APPLICATION OF PROBE DATA COLLECTED VIA INFRARED BEACONS TO TRAFFIC MANEGEMENT

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ABSTRACT

This paper describes a study of using probe data for traffic management. We equipped nearly one hundred taxies traveling around the center of Yokohama City with onboard units. The onboard units communicate via infrared beacons on the roadside to allow the collection of the probe data transmitted from the equipped vehicles. The results suggest that the probe data of only one hundred taxies can be successfully applied to traffic management if probe data are accumulated for sufficiently long periods of time and are used in combination with vehicle detector data.

INTRODUCTION

In Japan infrared beacons have been widely and rapidly installed since early 1990s with the advancements of Intelligent Transport Systems (ITS), with approximately 51,000 units on arterial roads. Through the two-way communication between infrared beacons and vehicles equipped with onboard units, the passing vehicles can be detected and data can be transmitted. Traffic Control Center collects information such as vehicle identification number and travel time via the beacons for traffic management purposes. Universal Traffic Management Society of Japan (UTMS Japan) has been actively working on various research by utilizing such special capabilities of the beacons.

The core functions of an urban traffic control system are signal control and information provision. To fulfill these functions, it is necessary to collect information of road traffic conditions. In the existing system, traffic flow has been observed mainly by vehicle detectors installed on arterial roads. The detectors enable the measurements of traffic volume and time occupancy, then to generate traffic attributes including congestion length, travel time and others. It should be noted, however, that such information is only available from arterial roads installed with the detectors.

On the contrary, there have been innovative and new approaches for traffic data collection recently. The new approach is based on the use of probe vehicles to collect travel data with the recent development of onboard units with a new capability to store large capacity of travel records. The advantage of probe data is that it enables traffic administrators to observe road traffic conditions of ordinary roads including local streets, where no additional vehicle detectors are required to be installed. Due to this advantage, there have been great expectations for the developments and implementation of the new concept. Originally, UTMS Japan had worked on research to use mobile phones as a communication media to obtain probe data [1]. Later, UTMS Japan decided to utilize the infrared beacons that have been deployed at many locations, which eliminates the high communication costs of mobile phones [2]. This paper examines the travel conditions of prove vehicles, and describes the feasibility of making use of this data for traffic management.

EXPERIMENTS

EXPERIMENTAL SYSTEM

An experimental system has been constructed at Traffic Control Center of Kanagawa Prefectural Police Headquarters [6]-[8]. Figure 1 illustrates the overview of the experimental system [9]. We equipped nearly one hundred taxies traveling around the center of Yokohama City with onboard units. The feature of our approach is that the travel records including the latitude and longitude of each vehicle at every second or fifteen meters are compressed in the onboard units and transmitted to Traffic Control Center via infrared beacons. The Traffic Control Center receives and decompresses the compressed the data, from which the travel trajectory and traffic condition of roads can be reconstructed [2]-[5].

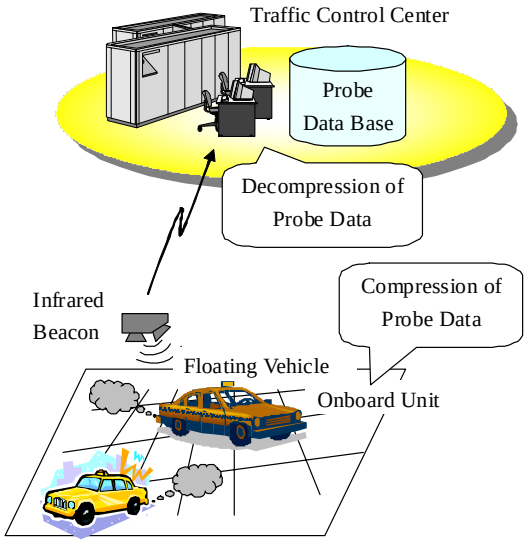

Figure 1 Overview of experimental system.

TRAVEL STATUS OF PROBE VEHICLES

The data used in these experiments were collected for six months from mid June through mid December 2007, and from early March to end of August 2008, respectively. Subsequently data were analyzed. First, to grasp actual travel conditions of probe cars, we conducted a survey on their operating status during the period. Figure 2 shows the fluctuation of the number of traveling vehicles with the change of time of day. The average number of traveling vehicles was 71.5 throughout a day while the number stayed around eighty vehicles from 11:00 to 2:00 midnight. Figure 3 describes the total travel distance by month, indicating that the ratio of the arterial roads was 83.3%, in other words, most vehicles traveled arterial roads. Figure 4 and 5 illustrate the total distance for each day and road type, respectively. The daily travel distance of a probe car turned out to be 90.0km on the average, with the maximum of 151.7km. Figure 6 gives the fluctuation of average speed for each road type. The average speed turned out to be 29.2km/h, 29.9km/h and 25.3km/h for all roads, arterial roads and the others, respectively [9].

