A FIELD TRIAL OF A HIGHWAY BUS LOCATION SYSTEM UTILIZING DSRC

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1. Overview

A bus location system collects real time information on the position of buses on their routes by determining the location of each bus through GPS. In addition to giving useful information to bus companies in managing their operations, information on the status of a bus on its route can be provided to bus riders. The means for transmitting this information is packet transmission via cellular phones.

For the trial we conducted, we configured a bus location system using 5.8GHz-DSRC road-vehicle communication, in addition to packet transmission. We also worked to improve the accuracy of transit information by obtaining passage information from on-board ETC devices in addition to probe data on trajectory history.

2. Bus Transport Revitalization Project

2.1 Status of the Introduction of Bus Location Systems in Japan

As of 2004, bus location systems were installed on 28% of bus routes in Japan. This figure, however, only totaled 5% for express bus routes (approximately 4,000 buses in operation). Of the total 8,300km of motorway on which express route buses traveled, routes with installed bus location systems accounted for only 1,300km (16%), showing that the installation of bus location systems lags behinds that for regular bus routes.

Moreover, the environment for bus transit in urban areas has deteriorated due to chronic traffic jams, and nationwide, people are increasingly more...
reluctant to take buses. The number of passengers transported by bus has declined approximately 30% over the past 10 years, from 6.5 billion people in 1990 to 4.5 billion people in 2002.

However, according to a survey of areas in which bus location systems have been introduced, 20-30% of the bus riders say they have been riding the bus more often after the system was introduced and that they had switched their transportation modes from their own autos to buses (Figure 1).

2.2 Rolling Out the Bus Transit Revitalization Project

Japan’s Ministry of Land, Infrastructure and Transport has been working on the Bus Transit Revitalization Project since fiscal year 2005 as a joint initiative of auto transport and road authorities. This is part of a comprehensive effort to revitalize bus transport and to achieve a barrier free society, an improved environment, and revitalization of local communities. Measures to achieve this include the three cornerstones of reducing bus waiting times through the introduction of a bus location system using ITS technology; improving the environment for bus transit through such means as restricting the use of personal cars, expanding priority/exclusive bus lanes and resolving traffic jams; and promoting the improvement of bus infrastructure by installing bus stop shelters, an information system for transfer, etc.

Through the Bus Transit Revitalization Project, it is hoped that installing a bus location system on express route buses will lead to the revitalization of bus transit system, and the project is providing across-the-board support for the introduction of this system. This field trial is one step in this project, the aim of which is to reduce bus waiting times and improve the environment for bus transit through the trial introduction of a system utilizing DSRC technology.

3. Express Bus Location System Utilizing DSRC

3.1 System Overview

The bus location systems installed in various cities throughout Japan primarily use packet transmission via cellular phone as the communication method for collecting transit information from each bus. The express route bus
location system configured for this pilot study uses 5.8GHz-DSRC road-vehicle communication instead of packet transmission on expressways (Figure 2).

Information on bus trajectory is collected via DSRC transmission through on-board ITS devices installed on the buses and wireless devices installed roadside along the expressway (approximately every 5-10 kilometers). This data is transmitted to a server in the bus center and information on the current operational status of the bus and its estimated time of arrival is transmitted back to an information display at bus stops and over the Internet to PCs and cellular phones. The information collected by the bus center server is also used by bus companies for their management of operations.

The use of DSRC, which incurs no transmission fees, enables a reduction in running costs. In addition, since probe data of each bus’s trajectory (position and time), which is collected every second or every 15 meters, can be obtained, it is possible to grasp traffic conditions in more detail than ever before.

3.2 Effective Use of Existing On-Board ETC Devices

The roadside wireless devices (beacons) on the expressways collect probe data of the ITS devices on the express route buses; in addition to this, they also obtain passing information from an on-board ETC device installed in each vehicle (LID: Randomized IDs for devices installed in vehicles for privacy protection purposes; bears no relation to toll charges), thereby utilizing a parallel running method.

Each roadside wireless device consists of a mechanism that controls two frequency bands for ITS probes and ETC probes (Figure 3).
We expect to improve the accuracy of bus transit information by obtaining passage information from the on-board ETC devices and probe data from the on-board ITS devices.

4. Utilizing the Data Acquired to Improve Road Management

The express route bus location system configured for this field trial is a practical experiment in improving the systems for more sophisticated road management and traffic control for the future. We have therefore enabled the calculation of expressway travel times and detection of abnormal traffic flows on the central server.

4.1 Calculation of Travel Times

Travel time between beacons, link travel times, travel time between interchanges, and travel time between bus stops can be calculated.

Travel time between beacons, installed at 5-10km intervals, is calculated based on beacon passage information from the on-board ETC devices (LID) installed on regular vehicles.

The link travel times are calculated for each link (a section of about 100 meters) at one second intervals, smoothing passing data from on-board ITS devices, including cumulative data from the past (Figure 4, left). This is supplemented by the calculated results of travel time between beacons when there is insufficient passing data.

