戦略的イノベーション創造プログラム

Cross-ministerial Strategic Innovation Promotion Program (SIP)/Automated Driving for Universal Services/Technical Study and Evaluation of Automated Driving Control Using Lane-specific Probes or the Like

FY2021 Annual Report

Summary

Pacific Consultants Co., Ltd.

March 2022

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1. Study Outline

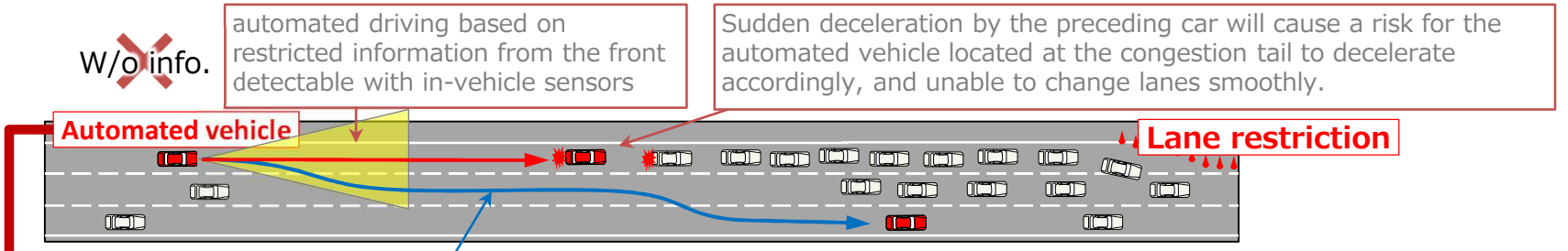
1.1. Project Goals

In automated driving on expressways, there may be cases where it is difficult to change lanes smoothly from the traveling lane to the deceleration lane due to the insufficiency or inaccuracy of information available in advance, such as when there are stopped vehicles or fallen objects ahead or there is congestion at the exit. One way to solve such cases is to allow automated vehicles to obtain lane-specific road traffic information, which will enable early lane change and consequently safe and smooth automated driving.

1.1. Project Goals

Necessity of Lane-level Road Traffic Information

- Lane-level road traffic information is necessary to achieve safe and smooth driving by obtaining the status at the front that cannot be detected by in-vehicle sensors, and changing lanes early, or other means.
- To generate lane-level road traffic information, it is effective to use vehicle probe information that can obtain traffic conditions in areas, and further sophistication of information by adding information from road/traffic controllers or others is expected.



Needs by vehicle

- What lane should be used?
- When to change lanes?

→ **Lane-level road traffic information is necessary** to determine the above.

Respond to needs

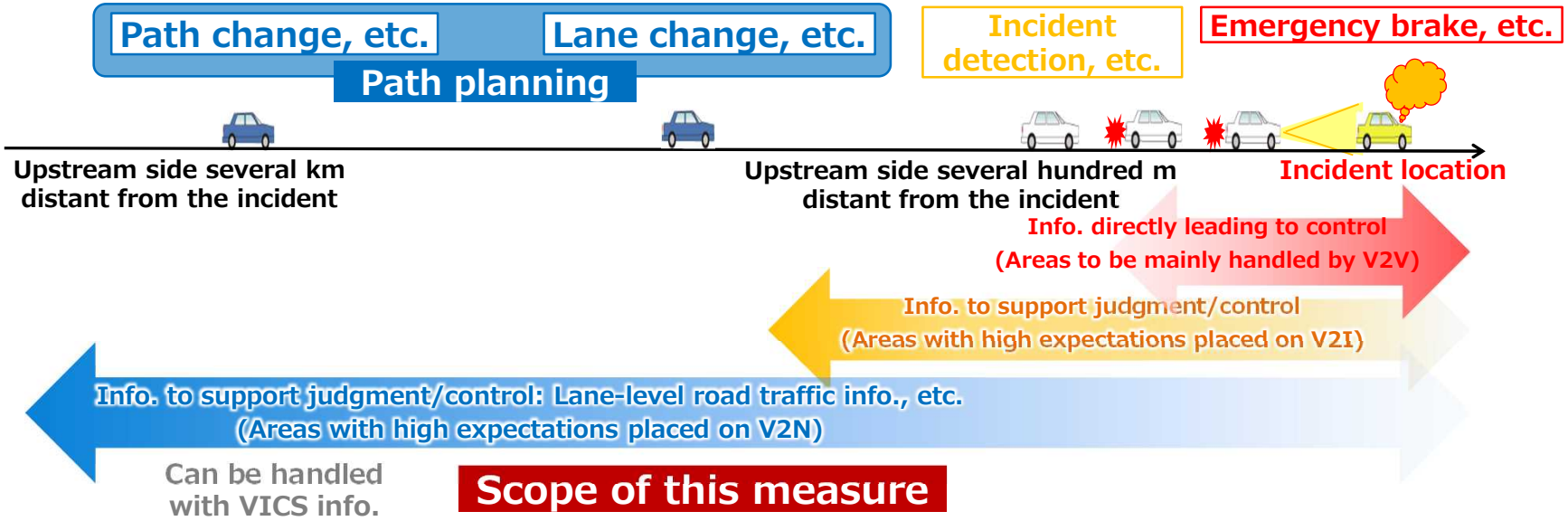
Effectively generating information by combining information from various sources

- ○ **Vehicle probe information**
  Can obtain areas and positions precisely
- ○ **Road/traffic controller information**
  Can obtain information such as incident causes that cannot be obtained through vehicles
- ○ **Others (emergency information, etc.)**
  Can obtain emergency information immediately

1.1. Project Goals

Scope of This Measure

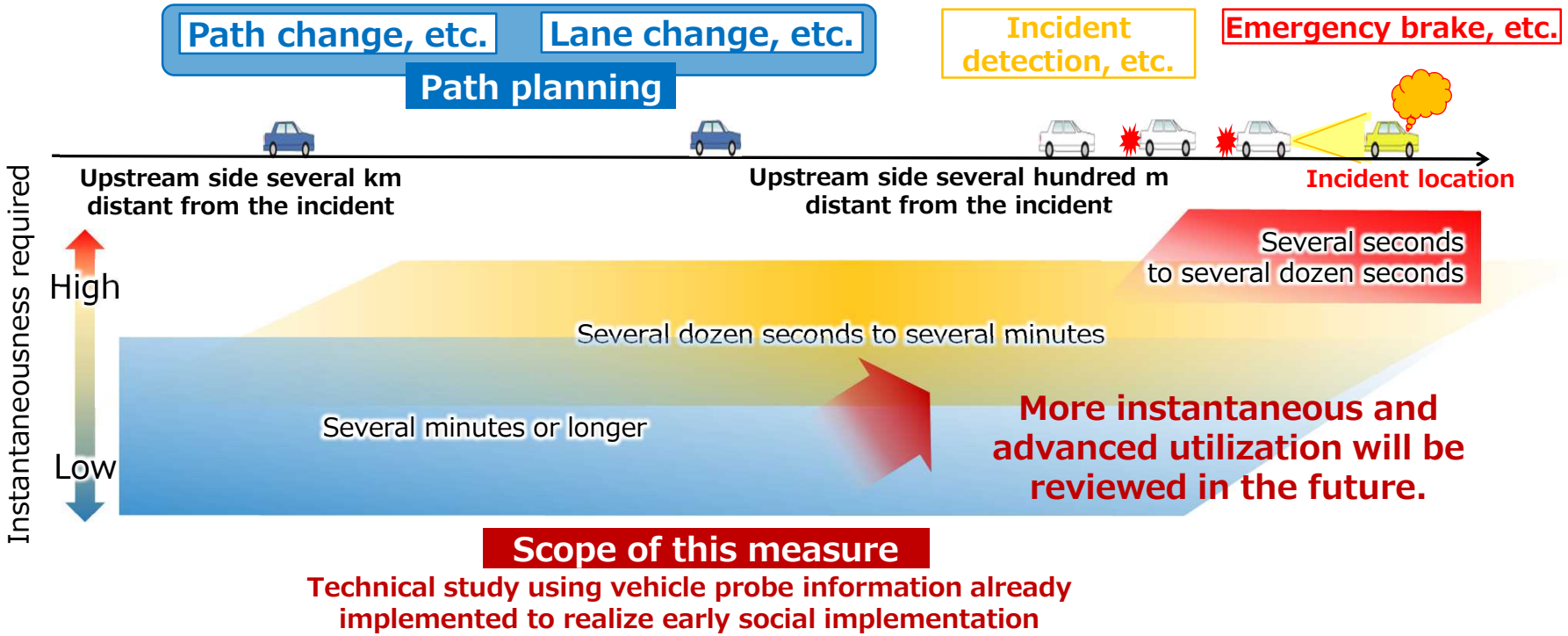
- There are multiple stages for automated vehicles to appropriately control or make judgment, depending on the distances to the point to perform controls necessary for individual scenes. Thus lane-level information is required for each stage.
- It is important to use various communication measures depending on the characteristics of each stage, and integrally combine obtained information.
- Lane-level road traffic information according to characteristics of scenes is being reviewed for the effectiveness or use, and this measure first reviews use of path planning mainly for lane change.



1.1. Project Goals

Scope of This Measure

- This measure utilizes vehicle probe information already implemented to realize early social implementation and starts activities from reviewing technologies to generate/provide information in real time similar to conventional road traffic information.
- It also aims to generate/provide further instantaneous information in the future.

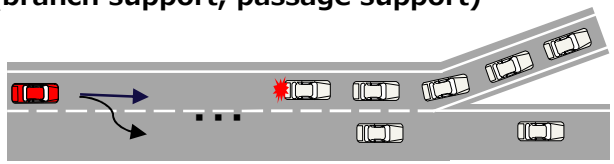


1.1. Project Goals

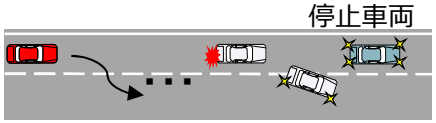
Target Use Cases and Advantage of Information Provision

Target use cases Targets **three use cases** being studied by Japan Automobile Manufacturers Association

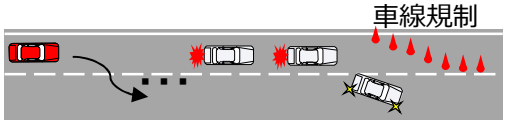
A: Congestion tail (branch support, passage support)



B: Traffic accidents, disabled vehicles, fallen objects, and other obstacles



C: Lane restrictions (due to construction work, etc.)



