Cross-ministerial Strategic Innovation Promotion Program

The Second Phase of Cross-ministerial Strategic Innovation Promotion Program (SIP) Automated Driving for Universal Services (Expansion of Systems and Services)/Infrastructure Preparation, Advance Verification, and Maintenance and Management for the Metropolitan Expressway Routes Connecting Haneda Airport and the Waterfront City Area, etc.

FY2019-2021 Report

Overview

Mitsubishi Electric Corporation

May 2022

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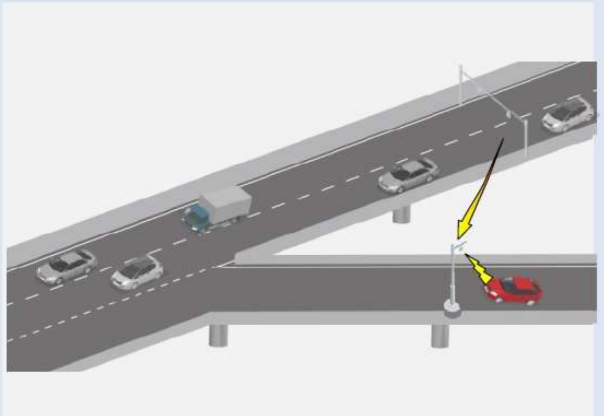
1. FOTs in the Tokyo Waterfront area - Overview of the Metropolitan Expressway FOTs

1.1. Overview of the FOTs in the Tokyo Waterfront area and scope of this commissioned project

Advanced automated driving on ordinary roads through distribution of traffic signal information by ITS wireless roadside units

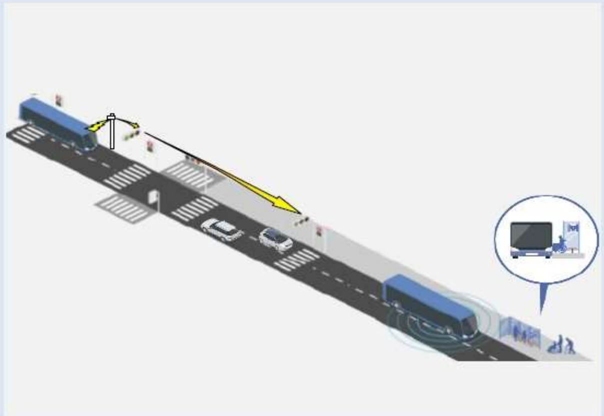
(1) Waterfront City area
(3) Haneda Airport area

Advanced automated driving on expressways through distribution of driving support information and lane-level roadway traffic environments



(2) Expressway routes connecting Haneda Airport and the Waterfront City area, etc.

Advanced Rapid Transit (ART) using bus automated driving technology in mixed transportation environments through the use of infrastructure equipment by setting ODDs, advanced PTPS, etc.



(3) Haneda Airport area

Scope of this commissioned project

Figure 1-1 FOTs in the Tokyo Waterfront area - Overview of cooperative infrastructure technology FOTs (from Cabinet Office materials)

1. FOTs in the Tokyo Waterfront area - Overview of the Metropolitan Expressway FOTs

1.2. Metropolitan Expressway FOTs area (Haneda Line, Airport West (Entrance))

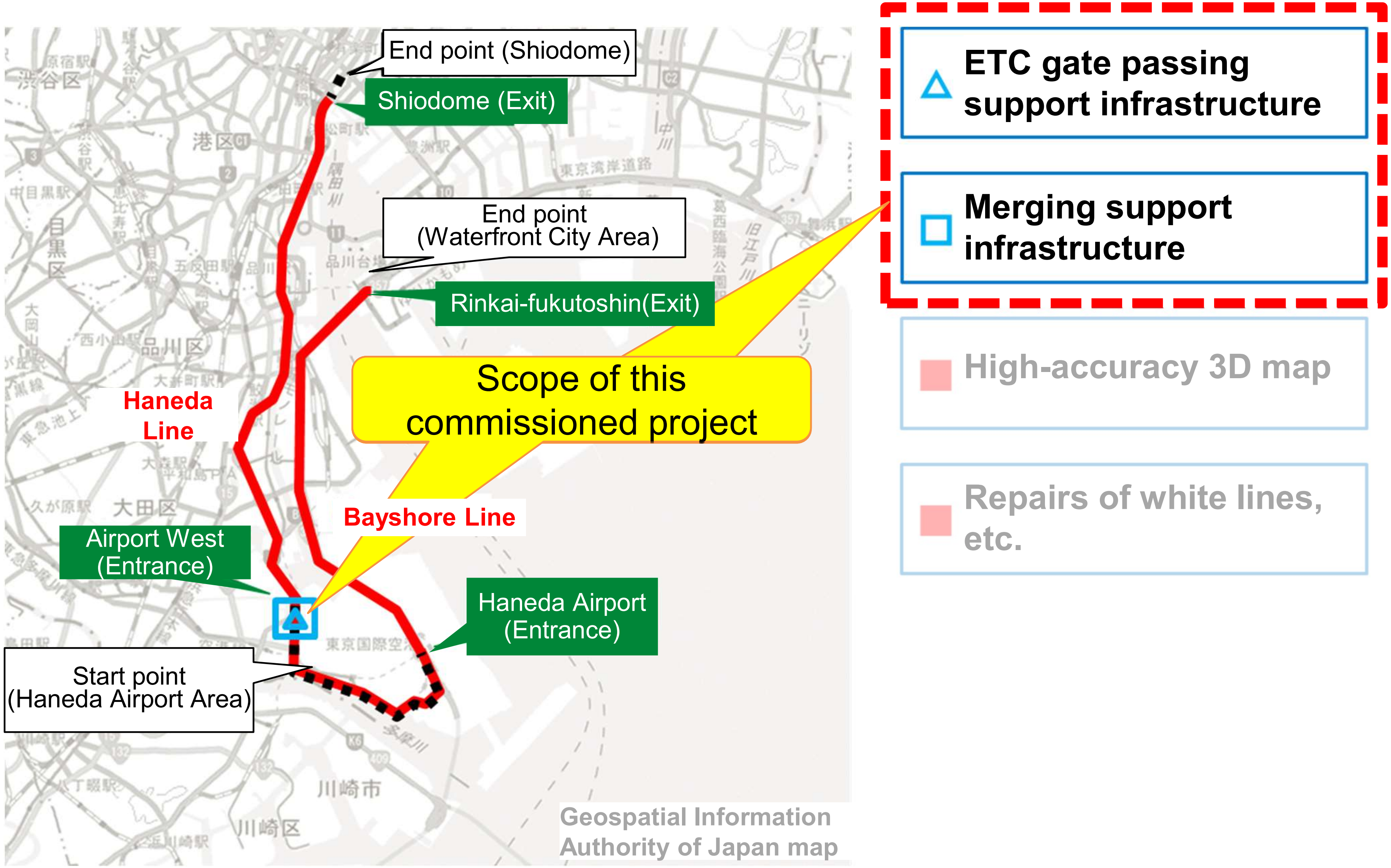


Figure 1-2 Metropolitan Expressway routes connecting Haneda Airport and the Waterfront City area, etc. - FOT area (from Cabinet Office materials)

1. FOTs in the Tokyo Waterfront area - Overview of the Metropolitan Expressway FOTs

1.3. Metropolitan Expressway ETC gate passing/merging support information delivery FOTs verification items and targets

Issues

- Smooth ETC gate passing support
- Support for merging with cruising lines based on actual cruising line vehicle speeds

Hypotheses regarding effectiveness of cooperative infrastructure technologies

- Support gate selection and passing by providing information
- Support adjustment of vehicles speeds in order to merge into cruising lines by providing information

Verification item

- **Appropriateness of operation** of cooperative infrastructure system
- **Effectiveness** of provision of support information to autonomous vehicles, etc.
- Verification of infrastructure installation conditions

Arrival target

- Examine infrastructure specification improvements
- **Derive infrastructure installation conditions** for Airport West (Exit/Entrance)
- **Clarify issues** in order to define specifications based on FOT
- Identify need for infrastructure and identify **prioritization conditions**

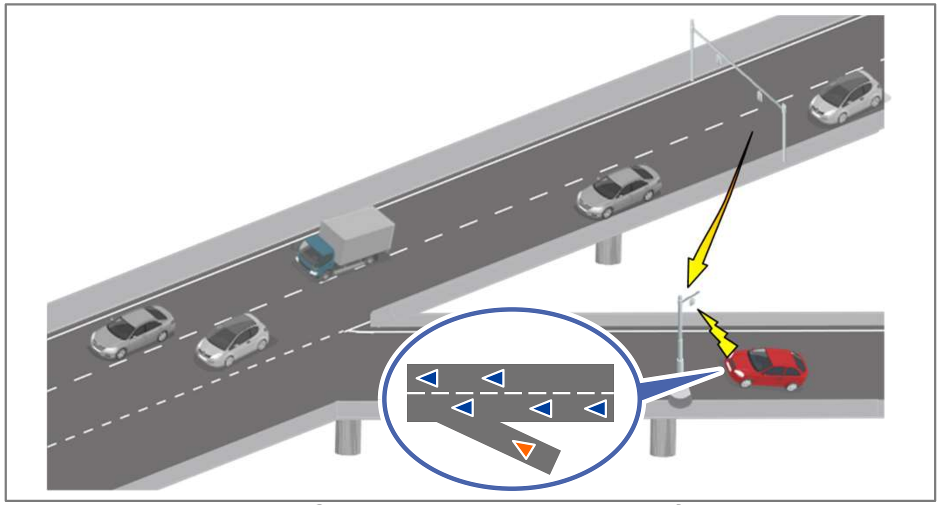


Figure 1-3 Conceptual image of merging support on expressways

Prepared by SIP

Infrastructure	Test vehicle on-board equipment
• Roadside unit for expressway experiments (provision of merging support information and ETC gate passing support information) • High-accuracy 3D map	• Test vehicle on-board equipment for expressway experiments • High-accuracy 3D map and delivery information overlap display viewer • Output function to vehicle control • Data logger (movement management) • Drive recorder

2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.1. Background and objectives of this research and development

[Background behind this research and development project]

* SIP Phase 2 Automated Driving (Expansion of Systems and Services) establishes core technologies for collecting and delivering road traffic information, etc., as a collaborative area effort, and promotes the creation and societal implementation of a automated driving level 4 foundation
* Since the March 2018 meeting of the Growth Strategy Council on Investment to the Future, government agencies and related industrial organizations such as JAMA have coordinated, conducting studies and investigations in preparation for the FOTs in the Tokyo Waterfront area.

[Objectives of the overall project and this commissioned project]

* In Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase Two/Automated Driving (Expansion of Systems and Services), FOTs are carried out with the objectives of building systems for utilizing roadway traffic environmental data such as traffic signal information and merging support information provided by traffic infrastructure and rapidly achieving the practical implementation of advanced cooperative infrastructure automated driving.

In relation to the above objectives, this commissioned project prepares the infrastructure environments necessary for FOTs on expressways, performs advance verification, and carries out maintenance and management

<Specific implementation items>
(1) Development of infrastructure equipment necessary for implementing and performing verification of FOTs related to merging support and ETC gate passing support for expressways
(2) Installation of actual environments on Metropolitan Expressway to enable test participants to perform automated driving technology tests
(3) Verification of infrastructure installation conditions, etc., related to merging support and ETC gate passing support

2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.2. Implementation of FOTs and development of equipment necessary for ve

[FY2019 results]

Device structure of infrastructure equipment used to provide merging support

Device name	Role
Roadside sensor	Detect information regarding ordinary vehicles driving on expressway cruising lines (vehicle speeds, vehicle lengths) * Provided by joint research by NILIM. In this project, we prepared sensor mounts
Processing roadside unit	Use the detection results of roadside sensors to calculate how long it will take for ordinary vehicles travelling on expressway cruising lines to reach merging points (* Provided by joint research with NILIM. In this project, we prepared the outdoor units that contain these devices.)
Wireless roadside unit for expressway experiments	Transmit merging support information to on-board equipment for expressway experiments on test vehicles driving on merging lanes
Camera/recording device	Record video/images of expressway traffic conditions near test implementation sites

Device structure of infrastructure equipment that provides ETC gate passing support information

Device name	Role
ETC gate equipment	Acquire ETC gate operation status information in the form of gate open/close status (ETC, general, closed, etc.)
ETC gate open/close status data provision device	Receive ETC gate open/close information obtained from existing ETC equipment in toll booths and generate information to deliver to autonomous vehicles
Wireless roadside unit for expressway experiments	Transmit ETC gate passing support information to on-board equipment for expressway experiments on test vehicles driving on ramps in front of toll booths

2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.3. Infrastructure preparation for the Metropolitan Expressway - Equipment configuration and division of responsibility for equipment

[FY2019 results]

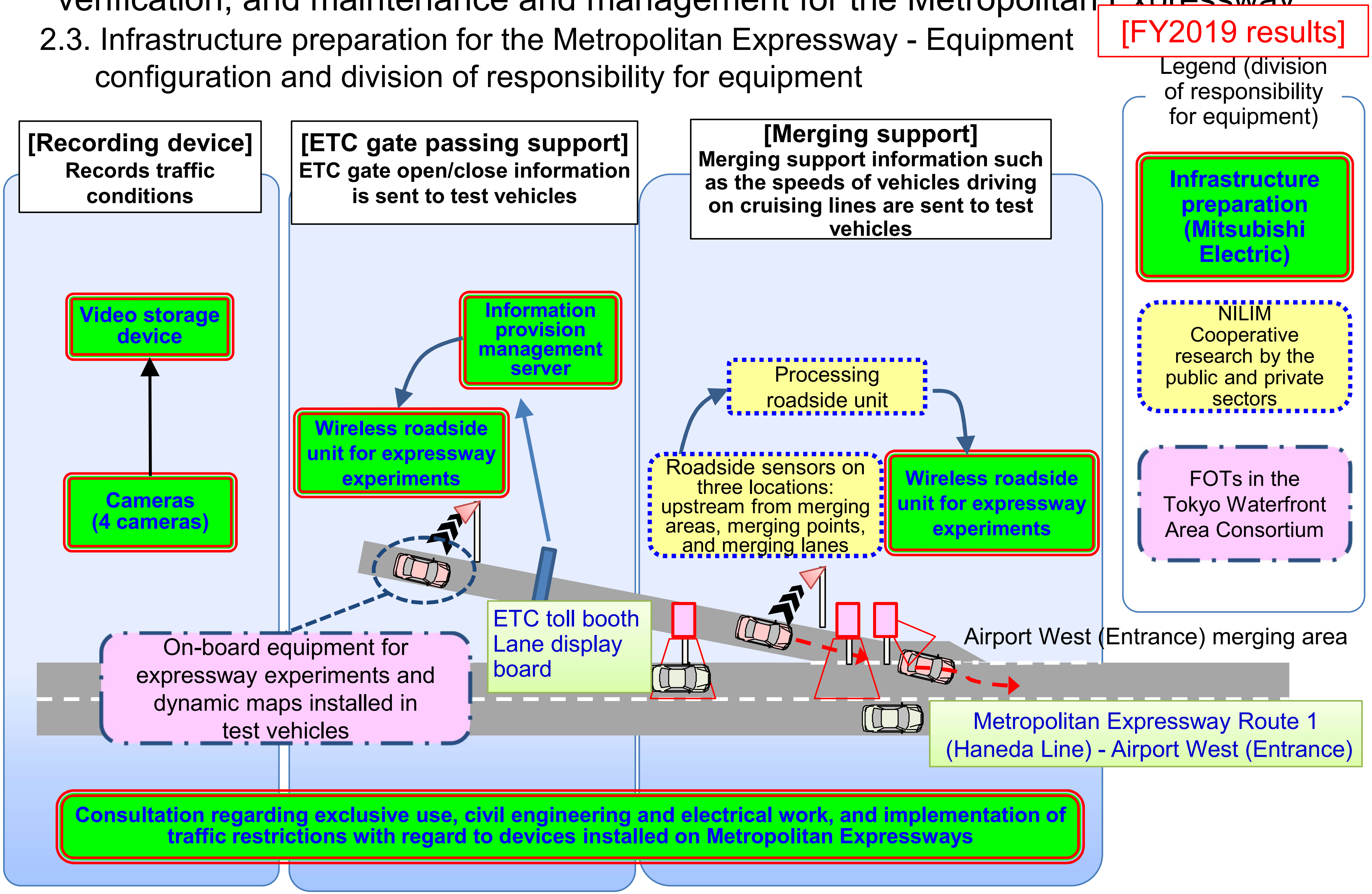


Figure 2-1 Configuration of test equipment in and around the Metropolitan Expressway Airport West (Entrance) and division of responsibility for equipment preparation

2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.4. Conceptual image of operation of the Metropolitan Expressway FOTs system

[FY2019 results]

Wireless roadside units that transmit ETC gate passing support information also detect the passage of test vehicles.
Wireless roadside units that send merging support information only transmit information when they detect that a test vehicle is passing. When they do not detect passing test vehicles, they turn off their radio signal output.

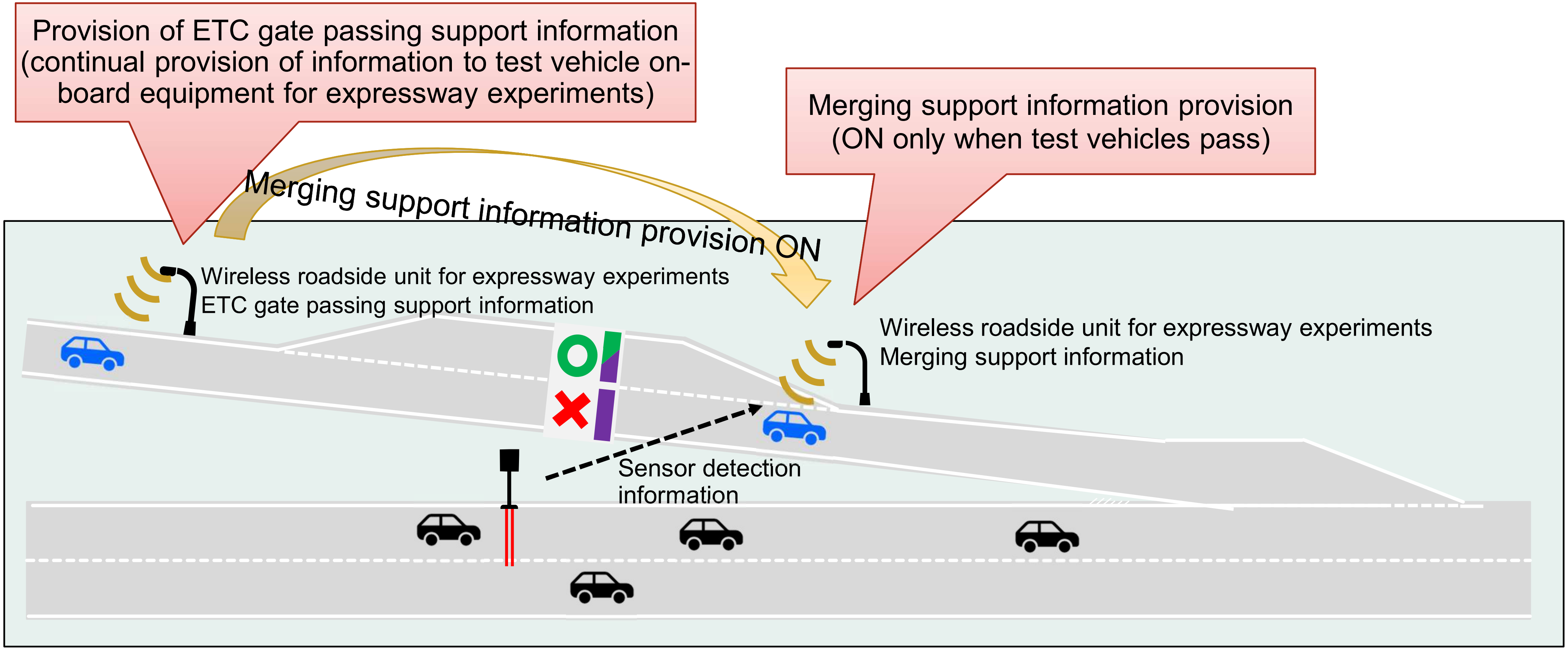
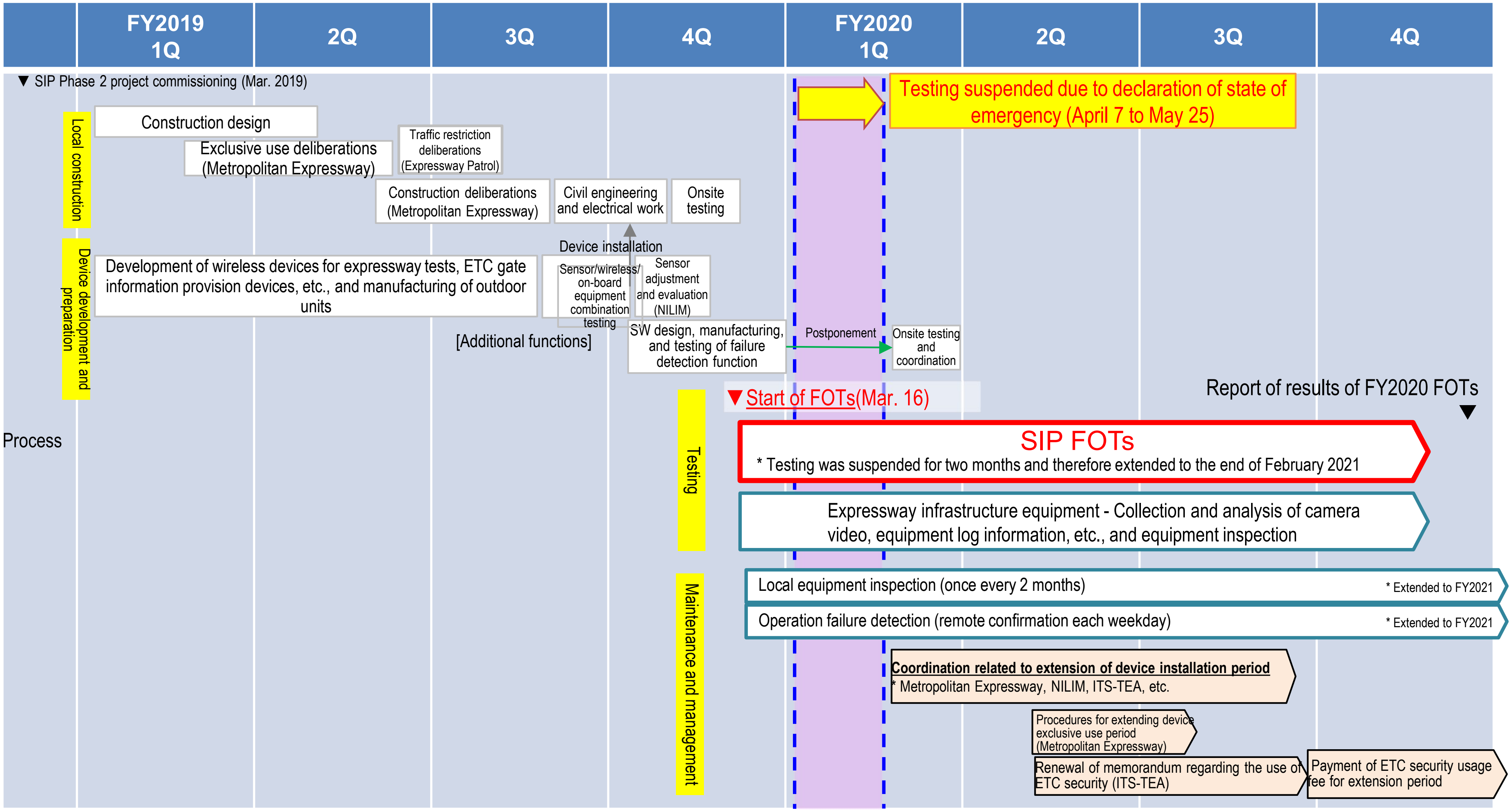


Figure 2-2 Conceptual image of system operation at the Metropolitan Expressway Airport West (Entrance)

2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.5. Overall process of infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

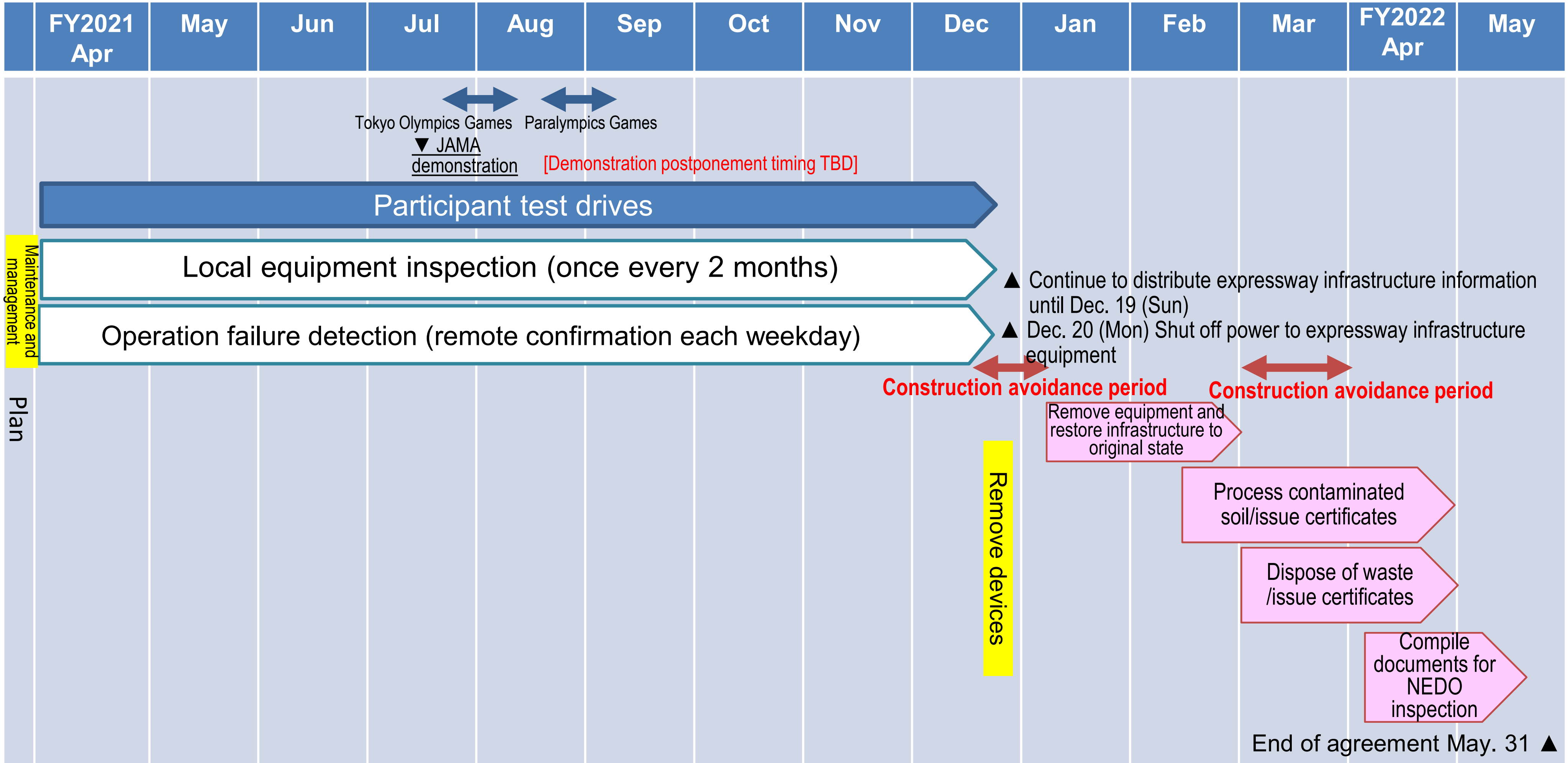
Consultation regarding exclusive use, civil engineering and electrical work, and the development of related devices involved in the installation of test infrastructure equipment on the Metropolitan Expressway have been completed according to schedule. Testing began on March 16, 2020.
The overall process for the two-year period of FY2019 and FY2020 is shown below.



2. Contents of research and development related to infrastructure preparation, advance verification, and maintenance and management for the Metropolitan Expressway

2.6. Overall process of maintaining and managing infrastructure equipment from FY2021 onwards

Shown below is the overall process of maintaining the infrastructure equipment used in Metropolitan Expressway FOTs from FY2021 onwards.



3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.1. Overall view of infrastructure equipment (Metropolitan Expressway Airport West (Entrance))

Installation of the equipment necessary for conducting FOTs at the Airport West (Entrance) was completed as shown below.

