“Strategic Innovation Promotion Program (SIP)
Phase Two / Automated Driving
(Expansion of Systems and Services)/
Research and Development on Traffic Signal Control using GNSS (location information) and other technologies”

Progress Report for Fiscal Year 2020

Overview

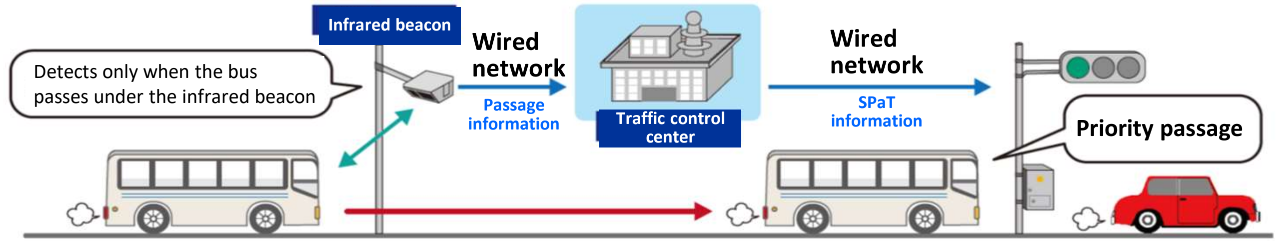
UTMS Society of Japan

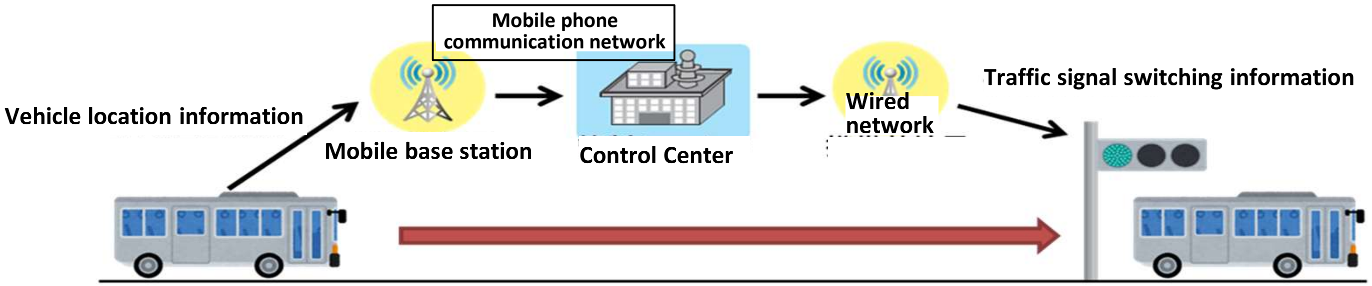
KOITO ELECTRIC INDUSTRIES, LTD.

March 2021

1. Introduction
1.1 Purpose of Research and Development

The R&D aims to enable a broader societal implementation of real-time priority traffic signal control by linking prefectural police traffic control systems with automated driving buses using location information from the Global Navigation Satellite System (the GNSS) and a mobile phone communication network.

<table>
<tr><td rowspan="2">Current priority traffic signal control</td><td>Priority traffic signal control is performed by detecting public transportation vehicles when they pass under an infrared beacon.</td></tr>
<tr><td>

Problem: Fixed-point detection makes it impossible to respond to changes in traffic conditions (e.g., traffic congestion) after the detection.
Services can only be provided at locations where infrared beacons are installed.</td></tr>
<tr><td rowspan="2">Priority traffic signal control using GNSS, etc. aimed at in this R&D</td><td>• Performs real-time traffic signal control by obtaining the location information of public transportation vehicles using GNSS, etc.
• The service can be provided even in places where infrared beacons are not installed.</td></tr>
<tr><td>
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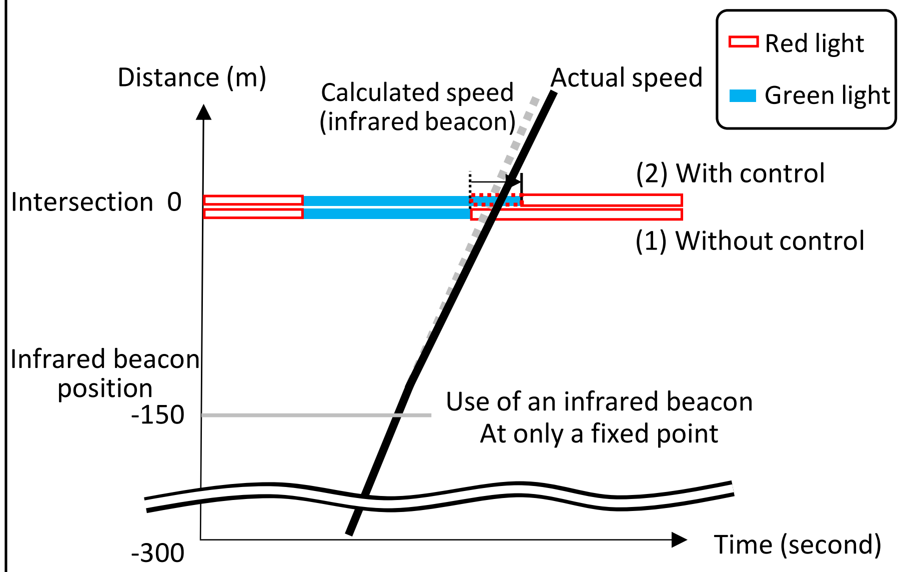
2. Current priority traffic signal control and issues

Comparison of with and without priority traffic signal control using infrared beacons