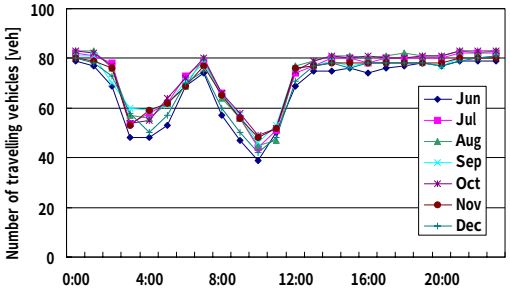

Figure 2 Number of traveling probe vehicles.

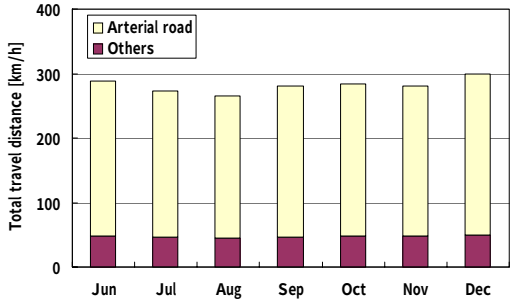

Figure 3 Total travel distance by month.

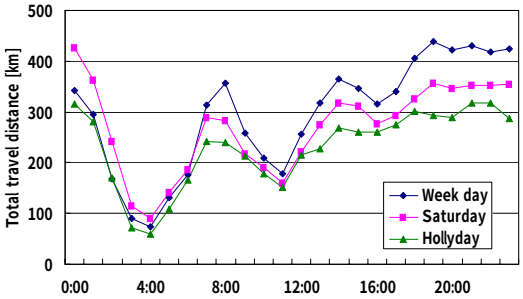

Figure 4 Total travel distance for each day type.

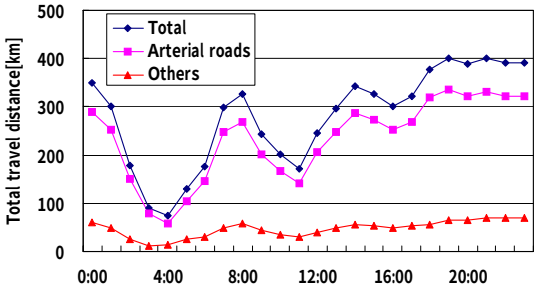

Figure 5 Total travel distance for each road type.

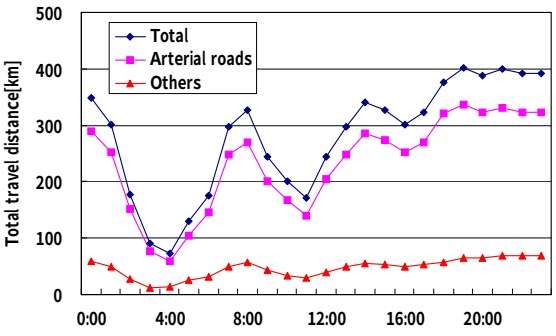

Figure 6 Average speed for each road type.

ANALYSIS OF TRAFFIC INDEXES

TRAVEL TIME

Travel time is one of most important traffic information. It is usually estimated based upon vehicle detector data, and applied to provision information system called VICS (Vehicle Information and Communication Systems). To verify the travel time calculated by probe data, this paper examined the difference between travel times provided VICS and obtained by probe data. Figure 7 and 8 show the fluctuation of the travel times on inbound and outbound direction on National Highway Route 16, respectively. Figure 9 illustrates the travel times on inbound direction on Kamakura-kaido. The ratios of root mean squared errors in these Figures are 15.7%, 14.2% and 17.2%, respectively based on an assumption that VICS travel time is the ground truth. Figure 10 gives the comparison of travel times on inbound Hirato-sakuragicho-sen, and the correlation coefficient is 0.80. These results do not necessarily secure sufficient accuracy. In future we would be overcome with long-term data storage.

