Effect Verification of Information Provision for Vehicle-Infrastructure Cooperative System - Result of Aichi DSSS Field Verification Test -

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ABSTRACT

This article describes the results that we experimented on with a field of Toyota-City about vehicle-infrastructure cooperative systems. In the field verification, roadside equipments were installed at selected intersections, and on-board units were equipped for the each test vehicles and recorded a driving action of a driver. Then we observed a change of driving actions of the test drivers by the information supports. The experiment results are described. Also future study for the field verification is pointed out.

Introduction / Necessity of Vehicle Infrastructure Cooperative Systems

Accident Realities in Japan

When we look at the number of traffic accidents in Japan over the years, the number of fatalities tends to decrease and became less than 7,000 in 2005. On the other hand, the number of casualties continues to increase as the number of vehicles and licensed drivers increased. For purpose of reducing the number of fatalities and casualties, there are still a lot of problems to be solved.

Role of Vehicle-Infrastructure Cooperative Systems

As a strategy to reduce traffic accidents, we had examined up measures around vehicles alone (autonomous systems), and had 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 intersections 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 roadside, concerning "information of traffic controls (such as traffic signal information and road sign information)" and "events outside the scope of vehicle sensors (to detect vehicles approaching intersections)". All of there information 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

Taking consideration of the accidents factors resulting in injury or deaths, necessary systems were derived based on the role of the vehicle infrastructure cooperative systems.

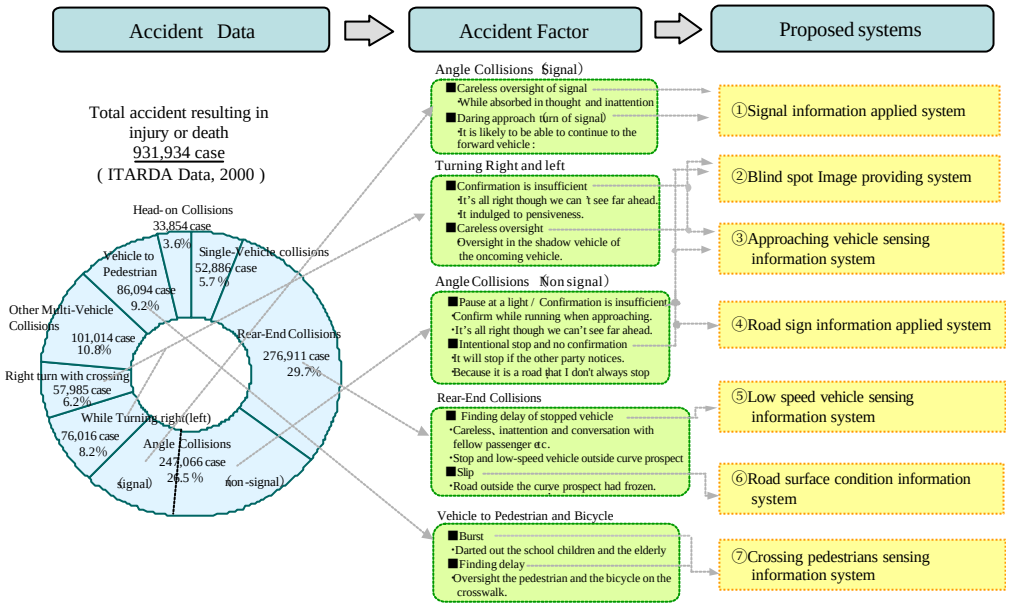

Figure 1: Accident factors and Proposed systems

Among the proposed systems above, following two systems were chosen in order to prevent the drivers from miss-recognizing the traffic regulations by using traffic control information.

1. Signal Information Applied System
   This system is to prevent the red signal violation at intersections. When it is expected that a driver overlook the red signal, this system gives the caution and helps to prevent the red signal violation. The image of this system is described in Figure 2.

2. Road Information Applied System (Stop Sign)
   This system is to prevent the stop sign violation at intersections. When it is expected that a driver overlook the stop sign, this system gives the caution and helps to prevent the stop sign violation. The image of this system is described in Figure 3.

