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Field Verification of Public Transport Priority System Functions Using Intelligent Transport Systems in Hiroshima City

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Abstract

This study verifies the functions of a public transport priority system using intelligent transport systems under real traffic conditions in Hiroshima City. On March 12, 2025, a test run was conducted at the Sendamachi 3-chome intersection, focusing on two of the six use cases defined in SIP Phase 3: driver pre-emptive deceleration support using signal information, and intersection passage smoothing support through signal modifications (extending green time/shortening red time). The results confirmed correct operation of vehicle-passage detection via virtual beacons, public transport priority system control for green extension and red shortening, and a driver-facing indicator showing whether public transport priority system control was available. At the same time, the results revealed the need for advance notification to drivers regarding whether public transport priority system control would be executed. Based on these findings, we will proceed with trials in a model area as technical verification toward further advancement of public transport priority system.

Keywords: public transportation priority system, intelligent transport systems, traffic signal control, tram, bus, field operational test.

1 Introduction

The "Development of Smart Mobility Platform" in Phase 3 of the Cross-ministerial Strategic Innovation Promotion Program (SIP), led by the Cabinet Office of Japan,

aims to realize “a society without mobility divides, where people, goods and services can move freely and independently, safely, comfortably, and in an environmentally, people and community friendly way.” [1, 2]
Under the leadership of Hiroshima University, the project is working on the following four themes: [3]

- Development of local mobility diagnostic guidelines and mobility re-design simulation model
- Tactical mobility re-design practices
- Construction of a cyber-physical road space digital system infrastructure (digital sandbox) to realize safe, comfortable, and affluent mobility
- Extraction of requirements for vehicles, infrastructure that contribute to re-design

This study focuses on the last theme above. More specifically, this study addresses the advancement of a public transport priority system (PTPS), as well as verification of its technical validity and social benefits.

This study is based on an innovative advanced safety vehicle service using vehicle-to-vehicle communication between tramcars and cars, which was demonstrated in Hiroshima City as part of the post-congress tours of ITS World Congress 2013 [4]. It also builds on the technical background of the “Hiroshima Sandbox” project (fiscal years 2018 to 2020) [5].

The Hiroshima Sandbox project, led by Hiroshima Prefecture, is a platform for solving regional issues through advanced technologies such as AI, IoT, and big data. In the program called “Development of a Public-Transport-Priority Smart City Using Cooperative ITS,” carried out from fiscal years 2018 to 2020, the feasibility of cooperative intelligent transport systems (ITS) functions including PTPS was examined at intersections where trams, route buses and general vehicles mixed. The examined functions included safe driving support, signal information support, public transport priority signal information provision and control and support for shared use of tram stops by trams and buses. More specifically, demonstration tests were conducted for collision avoidance support information through vehicle-to-vehicle communication (V2L, where V means vehicle and L means light rail transit), provision of signal information and pedestrian information at crosswalks through vehicle-to-infrastructure communication (V2I or L2I, where I means infrastructure), green-time extension and red-time shortening control using virtual beacons based on satellite positioning, and support for safe travel of trams and buses within track areas and shared use of tram stops through vehicle-to-vehicle and vehicle-to-infrastructure communication.

This paper presents the following:

- the use cases defined in SIP Phase 3 for situations where PTPS is effective
- the test-run verification conducted based on some of those use cases.

2 Definition of Use Cases for Public Transport Priority Infrastructure Cooperation Technology

In this study, the following six use cases were defined for public transport priority infrastructure cooperation technology for mobility re-design.