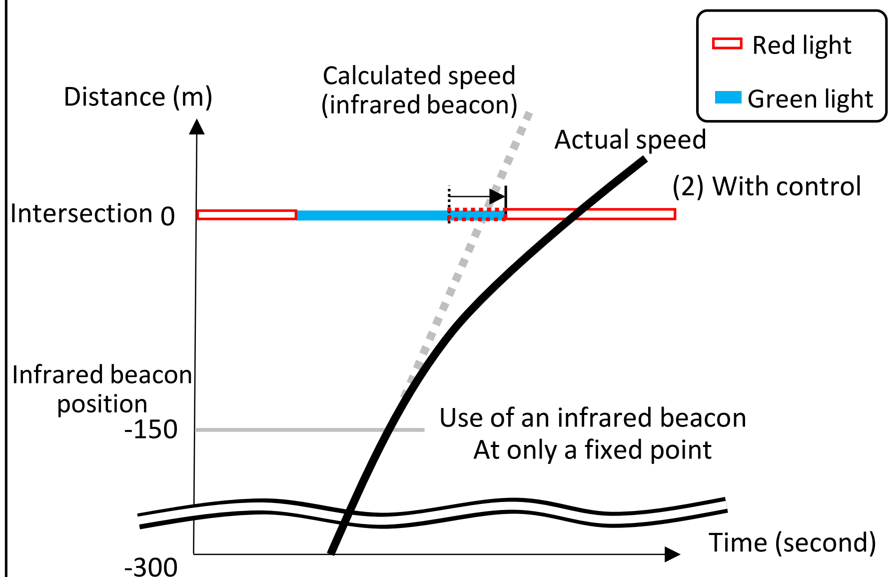


(1) Without control
Unable to pass through because the signal turns red by the time the bus enters the intersection.

(2) With control
The system detects the approach of the bus using an infrared beacon (at a fixed point) and performs control such that the signal turns green after a set number of seconds for the bus to arrive at the intersection based on a predetermined "calculated speed (*)." This allows the bus to pass through the intersection. Therefore, <u>the system is effective when the calculated speed and the actual speed are almost the same.</u>

* Calculated speed: Bus speed set in advance based on conditions such as the speed limit of the route.

Issues of priority traffic signal control using infrared beacons



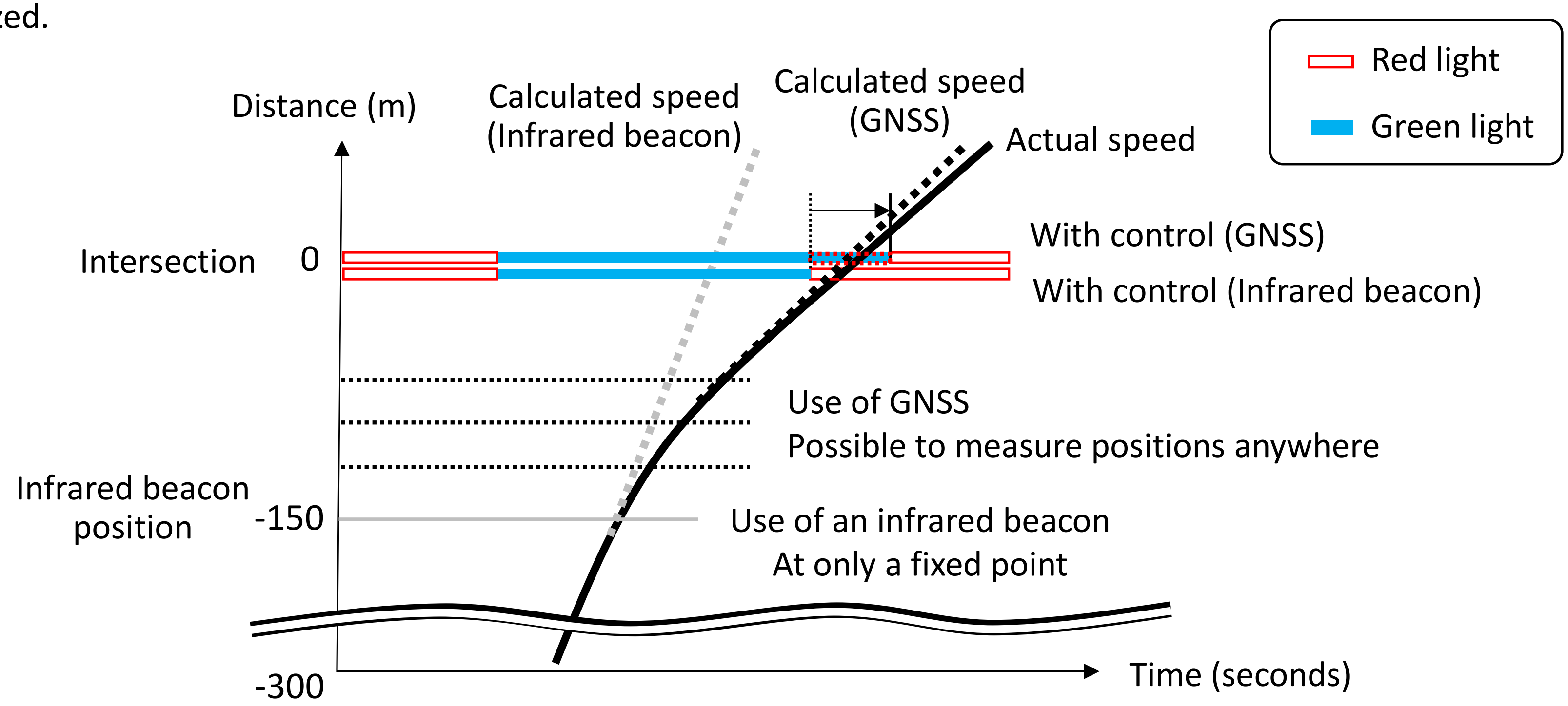
[Issue]
<u>If the difference between the calculated speed and the actual speed is large, the arrival time error at the intersection will also be large.</u>
There are times when a bus stops at a red light even after implementing green light extension control. (In this case, the extended green time results in wasted time.)
Example: Actual speed < Calculated speed (When the actual speed is reduced due to congestion, etc.)
The timing at which the vehicle enters the intersection is delayed by the same amount as the arrival time error, resulting in insufficient green time extension.
⇒Unable to pass through because the signal turns red by the time the bus enters the intersection.

