TF3-21-273 III 6revB

"Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase Two - Automated Driving (Expansion of Systems and Services) /Implementation of FOTs in the Tokyo Waterfront Area"

- FY2021 Results Report Overview -
Main Section

FOTs in the Tokyo Waterfront Area Consortium
Mitsubishi Electric Corporation (representative)

Aisan Technology Co., Ltd.
GeoTechnologies, Inc.
Sumitomo Electric Industries, Ltd.
Zenrin Co., Ltd.
Toyota Mapmaster Incorporated
Nippon Koei Co., Ltd.
Pacific Consultants Co., Ltd.
Pasco Corporation

March 2022

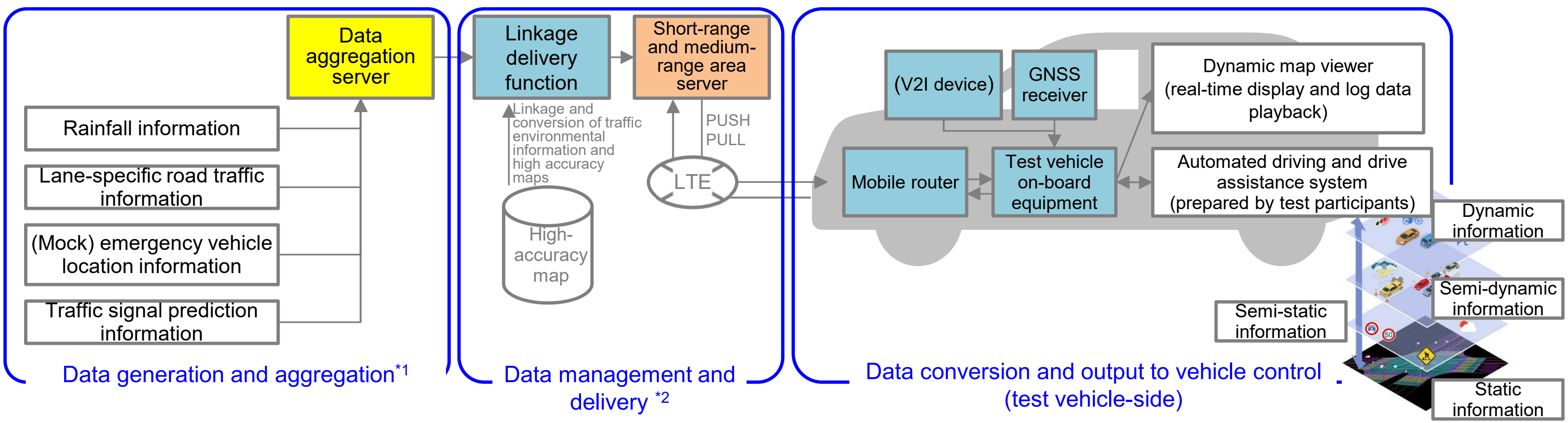
Results overview: Traffic environmental information delivery FOTs (V2N)

- In order to address the issues involved in utilizing information delivered via V2N, we created a testing environment envisioned for social deployment in the Tokyo Waterfront City. We then conducted tests of delivery of traffic environmental information (dynamic, semi-dynamic, and semi-static information).
- We maintained the previous year's testing structure, and there were a total of 22 participants, including foreign and domestic automotive manufacturers, universities, and venture companies.

Advantages of using V2N	Potential Issues involved in using V2N	Issues and response measures identified through FOTs
Enables the delivery of information for individual area units using a wide area public network	Information is transmitted via multiple servers, resulting in information processing and transmission delays	There are clear deviations in transmission delay times for different delivery methods :Select the method used to deliver information based on the type of information to be used (DM*3 dynamic, semi-dynamic, and semi-static information)
Makes it easy to expand the information that can be utilized and applied to include long-range information, information from other organizations, etc.	Need to develop systems and functions for utilizing (selecting) necessary information	The FOTs working group must deliberate in order for necessary information to be used (cooperative area)
Connected cars with V2N connectivity functions are becoming more widespread	Requires the preparation of servers with sufficient performance capabilities and transmission capacities for handling service scale expansion	Vehicle-side processing capabilities must also be taken into consideration with respect to information types, the amount of information to be delivered, etc. (results must be shared with related organizations)

V2N FOT activity themes
(Period: Nov. 2021 to Feb. 2022)

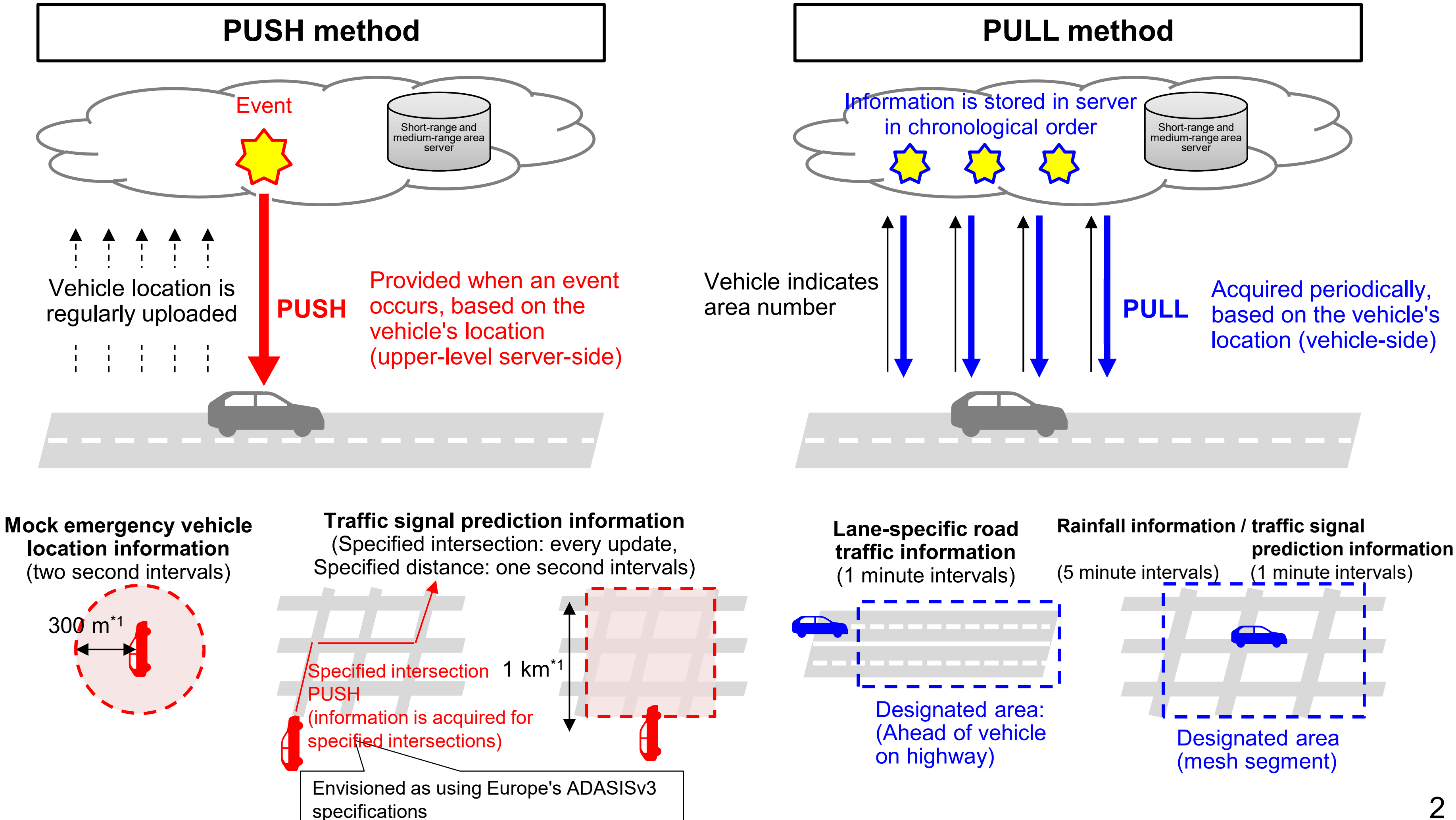
- Clarify issues and verify their effectiveness in preparation for development of V2N information provision systems, their practical implementation, and their deployment in society
- Confirm the effectiveness of provided information



*1:Handled by "Examination and Evaluation of Automated Driving Control Technologies that Use Lane-specific Probes, etc." contractors
*2:Handled by "Research and Development on the Collection, Integration, and Delivery of Short-range and Medium-range Information" contractors
*3: Dynamic Map (DM)

Results overview: PUSH and PULL delivery

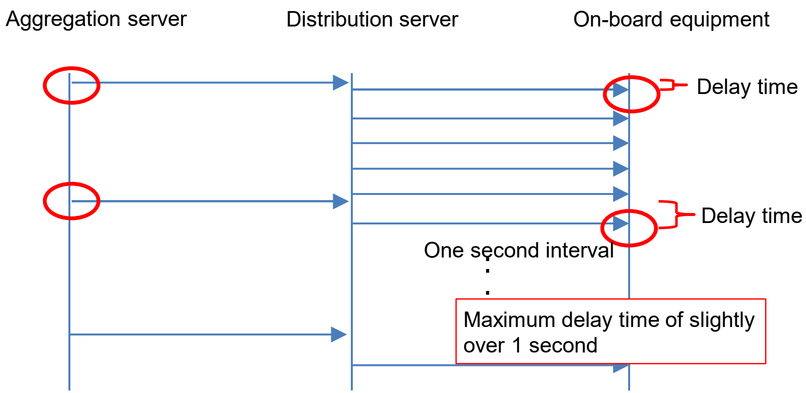
- We created and tested PUSH and PULL methods for processing information, minimizing transmission delays, and utilizing (selecting) necessary information



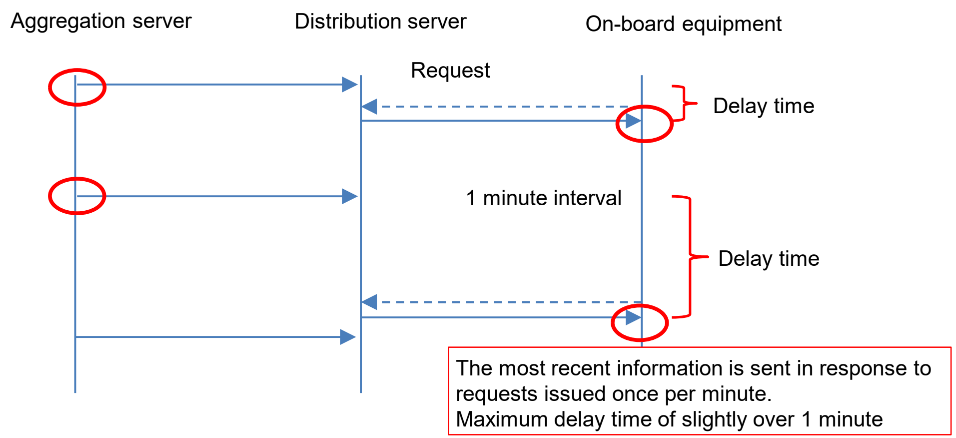
Results overview: PUSH and PULL delivery

● PUSH and PULL transactions

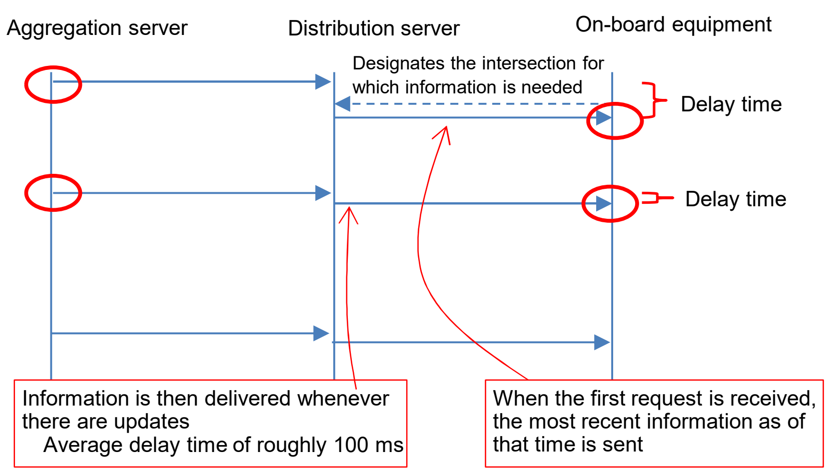
Specified distance PUSH method:



PULL method:



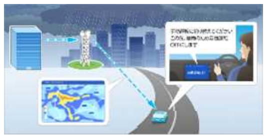
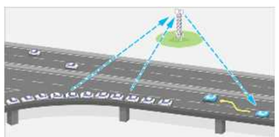
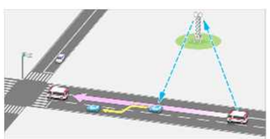
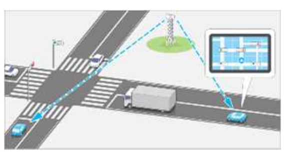
Specified intersection PUSH method:



- Specified distance PUSH method: Unless the traffic signal prediction information is updated, the same information is sent in 1 second intervals and output on the on-board equipment side in 100 ms intervals
- PULL method: The timing of requests from on-board equipment and information collection intervals are not coordinated (they are asynchronous), so in the current system there are delays of over 1 minute
- Specified intersection PUSH method: traffic signal prediction information is only provided when there are updates, and the vehicle side outputs received data in 100 ms intervals

Results overview: Information delivered via V2N, verification items, and results

- Delivered four types of information: rainfall information, lane-specific road traffic information, mock emergency vehicle location information, and traffic signal prediction information

Delivered information	Envisioned UC
Rainfall information 	• Make decisions regarding automated driving during poor weather and issue TORs sufficiently in advance
Lane-specific road traffic information (Caution information) 	• There are restrictions on driving using vehicle-mounted sensors alone and limits to the distance at which vehicle-mounted sensors can detect obstacles, so infrastructure look-ahead information must also be provided
Mock emergency vehicle location information 	• Appropriate response when an emergency vehicle approaches during automated driving* (stopping, pulling off onto the shoulder, TOR*, etc.)
Traffic signal prediction information (V2N) 	• Confirm achievement of reliable signal recognition • Confirm usage methods and effectiveness of prediction information delivered via V2N communications

*TOR: Take Over Request

Activities carried out as part of V2N FOT themes

① Information generation and provision specifications (coordinated with other SIP initiatives)

② Information delivery architecture (SIP FOT specifications)

③ Information delivery interfaces/message sets (SIP FOT specifications)

④ Transmission methods used to deliver information (SIP FOT specifications)

In preparation for the development of V2N information provision systems, their practical implementation, and their deployment in society, proposals were developed for ① through ④, they were deployed within an FOTs environment, measures were implemented to address issues, and the results of those measures were verified

Test data analysis results and feedback from test participants confirmed the effectiveness of the information delivered via V2N. They were also used to identify future issues that need to be addressed.

Results overview: Results for individual types of delivered information

(1) Rainfall information

Information source	● Rainfall information generated by the Japan Meteorological Business Support Center (generated every 5 minutes)
Delivery method	● PULL method
FOTs area	● Waterfront City area ● Expressway routes connecting Haneda Airport and the Waterfront City area, etc. ● Shin-Tomei Expressway Shimizu Ihara Interchange to Tsukuba JARI (Using wide area map data created in SIP Phase One)

	V2N issue countermeasures and results	FY2021 results
Application evaluation	● The PULL method, in which map mesh segments are selected, was used to select short- and medium-range information for necessary areas ● Every 5 minutes, 30 minute forecast information was delivered ● There were delivery delays of up to 3 minutes	● Participants verified that map mesh segments could be selected to choose the information they needed to have delivered ● Because the information is predictive, the impact of delivery delays is expected to be minor
Evaluation of information through questionnaires	● **We confirmed the future intent of participants to use the information in driving assistance and vehicle control** to make decisions regarding issuing TORs during inclement weather ● In addition to rainfall information, participants requested information regarding flooding, snowfall, icing, wind speeds, fog, earthquakes, tsunamis, etc. ● Instead of limiting delivered information based on the vehicle's current position, participants pointed out use cases for selecting and using information for other required locations and road sections (such as distant destinations, etc.)	

