

Evaluation of Measured Travel Time Utilizing Two-way Communication in UTMS

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ABSTRACT

UTMS (Universal Traffic Management Systems) totally manages and controls traffic flow to make it safe and smooth, and utilizes a two-way infrared communication between the infrastructure and vehicles carrying infrared vehicle detectors. Using these functions, UTMS can measure travel time by matching vehicle identification numbers, which are received as up-link information from infrared vehicle detectors. In order to evaluate the validity of this system, a UTMS Experiment was conducted in main routes in Kanagawa Prefecture, Japan. Considering the results of these evaluations, travel time using up-link information from in-vehicle units to infrared vehicle detectors was confirmed to be useful and effective for practical use.

1. INTRODUCTION

In Japan, for more than twenty years, traffic control systems have been introduced to solve traffic problems arising from a rapid progression of mobility, produced by the economic construction of the 1960s. These systems have made significant contributions toward smoother-flowing, safer, and more pleasurable driving by utilizing signal controls to aid vehicular traffic. However, limited space, and unceasing population growth in urban areas has created constant increases in traffic congestion, and this has prompted persistent requests that existing traffic control systems be improved.

In response, traffic information transmission systems have been erected in order to inform drivers about traffic conditions by utilizing roadside broadcasting and variable message sign boards. These systems do not transmit the most eagerly desired details, however. Specifically information regarding travel time between point of origin and destination is what travelers desire. In order to measure travel time, equipment has been developed, but installations has been limited. Another handicap concerning existing systems has been that different drivers request a wide variety of traffic information details of traffic information according to their destinations.

Therefore, new equipment which can recognize vehicle identification numbers and transmit traffic information to each driver is an absolute necessity. To solve these difficulties, the Universal Traffic Management Society of Japan is promoting UTMS (Universal Traffic Management Systems) Projects, in which a dual function utilizing an infrared vehicle detector is being developed. One function would measure traffic volume similar to today's conventional detectors, and the second would collect vehicle identification numbers and transmit detailed traffic information to individual drivers, by communicating directly to the in-vehicle units the cars are equipped with.

An advanced traffic information transmission system, AMIS (Advanced Mobile Information System); one of the UTMS subsystems, is currently being constructed using these superior infrared vehicle detectors. AMIS can measure travel time by matching vehicle identification numbers, received as up-link information from infrared vehicle detectors, and transmit traffic information to each driver. In order to evaluate the validity of this system, a UTMS Experiment was conducted on main routes in Kanagawa Prefecture, Japan.

2. UTMS OVERVIEW

UTMS seeks to join together six subsystems: ITCS (Integrated Traffic Control System), DRGS (Dynamic Route Guidance System), PTPS (Public Transportation Priority System), MOCS (Mobile Operation System), EPMS (Environment Protection Management System) and AMIS. Figure 1 shows the overall structure of UTMS. AMIS will measure travel time and provide drivers with real-time traffic information, so they can have advance notice of traffic jams and drive comfortably within the road network.

Traffic information collected by central computers will be transmitted to in-vehicle units individually from roadside infrared vehicle detectors. These infrared vehicle detectors will also transmit dynamic route guidance information to in-vehicle units in a timely fashion in response to individual drivers' requests.

