in response to various driver assistance conditions.

7. Test Results for the Haptic Warning by Brake Actuation System

7.1 Evaluation of Response Time to Warning

A test vehicle equipped with the haptic warning by brake actuation system was used to compare driver response time with voice guidance alone and with a combination of voice guidance and the haptic warning system.

Test conditions:

Haptic warning by brake actuation consisted of a maximum deceleration of approximately 2.5 m/s^2 applied three times on a 300-ms cycle. Fig. 7 presents an overview of this operation. The voice guidance consisted of a buzzer sound.

The test was run by three male subjects who were provided with warnings by voice guidance alone and by voice guidance and haptic warning at velocity of 11 m/s (40 km/h) and 22m/s (80km/h), 10 times each.

Test results:

The results are shown in Fig. 8.

The sensory evaluation results were as follows:

For voice guidance alone:

- This method requires more time because the driver must first understand the warning and then apply the brake.

For haptic warning by brake actuation and voice guidance:

- The intention of prompting the driver to stop is felt directly by the body, which therefore leads to the action of applying the brake.

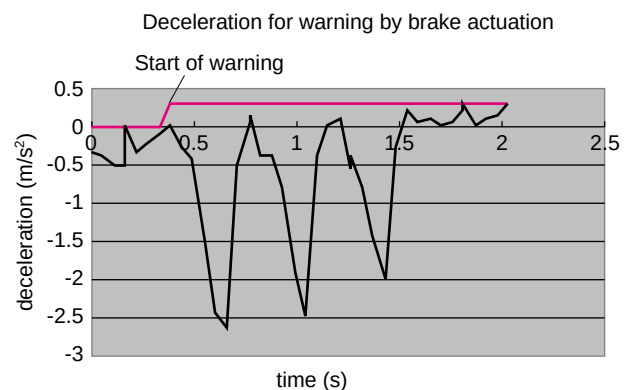


Fig. 7 Warning by brake actuation

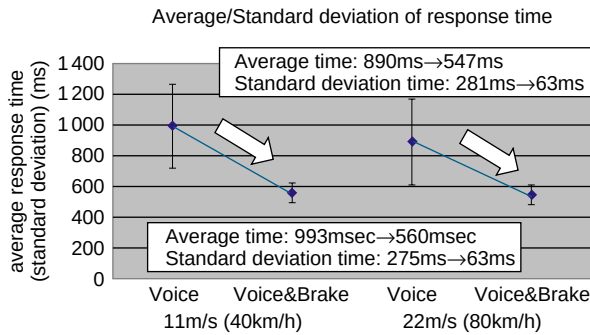


Fig. 8 Comparison of response times

- (1) When voice guidance was combined with the haptic warning, 43% less time elapsed on average before the driver applied the brake than with voice guidance alone at 11 m/s (40 km/h) and 39% less time elapsed at 22 m/s (80 km/h). The results are shown in Table 2.
- (2) When voice guidance was combined with the haptic warning, the standard deviation of the variations in time elapsed before applying the brake was reduced by 77% at 11 m/s (40 km/h) and by 78% at 22 m/s (80 km/h) relative to the use of voice guidance alone. The results are shown in Table 3.

Table 2 Average response time

Case \ Velocity	11m/s (40km/h)	22m/s (80km/h)
Voice guidance	990 ms	890 ms
Warning by brake actuation	560 ms	540 ms

Table 3 Standard deviation of response time

Case \ Velocity	11m/s (40km/h)	22m/s (80km/h)
Voice guidance	280 ms	280 ms
Warning by brake actuation	63 ms	63 ms

7.2 Evaluation of Driver Deceleration

A comparison was made of the amount of deceleration applied by the driver following haptic warning by brake actuation alone and warning by voice guidance alone.

Test conditions:

Haptic warning by brake actuation consisted of a maximum deceleration of approximately 2.5 m/s^2 applied three times on a 300-ms cycle. Fig. 7 presents an overview of this operation. The voice guidance consisted of a buzzer sound.

The test involved providing warning by voice guidance alone andTM by voice guidance and haptic warning by brake actuation at a velocity of 11 m/s (40 km/h).

The results showed that when voice guidance was combined with the haptic warning, the deceleration resulting from driver braking was approximately twice the deceleration that resulted with voice guidance alone. Fig. 9 shows deceleration after haptic warning when cruising at 11 m/s (40 km/h), and Fig. 10 shows the deceleration after warning by voice guidance.

7.3 Discussion

Fig. 11 shows driver brake timing after receiving a warning by voice guidance combined with the haptic

warning by brake actuation when cruising at 40 km/h.

It is apparent from these results that the timing at which the driver begins to apply the brakes coincides closely with the second actuation of braking by the haptic warning system. The brake timing was more or less the same for all the drivers, suggesting that the response time with the haptic warning is unrelated to individual differences, that it shows a constant value, and that it reduces variation.

The above results confirmed that the haptic warning system is an effective means for providing warnings to the driver and that it provides the following benefits.