Results overview: Results for individual types of delivered information

(2) Lane-specific road traffic information

Information source	Lane-specific road traffic information generated through another project (generated every 1 minute)
Delivery method	PULL method
FOTs area	Expressway routes connecting Haneda Airport and the Waterfront City area, etc. (Haneda Route/Bayshore Route)

V2N issue countermeasures and results

Application evaluation

- Lane-specific traffic congestion tail end information and traffic congestion alleviation location information in the direction of vehicle travel were expressed with a resolution of 100 ms using CRPs (in conformance with ISO17572-4)
- PULL delivery was performed in 1 minute intervals for information regarding areas ahead of the vehicle
- Delivery delay times between upper layer servers and test vehicle on-board equipment (including data request intervals) were confirmed to be 70 seconds or less

FY2021 results

- The information was confirmed to be more detailed than that provided by existing services
- It has been theoretically verified that required times could be shortened by changing lanes based on delivered information

Evaluation of information through questionnaires

- We confirmed the future intent of participants to use the information in driving assistance and vehicle control to make decisions regarding path planning
- There were requests for improvements to be made in preparation for societal deployment to rectify differences between delivered information and actual conditions

Activities will be continued in the FY2022 Tokyo Waterfront Area Follow-up FOTs

Results overview: Results for individual types of delivered information

(3) Mock emergency vehicle location information

Information source	● Mock emergency vehicle location information generated through another project (location information regarding the location of the vehicle every 100 ms is generated every 2 seconds)	FOTs area	● Waterfront City area
Delivery method	● PUSH method (specified distance)		

V2N issue countermeasures and results

Application evaluation

- Information indicating the location of the mock emergency vehicle every 100 ms was generated every 2 seconds (each packet contained 20 units of location information) and delivered to vehicles
- PUSH delivery was performed in 1 second intervals for information regarding areas around the vehicle (within the designated distance range)
- Delivery delay times between upper layer servers and test vehicle on-board equipment (including data request intervals) were confirmed to be roughly 1.3 seconds, on average

FY2021 results

- Confirmed that required information acquisition areas could be selected by specifying distances
- Verified that the information made it possible to determine that an emergency vehicle was approaching before it was visually observable
- Confirmed the impact of location deviation in multipath environments

Evaluation of information through questionnaires

- Basic data was acquired in order to investigate vehicle behavior (stopping, pulling off onto the shoulder, TOR*, etc.) when an autonomous vehicle encounters an emergency vehicle (the issues of request accuracy and what kind of actions should be taken must be deliberated on together with related organizations)
- There were requests for additional emergency vehicle type-specific information to be added in preparation for societal deployment

Results overview: Results for individual types of delivered information

(4) Traffic signal prediction information

Information source	● Traffic signal prediction information generated through another project (generated 3 seconds before the start of each cycle)
Delivery method	● PULL method, specified distance PUSH method, and specified intersection PUSH method
FOTs area	● Waterfront City area

V2N issue countermeasures and results

Application evaluation

- Traffic signal prediction information generated 3 seconds before the start of each cycle was delivered using three different delivery methods: PULL, PUSH, and specified intersection PUSH
- Delivery delay times between upper layer servers and test vehicle on-board equipment (including data request intervals) were:
  - ✓ 150 ms*1 or less for the specified intersection PUSH method
  - ✓ 1.2 s*1 or less for the PUSH method
  - ✓ Max. 63 s for the PULL method*1

*1:Actual measurements from this FOT environment

Evaluation of information through questionnaires

- In preparation for future utilization of this information for driving assistance and vehicle control, participants indicated that the following were necessary: fewer discrepancies between actual traffic signal colors and the contents of traffic signal prediction information, prior confirmation of traffic signal aspects for traffic signals with margins, and confirmed traffic signal prediction information

(Percentage of participants intending to use this information in the future: 76%, currently deliberating whether to use it: 24%)

FY2021 results

- Confirmed that of the methods prepared for these FOTs, the specified intersection PUSH method can deliver information with the smallest amount of delay

Recommendations have been made to the Implementation (infrastructure) equipment side

Activities will be continued in the FY2022 Tokyo Waterfront Area Follow-up FOTs
(verification from a vehicle perspective of methods for effectively using traffic signal prediction information verification)

Results overview: Test participant questionnaire

Feedback, observations, and requests regarding the FOTs

- ✓ Reaffirmed that linkage with dynamic information is vital to the development of automated driving
- ✓ FOTs on public roads are rarely conducted anywhere in the world and are therefore highly valuable
- ✓ Information can be organized regarding new issues and benefits
- ✓ Some participants only participated by performing theoretical studies, but were able to deliberate regarding information usage based on the data and materials, etc., provided from the equipment side
- ✓ Participants requested that the Daiba field continue to be available for use next fiscal year and beyond
- ✓ Participants plan to continue participating in preparation for the deployment of automated driving
- ✓ There were requests that identified issues continue to be discussed by participants
- ✓ More widespread deployment of infrastructure is critical for cooperative systems, and participants requested that this be deliberated on jointly by members of the public and private sectors

⇩

Activities will be continued in the FY2022 Tokyo Waterfront Area Follow-up FOTs
(Test participants requested that the test environment be maintained to assist with the research and development of cooperative infrastructure systems by individual companies)

Table of Contents

1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(1) Implementation structure

- Carried on test structure used in FY2019-2020 FOTs
- Total of 22 participants, including foreign and domestic automotive manufacturers, component manufacturers, universities, and venture companies

*FOTs in the Tokyo Waterfront Area Consortium
Mitsubishi Electric Corporation (representative)

Aisan Technology Co., Ltd.
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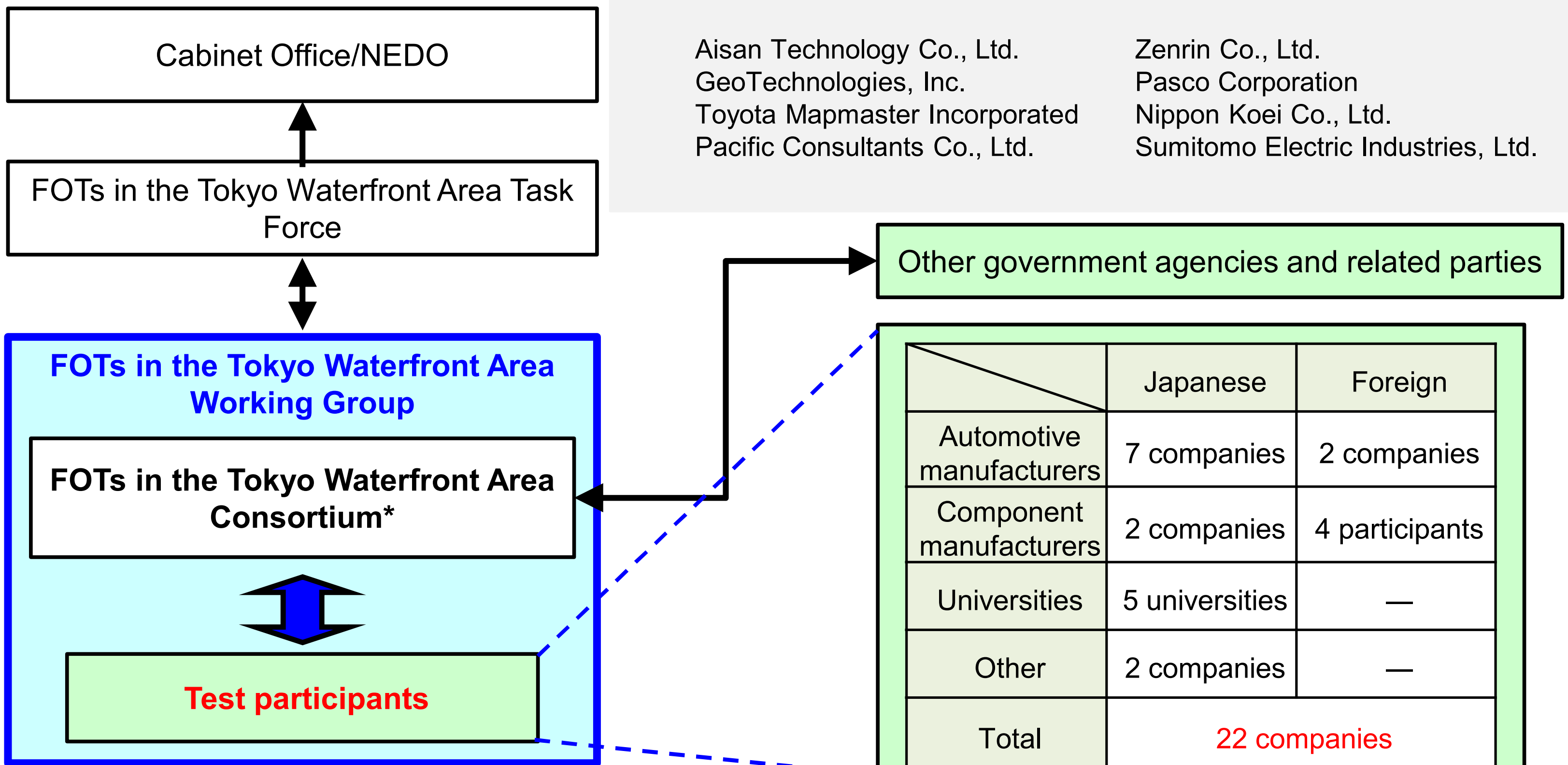
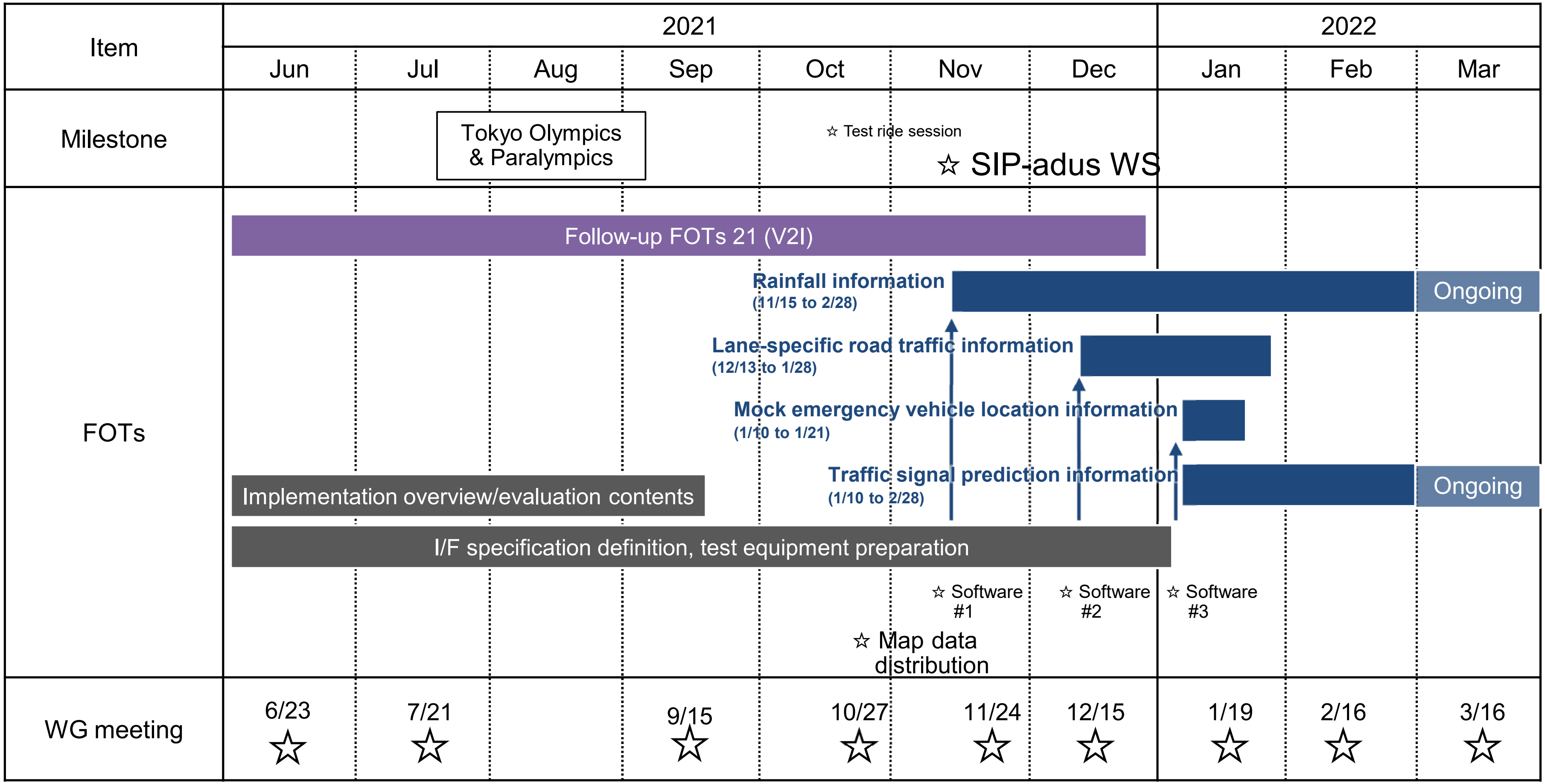


	Japanese	Foreign
Automotive manufacturers	7 companies	2 companies
Component manufacturers	2 companies	4 participants
Universities	5 universities	—
Other	2 companies	—
Total	22 companies	

1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(2) Testing schedule

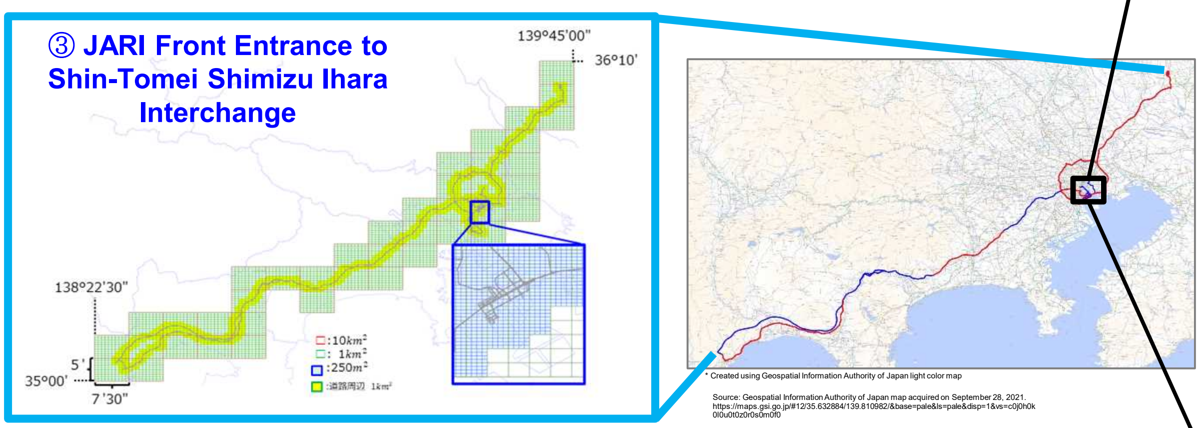
- Four types of traffic environmental information were delivered between November 2021 and February 2022

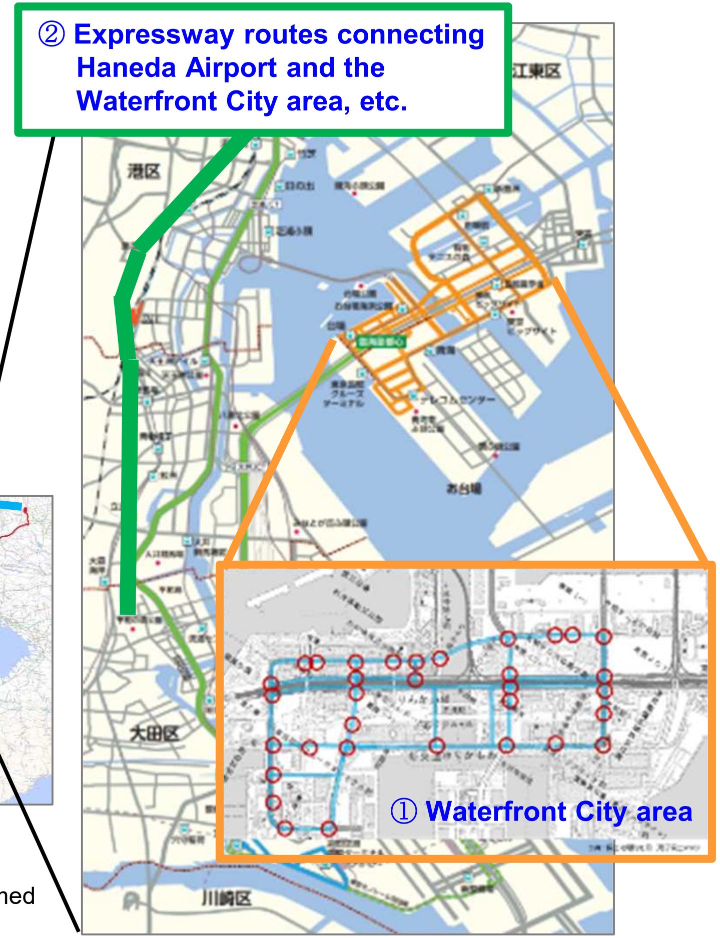


1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(3) FOTs area

- Tests were performed in three areas: ① Waterfront City area, ② Expressway routes connecting Haneda Airport and the Waterfront City area and ③ JARI Front Entrance to Shin-Tomei Shimizu Ihara Interchange*1