(a) Driver support using signal information (early deceleration)

- Overview: By transmitting and displaying signal information, such as signal color and cycle information including remaining time, to a public transport vehicle approaching a signalized intersection, the system supports the driver in making safer early deceleration and smoother driving with less acceleration and deceleration.
- Target location: Before a signalized intersection
- Target vehicles: Trams and route buses
- Notes (functional requirements, etc.):
  - ✓ Service area: Before a single signalized intersection, about 50 to 100 m
  - ✓ Communication: I2V
  - ✓ Connection type: one-to-many
  - ✓ Immediate response: not required
  - ✓ Information content: signal color and cycle information including remaining time

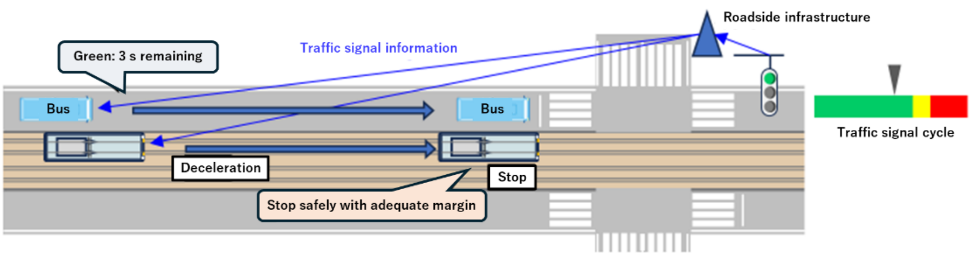


Figure 1: Driver support using signal information (early deceleration).

(b) Support for an automated driving system using signal information (early deceleration)

- Overview: By transmitting signal information, such as signal color and cycle information including remaining time, to a public transport vehicle equipped with an automated driving system and approaching a signalized intersection, the system supports the automated driving system in making safer early deceleration and smoother driving with less acceleration and deceleration.
- Target location: Before a signalized intersection
- Target vehicles: Trams and route buses equipped with an automated driving system
- Notes (functional requirements, etc.):
  - ✓ Service area: Before a single signalized intersection, about 50 to 100 m
  - ✓ Communication: I2V

- ✓ Connection type: one-to-many
- ✓ Immediate response: not required
- ✓ Information content: signal color and cycle information including remaining time

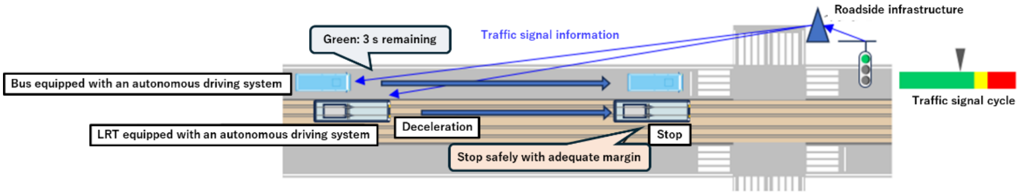


Figure 2: Support for an automated driving system using signal information (early deceleration).

(c) Support for smoother intersection passage by changing signal indication (green extension or red shortening)

- Overview: Based on information from a public transport vehicle approaching a signalized intersection, such as position, planned movement or stop, and vehicle or train-set length, the system appropriately extends the green time or shortens the red time according to the movement plan and the length of the approaching vehicle or train set and supports smoother passage through the intersection.
- Target location: Before multiple signalized intersections
- Target vehicles: Trams and route buses
- Notes (functional requirements, etc.):
  - ✓ Service area: Multiple signalized intersections
  - ✓ Communication: V2I, I2I
  - ✓ Connection type: one-to-many
  - ✓ Immediate response: required
  - ✓ Information content: position of approaching vehicle, planned movement or stop, vehicle or train-set length, etc.

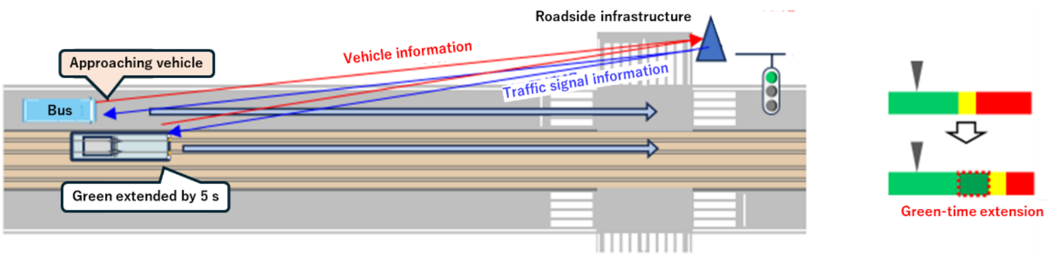


Figure 3: Support for smoother intersection passage by changing signal indication in the case of green extension.