⇩

[Issue] Minimization of arrival time error

3. Priority traffic signal control using GNSS and other technologies

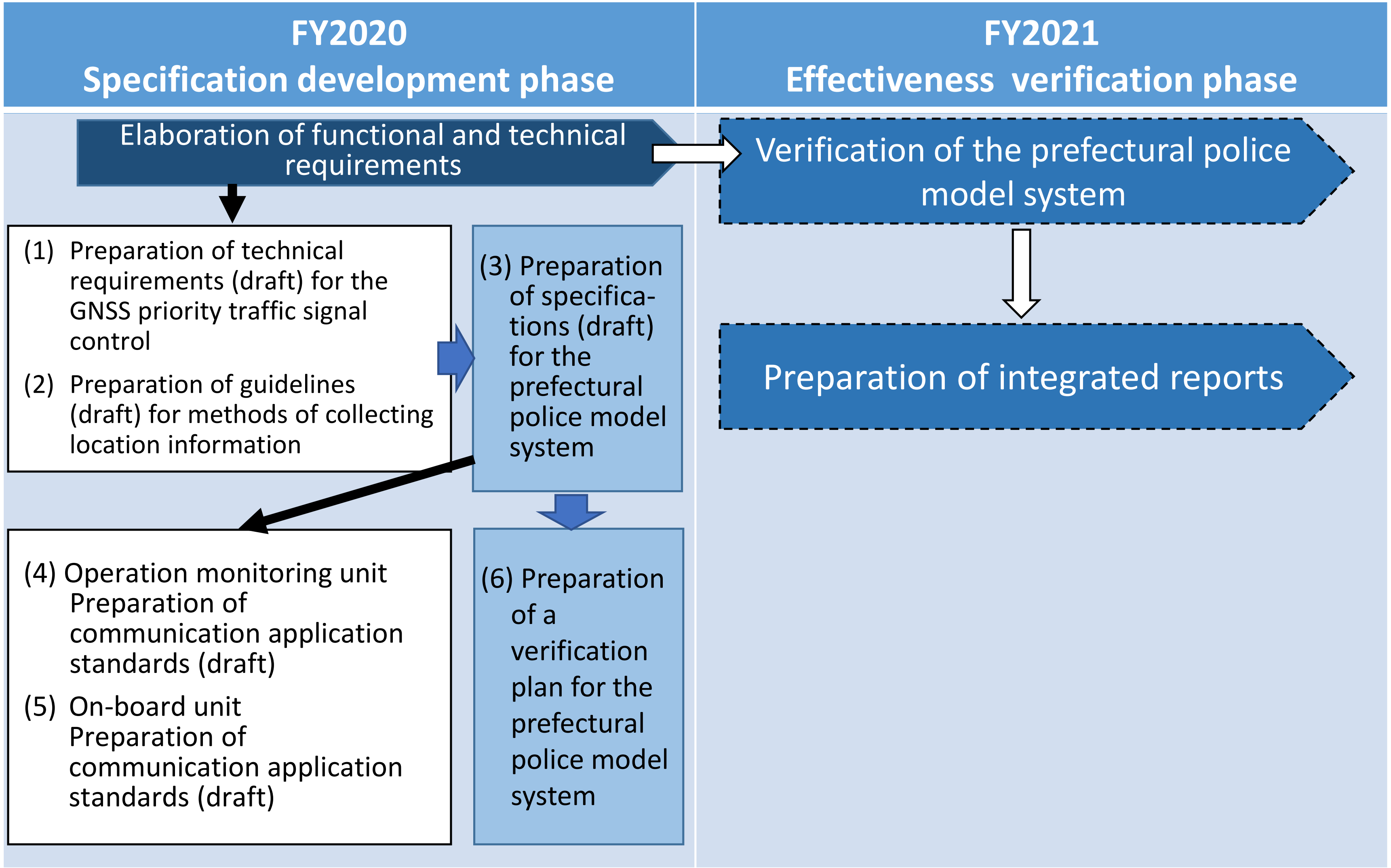
- To minimize the error of arrival time at intersections, priority traffic signal control using GNSS and other technologies **sets the final determination point to a position closer to the intersection** than infrared beacons.
- Since the arrival time is calculated based on the actual speed at the final determination point, the difference between the calculated speed and the actual speed can be suppressed, allowing the arrival time error to be minimized.



Comparison between with infrared beacon control and with control using GNSS, etc. (during traffic congestion)

- ➢ Reduction of arrival time error is expected to shorten travel time and reduce congestion in the intersecting direction.
- ➢ An easy-to-introduce system configuration will be examined by utilizing the current functions of signal controllers, control centers, etc. ⇨ Aims to further expand the use of the system in areas around the city center where the system is currently is currently implemented.