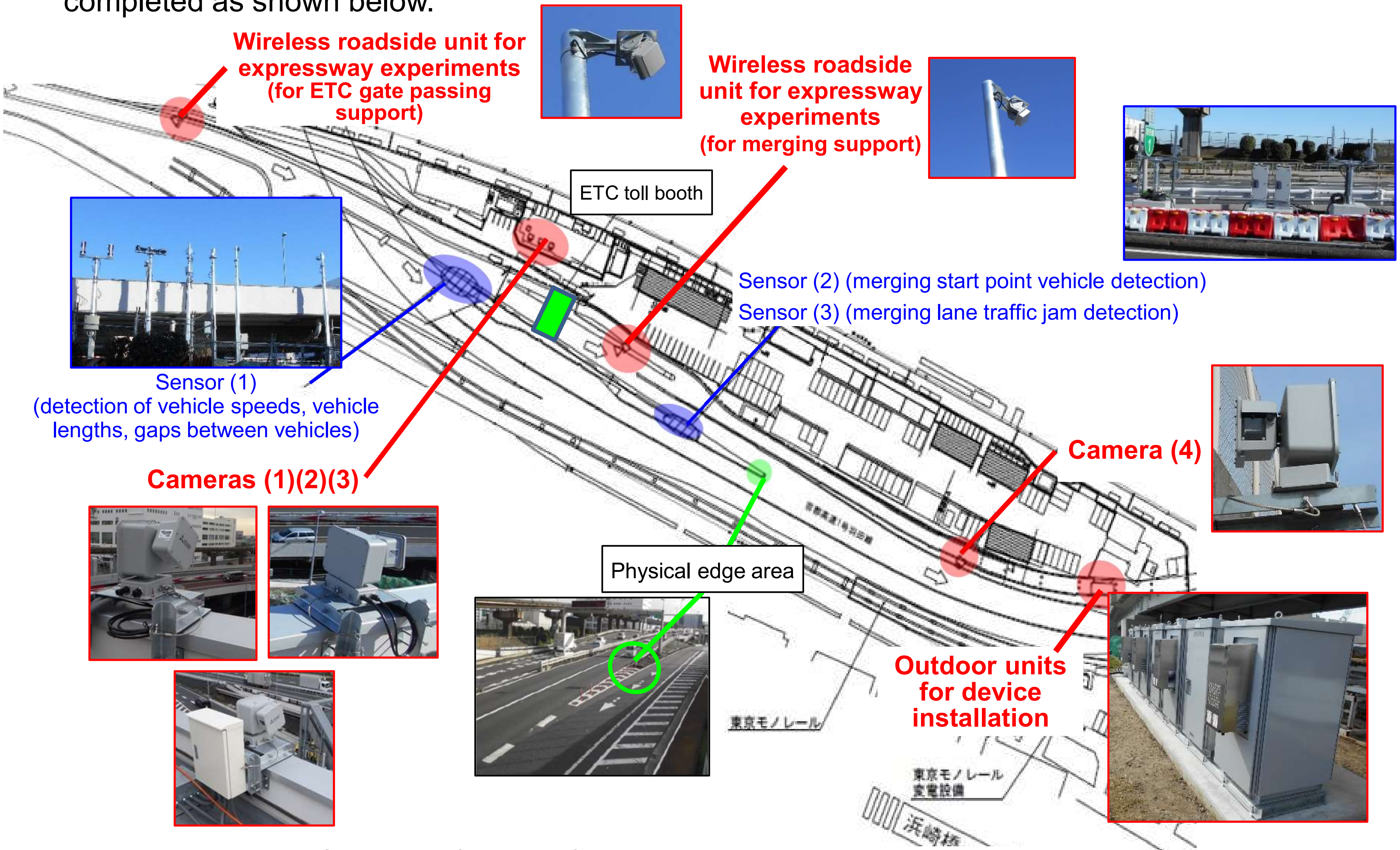


Figure 3-1 Overall view of locations of test equipment in and around the Metropolitan Expressway Airport West (Entrance)

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.2. Individual infrastructure equipment: Roadside sensors (NILIM, five companies in joint research)

Figure 3-2 Sensor (1) installation (roadside sensors of five companies in NILIM joint research)

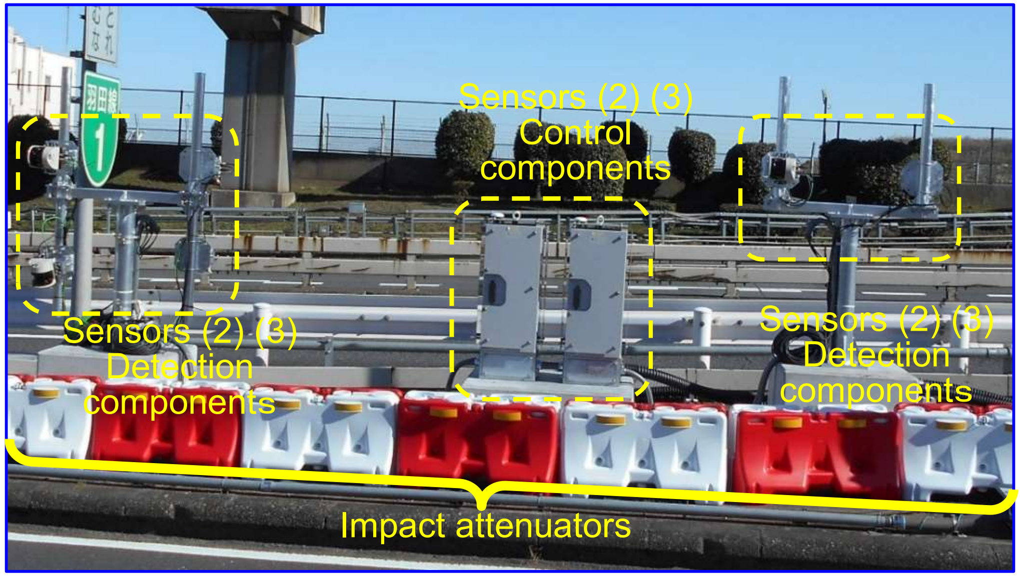


Figure 3-3 Sensors (2) (3) installation and appearance of impact attenuators

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.3. Individual infrastructure equipment: Wireless roadside unit for expressway experiments (for ETC gate passing support)

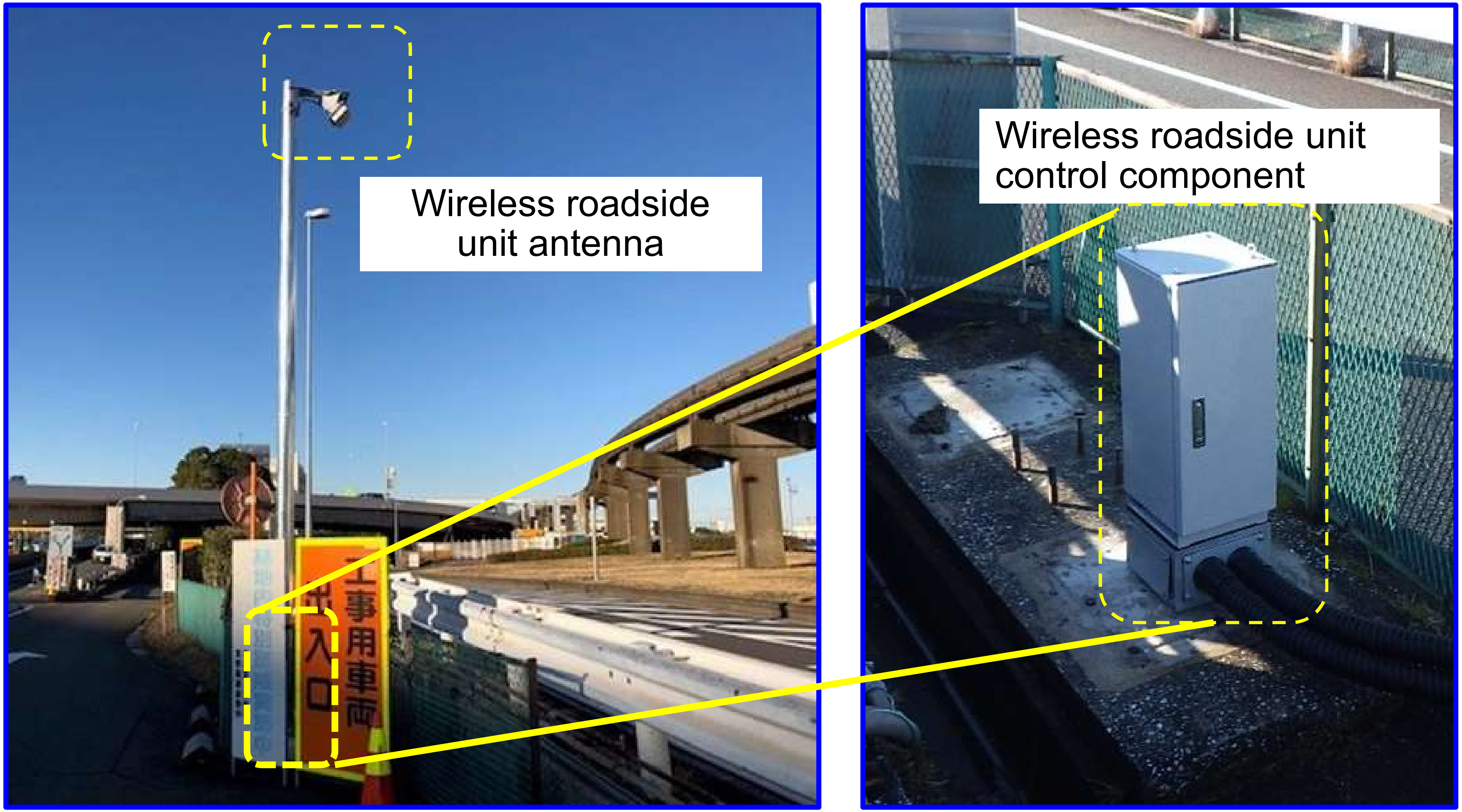


Figure 3-4 Wireless roadside unit for expressway experiments for providing ETC gate passing support information

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.4. Individual infrastructure equipment: Wireless roadside unit for expressway experiments (for merging support)

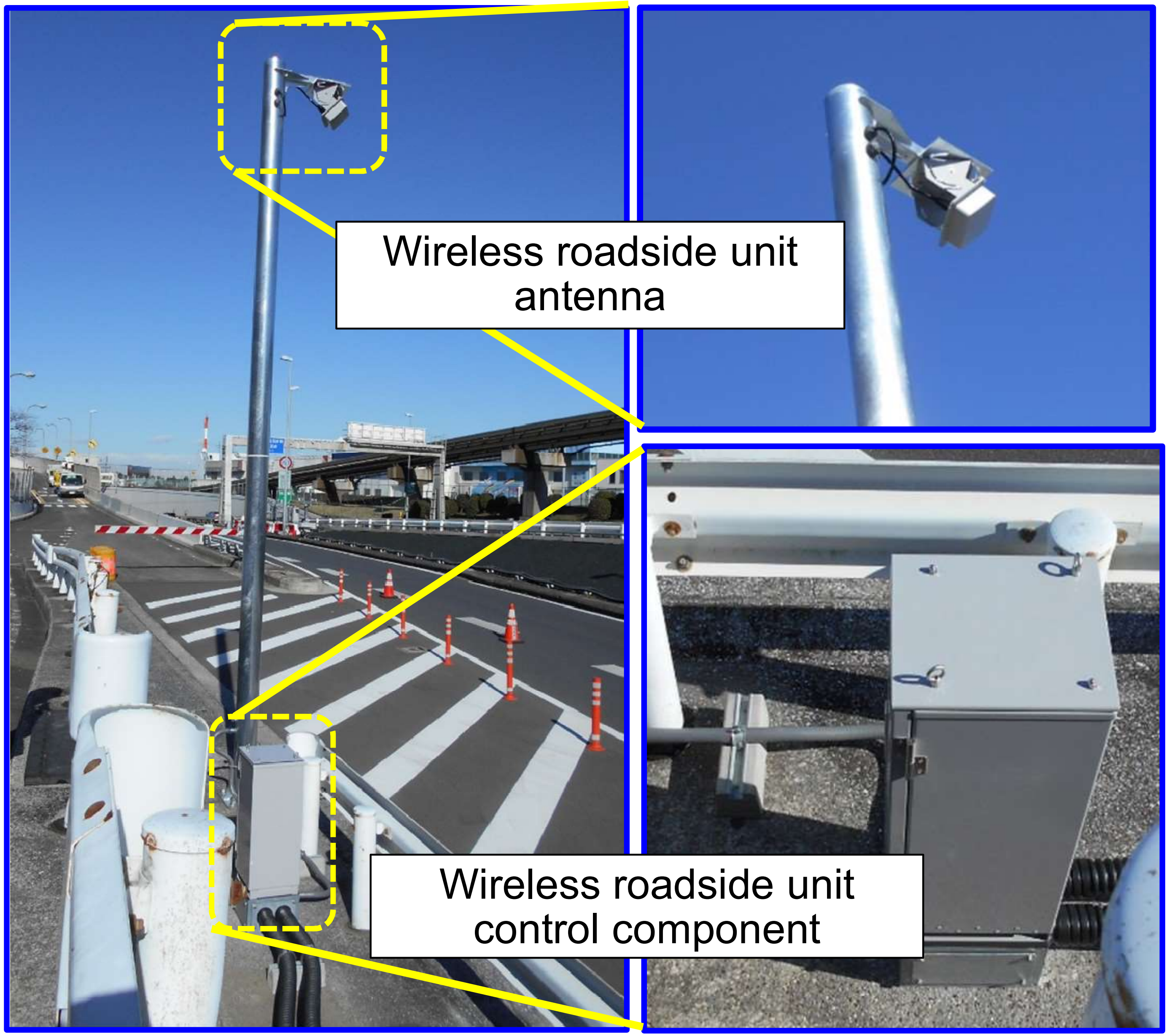


Figure 3-5 Wireless roadside unit for expressway experiments for providing merging support information

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.5. Individual infrastructure equipment: Outdoor units (containing information provision management servers and individual companies' processing roadside units)

Figure 3-6 Appearance of outdoor units that house ETC gate passing support information provision management servers and processing roadside units of individual sensor manufacturers

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.6. Individual infrastructure equipment: Cameras ((1) (2) (3): Roof of Shutoko Electrical Maintenance building/(4): Near merging area)

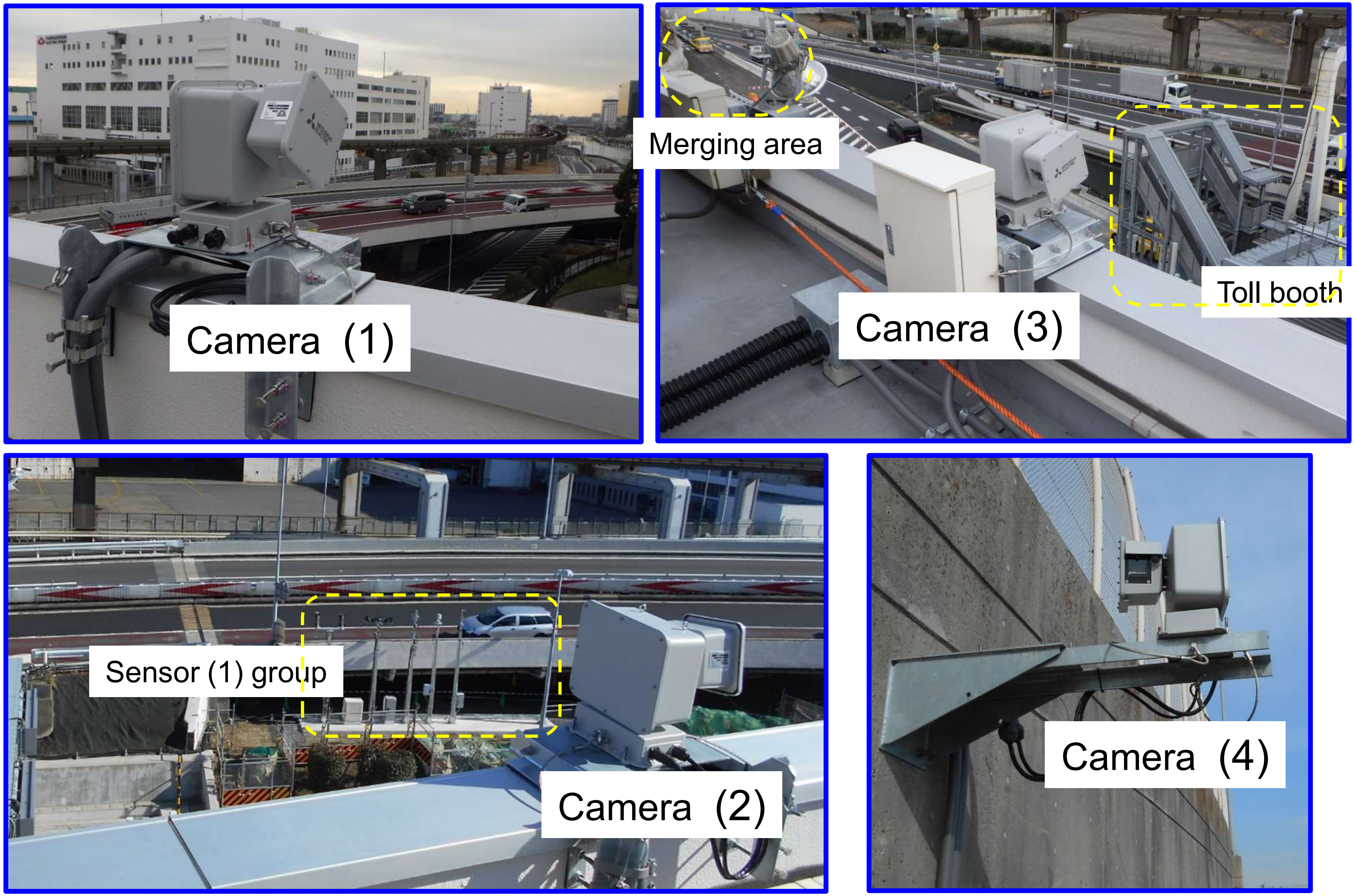


Figure 3-7 Cameras used to film traffic conditions on cruising lines and merging area

3. Metropolitan Expressway - Preparation of FOTs infrastructure equipment

[FY2019 results]

3.7. Infrastructure equipment soundness confirmation: Confirmation of information provision area using radio signal measurement

To confirm that radio signals sent out by installed test wireless roadside units do not affect existing expressway facilities, a third party (Shutoko ETC Maintenance Co., Ltd.) performed the following radio signal measurement drives.

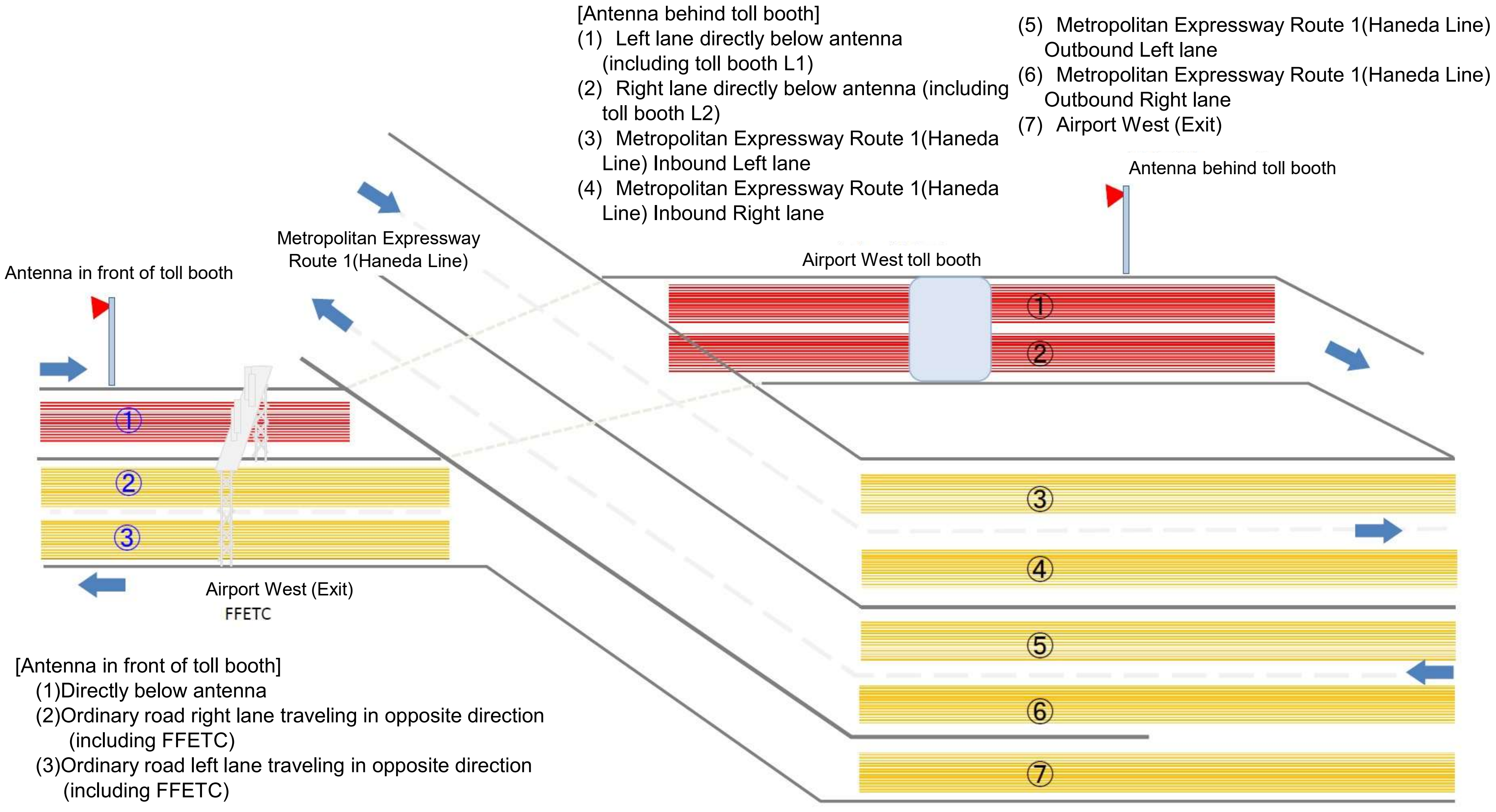


Figure 3-8 Radio signal measurement lanes on the Metropolitan Expressway Airport West ramp

4. Verification of installation conditions, etc., related to infrastructure equipment on Metropolitan Expressway

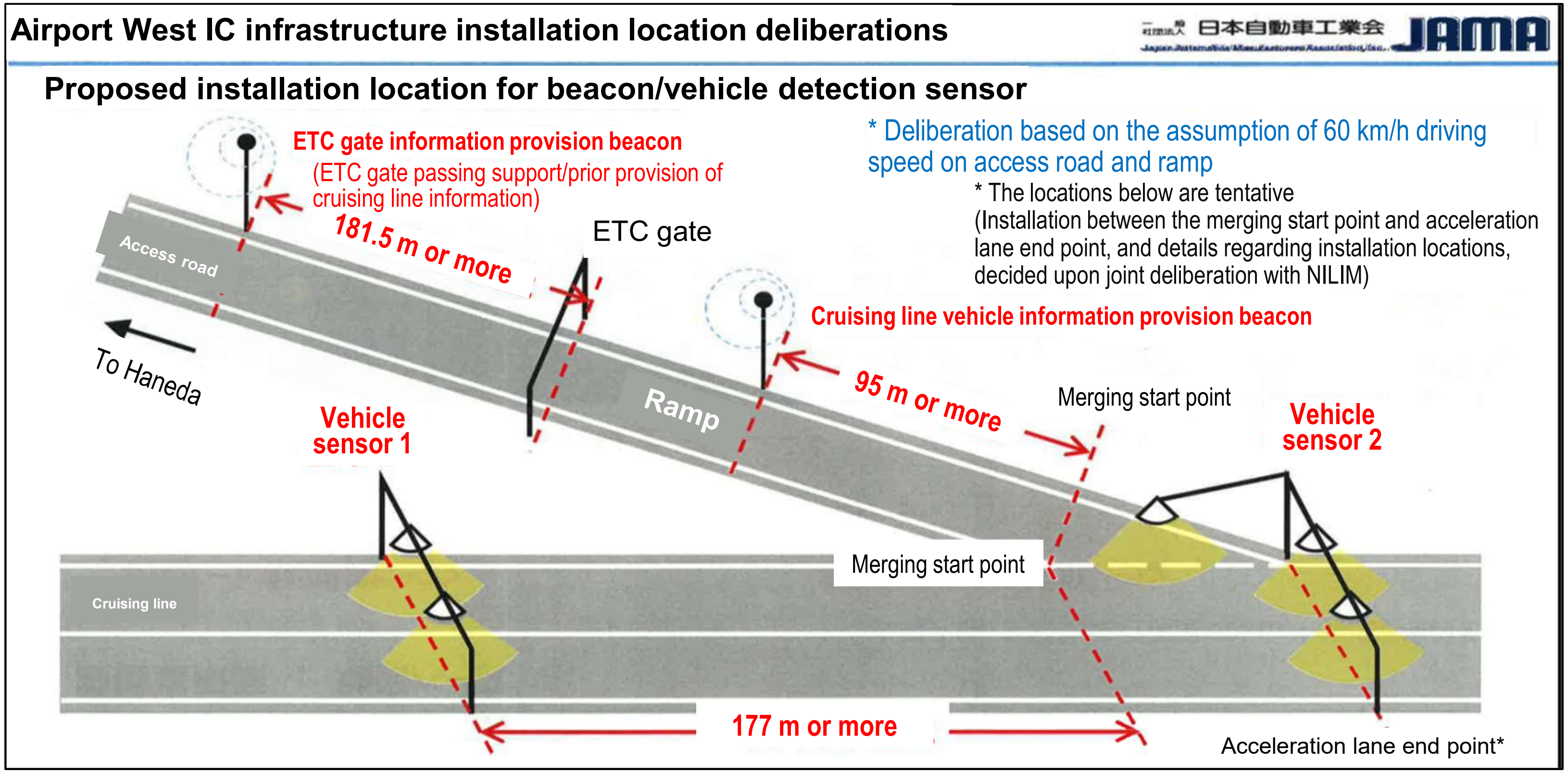
[FY2020 results]

4.1. Verification of installation conditions of infrastructure equipment used to provide merging support

4.1.1. Organization of information regarding installation locations requested by JAMA and actual installation locations

We organized information regarding differences between the locations of this actual installed infrastructure equipment and the locations in the ETC gate passing support and merging support system specifications formulated through joint research by NILIM/requests issued by JAMA.

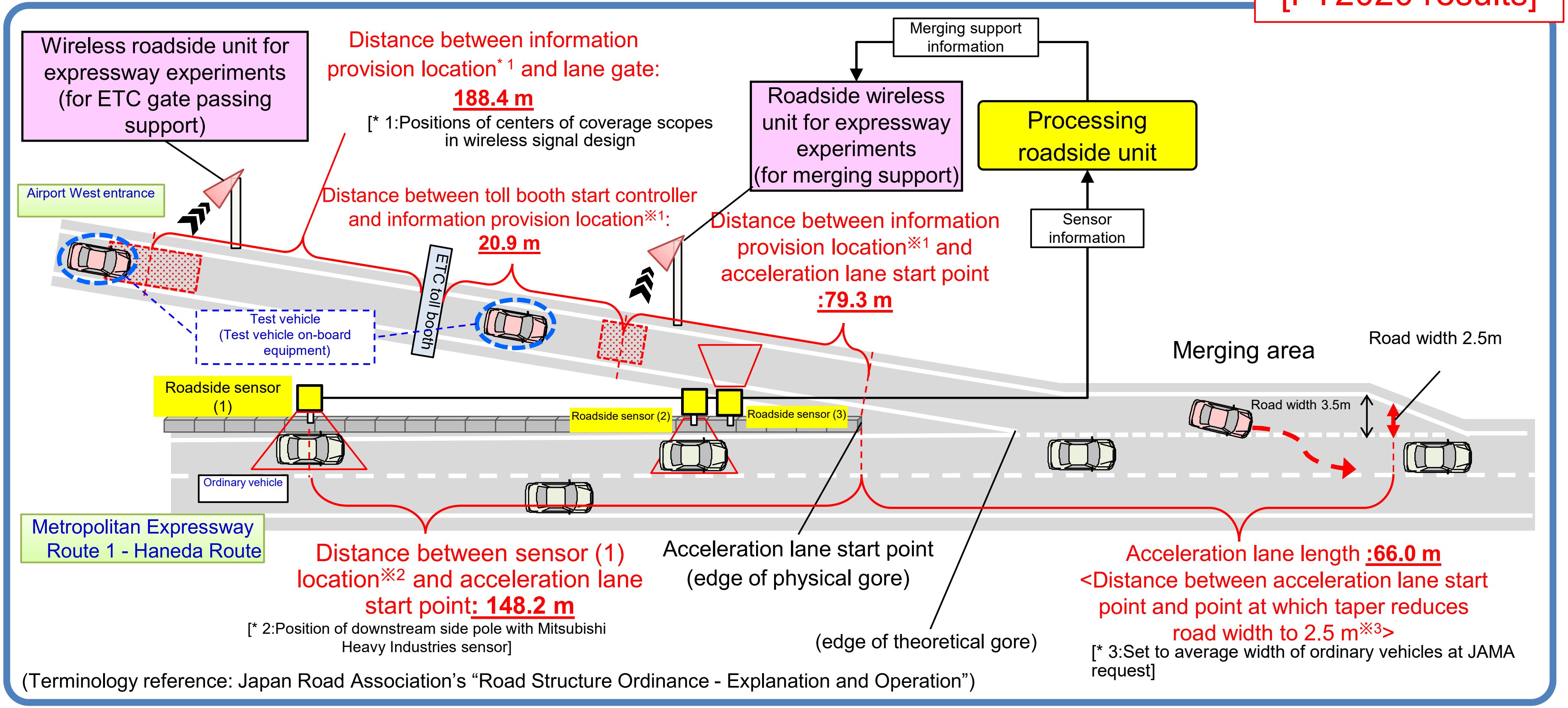
Location of Airport West ramp infrastructure equipment: Values requested by JAMA



Antenna and sensor location conditions requested by JAMA (Source: NILIM merging support system working group materials)

Location of Airport West ramp infrastructure equipment: On-site actual measurement value

[FY2020 results]



Locations of installed infrastructure equipment (distances between devices)

Location of Airport West ramp infrastructure equipment: Differences between requested values and actual values

Main distances	JAMA design values	Airport West construction values
Distance between information provision location and lane gate	181.5 or more	188.4
Distance between information provision location and acceleration lane start point	95 or above	79.3
Distance between sensor (1) location and acceleration lane start point	177 or above	148.3

(Unit: m)

JAMA design values differ from actual values, but detailed investigations of processing times, etc., have determined that these do not present problems. (These values have already been agreed on by JAMA and NILIM)

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

[FY2020 results]

(1) Radio interference countermeasures

In order to minimize the risk of the radio signals emitted by the equipment causing communication errors affecting the Airport West ETC toll booth, the location of the antenna behind the ETC toll booth was changed as indicated below.

