ABSTRACT

As same as many countries it is the one of the highest priority to optimize usage of existing road infrastructure under strict financial constraints in Japan. Therefore a Cooperative ITS called "ITS Spot Service" was launched nationwide in 2011 in order to make road transport safer and more efficient. More than sixteen hundreds of road side unit named "ITS Spot" were installed and three basic services have been provided via communications between ITS Spots and ITS Spot compatible on-board units.

This paper illustrates the outline of "ITS Spot Service" especially on its “Day-one applications” and shows the result of a series of user satisfaction survey on them.

Secondly, “Probe information utilization system” are explained, which make use of probe information collected by ITS Spot for efficient road management.

Finally, some ongoing R&D activities towards commencement of "Day-two applications" in the near future are reported.

KEYWORDS: Cooperative ITS, ITS Spot Service,
Therefore that will oblige road administrators to reduce their investment for constructions and improvement works of road infrastructure aiming to solve problems on the road network. Under such circumstance the role of soft countermeasures are becoming larger. Various ITS facilities and services have been gradually introduced in Japan in order to improve the service level of existing road network. For instance, Vehicle Information Communication System (VICS) has started its service in 1996 and been providing real time traffic information to drivers nationwide. The VICS users are able to choose their routes smartly with graphical image on the on-board navigation device, informing congestion routes, location of road work and accidents, and various informations about road traffic. Car navigation systems also can use real time traffic information to re-calculate the fastest route to the destination, and recommend it for its owners. Electronic Toll Collection (ETC) service is another ITS service which has been widely deployed nationwide. It has started in 2001 and the usage rate at toll gates on the expressways is 89.7 % and the number of passing vehicles is 6.74 million per day averagely as of January 2014.

Based on the successful deployments of the VICS and the ETC, National Institute for Land and Infrastructure Management (NILIM) under the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) Japan conducted “Joint Research” with some partners from private sector towards safer and more efficient road traffic. And eventually “ITS Spot Service” was developed as the next generation ITS service by MLIT in order to integrate VICS, ETC and additional safety support services [3]. It utilizes dedicated short range communication (DSRC) technologies between the unified OBU, named “ITS Spot-compatible on-board unit” (ITS Spot OBU) and roadside unit named “ITS Spot”, as shown in Figure 2(a). The DSRC technologies employed for the ITS Spot Service conform to the standards set of ISO15628.

In 2011, ITS Spots were installed at more than one thousand six hundred (1,600) locations mainly on expressways throughout Japan as Figure 2(b) shows. The ITS Spot Service, world-first operational Cooperative ITS service, was launched nationwide. As of January 31st 2014, more than 23 manufacturers deal ITS Spot OBUs and more than 220 thousand ITS Spot OBUs have been shipped into the market.
DAY-ONE APPLICATIONS OF ITS SPOT SERVICE

ITS Spot Service is a kind of Cooperative ITS so that it provides several applications. Figure 3 shows the applications of ITS Spot Service starting in 2011. Day-one service contains three main services for users, namely mobility service, safety service and ETC.

Mobility service consists of several applications such as dynamic route guidance, route selection support information in wide area, travel time information to destinations and still image information of traffic condition. Figure 3(a) shows examples of images on navigation display of mobility applications.

(b) Examples of image on car navigation screen of safety applications

Figure 3 Example of mobility and safety applications
Safety service also consists of several applications such as congestion tail information, caution on accident prone spot, caution on road works and obstacles, weather information, still image information of road surface condition and emergency information. Figure 3(b) shows examples of safety applications.

ETC service is fully compatible with existing facilities of the ETC service, which has been under operation since 2001 and its penetration rate at toll gates in the nation has reached around 90% averagely as above mentioned.

**RESULTS OF SATISFACTION SURVEY**

In order to evaluate effectiveness and find needs to be improvement of the day-one services of ITS Spot Service, MLIT has conducted satisfaction surveys throughout Japan [4]. Table 1 shows the number of answering respondents and occasions of the surveys. To conduct a monitoring survey using an online questionnaire system, approximately 700 ITS Spot-compatible car navigation systems were distributed to “monitors”, i.e. individuals such as general drivers, logistics service drivers, bus drivers, taxi drivers, and rental car drivers. 93% of monitors have more than 10-year experience of driving, and 40% of them drive daily and 80% of them drive more than once a week. As regard the monitors’ vehicle type, around 80% of them are passenger vehicles and the rest of them are commercial vehicles such as coaches and trucks. The degree of effectiveness of the services was surveyed, with the reasons and circumstances in which the services were evaluated as effective. The degree of effectiveness represents the ratio of people who experienced the services and evaluated it as “Very effective” and “Relatively effective”; that is, the ratio of monitors that appreciated the effects of the services.

