Cruise-Assist Services Utilizing Up-link Information

Harutoshi Yamada*1, Hiroshi Makino*1, Masao Takamune *1
Masahiro Wakamiya*2, Kenro Takenaka*2, Toshiyuki Nomoto*3, Hiroshi Inoue*4,

*1National Institute for Land and Infrastructure Management,
Ministry of Land, Infrastructure and Transport, Japan
1 Asahi, Tsukuba City, Ibaraki Prefecture 305-0804 Japan
Tel: (+81)29 864 4496   Fax: (+81)29 864 0565
E-mail: yamada-h92q9@nilim.go.jp, makino-h87bh@nilim.go.jp,
takamune-m924a@nilim.go.jp

*2Mitsubishi Electric Laboratory, AHS Research Association, Japan
11th floor, Sumitomo Fudosan Hibiya Building, 8-6 Nishi-Shinbashi 2-chome, Minato-ku,
Tokyo 105-0003 Japan
Tel: (+81)3-3504-0505, Fax: (+81)3-3504-2727
E-mail: Masahiro.Wakamiya@hq.melco.co.jp, Kenro.Takenaka@hq.melco.co.jp

*3Matsushita Electric Laboratory, AHS Research Association
E-mail: nomoto.toshiyuki@jp.panasonic.com

*4AHS Research Association
E-mail: inoue@ahsra.or.jp

ABSTRACT
Information on vehicle driving records and information acquired by vehicle sensors that has been accumulated by on-board unit in vehicles can be collected by roadside systems using DSRC (this process is hereafter called up-linking). Services that provide drivers with this cruise-assist information in real-time were studied. This study covered an overview of services, current problems, effects, necessary up-link information, and the feasibility of such services. There is also a report on the results of evaluating the equipment with a function of DSRC for the realization of these services.

KEYWORDS
AHS(Advanced Cruise-Assist Highway Systems), UP-LINK, DSRC, Dangerous Driving Location
BACKGROUND
Systems utilizing up-link information are capable of providing accurate information about obstacles on the road, icy road surfaces, and the location of rearmost congestion in real-time. Such systems can also provide real-time information about the locations of near miss situation and thus they are considered to contribute to safe driving. It is also considered that such information will be used by road administrators to improve the efficiency of their operations. The study done so far by AHSRA (AHS Research Association) of Japan revealed the effectiveness of cruise-assist information services for driving safety support that use message sign and an on-board unit to provide drivers with cruise-assist information regarding dangerous phenomena detected by sensors installed on the roadside.[1] Although roadside sensors are capable of detecting dangerous phenomena with a high degree of accuracy, there is a problem that cost restrictions limit the installation of such sensors to locations of frequent accidents or frequent congestion, or of other such problems. Resolving this problem will require a wide range monitoring system utilizing inexpensive devices. It is considered that up-linking with small numbers of Beacons will realize a linear and area-wide monitoring.

STUDY OF CRUISE-ASSIST SERVICES UTILIZING UP-LINK INFORMATION
The advantages of cruise-assist services that utilize vehicles as mobile sensors and function through the use of DSRC up-linking are following:
- The monitoring location is not limited, and information can be collected to cover a wide range, both in road length and area.
- It is possible to construct systems that are inexpensive compared to roadside sensor systems.
- It is possible to keep communication charges at inexpensive levels compared to portable telephones and other such media.
- It is possible to realize low-cost systems through the common use with DSRC Beacons for providing traffic information.
The three (proposed) services devised in light of the above advantages are described below.

Service for provision of information on forward obstacles in locations with poor visibility
This service seeks to prevent rear-end collisions at locations where forward visibility is poor (curves, crests). For this purpose, the service provides the moving vehicle with information on stationary vehicles, rearmost congestion, and other such obstacles through message sign or an on-board unit (Figure 1). The up-link information items are time, location, speed, and so on. These systems are able to provide information at a more reasonable cost than systems with roadside sensors. The flow of the service is as follows:
- The DSRC Beacon acquires vehicle driving history information from vehicles within its
communication area.

- The system detects obstacle information from the behavior of vehicles that slow down suddenly or come to a stop.
- The system uses message sign or the on-board unit to alert drivers to be cautious.

**Figure 1-Conceptual diagram of service for provision of information on obstacles in locations with poor visibility**

(1) Current measures and problems
At present, MEX (the Metropolitan Expressway Public Corporation) has installed roadside sensors on Sangubashi curve [1] and also ultrasonic vehicle detectors. These implement services by detecting dangerous phenomena through sensors installed on the road side. The problem is, however, that it is difficult in terms of cost to install high-performance roadside sensors at all locations with poor visibility (curves, crests).

(2) Expected effects
Approximately 30 accidents occur per month on the Sangubashi curve. There are approximately 100 other locations on the Metropolitan Expressway where accidents occur at similar high rates, and there are approximately 8500 such locations around Japan. This system can be expected to reduce accidents at such locations.

