

**AICHI DSSS (Driving Safety Support System)
FIELD VERIFICATION TEST
FIELD VERIFICATION TEST ON VEHICLE INFRASTRUCTURE
COOPERATIVE SYSTEMS**

Shin Yamamoto*¹, Kansei Mizutani*²

IT&ITS Planning Division, Toyota Motor Corporation
1-4-18, Koraku, Bunkyo-ku, Tokyo, 112-8701 Japan
Phone: +81-3-5800-7357*¹, +81-3-5800-7363*² Fax: +81-3-3817-9045
E-mail: s-yamamoto@mail.toyota.co.jp*¹
E-mail: kansei_mizutani@mail.toyota.co.jp*²

Masatada Seto

Universal Traffic Management Society of Japan
Airman's Building 7th Floor, 2-6, Ichigayatamachi, Shinjuku-ku, Tokyo, 162-0843 Japan
Phone: +81-3-3235-6520, Fax: +81-3-3235-6522
E-mail: seto@utms.or.jp

ABSTRACT

Based on accident realities in Japan, the necessity of vehicle infrastructure cooperative systems is explained at the introduction. The systems transmit information of traffic control (traffic signal and sign, etc.) and the event out of sight, which are difficult for the autonomous systems of vehicles to grasp. The systems attempt to decrease the accident by disseminating information and warning to drivers, and providing intervention control to vehicles. After the outline of the function and the assumed installation location are introduced, the outline of the field verification test scheduled in Aichi Prefecture in 2006 and 2007 for development of the systems is explained in this paper.

Keywords

Vehicle Infrastructure Cooperative Systems, Field Verification Test

Introduction / Necessity of Vehicle Infrastructure Cooperative Systems

(1) Accident realities in Japan

The life of 7,000 – 8,000 persons is lost every year, and the number of the persons injured by traffic accidents still remains at the level of one million or more, even though the death toll by traffic accidents is recently in the decreasing tendency. The increase in seat belt wearing rates, the effects of collision safety and preventive safety functions, etc. of vehicles, strengthening of traffic regulations, and enforcement of traffic violators are thought to be the background of the fatal accident decrease.

(2) Role of Vehicle Infrastructure Cooperative Systems

As a strategy to reduce traffic accidents, we have examined up measures around vehicles alone (autonomous systems), and have commercialized them. Accidents that can be dealt with autonomous systems are head-on collision accidents, rear-end collision accidents, and single accidents of vehicles. It has limits in dealing with accidents in the intersection and in the effect of decreasing accidents resulting from contact with two-wheeled vehicles and pedestrians. The examination of effective measures is urged for these fatal accidents.

The vehicle infrastructure cooperative systems deliver information from road side, concerning "information of traffic controls, etc. (traffic signal information and road sign information, etc.)" and "events outside the scope of vehicle sensors (to detect vehicles approaching intersections)," all of which are difficult to grasp for vehicles by its autonomous systems alone. Those are safe driving support systems that provide intervention control to vehicles and warning/disseminating information to drivers, which are judged inside vehicles, based on the state of drivers and running vehicles, etc. in addition to the information from infrastructures.

Image of Vehicle Infrastructure Cooperative Systems

(1) Derivation of Vehicle Infrastructure Cooperative Systems

After analyzing accident factors of all the accident resulting in injury or deaths, necessary systems were derived based on the role of the vehicle infrastructure cooperative systems.