Requirement	Target sections	Communication	Control application (vehicle control or information provision, etc.)	Quick response (response from vehicle after obtaining information)
	Expressways	V2I, V2N	Lane change, traveling plan change, speed adjustment	Not required

Note) Set based on the SIP Cooperative Automated Traveling Use Cases (1st Edition, September 3rd)

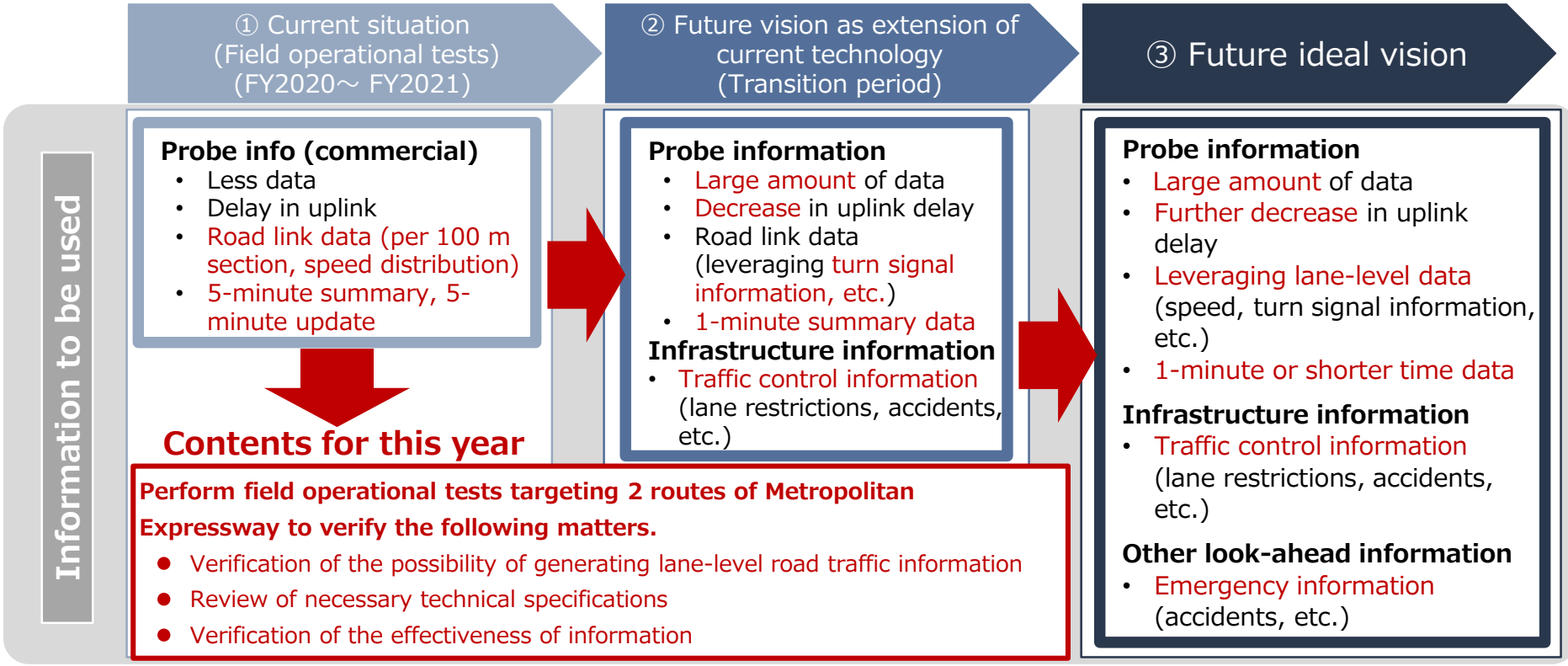
Advantages of info provision

- **Improvement on safety and smoothness, etc. is expected** thanks to smooth lane change and prevention of impact collision by the following car, as well as sudden deceleration of the automated vehicle when meeting an event shown in use cases by changing the lane in an early stage based on the situation of the front area.
- **Effective as support information for vehicles with automated driving levels 1 and 2.**

1.1. Project Goals

Future Visions and Scope of Study of This Year

- In the future, data amount will be increased in line with widespread use of connected cars, so we will proceed with the study assuming that latest information will be provided thanks to collection of data without uplink delay.



1.2. Project Outline

To put the above into practice, this study and evaluation project examines the technologies to collect lane-specific congestion information, stopped vehicle information, fallen object information, and incident/restriction information (hereinafter collectively referred to as "lane-specific information") and provide them to automated vehicles. Specifically, this study conducts a field operational test on the Metropolitan Expressway Haneda Line and Bayshore Route (hereinafter referred to as “FOT") in the course of the Tokyo Waterfront Area 2020 Field Operational Tests. The above measures are examined not only for the automated driving system, but also for the Level 1 and Level 2 driving support systems.

To achieve the above research and development objectives, the following research and development items are conducted.

a. Technical study on each element
   1) Study on lane-specific information generation technology
   2) Study and evaluation of lane-specific probe processing technology required for generating lane-specific information
   3) Study and evaluation of data integration technology for generating lane-specific information
   4) Study and evaluation of lane-specific information distribution technology
   5) Study and evaluation of technology for collecting various types of traffic environment information
   6) Study and evaluation of technology for distributing various types of traffic environment information
b. FOT
c. Study and verification of elemental technologies using quasi-dynamic level look-ahead information

In FY2019 through 2021, among the above research and development items, "a. Technical study on each element", "b. FOT" and "c. Study and verification of elemental technologies using quasi-dynamic level look-ahead information "were partly conducted.

1.2. Project Outline

Study Flow of This Research and Development

Study on requirements and specifications (a. Technical study on each element (1) Technical study)

a1) Study on lane-specific information generation technology

Probe data information obtained from vehicles

Incident information (restriction information, information on fallen objects and disabled vehicles)

Study on requirements for data processing technology
- Lane-specific information generation technology
- Probe information processing technology
- Data integration technology

c. Study and verification of elemental technologies using quasi-dynamic level look-ahead information

a2) Study and evaluation of lane-specific probe processing technology required for generating lane-specific information

a3) Study and evaluation of data integration technology for generating lane-specific information

a4) Study and evaluation of lane-specific information distribution technology

Link with high-precision 3D maps
- Setting Common Reference Points (CRP)
- Data generation based on the lane-level position reference method

a5) Study and evaluation of technology for collecting various types of traffic environment information

a6) Study and evaluation of technology for distributing various types of traffic environment information

Reflection on experiment and development

Feedback

b. FOT

FOT planning

1) Creation and update of node link maps of the FOT sections

2) Construction of an experimental system based on the technologies and specifications examined

3) FOT

(2) Technical evaluation

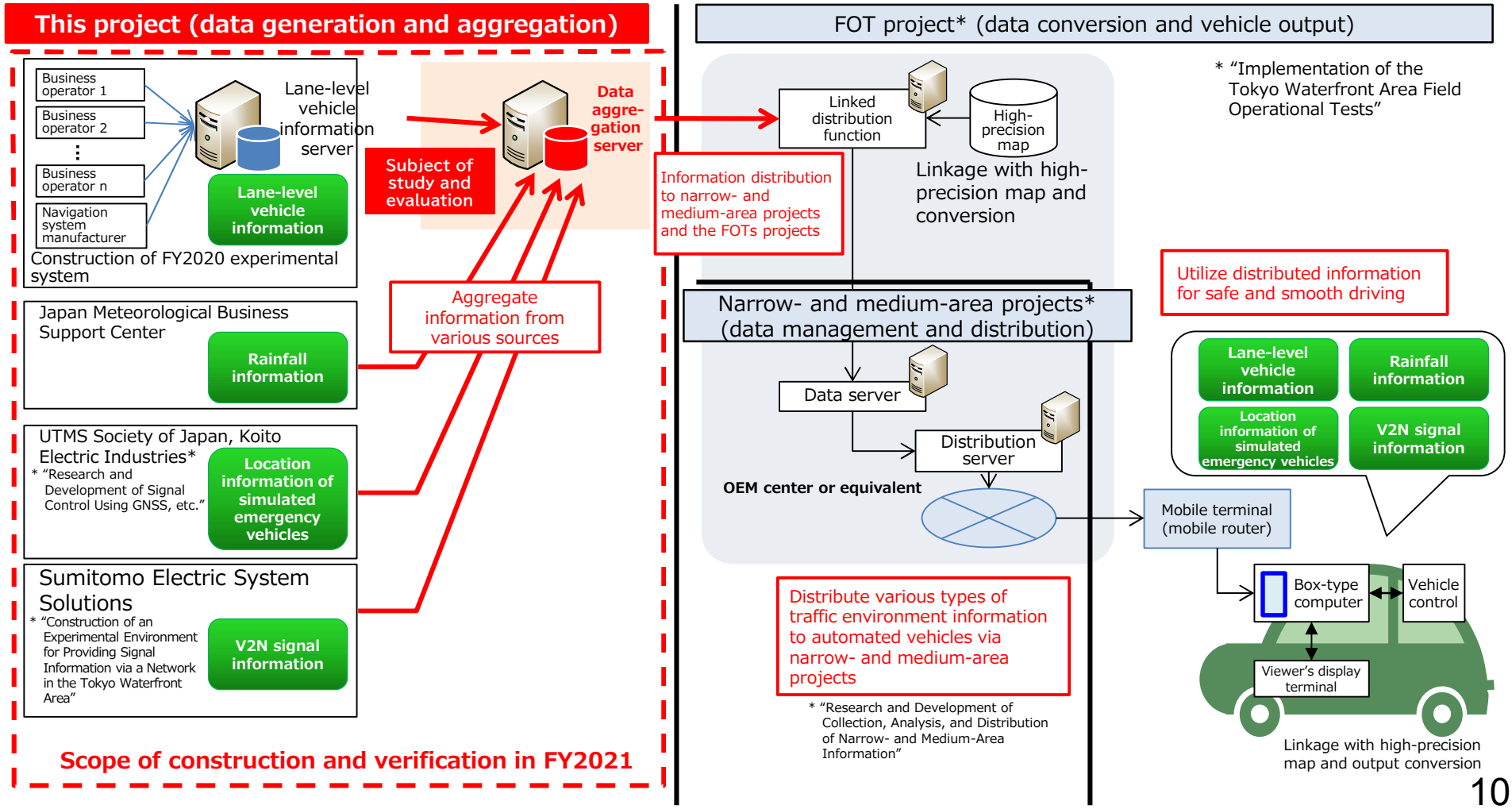
- Evaluation based on the use cases of lane-level road traffic information
- Evaluation of the certainty of information and position expression

* The FOT is assumed to be conducted mainly by the Tokyo Waterfront Area Field Operational Tests Consortium.

1.2. Project Outline

FOT system configuration

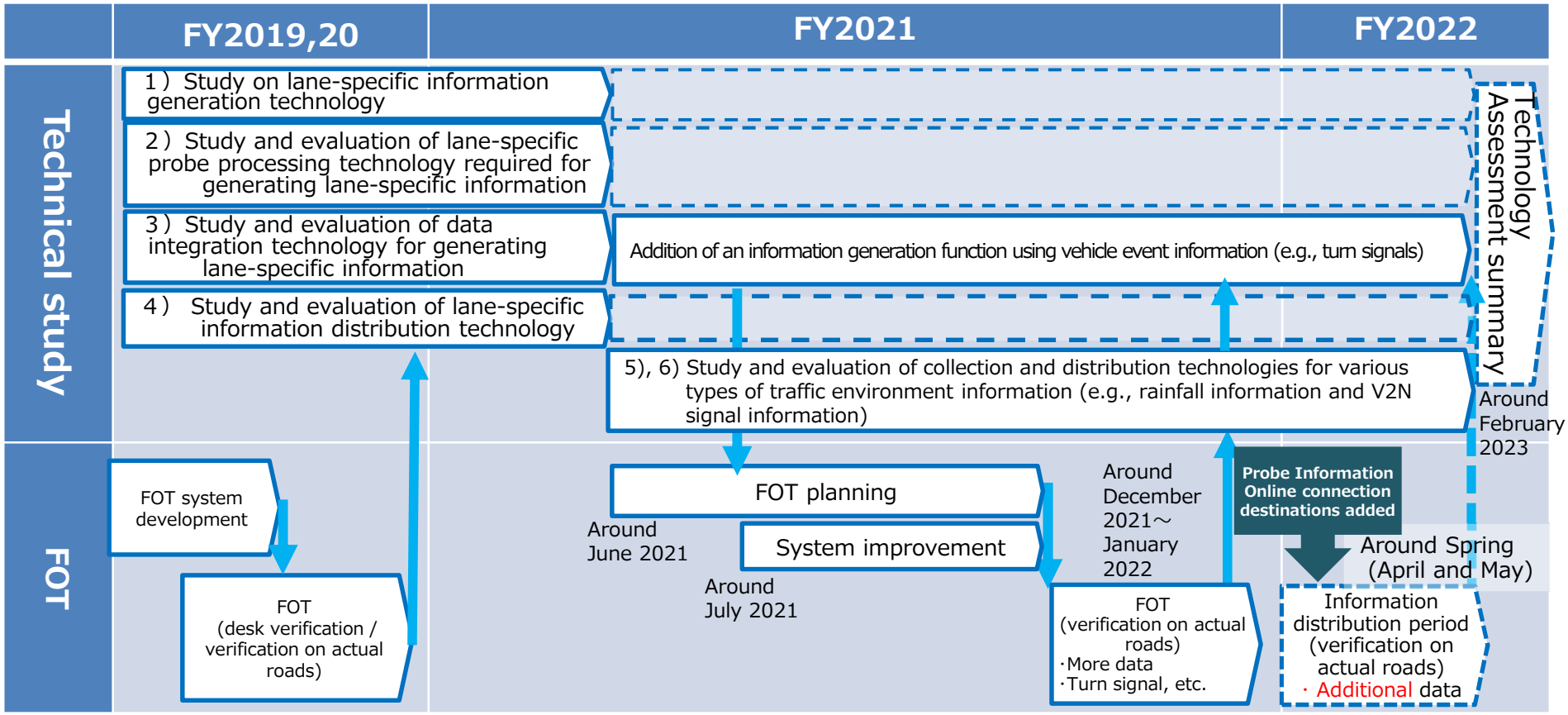
- Construct an experimental environment in which various types of traffic environment information useful to appropriately determine and control automated vehicles can be centrally aggregated with lane-level vehicle information, for which a FOT system has been constructed since FY2020, and then provided to the vehicle side (OEM center or equivalent), and implement the FOT.