<table>
<thead>
<tr>
<th>No.</th>
<th>Occasion of survey</th>
<th>Period after service commencement</th>
<th>Num. of answering respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sep. 2011</td>
<td>5 month later</td>
<td>430</td>
</tr>
<tr>
<td>2</td>
<td>Nov. 2011</td>
<td>7 month later</td>
<td>504</td>
</tr>
<tr>
<td>3</td>
<td>Jan. 2012</td>
<td>9 month later</td>
<td>495</td>
</tr>
<tr>
<td>4</td>
<td>Nov. 2012</td>
<td>19 month later</td>
<td>467</td>
</tr>
</tbody>
</table>

Figure 4 shows the result of the survey on major mobility services. “Dynamic route guidance” was received favorably by around 73%, “Route selection support information in wide area” was received favorably by around 58%, “Travel time information to destinations” was received favorably by around 67% and “Still image information of traffic condition” was received favorably by around 42%, in 2012. The reasons why the respondents evaluated the ITS Spot Services as effective were summarized as follows: “Being able to avoid congestions,” “Reduction in travel time” and “Sense of relief by informed the estimated arrival time.” “Dynamic route guidance” was evaluated by most of monitors as it was beneficial on routes that they drive for the first time rather than on their ordinal route. Besides, in the second year the degrees of effectiveness of each application increased compared with those of the first year. It is supposed that the more monitors experienced unfamiliar route or traffic situations, the more they appreciate usefulness of each application. In other words, the ITS Spot Services works effectively especially in unfamiliar circumstances.
Figure 4  Degrees of effectiveness of the mobility applications

Figure 5 shows the result of the surveys on major safety services. “Congestion tail information” was received favorably by around 84%, “Caution on accident prone spot” was received favorably by around 80%, “Caution on road works and obstacles” was received favorably by around 85%, “Weather information” was received favorably by around 80%, “Still image information of road surface condition” was received favorably by around 70% and “Emergency information” was received favorable by 100%, in 2012. The results indicate that the safety applications were valued over the mobility applications by users. The reasons why the monitors felt effectiveness were summarized as follows: “Being alerted of troubles ahead” and “Being able to slow down ahead of time.” Some drivers stated that “Caution on accident prone spot” was found the most beneficial in case they drove unfamiliar routes.

Figure 5  Degrees of effectiveness of the safety applications
EXAMPLE OF ANALYSIS USING PROBE DATA FOR ROAD OPERATORS

The radio communications between the ITS Spot and the ITS Spot-compatible car navigation is duplex so that ITS Spot can not only provide various informations to drivers but also collect information from vehicles in case each drivers gives a consent to upload what is called “probe information.” Figure 6 illustrates flow of probe information from the ITS Spot OBU via ITS Spots and the Probe server to road administrators/operators. The ITS Spot OBU has the capacity of storing and uploading probe information accumulated around 100km. The probe information uplinked to the ITS Spots can include data stored not only on expressways but also on ordinary roads, though most of ITS Spots are installed on expressways. Current probe information collected areas in Japan are also indicated in Figure 6. The probe information collected by the ITS Spots (ITS Spot probe) is composed of three records, namely, “Basic information,” “Travel records” and “Behavior records.” [5]

After the analysis of the business processes of road administrators, NILIM identified some candidate applications which might be executed with the ITS Spot probe, that is, “Travel speed survey,” “Congestion length survey,” “Routing study,” “Impact assessment of road works,” “Monitoring of unusual events on road network,” “Monitoring of trafficable route in case of disasters” and “Identifying near-accident prone spots.” Based on those candidates, NILIM developed a prototype system of “Probe information utilization system” considering necessary data volume, aggregation intervals, current data collection situation, etc. Table 2 lists the features of the prototype system. The prototype system and sample data was distributed among 9 regional development bureau offices of the MLIT and 6 expressway companies to be verified its performance and usability. NILIM conducted interviews and a questionnaire survey with whom the prototype system had been delivered so that it would be able to improve the system. In 2013 probe information utilization system has begun its

Figure 6  Schematic diagram of probe information collection system and collected areas
operation, with a multiple route selection function in addition to three applications of prototype system. Figure 7 illustrates examples of output of the application, “Sudden acceleration and braking point mapping.”