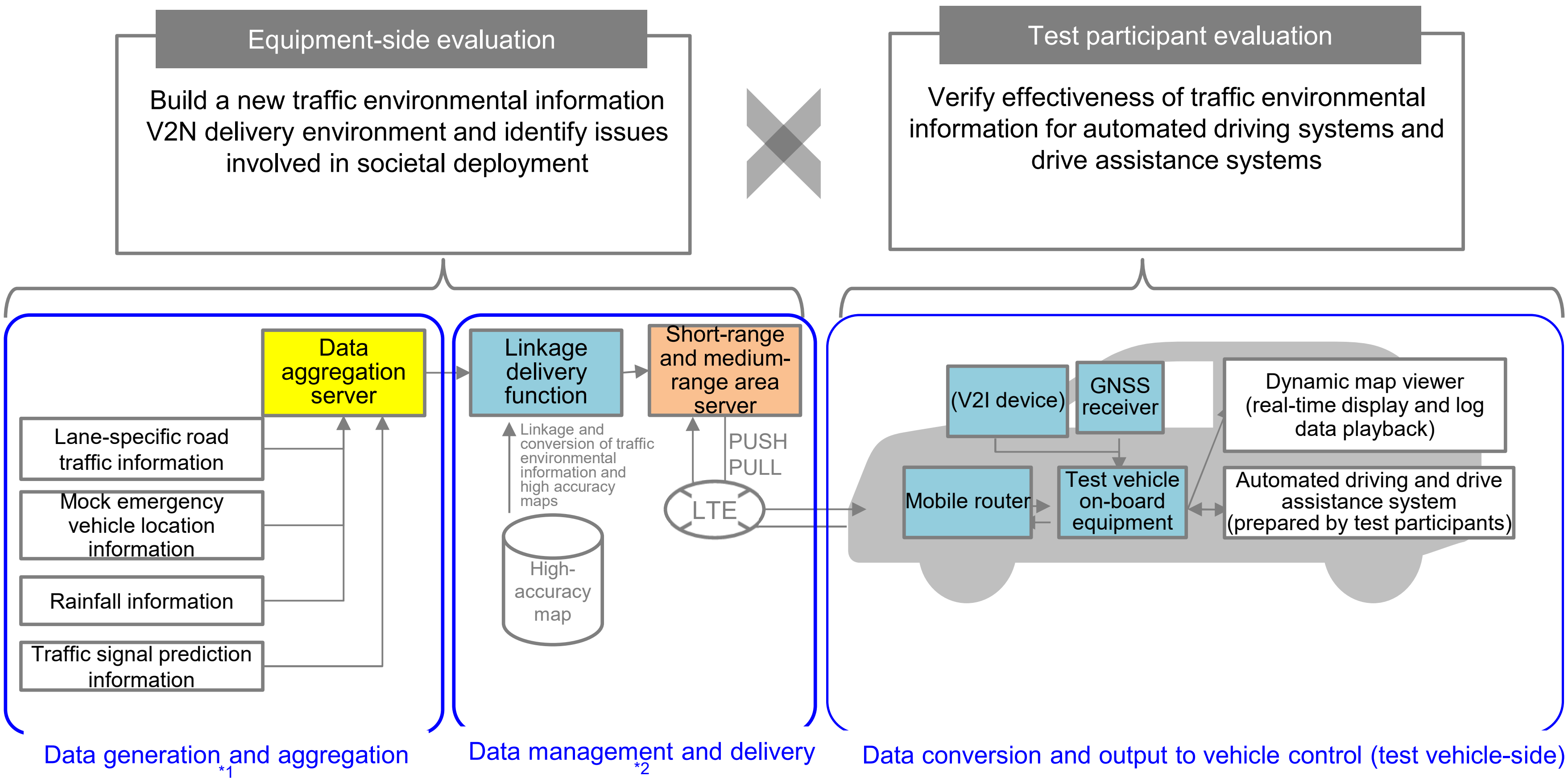


*1:The FOTS in the "③ JARI Front Entrance to Shin-Tomei Shimizu Ihara Interchange" area were performed using map data created during SIP Phase One
(this map data was created for evaluating long-range rainfall information, and due to differences between the data content and actual rainfall conditions, could not be used in vehicle control)

1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(4) Test system configuration

- A test system was created in conjunction with a contractor from another project, focusing on the perspectives of equipment-side and participant-side evaluation



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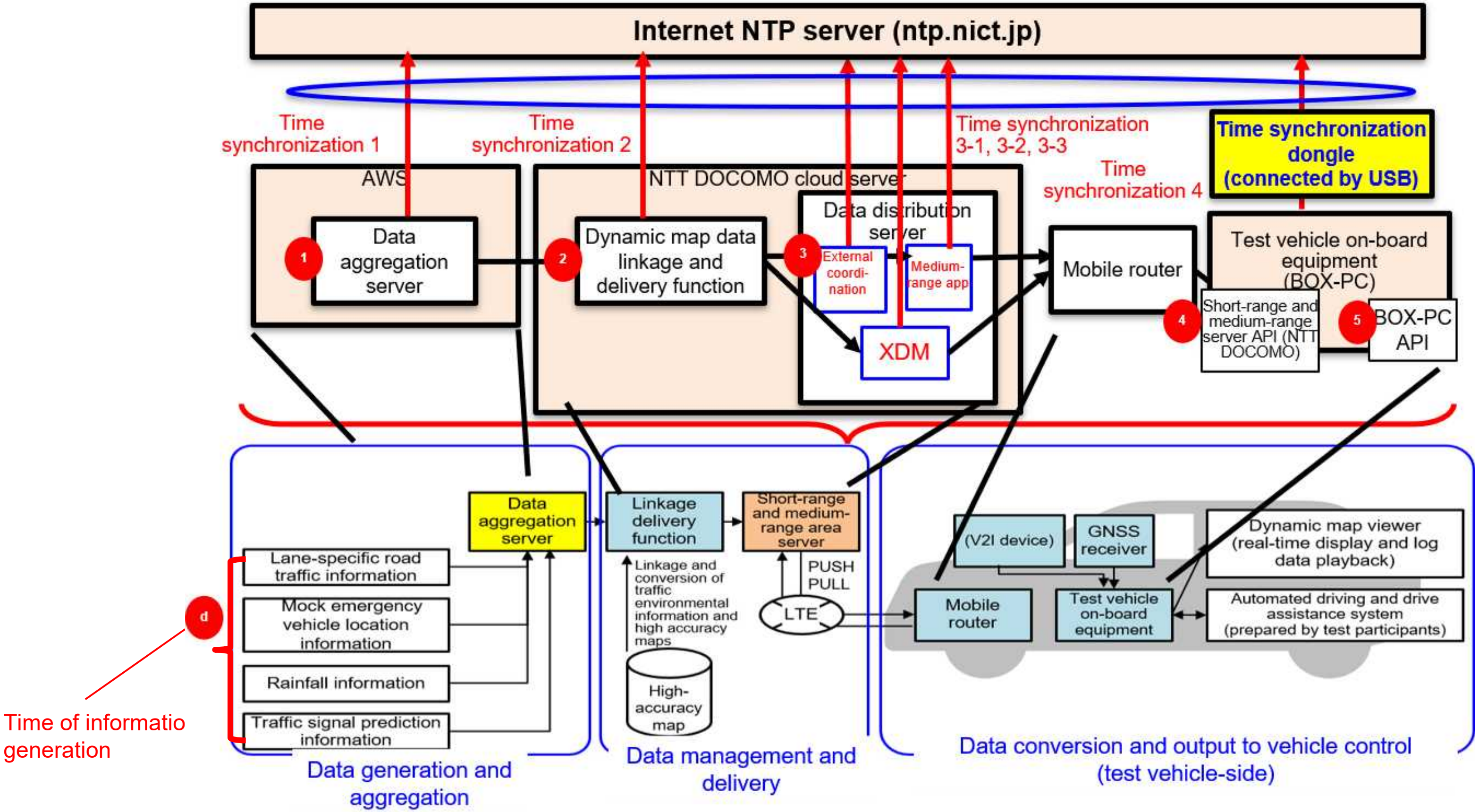
*2:Handled by "Research and Development on the Collection, Integration, and Delivery of Short-range and Medium-range Information" contractors

1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(4) Test system configuration (transmission time measurement system)

- Transmission time is measured by measuring the time between when data is sent from the data aggregation server to when it is received by the test vehicle on-board equipment
- Measured segments for mock emergency vehicle location information: d-①, ①-⑤, ③-④, d-⑤ *
- Measured segments for traffic signal prediction information: ①-⑤ *

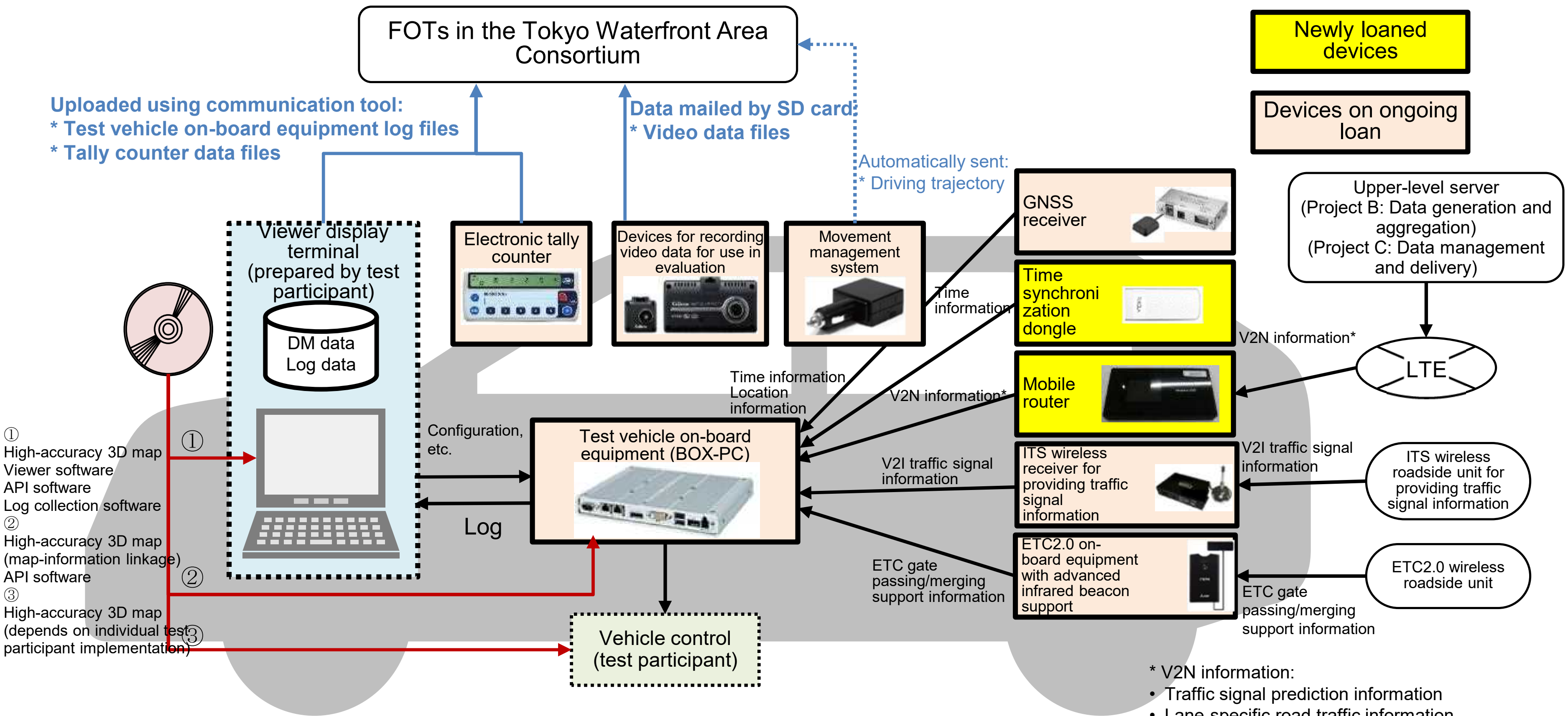
* See the attachment for the results of measurements between other devices



1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(5) On-board system configuration

- In FY2021, a dongle for synchronizing the time with the mobile router was added to the on-board system
- Other than the above, the same equipment prepared and loaned in the previous year were reused for these FOTs



* V2N information:
- Traffic signal prediction information
- Lane-specific road traffic information
- Mock emergency vehicle location information
- Rainfall information

(6) Data and transmission media used in the FOTs

- Traffic environmental information, which consists of dynamic information, semi-dynamic information, and semi-static information, is delivered via V2N (LTE)

Data	Data details	Transmission media
(1) Dynamic information	Traffic signal information	V2I: ITS wireless receivers & ITS roadside units (760MHz) for providing traffic signal information
	Traffic signal prediction information	V2N: LTE
	Mock emergency vehicle location information	V2N: LTE
(2) Semi-dynamic information	Lane-specific road traffic information	V2N: LTE
	Rainfall information (short range)	V2N: LTE
(3) Semi-static information	Rainfall information (long range)	V2N: LTE
(4) Static information	High-accuracy 3D map data	Cloud server
	High-accuracy 3D map update data	Cloud server

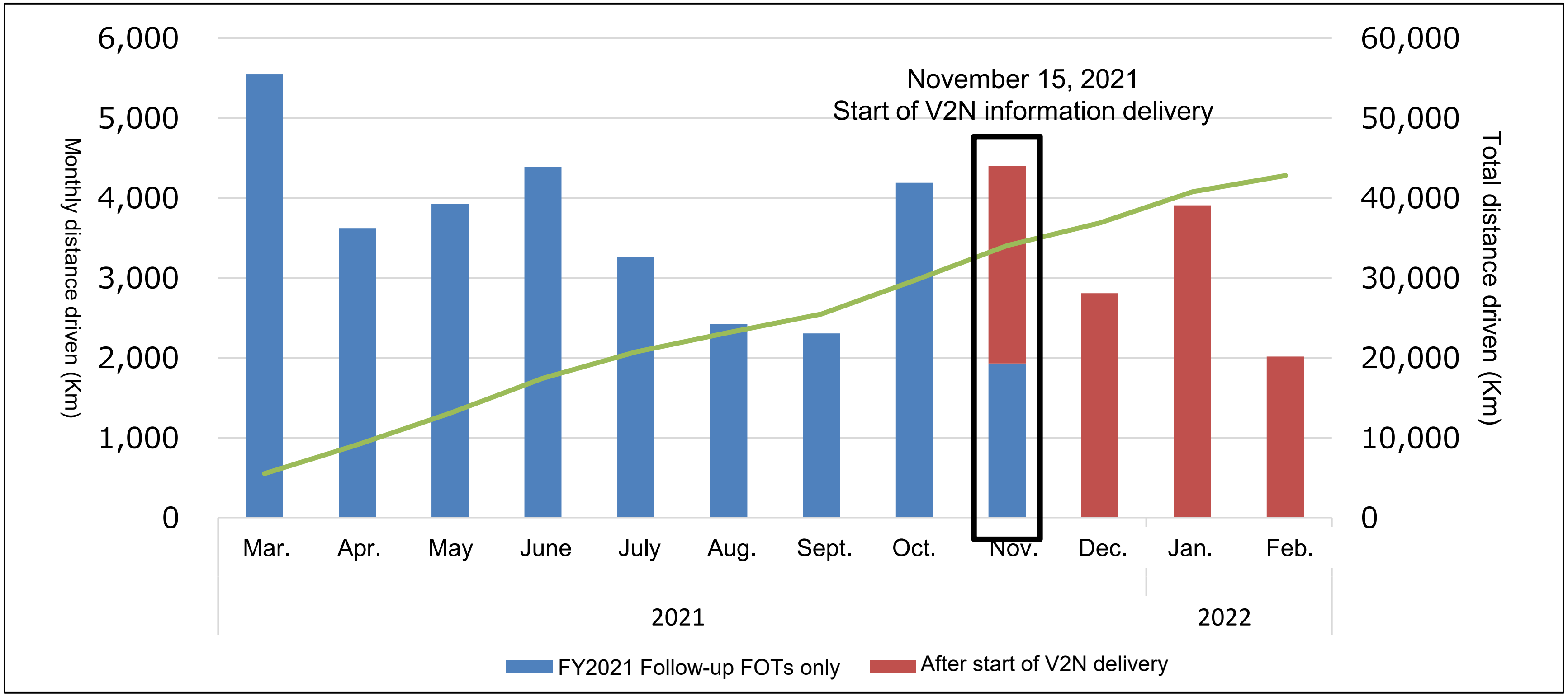
(4) Static information: High-accuracy 3D map planimetric features

- Road shoulders
- Road center lines
- Lane lines
- Road edges
- Stop lines
- Pedestrian crossings
- Road markings
- Traffic signals
- Road signs
- Road node linkages
- Lane node linkages
- Lane node linkages within intersections
- Intersections
- CRP nodes

1. Overview of the FOTs in the Tokyo Waterfront area (V2N)

(7) Participant driving results to date

- March 1, 2021, to February 28, 2022 (12 month period): Approx. 42,826 km (figures collected via movement management system)
  - FY2021 Follow-up FOTs only: Approx. 31,617 km (collected as indicated above)
  - After start of V2N delivery: Approx. 11,209 km (collected as indicated above)



Participant driving to date

2. Results of rainfall information-related testing

(1) Overview of delivered information

- Below is an overview of the information

Information source: Japan Meteorological Business Support Center

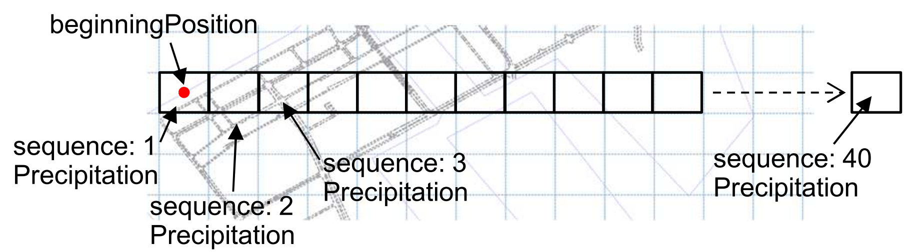
Provided information: High-resolution Precipitation Nowcasts or High-resolution Precipitation Nowcasts (5 minute precipitation amount) (cumulative rainfall over a 5-minute period in a grid square measuring 250 m x 250 m, current condition analysis and 30 minute forecasts issued every 5 minutes, binary data)