1.2. Project Outline

Implementation Schedule of This Research and Development

- In FY2021, the amount of probe data was increased to verify stable information generation on actual roads. Furthermore, an information generation function using vehicle event information (e.g., turn signals) was added to verify the feasibility of information generation other than congestion by branch direction. At the same time, how to realize social implementation was studied.



2. Technical Study on Each Element

2.1. Study on Lane-specific Information Generation Technology

- This project examines how to generate lane-specific information using
  (1) Statistical data of probe information (e.g. travel speed by link) collected from each company's vehicles, and
  (2) Lane-specific fallen object information, incident/restriction information, and others

  with regard to expressways and motorways.
- This project uses available data (i.e., data obtained not from automated vehicles but from existing vehicles) in order to achieve early commercialization.
- In FY2020, a basic study was conducted on how to generate lane-specific information. Also, probe suppliers were interviewed about available data.

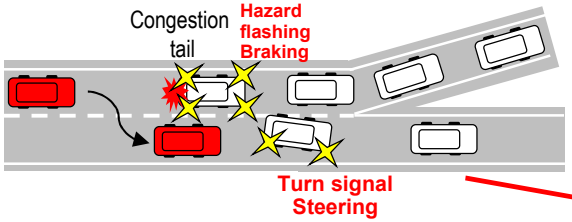
2.1. Study on Lane-specific Information Generation Technology

(1) Basic Study on How to Generate Lane-specific Information

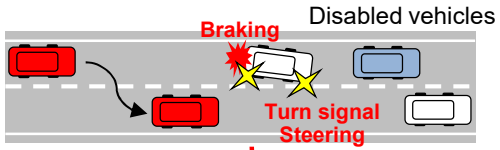
■ Target use case incidents and concept of detection based on probe information

- The following are three use cases where automated vehicles use lane-level road traffic information.
- Study how to detect incidents by using available probe information depending on the use case.

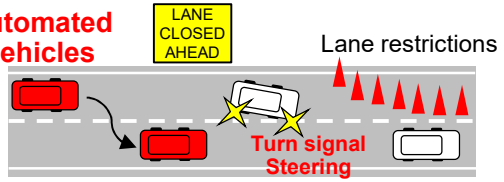
A: Congestion tail (branch support, passage support)



B: Traffic accidents, disabled vehicles, fallen objects, and other obstacles (e.g., oil leaks)



C: Lane restrictions (due to construction work, etc.)



Probe information (information source)

Target use cases and how to detect relevant incidents based on probe information

Use Case	A: Congestion tail (e.g. directional congestion)	B: Sudden incident (traffic accidents, disabled vehicles, fallen objects, and other obstacles (e.g. oil leaks))	C: Lane restrictions (due to construction work or the like)
Information obtained by automated vehicles	Lane-specific road traffic information * Quasi-dynamic information (1-minute level)		
How to detect location of incident at lane level (Information source)	● Low speed points in lane-specific probes (directional probes at junctions) ● Frequent hazard flashing/braking ● Frequent turn signals/steering	● Frequent turn signals ● Frequent steering ● Frequent braking	● Frequent turn signals ● Frequent steering
Behavior of automated vehicles	Early avoidance (e.g. lane change) or following the congestion tail	Early avoidance (e.g. lane change)	

2.1. Study on Lane-specific Information Generation Technology

(1) Basic Study on How to Generate Lane-specific Information

■ Concept of generating lane-specific road traffic information required for automated driving

- Determine the location of the incident (where lane change should be completed) using available probe information depending on the use case and provide it to automated vehicles.

Image of generation of lane-specific road traffic information to be provided to automated driving vehicles and matters to be clarified

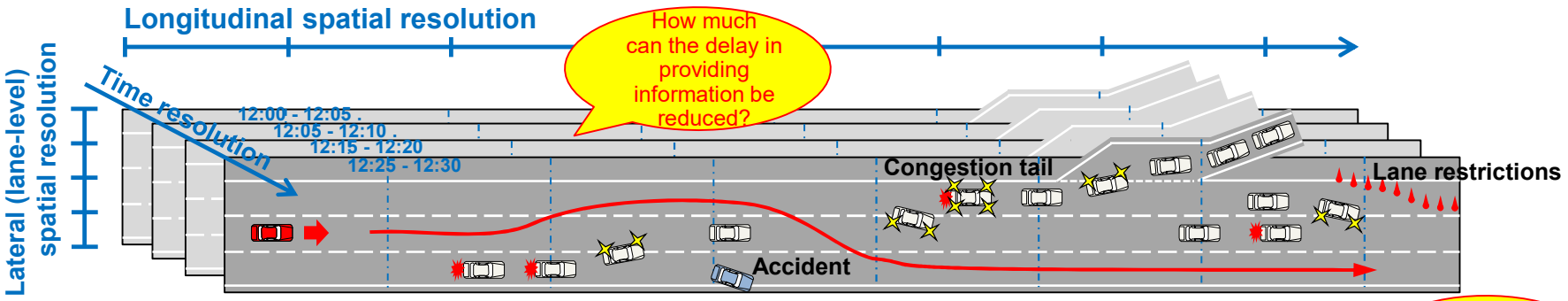


Image of the (lane-specific) probe information to be collected

What data is useful for incident determination?

Turn signal			Frequent (left)		Frequent (right)		Frequent (right)	
Braking		Frequent	Frequent		Frequent		Frequent	
Hazard flashing					Frequent			
Steering			Frequent (left)		Frequent (right)		Frequent (right)	
Sample frequency by speed range		Frequent in low speed range	Frequent in low speed range		Frequent in low speed range		Frequent in low speed range	
Speed by branch direction					Low speed on the left	Low speed on the left		

Image of lane-specific road traffic information to be generated

Data integration

What resolution is effective as support information?

Lane-specific road traffic information			Obstacle ahead in right lane		Congestion ahead in left lane		Obstacle ahead in left lane	

2.1. Study on Lane-specific Information Generation Technology

(1) Basic Study on How to Generate Lane-specific Information

■ How to pre-verify information generation method (draft)

○ Verification using actual data

- Obtain the actual probe information and verify the certainty of the information generation method, regarding lane restrictions (due to construction work or the like), which are announced in advance, and congestion starting from Route No.1 Haneda Line inbound Hamazakibashi JCT, where lane-specific traffic congestion constantly occurs, among the target use cases.
- The target incidents and vehicle behavior are checked with CCTV video images.

○ Verification using dummy data

- The certainty of the information generated is desirable to be verified based on the actual probe information. However, it is difficult to obtain lane-specific probe or turn signal information at 100-m intervals at an early stage, and only limited video images can be used for verification. Therefore, dummy data is also created and verified by reproducing use case incidents by means of traffic simulation and presuming the amount of probe information to be obtained.
- The verification clarifies the spatial variations in the points of turn signal indication with regard to the location of lane obstruction, the amount of data obtained at 100-m intervals, and the relationship with the sample frequency by speed range.

2.1. Study on Lane-specific Information Generation Technology

(2) Interviews with Probe Suppliers

- Interviews were conducted with multiple probe suppliers in order to organize the data format and information items regarding the available information obtained from vehicles and required for generating lane-specific information.

Interview period

・Late February to early March 2020

Interview method

・Send an interview sheet in advance and conduct an interview on the day.

Interview items

- Cooperation in providing probe information in the data format desired in this project
- Cooperation in providing information on-line during the FOT
- The cost, contract method, and coordination required to cooperate with this project, and more

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

i. Basic technology for generating lane-specific probes

- Among the methods discussed in 2.1, probe processing technology will be examined for those that are feasible to conduct FOT.
- In FY2019, the data format and information items were organized regarding the available information obtained from vehicles and required for generating lane-specific information.
- In FY2020, the information items, data aggregation definitions, and collection format (Json format) for collecting probe information from probe providers were organized. In addition, a hierarchical data format that takes into account the delay in unlinking from probe vehicles will be organized.

ii. Output format of lane-specific probes

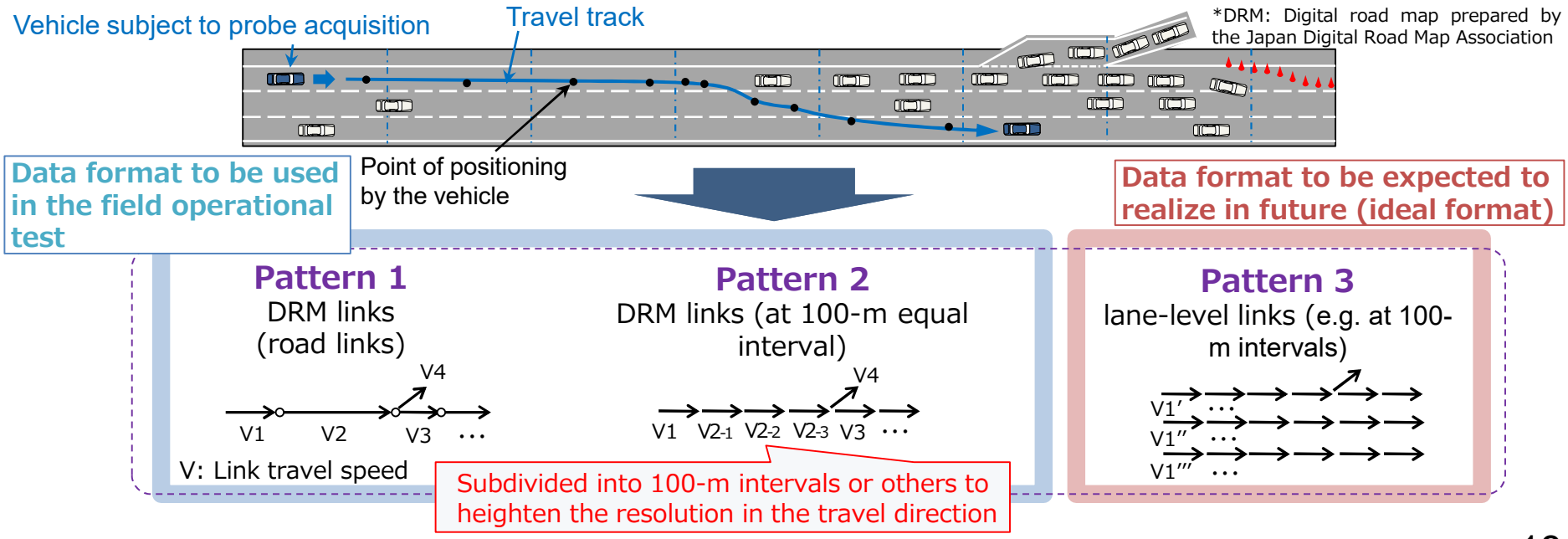
- As for the output format of lane-specific probes, we will verify whether the proposed interface specifications developed by JASPAR (Japan Automotive Software Platform and Architecture) can be used, and if this is difficult, we will create a proposed output format to achieve the purpose of the FOT.
- In FY2020, based on the interface specification draft developed by JASPAR, a draft of the output format was created to achieve the purpose of the verification experiment.