(d) Improvement of user convenience by changing signal indication (green shortening)

- Overview: Based on information from a public transport vehicle approaching or just passing a signalized intersection, such as position, planned movement or stop, and vehicle or train-set length, the system shortens the green time of the signal, which can reduce road-crossing waiting time for users and ease congestion at tram stops, thereby improving convenience.
- Target location: A signalized intersection near a stop
- Target vehicles: Trams
- Notes (functional requirements, etc.):
  - ✓ Service area: Signalized intersection
  - ✓ Communication: V2I, I2I
  - ✓ Connection type: one-to-one
  - ✓ Immediate response: required
  - ✓ Information content: position of approaching vehicle, planned movement or stop

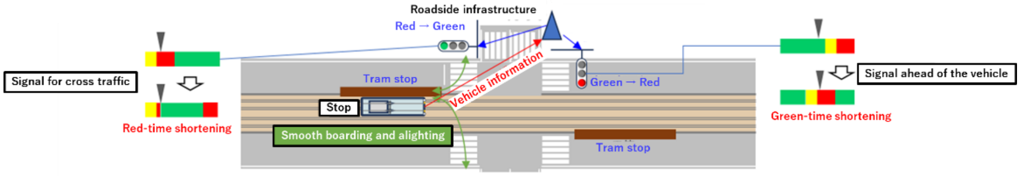


Figure 4: Improvement of user convenience by changing signal indication (green shortening).

(e) Support for smoother intersection passage by changing signal indication (green extension/shortening)

- Overview: Based on information from multiple public transport vehicles approaching a signalized intersection, such as position, planned movement or stop, and vehicle or train-set length, the system appropriately extends or shortens the green time according to the movement plan and the length of the vehicles or train sets that should be given priority, and supports smoother passage through the intersection.
- Target location: Multiple signalized intersections
- Target vehicles: Multiple trams and route buses, including vehicles from opposite directions
- Notes (functional requirements, etc.):
  - ✓ Service area: Multiple signalized intersections
  - ✓ Communication: V2I, I2I
  - ✓ Connection type: many-to-many
  - ✓ Immediate response: required
  - ✓ Information content: positions of multiple approaching vehicles, planned movement or stop, vehicle or train-set length, etc.

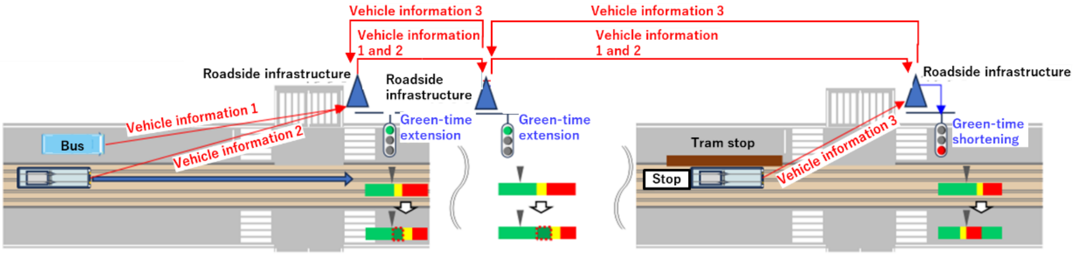


Figure 5: Support for smoother intersection passage by changing signal indication (green extension/shortening).

(f) Safe driving support when exclusive running space and tram stops are shared

- Overview: When a route bus equipped with an automated driving system shares a tram stop and track space used as an exclusive running area for trams, the system shares each vehicle's information, such as position, planned movement or stop, and vehicle or train-set length, through vehicle-to-vehicle communication and uses it for control, so that the public transport vehicle that should be given priority can travel safely and with priority.
- Target location: Multiple signalized intersections
- Target vehicles: Trams and route buses equipped with an automated driving system
- Notes (functional requirements, etc.):
  - ✓ Service area: Track space including tram stops
  - ✓ Communication: V2V
  - ✓ Connection type: many-to-many
  - ✓ Immediate response: required
  - ✓ Information content: positions of multiple vehicles, planned movement or stop, vehicle or train-set length, etc.