4. Positioning of Research and Development



In FY2020, the documents (1) through (6) toward the effectiveness verification phase were discussed by the "GNSS Utilization Committee," consisting of related administrative agencies, transportation infrastructure manufacturers, experts and others.

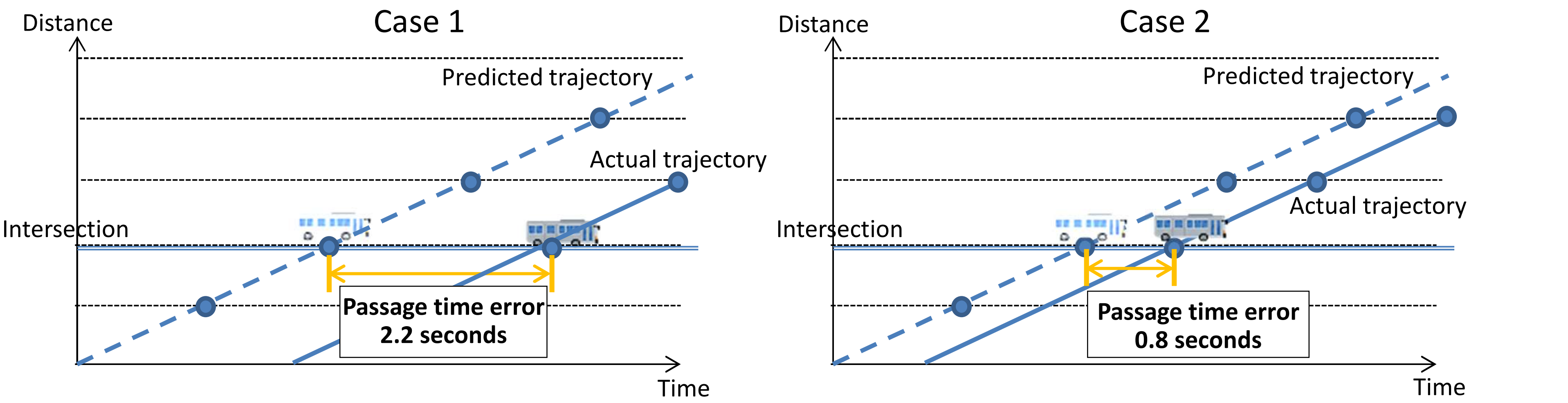
5. Elaboration of functional and technical requirements

5.1 Targeted position error accuracy performance

The errors in time of passing through the intersection (50 km/h is assumed)

Case 1 When the position error is 30 m, the passage time error is 2.2 seconds

Case 2 When the position error is 10 m, the passage time error is 0.8 seconds



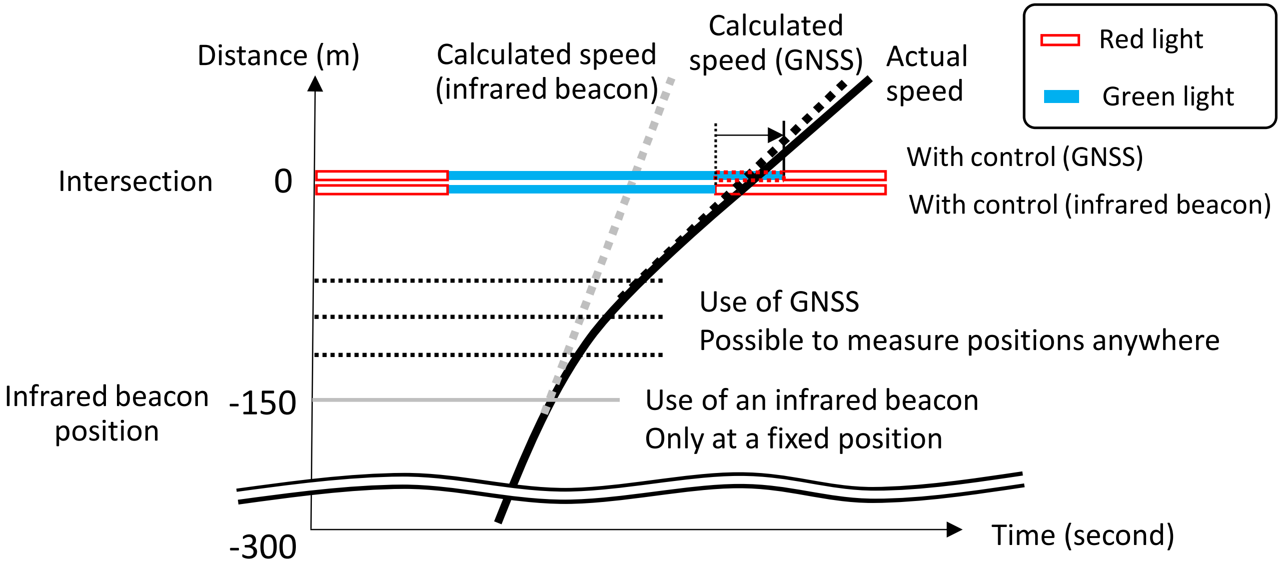
Error in time of passing through the intersection (**position error of 30 m**)

Error in time of passing through the intersection (**position error of 10 m**)

- The number of seconds set for the traffic signal controller is in increments of one second.
- It is desirable to keep the passing time error to less than 1 second.