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

■ Available probe information

- The spatial aggregation unit of probe information (such as speed) is generally a link aggregation such as DRM*. (Pattern 1)
- It is desirable to use lane-level probe information (Pattern 3) to generate lane-level road traffic information, but in real terms commercial-base data (data obtained by commercial vehicles) are road-specific linked information (Patterns 1 and 2)
- Therefore, using probe information of Patterns 1 and 2 to generate lane-level road traffic information is being studied.



2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

■ Details of Probe Information to be Used

- Uses of probe information obtained from probe operators are roughly divided into desk study to evaluate the reliability of information generated with the established method, and verification of experiment system by actually distributing information to experiment participating vehicles during the 2020 field operational test.
- Probe information will be totaled every 5 minutes, considering current data collecting status or other factors.

Probe information to be used in field operational test

Unit of links for data collection	Data item		Field operational test	
			Desk study (using past data)	Verification with experiment system (online/real-time data)
Pattern 1 In DRM links	Speed by branch direction (5-minute interval)	Speed by branch direction at links before junction	○	○
Pattern 2 In DRM links (100-m interval)	**Link speed** (5-minute interval)	Average speed	○	○
		No. of vehicles by speed range(1)	○	○
	Frequency on vehicle events (5-minute interval)	Brake	○	○(2)
		Turn signal		
		Steering		

Note 1) Image of data format on No. of vehicles by speed range

Speed category	No. of vehicles
0＜V≦10km/h	
10＜V≦20km/h	
:	
110＜V≦120km/h	
120＜V	

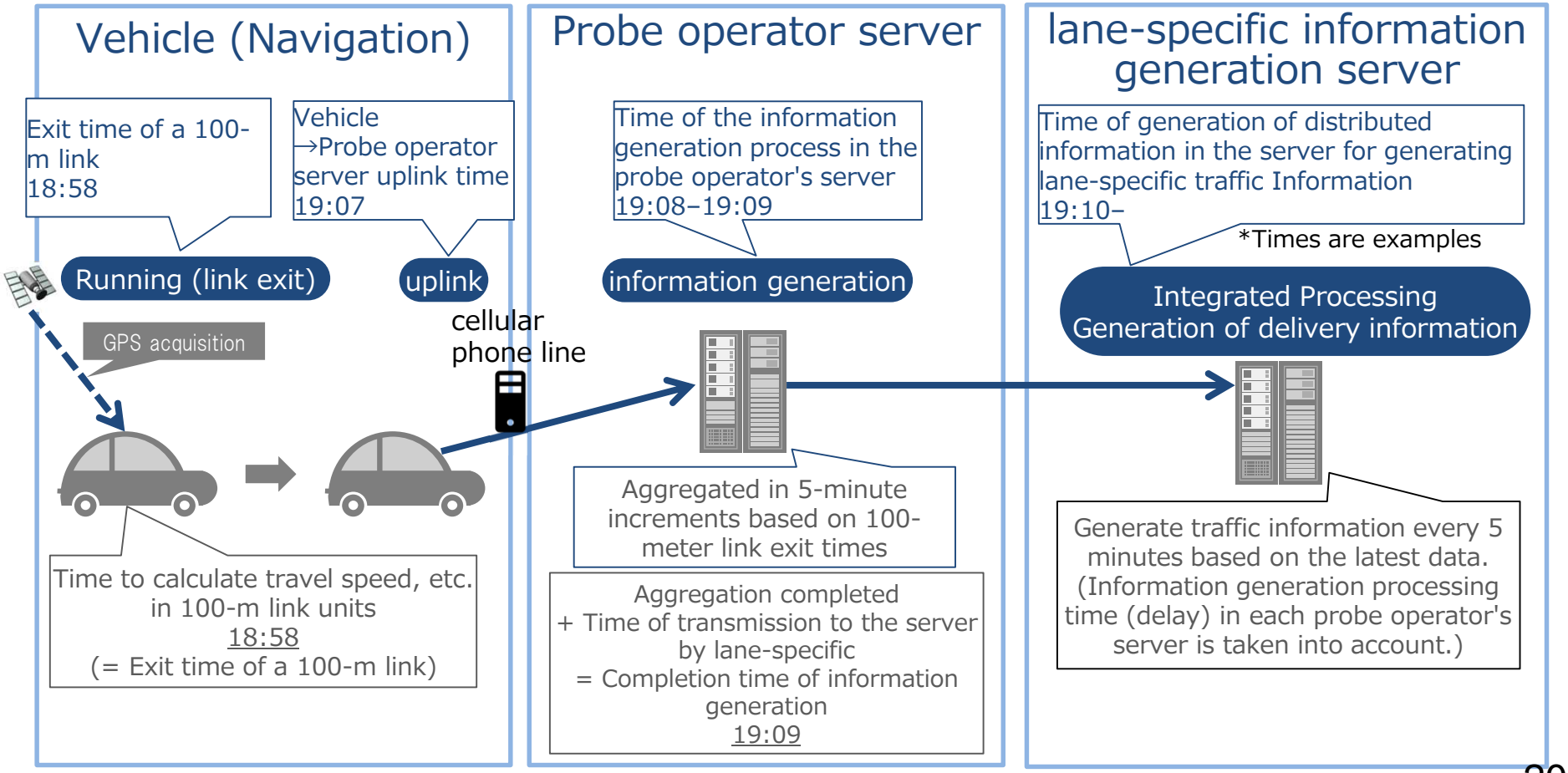
Note 2) Not used in the FY2020 FOT system

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

■ Data sharing (aggregation) (occurrence of uplink delays)

- It is assumed that there will be a certain amount of time before the driving information of the probe vehicle is uplinked to the information generation server of the probe provider, and this should be kept in mind when collecting probe information.



Flow from data acquisition to information collection at the vehicle

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

■ Data sharing (aggregation) (occurrence of uplink delays)

- It is assumed that there are many data that are uplinked late in the probe information, and it is possible that the required number of samples cannot be obtained only from the latest data.
- Therefore, the following should be considered in the data sharing (aggregation) phase.
  - Aggregation in 5-minute increments (called "class") based on probe vehicle travel times
  - Consolidates the most recent past data at each class (class 6). Class 1 consolidates data for the last 5 minutes, and class 6 for the last 30 minutes.
  - Examine the generation logic while checking the data acquisition rate of each hierarchical frame.

Verification items
・Data acquisition rate (occurrence of uplink delays)

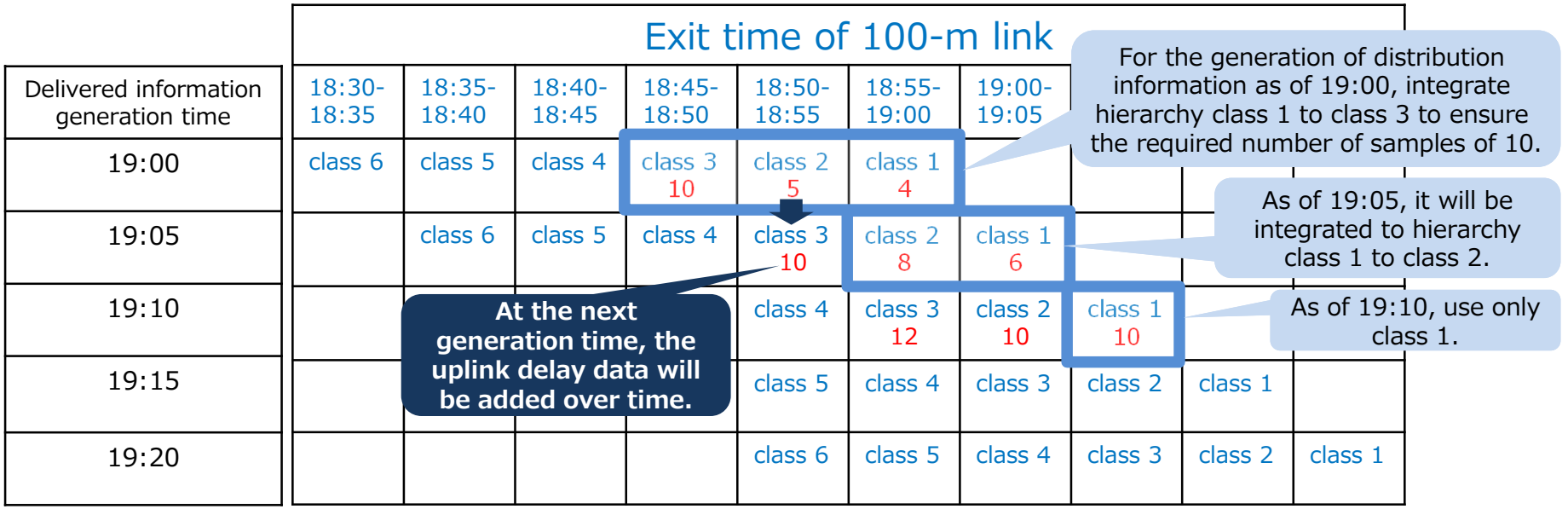


Image of data integration to ensure the required number of samples

***When the required number of samples is 10**

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.1 Technical Study

■ Data sharing (aggregation) (occurrence of uplink delays)

- The data collection format for aggregating data from probe providers is designed so that information up to 30 minutes prior to the collection deadline can be aggregated in 5-minute increments, taking into account uplink delays.

Format structure to be collected from probe providers

Configuration information		Main Information
Basic Information		Geodetic system, time zone, information generation time
Probe information	DRM Basic Information	DRM link version, secondary mesh code, link number
	class 1–6	Information up to 30 minutes prior to the collection deadline is aggregated in 5-minute increments.
	DRM link unit information	Average travel speed by direction
	class 1–6	Information up to 30 minutes prior to the collection deadline is aggregated in 5-minute increments.
	100m split link unit information	Split serial number, split link distance, average speed information, speed stratification information other vehicle information, average travel speed by direction

*From the probe provider, the data expression is in Json format, and the information is collected by file transfer using the HTTP protocol.

■ Data sharing (aggregation) (collected data items and definitions)

- Define uniform definitions for information items to be collected from probe providers.
- The definition of "other vehicle information (blinker, brake, etc.)" is also defined to count the number of events.

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.2 Technical evaluation

- Based on the results of the study in 2.1.1, it will be confirmed that the information necessary to create lane-specific information can be created from probe statistics (travel time by link, vehicle information by speed band, etc.) collected from probe providers. In addition, necessary improvements will be made based on the results of the FOT.
- In FY2020, we procured past probe statistics from several probe providers and confirmed the information generation rate by time zone section and the number of backward classes required for information generation.