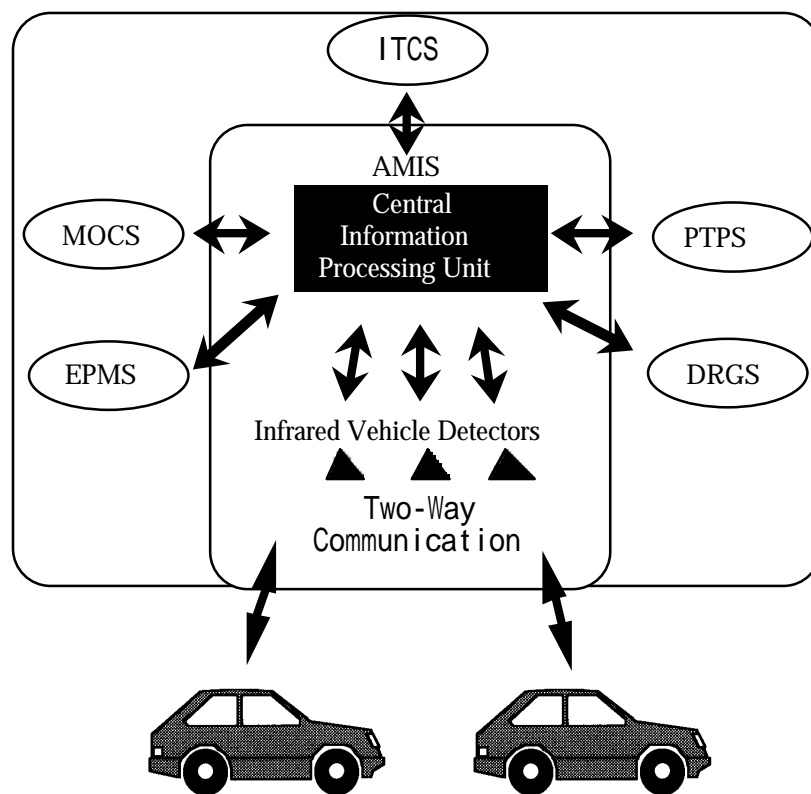


Figure 1 Overall Structure of UTMS

3. UTMS EXPERIMENT

3.1 Method of Analysis

The purpose of the UTMS experiment is to verify the validity of the calculated travel time by matching vehicle identification numbers which are received as up-link information from infrared vehicle detectors. This experiment was

conducted on National highway 1 toward up and down town in Yokohama and Kawasaki in Kanagawa Prefecture on the western shore of Tokyo Bay, adjacent to Tokyo. The total length of the experimental course was twenty two kilometers, and thirty infrared vehicle detectors were installed at main intersections along the course. One hundred probe-cars were equipped with up-link in-vehicle units, and driven along the experimental course. Infrared vehicle detectors collected vehicle identification numbers which were received as up-link information from passing probe-cars and transmitted to the Traffic Control Center of Kanagawa Prefectural Police Headquarters, where travel time was calculated every five minutes by matching vehicle identification numbers. In parallel with calculation of travel time using communication between infrared vehicle detectors and in-vehicle units, the actual travel time for all vehicles including probe-cars was measured by AVI (Automatic Vehicle Identification) equipments every five minutes. Using this information, the difference between calculated and actual travel time was examined from the two points listed below;

- (1) effects of the composition of the experimental course section and passage of the time in calculating travel time
- (2) effect of the ratio of vehicles equipped with in-vehicle units

3.2 Experiment System

The experiment system configuration is shown as Figure 2.

3.2.1 Central systems

Central Systems are composed of the traffic information host computer, traffic information front-end processors and information monitors, all combined with the LAN (Local Area Network). The traffic information host computer is connected to existing traffic control systems so traffic congestion information and other data can be transferred. Major functions to be conducted by each unit are as follows: the function of the traffic information host computers is to collect travel time calculated by the traffic information front-end processor; including traffic congestion data, traffic regulations and traffic accident data; then edit this traffic transmission information as down-link information for provision to each infrared vehicle detector. The function of the traffic information front-end processor is to receive such up-link information as vehicle identification numbers from infrared vehicle detectors, then calculate travel time matching these identification numbers. Additionally, it should collect down-link information edited by the traffic information host computer and send that data to each infrared vehicle detector. The function of the information monitor is to display traffic congestion information, travel time and other data on the in-vehicle units, and support setting up, or up-dating related parameters.

3.2.2 Local systems

Local systems, consisting of multiplexers/ transmitters and infrared vehicle detectors, exchange data between the central and in-vehicle units. An exclusive line is used for transmission using a 3.4 kHz frequency band at 9600 bits per second. The multiplexer / transmitter functions to concentrate every detector line, and send up-link information to the central system and down-link information to infrared vehicle detectors. An infrared vehicle detector can perceive the presence of passing vehicles, receiving up-link information from in-vehicle units while sending them down-link information. The maximum length of down-link information is 10 kilobytes and up-link information 256 kilobytes. Additionally, down-link information is sent at a transmission speed of 1024 kilobits per second, and up-link information at 64 kilobits per second. If a vehicle moves at a speed of less than 70 kilometers per hour, 10 kilobytes of down-link data and 256 bytes of up-link data can be guaranteed. Concerning the detection function, discovery of a vehicle moving at less than 120 kilometers per hour can be assured.