⇒ Set **the position error accuracy to 10 m or less**

5.2 Targeted measurement cycle performance



- **Measurement cycle** was set to **2 seconds** considering the communication delay time and processing delay time.
  (Reference: The existing infrared beacon detects the vehicle only once at about 10 seconds before the intersection (the installation position 150 m before the intersection))

5.3 Measurement method

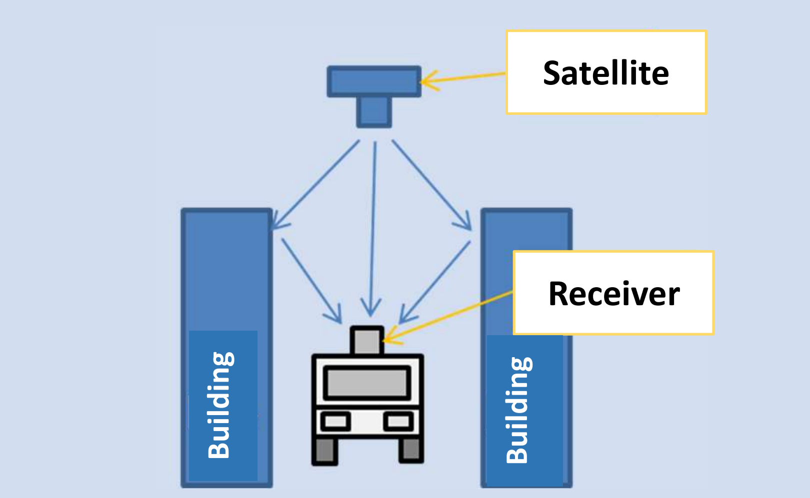
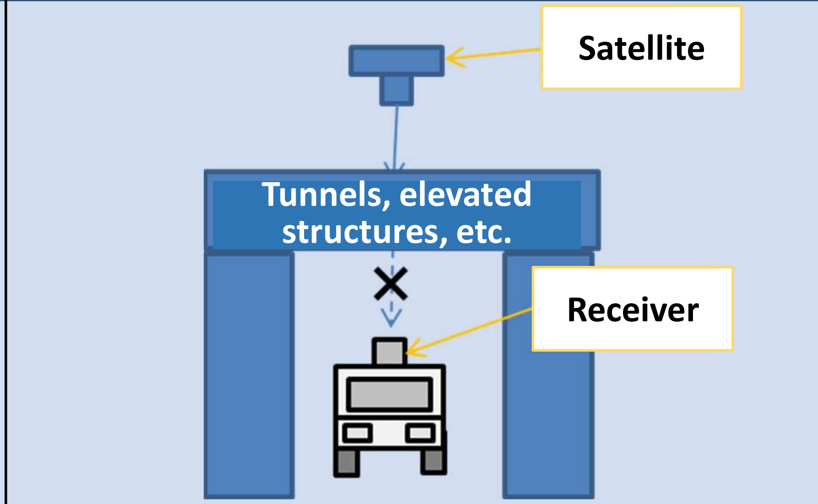
- The **RTK method** and **DGPS method** were adopted from among commonly and widely used methods (Both methods can also be used together).

5.4 Position correction method

Methods were left unspecified in light of the adoption of latest technologies in the future.

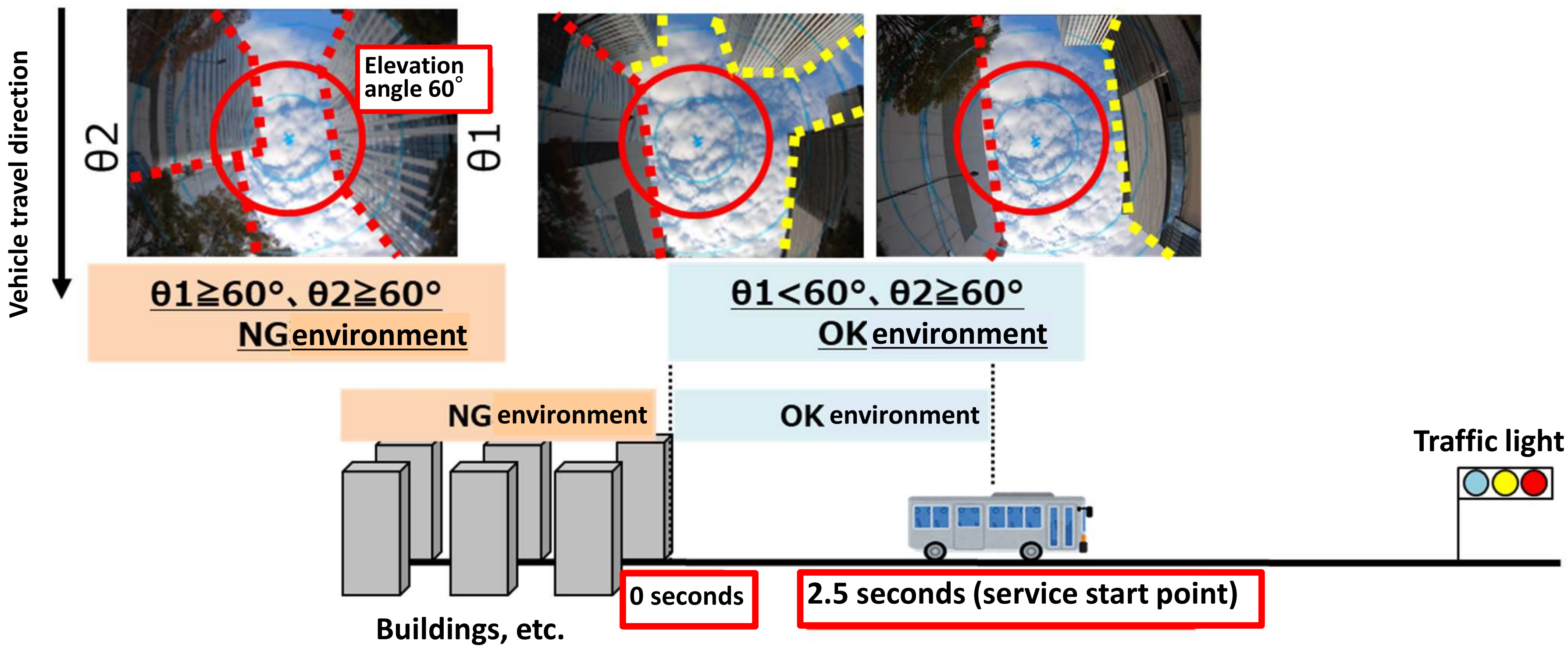
5.5 Definition of environmental conditions such as buildings that affect GNSS

Defined the following two environmental conditions.