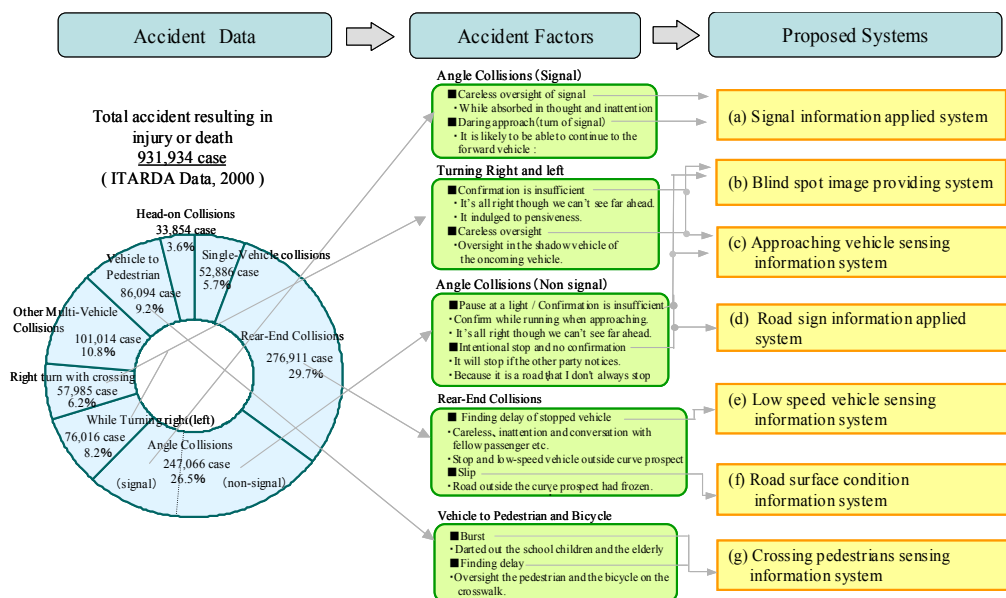


Fig. 1. Derivation of Vehicle Infrastructure Cooperative Systems from accident data

(2) General description of each system function

(a) Signal Information Applied System

Infrastructures notify signal phase timing charts, etc. to vehicles to give warnings to drivers and intervention controls to vehicles going into intersections at red signal.

(b) Blind Spot Image Providing System

Infrastructures deliver the video images of blind side to vehicles that are trying to make right turns or are stopping at stop signs. (Dissemination level)

(c) Approaching Vehicle Sensing Information System

Infrastructures deliver the detected information of position and speed, etc. of hidden vehicles in blind side to vehicles that are trying to make right turns or is stopping at stop signs. (Dissemination level)

(d) Road Sign Information Applied System

Infrastructures notify stop positions, etc. to vehicles before intersections without traffic signals to give warnings to drivers and intervention controls to vehicles that do not decelerate enough to stop at stop positions.

(e) Low Speed Vehicle Sensing Information System

Infrastructures deliver information on positions and speeds, etc. of vehicles that are stopped or driving at low-speed on roads and are outside the prospect of vehicles going into curves. Finally, this system aims at intervention control level while dissemination is the first stage.

(f) Road Surface Condition Information System

Infrastructures deliver information of road conditions to approaching vehicles. This system may be operated by the combination with another system with intervention control level.

(g) Crossing Pedestrians Sensing Information System

Infrastructures deliver information of positions of pedestrians and bicycles on/around crosswalks to approaching vehicles.

(3) Assumed installation location

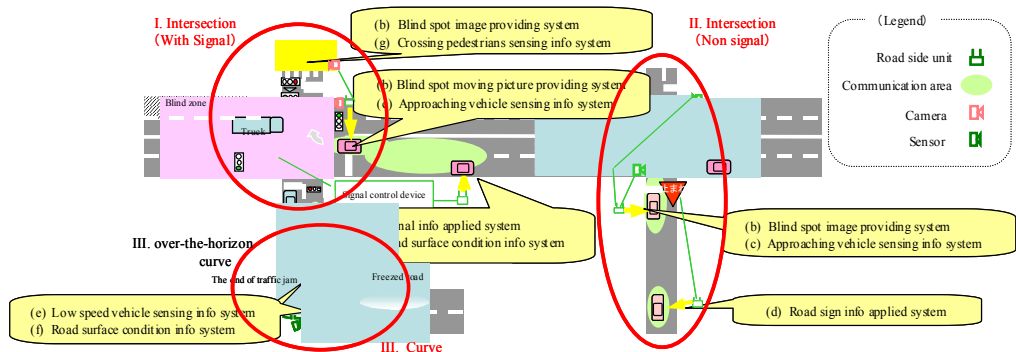


Fig. 2. Assumed installation location for each system

Technical Issues for Realizing Vehicle Infrastructure Cooperative Systems

Technical issues for realizing the vehicle infrastructure cooperative systems and the solutions regarding the wireless communications, the method of vehicle positioning, and the road sensors are as follows.