3.3 Calculation of Travel Time

3.3.1 Composition of the experimental course

The experimental course consists of nine minimal links as described in Figure 3. This course range is composed of several smaller courses where travel time is calculated, and these are composed of two points where infrared vehicle detectors were installed. The possible combination of two points yields to different smaller course sections. The traffic

control center calculated travel time for each vehicle between two course sections every five minutes by comparing the vehicle identification numbers transmitted from in-vehicle units installed in probe-cars through the infrared vehicle detectors. Figure 4 shows the compositions of experimental course.

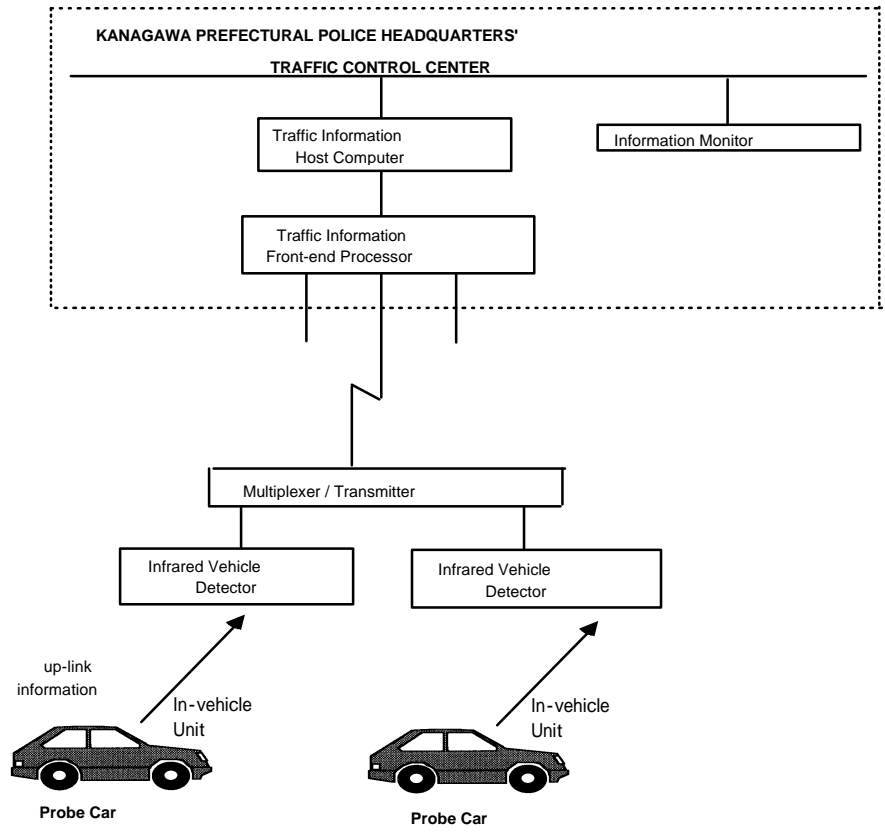


Figure 2 Experiment System Configuration

3.3.2 Travel time processing

Travel time processing was carried out using two methods described below:

- (1) Sum of travel times for smaller course sections during the same time slot (same-time slot travel time)
- (2) Sum of travel times for smaller course sections considering the passage of time (shift travel time)

Figure 5 shows the difference between these two methods.

