Trial Operation of A New Public Transportation Priority System Using Infrared Beacons For Two-Way Communication

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ABSTRACT

On urban streets in Japan, traffic congestion has become chronic. As one way to alleviate chronic congestion, respective prefectural police headquarters acting as traffic administrators have been promoting the use of route buses as a mass transit system, aiming at curbing the traffic of cars with a passenger capacity of five or six persons. For this end, traffic administrators have been taking various measures including signal control which gives priority to buses for right-of-way (i.e., bus-prioritized control), utilization of exclusive bus lanes during the morning and evening rush hours, etc.

However, with respect to these measures, various problems including an increase in the number of ordinary vehicles using exclusive bus lane and a demand for advancing the bus-prioritized signal control function to cope with an increase in the number of traffic signal controllers have become conspicuous.

The Universal Traffic Management Society of Japan (UTMS Japan) and the Hokkaido Prefectural Police HQ as a joint development team developed a new Public Transportation Priority System (PTPS) which performs bus-prioritized traffic-actuated control on traffic signal controllers at a group of intersections, right-turn bus-prioritized signal control at an intersection where a bus route turns right, and displays a warning message on a display board to alert a violating ordinary vehicle traveling on an exclusive bus lane by employing newly developed roadside infrared beacons and in-vehicle units mounted on buses both dedicated to two-way communication.

In the new PTPS, because the identification number (ID) information of a bus can be transmitted to the system through the roadside infrared beacon, the traveling position of the bus can be readily recognized by the system. Conversely, the system can convey various items of information to the bus through the roadside infrared beacon. This means that the PTPS of a traffic administrator can be linked to bus management systems independently operated by local bus service companies to form an integrated system, which can contribute to the rationalization of investment (savings in investment cost).

With assistance from a local bus service company, the joint team for PTPS development put the newly developed PTPS into trial operation in March 1966 on National Highway Route 36 in Sapporo City, Hokkaido Prefecture, verified the effectiveness of the developed PTPS for maintaining bus service on a fixed-time and fixed-speed basis, and experimentarily used information collected on the traveling position of each bus from roadside infrared beacons for information provision service to both the bus service company and the bus users.

INTRODUCTION

In order for any public mass transit service to secure the appropriate number of users, it is requisite that the users of the transit service can get to their destination faster and more comfortably. Public transportation facilities such as railways, etc. which have dedicated tracks can easily satisfy this requirement. However, with respect to route buses which travel on ordinary roads (excluding single-purpose roads) together with other motor vehicles, the facts about them are such that they are forced to stop and start repeatedly by traffic congestion and under the restriction of traveling by traffic signals, resulting in worsening the ride-in comfortability of passengers and a large delay in traveling.

As one way to cope with such situations, traffic administrators in Japan have been aggressively putting forward the introduction of exclusive bus lanes into roads on which route buses are in operation in the central part of each city. However, once lanes for ordinary vehicles get congested, an uncrowded exclusive bus lane is soon and unceasingly invaded by ordinary vehicles violating traffic rule in the absence of police supervision. As regards signalized intersections along each bus service route, traffic administrators have been promoting the introduction of the bus-prioritized signal control function which extends the green interval or shorten the red interval of each traffic signal upon detection of an approaching bus. However, the implementation of such function has so far been sporadic, because it has been restricted to major intersections.

Together with the Hokkaido Prefectural Police HQ, the Universal Traffic management Society of Japan (UTMS Japan) developed a new Public Transportation Priority System (hereafter referred to as the new PTPS or this system) which is more powerful than any conventional PTPS in Japan.