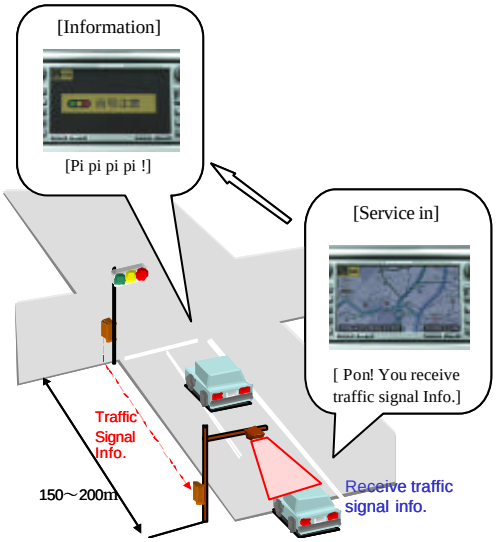

Figure 2:Signal Information Applied System

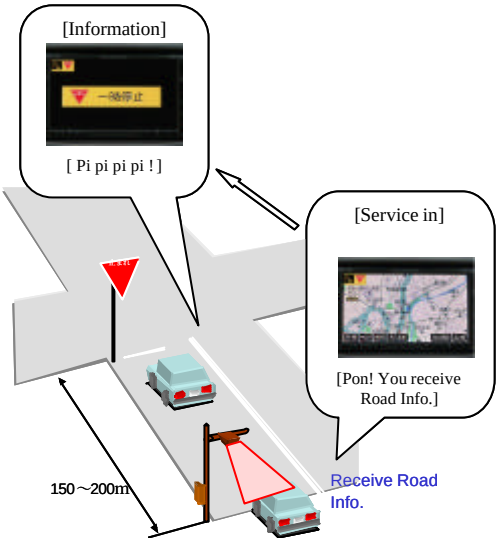

Figure 3: Road Sign Information Applied System (Stop Sign)

Outline of Field Verification System

Road Side Equipments (Infrared Beacon)

Infrared beacons were installed at experimental intersections. At the intersections with traffic signals, infrared beacons were connected to traffic signal equipments so that the infrared beacons can regularly transmit signal information such as signal cycles (see figure 4).

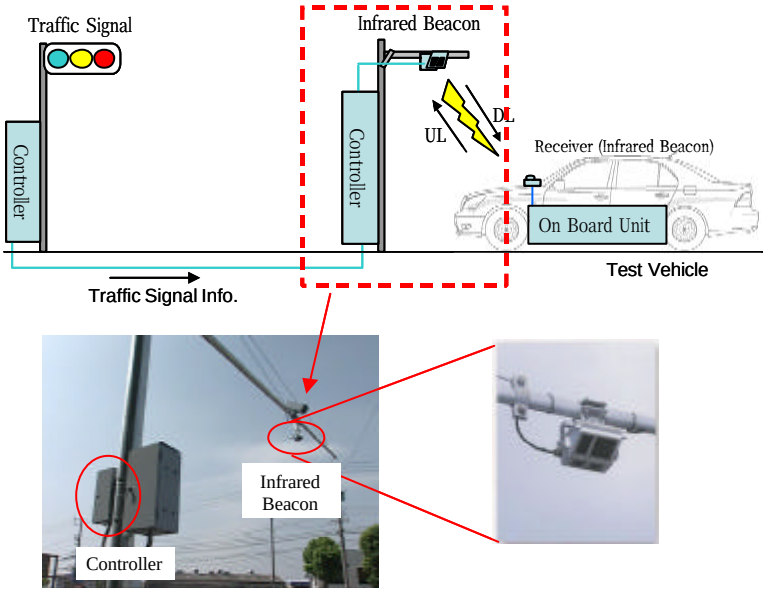

Figure 4: Road Side Equipment (Infrared Beacon)

On-Board Equipments

The Following items were installed on experimental vehicles (see figure 5).

- Infrared Beacon transceiver
- HDD navigation system
  This is to record all the data from infrared beacons, system logs and vehicle signals around experimental intersections. Some examples of vehicle signals are position (from GPS), velocity, and brake signal.
- Driving recorder
  This is to record sounds and images (driver's view and foot). The image of driver's view is used to check particularly for behaviors of precedent vehicles. The image of driver's foot is used to check for pedal operations such as brakes or accelerations.

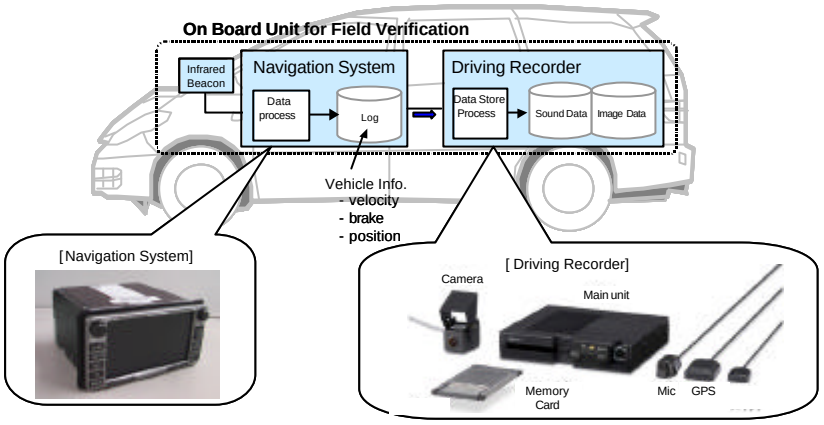

Figure 5: On-Board Equipments

Process of Field Verification

On-board equipments were installed onto experimental vehicles and recorded driving actions when test drivers ran experimental intersections every day. The field verification period was six months. For 1 and half month, recording of driving actions was performed without giving any information and caution. For rest of the period (4 and half months), information and caution were performed, and on-board equipments recorded driving actions when the test drivers ran into the experimental intersections.