(1) Wireless communications

Issues: Any wireless communication system cannot meet all requirements to realize the vehicle infrastructure cooperative systems in terms of communication area, capacity, reliability, and so on.

Solutions: Aiming at the early achievement, we will try to start up with available systems utilizing infrared beacons (When it is impossible with the infrared beacon, DSRC is used), and the function, the effect, and the acceptability are verified at Aichi DSSS field-testing. It is also necessary to develop a new communication system satisfying all the requirements to realize all the vehicle infrastructure cooperative systems.

(2) Method of vehicle positioning

Issues: Infrared beacon is the only system that has the possibility to have the function of vehicle positioning as well as wireless communications.

Solutions: The accuracy of the vehicle positioning function with infrared beacons will be verified by the DSSS field-testing.

(3) Road sensor

Issues: No existing sensor is accurate enough for the detection of other vehicles, bicycles, pedestrians, and road surface conditionings to realize the warning and the intervention control levels in those systems.

Solutions: The performance verification of the sensors and the study of the development scenario for the accuracy improvement are conducted in the DSSS field-testing.

Systems to be Aimed to Realize at the First Stage (Next Generation Systems)

We define “Next Generation Systems”, that can be realized for the early achievement, and their service levels from the viewpoint of the possibility of infrared beacons and sensors, etc., based on the issues and the solutions in the previous chapter (Refer to Table 1). Moreover, based on the new IT reform strategy published by the Cabinet Secretariat of Japan early this year, the systems thought to be able to achieve in 2010 are derived as Next Generation “A”, while the others thought to be realized beyond 2010 are defined as “B”. (Refer to Table 4.2)

Table 1. Potentiality for each system and restriction matters

	System name	Potentiality	Restrictions
a	Signal information applied system	High	Difficult to apply to traffic signals with actuated control due to spot type communication area.
b	Blind spot image providing system	Mid	Potential in case DSRC is used in terms of data speed
c	Approaching vehicle sensing information system	Mid	Depending on road sensor's accuracy
d	Road sign information applied system	High	—
e	Low speed vehicle sensing information system	Mid	<ul style="list-style-type: none"> • Difficult to provide information if situation is changed after vehicle passes spot communication area • Depending on road sensor's accuracy
f	Road surface condition information system	Mid	Depending on road sensor's accuracy

g	Crossing pedestrians sensing information system	Mid	<ul style="list-style-type: none"> • Difficult to provide information if situation is changed after vehicle passes spot communication area • Depending on road sensor's accuracy
---	---	-----	--

Table 2. Types of Next generation system and its service level (Draft)

Type	Next Generation "A"	Next Generation "B"
Target year	FY 2010	Beyond FY 2010
Service Level	Dissemination (*)	Dissemination (*), Warning/Intervention control
System	Signal information applied system Road sign information applied system Blind spot image providing system	Signal information applied system (W/I) Road sign information applied system (W/I) Blind spot image providing system (D) Approaching vehicle sensing information system (D) Low speed vehicle sensing information system (D) Crossing pedestrians sensing information system (D)

Notes D: Dissemination W/I: Warning/Intervention control

* The judgment of whether information is provided to driver or not and its timing depends on velocity and position of vehicle, etc.

Outline of Field Verification Test

(1) Aims

- 1) To obtain technical findings for the system design through the function verification in real fields.
- 2) Effect verification in real fields and verification of driver's acceptability
- 3) Improvement of social acknowledgment

(2) System for experiment

- (a) Signal Information Applied System
- (b) Blind Spot Image Providing System
- (c) Approaching Vehicle Sensing Information System
- (d) Road Sign Information Applied System
- (g) Crossing Pedestrians Sensing Information System

(3) Step of experiment execution

The experiments for the next generation vehicle infrastructure cooperative systems are divided into the following two phases, and will be implemented in stages.

