AHS for Making Traffic Flow Smoother by Optimizing Lane Utilization Rates at Expressway Sag Sections

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ABSTRACT

As part of the Next Generation Road Service 1) scheduled to start test operation in 2007, the authors are currently working on traffic smoothing services by optimizing lane utilization rates using AHS (Advanced Cruise-Assist Highway System) 2). To date, sag sections are focused, which are a main cause of traffic congestion on Japan’s intercity expressways. Utilizing AHS image processing sensors, time and spatially consecutive traffic phenomenon characteristics were grasped and analyzed. Based on the analysis, service proposal for a specific sag section was drawn up. Drivers’ acceptance of the service was proved by driving simulator tests, and proving tests on the actual sag section were conducted. This paper reports some of the testing results.

BACKGROUND

Looking at congestion occurrence on Japan’s intercity expressways, congestion caused by sag and tunnel sections comprise about half of all occurrences. Traffic smoothing countermeasures for such locations can be considered an issue of highest priority from here on.

When the amazing progress in information technology over recent years is considered, rather than hardware countermeasures over a wide range of roads, countermeasures that can be implemented at low cost to traffic operations is expected. Along with the development of sensing technology, it has become easy to automatically and continuously collect, process and create a large quantity of imaging data in real time, and an appropriate and diversified information provision service can use this data.
CONCEPT OF THE AHS SMOOTHING SERVICE

Following on from the above background, the authors have worked on developing a traffic smoothing cruise-assist service (AHS smoothing service, hereinafter) that uses the Advanced Cruise-Assist Highway System (AHS). The AHS smoothing service is designed to grasp the traffic condition on the overall road with sensors at the roadside, and provide information to drivers through ITS On-board Units and DSRC (Dedicated Short Range Communication) antenna positioned at the side of the road, to promote appropriate driving behavior with the aim of reducing congestion.

As part of the AHS smoothing service, the authors evaluated the practical application of the ‘lane utilization rates optimization service’ in sag sections that are main congestion locations on Japan’s intercity expressways. The lane utilization rates optimization service is designed to reduce congestion by realizing appropriate and effective use of capacity of each lane through delivering to drivers timely information with appropriate contents regarding concentration to passing lanes before congestion occurs, which is well known as a factor in causing congestion in sag sections. (Figure 1)

OUTLINE OF REALIZATION PROPOSAL FOR THE SERVICE TO OPTIMIZE LANE UTILIZATION RATES

Analysis and grasping of congestion causing factors in sag sections

In order to realize the lane utilization rates optimization service, the authors analyzed and grasped the traffic phenomena characteristics before and after congestion occurrence and the congestion creation factors through field work at the Yamato sag section (3 lanes for each direction) of the Tokyo – Nagoya (Tomei) expressway outbound from Tokyo.

Specifically, 13 fixed video cameras were installed along about 2 km of the sag section toward Tokyo and away from Tokyo to conduct continuous time and spatial observation of traffic flow. The results showed that before congestion occurs, 1) buildup on the passing lane already forms about 1.5 km upstream from the bottom of the sag section, and that 2) lane changing to the passing lane is frequent at the bottom of the sag section, and this is one factor causing the speed-reducing shockwave.

Proposal for service realization

Based on the above analysis, service methods were figured as lane utilization rates optimization services that were thought to be effective. Before congestion occurs, proposed countermeasure No. 1 is to provide information to urge changing to the cruising lane (to the left-hand lanes) before the sag section,
and proposed countermeasure No. 2 is to provide information to discourage changing to the passing lane (changing to the right-hand lanes) around the bottom of the sag section, in order to optimize lane utilization rates and to prevent the occurrence of the speed-reducing shockwave caused by lane change behavior. (Figure 2) These two countermeasures can be used together and the authors evaluated applying a service using both countermeasures.

The HMI (Human Machine Interface) of the information provision should be a simple diagram displayed on-screen in the vehicle, or combined with voiced information, but in selecting these options it is important to take into consideration driver psychology. That is to say, from the above observation results, observing that before congestion, the lanes from slowest to fastest are the first inside lane, the second inside lane and the outside lane, it cannot be denied that information provision urging lane changing to the left-hand lanes in this situation or urging maintenance of driving in the left lane has aspects of urging actions contrary to the driver’s private interests (the psychology of wanting to get to the destination faster). For this reason, it is considered effective to provide information “requesting cooperation to prevent congestion” that appeals to driver’s public mind for urging actions lead up to the public interest by allowing themselves lose little (are patient to runs slowly for a moment).