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

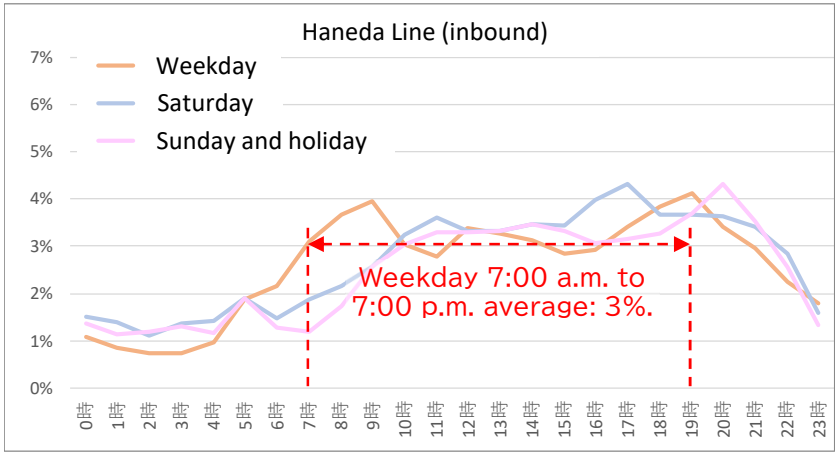
2.2.2 Technical evaluation

■Check the amount of probe information collected (contamination rate)

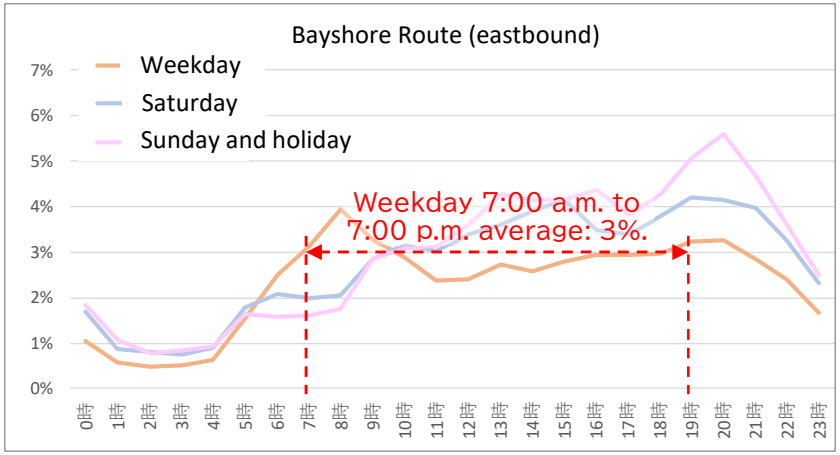
- The contamination rate of probe information (number of vehicles by speed stratification) that can be collected at present is about 3% on the Metropolitan Expressway (Route No.1 Haneda Line and Bayshore Route) (weekdays/daytime).
- Equivalent to 6 cars/5 minutes on Route No.1 Haneda Line (inbound) and 8 cars/5 minutes on Bayshore Route (eastbound).

○Number of units by speed stratum (100m section unit, mixing rate)
2020/7/8–8/7

Haneda Line (inbound)



Bayshore Route (eastbound)



*Comparison with FY2015 census traffic volume by time zone.

2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

2.2.2 Technical evaluation

■ Check the amount of probe information collected (number of units per 5 minutes)

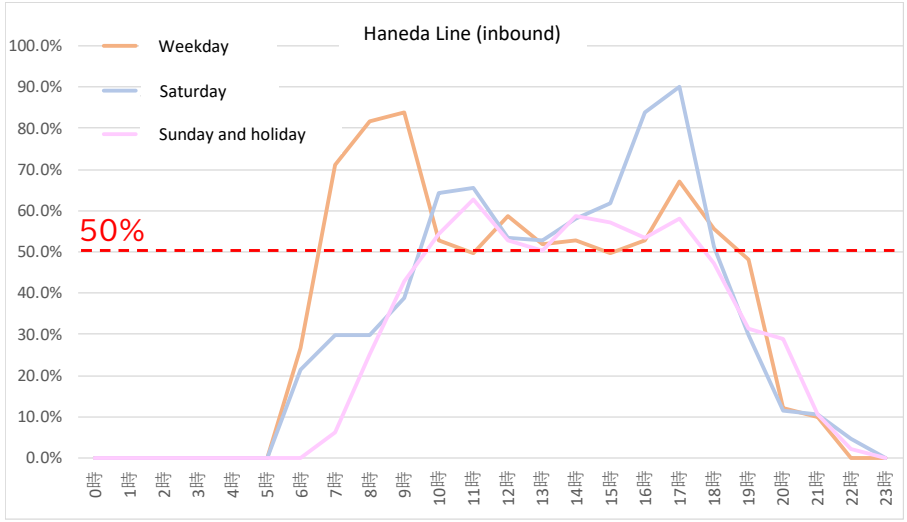
- On Route No.1 Haneda Line, regardless of the day of the week, generally more than 50% of the sections have 5 cars/5 minutes or more* during the daytime.
- On the Bayshore Route, generally more than 80% of the sections have 5 cars/5 minutes or more* during the daytime, regardless of the day of the week.
- Both routes cannot secure 5 cars/5 minutes at night.
  - ➢ In the daytime, there is a possibility of generating information with a certain level of accuracy with the current amount of collectable data.

*Number of samples for which the average travel speed can be calculated with an accuracy of ±10 km (95% confidence level) in the distribution of speeds on urban highways.

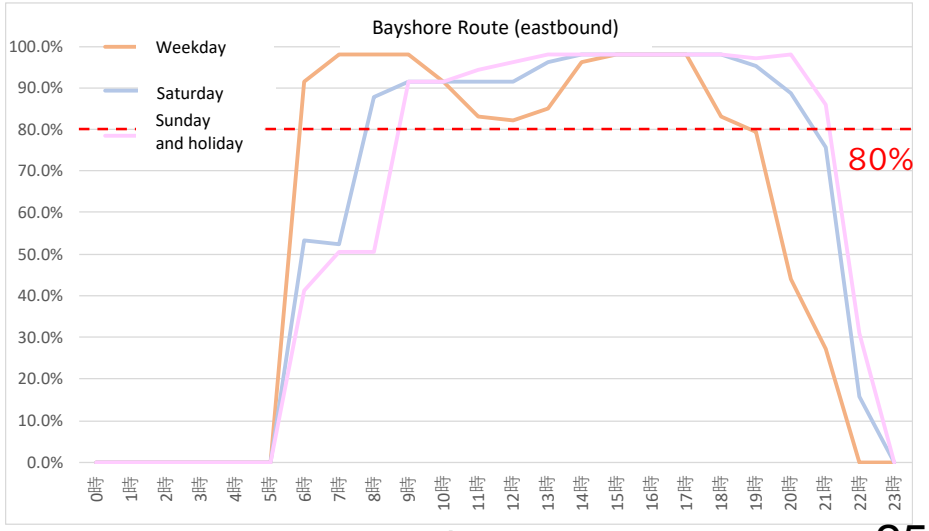
○Percentage of sections (in 100-meter increments) where the number of vehicles by speed stratum is 5 vehicles/5 minutes or more.

July 8, 2020 - August 7, 2020 Weekday average

Haneda Line (inbound)



Bayshore Route (eastbound)



2.2. Study and Evaluation of Lane-specific Probe Processing Technology Required for Generating Lane-specific Information

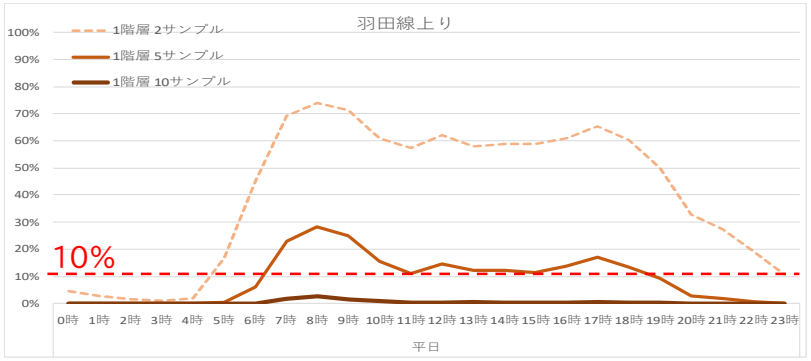
2.2.2 Technical evaluation

■ Uplink delay (backtracking time required to secure 5 units)

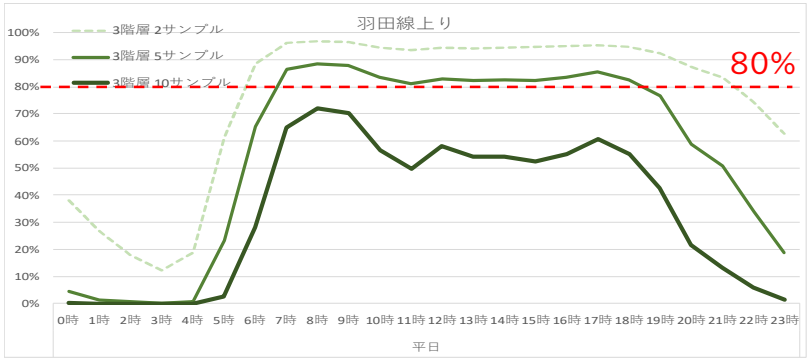
- Since there is a delay in the uplink when collecting probe information for each OEM, etc., data will be collected in 5-minute units up to 30 minutes in the past so that data collected late can be utilized.
- When trying to secure data for more than 5 units, the percentage of sections that can be collected in the last 5 minutes is 10%, 60% if you go back to the last 10 minutes, and about 80% if you go back to the last 15 minutes. (Haneda Line (inbound))
  - ➢ Taking uplink delays into account, it is expected to take about 15 minutes to collect data from five cars depending on the time of day and the segment, but this is expected to improve as the number of connected cars increases.

○Information generation rate Haneda Line (inbound) July 8, 2020 - August 7, 2020 Weekday average

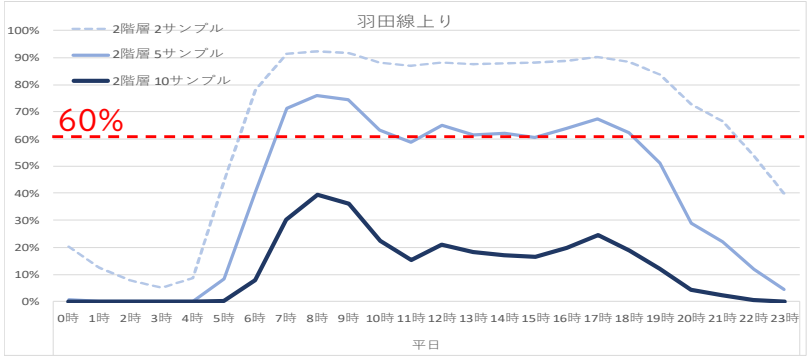
class 1 (Last 5 minutes)



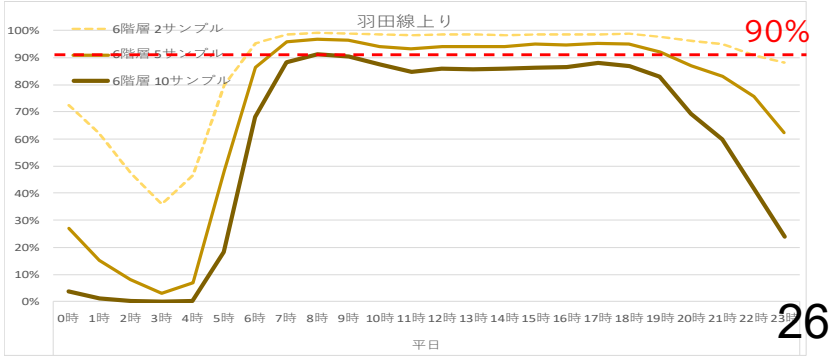
class 3 (Last 15 minutes)



class 2 (Last 10 minutes)



class 6 (Last 30 minutes)



2.3. Study and evaluation of data integration technology for generating lane-specific information

2.3.1 Technical Study

- Study how to integrate statistical data of probe information provided by each supplier into lane-specific information in consideration of the differences in the number of probe data items and accuracy while assuming the following.
- In FY2019～20, a basic study was conducted on the statistical processing method for integrating statistical data of probe information into lane-specific information.
- In FY2021, by improving the logic for generating lane-specific information, which is implemented in the FOT server, a logic that also uses vehicle event information (e.g., turn signal count) for generating lane-specific information was studied.

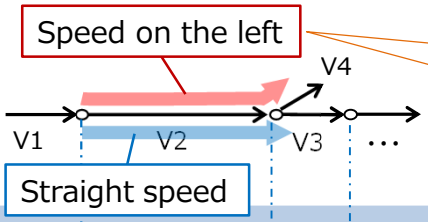
2.3. Study and evaluation of data integration technology for generating lane-specific information

2.3.1 Technical Study

■ Basic concept of information held by probe information links and lane-specific information

Information held by links for probe information to be used

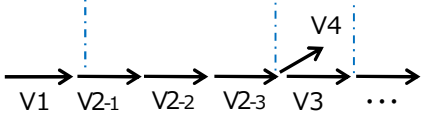
Pattern 1
DRM links (road link)
- Speed by direction at links before junction



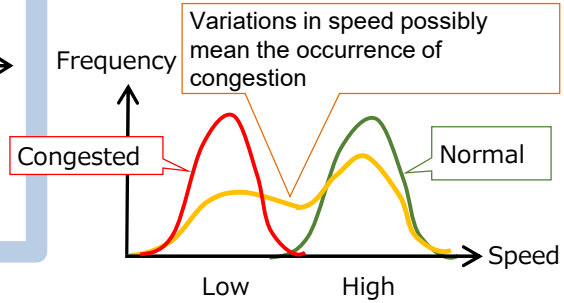
Speed by direction at links before junction

If the speed on the left is low, it is estimated that there is congestion in the left lane.