Provision scope: SIP Phase 1 and Phase 2 high-accuracy 3D map range (Waterfront City + Metropolitan Expressway, Joban Expressway, Tomei, Shin-Tomei)

Rainfall information received from data aggregation server (JasPar standard)

Item					Contents
container	basic	time	start		Data time
			expire		Expiration time (start + 5 min)
		section	**beginning Point**	latitude	Latitude of center of first 250 m grid square
				longitude	Longitude of center of first 250 m grid square
				accuracy	Location accuracy
	contents	environment	**sequence**		250 m grid square number
			rain		Amount of precipitation predicted over 30 minute period starting now
			accuracy		Precipitation amount accuracy
		:			
		environment			10 km row
	:				
	basic				
	contents				

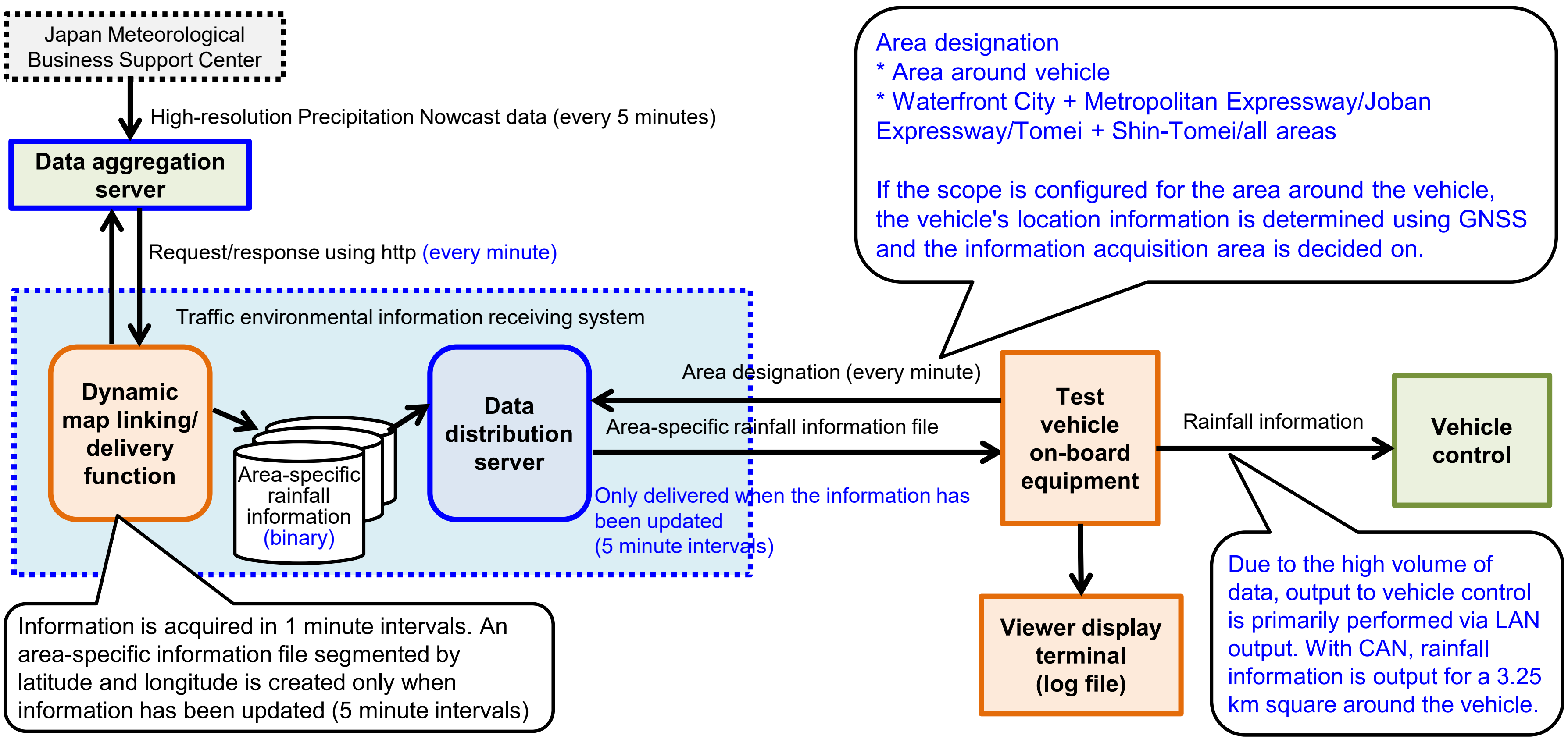
Precipitation amounts for 40 grid squares each measuring 250 m x 250 m, extending 10 km in the longitudinal direction, are packed a single item of content. Multiple pairs of basic and content information are used to provide precipitation information for an entire area.



2. Results of rainfall information-related testing

(2) Information delivery process (flow of data)

- A 30 km square around the current location of the vehicle or for the designated area (Waterfront City + Metropolitan Expressway/Joban Expressway/Tomei + Shin-Tomei /all areas) is specified to deliver rainfall information using PULL delivery and output it to vehicle control
- The CAN output area is only a 3 km square (due to data volume and delivery time considerations)



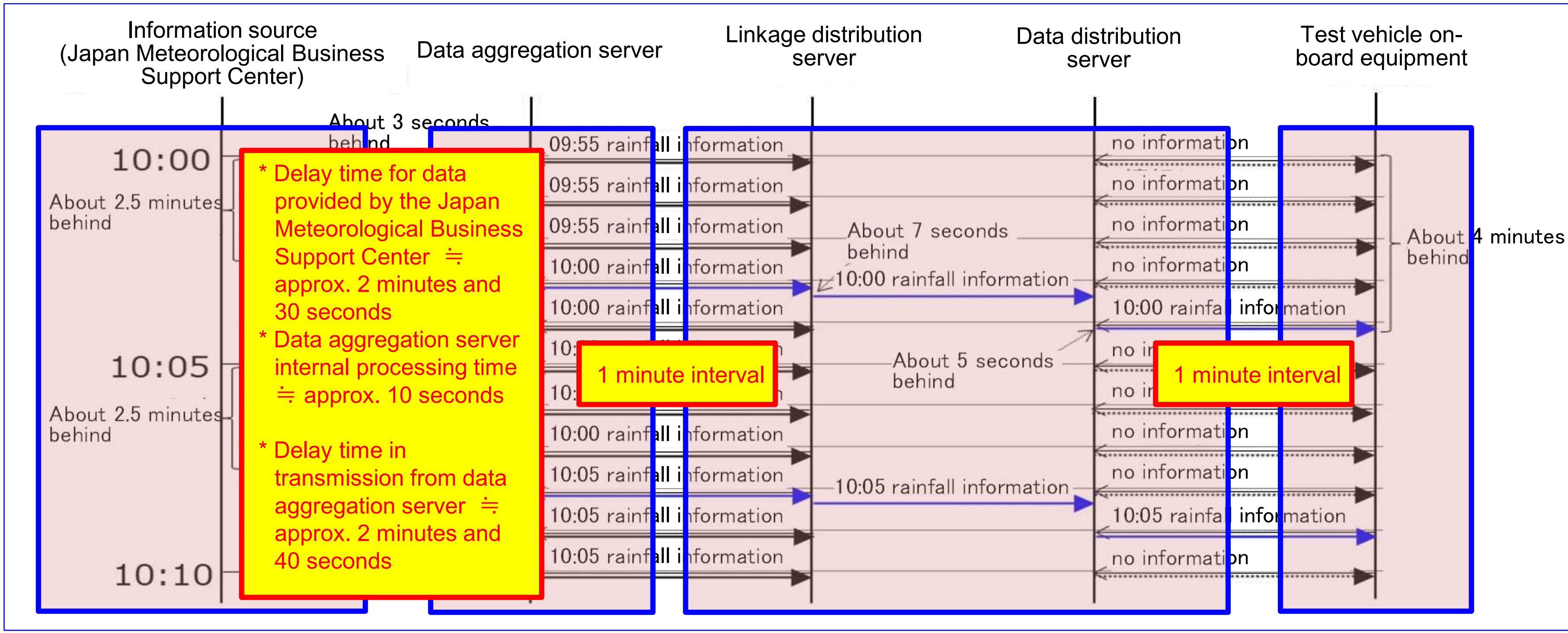
2. Results of rainfall information-related testing

(3) Transmission delay times

* System time synchronization method and transmission delay time confirmation procedure: See appendix

- The rainfall information received from the Japan Meteorological Business Support Center (information source) is sent approximately 2 minutes and 30 seconds after the designated time (this was determined from the times of the received data in the data aggregation server)
- Once per minute, the test vehicle (test vehicle on-board equipment) requests rainfall information from the data distribution server (PULL method)
- Once per minute, data is requested by the linkage delivery function and sent by the data aggregation server

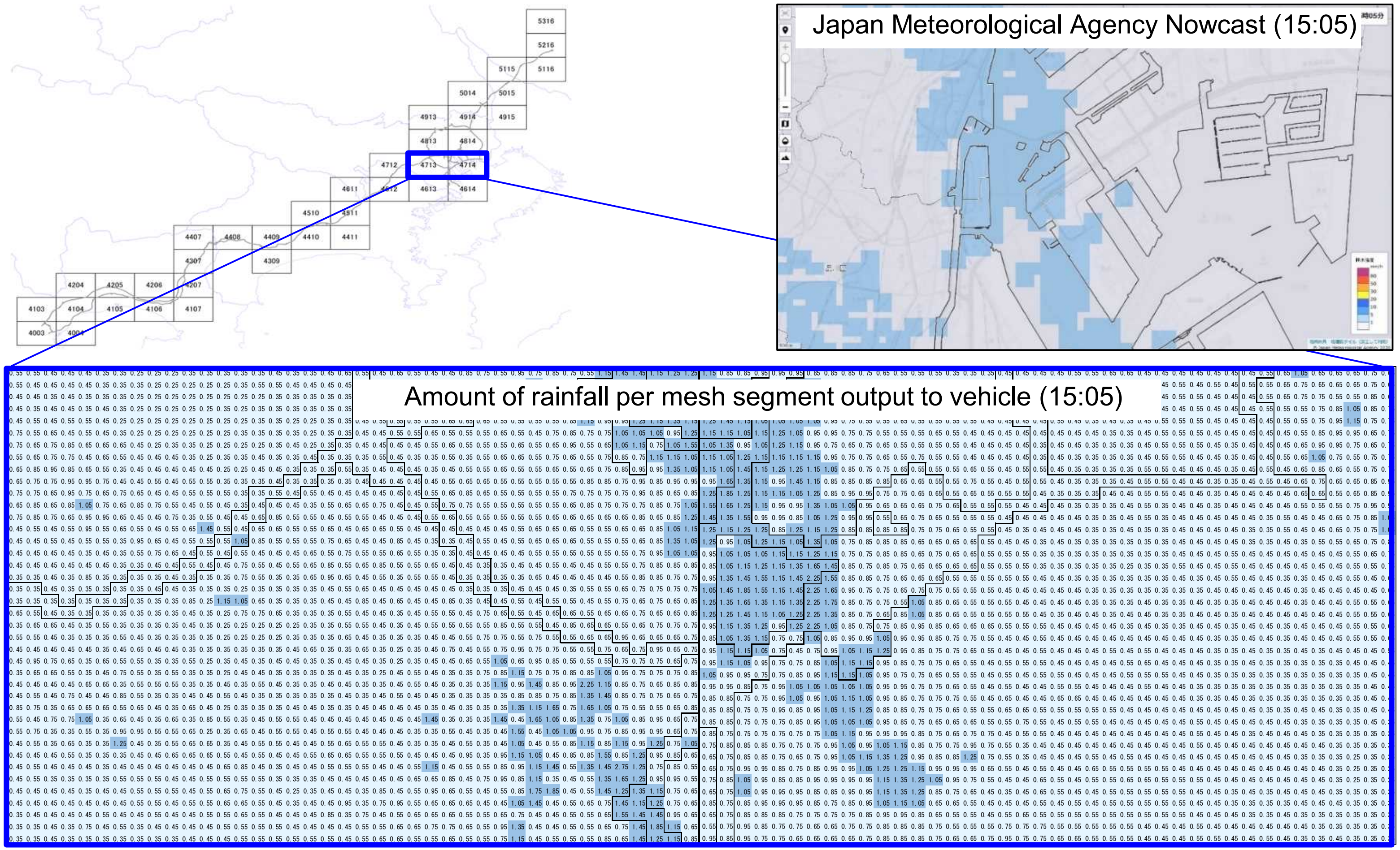
➡ In the system used in the FOTs, the delay between when rainfall information was generated by the information source and when it was received by the test vehicle (on-board equipment) was up to 4 minutes and 40 seconds (2 minutes and 40 seconds + 1 minute + 1 minute)after the designated time



2. Results of rainfall information-related testing

(4) Test results: Analysis of test participant driving data (on-site driving, rainfall)

- Rainfall information output to the vehicle based on the test environment was checked against rainfall information on the Japan Meteorological Agency website to verify if the information matched

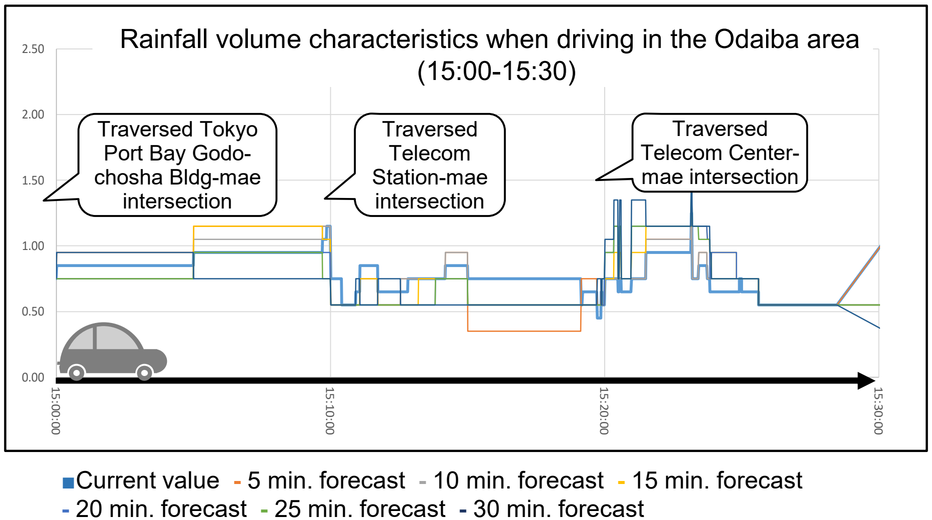


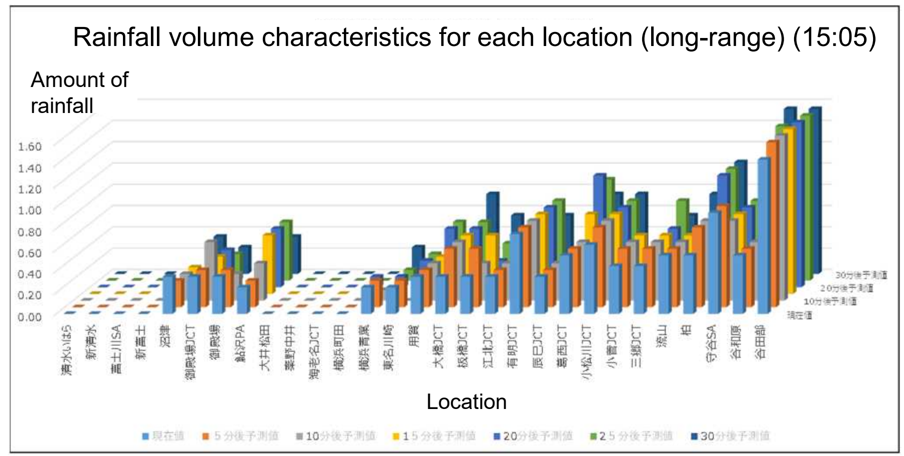
2. Results of rainfall information-related testing

(4) Test results: Analysis of test participant driving data (on-site driving, rainfall)

- We confirmed that vehicles were provided chronologically ordered information on the amount of rainfall for the mesh segment in which the vehicle was located
- We confirmed that long-range rainfall information could also be received in the Odaiba area via V2N

* See the attachment for equipment-side test results and the results of analysis of other test participant driving data





2. Results of rainfall information-related testing

(5) Evaluation questionnaire

- There were many comments requesting information other than rainfall (flooding, snowfall, icing, wind speeds, fog, earthquakes, tsunamis, etc.)

[Requests for information other than rainfall information]

- All participants requested that wind speed and road surface snow accumulation information be provided.
- "In addition to rainfall information, we would also like consideration to be given to delivering information about other weather conditions that could affect driving (such as snowfall and wind speed information).
  We are envisioning using the information in vehicle control when there are sudden downpours or showers in localized areas and when rainclouds are moving quickly, so we think the smaller the blocks of delivered rainfall information, the better."
- "We would like for pinpoint road flooding information and pinpoint road icing information to be provided."
- "We would like information on locations where there is the danger of slipping, such as areas with road icing."
- "Fog information: When there is fog, the detection capabilities of vehicle cameras are impaired, so we believe that receiving information in advance would be effective for automated driving mode selection, route selection (fog avoidance), and the like."
- "We would like information regarding natural disasters, such as earthquakes and tsunamis, to be provided."