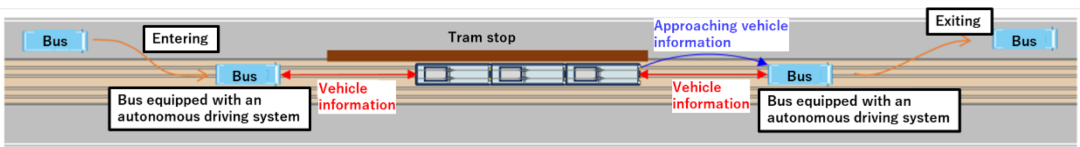


Figure 6: Safe driving support when exclusive running space and tram stops are shared.

3 Test-run verification

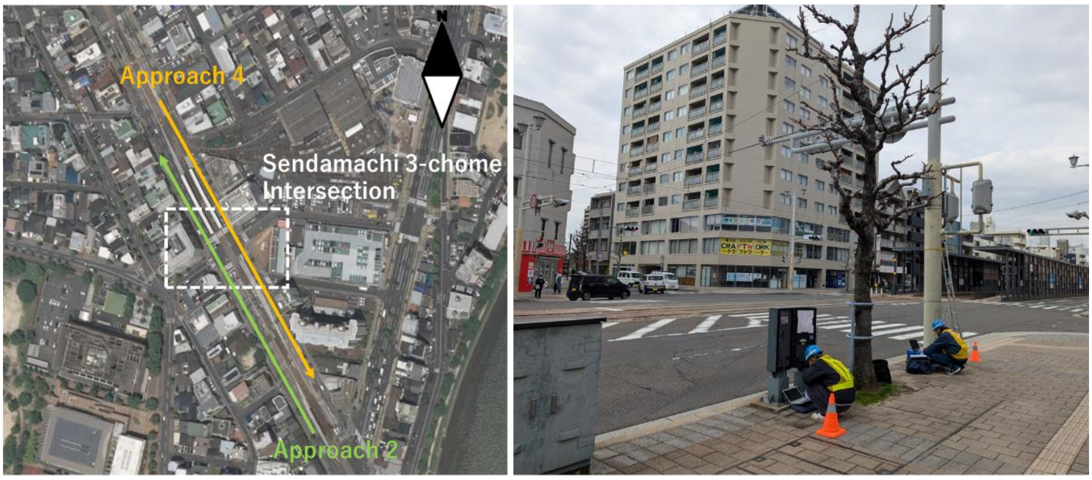
3.1 Outline of the test

A test run was conducted to confirm the functions for some of the use cases. The outline of the test is as follows.

- Date: March 12, 2025 (Wednesday)

- Target intersection: Sendamachi 3-chome intersection, located on the boundary between Sendamachi 3-chome and Higashi-Sendamachi 2-chome, Naka Ward, Hiroshima City, Hiroshima Prefecture
- Right or left turns at the intersection: None, straight movement only
- Direction of entry into the intersection: North-south direction (For the direction of entry, the southbound and northbound directions are defined as “Approach 2” and “Approach 4,” respectively.)
- Target use cases:
  - ➢ (a) Driver support using signal information (early deceleration)
  - ➢ (c) Support for smoother intersection passage by changing signal indication (green extension or red shortening)

Photographs of the target intersection are shown in Figure 7. In the figure, (a) shows an aerial image of the intersection with the definition of the entry directions, and (b) shows the intersection viewed from the southeast.



(a) (b)

Figure 7: Target intersection.

3.2 Equipment configuration

Figure 8 shows the configuration of the equipment used in the test. As shown in Figure 8, a traffic signal controller and an ITS roadside unit were already installed at the target intersection. The traffic signal controller is connected to the traffic control center system, and execution of PTPS is controlled by the system at the center. The ITS roadside unit communicates with an ITS onboard unit installed in the PTPS target vehicle.