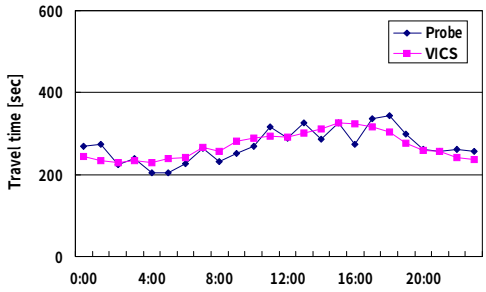

Figure 7 Comparison of travel times on inbound direction on National Highway Route 16.

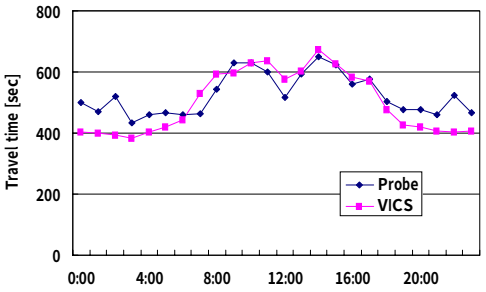

Figure 8 Comparison of travel times on outbound direction on National Highway Route 16.

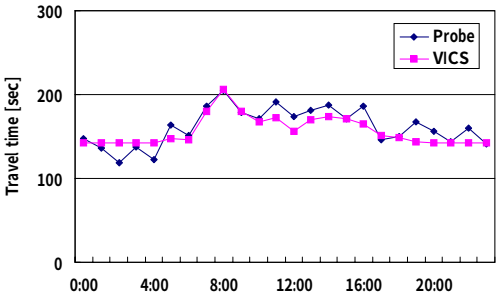

Figure 9 Comparison of travel times on inbound direction on Kamakura-kaido.

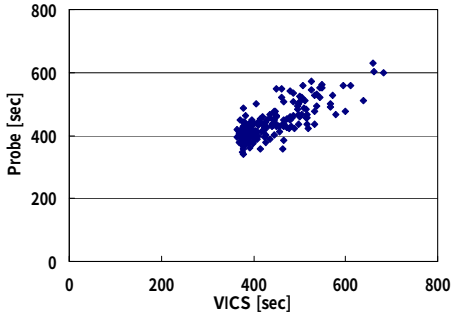

Figure 10 Correlation between travel times on inbound direction on Hitato-sakugagicho-sen.

TOTAL DERAY TIMES

Furthermore, using probe and vehicle detector data, we computed total delay time and examined a correlation between the delay and time occupancy obtained from vehicle detectors. Total delay time d_{ij} at phase i and approach j of an intersection is calculated using traffic volume q_{ij} measured via vehicle detectors and travel time t_{ij} obtained from probe data. The calculation follows the equation (1) as written below;

$$d_{ij} = q_{ij}(t_{ij}^0 - t_{ij}) \quad \cdots\cdots (1)$$

where $t_{ij}^0 = 0$ denotes criteria travel time at a regulation speed and $d_{ij} = 0$ if $t_{ij}^0 < t_{ij}$.

Figure 11, 12 and 13 describe the fluctuation of the total delay time of the Bando-bashi, Chojamachi-gocho-me and Hatsune-cho Intersection, respectively. The total delay time in these figures were calculated using the data collected in 2008. Table 1 gives the correlation coefficients of these intersections between the delay and time occupancy. These results show the correlation coefficient of each intersection was relatively high.

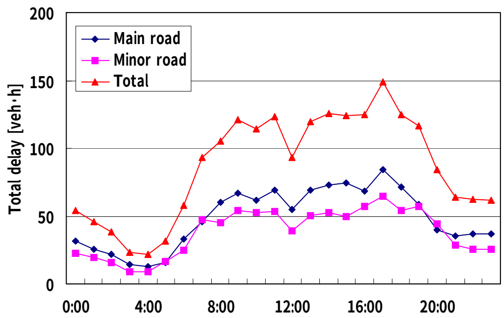

Figure 11 Total delay at Bando-bashi Intersection.

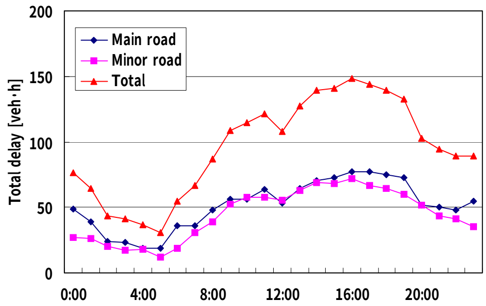

Figure 12 Total delay at Chojamachi-gocho-me Intersection.