The new PTPS has the following functions:

1. On receipt of the ID information of a bus from a roadside infrared beacon, the traffic control system supports the non-stop traveling of a bus to the next bus stop by extending the green interval or shortening the red interval of each signal at a group of intersections adjoining to each other in the moving direction of the bus. At the same time, a recommended speed for non-stop traveling is conveyed from the infrared beacon to the bus driver through an in-vehicle display unit (dedicated to the bus driver) inside the bus.
2. Through an exclusive bus traffic signal installed at each intersection where a bus route turns right, signal control giving priority to right-turn buses is executed to allow a bus to make right directly from the exclusive bus lane (leftmost lane).
3. Vehicles other than buses traveling on an exclusive bus lane are automatically detected with vehicle detectors for vehicle classification and a warning message is automatically output onto a roadside warning display board to prompt the offending driver to move from the bus lane to a lane for ordinary vehicles.
4. Each roadside infrared beacon collects information on the traveling position of a bus for transmission to the traffic control (TC) center, which in turn provides the information to the bus service company through a communications line.
5. Based on the information on the traveling positions of buses, bus location information is output from the TC center to an applicable bus stop for display.
6. Information on bus travel times to main destinations on a bus route calculated at the TC center and massage information input from a terminal by the bus service company are transmitted to the in-vehicle unit mounted on each bus through a roadside infrared beacon and provided to passengers on board through an in-vehicle display unit (dedicated to passengers).

This system was put into trial operation within a roadway section (approx. 5.7km) on National Highway Route 36 in Sapporo City, Hokkaido Prefecture for about two months from the end of March 1966. As a result, we in the joint development team found that the system was beneficial to the bus users as it helped operate the bus service on a fixed-time and fixed-speed basis.

LOCATION AND SCALE OF TRIAL OPERATION

Location and Roadway Section Where Trial Operation was Conducted

National Highway Route 36 is an arterial highway interconnecting the central part of Sapporo City in which the Hokkaido Government Office is located and the southern part of Hokkaido Prefecture, the northernmost and greatest prefecture in Japan. On this national highway featured by a large volume of traffic, route buses patronized by many citizens are in operation. For this reason, in a roadway section near the central part of Sapporo City, the leftmost lane of the three-lane roadway for traffic bounding for the center of the city is in use as an exclusive bus lane during the morning peak hours from 7:30 a.m. to 9:00 a.m. Because this roadway section is extending through the urban district of Sapporo, it has a number of signalized intersections and quite a few ordinary vehicles that traveled on the bus lane were observed during the peak hours. The trial operation of the new PTPS was conducted within a roadway section extending over about 5.7 km between a bus terminal and the central part of Sapporo, with respect to the direction and time zone in which the exclusive bus lane was in use. Figure 1 shows a skeltonized map of an area in which the bus route subjected to the trial operation is indicated by the solid bold line.