The PTPS target vehicle is a public transport vehicle such as a tram or a route bus, but in this verification a rental car shown in Figure 9 was used instead. The vehicle was equipped with an ITS onboard unit, and an ITS antenna and an HMI. The ITS antenna and the HMI were connected to the ITS onboard unit. The devices installed in the test vehicle and the devices installed on the roadside are shown in Figures 10 and 11, respectively. In Figure 10, (a), (b), and (c) are the ITS onboard unit, ITS antenna, and onboard HMI, respectively. In Figure 11, (a) and (b) are the ITS roadside unit and the traffic signal controller, respectively.

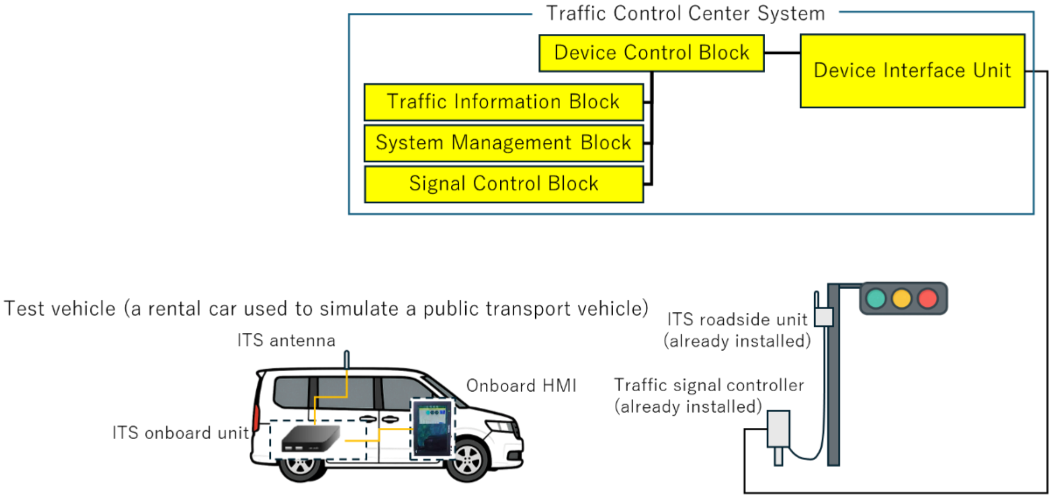


Figure 8: Configuration of equipment used in the verification.

Figure 9: Test vehicle (rental car).

(a) (b) (c)

Figure 10: Devices installed in the test vehicle.

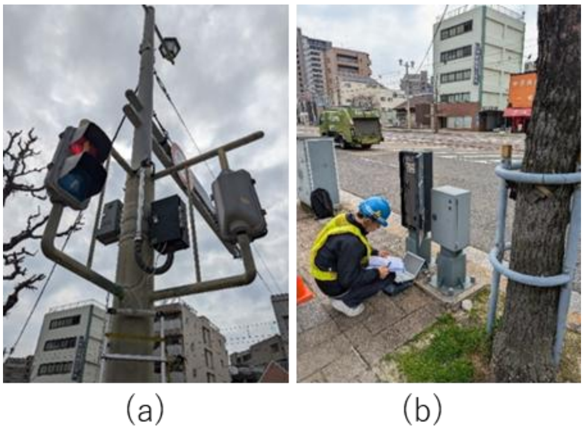


Figure 11: Devices installed on the roadside.

3.3 Verification items

This test-run verification targeted use cases (a) and (c) shown in Section 2. In practice, these use cases were divided into the following three functions, and each function was verified.

i. Vehicle-passage detection using a virtual beacon
ii. Execution of green extension and red shortening
iii. Presentation of PTPS control availability information to the driver

Figure 12 shows the outline of function 1. As shown in Figure 12, when the vehicle reaches the position of a virtual beacon set within the reception area of the ITS roadside unit, the vehicle sends vehicle information and PTPS priority information from the ITS onboard unit to the ITS roadside unit, and the roadside unit detects the passage of the vehicle.