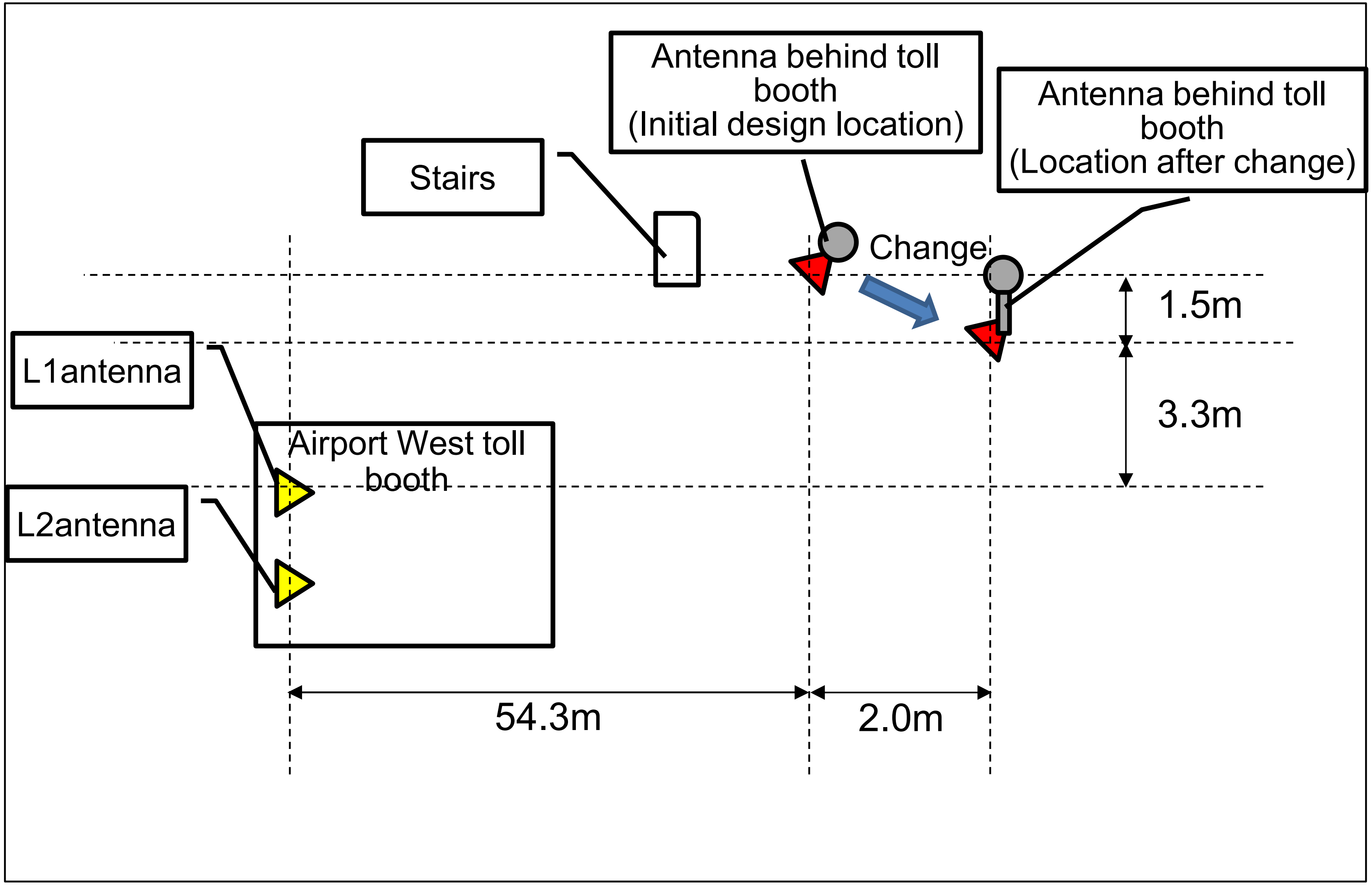


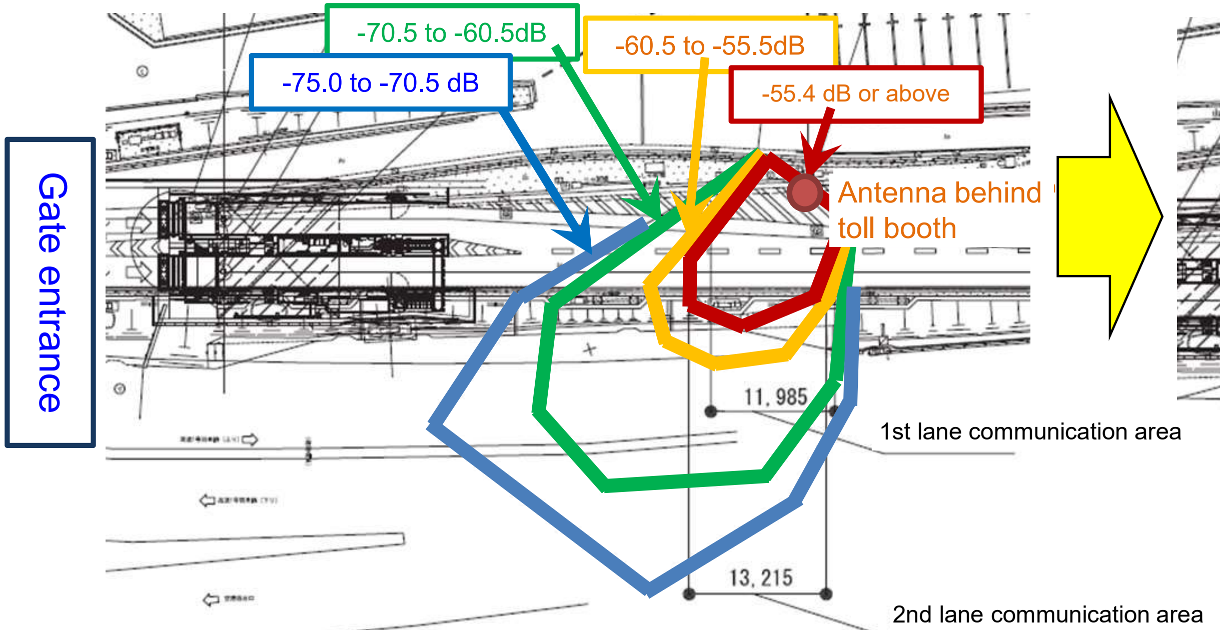
Diagram of location of antenna used to provide merging support information

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

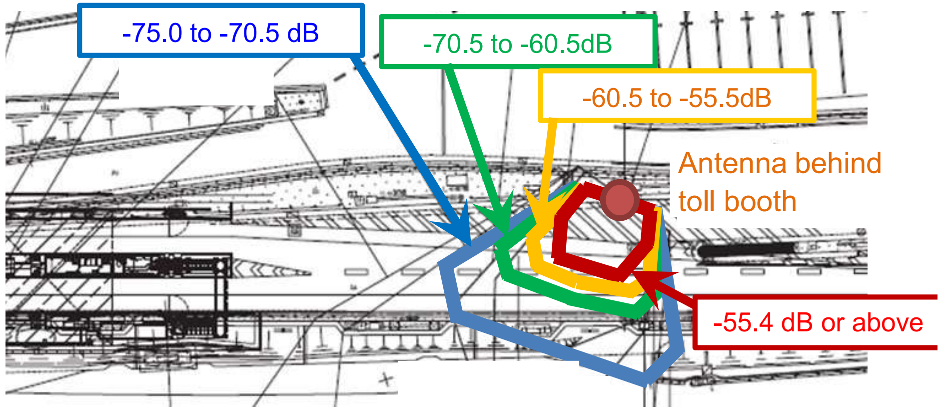
[FY2020 results]

(2) Design and confirmation of radio communication area around antenna behind toll booth (used for merging support)

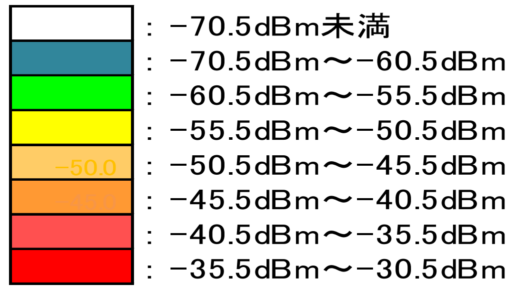
When installing the antenna behind the toll booth, consideration was given to both having a powerful enough radio signal on the lanes on which test driving is performed and avoiding radio interference with existing Metropolitan Expressway equipment such as ETC toll booth equipment, and the radio transmission range was designed accordingly. After local measurements were performed, the radio range was finalized.



Radio signal strength at antenna behind toll booth (design values)



Radio signal strength at antenna behind toll booth (actual measurement values: schematic diagram)



[Legend: Radio signal strength color coding]

* Quoted from results of radio measurement performed by the Metropolitan Expressway

Radio signal strength at antenna behind toll booth (actual measurement values: details)

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

[FY2020 results]

(3) Analysis of situations in which communications were not performed and countermeasures

(Analysis) Radio interference countermeasures were implemented, consisting of the location of the antenna, the signal emission angle, and the radio transmission output. As a result of these countermeasures, the range over which the signal strength was sufficiently strong for on-board equipment to receive information from the antenna behind toll booth did not sufficiently cover all of the communication area near the rear antenna that provided merging support information in the direction of vehicle movement. Communications were interrupted midway in some cases, depending on the driving position of the test vehicles (the vehicles exited the communications range). This was confirmed to be the reason that these vehicles did not receive merging support information.

For vehicles (on-board equipment) to complete communications normally while passing near the antenna behind toll booth at driving speed (envisioned as being 30 km/h), **sufficient radio signal strength (-60.5dBm or above) must be maintained for a distance of 5.67 m or more in the direction of vehicle motion.**

In the right lane, when passing the antenna at a speed of 30 to 39 km/h, the area in which radio signal strength and distance are sufficient for communications was confirmed to be within 1 m to 1.5 m of the center line.

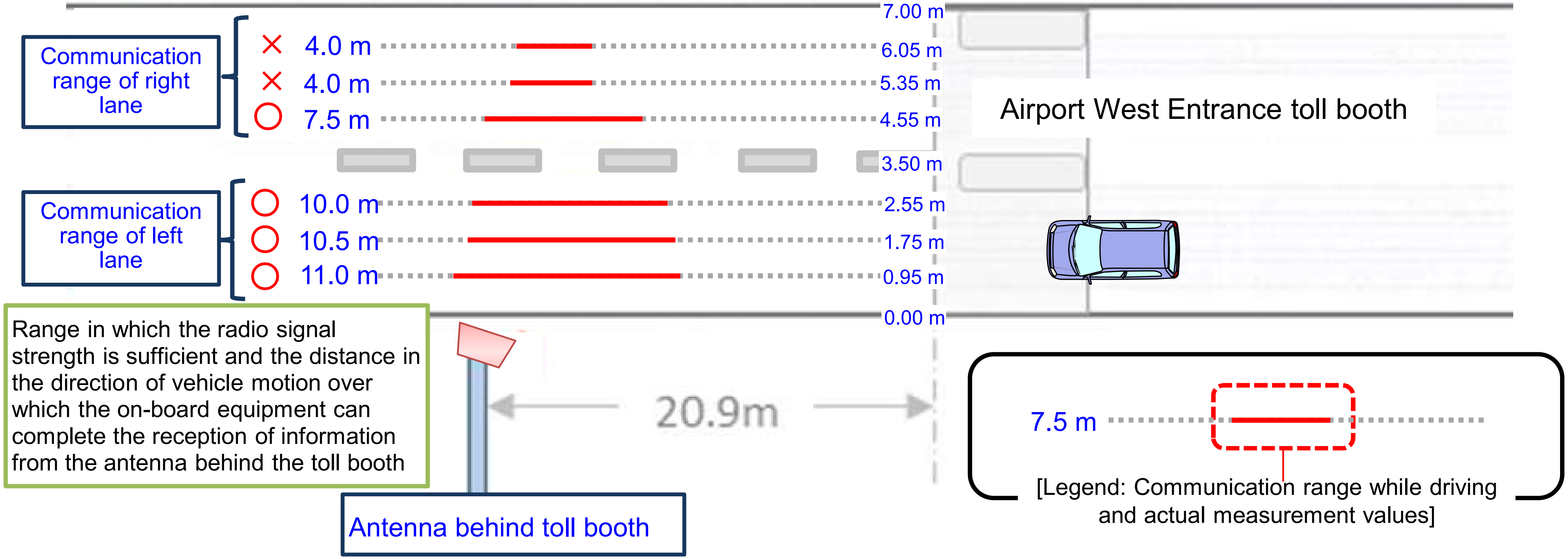


Fig. Antenna behind toll booth - Range of possible communication range by location in lane [for envisioned speed of 30 km/h]

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

[FY2020 results]

(3) Analysis of situations in which communications were not performed and countermeasures

(Countermeasure) Shorten communication processing time. Specifically, in order to improve the reliability of completing road-to-vehicle communications, required communication times must be reduced by aggregating and streamlining communication processing. As shown below, we have confirmed that communication time has been reduced by roughly 60% (see figure below) and there are no cases in our test run after countermeasures of on-board equipment no receiving information.

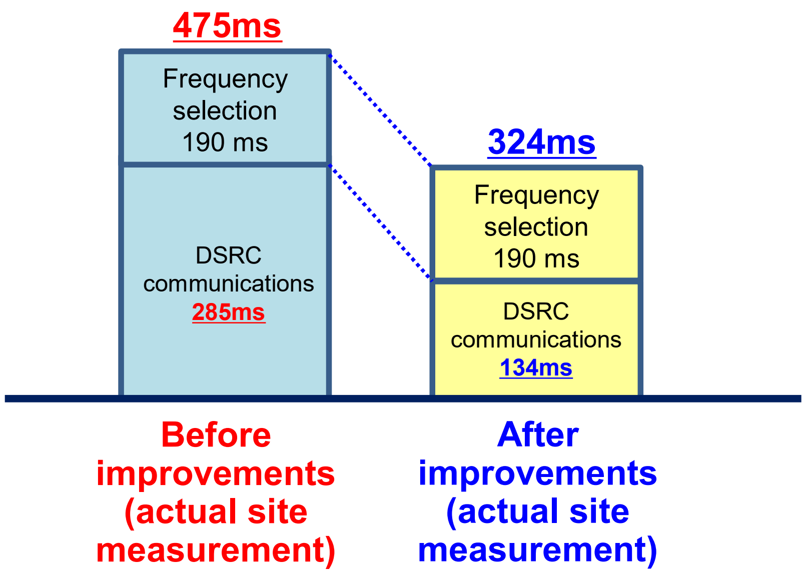


Fig. Comparison of required communication times before and after communication transaction improvements

Communication range of each lane (actual measurement values)	Test vehicle speed (length of radio range to be secured in order to ensure complete provision of information via road-to-vehicle communication): 20km/h (3.77m⇒1.94m)	30km/h (5.67m⇒2.92m)	35km/h (6.11m⇒3.14m)	40km/h (7.56m⇒3.89m)	50km/h (9.44m⇒4.86m)	60km/h (11.33m⇒5.83m)
①:4.0m		Improvement	Improvement	Improvement		
②:4.0m		Improvement	Improvement	Improvement		
③:7.5m					Improvement	Improvement
④:10.0m						Improvement
⑤:10.5m						Improvement
⑥:11.0m						Improvement

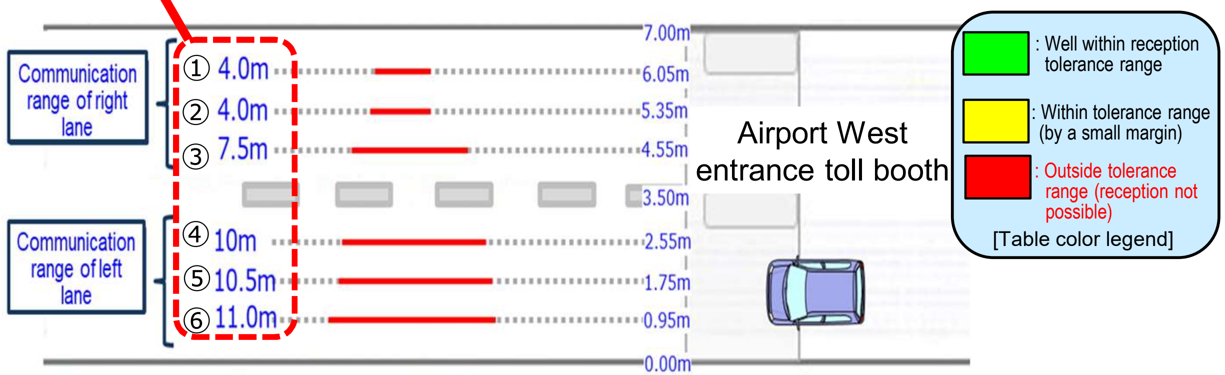


Fig. Evaluation of vehicle driving speed tolerance within radio range

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

[FY2020 results]

(4) Restrictions on roadside sensor locations

The three factors below placed restrictions on the placement of the roadside sensors. Because of these restrictions, it was not possible to place the roadside sensors at a distance of 177 meters or more from the physical gore, as requested by the JAMA. Instead, the sensor installation location was set at a distance of 148.3 meters, and the sensors were installed accordingly.

(1) Space was secured to install mounts and poles for the roadside sensors supplied by five manufacturers
(The foundations for the total of six poles were large, which limited the number of possible installation locations)

(2) The location at the JAMA-specified installation distance (177 meters or more) was a bridge area, and there was nowhere to build a foundation or erect scaffolding.

(3) The roadside sensor mounting jigs and poles cannot be buried or mounted on highway balustrades (concrete walls) due to the risk of reinforcing bars being cut.

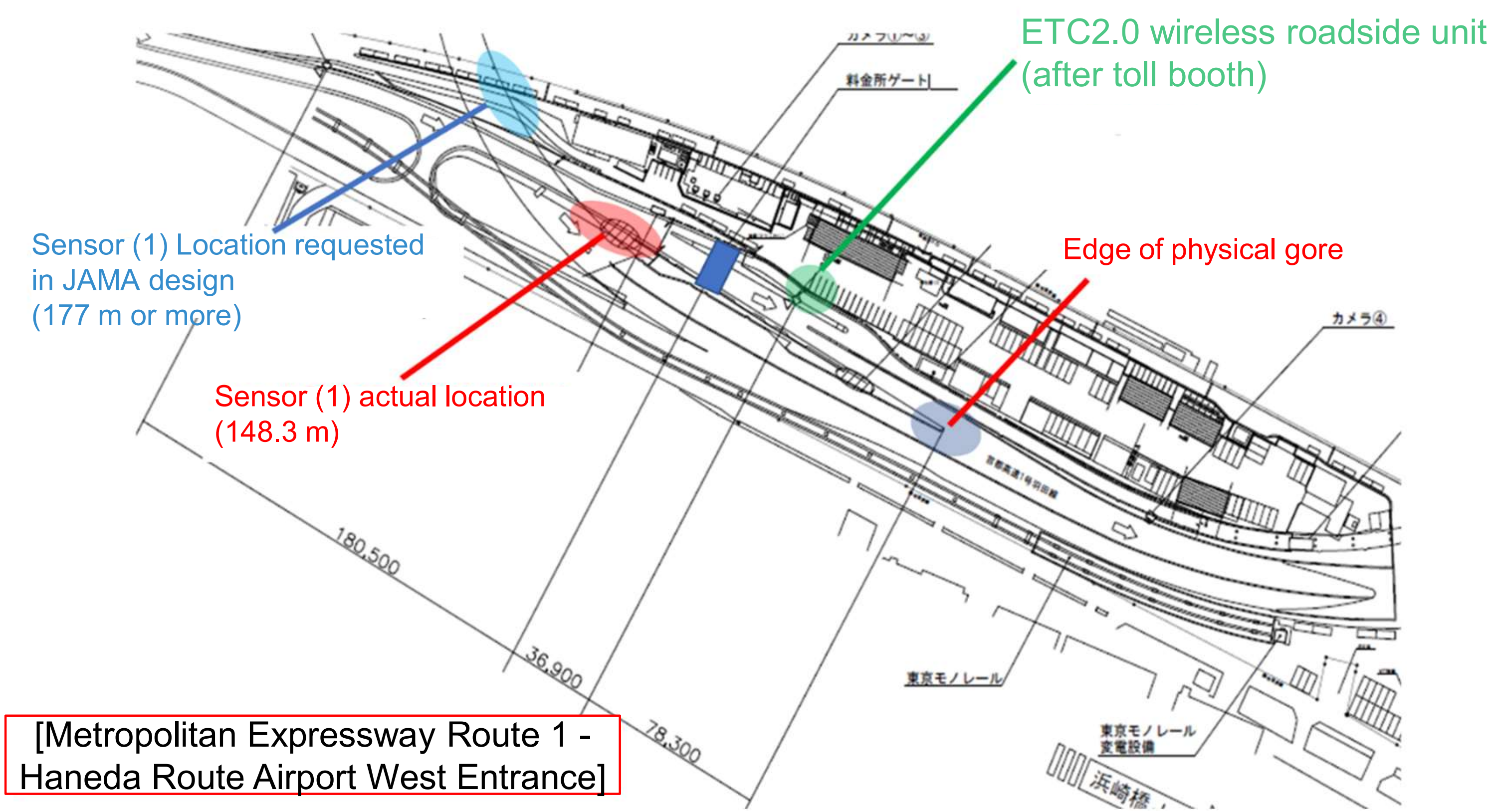


Fig. Comparison of roadside sensor locations requested in JAMA design and actual installation locations

4.1.2. Contents of restrictions placed by actual infrastructure equipment installation locations

[FY2020 results]

(5) Restrictions placed due to safety measures

The Metropolitan Police Department's Traffic Regulation Division pointed out the need to implement safety measures to protect the safety of road users with respect to roadside sensor (2) (cruising line merging area status sensor) and roadside sensor (3) (merging lane status sensor) to be installed in the merging physical gore after passing the ETC gate of the Metropolitan Expressway Haneda Route Airport West Entrance. Measures were implemented to protect ordinary vehicles from the installed roadside sensors. Impact absorbent material was installed to protect ordinary vehicles from collisions with the infrastructure equipment in the event of an accident. To guide the lines of sight of drivers driving on straight merging lanes, linear blocks were used instead of round tanks, and they were placed as shown in the diagram below.

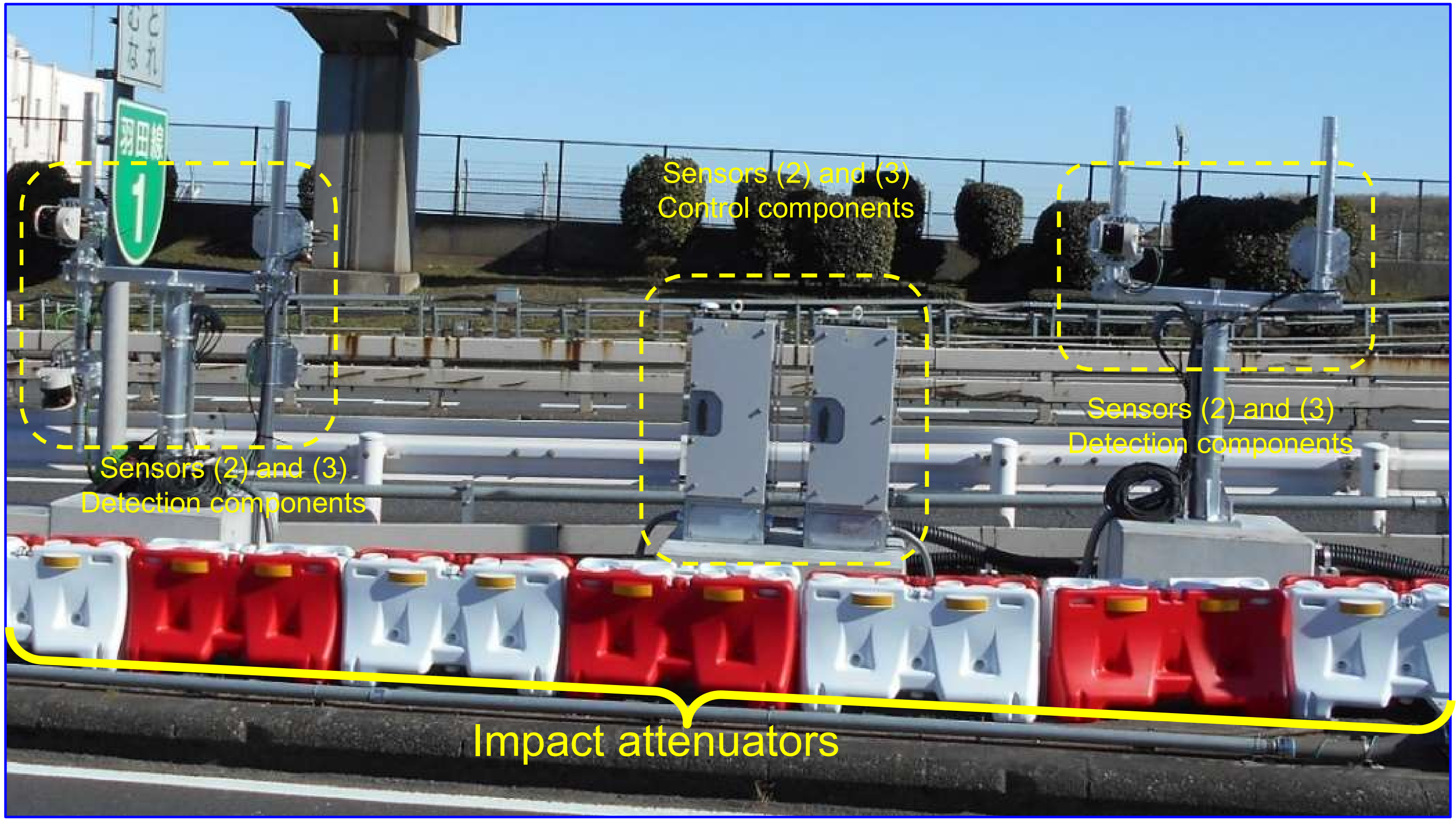


Fig. Comparison of roadside sensor locations requested in JAMA design and actual installation locations

4.1.3. Procedures involved in the on-site installation of infrastructure equipment and management of related procedures

[FY2020 results]

The table below details the procedures used when installing infrastructure equipment in managed expressway areas and the content of coordination with related organizations. By organizing this information, we believe we can determine what will be necessary for the future installation of equipment used to provide merging support on expressways, improve the accuracy of work planning, such as improving procedures, and help reduce risks.

Table. Procedures involved in the on-site installation of infrastructure equipment and management of related procedures

Procedure	Contents
Design and construction deliberation	When installing infrastructure equipment in managed expressway areas, it is essential to consult with the road administration company regarding the contents of designs and construction work. Through this consultation, coordination can be carried out regarding the impact of this work on other construction work (installation locations, work procedures, etc.). Design consultation and work consultation each take two or three months, but this can vary depending on the exclusive user and the object of exclusive use, so coordination should be performed with the road administrator.
Request for exclusive use of road/road exclusive use deliberation	Installing equipment on roads and continually using said roads is referred to as “exclusive use" of the road. Exclusive use of roads does not only apply to cases in which equipment is installed above-ground, but also the installation of electrical, water, or other conduits underground and the overhead suspension of power lines, etc. There are two procedures involved in the exclusive use of roads. (1) Submit request for permission for exclusive road use: This procedure is used for exclusive use by a party other than the national government (2) Road exclusive use deliberations: This procedure is used for exclusive use by the national government In this case, the exclusive use was for a SIP FOT by the Cabinet Office, so a request for deliberation regarding exclusive road use was submitted to the Japan Expressway Holding and Debt Repayment Agency. The amount of time required for this application will vary depending on the exclusive user and the object of exclusive use, so it is best to check and coordinate with the road administrator and Japan Expressway Holding and Debt Repayment Agency in advance.
Request for permission to perform construction work	Construction work, etc., performed on expressways is considered special usage that differs from the original purpose of the road, so permission from the police station chief is required before performing construction work. There are defined traffic restriction avoidance periods at different times of the year, etc., so it is best to confirm with the road administrator in advance.