[Other]

- "We expect there to be a need for information regarding distant locations and routes, linked to navigation systems. Instead of just delivering information based on the vehicle's current location, we'd like for the system to be expanded to make it possible to designate locations and road sections for which to receive information."

3. Results of lane-specific road traffic information testing

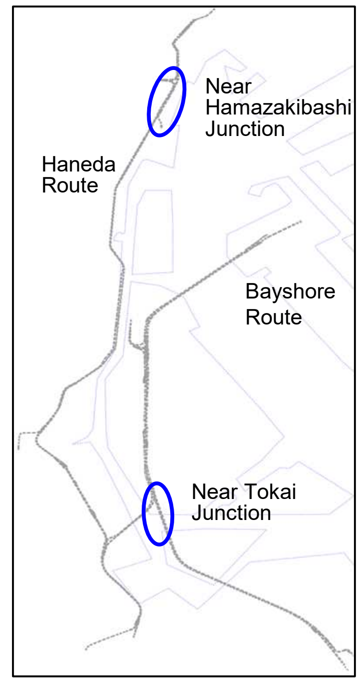
(1) Overview of delivered information

- Below is an overview of the information

Information source: Probe information (OEM), road traffic information (car navigation equipment manufacturer)
Provided information: Traffic congestion tail end location information for forking and merging areas, location information for locations of driving impediments, such as accidents or start of traffic congestion
Provision scope: Metropolitan Expressway Haneda Route and Bayshore Route
Envisioned traffic congestion start point: Near Haneda Route Hamazakibashi Junction, near Bayshore Route Tokai Junction

Lane-specific road traffic information (caution information) includes the following items and is updated once per minute.

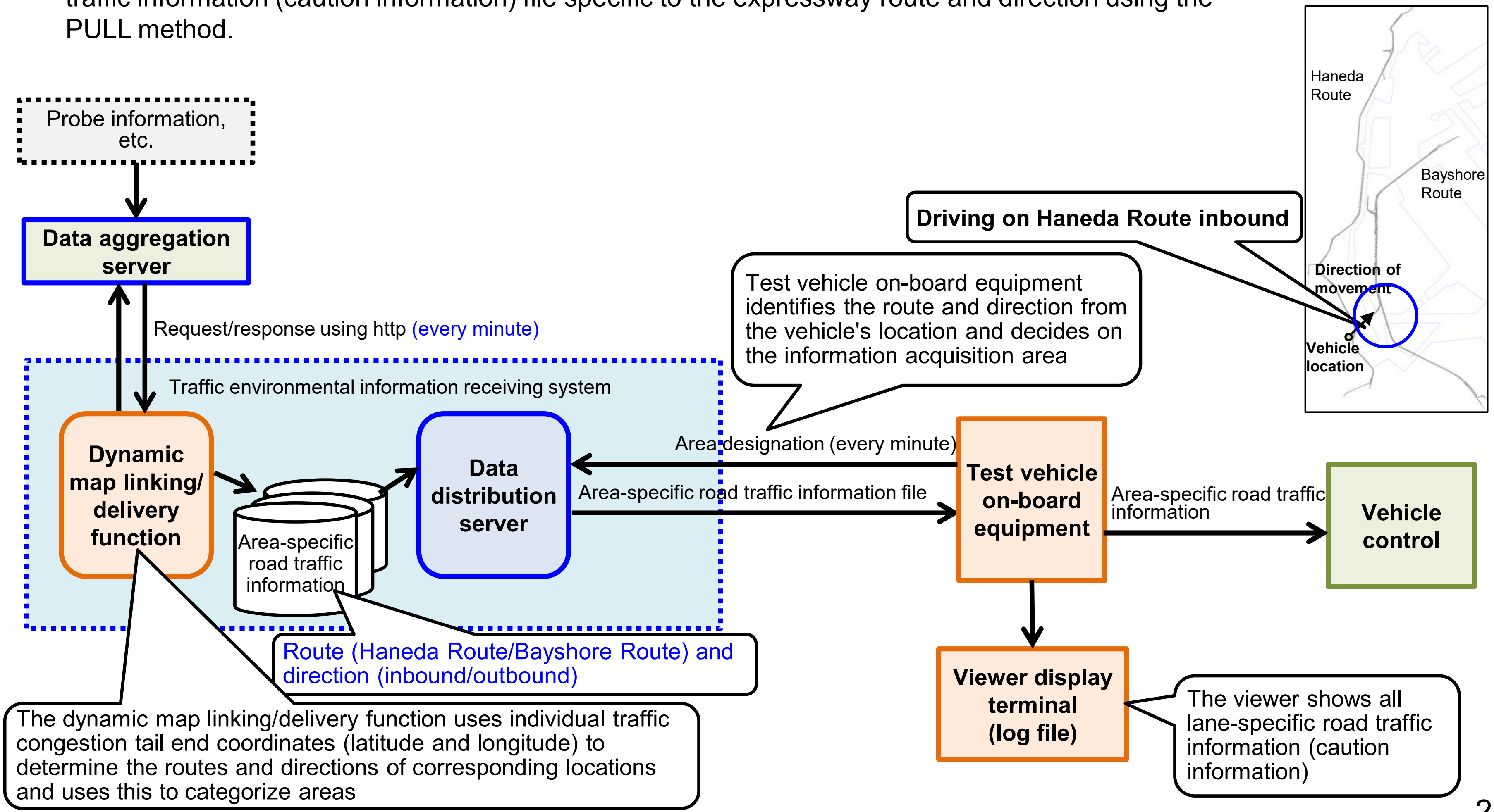
(1) Start time
(2) End time
(3) Location
(4) Route name
(5) Lane number
(6) Accuracy of location
(7) Accuracy of traffic congestion inference



3. Results of lane-specific road traffic information testing

(2) Information delivery process (flow of data)

- The GNSS information received by the test vehicle on-board equipment is used to determine the route the vehicle is driving and its direction (inbound/outbound) and to obtain a lane-specific road traffic information (caution information) file specific to the expressway route and direction using the PULL method.



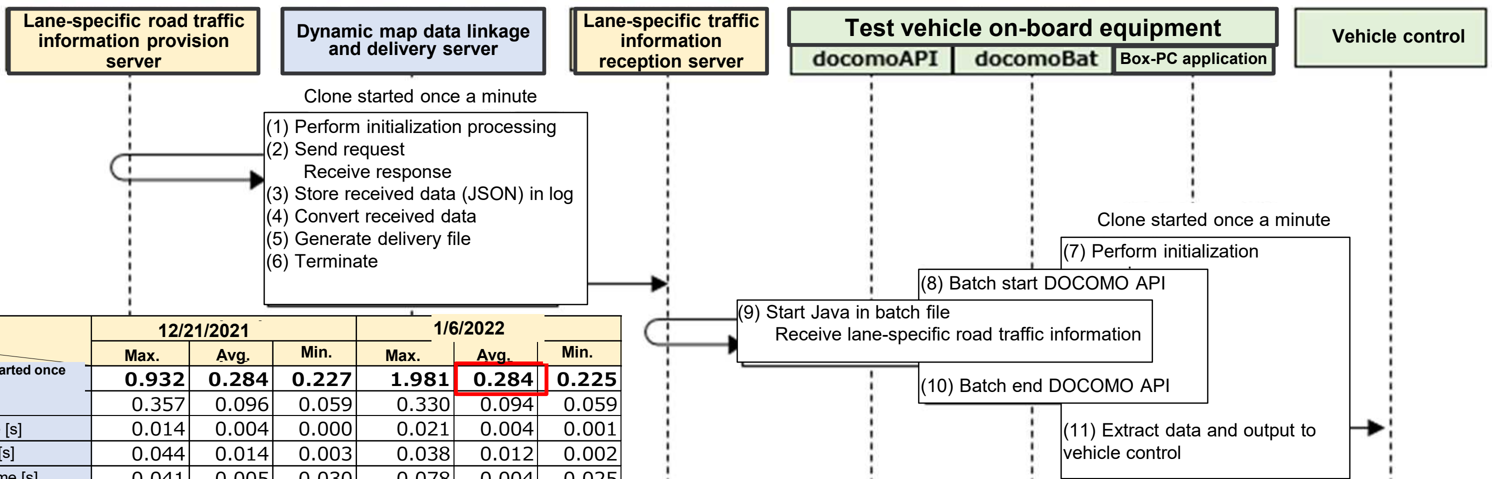
3. Results of lane-specific road traffic information testing

(3) Transmission delay times

* System time synchronization method and transmission delay time confirmation procedure: See appendix

- <u>The processing time was an average of 0.284 seconds for the linkage delivery function and 5.117 seconds for the test vehicle on-board equipment</u>
- The most current data was acquired from the test vehicle on-board equipment in <u>1 minute intervals</u>(using the PULL method)

➡ Depending on the timing, the delay between information being generated by the server providing lane-specific road traffic information and the information being output from the test vehicle on-board equipment could be <u>up to 65.4 seconds</u>



	12/21/2021			1/6/2022		
	Max.	Avg.	Min.	Max.	Avg.	Min.
Linkage and delivery function processing time [s] (started once per minute)	**0.932**	**0.284**	**0.227**	**1.981**	**0.284**	**0.225**
(1) Initialization processing time [s]	0.357	0.096	0.059	0.330	0.094	0.059
(2) JSON file reception and processing time [s]	0.014	0.004	0.000	0.021	0.004	0.001
(3) Received data (JSON) log storage time [s]	0.044	0.014	0.003	0.038	0.012	0.002
(4) Received data conversion processing time [s]	0.041	0.005	0.030	0.078	0.004	0.025
(5) Delivery file generation time [s]	0.148	0.077	0.057	1.360	0.081	0.060
(6) Termination processing time [s]	0.328	0.088	0.078	0.154	0.088	0.078
Test vehicle on-board equipment processing time [s] (started once per minute)	**12.259**	**4.674**	**3.264**	**20.957**	**5.117**	**3.281**
(7) Initialization processing time [s]	0.040	0.040	0.040	0.040	0.040	0.040
(8) Transmission API initialization processing time [s]	**8.539**	**4.266**	**2.944**	**20.228**	**4.727**	**2.976**
(9) Lane-specific road traffic information reception time [s]	3.524	0.332	0.265	0.594	0.316	0.250
(10) Transmission API post-processing time [s]	0.088	0.029	0.009	0.057	0.027	0.009
(11) Data extraction/vehicle control output time [s]	0.068	0.007	0.006	0.038	0.007	0.006

Unit (seconds)

3. Results of lane-specific road traffic information testing

(4) Test results: Method of verifying benefit analysis

[Verification approach]

- Analysis was performed by calculating to what degree required driving time was reduced by using lane-specific traffic congestion information to avoid traffic congestion in individual lanes.
- Driving result data was extracted for test drives in which test participants avoided traffic congestion in individual lanes and the required driving time was calculated using this data (situation 1). Based on the results data, we inferred the driving time that would have been required if the vehicles had gotten caught up in the traffic congestion in individual lanes (situation 2).
- We evaluated the amount of reduction in required driving time (the difference in required driving times between situation 1 and situation 2).

[Approach used when defining situations to compare]

Compared situations	Situation 1: Information was provided (Actual required time)	Situation 2: Information was not provided (Inferred required time)
Situation explanation	Vehicles received traffic congestion tail end information (lane-specific traffic congestion information) and drove smoothly in a traffic congestion-free lane adjacent to the lane with traffic congestion	We hypothesized the driving situation if the vehicle did not receive lane-specific information and got caught up in traffic congestion in an individual lane
Data used	Driving results data (extracted driving data from vehicles when they passed the location of lane-specific traffic congestion while it was occurring)	Data created for a hypothetical drive (based on actual driving results data: we envisioned driving speeds being reduced to 10 km/h in areas where there was lane-specific traffic congestion)

[Approach used with respected to analyzed drives]

(1) We extracted driving data from vehicles when they passed the location of lane-specific traffic congestion while it was occurring
(based on traffic congestion tail end information)

8 samples

→

(2) Of those samples, we extracted driving data for drives for which there was drive recorder video and in which it was possible to confirm in the drive recorder video that lane-specific traffic congestion had occurred

3 samples

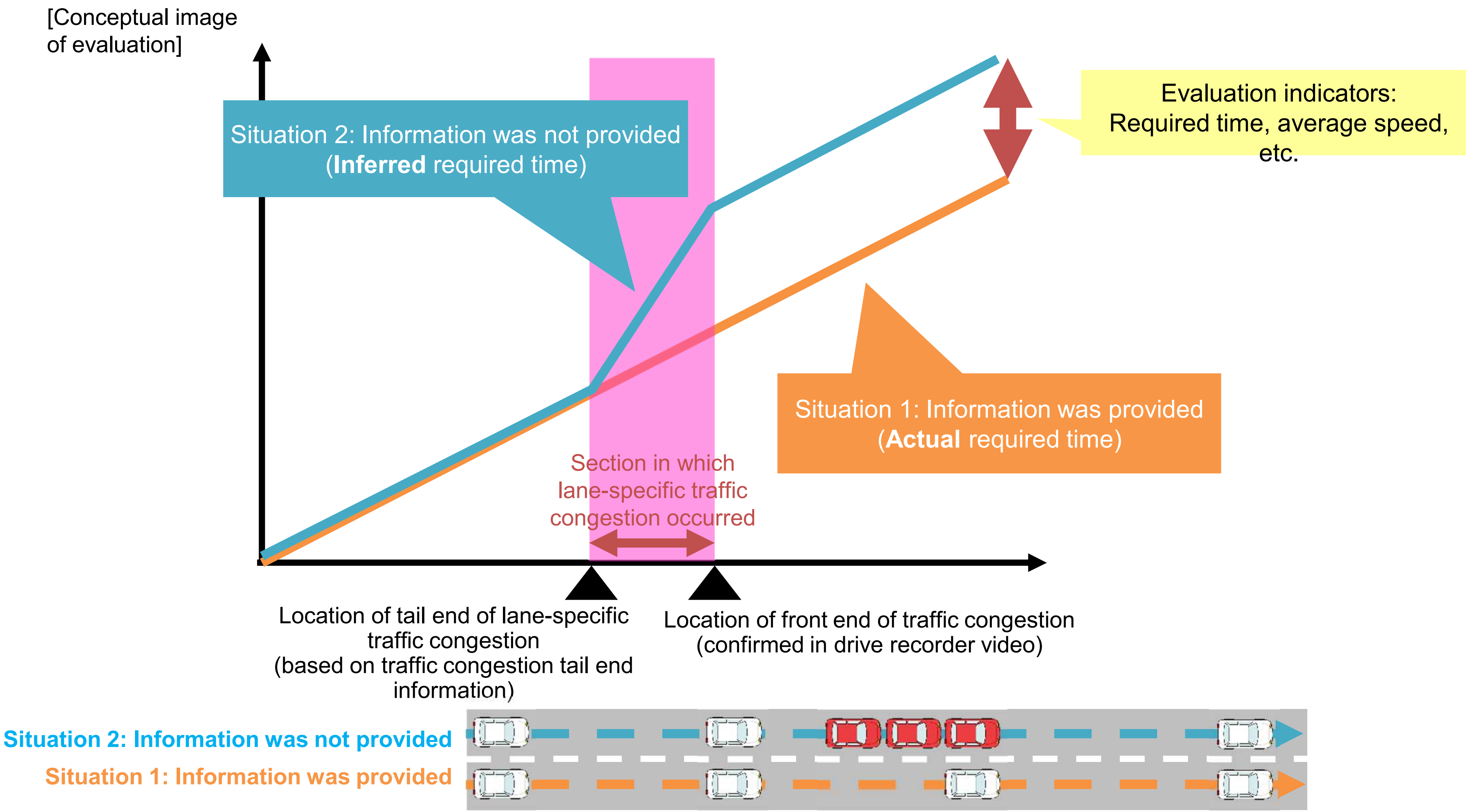
→

(3) Of those samples, we excluded data for lane-specific traffic congestion that occurred in a four lane stretch of road of which two lanes were merging/forking lanes and in which avoiding lane-specific traffic congestion would not be feasible