Figures 13 and 14 show the outline of function 2. Figure 13 shows a case in which the green signal is extended by PTPS. The left side shows the case where PTPS control is inactive, and the right side shows the case where PTPS control is active. Time progresses from top to bottom. As shown in Figure 13, when a public transport vehicle enters the intersection during the green signal, PTPS is expected to extend the green time until the vehicle has passed through the intersection.

Figure 14 shows a case in which the red signal is shortened by PTPS. As in Figure 13, the left side shows the case where PTPS control is inactive, the right side shows the case where PTPS control is active, and time progresses from top to bottom. As shown in Figure 14, when a public transport vehicle stops at the intersection during the red signal, PTPS is expected to shorten the red time and reduce waiting time at the intersection.

Figure 15 shows the outline of function 3. As shown in Figure 15, when a public transport vehicle reaches the position of the virtual beacon, PTPS control information is sent from the ITS roadside unit to the vehicle and displayed on the onboard HMI.

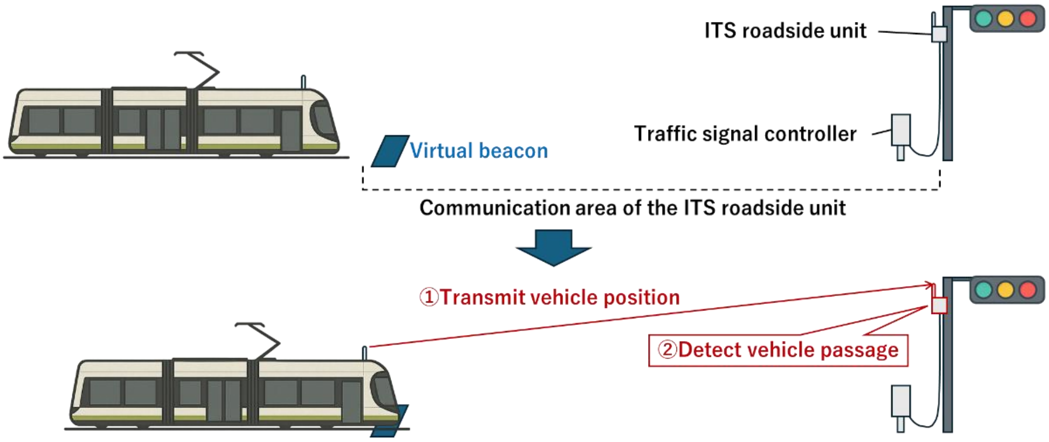


Figure 12: Vehicle-passage detection using a virtual beacon.

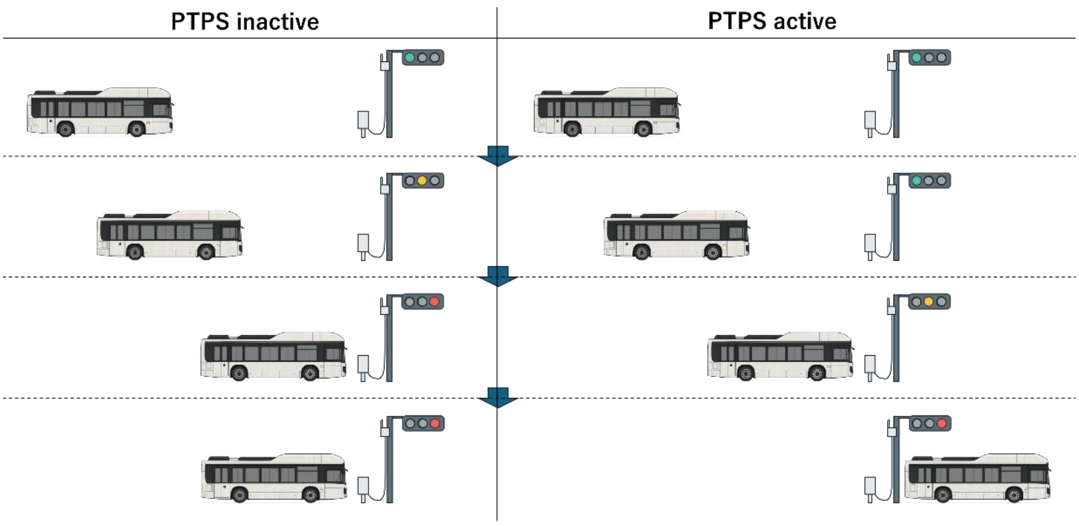


Figure 13: Green extension.