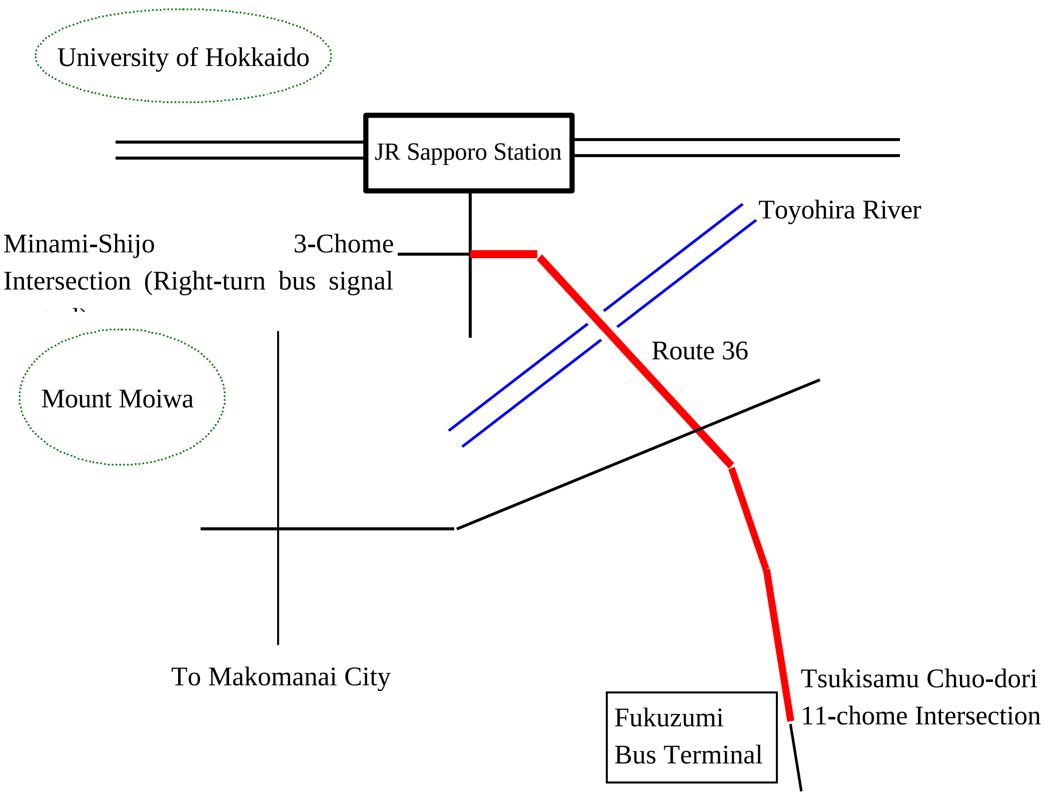

Figure 1 Skeltonized map of area including bus route under trial operation

Scale of Trial Operation

Signalized intersections, bus stops, warning displays, and buses equipped with an in-vehicle unit subjected to the trial PTPS operation were as follows:

- Number of bus-prioritized signalized intersections: 33 intersections
- Number of bus stops without bus location display: 11 stops
- Number of bus stops with bus location display: 1 stop