2 samples: Analysis scope

3. Results of lane-specific road traffic information testing

(4) Test results: Method of verifying benefit analysis

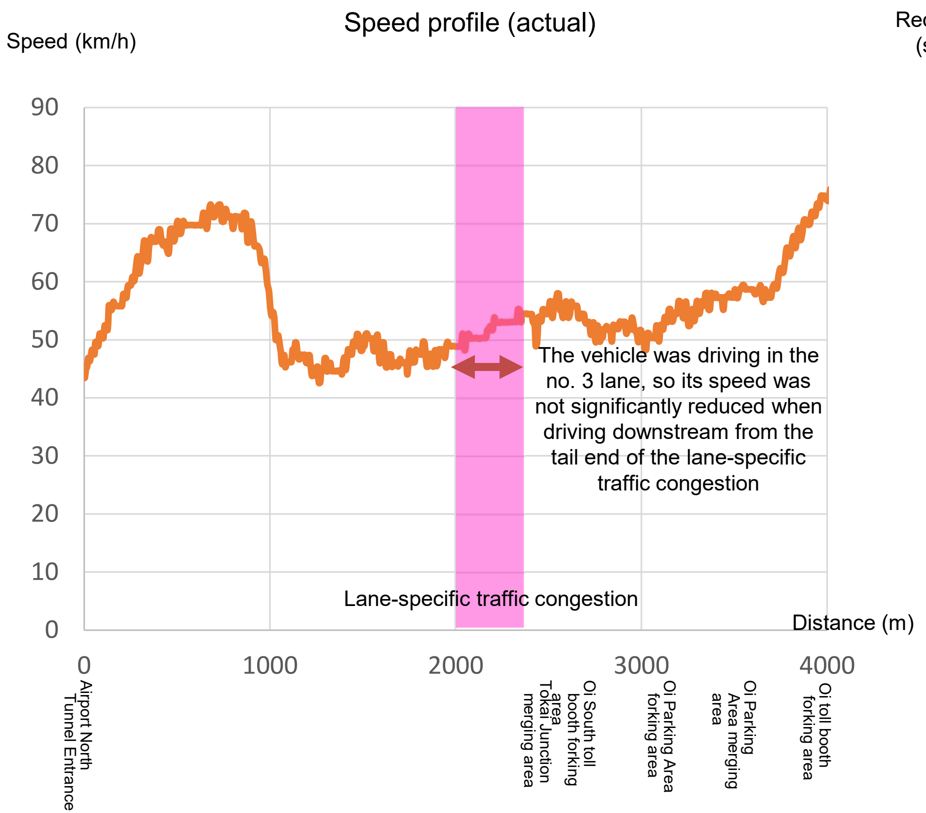


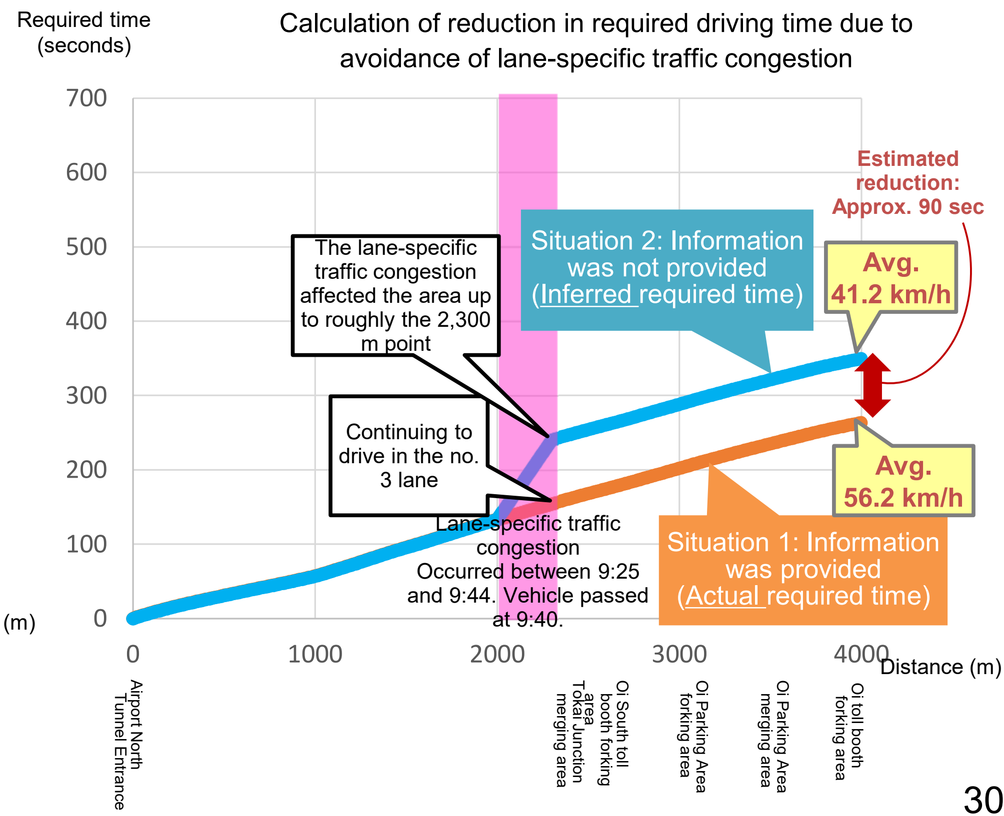
3. Results of lane-specific road traffic information testing

(4) Test results: Situation 1

(1) We identified test participant vehicles that passed locations where lane-specific traffic congestion was occurring (routes and locations)
(2) We extracted driving history data immediately before and after the lane-specific traffic congestion and used it to determine the actual required driving time
(3) We used drive recorder video to confirm the impact of the lane-specific traffic congestion on the lane the test participant was driving in, and inferred the benefit driving in this lane had over getting caught in the traffic congestion

[Analysis results] Avoiding lanes where traffic congestion was occurring is estimated to have reduced required driving time by approximately 90 seconds





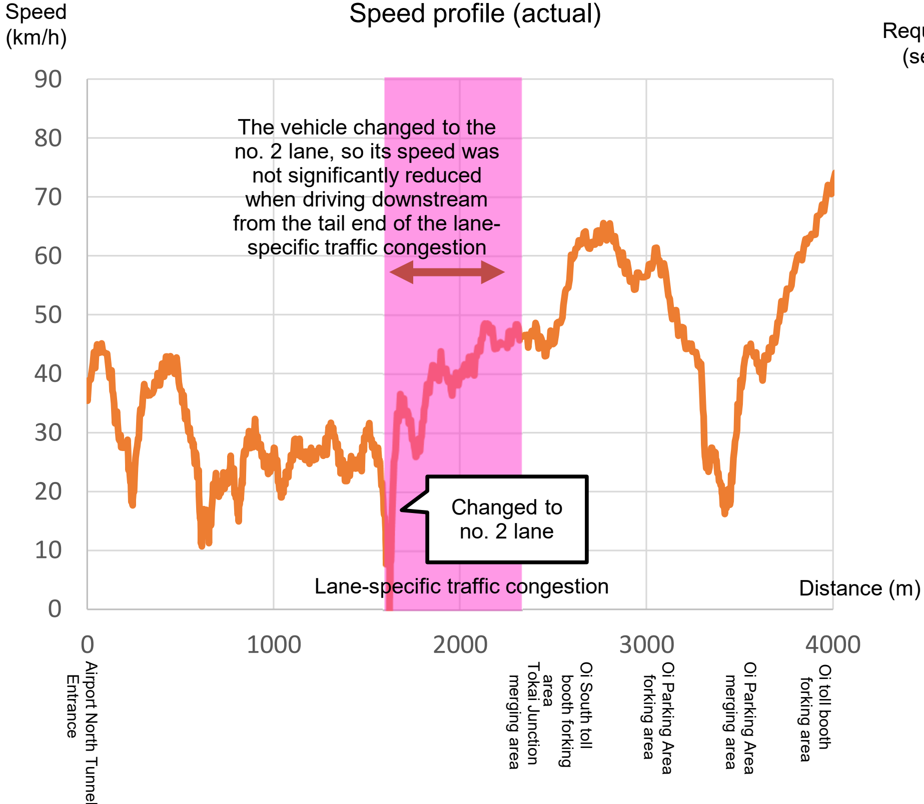
3. Results of lane-specific road traffic information testing

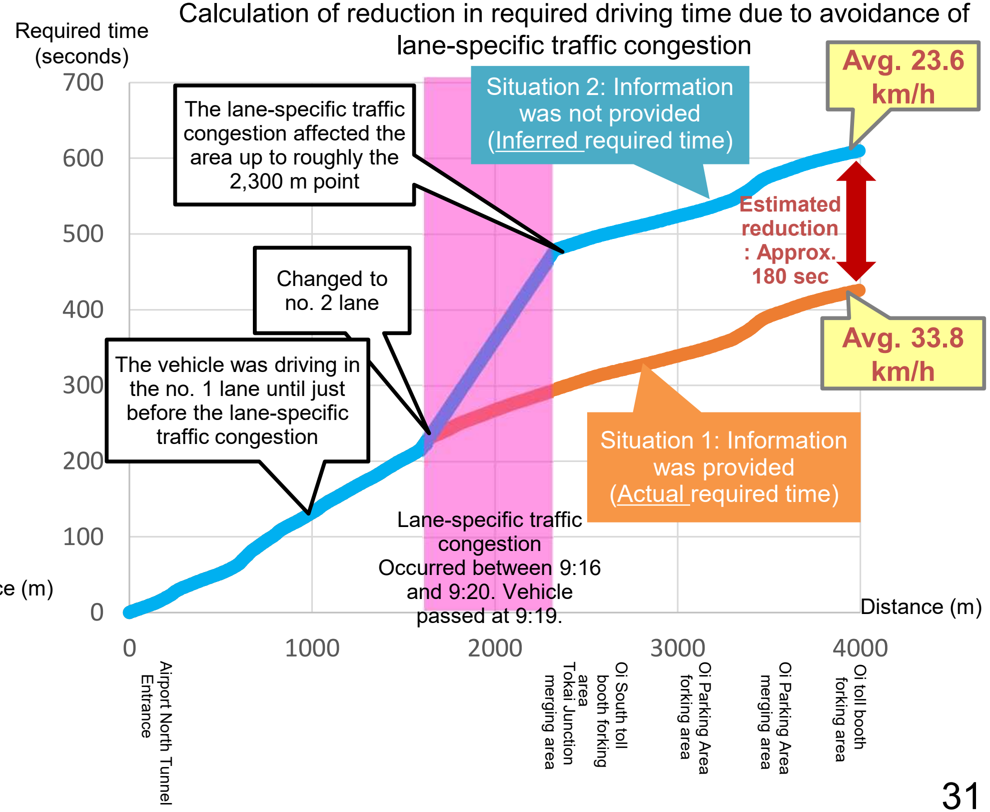
(4) Test results: Situation 2

* See the attachment for other equipment-side test results and the results of analysis of other test participant driving data

(1) We identified test participant vehicles that passed locations where lane-specific traffic congestion was occurring (routes and locations)
(2) We extracted driving history data immediately before and after the lane-specific traffic congestion and used it to determine the actual required driving time
(3) We used drive recorder video to confirm the impact of the lane-specific traffic congestion on the lane the test participant was driving in, and inferred the benefit driving in this lane had over getting caught in the traffic congestion

[Analysis results] Avoiding lanes where traffic congestion was occurring is estimated to have reduced required driving time by approximately 180 seconds





3. Results of lane-specific road traffic information testing

(5) Evaluation questionnaire

- There were many comments stating that the delivered information needed to better match actual traffic conditions

[Improvement requests]

- "The content of the information was significantly different from actual traffic conditions (traffic congestion tail end locations and traffic congestion lane information was wrong, traffic congestion front ends and tail ends weren't paired up, traffic congestion information was received when there was no actual traffic congestion, etc.)."
- "We need information that can be used to determine the reliability of the provided information, such as information regarding system limitations (delay time between information detection and delivery), data processing limitations (conditions under which inaccurate information might be provided), changes at traffic congestion locations (traffic congestion areas growing longer), etc."
- "It would be better if the average vehicle speed were indicated for the location in the traffic congestion tail end information." "We think the provided vehicle speed information could be used together with the test vehicle's own speed and location to decide when to start decelerating and to provide support information to the driver."
- "Shortening the information collection cycle and the information delivery cycle has the potential to shrink the gap between actual conditions and the delivered information."

[Other]

- "We didn't encounter enough traffic congestion tail ends."

4. Results of mock emergency vehicle location information testing

(1) Overview of delivered information

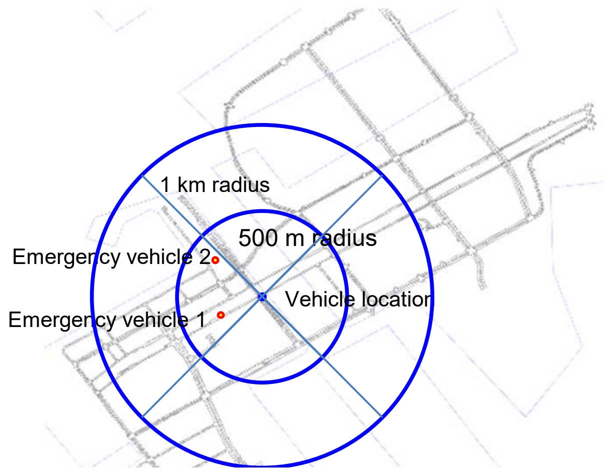
- Below is an overview of the information

Information source: The (mock) emergency vehicle
Provided information: Location information for (mock) emergency vehicle
updated every 100 ms, distributed every 2 seconds
Provision scope: General roads in the Waterfront City area

(Mock) emergency vehicle location information provided by data aggregation server

Item			Byte	Remarks
On-board equipment time	Year		1	BCD (last 2 digits)
	Month		1	BCD
	Day		1	BCD
	Hour		1	BCD
	Minute		1	BCD
	Second		1	BCD
	Millisecond		2	BCD (left-aligned, 3 digits)
Vehicle ID			5	
Reserved			1	
Driving state			1	1: Driving
No. of items of GNSS continuous information			1	0 to 20
Latest location	Latitude [10-7 deg]		4	JGD2011 (semi-dynamic correction unnecessary)
	Longitude [10-7 deg]		4	JGD2011 (semi-dynamic correction unnecessary)
GNSS continuous information 1	GNSS measurement time	Hour	1	BCD
		Minute	1	BCD
		Second	1	BCD
		Millisecond	2	BCD (left-aligned, 3 digits)
	Reserved		1	
	Latitude [10-7]		4	Dynamic map must be aligned with datum (present period → original period)
	Longitude [10-7]		4	Dynamic map must be aligned with datum (present period → original period)
	Movement speed [km/h]		1	
	Reserved		1	
	Sea level altitude [0.1 m]		2	Dynamic map must be aligned with datum (present period → original period)
	Geoid altitude [0.1 m]		2	Dynamic map must be aligned with datum (present period → original period)
	HDOP value		2	
	No. of satellite positioning measurements		1	
	Positioning state		1	0: No positioning, 1: Independent, 2: DGPS, 4. RTK Fix, 5: RTK Float
⋮				
GNSS continuous information n			24	The last location information is the latest information

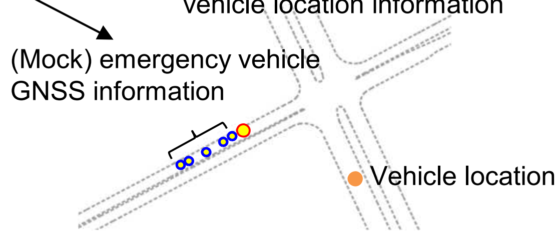
Contains up to 20 items of GNSS information for the (mock) emergency vehicle for a two second period, ordered chronologically from oldest to newest
(if the (mock) emergency vehicle is stopped for two seconds or longer, its direction of travel cannot be inferred)



Conceptual image of output area of (mock) emergency vehicle location information

In preparation for societal deployment, it will be essential to consider and standardize data formats, taking into consideration the ability to distinguish between multiple vehicles

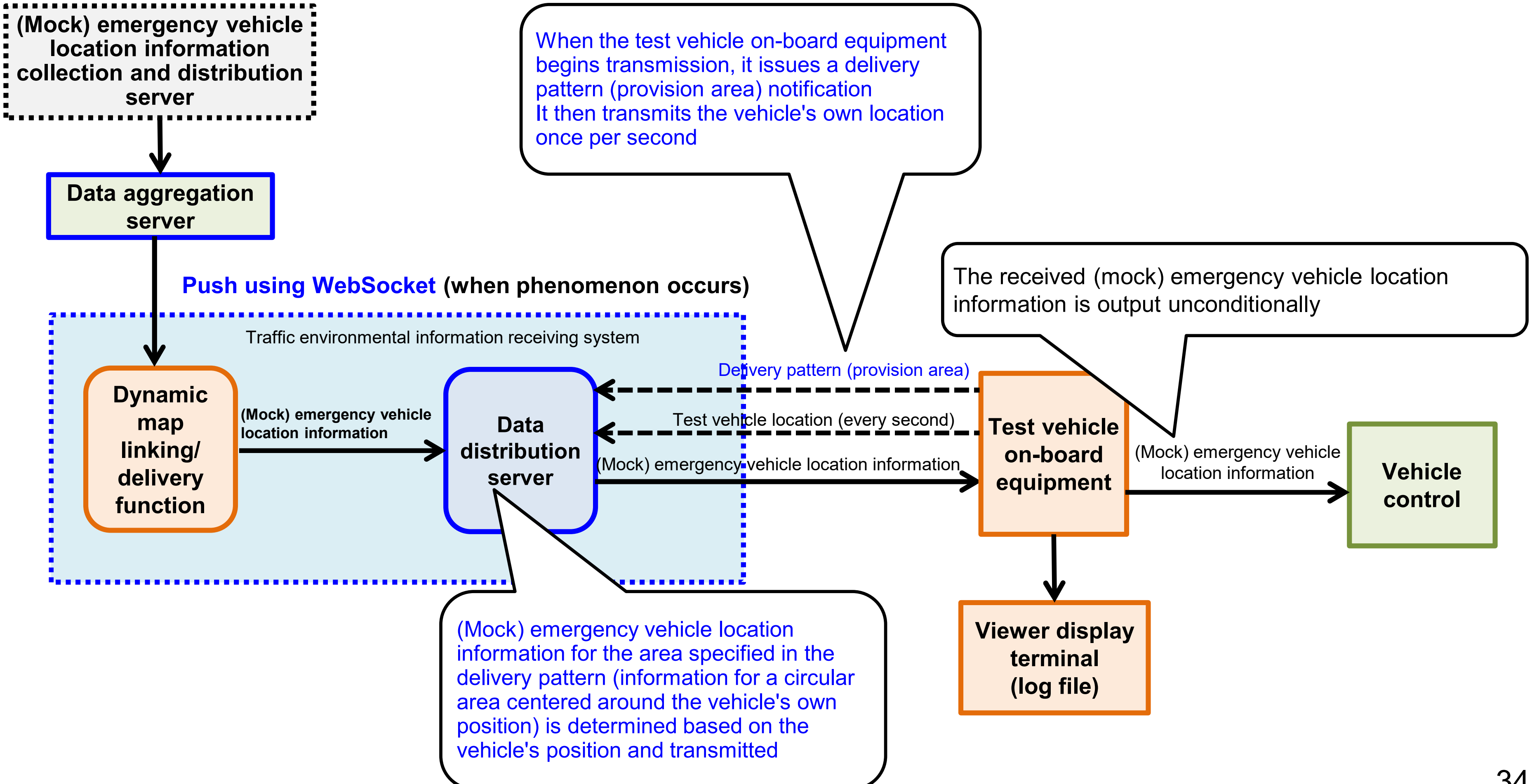
Conceptual image of (mock) emergency vehicle location information