Pattern 2
DRM links (100 m equal interval)
- No. of vehicles by speed range
- Frequency on vehicle events (such as turn signals)



Frequency by speed range (speed distribution))



Frequency on vehicle events

Turn signal	Freq.
Left turn signal	15
Right turn signal	0
Left steering	15
Braking	9
:	

If many vehicles indicate left turn, it is estimated that there is trouble ahead in the left lane.

If many vehicles use braking, it is estimated that there is trouble ahead.

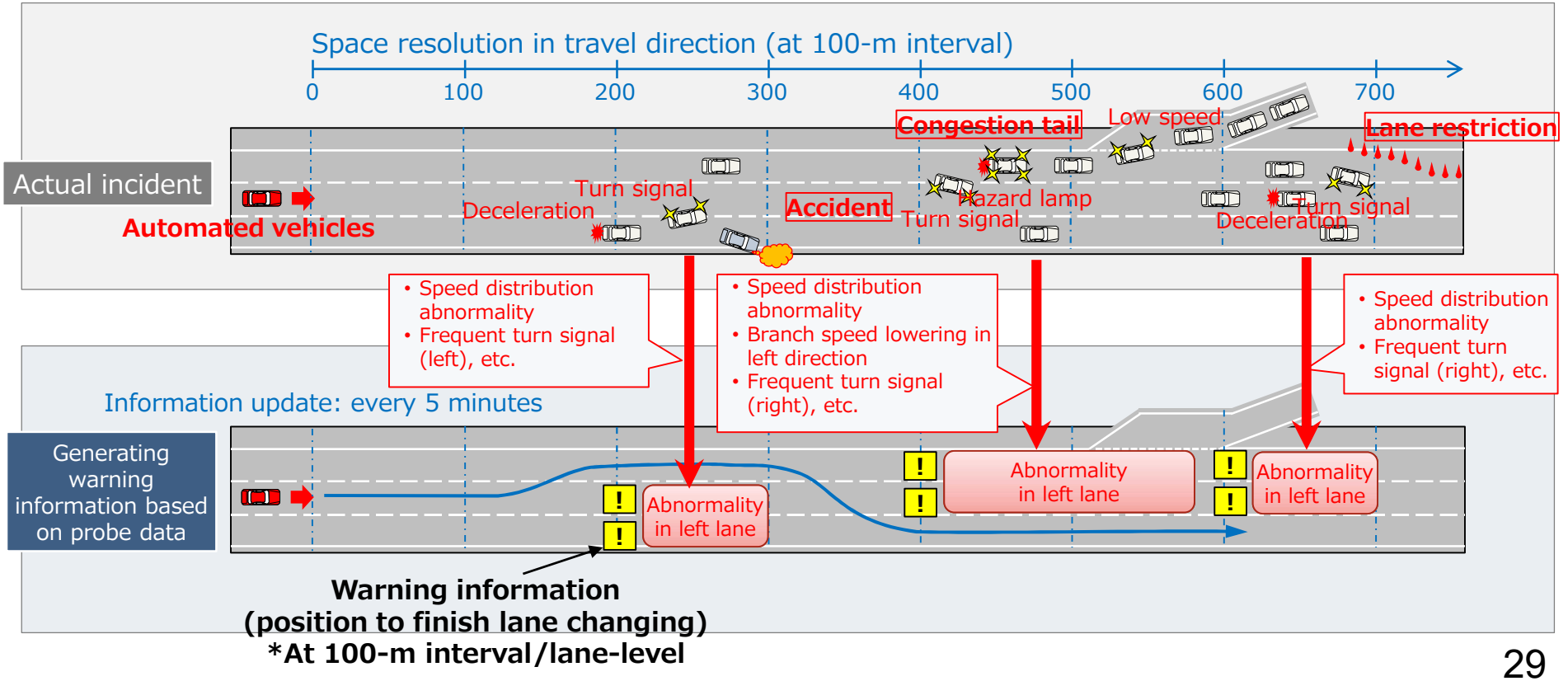
- Identifies a position where an abnormality occurs in the traveling direction at 100-m intervals from information on number of vehicles by speed range in Pattern 2.
- For lane-level abnormality, the direction (left or right) of the lane having the trouble is judged from turn signal information or the like in Pattern 2.
- At junctions, lane-level congestion status (left turn or straight) by branch direction is judged from the speed information by direction in Pattern 1.

2.3. Study and evaluation of data integration technology for generating lane-specific information

2.3.1 Technical Study

■ Lane-Level Road Traffic Information to be Generated

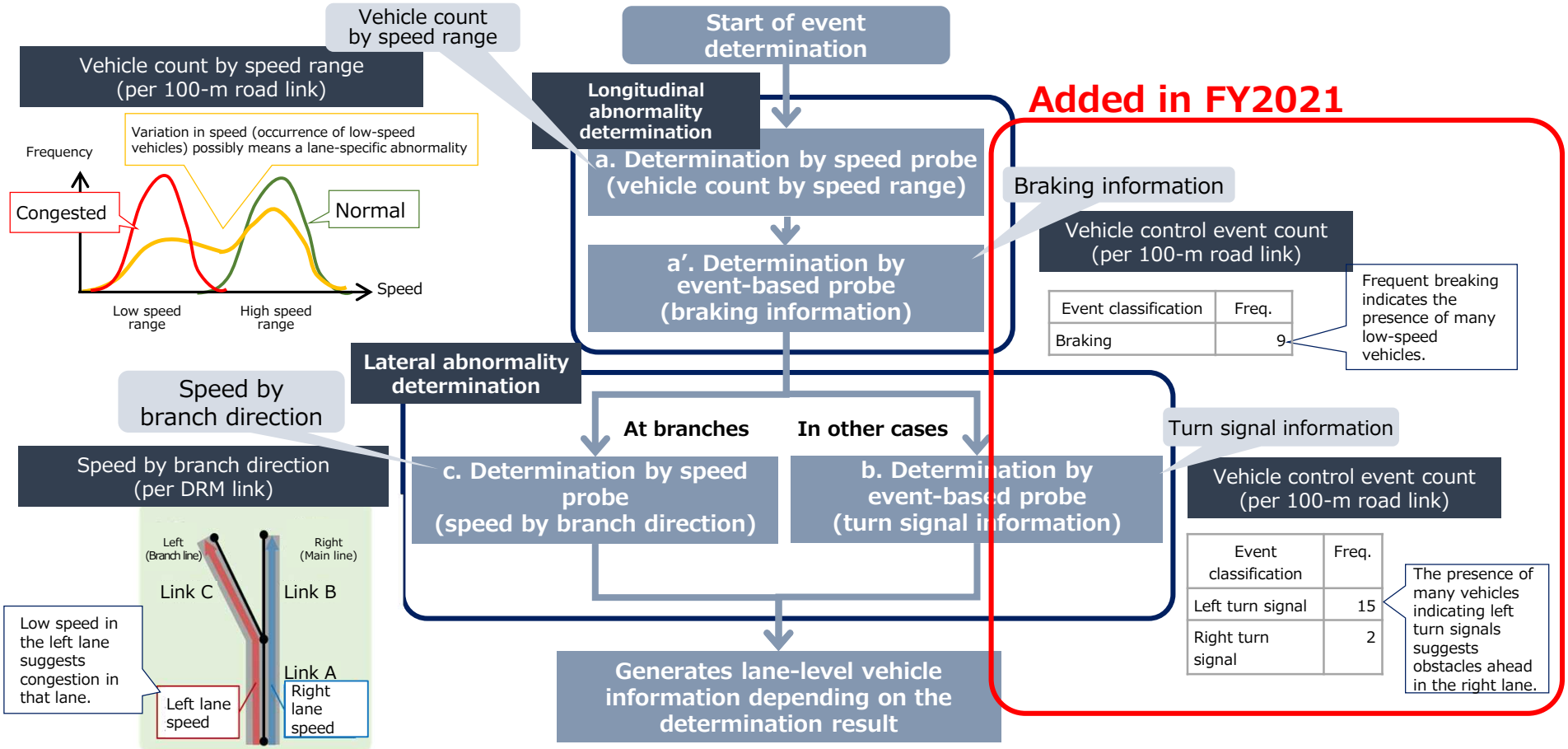
- Generation of the following warning information applicable to target use cases is studied.
- Since vehicle event information processing functions are not implemented in the experiment system for verification, use cases for congestion tails at the junction will be mainly verified.



2.3.1 Technical Study

■ Event determination flow for generating lane-specific vehicle information

- The event determination for generating warning information consists of two processes: congestion section determination (a, a') in the longitudinal (travel) direction and abnormality determination (b, c) in the lateral (lane) direction, which is for generating lane-level information.
- The lateral abnormality determination is divided into two processes: one to determine whether the congested lane is on the left or right based on the speed by branch direction (c) and the other to determine whether the obstructed lane is on the left or right in use cases other than branches (d).
- If an abnormality is determined only in the longitudinal direction, warning information is generated for all lanes.

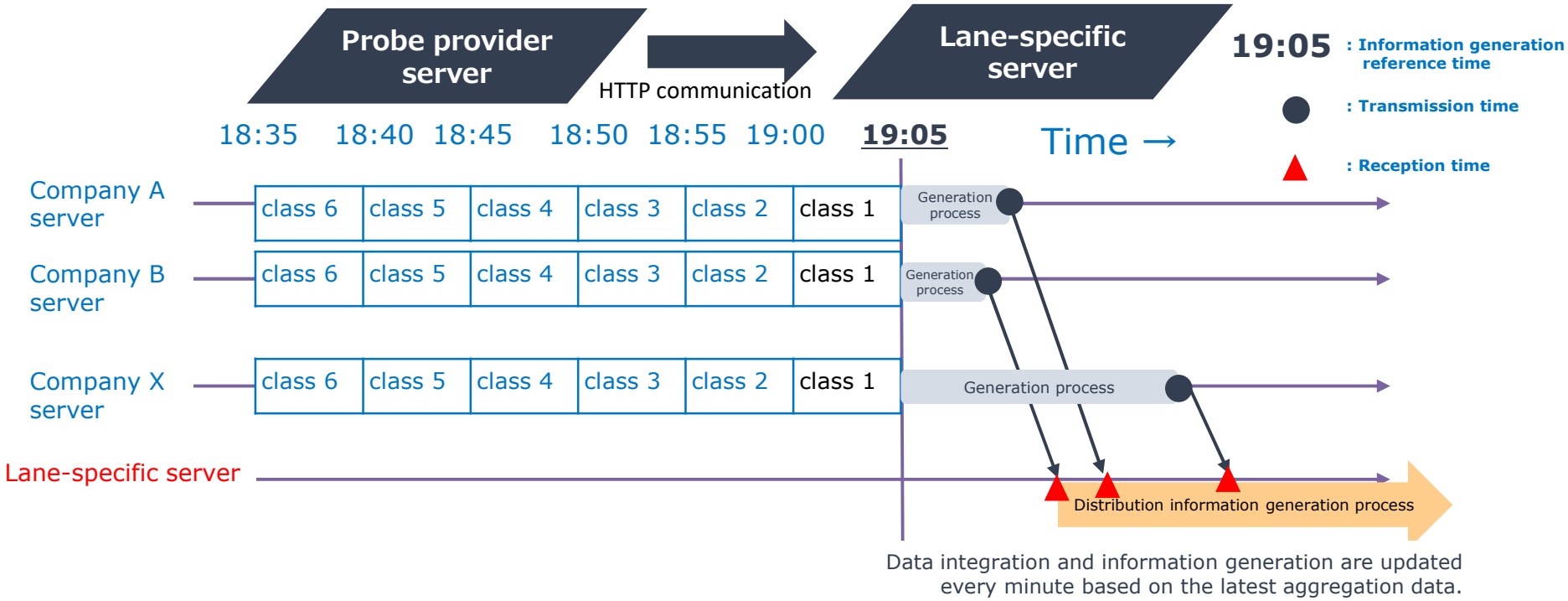


Basic flow of event determination and data used

2.3.1 Technical Study

■ Data integration and information generation considering variations in the time to receive information from different company servers

- In the experiment using real-time online data, the time when the FOT server can receive data varies depending on the time each probe provider requires to generate data.
- Therefore, data integration and information generation are set to be updated every minute based on the latest aggregation data, considering the delay in the time when the FOT server can receive probe information with respect to the information generation reference time as well as variations among probe providers.