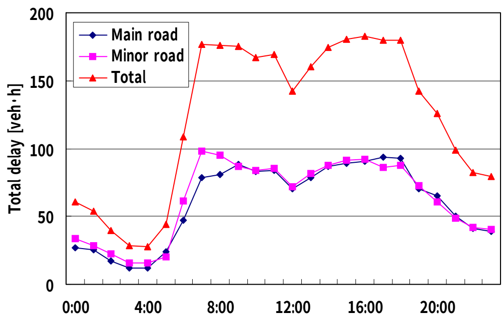

Figure 13 Total delay at Hatsune-cho Intersection.

Table 1 Correlation coefficient between time occupancy and total delay.

Intersection	Correlation Coefficient	
	2007	2008
Bando-bashi	0.77	0.70
Chojamachi-gocho-me	0.76	0.77
Hatsune-cho	0.85	0.68

CALCUILATION OF SIGNAL CONTROL PARAMETRES

USING PROBE DATA

Using the total delay time, we also computed split which is a critical factor in signal controlling. The split λ_i of phase i denotes a period time allocated to each phase in a cycle time, and is calculated based on the equation (2):

$$\lambda_i = \frac{\max_j d_{ij}}{\sum_i \max_j d_{ij}} \quad \cdots\cdots \quad (2)$$

where $\sum_i \lambda_i = 1$.

Figure 14 and 15 show the splits of major and minor roads at Bando-bashi and Chojamachi-gocho-me Intersection, respectively. These are calculated using the data collected in 2008. Figure 16 and 17 illustrate the comparison of operational and calculated splits of major road, respectively. As shown in these Figures, we succeeded to obtain values that are close to the actual operational values. We anticipate to conduct further studies based on collected data sets.

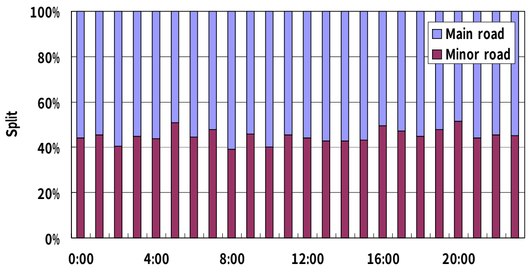

Figure 14 Split calculated based on probe data at Bando-bashi Intersection.

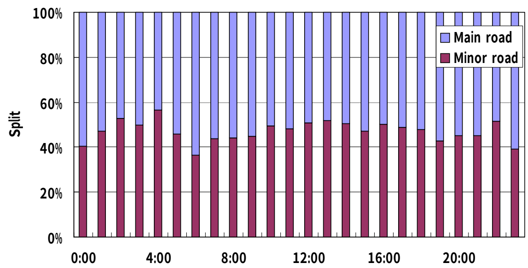

Figure 15 Split calculated based on probe data at Chojamachi-gocho-me Intersection.

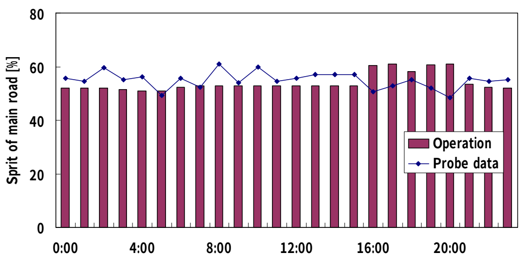

Figure 16 Comparison of operational and calculated splits of major road at Bando-bashi Intersection.

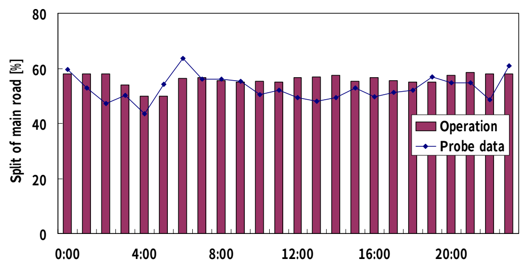

Figure 17 Comparison of operational and calculated splits of major road at Chojamachi-gocho-me Intersection.

CONCLUSIONS

In this paper, we analyzed probe data collected via infrared beacons to reveal the travel status of probe vehicles, and calculated several traffic indexes and signal control parameters to explore the feasibility of using probe data for traffic management purpose. Additionally, we examined the validity of the calculated data by comparing it with existing measured and operational data. The results suggest that the probe data of only one hundred taxies can be successfully applied to traffic management functions if probe data are accumulated for sufficiently long periods of time and are used in combination with vehicle detector data.

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