(3) Necessary up-link data
Proving tests will be conducted and other such means will be used in order to verify the efficacy and accuracy of the information. The up-link information considered necessary for this service is as follows:
- Location, time, and speed information
- Acceleration information (longitudinal, angular, lateral, etc.)
- Braking strength, steering angle
(4) Feasibility of service
Such factors as detection accuracy, detection delay time, and monitoring range must carefully be considered in order to detect information about obstacles. Delay times, in particular, tend to become quite long when the location of the phenomenon and the DSRC Beacon are far apart. Verification, therefore, must also include the DSRC Beacon location, intervals, and so on. With the aim of realizing this service, its effectiveness is also to be compared with the effectiveness of service that is successfully implemented using roadside sensors.

Information provision service at dangerous driving locations
This service seeks to prevent accidents at locations that become dangerous for driving because of changing weather, traffic restrictions due to road construction, among other such conditions by providing information on dangerous driving locations in real-time to cruising vehicles. The service may also include the statistical analysis of collected information in order to identify the locations of near miss situation, and those results could be plotted on maps to be provided to drivers and road administrators (Figure 2). The up-link information items are location, speed, sudden braking, sudden steering maneuvers, and so on. This system makes it possible to conduct information collection and provision in real-time and over a wide range.

The flow of the service is as follows:
- The DSRC Beacon acquires vehicle driving history information from vehicles within its communication area.
- The system detects dangerous locations from sudden braking, sudden steering maneuvers, and other such vehicle behavior.
- The system uses on-board unit to alert drivers to be cautious.

(1) Current measures and problems
Traffic restrictions due to road construction can be ascertained in advance by road administrators. However, the effects of such traffic restrictions, weather, and other such factors change from moment to moment, and make it difficult to determine the current status of any resulting dangerous locations. Driver questionnaires and other means are also being used to identify the locations of near miss situation as part of the effort to collect information on dangerous locations. There are problems including an inability to collect large numbers of samples and the trouble with tabulation.

(2) Expected effects
Situations that result in dangerous locations depend upon driver characteristics and physical condition, weather conditions, daytime, nighttime, and other factors in the driving environment, as well as traffic conditions. The use of up-link information to collect large amount of sample data across a wide range should clarify accident risks that had previously
remained unnoticed, and this system is expected to be used to provide feedback for road management, to improve the road environment, and so on.

(3) Necessary up-link data
The longitudinal acceleration, speed, location, sudden braking, and vehicle properties are used to identify vehicles that are either starting to move suddenly or are suddenly slowing down. A vehicle's angular acceleration, lateral acceleration, sudden steering maneuvering, and other such factors can also be used to determine whether the vehicle has made lateral evasive movements. Proving tests will be conducted and other such means will be used in order to verify the efficacy and accuracy of the data. The up-link information considered necessary for this service is as follows:

- Location, time, and speed information
- Acceleration information (longitudinal, angular, lateral, etc.)
- Braking strength, steering angle
- ABS operation signal, vehicle stability control system operation information
- Road surface sensors

(4) Feasibility of service
Implementation of service depends necessarily upon the detection accuracy of the vehicle sensors, the algorithms used to identify phenomena, the setting of threshold values for identification, and other such factors. It is also necessary for on-board units to be installed on large numbers of vehicles, and the following kinds of measures are conceivable for that purpose:
Methods for giving incentives to ordinary drivers, such as a monitoring system for loaning out the equipment, could be used to have on-board units installed in ordinary drivers' vehicles. Methods for installing dedicated on-board units that is coordinated with systems for improving the operational efficiency of taxi companies and distribution companies could be used to have the equipment installed in the vehicles of taxi and distribution companies. For road management vehicles, methods for installing dedicated on-board unit that is coordinated with systems for improving the efficiency of road management could be used. These measures and means of investigation are to be implemented with the aim of realizing this service.

**Information Provision Service for Road Surface Conditions Ahead**

This service seeks to prevent accidents caused by ice or wet on road surfaces, poor visibility, and other such factors. To that end, it provides cruising vehicles with information on road surface conditions, etc. by means of message sign and on-board units (Figure 3). The up-link information includes vehicle sensor information (operational status of vehicle stability control system, information from outside air temperature sensors, fog light operational status) and other such information. This system is able to provide a wide range of information about road surface conditions ahead at a reasonable cost.

(1) Current measures and problems

As things stand at present, efforts to monitor ice and wet on the road surface and poor visibility are carried out using road management vehicles to check conditions and roadside sensors to measure conditions. The constant use of road management vehicles for monitoring, however, provokes a cost problem. Moreover, the use of roadside sensors to measure road surface temperatures is feasible in sections where road surfaces are subject to freezing, but it would be difficult to monitor all road surfaces.
(2) Expected effects
Road surface conditions change from moment to moment, therefore, they must be monitored constantly. Collecting vehicle sensor information from cruising vehicles makes it possible to estimate road surface conditions across a wide range in real-time. The provision of such information is expected to let safe driving information be communicated promptly to vehicles following behind.