The travel time between interchanges and the travel time between bus stops are calculated at one minute intervals by collecting the results calculated for link travel times (Figure 4, right). Linear interpolation from the travel times for the adjacent link is used when a link segment does not have a valid link travel time.
It is possible to display the travel times calculated by the central server on operating monitors as a summary chart of past and current times. It is also possible to display travel times between interchanges and average speeds on a road diagram (Figure 5).

**Calculation of Link Travel Time**
- Smoothing of trajectory records from on-board ITS, including past data.
- Travel time for each link (Calculated at one second intervals, about every 100 meters).
- When a valid travel time for a link is not available, it is derived through linear interpolation of the travel times for the adjacent links.

**Calculation of Travel Time between Interchanges**
- Travel time between interchanges calculated at one-minute intervals (Travel time between bus stops is calculated in the same manner).

Figure 4: Conceptual Diagram of Calculation of Travel Time by Central Server

Figure 5: Diagram of Travel Times between Interchanges Displayed on Road Diagram (an example)
We have configured the system to enable the creation of a spacial variation graph that shows cumulative results for designated beacon intervals by calculating link travel times in the central server (Figure 6). The horizontal axis shows the distance while the vertical axis shows cumulative travel time.

We have also enabled the creation of graphs showing time variation for travel speeds between interchanges (horizontal axis, time; vertical axis, travel speed).

4.2 Detection of Unusual Traffic Flow

Various types of existing sensors have been used to detect unexpected phenomena (accidents, falling objects, etc.) and provide information on these; however, detection is limited to the narrow area surrounding the sensor.

The use of trajectory data, however, shows us the behavior of each vehicle in the course of cruising. This has enabled us to capture conventionally unobtainable traffic conditions such as the point at which vehicles changed lanes to avoid an unexpected event or segments of road jammed with traffic. These factors are expected to lead to greater efficiency and rapid improvements in the systems for road management and traffic control.

Figure 6: Spacial Variation Graph (an example)
The central server can be used to detect unusual traffic flow through five different methods: abnormalities in LID travel time; abnormalities in vehicle running paths; abnormal distribution of trajectories (avoidance); abnormal vehicle behavior; and beginning and ending points of traffic jams (decided by the deceleration and acceleration of vehicles) (Figure 7).

<table>
<thead>
<tr>
<th>Determining Criteria</th>
<th>Detection Summary</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormalities in LID travel times</td>
<td>Discerns decreases in travel speed and blocked lanes from results calculated from travel times between beacons by LID</td>
<td>Excludes time periods with extremely light traffic volume</td>
</tr>
<tr>
<td>Abnormalities in vehicle running paths</td>
<td>Determines abnormalities from past (statistical results) and present vehicle position (traverse direction)</td>
<td>Accuracy of coordinates is sufficient for lane width direction</td>
</tr>
<tr>
<td>Abnormalities in trajectory distribution(avoidance)</td>
<td>Discerns deviation from past (statistical results) and present vehicle position distribution (traverse lane)</td>
<td>Coordinates must be sufficiently accurate for lane width direction</td>
</tr>
<tr>
<td>Abnormalities in vehicle behavior</td>
<td>Discerns abnormal values from information on acceleration rate and angular velocity gathered within</td>
<td></td>
</tr>
<tr>
<td>Beginning and end of traffic jams</td>
<td>Discerns when deceleration exceeding a fixed value has occurred in between road links</td>
<td></td>
</tr>
</tbody>
</table>

![Diagram](image1.png)  ![Diagram](image2.png)

**Figure 7: Overview of the Detection Function for Abnormalities in Traffic Flow**

The detection of abnormalities in LID travel times discerns a reduction in travel speed and lane blockage from the changes in travel times between beacons. This is calculated from beacon passing information (LID) from onboard ETC devices.

Abnormalities in vehicle running paths are detected by comparing the current path of a traveling vehicle with the standard path derived from past statistical results. Segments (links) where lateral discrepancies occur are judged as links with abnormal a path.

Abnormalities in trajectory distribution (avoidance) are detected by comparing the distribution of the current trajectory with the past statistical results. Deviations in the trajectory are determined from the distribution width of traverse lane changes.

Abnormalities in vehicle behavior are derived from information on vehicle acceleration rate and angular velocity, compiled for a specific time period. This detects vehicle behaviors showing abnormal values.
Detection of the beginning and end of traffic jams (decided by the deceleration and acceleration of vehicles) is determined by deceleration in speed beyond a specified value. This detects the beginning and end of a traffic jam.

It is also possible to set detailed parameters for the determinant conditions for each of the detection methods.

It is possible to display abnormal traffic flow phenomena detected by the central server on operating monitors as a summary of past and present events. It is also possible to display the occurrence of current road obstructions on a road diagram (Figure 8).

5. Future Development

We are using this field trial under actual traffic conditions to evaluate the effectiveness of this express route bus location system, verify the methods of communication, and assess practical applications.

We plan to continue to explore the expanded introduction of the bus location system and development of technology to provide information on roads and traffic using 5.8GHz-DSRC, based on the results of this evaluation.