Multipath environment	Environment where positioning is impossible
	
An environment where the elevation angle of satellite radio wave shields, such as buildings on both sides of the direction of travel, is 60° or more. (Satellite radio waves reflect off buildings, etc., which causes the propagation distance to become longer than when radio waves reach the receiver directly, resulting in larger position errors.)	An environment where satellite radio waves are blocked by tunnels and elevated structures and cannot be received. (Positioning becomes temporarily impossible and the accuracy is degraded for some time even after the passage through the area)

5.5.1 Requirements for service coverage areas, such as buildings around the areas (a multipath environment)

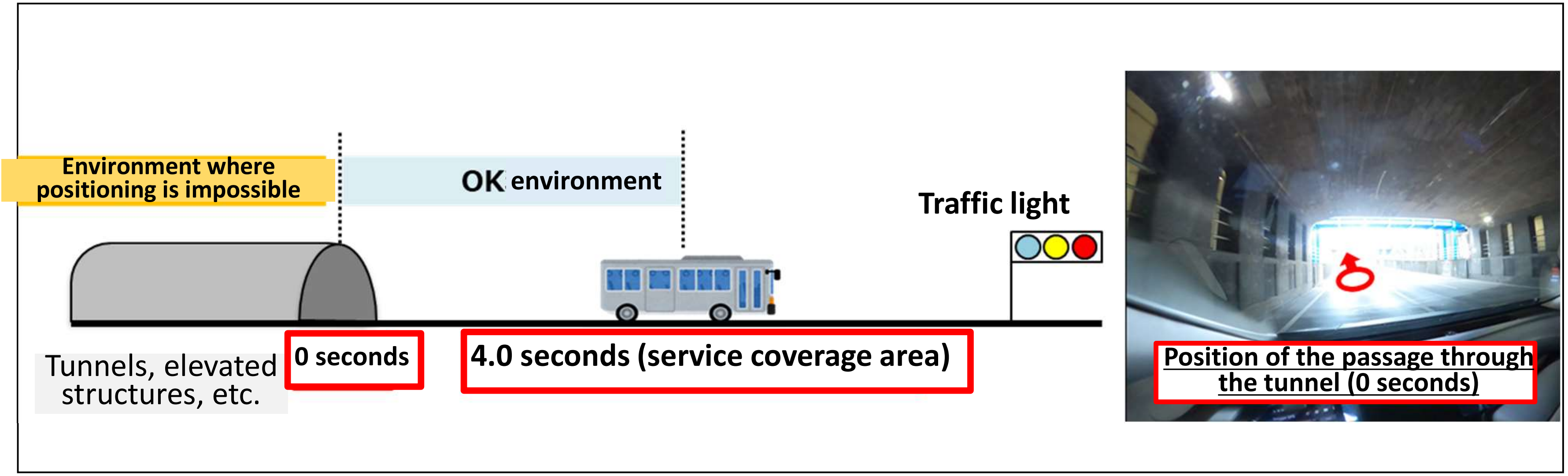
There shall be no service coverage areas in the section where an area having an elevation angle of less than 60 degrees on either the left or right side continues for 2.5 seconds after passing through an environment where the left and right elevation angles are 60 degrees or more (a multipath environment).



Effects of buildings, etc. around the service coverage area (a multipath environment)

5.5.2 Requirements for service coverage areas, such as buildings around the areas (an environment where positioning is impossible)

There shall be no service coverage areas in the section where an area having an elevation angle of less than 60 degrees on either the left or right side continues for 4 seconds after passing through an environment where GNSS location measurement is temporarily interrupted (an environment where positioning is impossible).



Effects of buildings, etc. around the service coverage area (an environment where positioning is impossible)