(3) Necessary up-link data
Proving tests will be conducted and other such means will be used in order to verify the efficacy and accuracy of the data. The up-link information considered necessary for this service is as follows:
- Location and time information
- Road surface sensors, temperature and humidity meter
- Windshield wiper operation, ABS operation signal, vehicle stability control system operation information
- Information on status of fog lights and other vehicle lights
- Acceleration information (longitudinal, angular, lateral, etc.)

(4) Feasibility of service
It is also necessary to assess the efficacy of detecting road surface conditions in light of variation in the accuracy of the sensors of each vehicle. With the aim of realizing this service, its effectiveness will also be compared with that of roadside sensors, installation locations for the roadside equipment to be utilized will be investigated, and so on.

EQUIPMENT EVALUATION TEST
Configuration of test equipment and test items
The test was intended to realize the service described in above sections. The purpose was to conduct equipment evaluations of the DSRC Beacon and the on-board unit with DSRC (5.8-GHz band) up-link capability.
The test was carried out in February 2005 on the NILIM (National Institute for Land and Infrastructure Management of the Ministry of Land, Infrastructure and Transport) test course. The configuration and specifications of the test equipment are shown in Figure 4-6. The system uses the QPSK modulation method for DSRC.

The test items are as follows.
(1) Verification of up-linking
The functionality of the on-board unit in up-linking vehicle driving history information stored in the equipment was verified using the equipment's memory access function. The memory
The access function is defined as part of the basic application interface. The purpose of this application is to respond to requests from the DSRC Beacon by reading data from the on-board unit memory. The up-linked vehicle driving history is also analyzed using devices at the system center to investigate the system's capability to identify information on obstacles.

(2) Verification of communication capacity
Envisioning common use of the traffic information provision service or other such information provision system with the DSRC Beacon of the information collection system (up-linking system), the relationship between the downloadable and up-linkable data volume was verified in various vehicle speeds and other such conditions.

Figure 4-Configuration of test equipment

Figure 5-Scenes of testing
Test results

(1) Verification of up-linking
The ability of the on-board unit to up-link the vehicle driving history information stored in the equipment was verified using the memory access function of the on-board unit. The verification method was as follows.

・ The driving history information was stored in the on-board unit memory while the vehicle was driving on the test course.
・ The information was up-linked in the DSRC communication area.
・ The information sets before and after up-linking were compared to confirm that both information sets were identical to each other.

Next, it was examined whether evasive maneuvering of the vehicle was able to be detected. The result is that detection of evasive maneuvering is possible. The verification method was as follows.

・ The obstacle (the top of Figure 7) was placed on the test course.
・ The vehicle was driven on the course that would avoid the obstacle (the vehicle moves from
During this procedure, the information on vehicle location, time, speed, and direction was stored in the on-board unit at one-second intervals.

That information was up-linked and the location of the evasive maneuvering was identified. The results of this identification are shown in Figure 7, going from the top down, as the points of vehicle location (circle marks), speed (cross marks), and direction (arrow marks).

(2) Verification of communications capacity

The amount of data that the system is able to up-link was verified. The results are shown in Table 1. One example of the verification results shows 25 KB of data downloaded while the vehicle speed is 100 km/h. In that case, it was confirmed that 6 KB of data could be up-linked.

<table>
<thead>
<tr>
<th>Downloaded data volume</th>
<th>Up-linked data volume</th>
</tr>
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<tbody>
<tr>
<td>At vehicle speed of 20 km/h</td>
<td>At vehicle speed of 60 km/h</td>
</tr>
<tr>
<td>6 KB</td>
<td>20 KB or more</td>
</tr>
<tr>
<td>11 KB</td>
<td>20 KB or more</td>
</tr>
<tr>
<td>25 KB</td>
<td>20 KB or more</td>
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</tbody>
</table>

CONCLUSIONS AND FUTURE DEVELOPMENT

Three examples of cruise-assist services utilizing up-link information that can be considered effective services were presented. The proving tests making use of DSRC confirmed that the system is capable of up-linking vehicle driving history information by means of its memory access function. The test also proved that the system is capable of up-linking 6 KB or more of data in the condition of using the downloading function for a standard traffic information at the same time. The up-link service was shown to be feasible in terms of equipment performance.

The algorithm for detecting dangerous phenomena will be subjected to development evaluation and the methods for deploying DSRC Beacons (installation locations and intervals) will be investigated with the aim of early realization of practical services with up-link functions.

REFERENCES