Phase 1(fiscal year 2006):

- Function and performance verification of the element technologies for infrared beacons and road sensors, and basic data collection for specification and parameter decision for prototype development.
- A part of effect verification prior to one planned to be conducted in phase two.

Phase 2 (fiscal year 2007):

- The prototypes are made.
- The function for practical use, the effect of the application system, and the social acceptability are verified.

(4) Test items in fiscal year 2006

The proposed test items were derived after extracting the technical issues for the realization of the vehicle infrastructure cooperative systems in Aichi DSSS Working Group.

A. Element technology verification

(a) Signal Information Applied System

- The verification of the signal information transmission to vehicle from traffic signal controller
- Verification of accuracy of vehicle positioning system using infrared beacons

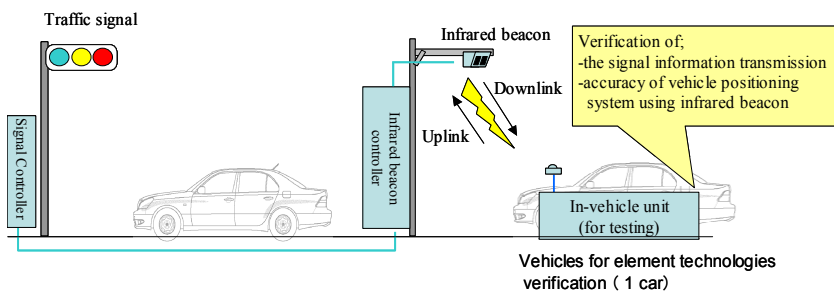


Fig.3. Image for element technology verification (Signal Information Applied System)

(b) Blind Spot Image Providing System

- Evaluation of the potentiality of this system as applications
- Measurement of electric wave propagation characteristics of DSRC (Dedicated Short-Range Communication system)

(c) Approaching Vehicle Sensing Information System

- Evaluation of detection performance at existence, position, and speed of approach vehicle utilizing three types of the following road sensor systems
 - 1) Visual Image Processing Optical Detector, Infrared Imaging Detector, millimeter wave radar, and sensor fusions
 - 2) Infrared Imaging Detector
 - 3) Visual Image Processing Optical Detector (Spatio-temporal MRF Model)

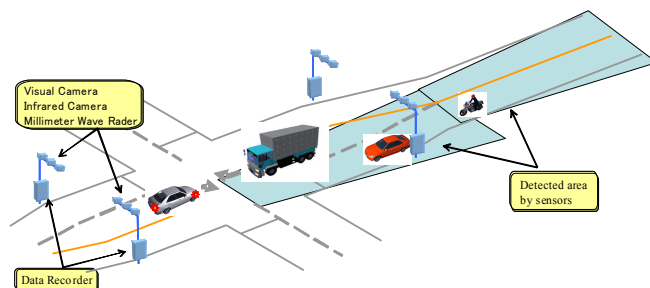


Fig.4. Image of performance verification for Approaching Vehicle Sensing Information System (in case of Visual Image Processing Optical Detector, Infrared Imaging Detector, millimeter wave radar, and those sensor fusions)

(g) Crossing Pedestrians Sensing Information System

Evaluation of detection performance of existence, position, and speed of crossing pedestrians and bicycles

- 1) Visual Image Processing Optical Detector with Stereo Visible Cameras (Integration with laser sensor is examined for the improvement of detection accuracy)

B. Effect and acceptability verification

- (a) Signal Information Applied System

- (d) Road Sign Information Applied System

Evaluation of effect of dissemination to drivers by in-vehicle unit and driver’s acceptability

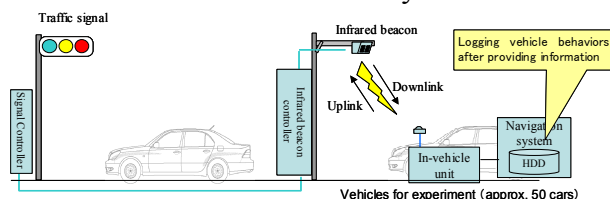


Fig.5. Image for effect and acceptability verification (in case of Signal Information Applied System)

(5) Locations

The following experimental locations were selected based on the accident data, the requirement of the experiment content, and the easiness in the infrastructure installation in Toyota City.