4. Verification of installation conditions, etc., related to infrastructure equipment on Metropolitan Expressway

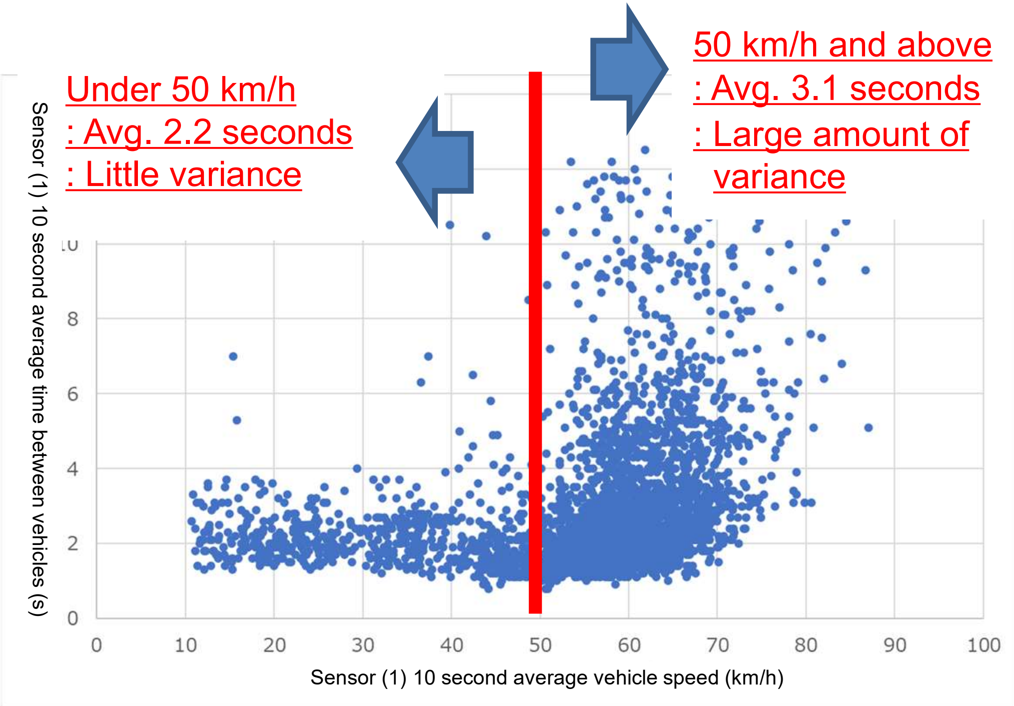
[FY2020 results]

4.2. Evaluation of information accuracy and locations of installed infrastructure involved in providing merging support information

4.2.1. Lap time measurement:Analysis of traffic conditions

[Sensor (1) Relationship between average vehicle speed and average time between vehicles]

- The average time between vehicles was <u>2.2 seconds for vehicles traveling under 50 km/h and 3.1 seconds for vehicles traveling at 50 km/h or faster</u>
- Most times between vehicle were between 1.5 and 3.5 seconds for vehicles traveling under 50 km/h
- At speeds above 50 km/h, the amount of variance in time between vehicles increased



* Average time between vehicle is a variable of up to 12.5 seconds (in units of 0.1 seconds), so analysis was performed on 3,269 samples after excluding 49 samples with times of 12.6 seconds or greater

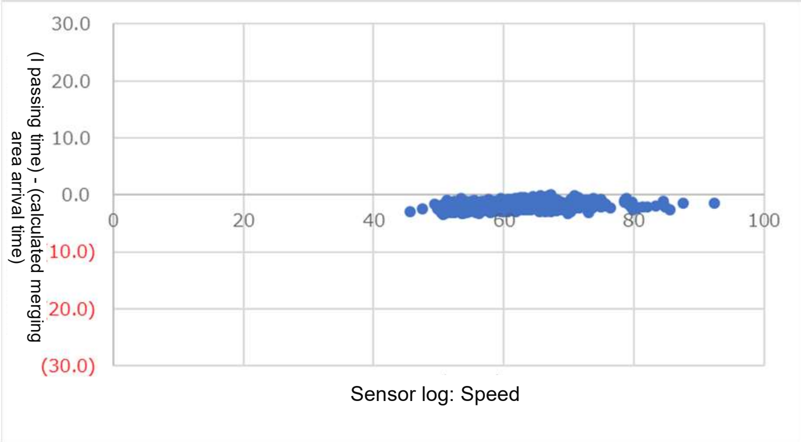
Avg. vehicle speed	No. of samples	Average time between vehicles (s)				
		Avg.	Max.	Min.	Variance	Median
Under 50 km/h	662	2.2	10.5	0.8	1.2	2.0
50 km/h and above	2,607	3.1	12.5	0.8	3.3	2.4
All samples	3,269	2.9	12.5	0.8	3.8	2.2

4.2.2. Analysis of deviation between calculated merging area arrival times and actual arrival times

[FY2020 results]

Uncongested

<3/30 12:35 to 13:05>

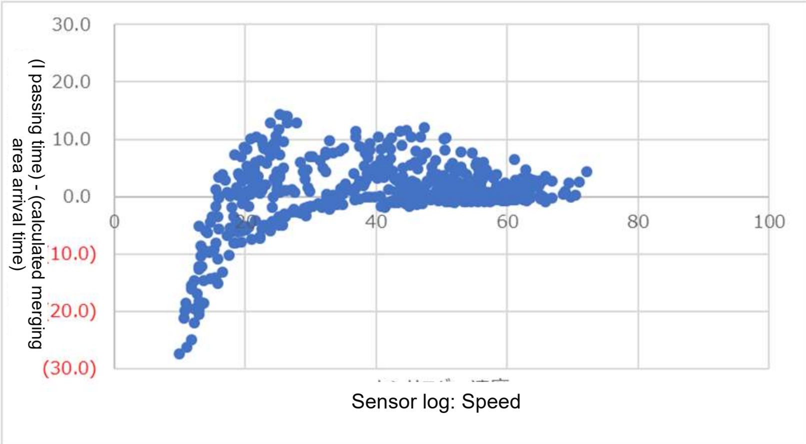


[Uncongested]

- The majority of vehicles drove at 50 to 75 km/h
- The average time deviation was roughly -0.3 seconds (almost no deviation)

Critical

<3/24 6:25 to 6:55>

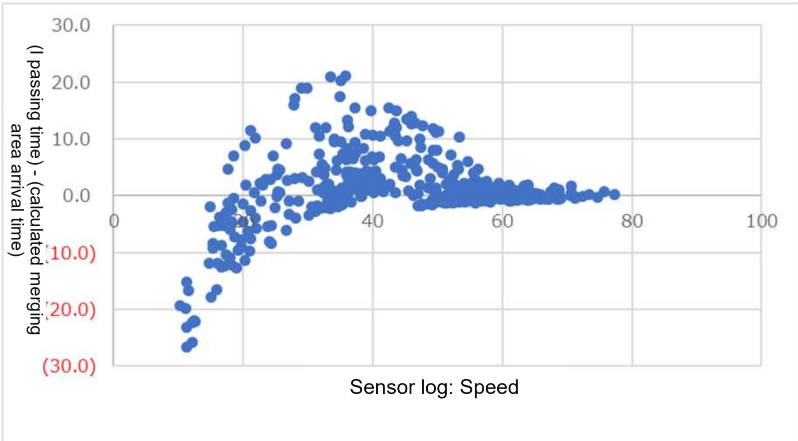


[Critical/traffic jam]

- There were vehicles driving between 10 and 40 km/h →Speeds slowed due to traffic jams
- There was a great amount of time deviation for slow vehicles

Traffic jam

<3/13 9:25 to 9:55>



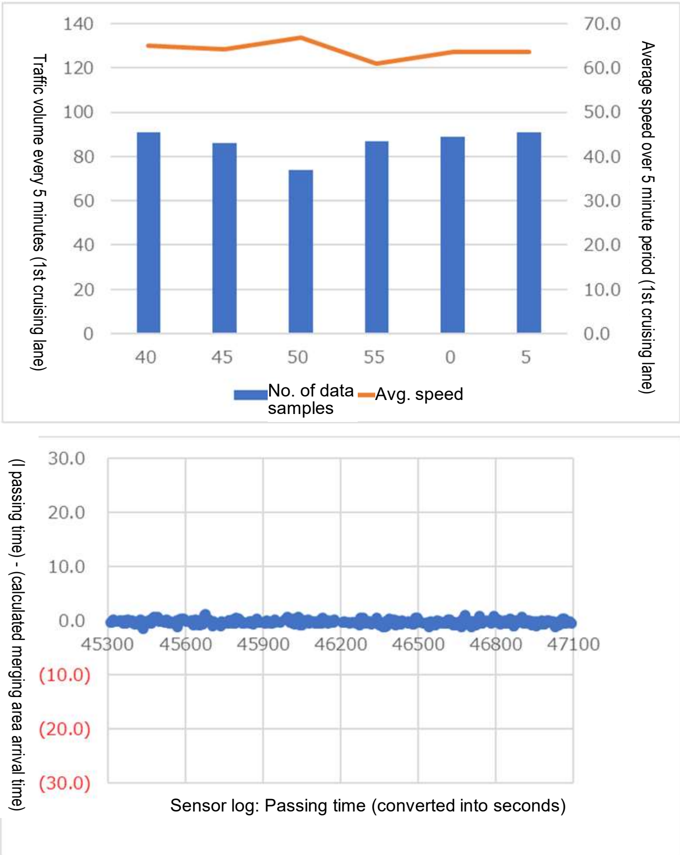
- Even vehicles driving at 50 to 60 km/h had a greater amount of time deviation than vehicles driving when the road was uncongested →Traffic conditions had a major impact

4.2.2. Analysis of deviation between calculated merging area arrival times and actual arrival times

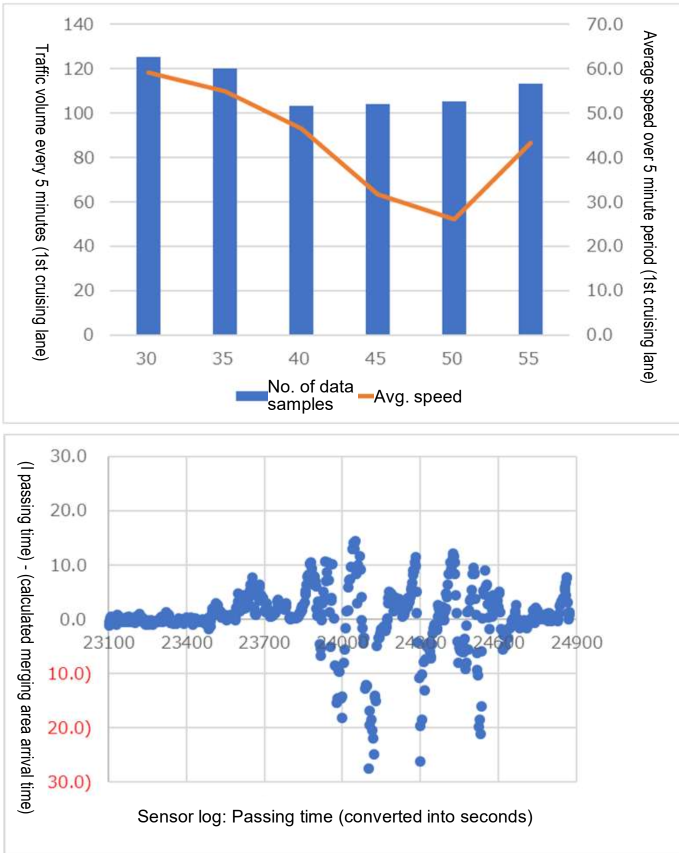
[FY2020 results]

Comparison of traffic conditions and variance in arrival times every 5 minutes
→ When average speeds changed suddenly, deviations from calculated arrival times increased

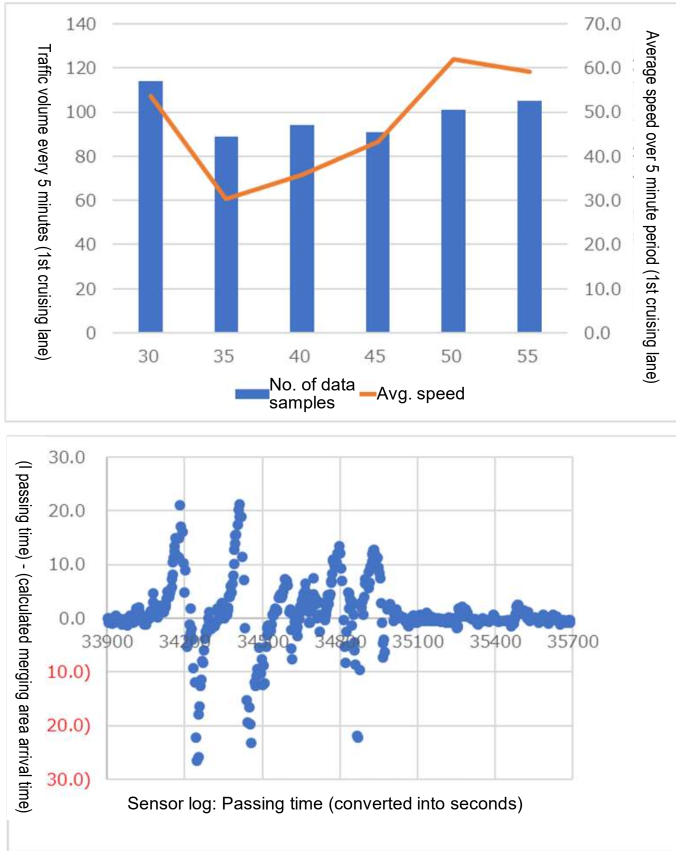
Steady
Mar. 30 12:35 to 13:05



Critical
Mar. 24 6:25 to 6:55



Traffic jam
Mar. 13 9:25 to 9:55



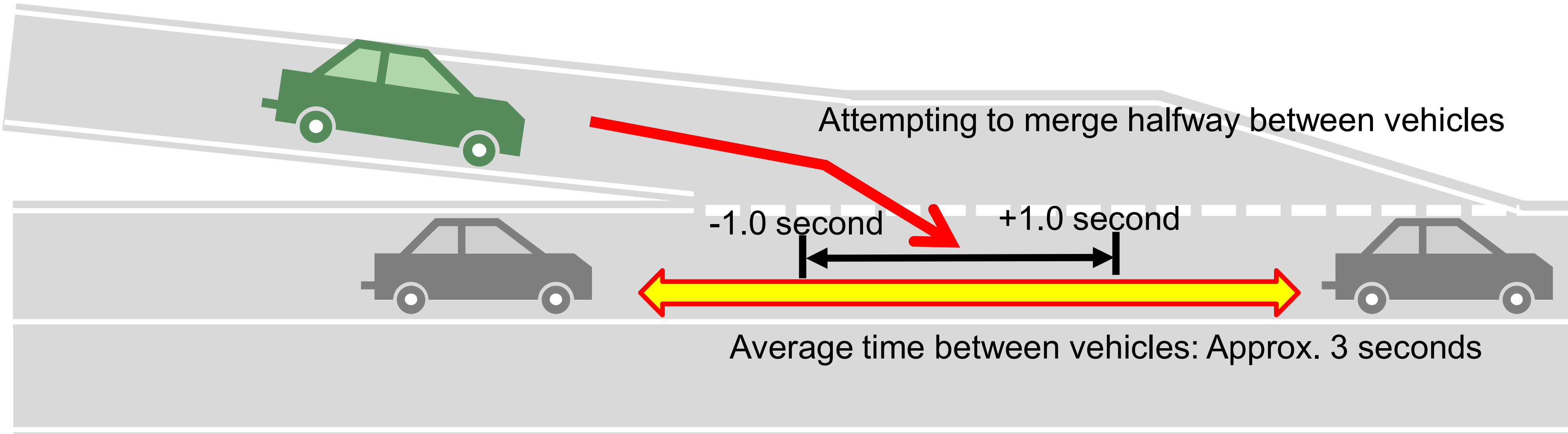
Traffic conditions can only be confirmed after-the-fact
→ Verify which situations reflect traffic conditions and which information is effective when provided to merging vehicles

4.2.3. Evaluation of merging area arrival times

[FY2020 results]

[Evaluation indices for calculated merging area arrival times]

- The average time between vehicles driving in the cruising line near the No. 1 Haneda Route Airport West entrance was approx. 3 seconds.
- If, hypothetically, a test vehicle controlled its speed based on the calculated merging area arrival time in order to arrive halfway between vehicles in the cruising line, merging into the desired area would be assumed to be possible provided that the difference between the calculated and actual merging area arrival times was ±1.0 seconds or less.



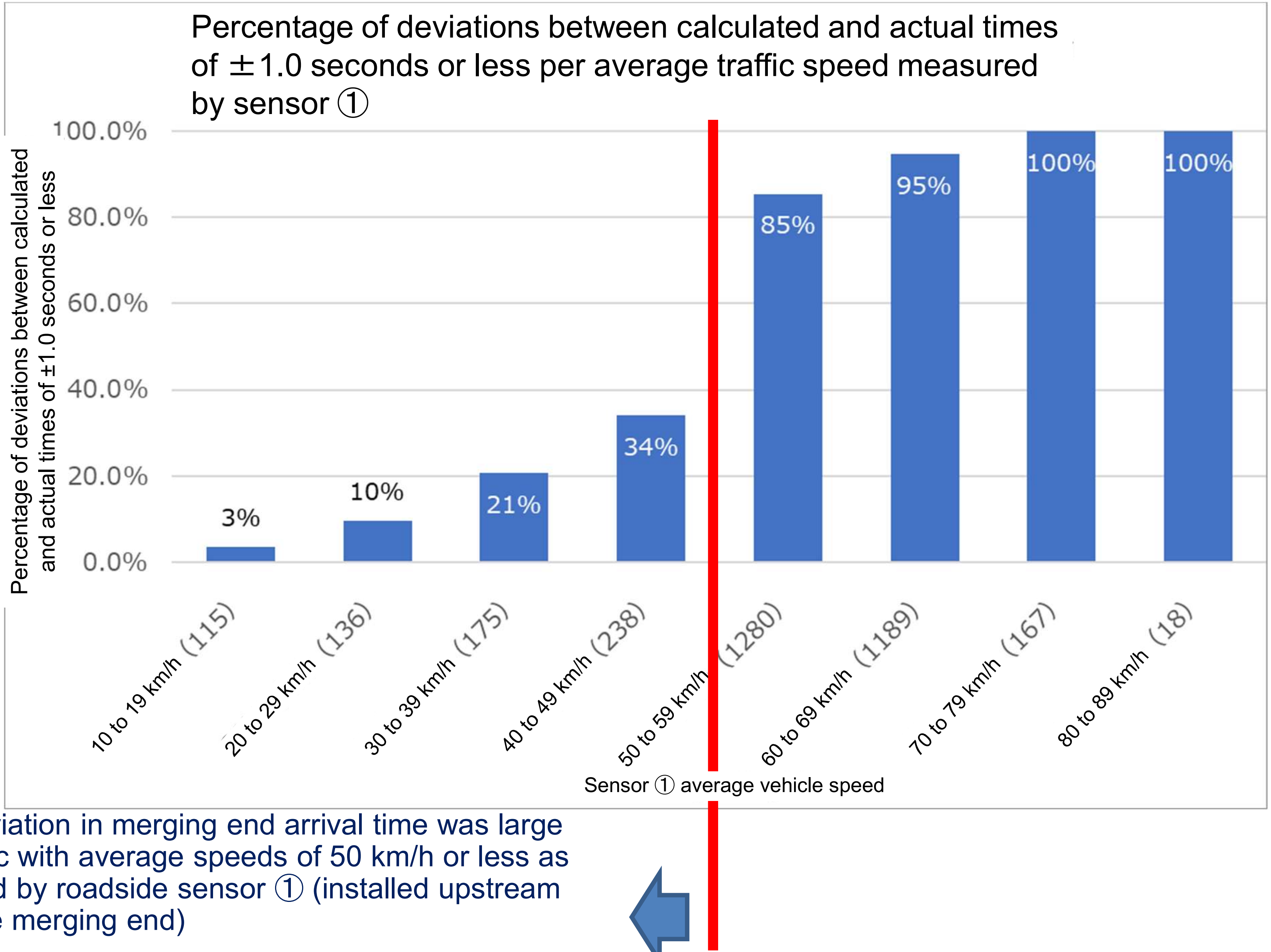
➡ The percentage of data for which the difference between the calculated merging area arrival time and the actual arrival time was ±1.0 seconds or less was confirmed from the on-site data from the expressway infrastructure and used to perform evaluation.

4.2.3. Evaluation of merging area arrival times

[FY2020 results]

Evaluation based on FOTs data

Percentage of deviations between calculated and actual times of ±1.0 seconds or less per average traffic speed measured by sensor ①



The deviation in merging end arrival time was large for traffic with average speeds of 50 km/h or less as detected by roadside sensor ① (installed upstream from the merging end)

4.2.3. Evaluation of merging area arrival times

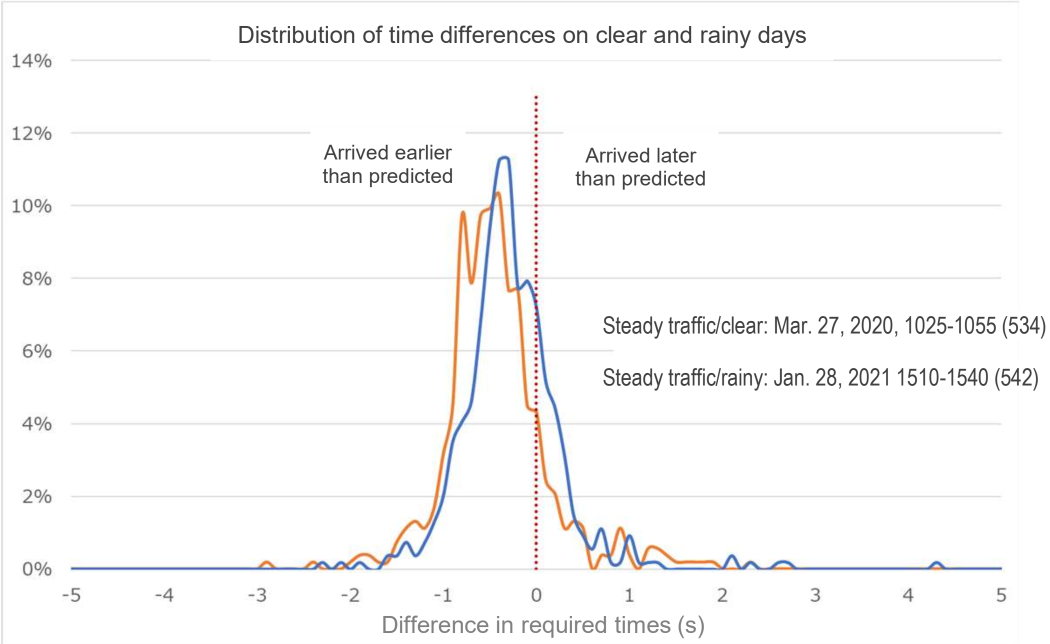
[FY2020 results]

Reference evaluation

Percentage of deviations between calculated and actual times of ±1.0 seconds or less by weather condition

Under the same traffic flow conditions, we confirmed the difference between the calculated merge arrival time and the actual merge arrival time by weather (sunny / rainy), and confirmed that it was not affected by the weather..

Comparison of differences in times in measurements on a day with clear weather (Mar. 27) and a day with rain (Jan. 28) found little difference and equivalent distribution
⇒ It appears that rain has little impact on differences in calculated arrival times



	Steady traffic /clear: Mar. 27, 2020, 1025-1055	Steady traffic /clear: Mar. 27, 2020, 1250-1320	Steady traffic /clear: Mar. 30, 2020, 1235-1305	Steady traffic /clear: Mar. 30, 2020, 1305-1335	Borderline traffic /clear: Mar. 24, 2020, 0625-0655	Traffic jam /clear: Mar. 13, 2020 0925-0955	Steady traffic /rainy: Jan. 28, 2021 1510-1540
No. of data samples	534	513	505	500	647	577	542
Average deviation	-0.427	-0.402	-0.260	-0.267	0.492	0.746	-0.275
Median	-0.5	-0.4	-0.3	-0.3	0.3	-0.1	-0.3
Maximum deviation	2.3	2.6	1.2	2.4	14.3	21.1	4.3
Minimum deviation	-2.9	-1.9	-1.4	-1.5	-27.5	-26.6	-2.3
Variance	0.3	0.2	0.1	0.2	28.5	31.5	0.3
Peak by group	-0.4	-0.3	-0.3	-0.2	-0.3	-0.5	-0.3
Peak group ratio	**10.3%**	15.8%	15.2%	15.6%	3.7%	5.2%	**11.3%**
±0.5 deviation ratio	**52.4%**	66.3%	79.8%	78.6%	26.9%	30.0%	**69.9%**
±1.0 deviation ratio	**89.7%**	95.7%	98.0%	96.6%	40.8%	49.6%	**93.9%**

* Comparisons on clear and rainy days were performed by selecting times of day with similar five minute average speeds (comparison shown on following page)

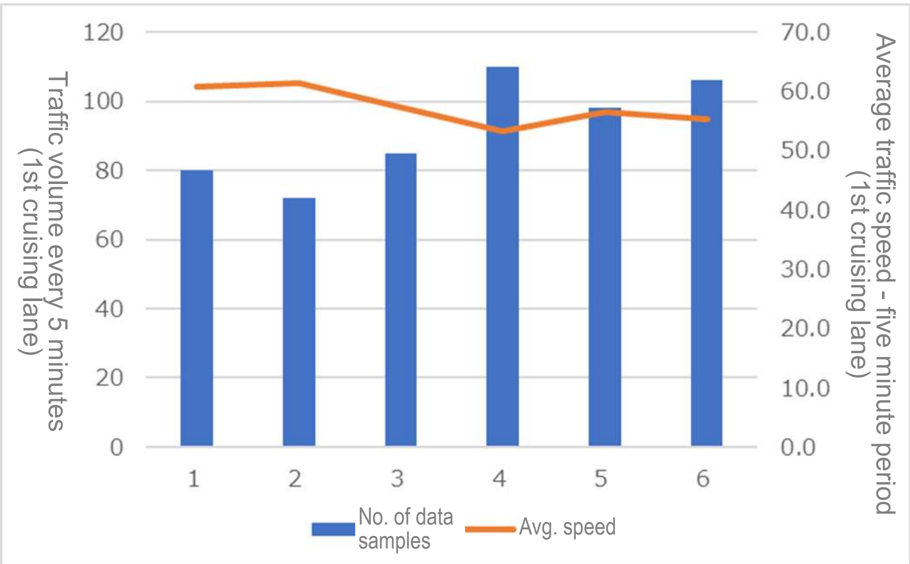
4.2.3. Evaluation of merging area arrival times

（Comparison of rainy and clear conditions）

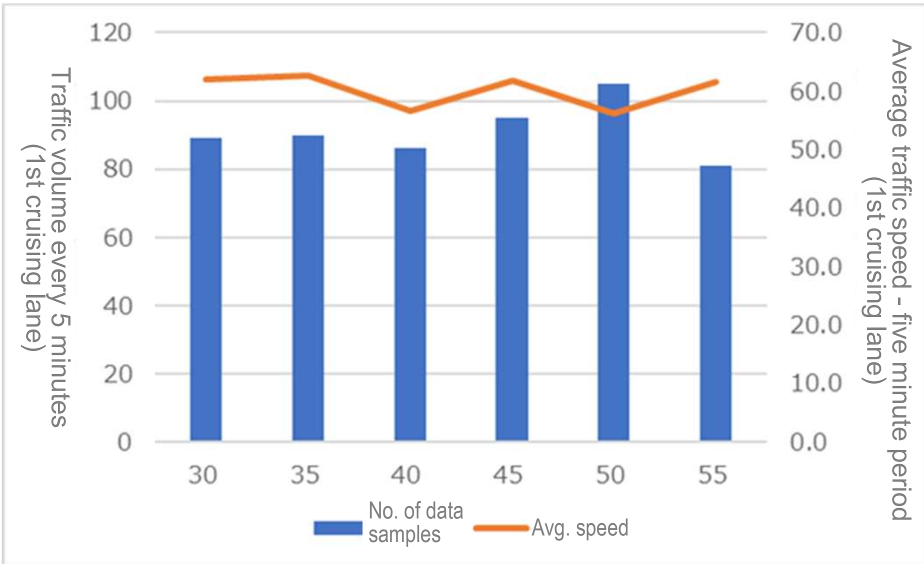
[FY2020 results]

Date/ time	Jan. 28 (Thu) 15:10 to 15:40	Mar. 27 (Fri) 10:25 to 10:55
Weather	Rain	Clear skies
Traffic conditions	Steady No. of vehicles in 1st cruising lane: 566 vehicles Total number of merging vehicles: 46 vehicles Average time between vehicles: 2.9 seconds	Steady No. of vehicles in 1st cruising lane: 518 Total number of merging vehicles: 70 Average time between vehicles: 2.8 seconds