Data integration and information generation considering variations in the time to receive information from different company servers

2.3. Study and evaluation of data integration technology for generating lane-specific information

2.3.2 Technology Assessment

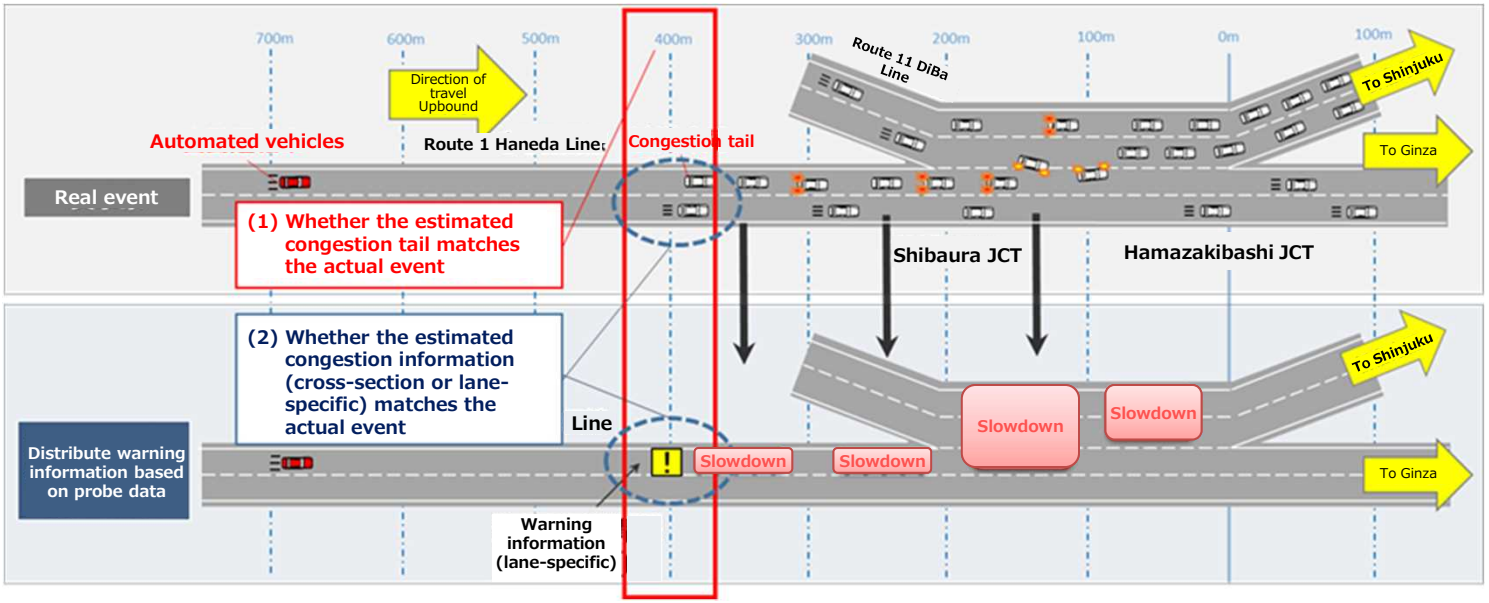
- Build a data integration server and create lane-specific information using a statistical processing method based on the technical study described in the previous section. Analyze the issues for practical use such as information accuracy of the created lane-specific information, and make necessary improvements.
- In FY2020, a data integration server was constructed and lane by lane information was generated using past probe statistics. Furthermore, the accuracy of the information was evaluated by comparing it with actual traffic conditions.
- In FY2021, the method for generating lane-specific information was verified by generating the information in a section other than branches (junction at Tokai JCT) using past probe statistics including turn signal information.

2.3.2 Technical Evaluation

■ Preliminary verification of information generation accuracy (event detection based on the vehicle count by speed range)

Verify the number of samples (by speed range) required to detect the congestion tail and speed differences by lane from the speed information. Specifically, compare the lane-specific traffic situation estimated based on the pseudo-probe information generated by simulation results with that (true value) obtained from the traffic micro-simulation results, and evaluate it by the event detection rate with respect to the true value.

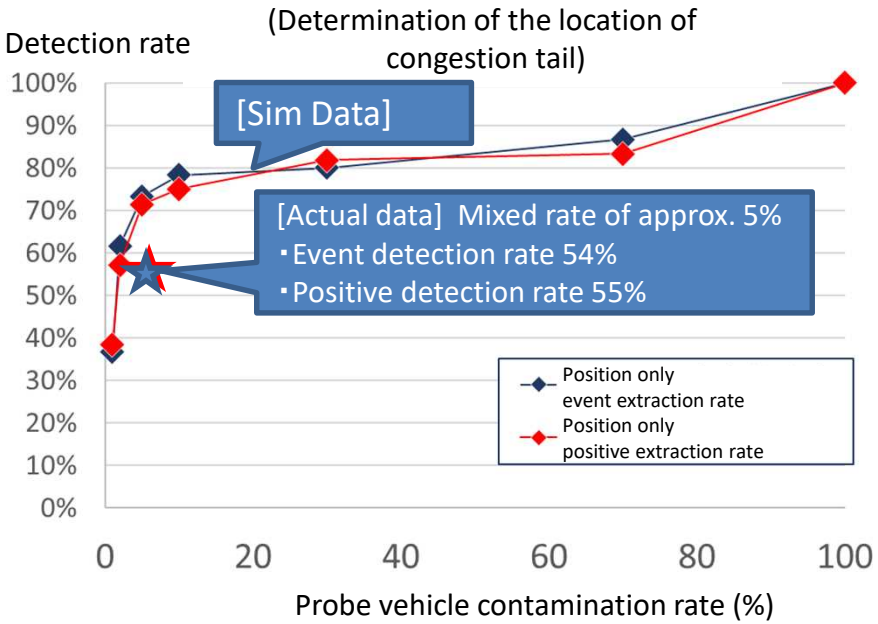
Image of validation of event detection method using speed information

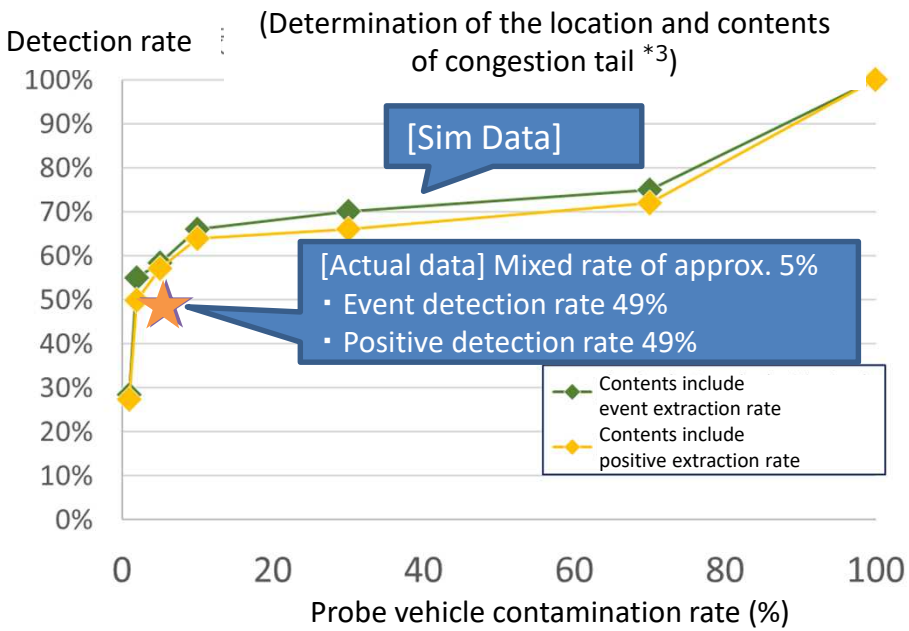


2.3.2 Technology Assessment

Preliminary verification of information generation accuracy (event detection using speed stratified volume data)

- Sorting out the accuracy of information generation according to probe vehicle mixing rate from traffic simulation results.*1
  - ➢ Information generation accuracy of about 70% is expected with a contamination rate of about 10%.
- The accuracy of information generation using the actual data collected this time*2 is 50-60% for the location of the congestion tail, and about 50% if the content (lane-specific traffic jam or cross-sectional congestion) is included.
  - ➢ Slightly lower accuracy than simulation results because uplink delay is taken into account in real data.





*1 Probe vehicle contamination rate: 1%, 2%, 5%, 10%, 30%, 70%, Number of judgment samples: 1% and 2% contamination rate ⇒ 2 vehicles, 5% and 10% contamination rate ⇒ 5 vehicles, 30% and 70% contamination rate ⇒ 10 vehicles

*2 Compared with the true value (lane-specific traffic jam and cross sectional traffic jam) confirmed by CCTV images and driving images

*3 Content judgment: Determine whether the traffic jam is lane-specific or cross-sectional.

●Event extraction rate = Percentage of congestion events detected by estimation out of actual congestion events

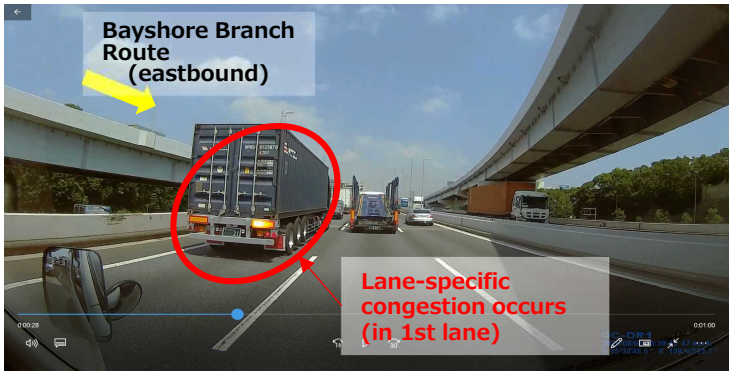
●Positive extraction rate = Proportion of congestion events detected by the estimation that are exactly on target

Relationship between probe vehicle mixing rate and event determination accuracy (Before Route No.1 Haneda Line inbound Hamazakibashi JCT)

2.3.2 Technical Evaluation

■ Verification of lane-level information generation using turn signal information based on past data (congestion at the junction at Tokai JCT)