- Bus lane violation warning display boards (including vehicle classification detectors) : 3 places
- Number of buses with in-vehicle unit for two-way (uplink & downlink) communication: 5 units
- Number of buses with in-vehicle unit for one-way (uplink on) communication: 207 units

OVERVIEW OF THIS SYSTEM

System Configuration

The configuration of the new PTPS system is as illustrated in Figure 2.

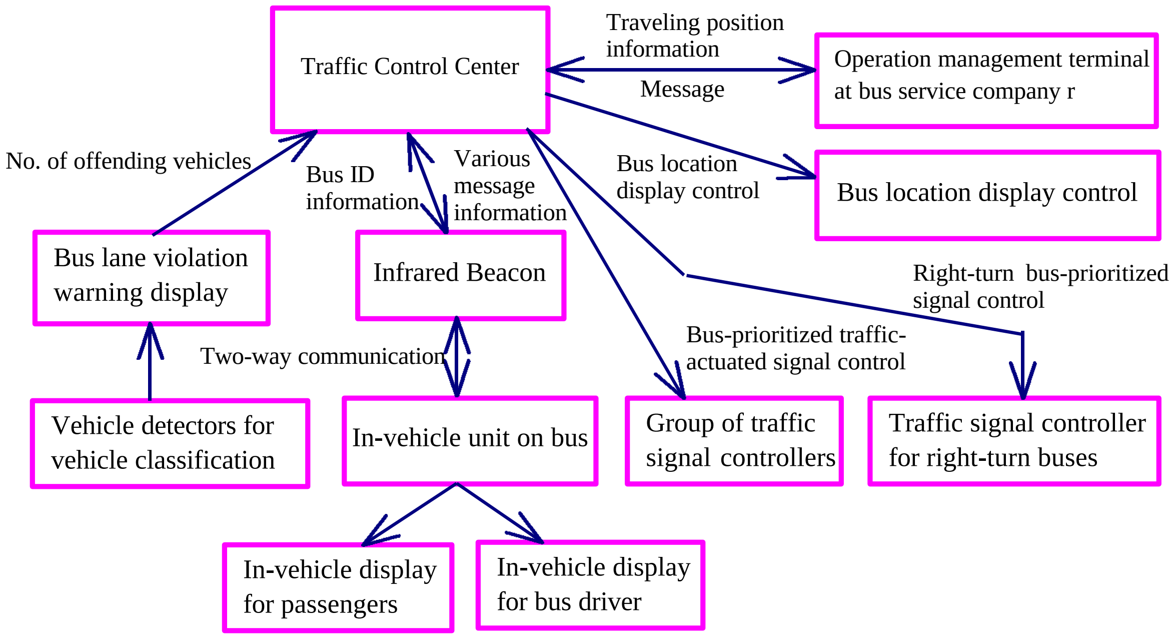

Figure 2 Configuration of Sapporo PTPS system

System Functions

The main functions of this system are as outlined below.