Jan. 28 Rain



Mar. 27 Clear



[Traffic volume and speed of 1st cruising lane (CD section)]

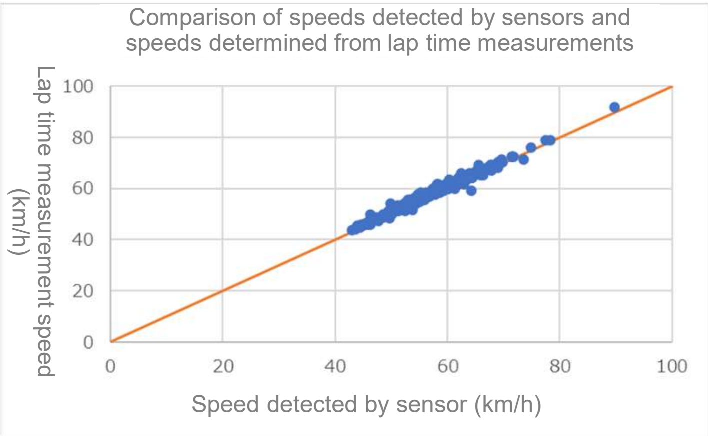
4.2.3. Evaluation of merging area arrival times

(Analysis of variance between calculated merging area arrival time and actual arrival time)

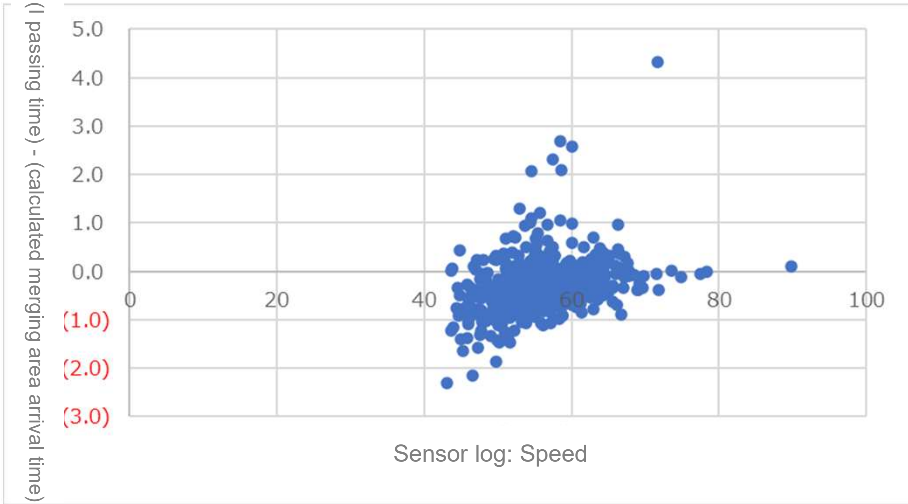
[FY2020 results]

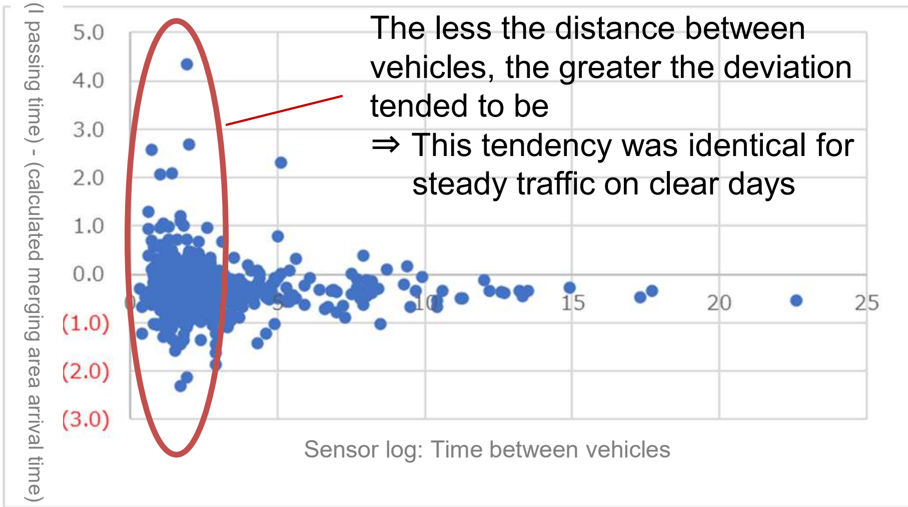
Difference between physical gore passing time and calculated arrival time
= physical gore passing time - calculated arrival time
Positive: The vehicle was predicted to arrive before it actually passed the physical gore
Negative: The vehicle was predicted to arrive after it actually passed the physical gore

No. of data samples	542
Average difference [seconds]	-0.275
Maximum difference [seconds]	4.333
Minimum difference [seconds]	-2.312
Variance	0.314



Sensor detection times were compared with CD segment speeds based on measured lap times
⇒ The speeds matched, so we confirmed that <u>the issue of sensor accuracy decreasing during rainy weather had been solved</u>





4.2.4. Observations of trends at the Airport West Entrance

[FY2020 results]

- When traffic on the cruising line is steady (50 km/h or above) and the average time between vehicles is 3.1s, 85% or more of calculated arrival times are ±1.0 second of the actual arrival time
- However, when the state of the traffic on the cruising line is in critical condition, or there is a traffic jam (under 50 km/h), the average time between vehicles is 2.2 seconds and there is an extremely large amount of variance between calculated and actual arrival times

➡ Based on situations which can be detected by sensors, it appears possible to issue notifications that accuracy is likely to be low

[Suggestions for improvement of merging support information]

- When providing merging vehicles with information when the sensor (1) average vehicle speed is under 50 km/h, also notifying them that the accuracy of the calculated arrival time information is likely to be low could assist with vehicle control
  (the following page contains a proposal for the information provision format to be used)

4.2.5. Recommendations Regarding Merging Support Information Provision Format (Draft)

[FY2020 results]

if the contents within red frame below suggest accuracy deterioration of merging area arrival times, it is recommended to set a value to notice accuracy deterioration in Information reliability（shown within blue frame）

No.	Item			Bit length	Bytes
1	Radio beacon common header	Type of information		8	2
2		Control flag	Information menu existence flag	1	
3			Center-edited information identification flag	1	
4			Reserved	6	
5		Information menu (when existence flag value=1 only)		32	4
6		Message size		16	2
7	Date of information generation (year)			12	6
8	Date of information generation (month)			4	
9	Date of information generation (day)			5	
10	Date of information generation (hour)			5	
11	Date of information generation (minute)			6	
12	Reserved			6	
13	Date of information generation (second) [100ms units]			10	
14	Reserved			6	6
15	Merging support system ID			18	
16	Reserved			1	
17	No. of conforming merging support system specification			7	
18	Service type=0			2	
19	System state	Overall system		1	
20		Sensor (1)		1	
21		Sensor (2)		1	
22		Sensor (3)		1	
23		(Cruising line) Lane restriction, etc.		2	
24	Information provision range	No. 1 cruising lane		1	
25		No. 2 cruising lane		1	
26		No. 3 cruising lane		1	
27		No. 4 cruising lane		1	
28		No. 5 cruising lane		1	
29		No. 6 cruising lane		1	
30		Reserved		2	

No.	Item				Bit length	Bytes
31	Overview of traffic conditions	Upstream cruising line (sensor (1))	Traffic volume (past 10 seconds)		5	6
32			Average vehicle speed (past 10 seconds)		11	
33			Reserved		1	
34			Average time between vehicles (past 10 sec[onds])		7	
35		Connecting road merging area (sensor (3))	Vehicle transit time 1	Reserved	3	
36				Transit time (hour)	5	
37				Transit time (minute)	6	
38				Transit time (second)	10	
39			Vehicle transit time 2	Reserved	3	8
40				Transit time (hour)	5	
41				Transit time (minute)	6	
42				Transit time (second)	10	
43			Vehicle transit time 3	Reserved	3	
44				Transit time (hour)	5	
45				Transit time (minute)	6	
46				Transit time (second)	10	
47			Traffic volume (past 10 seconds)		5	
48		Cruising line merging area (sensor (2))	Sensing type		3	
49			Average vehicle speed (past 10 seconds)		4	
50			Traffic conditions (past 10 seconds)		2	
51		Downstream merging area	Traffic conditions		2	
52	Weather conditions	Reserved			5	2
53		Weather			3	
54		Reserved			1	
55		Amount of rainfall/snowfall			7	
56	Basic information (merging area)	Merging direction			2	5
57		Acceleration lane length			14	
58		No. of acceleration lanes			4	
59		Number of connecting road lanes			4	
60		Reserved			1	
61		Distance between information provision location and acceleration lane start point			15	
62		Physical gore latitude			32	8
63		Physical gore longitude			32	
64	Basic information (cruising line area)	Reserved			1	6
65		Distance between sensor (1) location and acceleration lane start point			15	
66		Reserved			1	
67		Distance between sensor (2) location and acceleration lane start point			15	
68		Reserved			1	
69		Distance between sensor (3) location and acceleration lane start point			15	
70		No. of corresponding vehicles n			8	1
71			Vehicle no.		10	

No.	Item				Bit length	Bytes
72		No. of corresponding vehicles (n)			8	1
73	Calculated arrival time information	Vehicle 1	Vehicle no.		10	8
74			Lane information	No. 1 lane	1	
75				No. 2 lane	1	
76				No. 3 lane	1	
77				No. 4 lane	1	
78				No. 5 lane	1	
79				No. 6 lane	1	
80			Reserved		3	
81			Merging area arrival day		5	
82			Reserved		3	
83			Merging area arrival hour		5	
84			Merging area arrival minute		6	
85			Merging area arrival second		10	
86			Reserved		2	
87			Information reliability		3	
88			Speed		11	
89			Reserved		7	4
90			Vehicle length		9	
91			Reserved		6	
92			Time between own vehicle and vehicle in fro[nt]		10	
93			Vehicle location information	Reserved	3	5
94				Measurement time (hour)	5	
95				Measurement time (minute)	6	
96				Measurement time (second)	10	
97				Distance from acceleration lane start point (+, -)	1	
98				Distance from acceleration lane start point	15	
99		:			:	:
100		Vehicle 30			64	8
101					32	4
102			Vehicle location information		40	5
103		:			:	:
104		Vehicle n			64	8
105					32	4
106			Vehicle location information		40	5

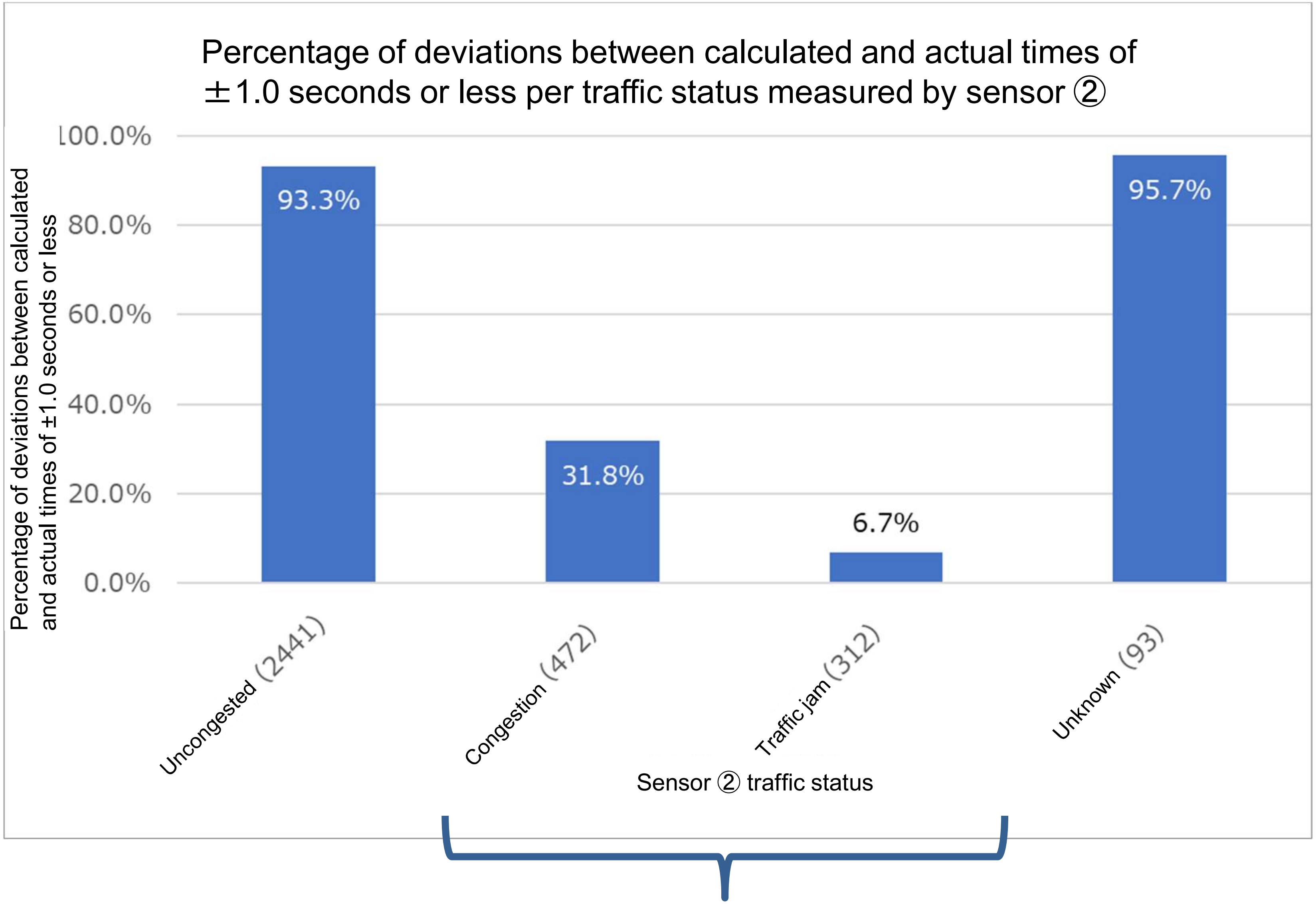
□: Data that is believed to have potential as reference data for vehicle control

4.2.5. Recommendations Regarding Merging Support Information Provision Format (Draft)

[FY2020 results]

Reference evaluation

Percentage of deviations between calculated and actual times of ±1.0 seconds or less per traffic status measured by sensor ②



The deviation in merging end arrival time was large when roadside sensor ② (installed at the merging end) detected traffic conditions as “congestion” or "traffic jam”

4.2.5. Recommendations Regarding Merging Support Information Provision Format (Draft)

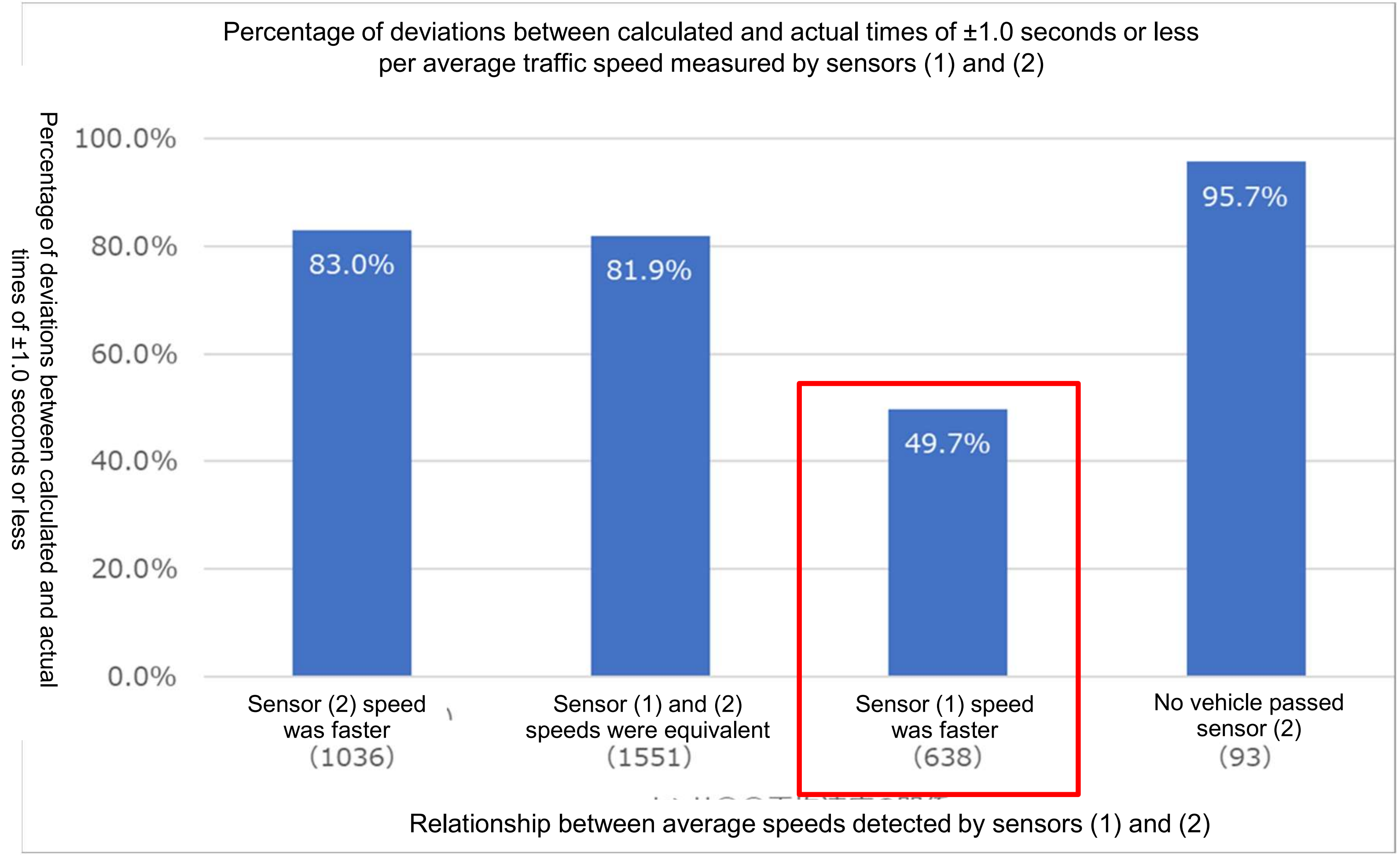
Reference evaluation
Percentage of deviations between calculated and actual times
of ±1.0 seconds or less per average traffic speed measured by sensors (1) and (2)

[FY2020 results]

Deviations between calculated and actual times were greater for samples in which the average speeds measured by sensor (1) were faster than the average speeds measured by sensor (2) (=when the merging area was congested so vehicle speeds decreased)

Average vehicle speeds measured by sensor (2) were assigned class values in 10 km/h increments, starting from 0 km/h→
Average vehicle speeds measured by sensor (1) were also converted into class values, and data for identical class values was compared

* Average vehicle speeds were considered equivalent when class values were equal E.g.) Sensor (1) speed of 55 km/h and sensor (2) speed of 50 km/h to 59 km/h



4.2.6. Analysis of deviation between calculated merging area arrival times and actual arrival times by provided information

[FY2020 results]

We investigated potential factors that could have an impact on the prediction accuracy of calculated merging area arrival times.

No.	Analysis index	Results
1	10 second traffic volume at cruising line sensor	-
2	10 second traffic average speed at cruising line sensor	Large amount of deviation between predicted times and actual times for speeds below 50 km/h
3	10 second traffic average time between vehicles at cruising line sensor	Deviation between predicted times and actual times for times between vehicles of less than 3.5 seconds
4	Times between vehicles when passing cruising line sensor	Deviation between predicted times and actual times for times between vehicles of less than 3.5 seconds
5	Traffic conditions in cruising line merging area	Large deviations between predicted times and actual times when road was congested or there was a traffic jam
6	10 second average speed in cruising line merging area	Large deviations between predicted times and actual times for speeds below 50 km/h
7	10 second traffic volume in merging lane merging area	-
8	Vehicle type	-
9	Vehicle type of preceding vehicle	-
10	Combination of vehicle type and vehicle type of preceding vehicle	-
11	Visibility of merging vehicle in cruising line merging area	-
12	Difference in speeds between vehicle and preceding vehicle	

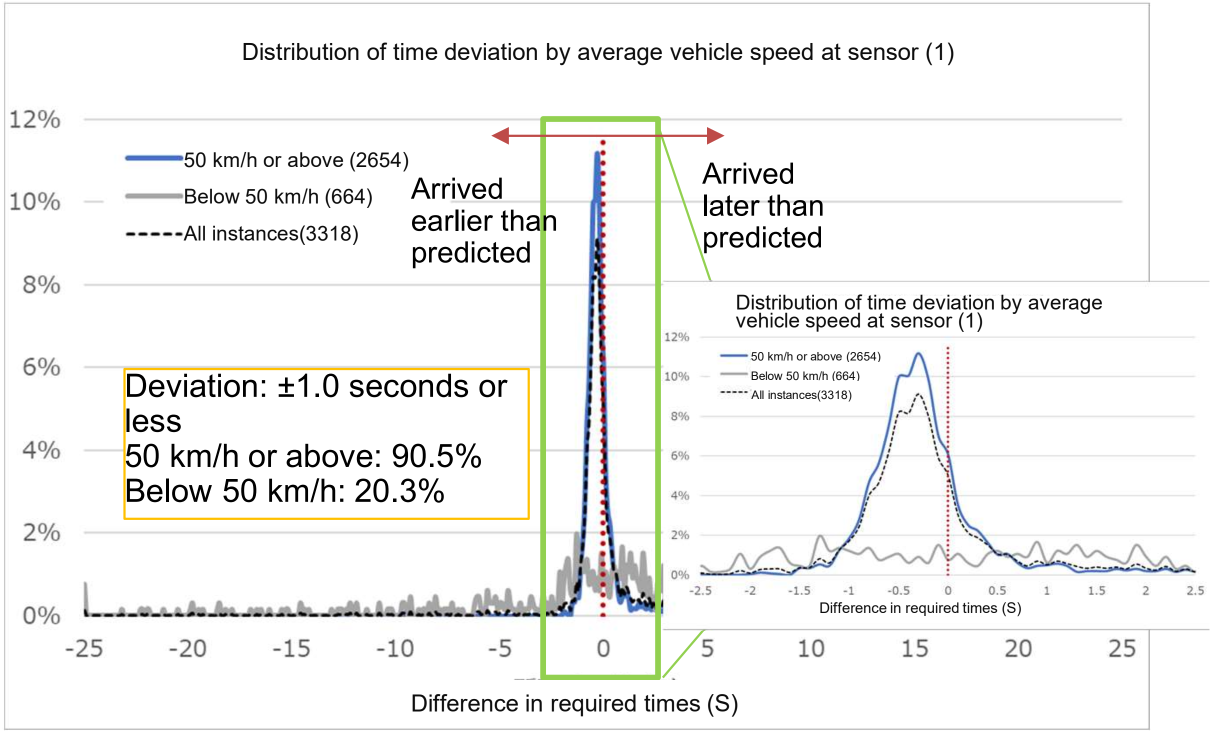
4.2.6. Analysis of deviation between calculated merging area arrival times and actual arrival times by provided information

[FY2020 results]

≪2≫ By 10 second traffic average speed at cruising line sensor (traffic condition information: sensor (1) average speed)

[Trends differed for speeds above and below 50 km/h]
50 km/h or above:
The center of pictogram is the group with a deviation of -0.3 seconds

Below 50 km/h:
Greater deviation than vehicles driving at speeds of 50 km/h or above
→ Large deviation between calculated arrival time and actual arrival time
(The majority of the vehicles arrived later than predicted)



	50 km/h or above	Below 50 km/h
No. of data	2654	664
Average deviation	-0.1	0.6
Median value	-0.3	0.9
Maximum deviation (positive)	12.4	21.1
Maximum deviation (negative)	-2.0	-27.5
Distribution	1.1	52.2
Peak by group	-0.3	-1.3
Peak group ratio	11.2%	2.0%

Difference in required times
= Lap time Point I passing time - calculated arrival time

The values shown in the pictogram have been rounded to the second decimal position

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

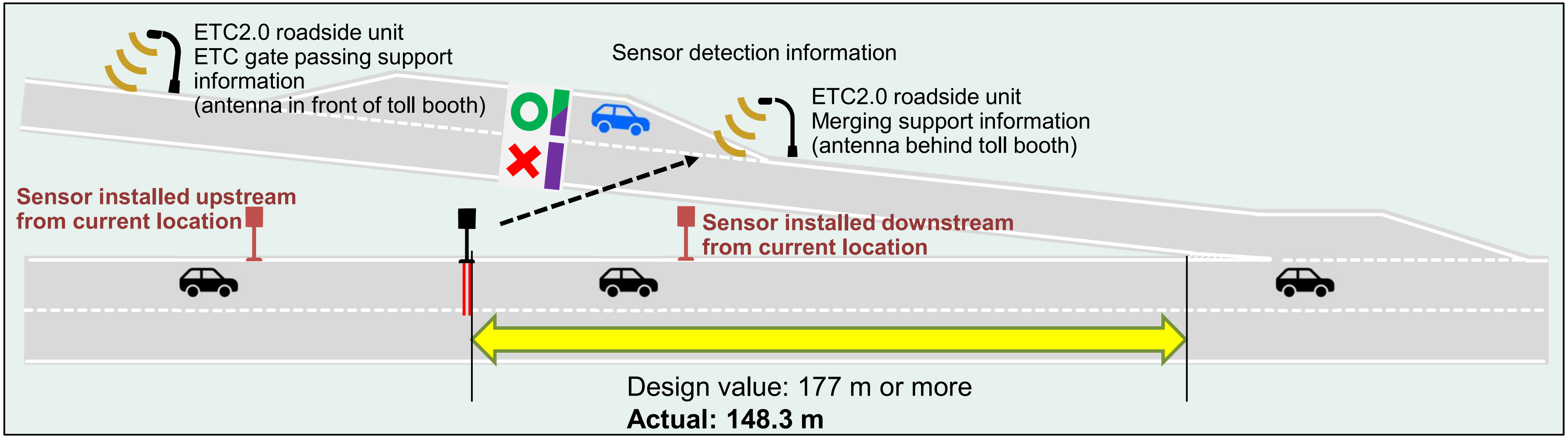
[FY2020 results]

[Objectives of analysis of sensor locations]

- In this FOT, the sensor used to detect cruising line vehicles was installed 148.3 m upstream of the merging start point
- The calculated arrival time provided to merging vehicles was calculated based on the assumption that the speed of vehicles when passing the sensor on the cruising line would be maintained until the vehicles reached the merging start point
- It is possible that the sensor location could affect the difference between the actual arrival time and the calculated arrival time
  → If the sensor is close to the merging area: The speed is maintained until the merging area is reached, and there is little deviation variance
  → If the sensor is far from the merging area: The speed changes before reaching the merging area, so there is a great deal of deviation variance

[Verification method]

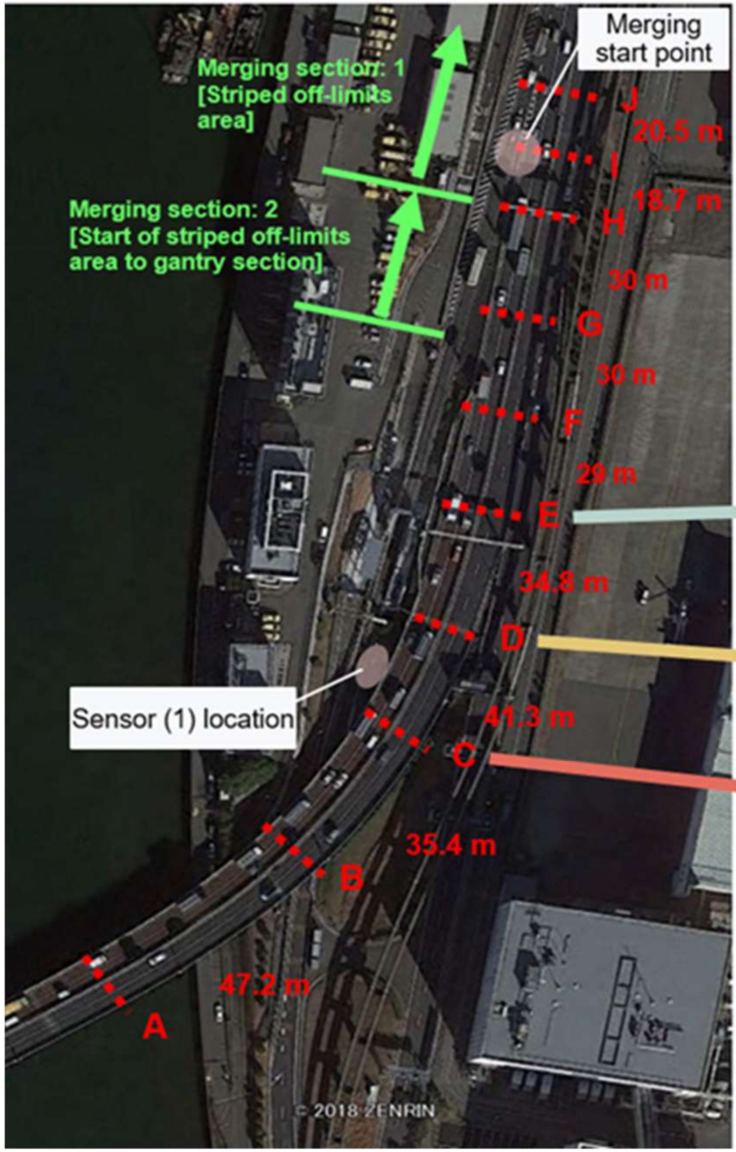
- The speeds determined at various points based on lap time measurement were used to calculate arrival times, and the difference between calculated and actual arrival times was calculated
- The distances between each point and the merging area were compared with the amount of variance in the deviation between the calculated and actual times to determine their degree of relation