- The time that elapsed until the drivers applied the brake was reduced approximately 40%.
- The variation in the time elapsed until the drivers applied the brake was reduced approximately 80%.
- The drivers applied greater deceleration due to the haptic warning by brake actuation.

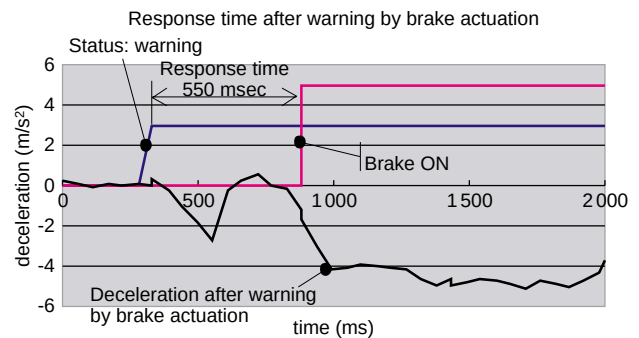


Fig. 9 Example of warning of brake actuator

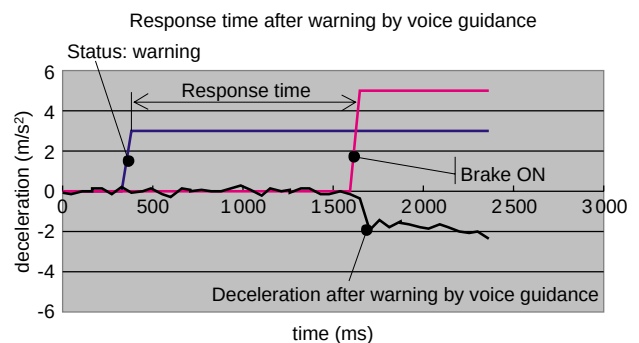


Fig. 10 Example of warning by voice guidance

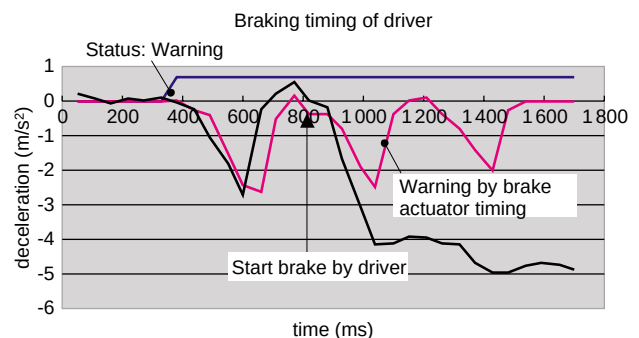


Fig. 11 Braking timing of driver

8. Conclusion

An AHS test vehicle was built in order to test and evaluate the Smart Cruise Systems at the National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transportation. Participation by this test vehicle in the ASV/AHS joint proving tests allowed verification of the timing effective for providing information or warnings and verification of haptic warning by brake actuation.

9. Future Issues

Validity of the road-infrastructure and driver acceptance were evaluated during these proving tests. Although the effectiveness of warning by brake actuation was also evaluated, the limited time available for the proving tests meant that it was not possible to more thoroughly check the system with more test subjects, or to test the finer details of the magnitude, interval, and start of deceleration, and so on. Consequently, it is considered necessary to carry out verification of issues such as the following:

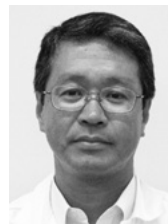
- Theoretical review and evaluation of the human-vehicle system.
- Verification of the effects of different road environment conditions, driver age, gender, and so on.

The 5-year Advanced Safety Vehicle phase 3 will begin this fiscal year, and again Honda will participate. It is hoped that the road-to-vehicle cooperative system will be brought to the point of practical application.

References

- (1) Asanuma, N., et al., Introduction of Honda ASV-2 (Passenger Car), HONDA R&D Technical Review, Vol.12, No.2, p. 1–8 (2000)
- (2) Kamata, G., Focusing on Principal User Service, Report of the Second AHSRA Research Seminar, Advanced Cruise-Assist Highway System Research Association (AHSRA), p. 106–109 (1998)
- (3) Tsubouchi, K., Sense of Sight and Response Movement, Ergonomics, Tokyo: Nikkan Kogyo Shimbun, Ltd., p. 141–149 (1965)
- (4) Furukawa, Y., Verification Tests of Vehicle/Road-infrastructure Cooperated System in ASV Phase 2 Project, ASV Phase 2 Promotion Project Conference Proceedings, The Way to a Safe Vehicular Society by ITS, p. 39–56 (2001)
- (5) Study Group for Promotion of ASV, Road Transport Bureau, Ministry of Land, Infrastructure and Transportation, Coordination with Infrastructure, a Report on the Advanced Safety Vehicle (ASV) Promotion Project (Phase 2), p. 51–59 (2001)

■ Authors ■



Hiroshi MASHIMO



Yoshimi FURUKAWA



Nobuyoshi ASANUMA



Tomoyuki FUKUMARU



Hideki KASEYAMA