<u>Two-way communication between roadside beacon and bus (in-vehicle unit)</u>

A beacon capable of two-way communication with a bus through infrared light is located on the directly upstream roadside (Arrival side) and the directly downstream roadside (Departure side), respectively of a bus stop. An in-vehicle unit incorporating an infrared light transmitter-receiver capable of communication with this infrared beacon is mounted on each bus.

The physical design requirements of this two-way communication are as follows:

1. Wavelengths of infrared light
   (a) Emitted from beacon: 850 nm ± 50 nm
   (b) Received by beacon: 850 nm ± 50 nm or 950 nm ± 50 nm
   (c) Emitted from in-vehicle unit: 850 nm ± 50 nm or 950 nm ± 50 nm
2. Transmission speed:
   (a) Downlink data transmission: 1,024 kbits/s
   (b) Uplink data transmission: 64 kbits/s
3. Communication ranges of beacon: See Figure 3.

The contents of uplink and downlink information are as follows:

1. Uplink information from in-vehicle unit: Bus ID information
2. Downlink information from beacon:
   (a) Recommended speed of bus traveling between intersections
   (b) Most up-to-date information on bus travel times to the center of Sapporo City
   (c) Other message information

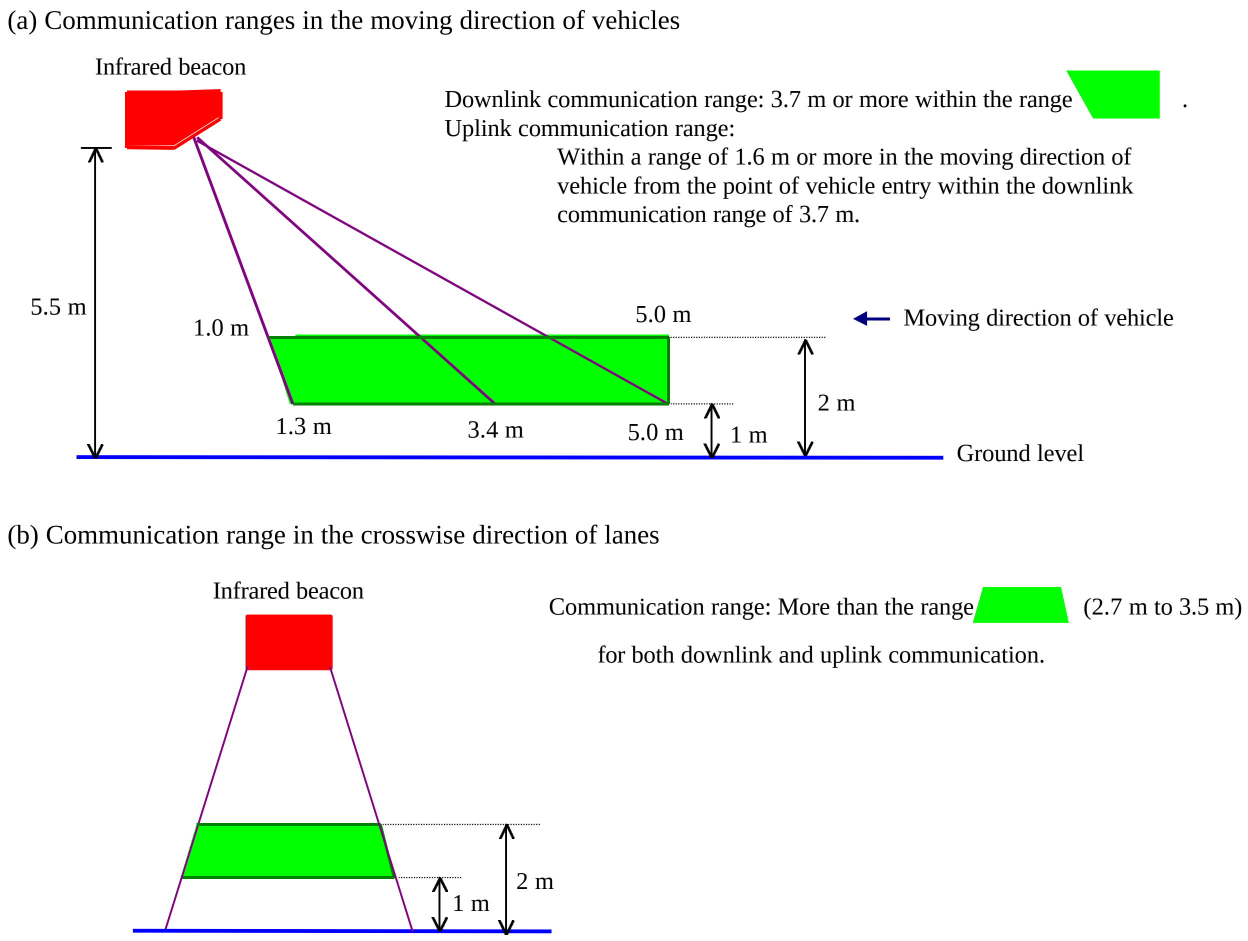

Figure 3 Communication ranges of roadside infrared beacon

Bus-prioritized traffic-actuated signal control

On receipt of the ID information of a bus from a roadside infrared beacon installed directly upstream (on the departure side) of a bus stop, the signal control subsystem at the TC center supports the non-stop traveling of the bus to the next bus stop by extending the green interval or shortening the red interval of each signal for several seconds at a group of intersections adjoining to each other and located between the two bus stops. At the same time, a recommend speed for non-stop traveling to the next bus stop is transmitted from the infrared beacon to the in-vehicle display unit for indication to the bus driver. An imaginary view of this bus-prioritized control is illustrated in Figure 4.