**EVALUATION OF SERVICE ACCEPTANCE BY USER TESTING ON DRIVING SIMULATOR**

**Test outline**

In order to implement the service proposed above on public roads, it is necessary to firstly verify the effectiveness of information provision (driver response ratio) and that it does not invite dangerous driving behavior. It is anticipated that the traffic situation surrounding the test driver at the time of information provision by this service will strongly affect the driver’s response, so a method using driving simulator ('DS' hereinafter) close to the real view and body feeling, and where the traffic flow scenario can be adjusted is considered to be effective.
From the viewpoint described above, driver trials were conducted using the simulation test environment at the Institute of Industrial Science, University of Tokyo (Figure 3) \(^4\). This simulation test environment combines the traffic simulator (hereafter ‘TS’) and the DS, and the traffic flow simulated on the TS can be applied to the DS so that the test driver can drive among the simulated traffic flow.

In this simulation trial, the simulation test environment was constructed by re-creating the traffic flow of high density on the TS with the actual observed data (traffic flow, speed and distance between vehicles for each lane) for 10 - 15 minutes before the traffic congestion on the Yamato sag section of the outbound Tokyo – Nagoya (Tomei) expressway, and generating the traffic flow on the TS as actions of vehicles surrounding the test driver’s vehicle in the driving environment of the road structure for the applicable section re-created on the DS. (Figure 4)

**Trial scenario**

Using the DS, 36 test drivers (male, in their 30s and 40s) driving in traffic flow of high density immediately before congestion occurrence were provided with the previously described information urging them to change lanes to the left or to stay in their current lane, using a combination of a simplified diagram on an on-board display and voice announcement. The test drivers did not know in advance that this information would be provided. They were in the trial scenario where they were requested to drive as usual and were free to change lanes.

The trial scenario is that each test driver runs twice with provided combination of two sets of information (Table 1), different contents (long or short voice announcement, no voice announcement), and the comprehension of test driver about the service announcement and relationship to lane changing action was compared for each variable. Whether or not the driver was induced dangerous driving behavior was also confirmed (negative check).

Before the trial, the degree of understanding and action intentions of about 1,000 users of the Tokyo – Nagoya expressway concerning

<table>
<thead>
<tr>
<th>Table 1 : Information Provided to Respondent Drivers</th>
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<tbody>
<tr>
<td><strong>On-board display screen</strong></td>
</tr>
<tr>
<td><strong>Move one lane to the left</strong></td>
</tr>
<tr>
<td><strong>Stay in current lane</strong></td>
</tr>
<tr>
<td><strong>Voice announcement</strong></td>
</tr>
<tr>
<td><strong>Long message</strong>: There is a congestion-prone area 2 km ahead. Congestion is presently starting to occur, beginning in the passing lane. Please cooperate by moving one lane to the left, where traffic is smoother, and driving in that lane even if speed is slow.</td>
</tr>
<tr>
<td><strong>Voice announcement provided</strong>: There is a congestion-prone section 1 km ahead. Please avoid changing lanes toward the right, and remain in current lane. In this section, the time difference between the cruising lanes and the passing lane is 20 seconds or less.</td>
</tr>
</tbody>
</table>
various information messages was surveyed by Internet survey, and the screen display and voice announcement with a high acceptance result were selected. 5)

**Trial results**

From the DS driving record and survey results after driving, analysis and negative check of the influence of differences due to long or short message or no message were conducted, with the following results obtained.

**Information provision urging lane change to the left**

* In 58 times (81%) out of a total of 72 times driving, the driver changed to the left-hand lanes after receiving the information. Reasons given for not changing lanes often included: “I understood the message, but I thought that my current lane was faster.”, and “The distance between cars in the next lane was short and I lost the opportunity to change lanes.”

* Those who changed lanes with the intention of “co-operating with preventing congestion” occurred in 39 times driving, 54% of total driving.

* Those who correctly understood and changed to the left-hand lanes was 74% (21 times out of 29 times driving) for the long voice message, and 64% (18 times out of 28 times driving) for the short voice message, with the ratio slightly higher for the long message, but no significant difference.

* Ease of listening to the message is better for the short message. Concerning the long message, some test drivers complained of the impression that it was “annoying” and “distracts from driving operation”.

**Information provision urging staying in the current lane**

* Among the 29 test drivers (58 times driving) who changed to the left-hand lanes upstream (before sag section), those who later changed to the right-hand lanes downstream (immediately before sag) comprised 31% (9 times out of 29 times driving) who received information to urge staying in the current lane, and 55% (16 times out of 29 times driving) who did not receive this information.

* Drivers who changed to the right line despite information provision to maintain the same lane (9 drivers) either changed lanes before the information provision or after it was completely finished, and while the screen was displayed (about 30 seconds) all drivers maintained the same lane.

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**Figure 5 : Reasons to Move to the Left-hand Lane**

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**Information provision urging staying in the current lane**
Negative check at the time of information provision

* There were no cases where the information provision puzzled drivers or induced drivers to take dangerous driving behavior such as accelerate sharply, swerve sharply or force their way into an inadequate gap. (In all drives, the acceleration or deceleration speed directly after information provision was within ±0.1 G. See Figure 7.)