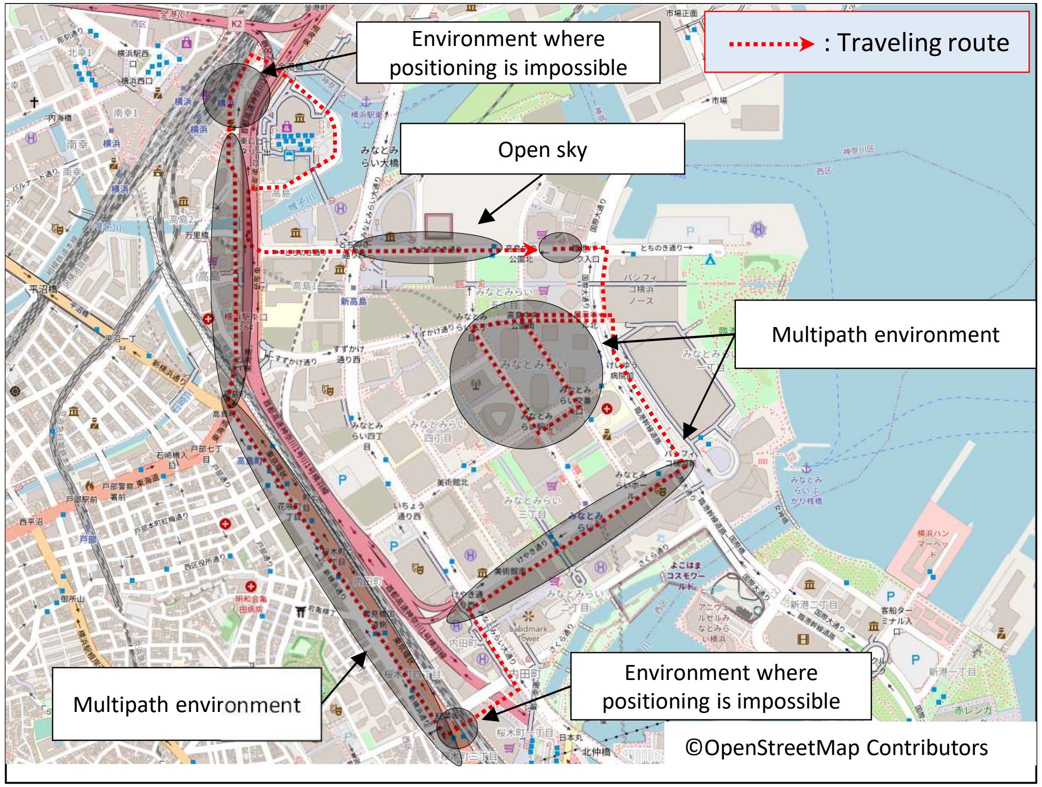
5.6. Verification of position error accuracy of GNSS receivers

5.6.1 Purpose of evaluation on public roads

Verify that the defined performance requirements are feasible under the defined environmental conditions.

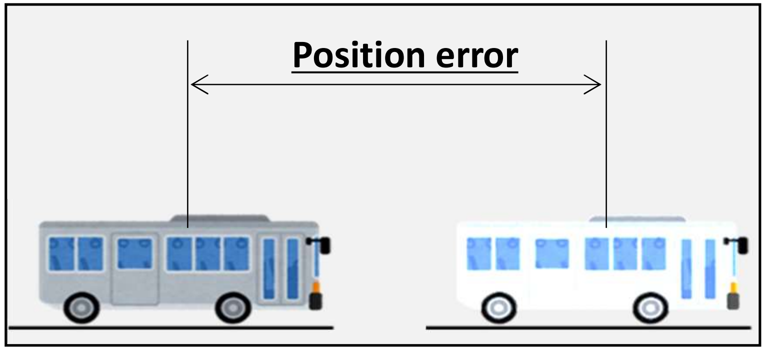
5.6.2 Selection of route

Minato Mirai area (Yokohama)" was selected where there are many multipath environments and environments in which positioning is impossible, and position error accuracy was evaluated on public roads.



Travel routes in Minato Mirai area

- Date : October 29, 2020 (Thu)
- Time : 10:00 – 16:00
- Weather : Sunny
- Number of trips: 4 laps
- Vehicle : Honda FIT (GK3)



Position error calculation method

5.6.3 Results of evaluation on public roads

(1) Change in position error accuracy after passing through the multipath environment

		Distance (m) against time (sec) after passing through the multipath environment						
Positioning method	**Inertial navigation**	**0.0 (sec)**	**0.4**	**0.8**	**1.2**	**1.6**	**2.0**	**2.4**
RTK+DGPS	Valid	1.3(m)	1.0	1.0	1.0	1.2	1.4	**1.6**
DGPS	Valid	3.0	2.8	2.8	2.7	2.8	2.8	**2.9**

(2) Change in position error accuracy after passing through the environment where positioning is impossible

		Time after passing through tunnel (sec)										
Positioning method	**Inertial navigation**	**0.4**	**0.8**	**1.2**	**1.6**	**2.0**	**2.4**	**2.8**	**3.2**	**3.6**	**4.0**	**4.4**
RTK+DGPS	Valid	12.2	8.6	7.7	7.7	7.2	6.5	5.8	5.4	5.0	**3.5**	4.0
RTK+DGPS	Invalid	8.0	6.0	9.0	9.0	8.4	8.2	8.1	7.4	7.0	**6.6**	6.3
DGPS	Valid	9.2	8.4	7.6	6.3	4.9	3.8	3.6	3.1	2.9	**2.6**	2.5
DGPS	Invalid	9.0	7.1	5.9	4.9	4.1	3.6	3.7	2.9	2.6	**2.2**	1.9

- The maximum position error accuracy 2.4 seconds after passing through the multipath environment was 2.9 m.
- The maximum position error accuracy 4 seconds after passing through the environment where positioning is impossible was 6.6 m.