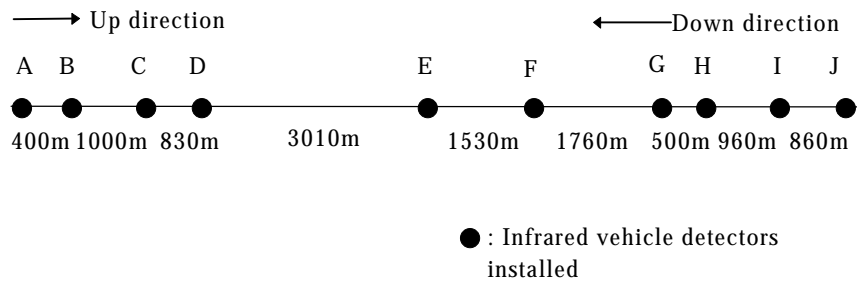


Figure 3 Experimental Course

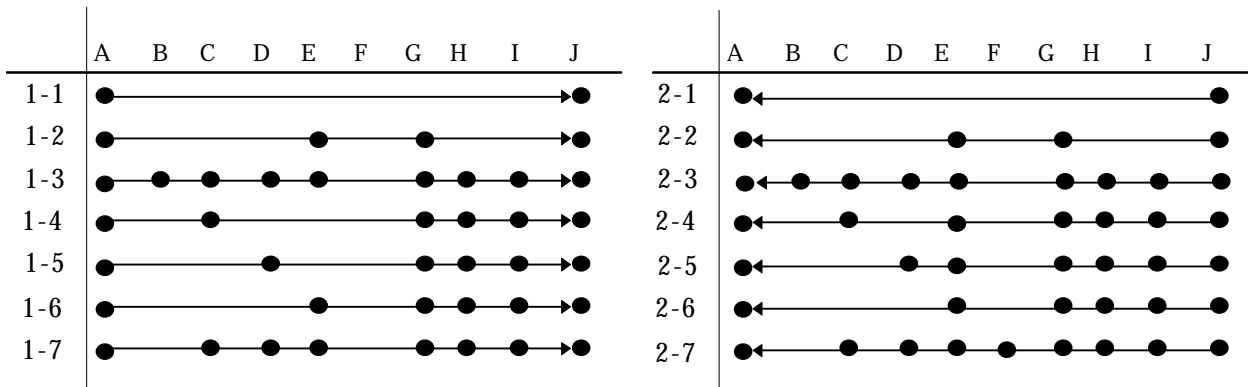


Figure 4 Composition of experimental course

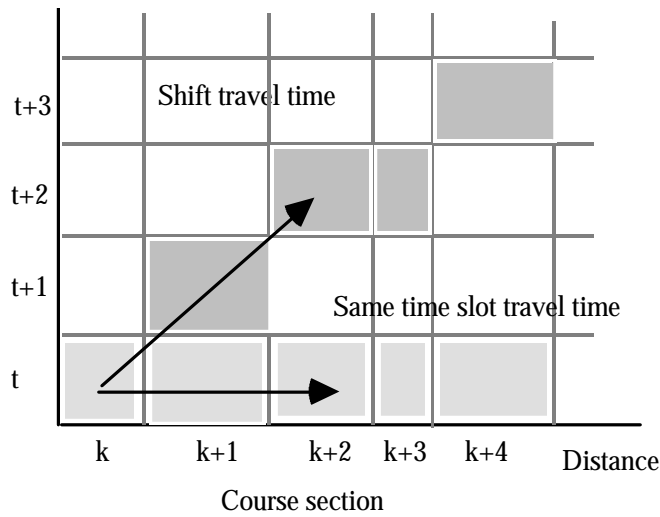


Figure 5 Difference in calculation of travel time

3.4 Effects of the Ratio of Vehicles Equipped with an In-vehicle Unit

To analyze the relation between the ratio of vehicles equipped with in-vehicle units and the accuracy of calculated travel time, travel time using vehicle identification numbers sampled at random from all collected up-link information was calculated, and compared to actual travel time. Four ways of random sampling tests were carried out fifty times, respectively.

4. RESULTS OF EXPERIMENT

4.1 Travel Time Calculation Method

Figure 6 shows a comparison of the time series for calculated and actual travel time of the course section in the down direction. Tables 1 and 2 describe the accuracy rate of calculated travel time for each direction. These results indicate the following;

(1) For any selected combination, shift travel time was found to be consistently more accurate than same-time slot travel time with margin error being less than ten percent compared with the actual travel time, especially in the time zone of fluctuating traffic during the morning peak.

(2) There was no definite difference between the accuracy of calculated travel time and the composition of smaller course sections.