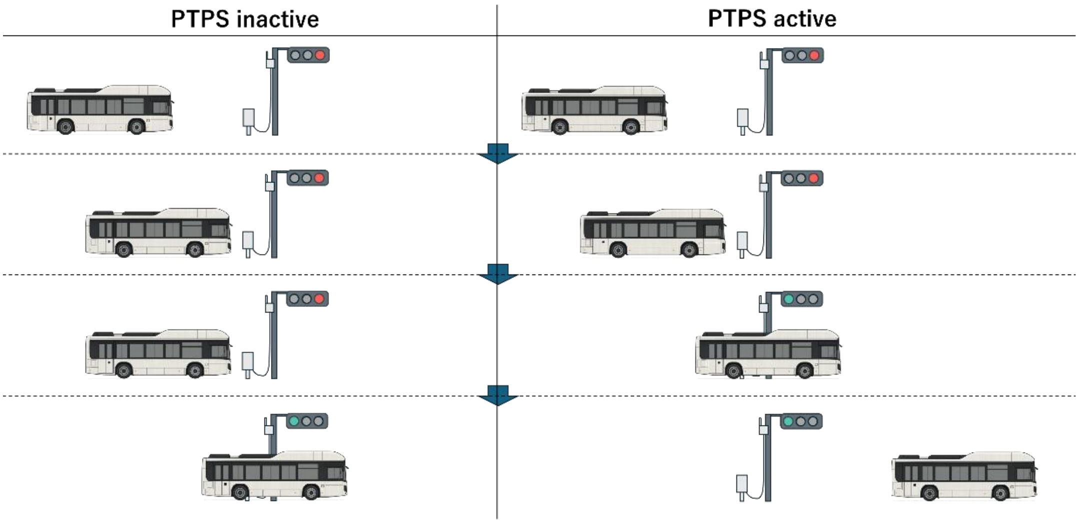


Figure 14: Red shortening.

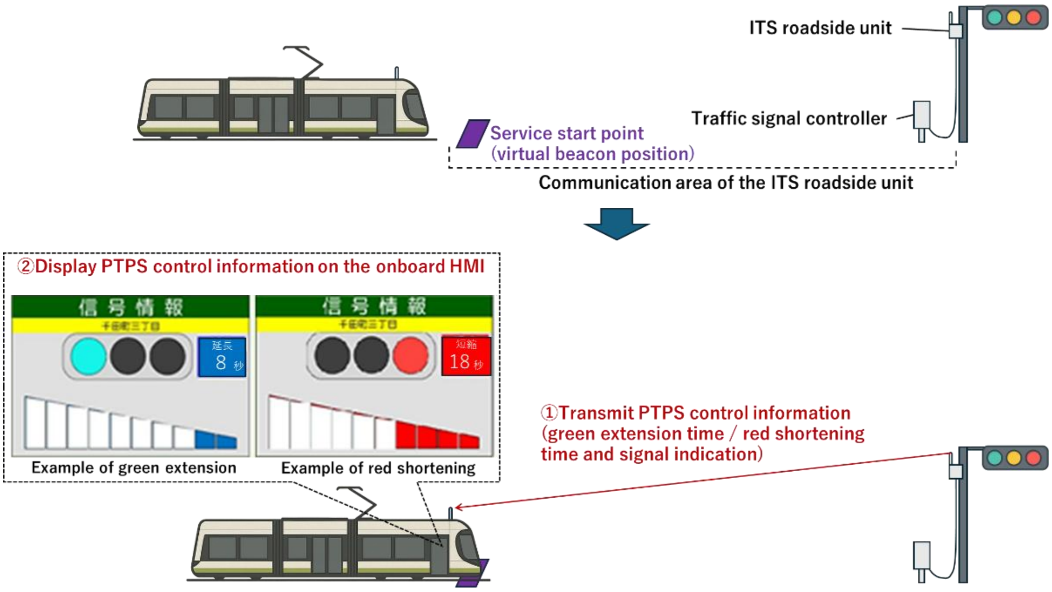


Figure 15: Presentation of PTPS control availability information to the driver.