⇨ **Confirmed that the defined performance requirement "position error accuracy of 10 m or less" is feasible.**

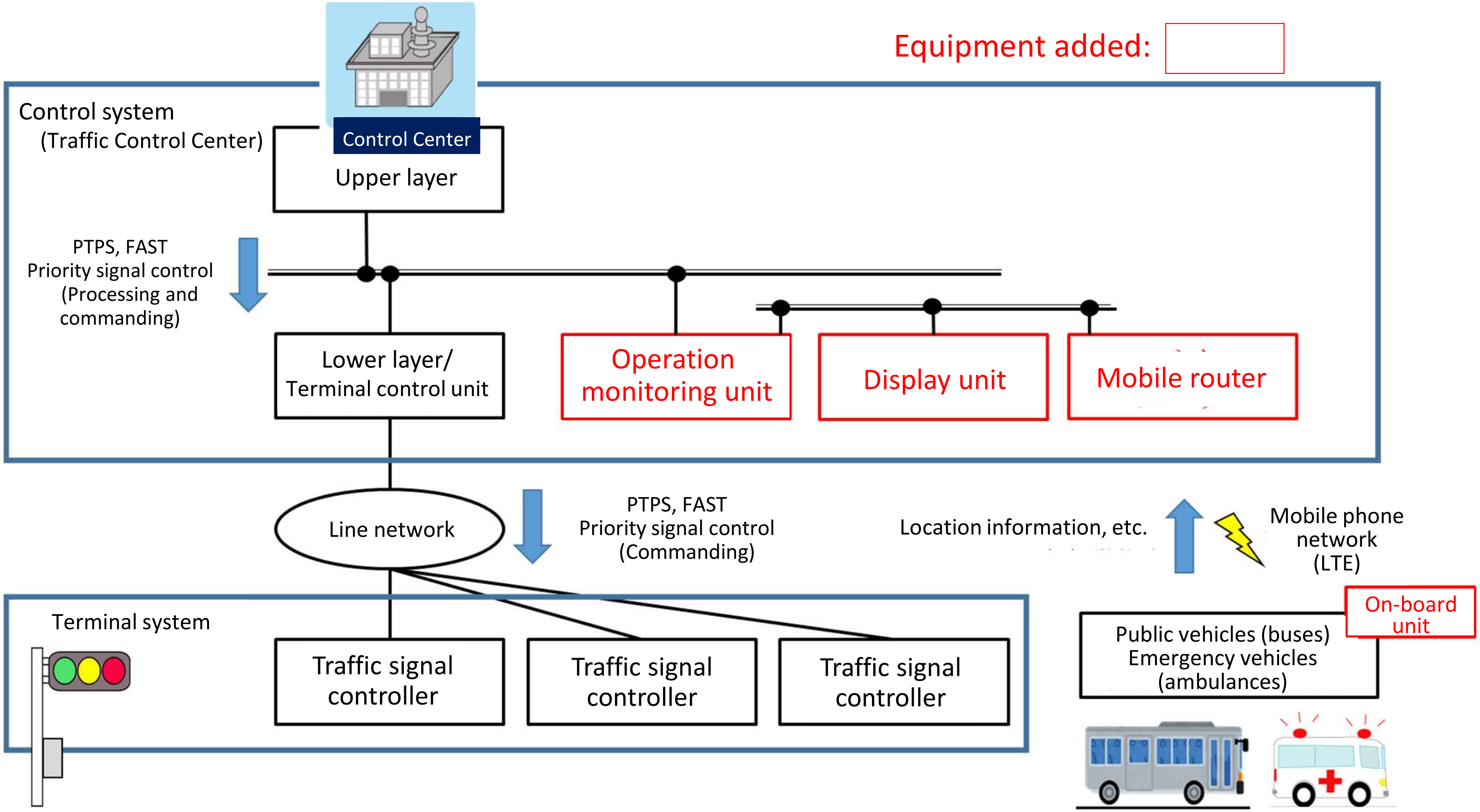
6. Development of draft specifications and others toward the model system verification

In FY2020, the following six documents were developed with the approval of the GNSS Utilization Committee.

FY2020 deliverables	Outline
"GNSS priority traffic signal control technical requirements" (draft)	Provides system requirements for the GNSS priority traffic signal control, functional and performance requirements for each unit and an outline of the interfaces between each unit.
"Guidelines for methods of collecting location information" (draft)	Provides an overview of GNSS and points to note during its operation in the collection of location information used for the GNSS priority traffic signal control.
"Specifications for the prefectural police model system" (draft)	Specifications for the model system demonstration experiment scheduled to be implemented in FY2021. It provides specification for the operation monitoring unit/display unit/on-board unit used for the experiment, and improvement specification for the existing control system.
"Operation monitoring unit communication application standards" (draft)	Provides the concept of interface conditions/communication standards for exchanging information between the model system's operation monitoring unit and the existing control system.
"On-board unit communication application standards" (draft)	Provides the concept of interface conditions/communication standards for exchanging information between the model system's on-board unit and operation monitoring unit.
"Prefectural police model system verification plan"	Provides the verification plan for the FY2021 model system demonstration experiment which aims to perform operation verification/effectiveness confirmation/verification of concerns (processing delay/location error) of the GNSS priority traffic signal control system.

7. Model system verification configuration

The verification will be implemented in FY2021 using a versatile configuration that enables the introduction of the GNSS priority traffic signal control by adding to the existing control system an “operation monitoring unit” that has a function to collect bus location information and perform priority traffic signal control for buses, and an “on-board unit” that has a function to transmit location information.



8. Future plan

- Because this is a system that links the mobile phone network with the traffic control center of the prefectural police, it is necessary to verify its effectiveness such as smoother traffic flow, including the delay time of the entire system and the effects of position error.
- In the model system demonstration experiment in FY2021, the effectiveness will be compared with that of the current system on routes where existing infrared beacons are installed and costs required to introduce the GNSS priority signal control will be estimated.

Item	2021			
	1Q	2Q	3Q	4Q
Verification based on the verification plan for the prefectural police model system				
• Verification preparation (Preliminary survey of the control areas)				
• GNSS impact survey				
• Preparation for effectiveness measurement (Preliminary confirmation)				
• Verification of verification items				
• Compilation of verification results				
Preparation of integrated report				
• **Estimation of costs for introducing the system** and a summary				
• “Specifications for the prefectural police model system” and a summary of effectiveness verification				