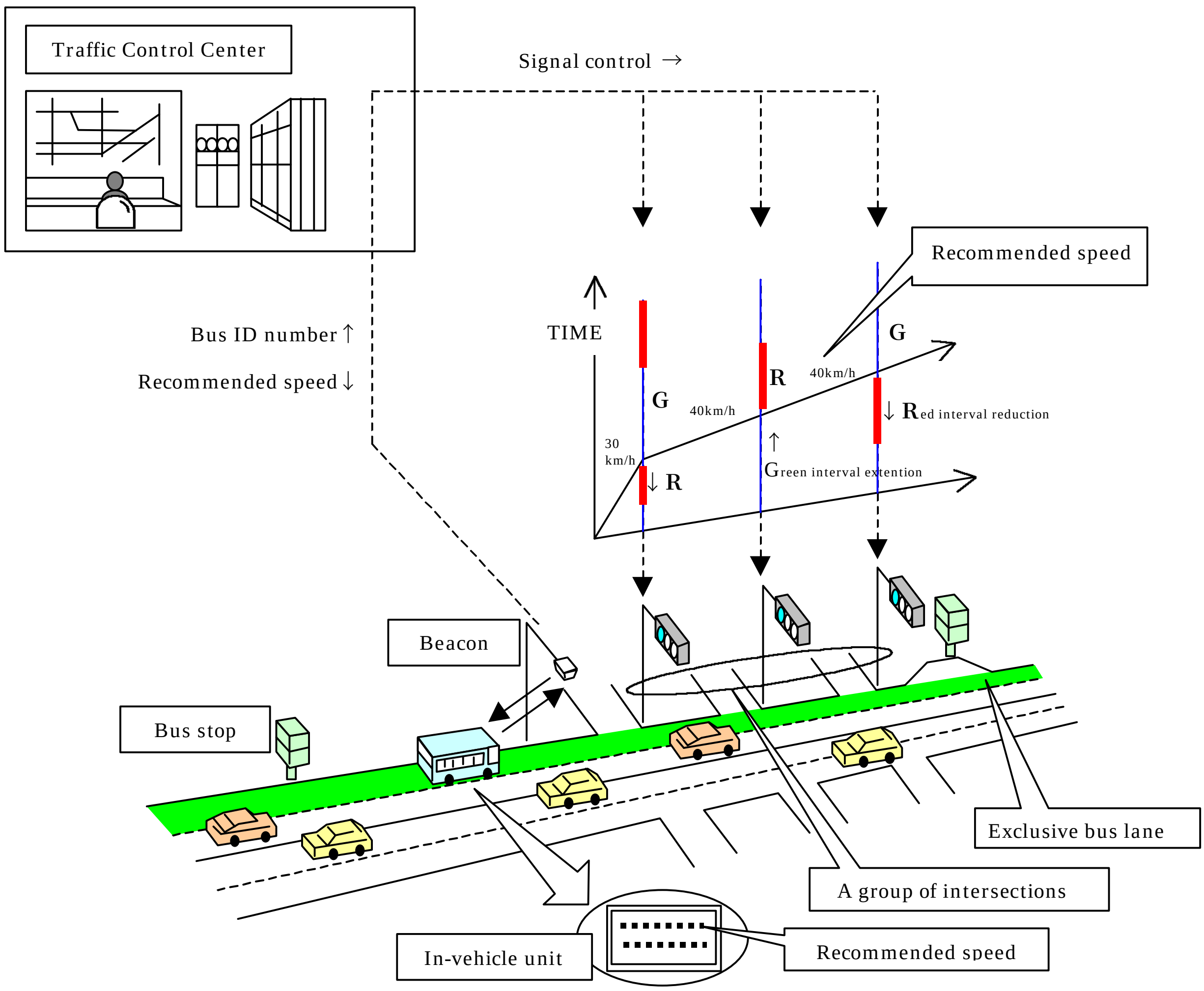

Figure 4 Imaginary view of bus-prioritized traffic-actuated signal control

The recommended bus traveling speed is determined by the system based on the following conditions:

1. Distance from the roadside infrared beacon to the first intersection in a group of intersections located between two bus stops
2. Signal control parameters presently in effect at the affected intersections
3. Signal display timing of a group of intersections ahead when the applicable bus has passed through the roadside position of the infrared beacon.

Signal control giving priority to right-turn buses

At an intersection where a bus route turns right, upon receipt of the ID information of a bus from a roadside infrared beacon, the signal control subsystem at the TC center executes bus-prioritized signal control which allows the bus to safely make right turn directly from the leftmost exclusive bus lane at the intersection by turning the traffic signal light for the ordinary vehicle lanes to Red and turning the signal light for the exclusive bus lane to Green or Green Arrow.

Elimination of ordinary vehicles illicitly traveling on bus lane

Upon detection of a vehicle other than a bus traveling on the exclusive bus lane by one of the vehicle detectors for vehicle classification installed roadside, the lane violation warning display board located ahead of the offending ordinary vehicle displays a warning message to prompt the driver to move from the bus lane to a lane for ordinary vehicles.

Provision of bus ID and traveling information for bus service management

Based on the bus ID information received from each roadside infrared beacon, the Traffic Control Center can grasp the current traveling position of each bus. Information on the ID number of each bus and its current traveling position is provided to the bus service company from the TC center through a communications line so that the bus service company can make the best use of the information for its bus service management.

Bus location display at bus stop as service to passengers awaiting buses

Using the bus ID information received from roadside infrared beacons, bus location information is provided to passengers awaiting buses at a bus stop through display to inform that buses have departed from the first two bus stops upstream of this bus stop.