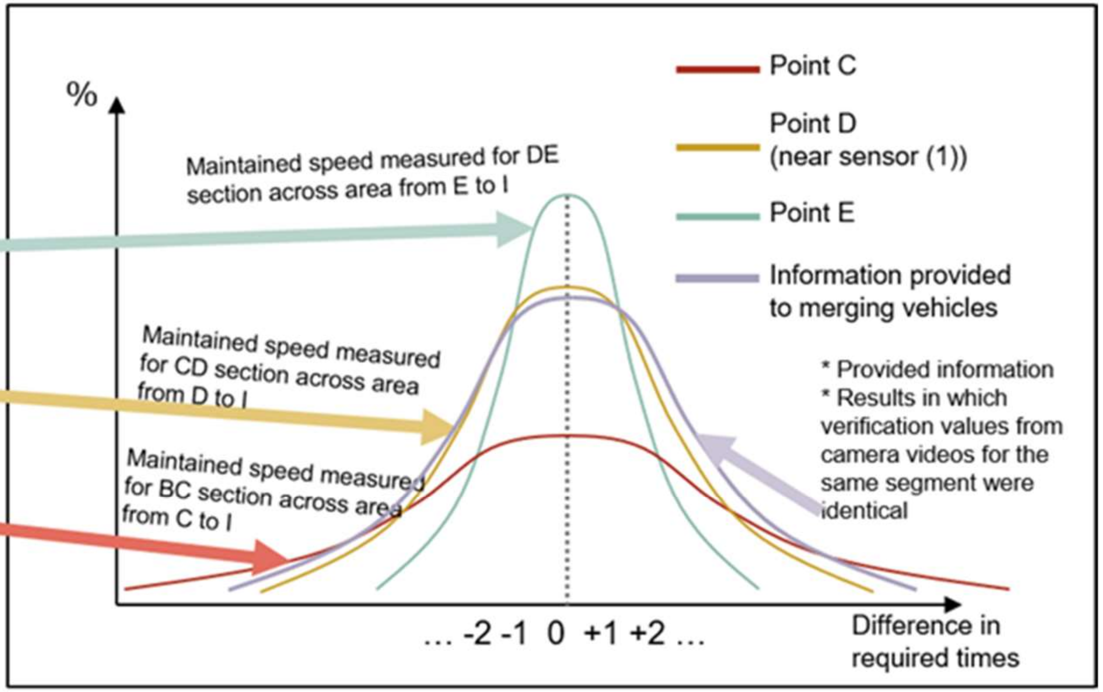


4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

- Overview of lap time analysis performed to verify the validity of the position of the sensor used to provide merging support information





4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

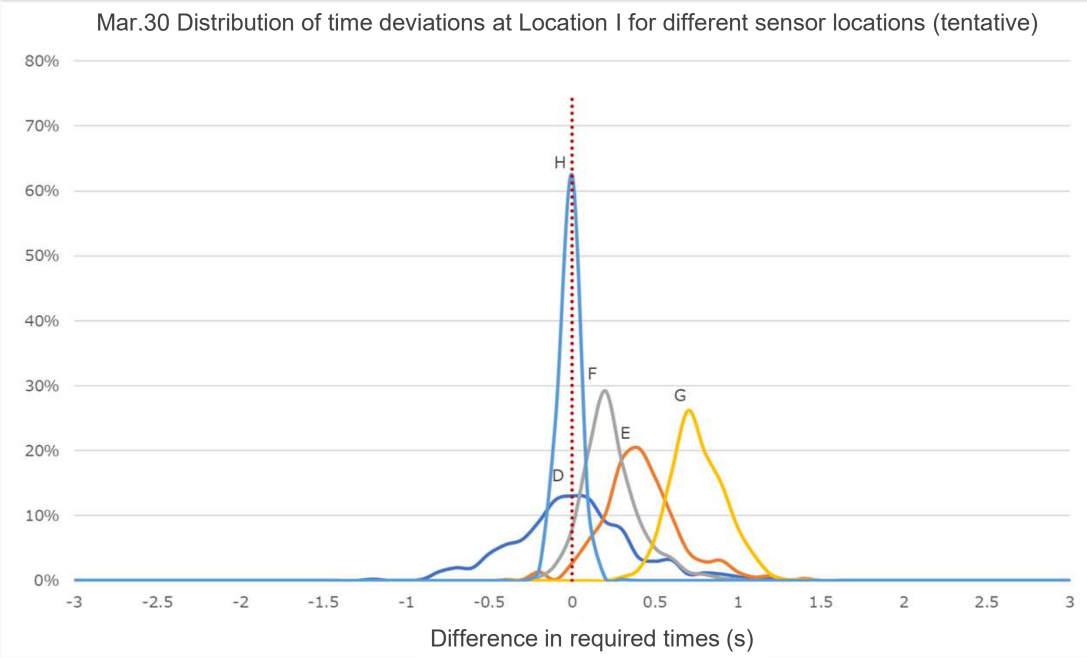
[FY2020 results]

Distribution of time differences when sensor was moved downstream

Difference between physical gore passing time and calculated arrival time = physical gore passing time - calculated arrival time

Positive: The vehicle was estimated to arrive before it actually passed the physical gore

Negative: The vehicle was estimated to arrive after it actually passed the physical gore



Sensor location	Speed assuming linear motion at a constant speed
D	CD segment speed
E	DE segment speed
F	EF segment speed
G	FG segment speed
H	GH segment speed

Installing the sensor in location G would tend to produce predictions of arrival earlier than the predictions that would be produced if the sensor were installed in other locations

→ There are two possible reasons for this

(1) Lap time measurement error

At both locations F and G, the angle of view is such that vehicles are seen from behind, so their speeds may be overestimated

(2) Road shape

The straight line to the merging area and the downward grade may cause speeds to increase in the FG segment

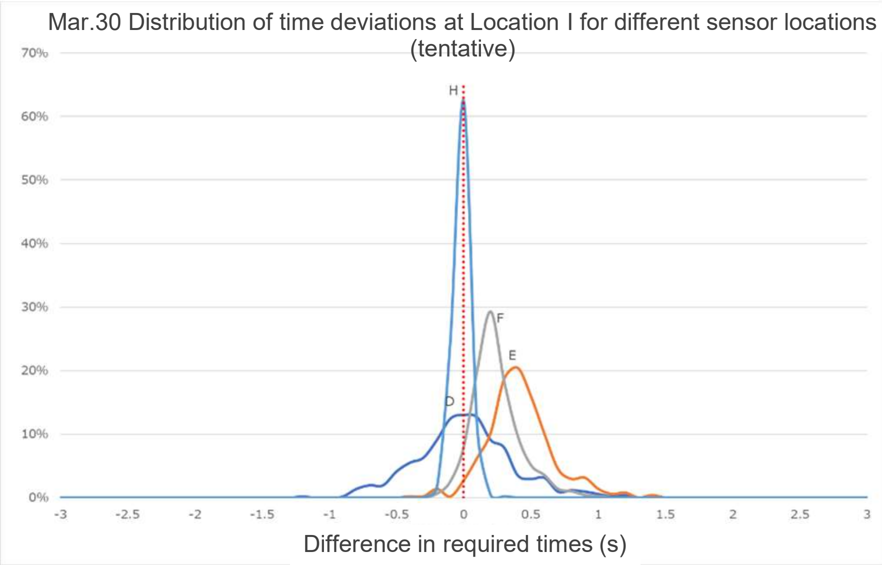
→ Location G had a large degree of deviation, so it was excluded from the analysis

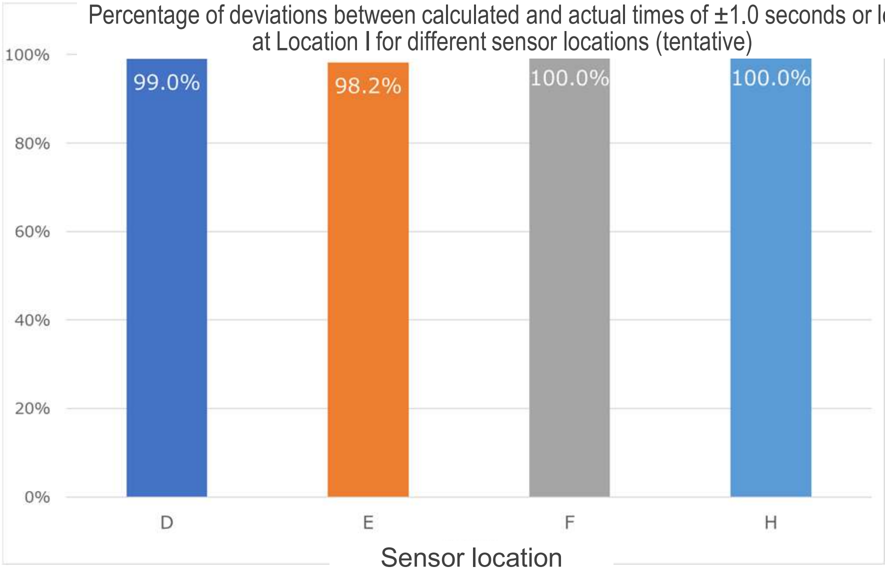
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

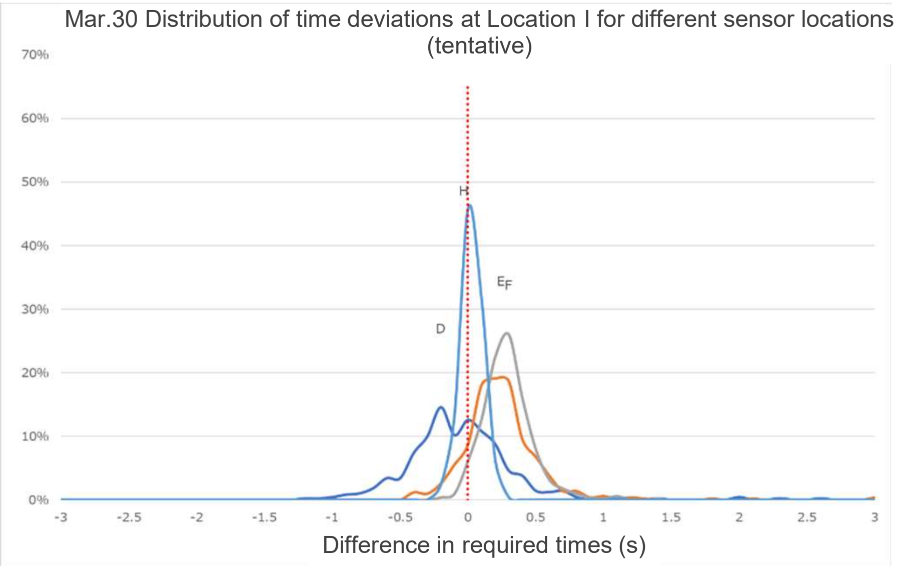
Distribution of time differences when sensor was moved downstream

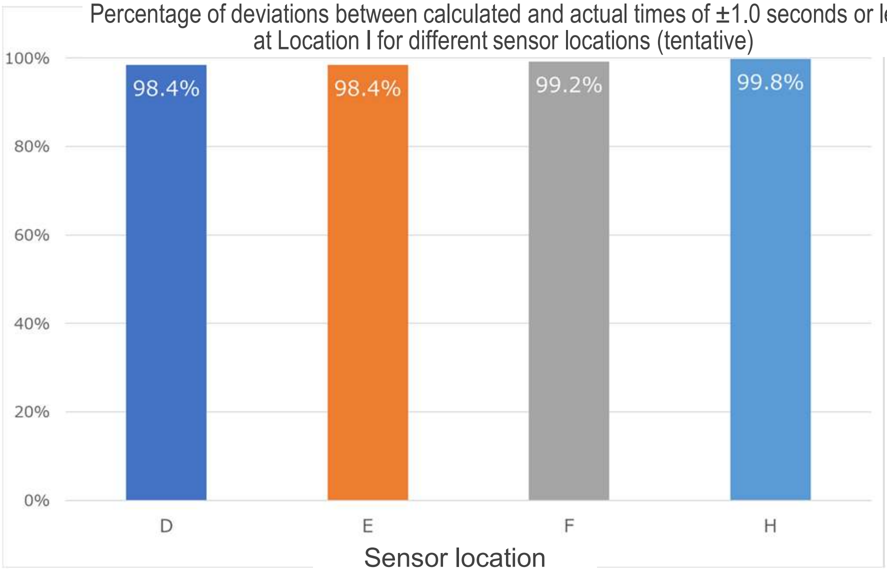
Mar. 30 12:35-13:05





Mar. 30 13:05-13:35



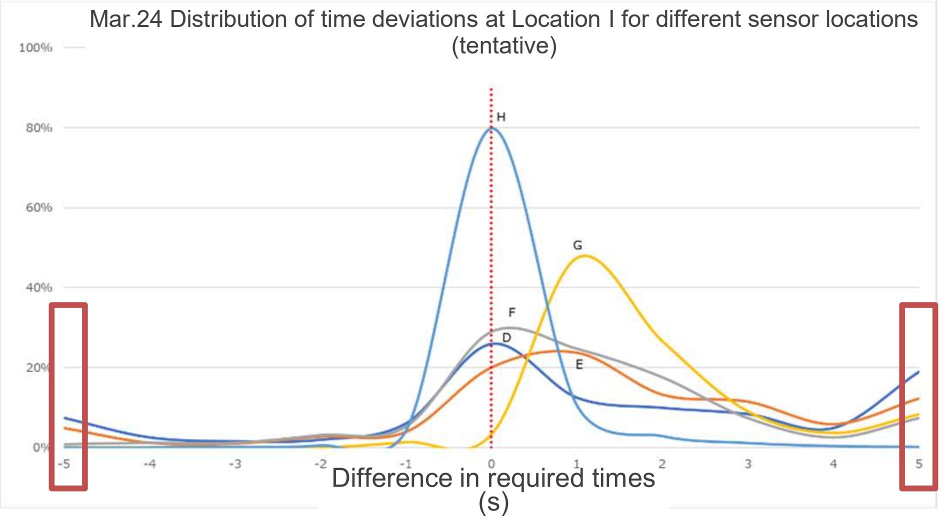


4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

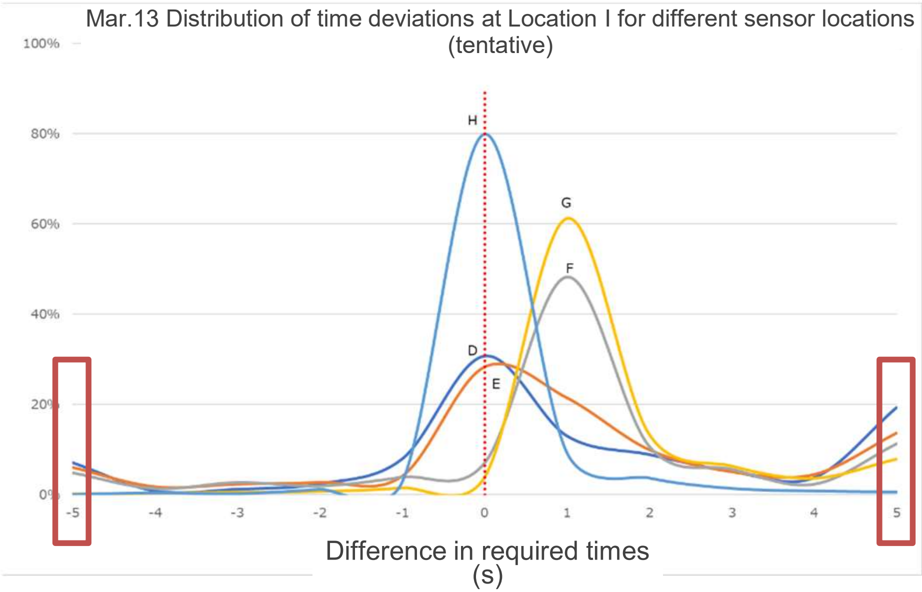
[FY2020 results]

Distribution of time differences when sensor was moved downstream

Mar. 24 06:25-06:55



Mar. 13 09:25-09:55



[Reference]
Critical condition (Mar. 24), traffic jam (Mar. 13)

- There were many cases of deviations of ±5 seconds or more
- The amount of variance was smallest for Location H, which was the closest to the merging area
- At Location G, the forecast arrival time was faster than for other locations, just as when the traffic was steady

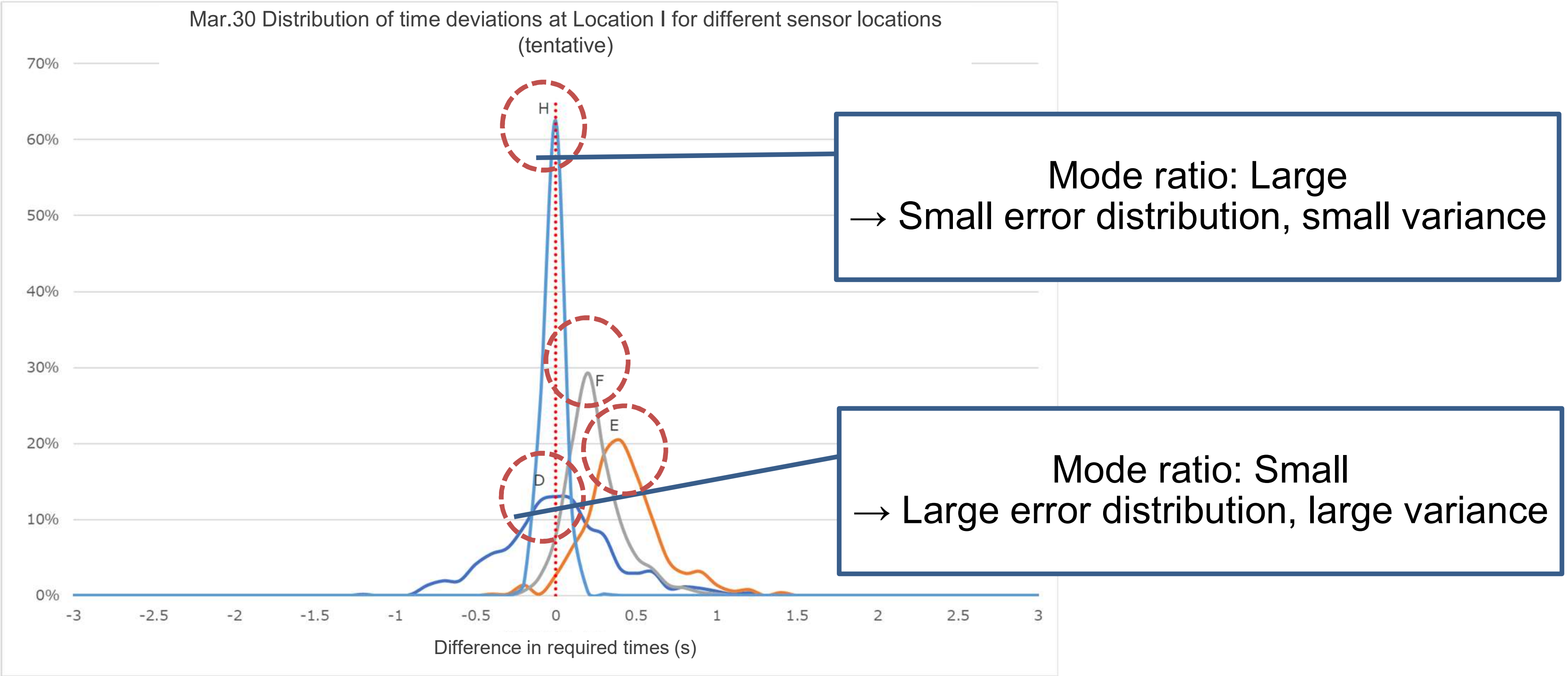
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between sensor location and deviation variance

The distances between each point and the merging area were compared with the amount of deviation variance to determine their degree of relation

→ Comparison was performed using the mode ratio of the error distribution



4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

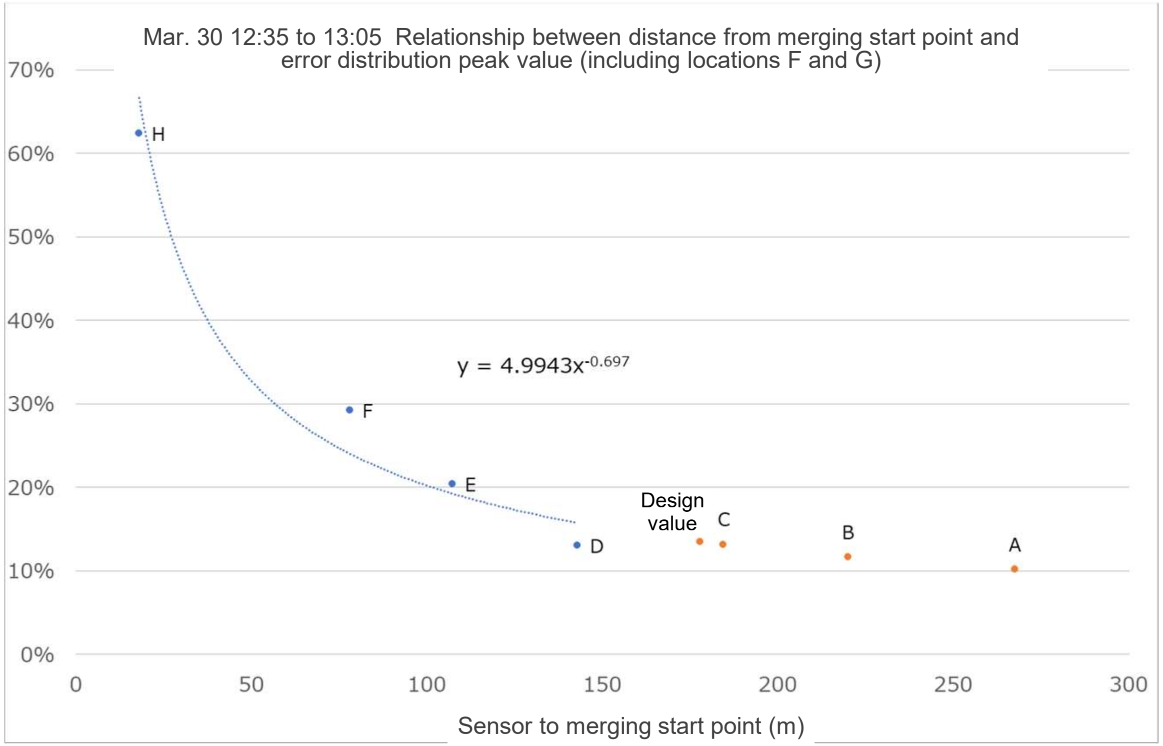
[FY2020 results]

Relationship between sensor location and deviation variance

The further away from the merging area, the smaller the peak value→ We have hypothesized a power approximation

We calculated an approximate curve based on the relationship between lap time measurements (locations D, E, F, and H) and distances

We inferred peak values for locations outside the roadside camera range (locations A, B, and C) based on their distances



Distance from each location to the merging start point and corresponding peak values

	H	F	E	D	C	B	A
Distance (m)	18.02	78.03	107.23	142.86	184.48	219.92	267.52
Peak value (%)	62%	29%	20%	13%	13%	11%	10%

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

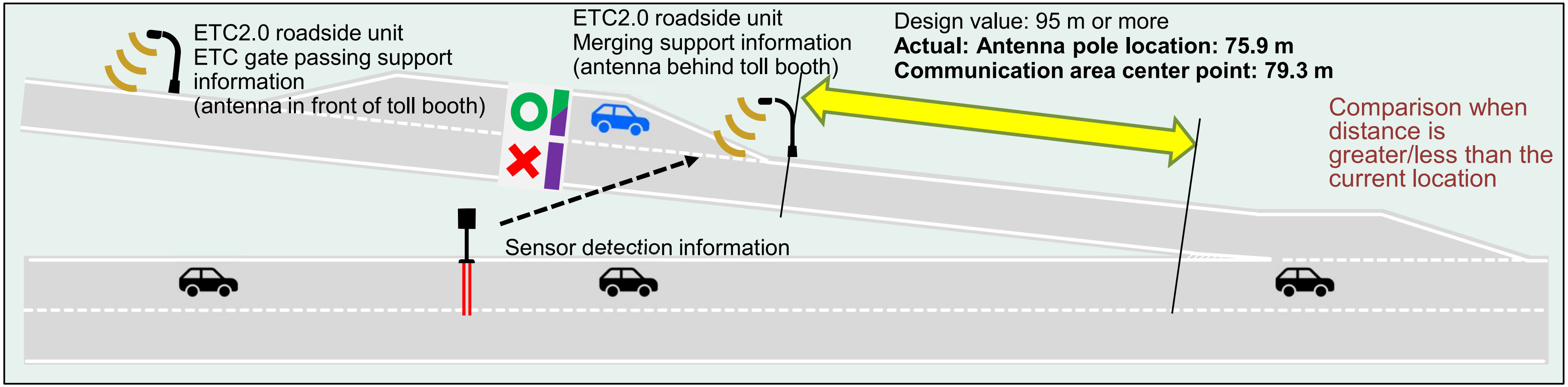
[FY2020 results]

[Objectives of analysis of information provision locations]

- In this FOT, the antenna used to deliver merging support information was installed 79.5 m upstream of the merging area
- The greater the distance between the information provision point and the merging area, the greater the margin for adjusting merging timing by adjusting acceleration

[Verification method]

- The time required to arrive at the merging area was calculated based on the envisioned speed profiles (fastest and slowest profiles) of the merging vehicle after passing the ETC gate
- The distance between the antenna and the merging area was modified and the relationship between the antenna distance and the margin for making adjustments was derived
  → Verification was performed for each target speed



Airport West Entrance Location of antenna used to provide merging support information

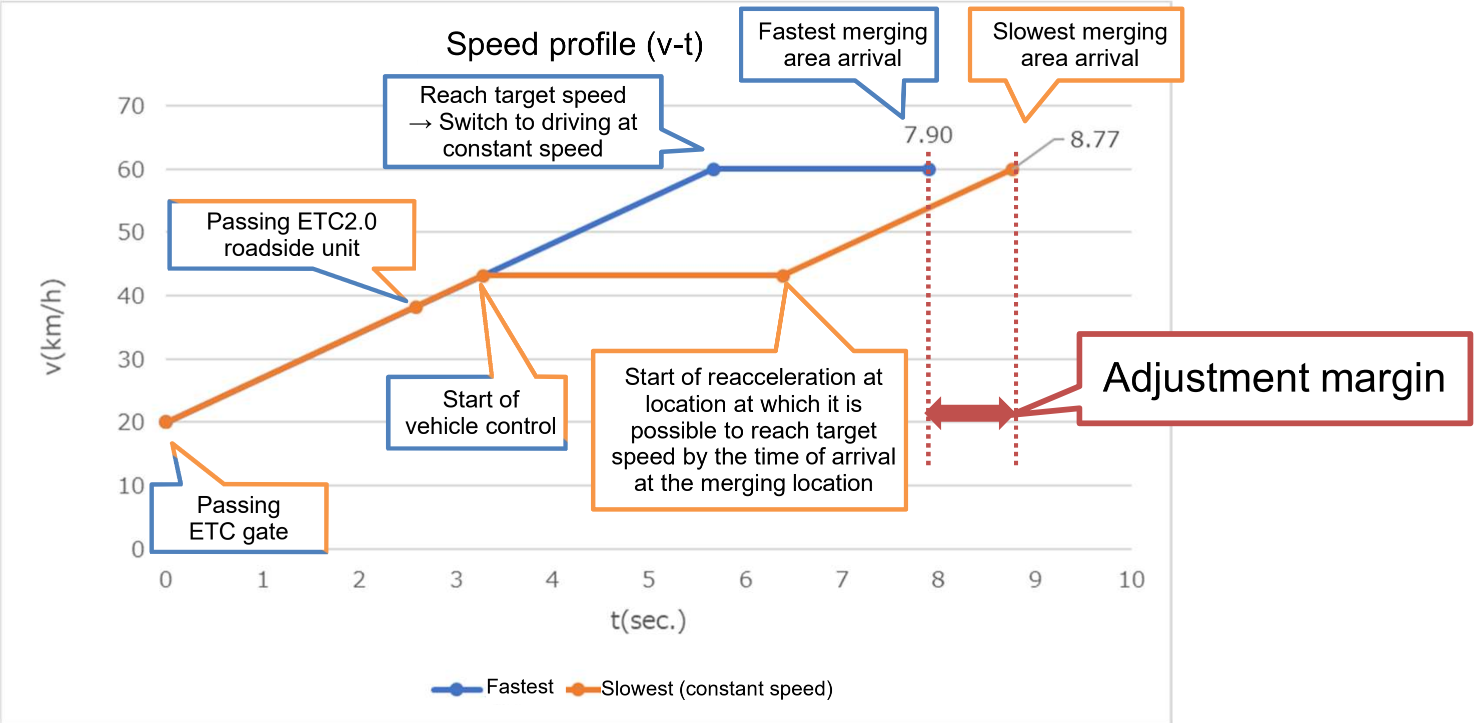
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Calculation of adjustment margin