A. Element technology verification

- (a) Signal Information Applied System : Tsuchihashi 1
- (b) Blind Spot Image Providing System : Honshin-cho 5
- (c) Approaching Vehicle Sensing Information System : Honshin-cho 5, Kosaka-cho 10
- (g) Crossing Pedestrians Sensing Information System : Tsuchihashi 1

B. Effect and acceptability verification

- (a) Signal Information Applied System : Tsuchihashi 1, Yamanote-sho SE, Miyuki-hommachi 3E
- (d) Road Sign Information Applied System : Umetsubo-cho, Uehara-cho

(6) Schedule

Items	FY 05	FY 06				FY 07
		1Q	2Q	3Q	4Q	
Phase 1	Planning	Planning Spec examination	Documents of experiment design & procedures			
	Development Preparation	Development of infrastructures Planning & preparation for construction & setting	Constructions & Settings Constructions & Settings			
	Experiment	Development of in-vehicle unit (for element tech. verification) Development of in-vehicle unit (for effect & acceptability verification)	Element tech verification (Infrared beacon) Element tech verification (Road sensor)		Effect & acceptability verification	
	Reporting				Reporting	
Phase 2				7	Planning & preparation Prototype development of infrastructure & vehicle	Experiment execution Reporting

(7) Aichi DSSS WG Organization

Aichi DSSS WG is subordinate to DSSS sub-committee under the UTMS Japan and the WG members are as follows.

- Chairman: Toyota Motor Corporation
- Sub-chairman: Sumitomo Electric Industries
- Member: Denso, Fujitsu, Koito, Kyosan, Matsushita, Mitsubishi, NEC,
Nippon Signal, Omron
- Supervisor: National Police Agency, Japan, Aichi Police, UTMS Japan

Necessity of new wireless communication media

To achieve all the infrastructure cooperative systems proposed this time, considering traffic actuated controls at traffic signals and updating information detected by road sensors to vehicles, the wireless communication media with zone type and the high connection reliability are necessary. (When the reaction time of drivers and the distance for braking are taken into consideration, approximately 100m - 200m in length is necessary for the zone.) The existing wireless communication medias for ITS applications such as infrared beacons do not support the enough area. On the other hand, the zone type communication medias, most of which are developed for non-ITS applications, such as wireless LAN, do not have enough connection reliability required for ITS safety applications due to the reflection wave and the shadowing issues, etc. Therefore, it is necessary to develop a new wireless communication media that will satisfy the requirements to realize all the systems in future.

Conclusions

- 1) The vehicle infrastructure cooperative systems are necessary in addition to the vehicle autonomous systems in order to reduce traffic accidents.
- 2) The existing communication medias such as infrared beacons will be used for the early stage achievement of the infrastructure cooperation systems from the possible systems one by one. The function, the effect, and the acceptability are verified in Aichi DSSS field test in the fiscal year 2006 and 2007.
- 3) It is also necessary to develop a new wireless communication system satisfying all the requirements to realize all our proposed vehicle infrastructure cooperative systems.

References

- 1) National Police Agency, Traffic Bureau, Traffic Management and Control Division, Specifications for infrared beacon, Keikoshiki No. 305 ver.1, Dec. 25, 2002
- 2) Universal Traffic Management Society of Japan, Standard for Infrared vehicle detector and Infrared beacon Interface ver.2, Aug. 3, 2001
- 3) Association of Radio Industries and Business, Dedicated Short-Range Communication System, ARIB Standard-T75 ver.1.3, Nov. 31, 2005