Implementation of Field Verification

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

- Selection of Intersections
  Signal Information Applied System: 3 intersections
  Road Information Applied System (Stop Sign): 2 intersections
- Period of Experiment
  Dec 2006 – May 2007 (six months)
- Test Drivers
  47 drivers whose ages were between 20's and 50's.

Effect Inspection Method

STEP 1
The recorded data were evaluated in the way that information support may have influenced on the changes in driving actions.

STEP 2
Using statistics of accidents data in the past, we estimated the accident reduction effects in consideration of the changes in the driving actions that are mentioned in step 1. Then we compared the data between driving actions with/without information supports. The procedures for data analysis were as follows.

1) Remove null and void data for analysis such as "passing through with green light"
2) Remove void data that was influenced by neighboring traffic (precedent vehicles) using front image data.
3) Perform comparison analysis for change in driving behaviors with/without information supports. We especially examined tendencies of deceleration behaviors, release timing of accelerator pedal, and so on.

Result of Field Verification

Comparison of Release Timing of Accelerator Pedal

Intersections with traffic signal We compared the difference of driving actions with/without information supports depending on the stage of the traffic signal. Figure6 shows the relations when information support was performed with green signal. Figure7 shows the relations when information support was performed with red signal.

When the information supports were performed on the stage of green signal, the release timing of accelerator pedal tend to be put in advance compared with the data of the driving action without any information supports. On the other hand, when the information supports were performed on the stage of red signal, a remarkable difference was not seen.

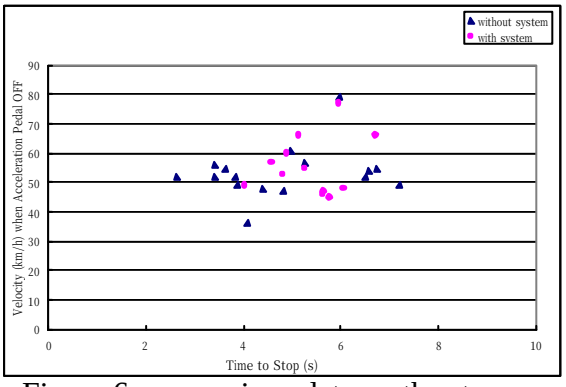

Figure 6: comparison data on the stage of green signal

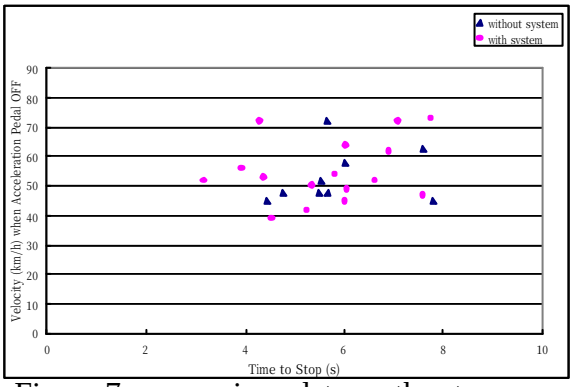

Figure 7: comparison data on the stage of red signal

Figure 8 shows medians and averages of the comparison data. When the information supports were provided at the stage of green signal, the release timing of accelerator pedal was 0.8s (median value) advanced compared to the one with no information support. Moreover, when the information supports were provided at the stage of red signal, the release timing was only 0.3s (median value) advanced.

	Median			Average		
	Without Info.	With Info.	Change	Without Info.	With Info.	Change
All	5.3s	5.6s	0.3s advanced	5.3s	5.5s	0.2s advanced
Only at green state	4.6s	5.4s	0.8s advanced	4.7	5.3	0.6s advanced
Only at red state	5.5s	5.8s	0.3s advanced	5.9	5.6	0.3s late

Figure 8: release timing of accelerator pedal

Intersections with stop sign Figure 9 shows the relations between velocity and time (to stop) when there were no preceding vehicles in front. It was hard to tell its difference as long as concerned in figure 9 generally. Then the median and average of these data were compared in figure 10. The release timing of accelerator pedal was 4.1s before the vehicle reached the intersections when the information supports were not provided. On the other hand, the release timing of accelerator pedal was 5.4s with information supports.