3.4 Verification results

The experiment was conducted between 9:30 and 16:00, and data from 27 runs were collected as shown in Table 1. Each row in Table 1 represents one test run. From Table 1, the verification results can be summarized as follows.

- The time when the vehicle passed the virtual beacon was recorded without omission by the ITS roadside unit.
- PTPS control was executed in most applicable cases when the time from the start of the signal cycle to virtual-beacon passage was approximately 78 seconds or less.

- The green extension time was 4 to 10 seconds.
- The red shortening time was 8 to 10 seconds.
- In all tests, PTPS control availability information was provided to the driver.

Approach	Start time of signal cycle	**Start time of driver support recorded by ITS on-board unit**	**Virtual beacon passage time recorded by ITS roadside unit**	Time interval from signal cycle start to virtual beacon passage [s]	Finish time of driver support recorded by ITS on-board unit	**Results of PTPS recorded by ITS on-board unit [s]**
4	9:48:38	9:49:29	9:49:32	54.859	9:50:50	-10
2	10:00:38	9:59:13	10:01:26	48.574	10:01:46	6
4	10:14:39	10:15:22	10:15:29	50.663	10:16:55	8
2	10:28:37	10:29:12	10:29:14	37.561	10:29:35	0
2	10:44:39	10:44:02	10:45:45	66.243	10:46:43	-10
4	10:52:37	10:53:46	10:53:49	72.091	10:54:38	-10
2	11:18:39	11:19:27	11:19:50	71.532	11:20:42	-10
4	11:28:37	11:29:26	11:29:30	53.140	11:30:39	-10
2	11:34:38	11:34:56	11:35:25	47.802	11:35:45	5
4	11:44:37	11:46:26	11:46:37	120.593	11:47:01	0
2	11:52:38	11:53:09	11:53:27	49.118	11:53:49	8
4	12:06:39	12:07:26	12:07:30	51.275	12:07:46	10
2	12:12:41	12:12:09	12:13:32	51.303	12:13:54	9
2	13:24:36	13:24:35	13:25:26	50.827	13:25:54	8
4	13:40:36	13:40:10	13:41:30	54.199	13:42:36	-10
2	13:50:36	13:51:54	13:51:45	69.442	13:52:50	-10
4	13:58:35	13:58:37	13:59:26	51.745	14:00:44	9
2	14:12:36	14:13:36	14:13:28	52.387	14:13:56	9
4	14:16:42	14:16:08	14:17:30	48.744	14:17:56	7
4	14:40:36	14:40:25	14:41:29	53.206	14:42:52	-10
2	14:50:36	14:51:31	14:51:23	47.040	14:51:51	4
2	15:14:37	15:15:32	15:15:24	47.959	15:15:51	6
4	15:20:38	15:20:27	15:21:27	49.510	15:21:54	6
2	15:38:37	15:37:21	15:39:24	47.276	15:39:39	4

4	15:44:38	15:45:25	15:45:29	51.768	15:45:43	9
2	15:48:42	15:49:49	15:49:53	71.342	15:50:44	-8
4	15:56:35	15:57:49	15:57:53	78.014	15:58:36	-8

Table 1: Verification results (In column 7, positive values indicate green-phase extension, negative values indicate red-phase shortening, and 0 indicates no priority control executed.)

These results indicate that the three functions described in Section 3.3 were successfully verified in this test. However, observations during the experiment also showed that drivers were not informed in advance whether PTPS control would be executed before the control started.

4 Conclusions

This study defined use cases for situations in which PTPS is effective and verified some of the corresponding functions through a field test under real traffic conditions. The results confirmed vehicle-passage detection using virtual beacons, PTPS control through green extension and red shortening, and the presentation of PTPS control availability information to the driver. Future work will address advance notification of PTPS control execution and further verify advanced PTPS technologies in a model area in fiscal years 2026 and 2027.

Acknowledgements

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