- The adjustment margin was calculated using the envisioned speed profile of the merging vehicle

(Adjustment margin) = (Required time for slowest profile) - (Required time for fastest profile)



[Variables] The input values in the graph above are as shown below

Target speed: 60 km/h

Distance between ETC2.0 roadside unit and merging start point: 79.3 m (actual roadside unit installation location for Airport West)

[Constants]

Speed when passing ETC gate: 20 km/h

Distance between ETC gate and ETC2.0 roadside unit: 20.9 m

Time required from passing ETC2.0 roadside unit to end of CAN output: 0.7 seconds

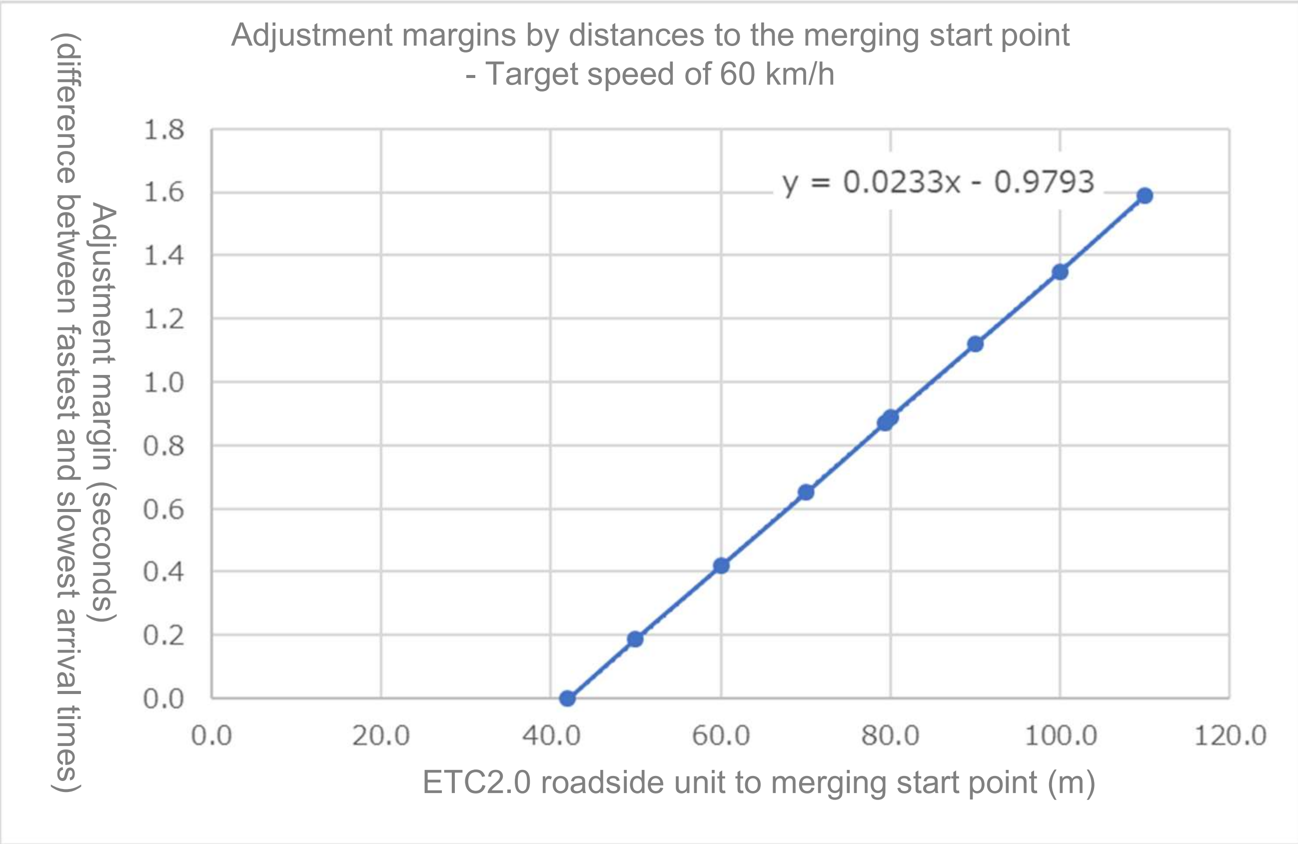
Acceleration: 0.2 G

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between distance to merging start point and adjustment margin

Using a target speed of 60 km/h, we calculated the adjustment margins for different distances between the ETC2.0 roadside unit and the merging area



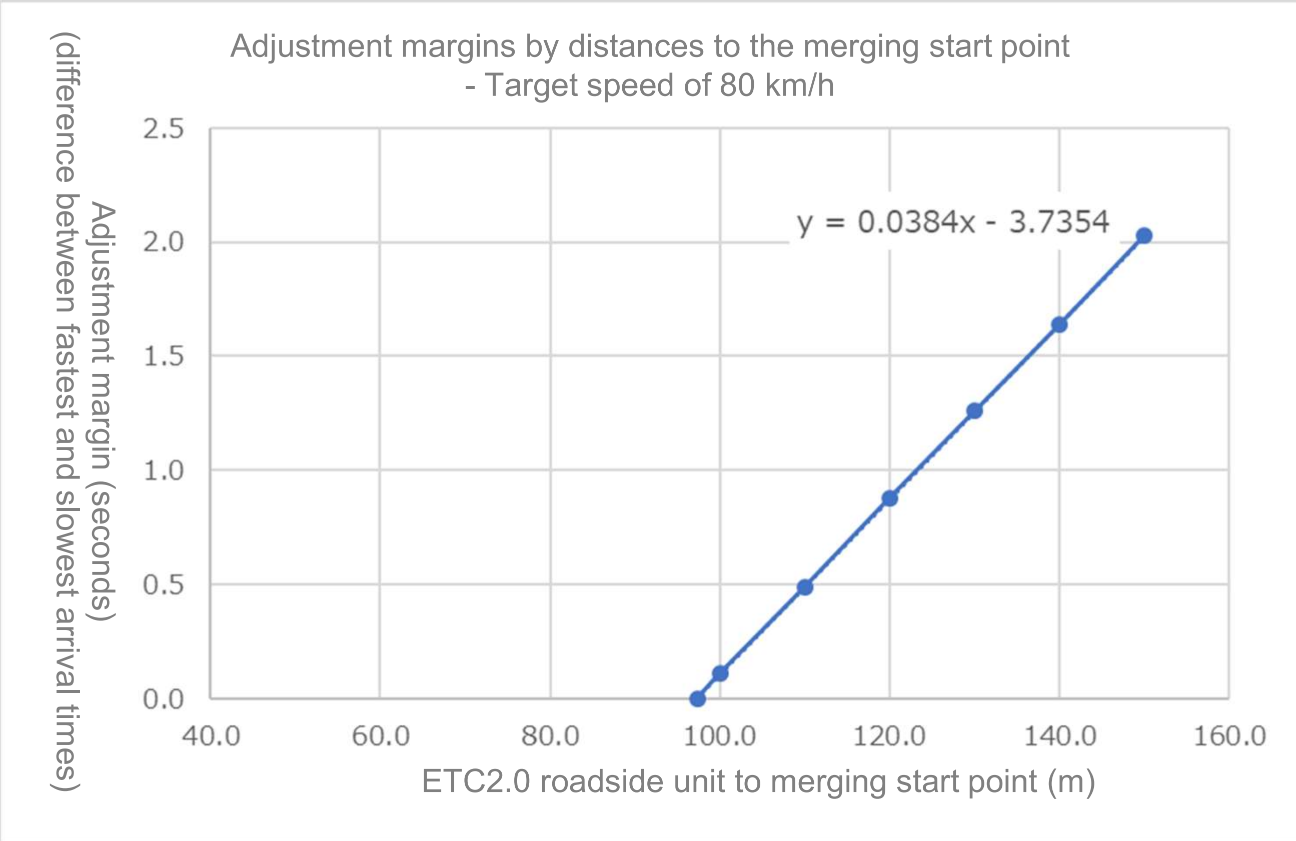
- When the distance between the ETC2.0 roadside unit and the merging area was less than 42 m, a speed of 60 km/h could not be reached by the time of arrival at the merging area
- The actual location of the roadside unit for Airport West was 79.3 m from the merging start point (distance to the center point of the communication area), and the adjustment margin was 0.78 seconds

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between distance to merging start point and adjustment margin

Using a target speed of 80 km/h, we calculated the adjustment margins for different distances between the ETC2.0 roadside unit and the merging area



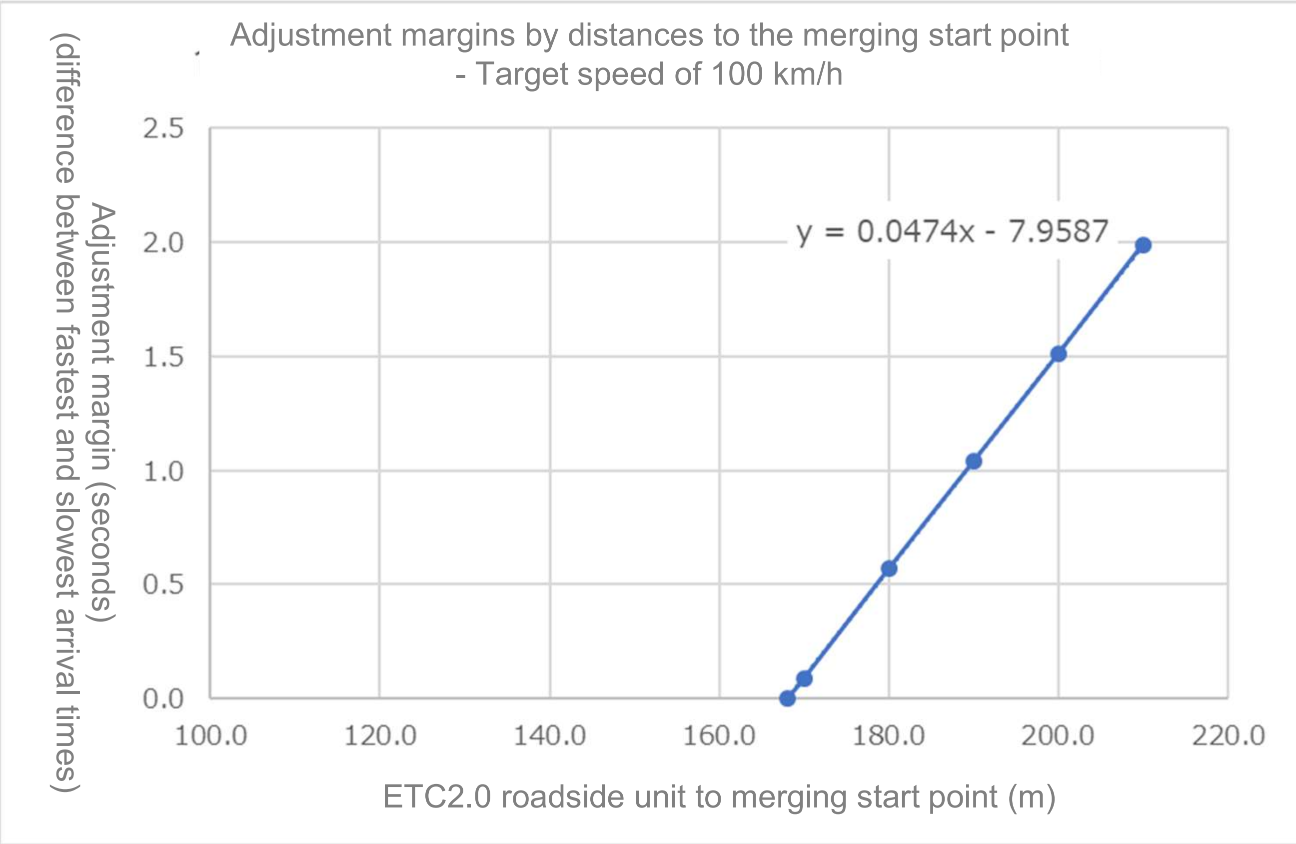
- When the distance between the ETC2.0 roadside unit and the merging area was less than 97.3 m, a speed of 80 km/h could not be reached by the time of arrival at the merging area
- The actual location of the roadside unit for Airport West was 79.3 m from the merging start point (distance to the center point of the communication area), so sufficient acceleration was not possible

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between distance to merging start point and adjustment margin

Using a target speed of 100 km/h, we calculated the adjustment margins for different distances between the ETC2.0 roadside unit and the merging area



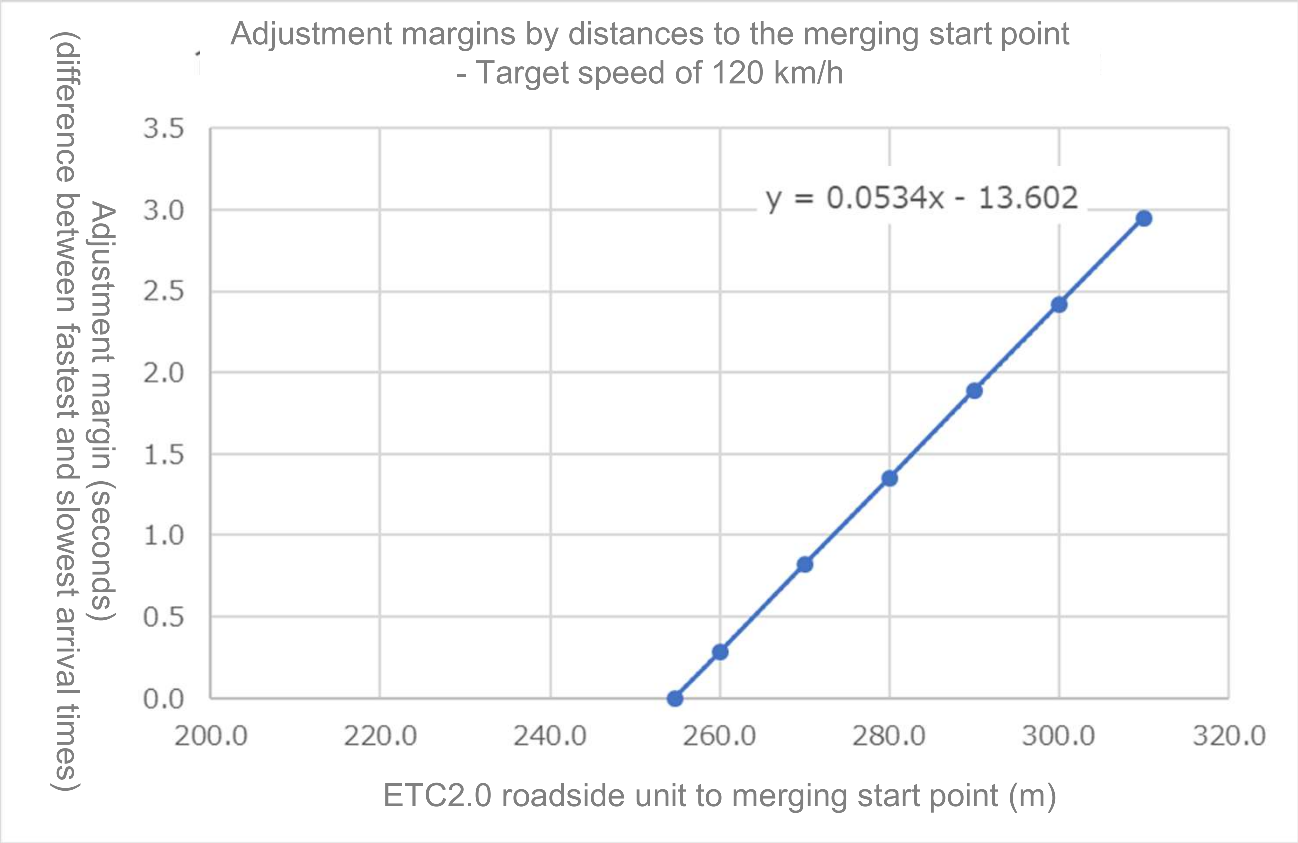
- When the distance between the ETC2.0 roadside unit and the merging area was less than 168.0 m, a speed of 100 km/h could not be reached by the time of arrival at the merging area
- For merging support on road sections with high cruising line speeds, such as intercity expressways, sufficient distance must be secured to accelerate after information is provided

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between distance to merging start point and adjustment margin

Using a target speed of 120 km/h, we calculated the adjustment margins for different distances between the ETC2.0 roadside unit and the merging area



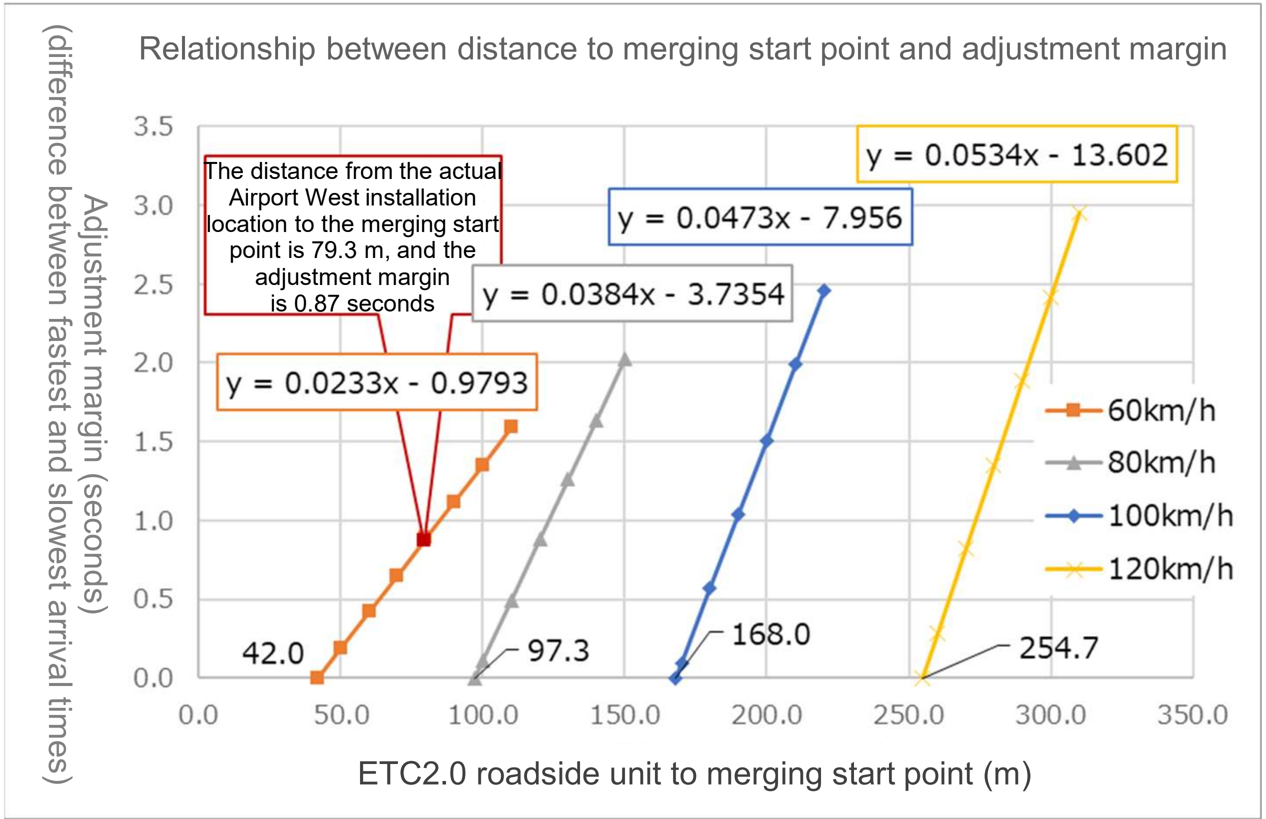
- When the distance between the ETC2.0 roadside unit and the merging area was less than 254.7 m, a speed of 120 km/h could not be reached by the time of arrival at the merging area
- For merging support on road sections with high cruising line speeds, such as intercity expressways, sufficient distance must be secured to accelerate after information is provided

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between distance to merging start point and adjustment margin

- The relationships between the distances from ETC2.0 roadside units to merging areas and adjustment margins are shown below



- Adjustment margin of 0 seconds ⇒ Distance needed to reach target speed under fastest profile
  → The higher the target speed, the greater the distance necessary for acceleration

- The greater the distance between the ETC2.0 roadside unit and the merging area, the greater the adjust margin
  → Information provision locations should be defined based on the average following distance near the cruising line merging area in order to secure sufficient distance for the required adjustment margin

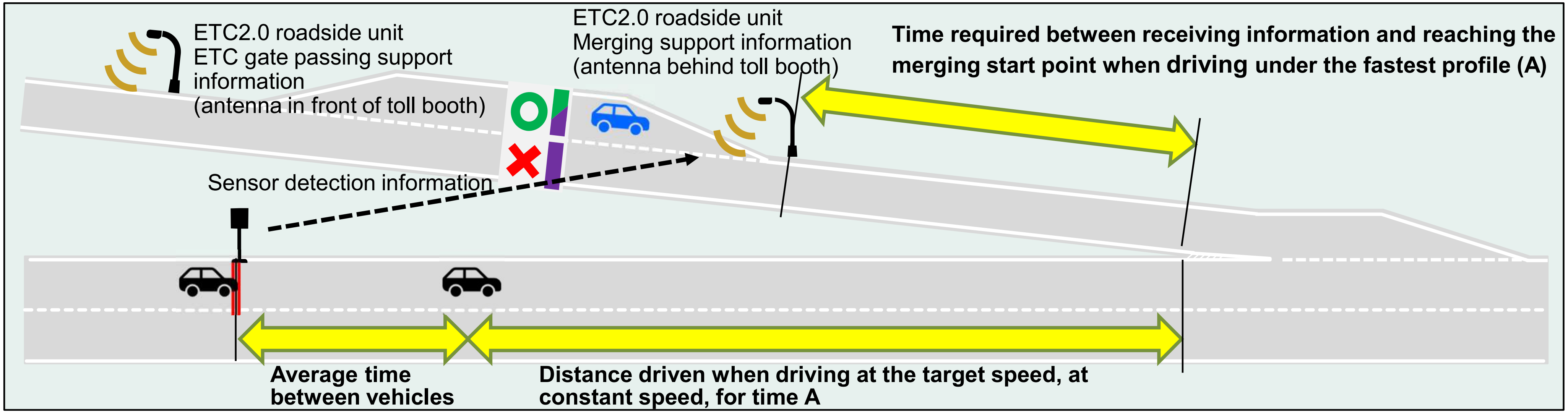
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between information provision location and sensor location for Airport West: Analysis objectives

- The greater the distance between the information provision point and the merging area, the greater the margin for adjusting merging timing by adjusting acceleration (this has been confirmed through our study of information provision locations)
- However, this requires placing the sensor further upstream, which reduces forecast accuracy (this has been confirmed through our study of sensor locations)

[Verification method]
- Determine cruising line actual speed based on data acquired through the FOT (=target speed)
- We varied the distance between the information provision location and the merging area and calculated the required time under the fastest profile
- We calculated the distance (and sensor installation location), hypothesizing that vehicles on the cruising line travel at the target speed at a constant speed for the time required to reach the merging area + the average time between vehicles
- For each sensor installation location, we organized information regarding how much the accuracy of forecasts could be affected



4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

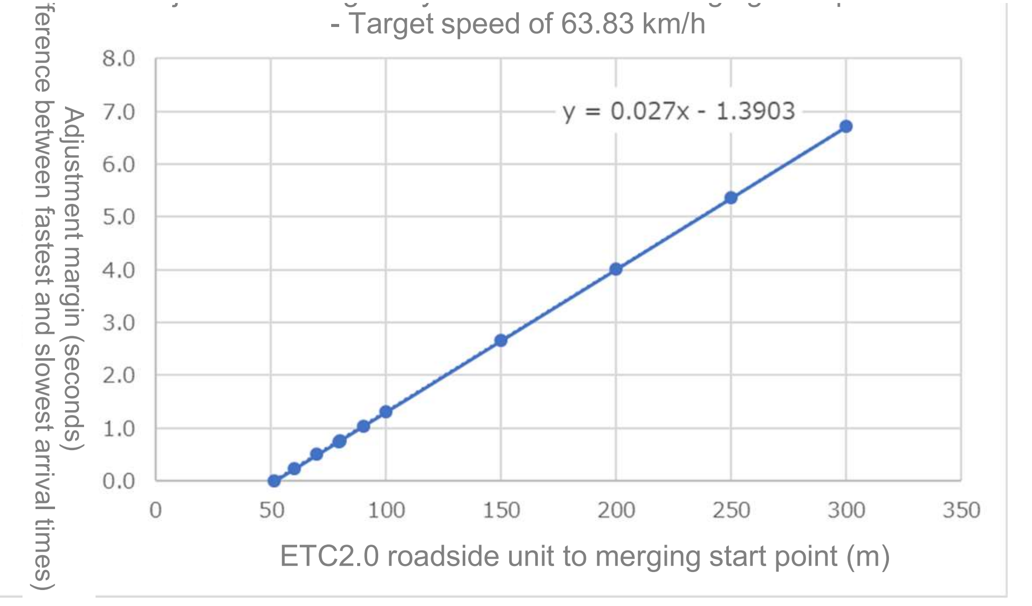
Relationship between information provision location and sensor location for Airport West: Analysis objectives

[Determine cruising line actual speed (=target speed) and average time between vehicles]

- Mar. 30 12:35-13:05 Lap time measurement found the average detected C-D over-all speed to be 63.83 km/h and the average time between vehicles to be 3.27 seconds

[Confirmation of merging vehicle speed profile]

- For a target speed of 63.83 km/h, we calculated the required time for each distance between the information provision location and the merging area for both the fastest and slowest profiles
  → We then calculated the speed adjustment margins for merging vehicles



Information provision location to merging start point (m)	Speed adjustment margin for merging vehicles (s)
51.5	0.00
100.0	1.31
150.0	2.66
200.0	4.01
250.0	5.36
300.0	6.71

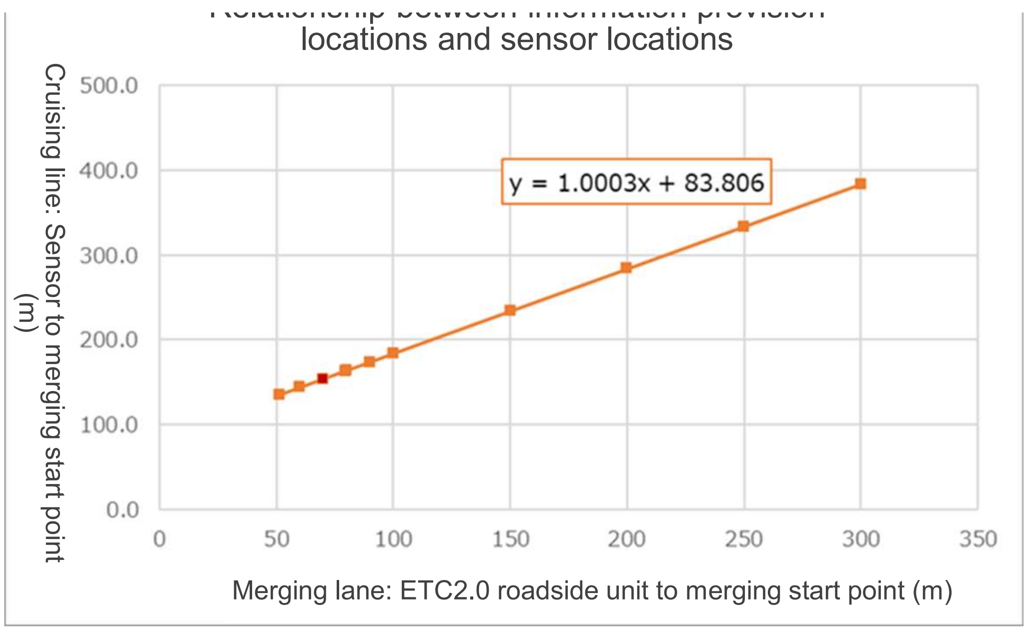
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between information provision location and sensor location for Airport West: Analysis objectives

[Calculation of cruising line sensor locations for each information provision location]

- For a target speed of 63.83 km/h, we calculated the required time for each distance between the information provision location and the merging area for the fastest profile
- We added 4.0 seconds to the required time for the fastest profile and calculated the sensor location



* By adding 4 seconds to the time of the fastest profile, we were able to include within the information provision range the vehicles following the vehicle in the cruising line that arrives at the merging start point at the same time as the merging vehicle
→ This makes it possible to determine the length of the gap to be merged into

Information provision location to merging start point (m)	Speed adjustment margin for merging vehicles (s)	Sensor to merging start point (m)
51.5	0.00	135.3
100.0	1.31	183.9
150.0	2.66	233.9
200.0	4.01	283.9
250.0	5.36	333.9
300.0	6.71	383.9