* The safety index TTC (Time to Collision, the time until collision with the vehicle in front if your vehicle continues at the same speed when the other vehicle stops) generally has 2 seconds as the safety level, but many of the test drivers kept a gap of 10 seconds or more, and 2 seconds or less was not found, so it can be said that there was no dangerous actions.

Evaluation of service acceptance

For information provision urging lane change to the left upstream, about half of test drivers indicated “cooperation with congestion reduction” and changed to the left-hand lanes, so it can be said that a high level of comprehension and response rate was achieved. Furthermore, considering also that dangerous driving behavior due to the information provision was not observed, it can be considered that the possibility of acceptance of this information provision system by drivers was confirmed. And for information provision urging lane change to the left upstream, almost no difference was found in the comprehension level or response rate between the long and short voice message, but from the viewpoint of being easy to hear, the short message has higher acceptance. On the other hand, for information provision urging to maintain the same lane downstream, as expected having the voice information message showed high understanding and response rate, and it can be said that its effectiveness has been confirmed by the fact that all drivers maintained the same lane while the screen displayed the message.
As described above, as an overall evaluation, it can be said that the possibility of this information provision service being accepted by drivers has been confirmed, but the attributes of the trial subjects were limited to a specific gender and age groups due to limitations of the experimental scale, so expansion of the subjects’ attributes in future is an important issue for generalizing from the results of this time. And it is so necessary to further evaluate the HMI (information provision method, timing, statement contents, etc.) in order to appropriately convey to the driver the interval that lane maintenance or lane change to the left is requested with the aim of optimizing lane use, considering possibility that disappearance of the screen display can be interpreted as “end of lane maintenance interval”.

After this drive trial using DS, the authors tested the same contents by conducting trial driving on public roads. In order to maintain safety, driving is done during times when traffic volume is comparatively light, and survey staff rides in the vehicle with the driver, using the method of manually providing information installed beforehand into the on-board unit inside the vehicle. Under these conditions, almost the same level of service acceptance is confirmed as for the driving trial using DS.

**FURTHER ISSUES**

Following on from the above results, further driver trials will be conducted under conditions of different traffic volume and test driver characteristics on the simulation test environment (TS-DS trial) and on public roads. And further evaluation will be conducted regarding HMI of information provision, and system development will proceed towards trial introduction. The system configuration as shown in Table 2 and the following basic algorithms are being considered for service implementation.

* The traffic condition just before congestion is grasped by sensors at upstream and downstream, and the service will be provided when a change is detected from a dispersed condition to a congestion condition through periodic judgment using traffic volume, speed and lane occupancy rate.

* Also, using at the same time judgment triggered by the occurrence of an event such as a speed-reduction shockwave, the service will end when excessive lane changing or a change to a congestion condition is detected.

<table>
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<tr>
<th>Component device</th>
<th>Function outline</th>
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<tbody>
<tr>
<td>Laser-type AHS sensor</td>
<td>Installed on sag sections. Measures traffic volume, speed-reduction shockwave, and congestion at 1-minute intervals.</td>
</tr>
<tr>
<td>Image sensor</td>
<td>Installed near service start position, before the sag section. Measures traffic volume, speed-reduction shockwave, and congestion at 1-minute intervals.</td>
</tr>
<tr>
<td>Roadside processing device</td>
<td>Using detection results from each sensor, judges the start of service to the end of service.</td>
</tr>
<tr>
<td>Road-vehicle communication device</td>
<td>Information is transmitted to ITS On-board Unit inside the vehicle with 5.8GHz DSRC-antenna. (ITS On-board Unit possesses a store and forward function that it holds information temporarily and provides at assigned positions.)</td>
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</tbody>
</table>

*Separately, information provision is planned using a LED sign vehicle or movable LED display panel.

And it is possible to adjust the issuance location of each message by using a store and forward function (see Tab 2) on the ITS On-board Unit, so that the parameters such as the threshold value to judge the traffic condition, lane change invitation interval length and lane maintenance interval length can be optimized through verification and application in the scheduled public road tests.
SUMMARY

As part of tackling realization of the traffic smoothing service by AHS, this paper reports test results of a lane utilization rates optimization service for sag sections on intercity expressways. Specifically, based on results from grasping and analyzing traffic phenomena characteristics and congestion occurrence factors, specific proposals have been made for the method and contents of an information provision service. Preceding verification tests on public roads, drive trials were conducted using a simulation test environment (TS-DS trial) and the possibility of acceptance by drivers was confirmed. Also, effective views about HMI were obtained concerning the image and voice information message from OBU.

This information provision service is contrary to driver psychology of “wanting to drive fast”. It requests cooperation to prevent traffic congestion. It is difficult to accurately reproduce such driver psychology in a virtual test environment and driver trial. Thus, verification is required in social tests involving ordinary road users. During 2007, evaluation will proceed toward test introduction of the system on public roads, together with social testing.

REFERENCES