4. Results of mock emergency vehicle location information testing

(2) Information delivery process (flow of data)

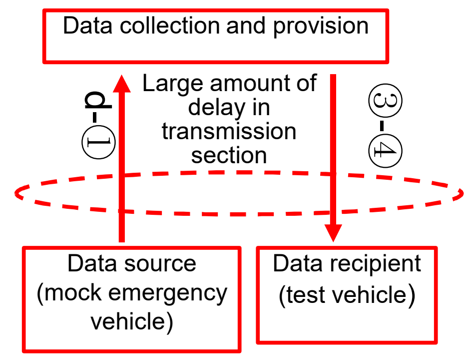
- The vehicle issues notice of the area for which it requires information (a circle around the vehicle), and (mock) emergency vehicle location information is delivered to the vehicle using PUSH delivery



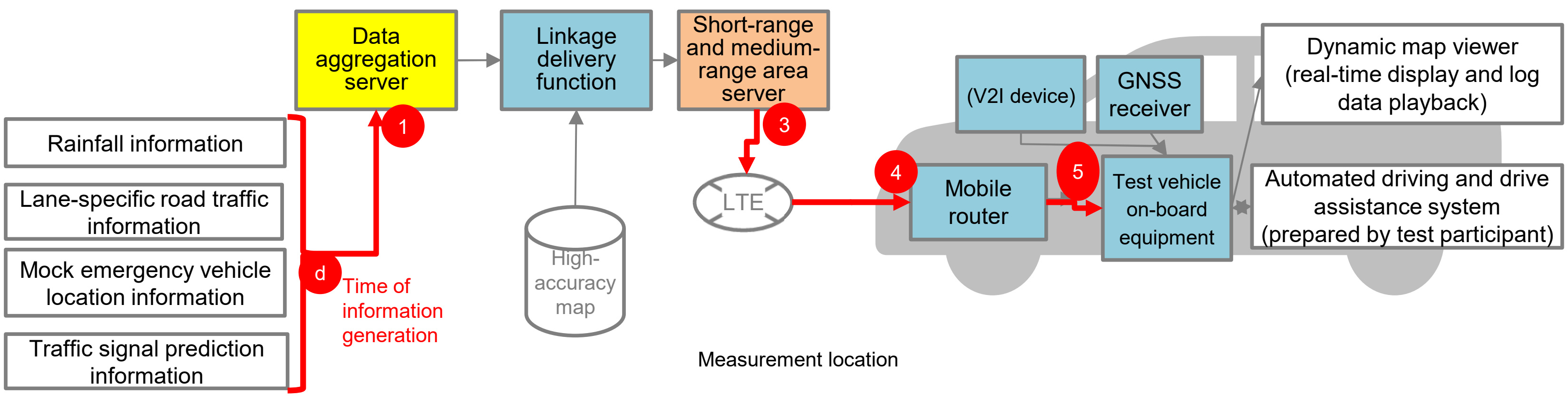
4. Results of mock emergency vehicle location information testing

(3) Transmission delay times

- Time required for uplink from mock emergency vehicle to data aggregation server (d-①):
  Avg. 0.25 to 0.26 seconds
- Amount of time required for delivery from the data aggregation server to the test vehicle on-board equipment (①-⑤):
  Avg. 0.97 to 0.99 seconds
- Amount of time required for delivery from the data delivery server to the test vehicle on-board equipment (③-④):
  Avg. 0.95 to 0.98 seconds



➡ Amount of time required for delivery from the mock emergency vehicle to the test vehicle on-board equipment (d-⑤):
Avg. 1.22 to 1.25 seconds
(When the mock emergency vehicle was driving at high speeds, there was a large difference between the location in the received data and the actual location where the vehicle was confirmed to be)

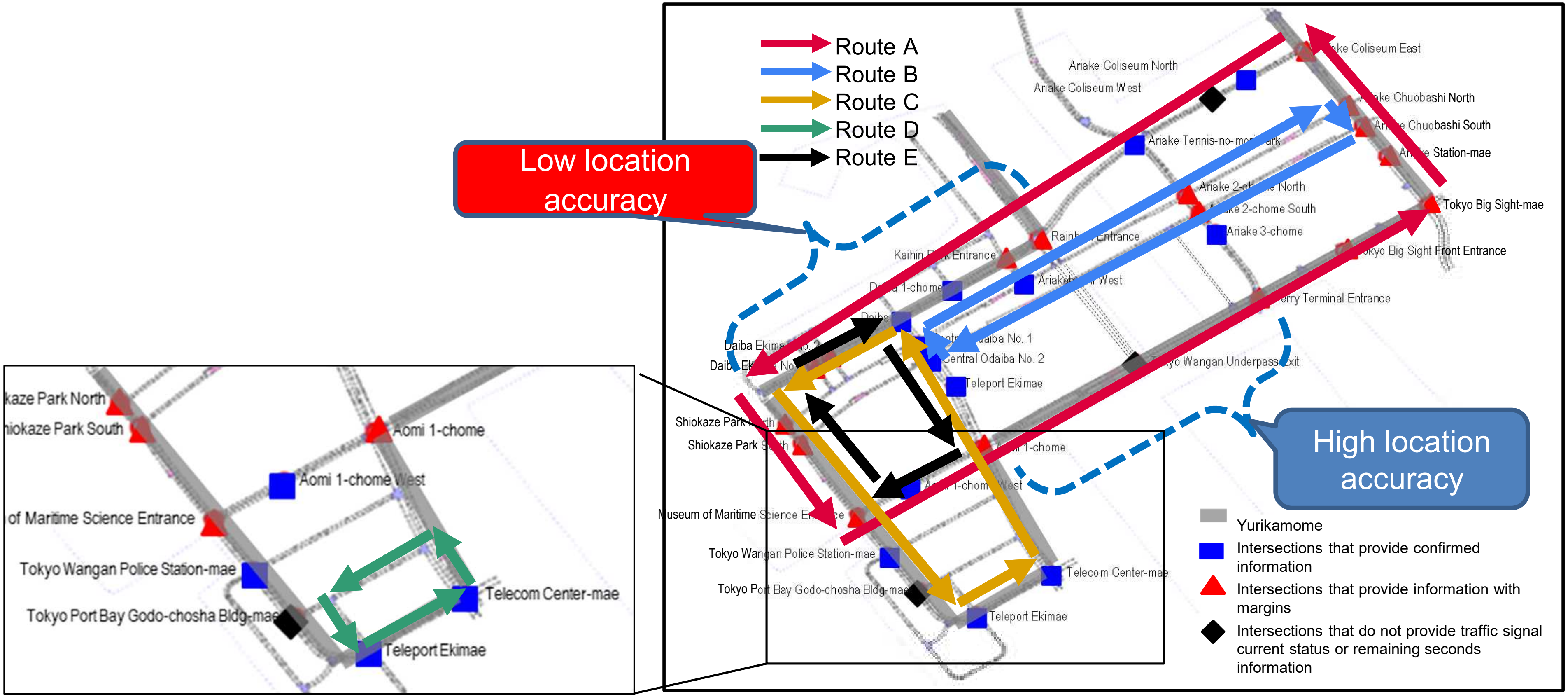


* See the attachment for details regarding the system time synchronization method, the transmission delay time confirmation procedure, and time deviation histograms for mock emergency vehicle no. 1 and no. 2

4. Results of mock emergency vehicle location information testing

(4) Test results

- Five routes were defined (named A through E) and testing was performed
- <u>Location information accuracy was confirmed to decline in multipath environments (under the Yurikamome overpass and nearby buildings). The amount of deviation was particularly large in the vertical direction</u>
  (measures must be taken to improve location accuracy using map matching technologies, IMU, etc.)

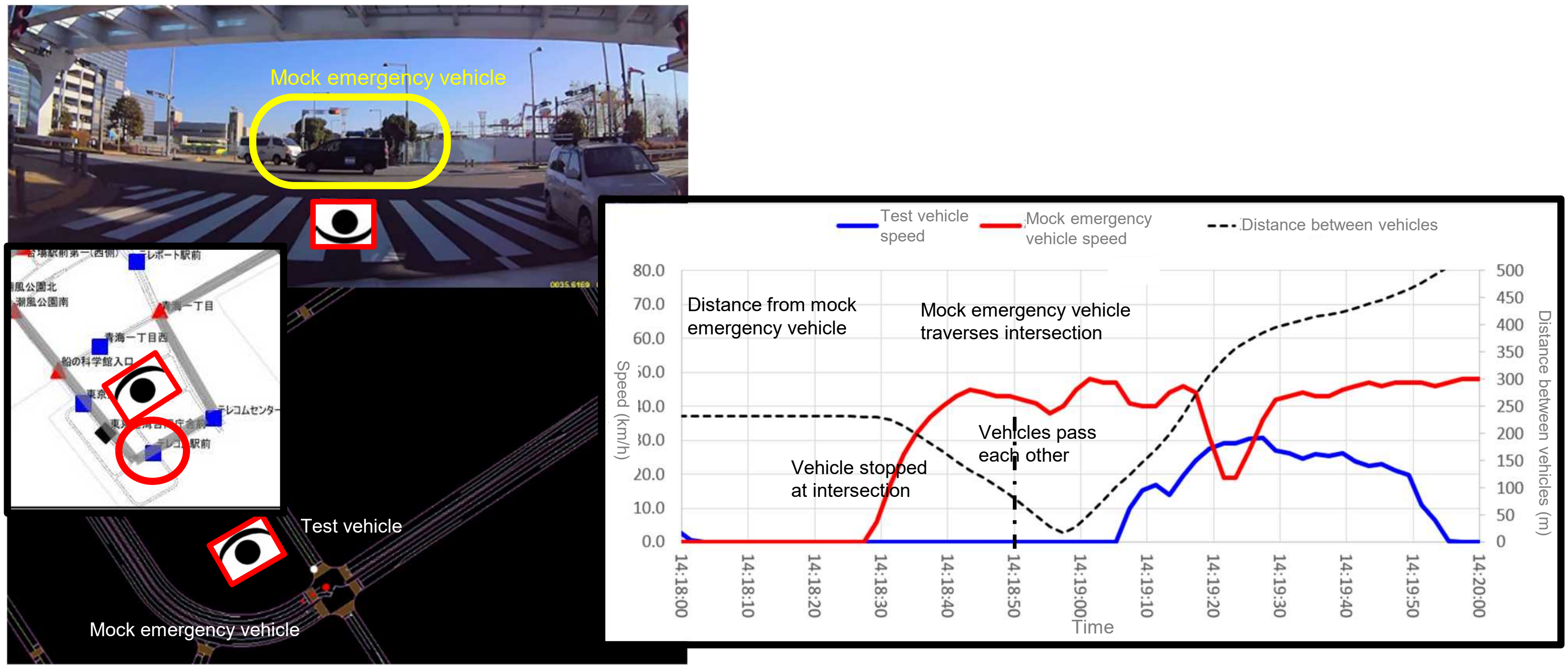


Mock emergency vehicle driving routes

4. Results of mock emergency vehicle location information testing

(4) Test results

- The amount of time required for information to reach the test vehicle on-board equipment from the mock emergency vehicle was 1.22 to 1.25 seconds, on average
  This is the equivalent of roughly 13 m for a mock emergency vehicle traveling at 40 km/h and roughly 21 m for a mock emergency vehicle traveling at 60 km/h
- When emergency vehicles are closest to test vehicles and can be detected by vehicle sensors, delay times and location accuracy requirements may not be very high, so there needs to be deeper exploration of autonomous vehicle use cases for emergency vehicle location information, and the requirements placed on cooperative systems need to be organized



4. Results of mock emergency vehicle location information testing

(4) Test results: Method of verifying benefit analysis

[Verification approach]
(1) Drive recorder video was used to confirm at what time the mock emergency vehicle was visually identified (T1)
(2) Reception log files were used to determine the times when data was received for specified distances between the test vehicle and the mock emergency vehicle (300 m and 500 m) (T2)
(3) The time differences between the T1 and T2 values were used to tabulate how many seconds earlier the vehicle received location information before the vehicle was visible in the drive recorder video. This data was tabulated for each encounter situation

The time differences between the T1 and T2 values were used to evaluate how many seconds earlier the vehicle received location information before the vehicle was visible in the drive recorder video

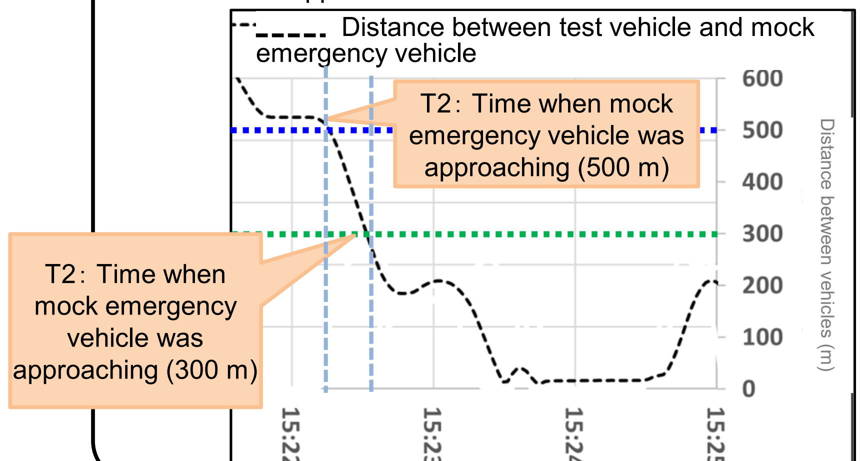
T1: Confirmed mock emergency vehicle visual confirmation time using drive recorder video (Time: 15:23:30)

Calculated time difference

T2: Time acquired from reception log file when mock emergency vehicle was approaching (300 m, 500 m)

	Reception log time (sample)
500 m	15:22:22.231
300 m	15:22:33.434

Reception log files used to acquire mock emergency vehicle approach times



4. Results of mock emergency vehicle location information testing

(4) Test results: Results of verification of benefit analysis

* See the attachment for other equipment-side test results and the results of analysis of other test participant driving data

(1) Drive recorder video was used to confirm at what time the mock emergency vehicle was visually identified and to arrange the data by encounter situation

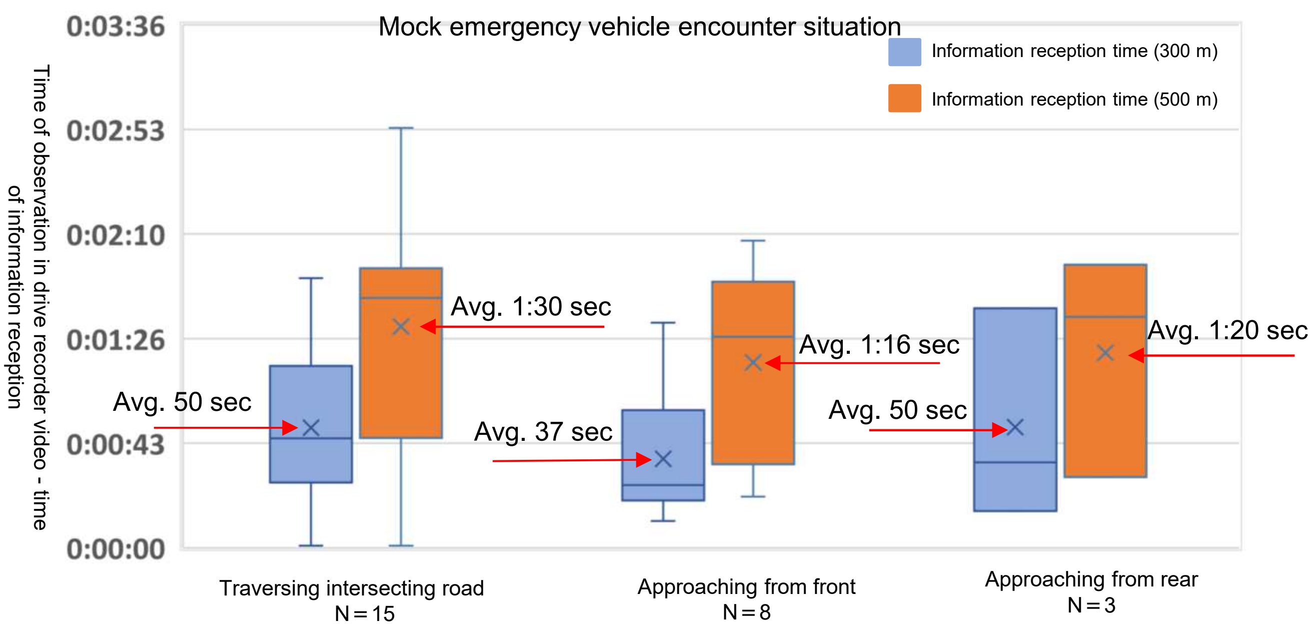
(2) The mock emergency vehicle visual confirmation times and information reception times (no. of seconds information was received in advance of visual confirmation being possible in drive recorder video) were tabulated

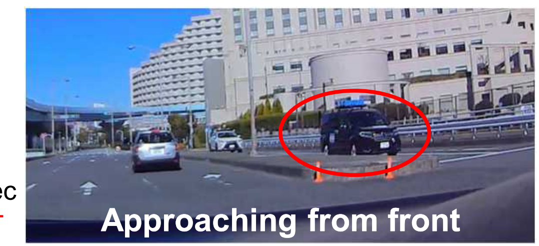
[Analysis results]

For the 300 m information reception times, on average, information was received roughly 40 to 50 seconds before the vehicle was visible. For the 500 m information reception times, on average, it was received roughly 1:20 to 1:30 seconds before the vehicle was visible.