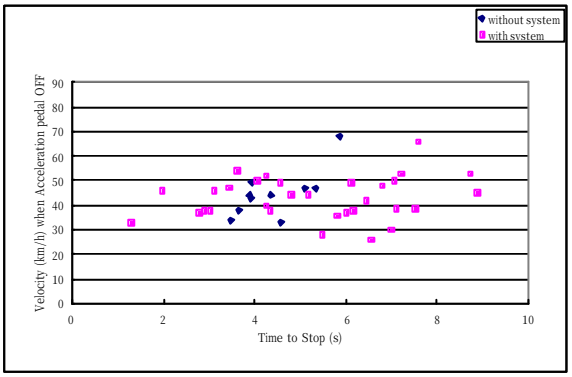

Figure 9: Intersections with Stop Sign

	Median			Average		
	Without Info.	With Info.	Change	Without Info.	With Info	Change
All	4.1s	5.4s	1.3s advanced	4.4s	5.3s	0.9s advanced

Figure 10: release timing of accelerator pedal

Comparison of Brake Start Timing

Intersections with traffic signal Now let us turn to the data about the brake start timing. There were the relations between the velocity and the time to intersection. Therefore, the recorded data were compared with linear approximation.

As same as the above-mentioned release timing of acceleration pedal, the data were classified with the stage of signal and compared them. Figure11 shows the relations when information supports were performed with green signal. Figure12 shows the relations when information supports were performed with red signal. When the information supports were provided on green signal, the change was not seen in brake start timing, in which was not like a release timing of acceleration pedal. The same result was seen when the information supports were provided on red signal. The reason for this result is not clear yet.

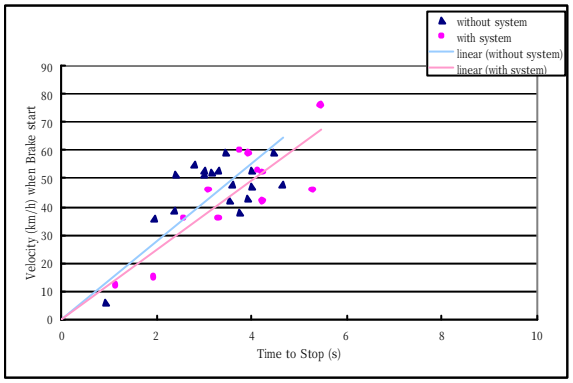

Figure 11: comparison data on the stage of green signal

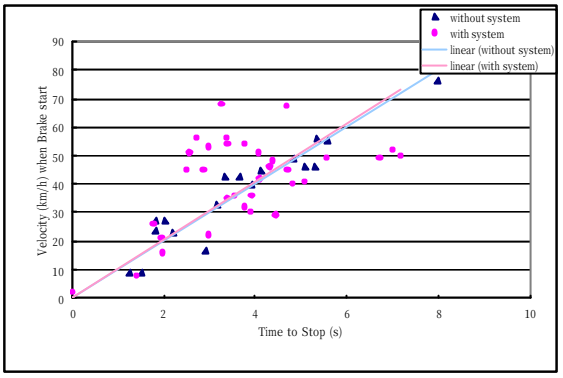

Figure 12: comparison data on the stage of green signal

Intersections with stop sign Figure 13 shows the relations of brake start timing between velocity and time (to stop) when there were no preceding vehicle in front. The change in brake start timing was not seen as well whether the information supports were provided or not.

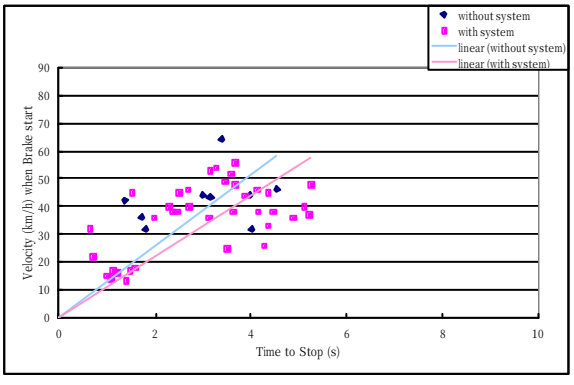

Figure 13: Intersection with stop sign

Consideration of Field Verification

As far as we can tell from these graphs and data, the information supports have influence on change in driving actions, especially for release timing of acceleration pedal. It was clearly appeared when we compared data between the state of green signal and red signal. This lead to that the information supports against something invisible have more influence on driving actions.

For the future study, in order to inspect the safety effects of the systems, we need to find the methods and appropriate parameters to extract the change of driving actions. Moreover, we need to take a closer look at the effects when the driver gets used to the information supports over some periods of time.