4.2 Effects of the Ratio of Vehicles Equipped with In-vehicle Units

Tables 3 and 4 show the results of four random sampling tests for direction. These proved that calculated travel time using up-link information becomes more accurate while variations of calculated travel time become smaller as the ratio of vehicles equipped with in-vehicle units goes higher. Further, it became clear that the accuracy rate of calculated travel time decreased 2% on an average when ratio of vehicles equipped with in-vehicle units was less than 10%, compared to a case of the ratio being more than 30%. It would be possible that the accuracy will average within 10% if the equipped ratio reaches 10%.

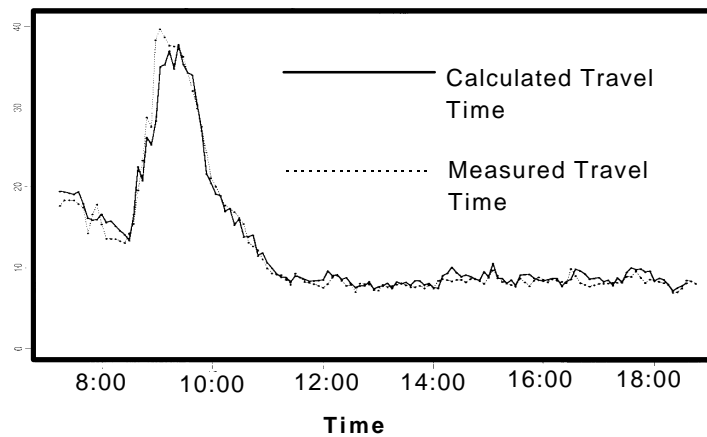


Figure 6 Comparison of the time series for calculated and actual travel time

Table 1 Accuracy of calculated travel time in up direction

No. of composition	Same-time slot travel time	Shift travel time
1-1	6.7%	6.7%
1-2	7.1%	6.5%
1-3	7.0%	6.4%
1-4	6.7%	6.3%
1-5	6.7%	6.9%
1-6	7.0%	6.6%
1-7	6.8%	6.5%

Table 2 Accuracy of calculated travel time in the down direction

No. of composition	Same-time slot travel time	Shift travel time
2-1	5.1%	5.1%
2-2	6.1%	5.7%
2-3	5.5%	5.0%
2-4	5.8%	5.5%
2-5	6.0%	5.7%
2-6	6.3%	5.6%
2-7	5.7%	5.5%

Table3 Effect of ratio of vehicles equipped with in-vehicle units in the up direction

Ratio of vehicles equipped with in-vehicle units	Accuracy of calculated travel time	Standard deviation
60.0%	6.7%	—
(1) 49.3%	6.9%	0.12
(2) 32.6%	7.4%	0.33
(3) 18.4%	8.2%	0.36
(4) 9.7%	9.1%	0.43

Table4 Effect of ratio of vehicles equipped with in-vehicle units in the up direction

Ratio of vehicles equipped with in-vehicle units	Accuracy of calculated travel time	Standard deviation
42.6%	5.1%	—
(1) 36.6%	5.1%	0.10
(2) 24.4%	5.8%	0.18
(3) 15.3%	6.6%	0.32
(4) 11.1%	7.2%	0.41

5. CONCLUSIONS

Considering the results of these evaluations, up-link information from in-vehicle units to infrared vehicle detectors was confirmed to be useful. Further, UTMS is useful and effective for practical use.

In the future, there are plans to install more infrared vehicle detectors to increase the information service and up-link information collection points. The more system construction is promoted, the more in-vehicle units are expected to be used. Additionally, the more in-vehicle units are spread, the higher the accuracy of calculated travel time will become, and the more detailed information service will be. To produce a synergetic effect between system construction and the provision of in-vehicle units, it is necessary to have a public relations promotion through such events as the UTMS Demonstration that was conducted in summer, 1994.

These systems began operation at the Traffic Control Center of Kanagawa Prefectural Police Headquarters, Japan in spring, 1996. Based upon the results of these studies, it is strongly believed these systems will be an effective solution to traffic congestion problems presently plaguing drivers on today's roadways.

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