<table>
<thead>
<tr>
<th>Application</th>
<th>Outline of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time–space diagram writer</td>
<td>Aggregation of each DRM link section or average speed by hour of selected route, shown on the sheet and illustrated on the map in different colors</td>
</tr>
<tr>
<td>Required travel time tabulator</td>
<td>Aggregations of required time to follow the shortest route or selected route by section or time, as shown on the graphs.</td>
</tr>
<tr>
<td>Sudden acceleration and braking point mapping</td>
<td>Mapping points of the selected areas on a map to indicate locations where sudden acceleration &amp; braking occurred.</td>
</tr>
</tbody>
</table>

Figure 7  Examples of “Probe information utilization system” output

R&D TOWARDS DAY-TWO APPLICATIONS

Mobility application

In Japan, around 60% of congestion on the inter-urban expressways occurs at “Road sag” sections, where vertical road alignment are changing gradually to an upward grade. NILIM has been conducting study on and identified factors which cause congestions at sag section, that is, poor lane utilization due to traffic concentration in passing lanes, amplification and propagation of deceleration waves due to the formation of large, dense car groupings, unconscious deceleration due to the changing grade, and decreased traffic flow rates due to careless driving after congestion occurs [6][7]. NILIM, in cooperation with various automobile manufacturers, is therefore investigating ways of applying ITS Spot facilities to traffic-smoothing measures in areas of congestion due to road sag [8][9], as shown in Table 3. Figure 8 illustrates one of the concepts of congestion mitigation services, equalizing the gap between vehicles.
Table 3  Congestion mitigation services at expressway sag section

<table>
<thead>
<tr>
<th>Congestion cause</th>
<th>Service overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before congestion</td>
<td></td>
</tr>
<tr>
<td>Traffic concentration in the passing lane</td>
<td><strong>Service 1</strong> Equalize lane utilization</td>
</tr>
<tr>
<td>Formation of dense vehicle platoon</td>
<td><strong>Service 3</strong> Equalize the gap between vehicles</td>
</tr>
<tr>
<td>Unconscious speed drop at uphill sections</td>
<td><strong>Service 4</strong> Improve the platoon stability</td>
</tr>
<tr>
<td>After congestion</td>
<td></td>
</tr>
<tr>
<td>Delay in speed recovery after clearing the congestion</td>
<td><strong>Service 2</strong> Promote quick acceleration</td>
</tr>
</tbody>
</table>

Provide information to promote drivers to use cruising lanes
Use ACC to prevent the propagation of the deceleration wave to following vehicles
Achieves stable traffic flow with CACC using V2V communication
Provide information on the end of congested sections to promote drivers to recover their speed.

ACC: Adaptive Cruise Control, CACC: Cooperative ACC

Figure 8  Example of service concept (service 3)

Keep appropriate following gap and constant speed to prevent traffic breakdown.

Fundamental tests have been conducted at the test course of NILIM and at Tomei-Expressway by the research members. It is planned to introduce a part of above mentioned services as a day-two application of ITS Spot Services in the near future.

Heavy vehicle monitoring application

It is necessary to prevent inappropriate usage of road infrastructure by heavy vehicles which exceed designed weight load and size for each part of road facility in order to maintain them in good and long lasting condition. In Japan, it is required by a law that whoever planning to drive an over specification vehicle in terms of weight, size, shape and etc. to apply and to get a permission issued by the respective road authority. The permission regulates authorized routes, driving time, speed limit and so on. However, checking and monitoring activities enforcing the law have been inadequately conducted at limited number of places. In order to improve performance of measuring compliance degree of above mentioned permissions, MLIT has been promoting R&D of a heavy vehicle monitoring system which utilizes the existing ITS Spot Service facilities [10][11].
Following the past researches, it is planned to conduct a field test using the ITS Spot Service facilities and thousands of ITS Spot OBUs which would be equipped on heavy vehicles, starting in the first quarter of 2014. Through the field test, it will be verified that adequate probe information will be able to be collected properly via ITS Spot Service facilities for checking vehicle’s travel route, and to be merged effectively with other existing information from such as “Weigh in motion system” and “Heavy vehicle permission systems. After the field test and necessary institutionalizations, it is anticipated that “Heavy vehicle monitoring” will be added to the ITS Spot Service as one of its day-two applications.

SUMMARY

In this paper a Cooperative ITS called "ITS Spot Service" is outlined. Results of satisfaction surveys of day-one applications are reported. Probe information utilization system which support various analysis by road administrators is also explained. Besides, ongoing R&D activities towards commencement of "Day-two applications" in the near future are reported. Japanese cooperative ITS, ITS Spot Service, has been launched in 2011 with three main applications mainly for drivers. The number of ITS Spot OBUs has been continuously increasing so that additional applications which require a mass of ITS Spot OBUs on the road network are expected to be launched in the near future. Besides additional installation of ITS Spots especially along National Highways is desired to enable drivers to enjoy ITS Spot service at more locations, and road administrators to collect probe information from larger part of road networks which would be useful for efficient and effective road management.

REFERENCES