Information provision to bus passengers on board

Information on bus travel times to main destinations on a bus route calculated at the TC center and message information input from a terminal at the bus service company are transmitted to the in-vehicle display unit mounted on a bus through a roadside infrared beacon and provided to passengers on board through a small character-scroll type in-vehicle display unit (dedicated to passengers).

EFFECT OF TRIAL PTPS OPERATION

Exclusive bus lanes have all been established with the objective of maintaining bus service on a fixed-time and fixed-speed basis. In reality, however, the securement of this regularity in bus operation time is difficult by reason of interruption caused by ordinary vehicles invaded bus lanes. The results of the trial PTPS operation we conducted in Sapporo City suggest the possibility or impossibility of securing this regularity in bus service operation.

We collected bus travel-time data for two weeks each before and after the start of the trial operation for the comparative analysis of average travel-time data to evaluate the effectiveness of the new PTPS.

Table 1 shows a comparison of the average bus travel times (by time zone and day of the week) of the bus route section subjected to test before and after the trial operation. Based on the conditions of fluctuations in general traffic, time zone was divided into 30-minute zones (7:30 a.m. to 8:30 a.m.and 8:00 a.m. to 8:30 a.m.) to analyze data on buses departing from the start point of the test bus route section (i.e., the bus stop at the Fukuzumi Bus Terminal). Data on buses which departed from the bus stop after 8:30 a.m. were excluded from the comparative analysis, because the bus lane enforcement time might have expired while the buses were traveling within the test section. The collected data on Mondays and Fridays were segregated from those on other weekdays, because traffic congestion in Sapporo is usually heavy at the beginning and end of the week. The collected data on Saturdays and Sundays on which the exclusive bus lane is not enforced by the police were excluded from the comparative analysis.

Table 1 Comparison of averaged bus travel times before and after trial operation

Time zone	7:30 to 8:00 a.m.			8:00 to 8:30 a.m.		
Classification	Time before trial oper	Time after trial oper	Time difference	Time before trial oper	Time after trial oper	Time difference
Mondays	23m51s	21m36s	-2m15s	24m25s	22m27s	-1m58s
	19m50s	17m54s	-1m56s	20m03s	18m06s	-1m57s
Tuesdays,Wednesdays, Thursdays	22m41s	21m25s	-1m16s	23m16s	22m16s	-1m00s
	18m48s	17m21s	-1m27s	18m47s	17m31s	-1m16s
Fridays	23m16s	22m10s	-1m06s	23m23s	23m53s	+0m30s
	19m20s	17m42s	-1m38s	19m09s	18m44s	-0m25s

(Upper row: Average bus travel time ; Lower row: Average bus travel time less stoppage time at bus stop)

From the results of our comparative analysis as shown in Table 1, we found that average bus travel times in general during the trial operation were shortened as compared with those before the trial operation. However, because the bus operation schedule of the bus route section subjected to test has been established based on the required travel time of 20 times, we still have room for improvement before buses can travel as scheduled. From this trial operation, we are convinced that we can further improve average travel times by improving signal control parameters, eliminating traffic impedances to non-stop traveling of buses, etc.

The main objective of this system is to secure regularity in bus operation time. Through this trial operation, we were able to demonstrate that data collected for the PTPS could be used at the same time for Mobile Operation Control Systems (MOCS), which was a great outcome of the trial operation. In other words, bus service companies can look forward to the implementation of a system which allow them to manage their bus service by obtaining bus location information from a traffic control system without the need of their investment in roadside facilities and equipment.

CONCLUSION

The introduction of infrared beacons capable of two-way communication into our Public Transportation Priority System has contributed toward enhancing close connection between public transportation (bus) and its vehicle operation management system. This, we believe, will contribute greatly toward strengthening cooperative systems or organizations between traffic administrators and public transportation service providers and enhancing the convenience of citizens who use public transportation. The system we used for trial operation in Sapporo City was limited in its scale and functions, but we will be very happy if it can serve as an incentive to find the future direction of Public Priority Transportation Systems.