⇒ This enabled smooth slowing and stopping, and it appears that this information would prove effective in assisting with safe driving when emergency vehicles are approaching

* Analysis was only performed for drives in which the mock emergency vehicles and the test participants were driving on driving route A.
(This is because this FOT was envisioned for situations in which emergency vehicles are encountered in urban areas)





4. Results of mock emergency vehicle location information testing

(5) Evaluation questionnaire

- In addition to current location information, there were also comments requesting the provision of information such as traveling direction, planned route, and turn signal status.

[Effectiveness of delivered information]

- "With this information, we can determine the relative positions and relative speeds of emergency vehicles with respect to our vehicle, so we think it would be extremely effective when the approach of an emergency vehicle would affect our own vehicle's behavior."
- "In addition to informing the driver and controlling automated driving, it would be best to make a stop determination roughly 20 seconds in advance to gradually bring the vehicle to a stop from 60 km/h. The vehicle control wouldn't need to be based on the emergency vehicle's exact location, so a delay of 2 or 3 seconds would be acceptable."

[Improvement requests]

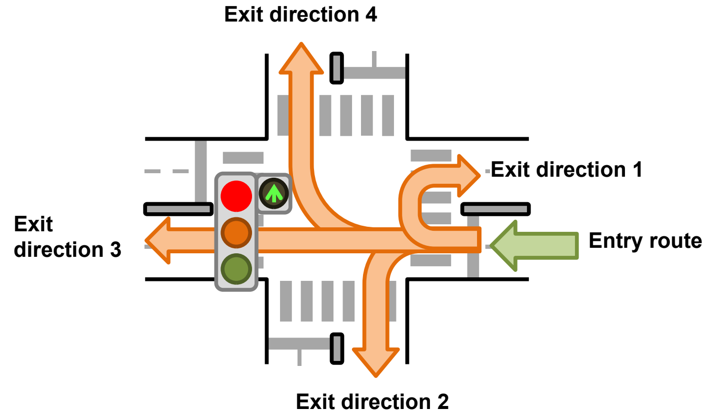
- "The information would be even more effective if it included the emergency vehicle's traveling direction and (if possible) information on its planned route."
- "We would like to have planned route information, turn signal status information, and the like for emergency vehicles."
- "Even if we know the current location of the emergency vehicle, we don't know what route it will take in the future, so we determined that this information wasn't enough for us to make route changes for our own vehicle."
- "When the emergency vehicle stops, we need to know if it's temporarily stopped on its way to its destination, or if it has stopped because it reached its destination." "Knowing the intentions of the emergency vehicle would make the information even more effective."
- "It would be best if the information were linked with a high accuracy map to properly distinguish if emergency vehicles are currently on elevated roads or on frontage roads."

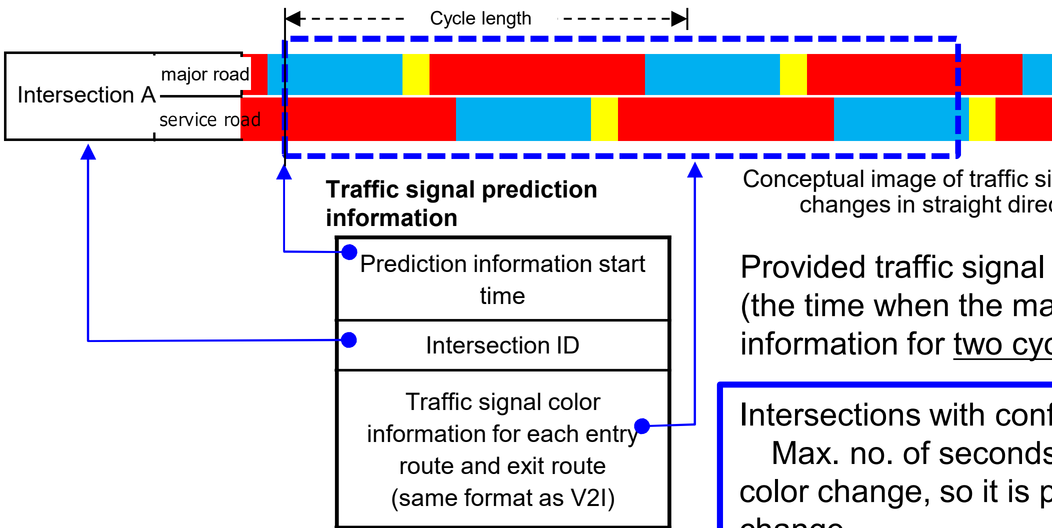
5. Results of traffic signal prediction information testing

(1) Overview of delivered information

- Below is an overview of the information

Information source: Metropolitan Police Department
Provided information: Traffic signal color prediction information when traffic signal cycle is confirmed
Provision scope: Traffic signals in Waterfront City area





Conceptual image of traffic signal color changes in straight direction

Provided traffic signal prediction information contains the cycle start time (the time when the major road's traffic signal turns green) and light color information for <u>two cycles for each exit direction of each entry route.</u>

Traffic signal prediction information is generated and provided three seconds before start of prediction information

Intersections with confirmed traffic signal prediction information :
Max. no. of seconds remaining = min. no. of seconds remaining before color change, so it is possible to predict the timing of the traffic signal color change

Intersections with traffic signal prediction information with margins :
Max. no. of seconds remaining > min. no. of seconds remaining before color change, so it is not possible to predict the timing of the traffic signal color change

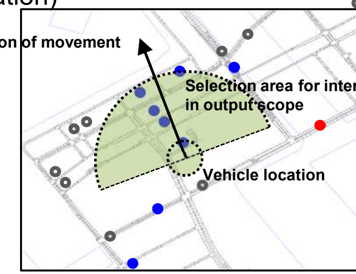
For traffic signals with no traffic signal aspect/remaining seconds,
no traffic signal prediction information is provided

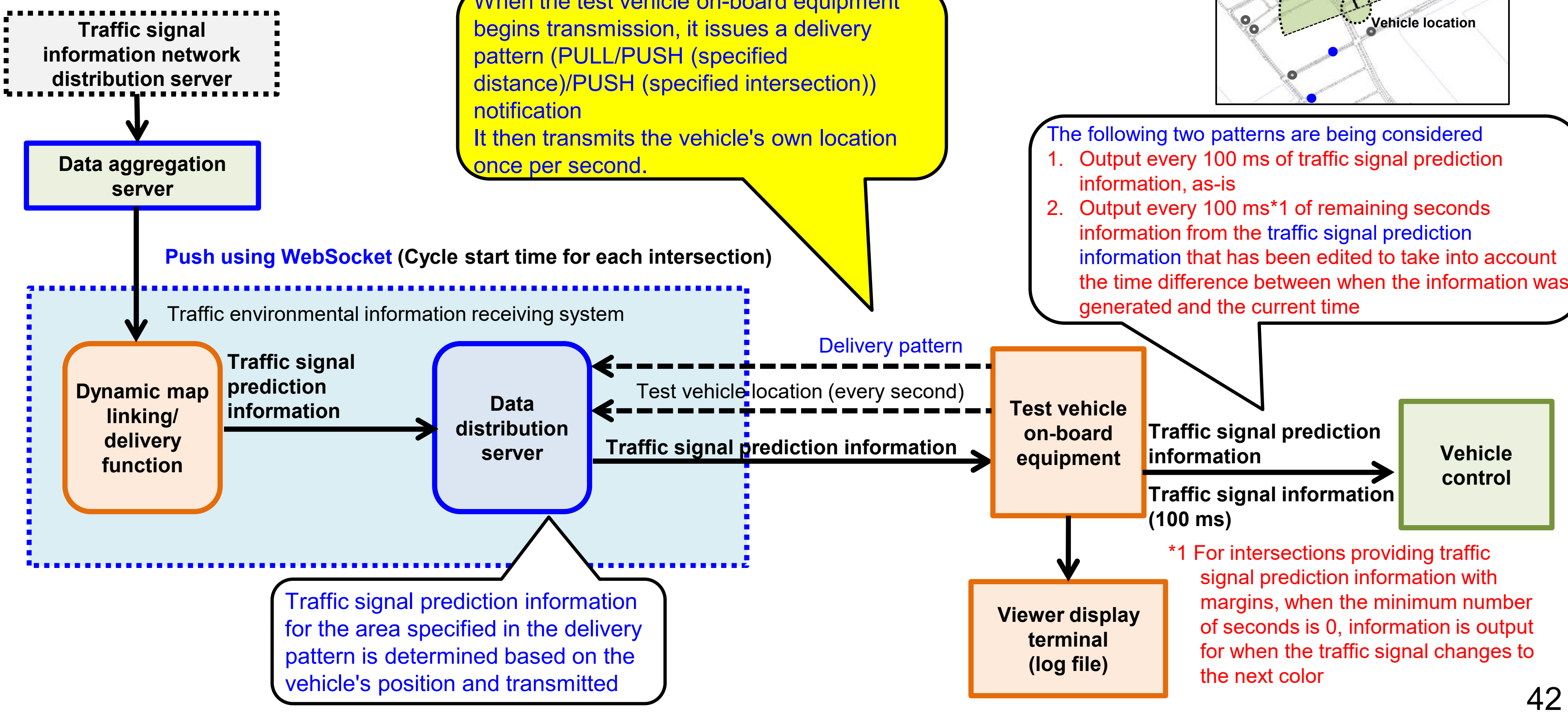
5. Results of traffic signal prediction information testing

(2) Information delivery process (flow of data)

- Traffic signal prediction information sent from Metropolitan Police Department servers when the traffic signal cycle is confirmed is delivered using the PULL/PUSH (specified distance) or PUSH (specified intersection) method. The test vehicle on-board equipment then outputs the prediction information the modified remaining seconds information (choose one) (CAN output filtering will also be performed)

The test vehicle on-board equipment's traffic signal prediction information output scope consists of intersections within a 30 m radius of the vehicle's position and a half-circle with a 330 m radius facing the direction in which the vehicle is travelling (the same as V2I traffic signal information)





5. Results of traffic signal prediction information testing

(3) Transmission delay times

* See the attachment for details regarding the system time synchronization method, the transmission delay time confirmation procedure, and time deviation histograms

- The required time was shortest when using the specified intersection PUSH method. Data was delivered from the data aggregation server to the vehicle with an average delivery time of 94 ms and a maximum delivery time of 324 ms, regardless of the number of intersections (between 1 and 30 intersections)
- With the current system, it would be best to use the specified intersection PUSH method, as it can minimize delivery delay time

Unit (seconds)

	Characteristic	Amount of time required for delivery from the data aggregation server to the test vehicle on-board equipment
Specified distance PUSH method	● The server uses the vehicle's location and the designated distance to determine which intersections correspond and delivers the corresponding information to the vehicle ● The delivery interval is set to 1 second ● The delay time in transmitting information from the aggregation server to the distribution server is further increased by distribution server processing time and 0 to 1 seconds of wait time	see table below
PULL method	● The vehicle periodically (in 1 minute intervals) pulls information from the distribution server ● The distribution server saves delivered traffic signal prediction information and, upon request, provides information to vehicles for the block they are in and the blocks around them ● With the current system, a delay time of slightly over 1 minute can occur ● Shortening the delivery interval (to once every several seconds) would be difficult due to the transmission load that would be involved	see table below
Specified intersection PUSH method	● The vehicle (using the MQTT protocol) notifies the distribution server of the intersections for which it wants information ● The distribution server delivers the latest traffic signal prediction information for the requested intersections, and then delivers traffic signal prediction information for the designated intersections whenever there are updates ● This method has the shortest delay time of the three methods	see table below

Specified distance PUSH method:

No. of intersections	Min.	Avg.	Max.
1	0.352	0.597	0.814
4	0.468	0.710	1.039
17	0.069	0.766	1.153
30	0.100	0.598	1.338

PULL method:

No. of intersections	Min.	Avg.	Max.
1			
5	1.582	30.957	62.423
17	0.958	33.917	63.012
30			

Specified intersection PUSH method:

No. of intersections	Min.	Avg.	Max.
1	0.075	0.089	0.106
5	0.043	0.075	0.112
17	0.080	0.094	0.139
30	0.046	0.081	0.324

5. Results of traffic signal prediction information testing

(4) Test results

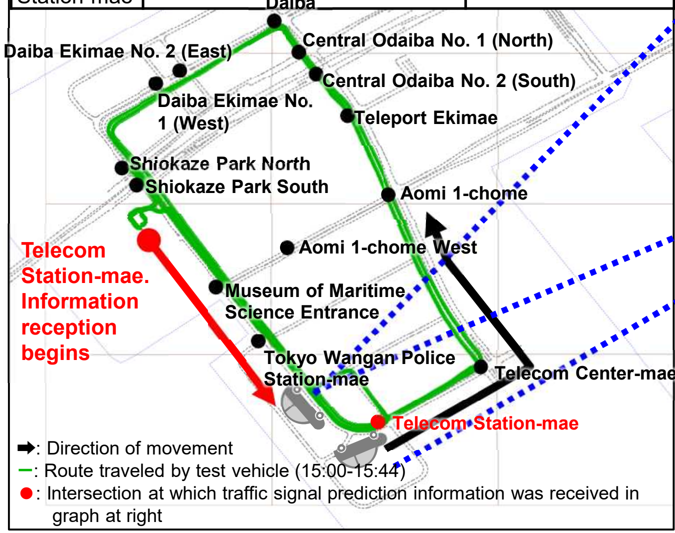
* See the attachment for other equipment-side test results and the results of analysis of other test participant driving data

- Traffic signal aspect information was received via V2N for intersections that were in front of the vehicle but were not visible. The information could be used to support driving assistance and automated driving when entering intersections so, as with V2I, recognition can be improved by use of dual information systems
- With regard to the potential for using this information for traffic signal color recognition when using driving assistance or automated driving, the FOTs found that, due to the following issues, there are problems with using the information for dilemma avoidance and with recognizing traffic signal colors at or near the times when traffic signal colors changed. Measures must therefore be considered for addressing these issues.

(1) There were discrepancies between when traffic signals actually changed and the content of the supplied information (time difference of approx. 2 seconds)

(2) For intersections with remaining seconds margins, it is not possible to notify vehicles (or make predictions) of when traffic signals will change

Name of intersection	Time traffic signal color was recognized in drive recorder video	Traffic signal prediction information reception time	Use of green traffic signal information for first cycle of traffic signal prediction information
Telecom Station-mae	15:26:36	15:25:56	



5. Results of traffic signal prediction information testing

(5) Evaluation questionnaire

- There were comments regarding time deviations between actual traffic signal color changes and traffic signal prediction information, requesting the provision of traffic signal prediction information for intersections that provide information with margins, other requests regarding societal deployment, etc.

[Time deviations between actual traffic signal color changes and traffic signal prediction information]

- "Actual traffic signal aspects differed from predictions (times when signals were predicted to change) by up to two seconds. A deviation of two seconds is large enough to negate any dilemma zone avoidance benefits. A deviation of roughly ±300 ms would be within acceptable bounds."
- "There's too much of a gap between actual traffic signal changes and the timing predicted in the information that was supplied."

[Provision of traffic signal prediction information for intersections that provide information with margins]

- "We believe that, during the cycle, information needs to be updated after the preliminary finalization of the number of seconds and after the information with margins aspect step. For traffic signals providing information with margins, we would like for traffic signal aspect information to be delivered via V2N."

[Other (preparation for societal deployment)]

- "If information delivery services are available for some traffic signals but not for others within the same area, the information would be less effective. It would be best if information were delivered for all intersections in areas where information is provided."
- "We would like for societal deployment to occur in around 2023. The sooner the better."

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.