4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

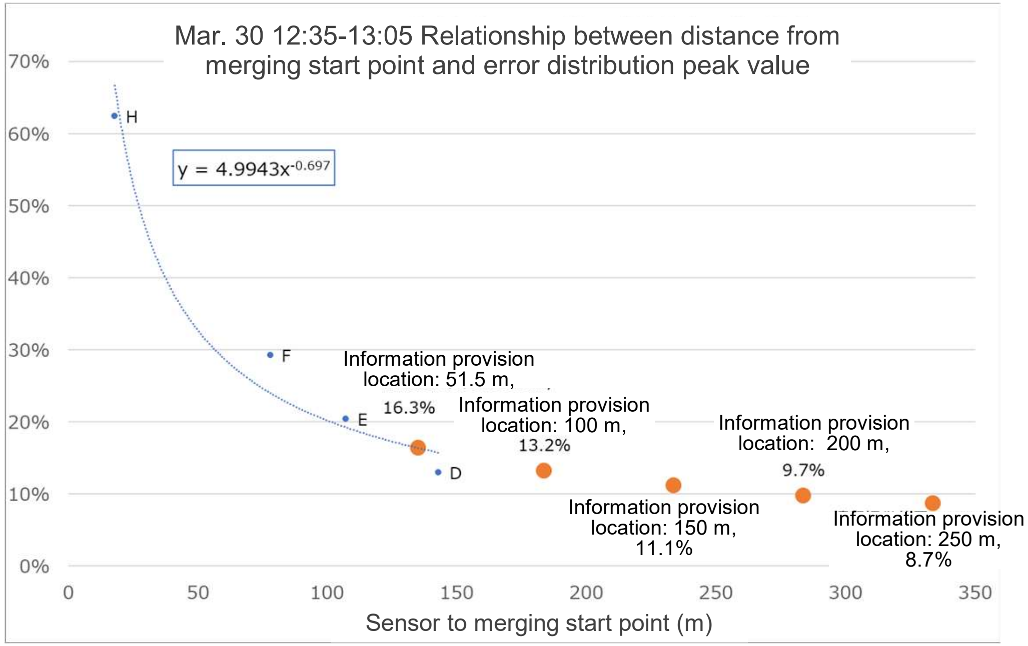
[FY2020 results]

Deviation variation at each sensor location

[Inference of amount of variation in forecast accuracy at each sensor location]

- We used the curve calculated in our sensor location analysis to infer the mode ratio of the error distribution for each distance between sensor location and merging start point given each information provision location

- Based on the lap time measurement results, we hypothesized an error distribution function and calculated data ratios that would produce deviations of ±1 seconds or less and ±0.5 seconds or less at each sensor location



Information provision location to merging start point (m)	Speed adjustment margin for merging vehicles (s)	Sensor to merging start point (m)	Deviation: ±1.0 seconds or less	Deviation: ±0.5 seconds or less
51.5	0.00	135.3	99.8%	93.7%
100.0	1.31	183.9	99.0%	86.8%
150.0	2.66	233.9	97.0%	79.4%
200.0	4.01	283.9	94.5%	73.3%
250.0	5.36	333.9	91.5%	67.7%
300.0	6.71	383.9	88.4%	63.2%

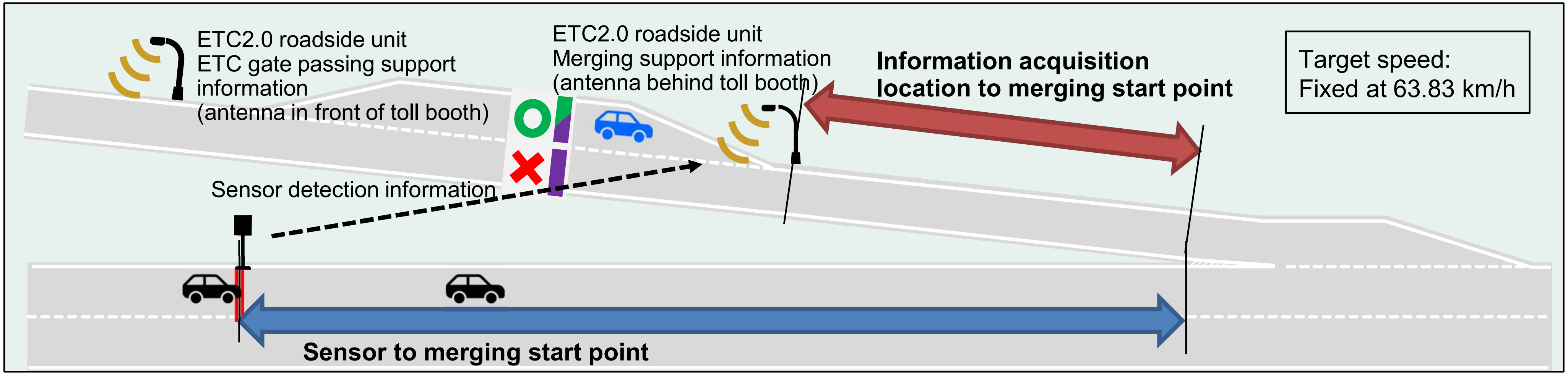
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Deviation variation at each sensor location

- The greater the distance between the information provision point and the merging area, the greater the margin for adjusting merging timing by adjusting acceleration. However, this requires placing the sensor further upstream, which reduces forecast accuracy.
  From the table below, it was confirmed that the location of the infrastructure equipment installed this time is optimal under the restrictions of the road environment.

Information provision location to merging start point (m)	**Speed adjustment margin for merging vehicles (s)** Difference in required times for merging vehicles under fastest and slowest profiles	**Sensor to merging start point (m)** Distance driven when driving at the target speed at constant speed for the required time under the merging vehicle's fastest profile + 4 seconds	**Deviation: ±1.0 seconds or less**	**Deviation: ±0.5 seconds or less**
51.5	0.00	135.3	99.8%	93.7%
(Current location) 79.8	0.75	163.1	99.4%	89.7%
(JAMA request) 95.0	1.18	178.9	99.1%	87.3%
100.0	1.31	183.9	99.0%	86.8%
150.0	2.66	233.9	97.0%	79.4%
200.0	4.01	283.9	94.5%	73.3%
250.0	5.36	333.9	91.5%	67.7%
300.0	6.71	383.9	88.4%	63.2%



4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

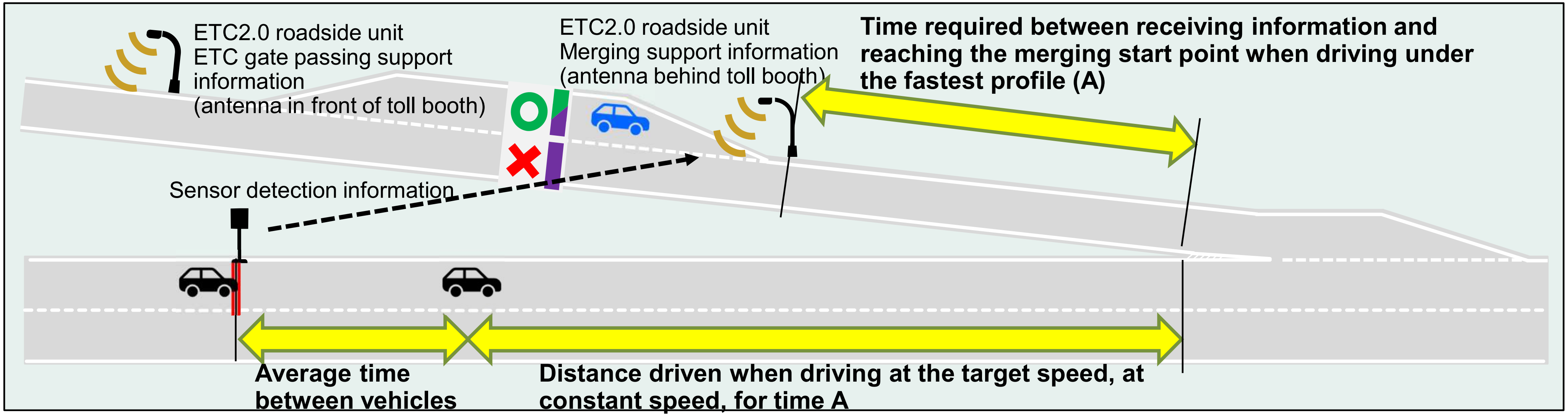
[FY2020 results]

Analysis performed taking application in other locations into consideration: Analysis objectives

- If this system is implemented in other expressway merging locations, merging must be performed using the cruising line speeds at each location as the target speed
- The minimum required distance between the information provision location and the merging start point differs depending on the target speed, so we organized information regarding the relationships between target speeds and sensor locations

[Verification method]

- We calculated the distance between the information provision location and the merging area based on the time required to <u>ensure a 1 second adjustment margin</u> under the fastest profile for different target speeds
- We calculated the distance (and sensor installation location), hypothesizing that vehicles on the cruising line travel at the target speed at a constant speed for the time required to reach the merging area + the average time between vehicles



4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

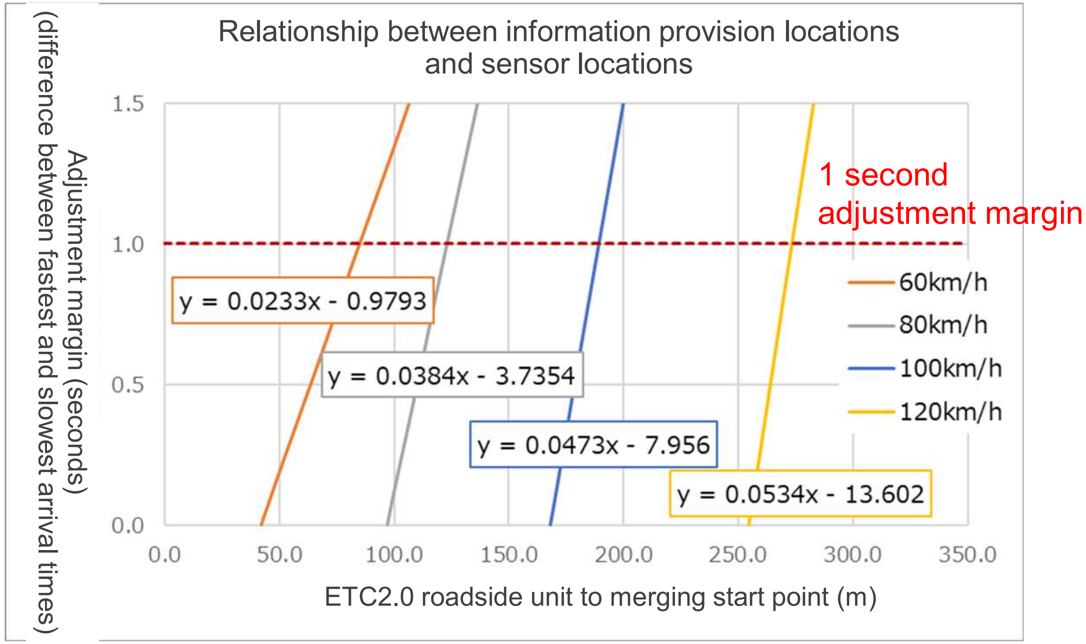
Relationship between information provision locations and sensor locations

[Calculation of information provision locations]

- We calculated information provision locations that would ensure 1 second of coordination margin for target speeds of 60, 80, 100, and 120 km/h

[Calculation of sensor locations for combinations of target speeds and information provision locations]

- We calculated the required time for merging vehicle fastest profiles based on the target speed and information provision location
- We added 4.0 seconds to the required time for the fastest profile and calculated the sensor location



* On expressways, following distances are usually linked to speeds, so by adding 4 seconds, we were able to include the vehicles following the vehicle in the cruising line within the information provision range

Target speed (km/h)	Information provision location to merging start point (m)	Sensor to merging start point (m)
60	84.9	161.0
80	123.3	246.4
100	189.0	375.3
120	273.4	528.3

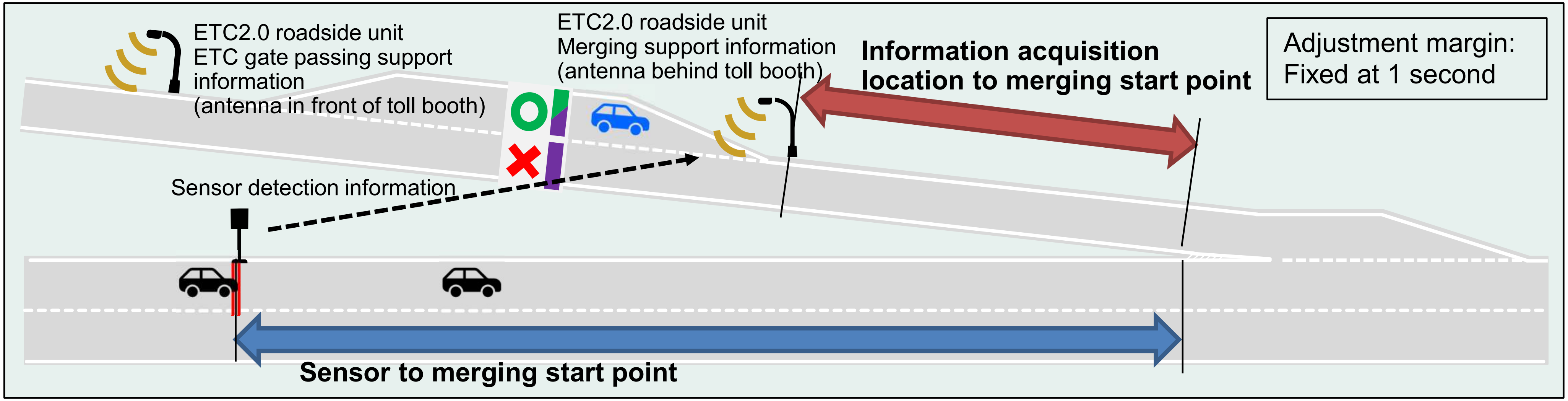
4.2.7. Evaluation of and observations regarding locations of installed infrastructure involved in providing merging support information

[FY2020 results]

Relationship between information provision locations and sensor locations

- The faster the target speed (=cruising line speed), the greater the distance between the information provision point and the merging area required to secure an adjustment margin of 1 second, and the greater the distance between the sensor and the merging start point

Target speed (km/h)	**Information provision location to merging start point (m)** Distance required to ensure 1 second of difference in required times for merging vehicles between fastest and slowest profiles	**Sensor to merging start point (m)** Distance driven when driving at the cruising line speed at constant speed for the required time under the merging vehicle's fastest profile + 4 seconds
60	84.9	161.0
80	123.3	246.4
100	189.0	375.3
120	273.4	528.3



4. Verification of installation conditions, etc., related to infrastructure equipment on Metropolitan Expressway

[FY2020 results]

4.3. Evaluation of processing capabilities for merging support information/ETC gate passing support information

We confirmed how long it took between the acquisition of information by roadside sensors (such as vehicle detection and ETC gate information) and transmission completion (road-to-vehicle communication by expressway test wireless roadside units to test vehicles and completion of CAN output). Confirmation was done by calculating average times based on log information from individual units.

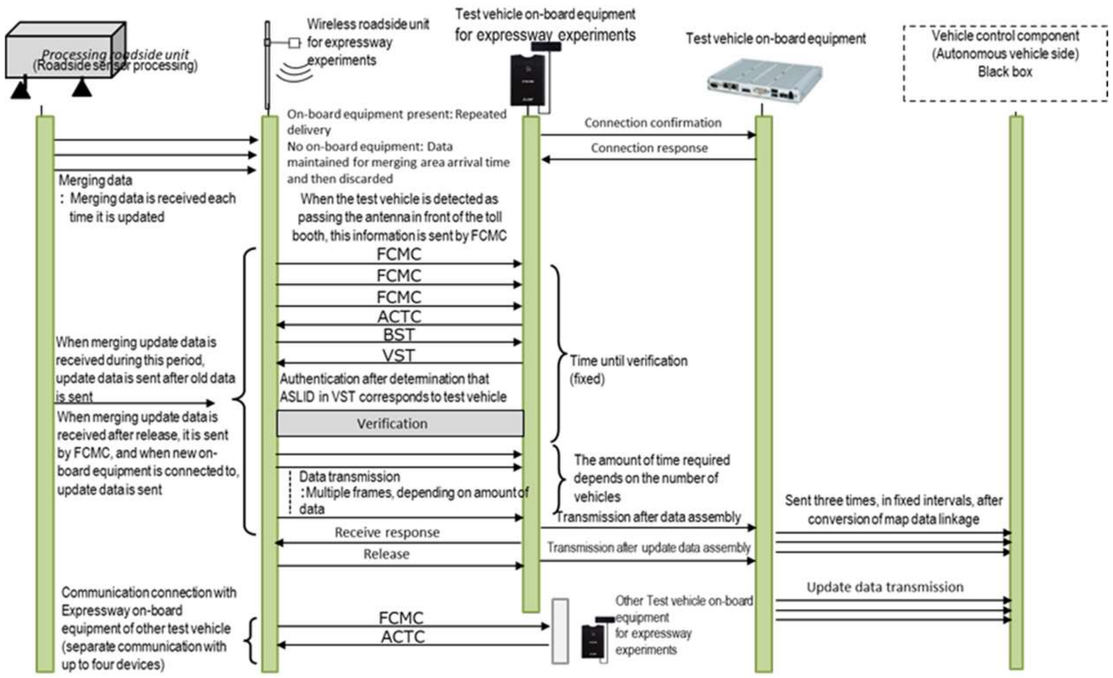


Fig. Transmission sequence between units when providing merging support

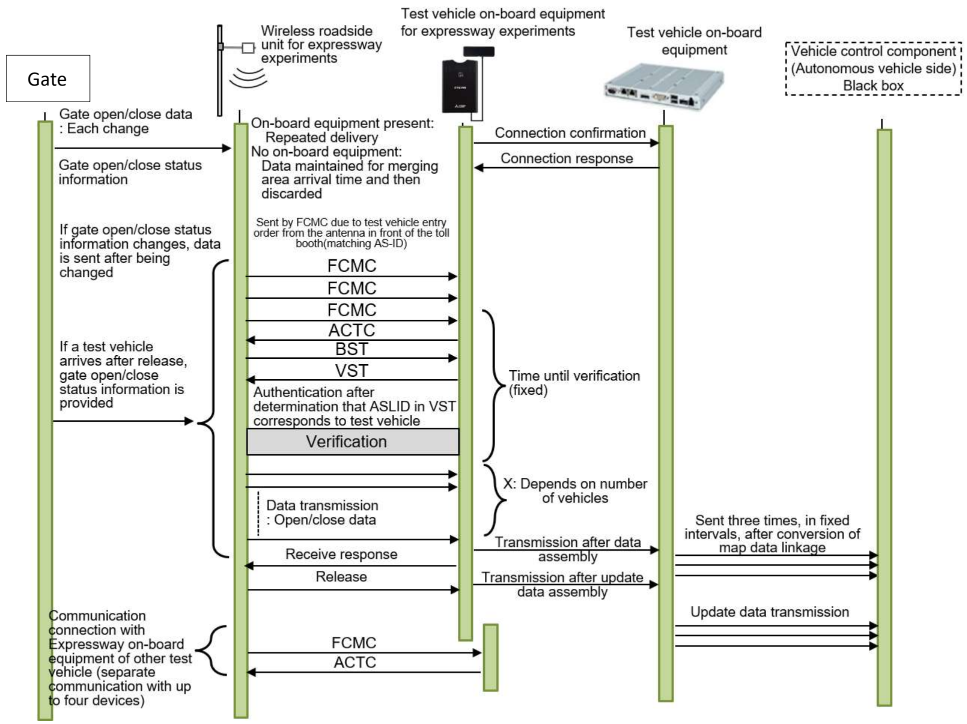


Fig. Transmission sequence between units when providing ETC gate passing support

4.3.1. Evaluation of processing capabilities of merging support infrastructure equipment

[FY2020 results]

The performance of merging support infrastructure equipment was evaluated using the following procedure.

(1) Determining the sensor-side processing time: Average required time for the process of vehicle detection, merging area arrival time calculation, transmission to expressway FOT wireless roadside unit

(2) Determining the wireless roadside unit-side processing time: Average required time for the process of receiving the merging area calculated arrival time from the processing roadside unit, transmission to the wireless roadside unit, road-to-vehicle communication, and completion of reception of the merging area calculated arrival time by the FOT on-board equipment

(Evaluation of the processing time on the vehicle side, after receiving the merging area calculated arrival time, is not included in the scope of this project)

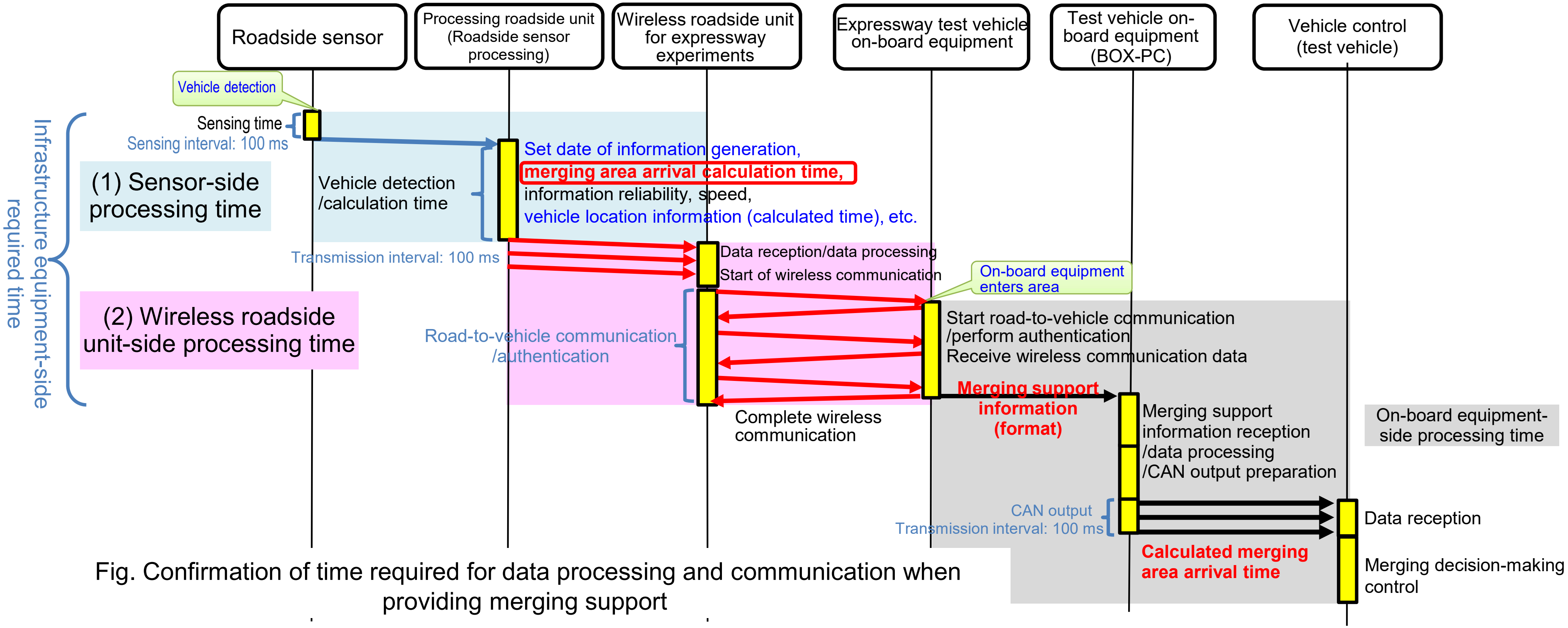


Fig. Confirmation of time required for data processing and communication when providing merging support

Table. Preliminary estimates and actual measurements of processing capabilities when providing merging support

Processing time	Actual measured required time (average for 100 drives)
Sensor-side processing time	500 ms
Wireless roadside unit-side processing time	422 ms (Data processing: 137 ms + road-to-vehicle communication: 285 ms)

4.3.1. Evaluation of processing capabilities of ETC gate passing support infrastructure equipment

[FY2020 results]

The performance of ETC gate passing support infrastructure equipment was evaluated using the following procedure.

(1) Determining the wireless roadside unit-side processing time: Average required time for the process of the wireless roadside unit receiving gate open/close status information from the ETC gate, road-to-vehicle communication, and completion of reception of the information by the FOT on-board equipment

(Evaluation of the processing time on the vehicle side, after receiving the ETC gate passing support information, is not included in the scope of this project)

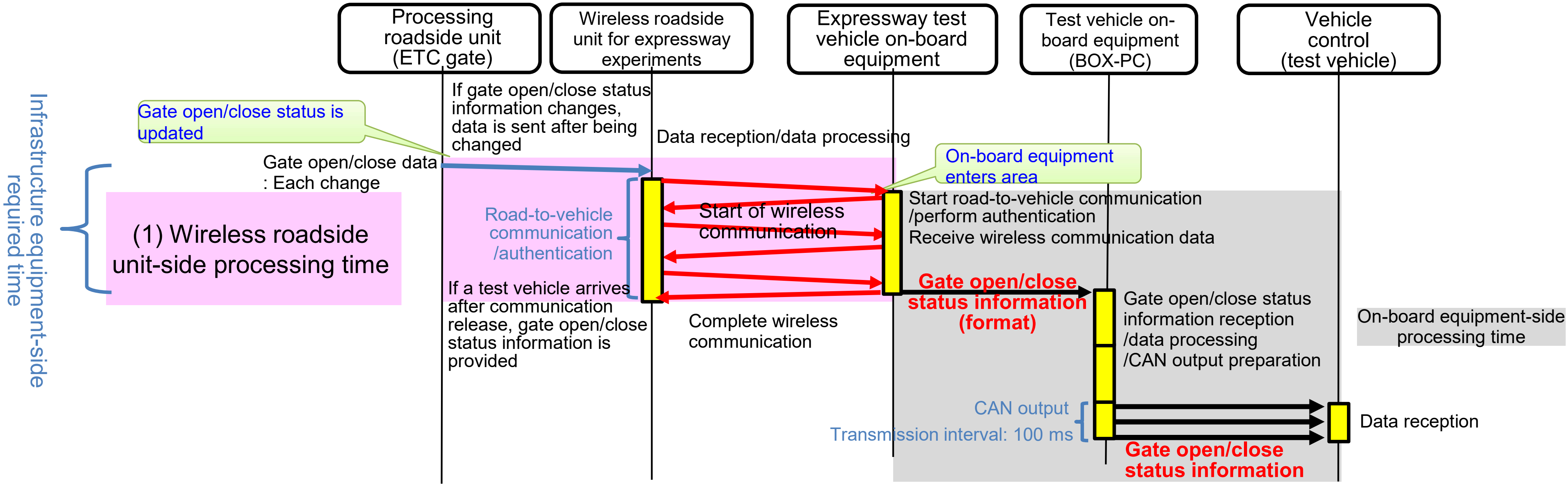


Fig. Confirmation of time required for data processing and communication when providing ETC gate passing support

Table Preliminary estimates and actual measurements of processing capabilities when providing ETC gate passing support

Processing time	Actual measured required time (average for 100 drives)
Wireless roadside unit-side processing time	345 ms (Data processing: 100 ms + road-to-vehicle communication: 245 ms)

5. Metropolitan Expressway - Summary of results of FY2019-2021 infrastructure equipment FOTs and future issues

[FY2020 results]

5.1. Summary of the results of the demonstration experiment infrastructure equipment in FY2019-2020

In this contract, the infrastructure environment on the expressway will be improved over the two years of 2019 and 2020.

Prior verification, maintenance and management were carried out, the operational suitability of the infrastructure equipment was evaluated from the experimental data, and the infrastructure equipment installation conditions were derived.

The results of this contract are summarized below.

- We were able to coordinate and cooperate with each institution to build infrastructure equipment as scheduled and start the experiment as planned.
- The merging support system was evaluated based on the log data of the field demonstration experiment and various information such as sensors, and it was confirmed that the current installation position of the infrastructure equipment is the optimum position under the restrictions of the road environment.
- It was recommended to improve the merge support format of the merge support system.
- We were able to organize the know-how such as applications and procedures related to the installation of infrastructure equipment.

5. Metropolitan Expressway - Summary of results of FY2019-2021 infrastructure equipment FOTs and future issue1

[FY2021 results]

5.3. Maintaining and managing infrastructure equipment

We carried out maintaining and managing infrastructure equipment for「Follow up FOTs」of FY2019-2021 with related organizations.

By checking infrastructure equipment on every weekday, and every month inspections,
We can maintain infrastructure equipment for period of FOTs.

(a) checking an infrastructure equipment

(a-1) On-site inspection in normal operation

- Inspection of equipment that requires traffic regulation (roadside sensors, etc.)
- Inspection of equipment that does not require traffic restrictions (outdoor panel mounting equipment, etc.)

(a-2) On-site inspection in case of abnormality

※ In 2021, the relevant abnormal situation did not occur and there were no problems with the infrastructure equipment.

(a-3) Remote inspection in normal operation

(b) Abnormality detection by inspection and response when anomalies occur due to disasters, etc.

(c) Securing spare parts in case of equipment failure

This report documents the results of Cross-ministerial Strategic Innovation Promotion Program (SIP) 2nd Phase, Automated Driving for Universal Services (SIP-adus, NEDO management number: JPNP18012) that was implemented by the Cabinet Office and was served by the New Energy and Industrial Technology Development Organization (NEDO) as a secretariat.