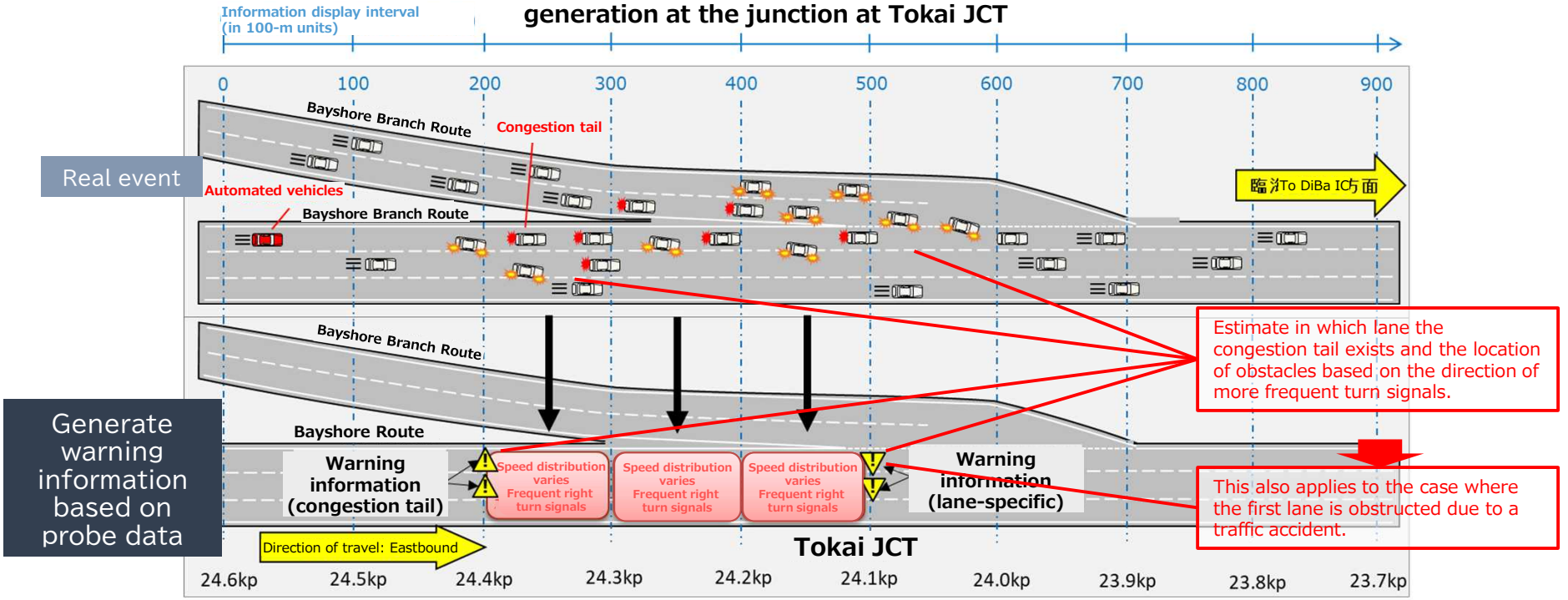
- On weekday mornings and evenings, lane-specific congestion is prone to occur mainly in the first lane at Tokai JCT on the eastbound Bayshore Route due to large numbers of vehicles merging from the Bayshore Branch Route.
- Verify from past probe data whether it is possible to generate warning information at the head and tail of congestion based on the information on continuous abnormal speed sections obtained from speed probe information and the information on behavior at junctions and congestion tails obtained from turn signal information.



Lane-specific congestion in front of a junction
(captured around 10:39 on August 6, 2020, during preliminary verification)

210928_review meeting

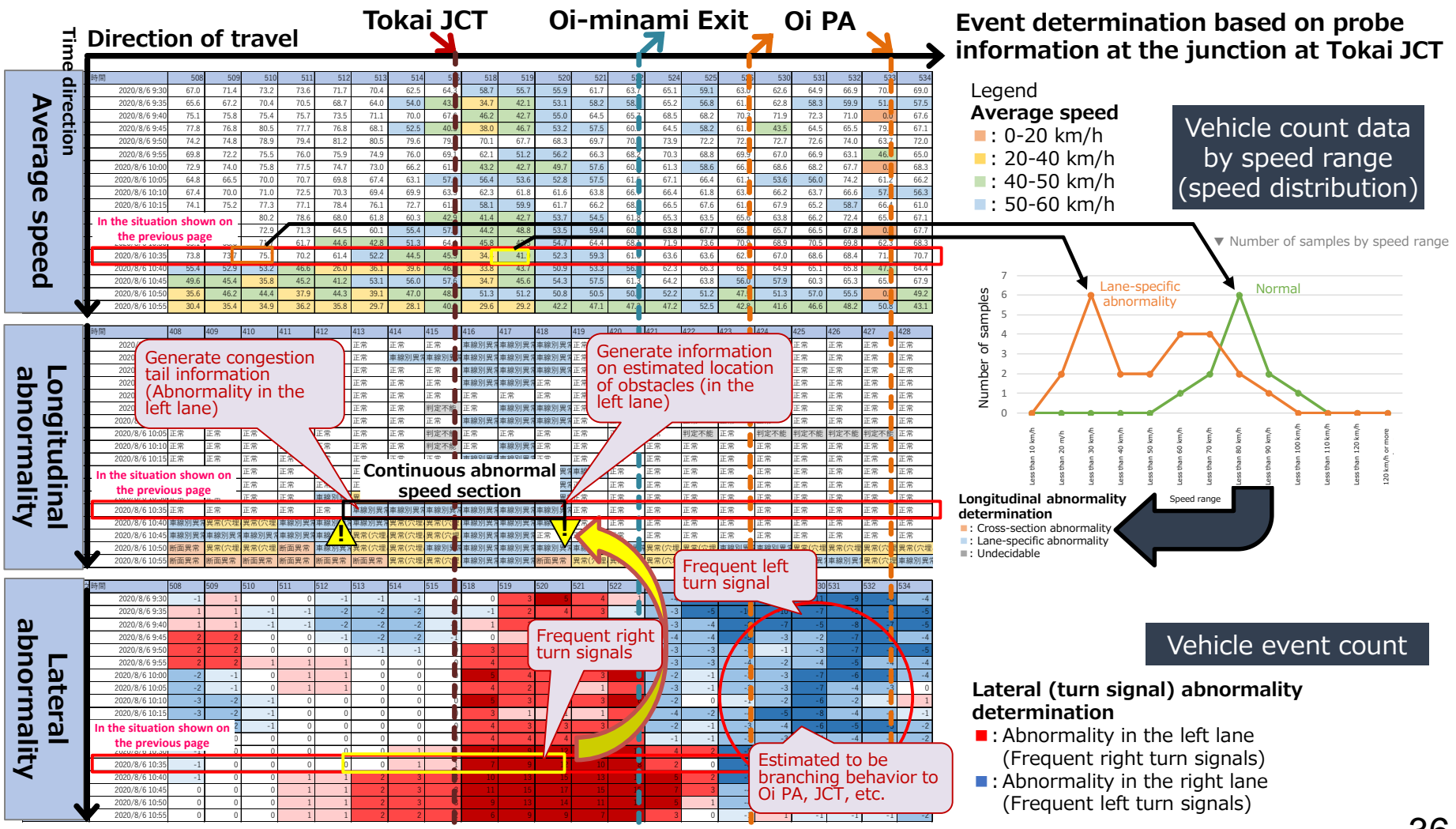
Concept of traffic phenomena and information generation at the junction at Tokai JCT



2.3.2 Technical Evaluation

■ Verification of lane-level information generation using turn signal information based on past data (congestion at the junction at Tokai JCT)

● By combining information on longitudinal abnormality (abnormal speed distribution) and lateral abnormality (frequent turn signals), it is possible to detect lane-specific congestion due to merging at Tokai JCT and generate information on the location of obstacles and the congestion tail (lane-specific in some time of day).



(From probe data during preliminary verification on August 6, 2020)

2.4. Study and Evaluation of Lane-specific Information Distribution Technology

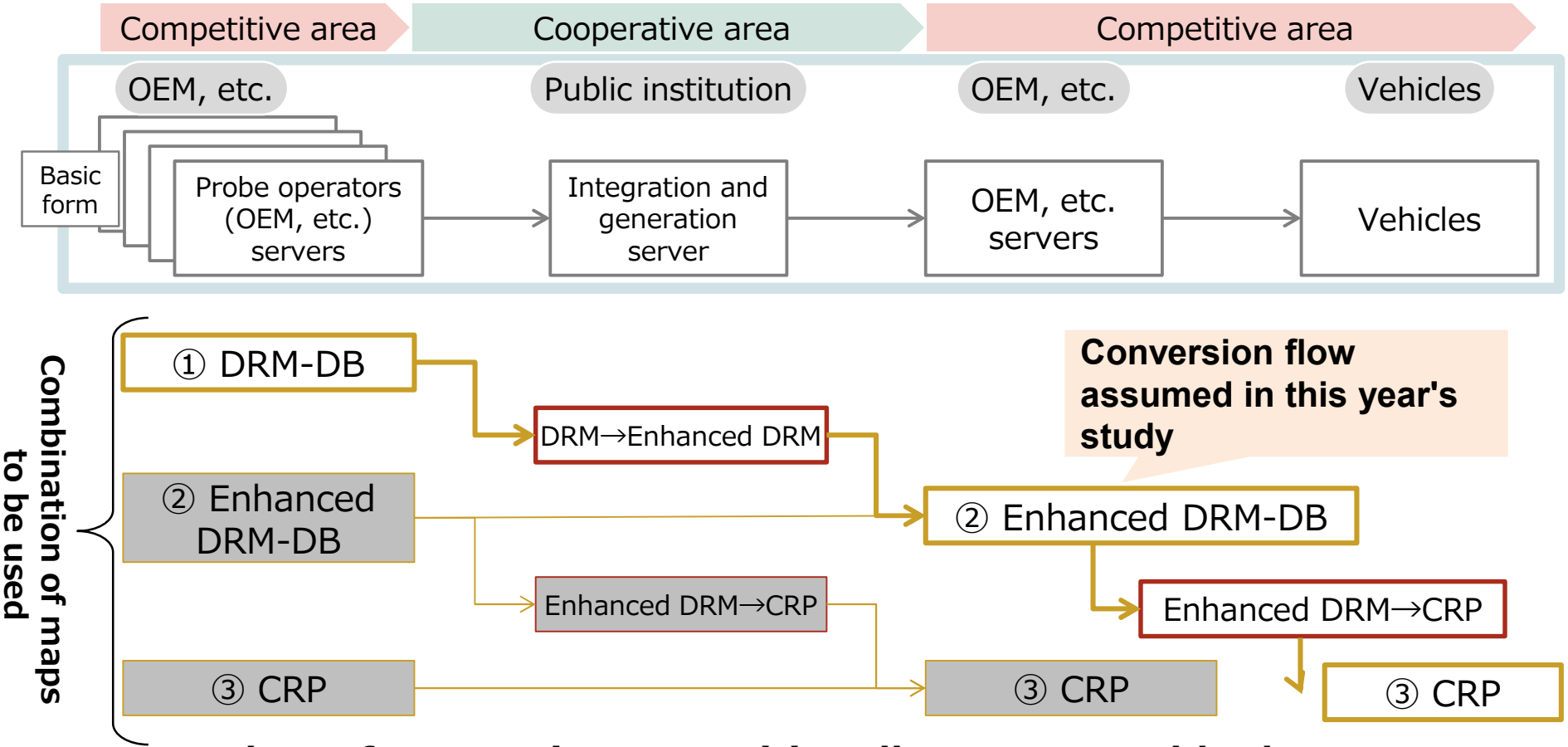
2.4.1 Technical Study

- Examine the technology for providing the lane-specific information integrated in 2.3 above to vehicles participating in the experiment or servers that relay the information (which are expected to be substituted by telematics centers of automobile manufacturers at the stage of social implementation in the future).
- Specifically, examine the message format after examining the location reference method for superimposing lane-specific information on high-precision 3D maps, lane-specific information items to be provided depending on the location, and so on. The examination will be based on other SIP measures and examinations conducted by other parties.
- Then, examine the position reference method, the contents of the lane-specific information items to be provided, the encoding scheme, and others to embody the encoding method.
- In FY2020, how to create node link maps was examined based on the position reference method for superimposing lane-specific information on high-precision 3D maps.

2.4.2 Technology Assessment

■ Conversion to positionally representable data

- In the data flow from the probe provider to the vehicle, the combination of maps to be used is assumed to be as follows.
  - ➢ This section summarizes the issues to be addressed for future practical use in generating the necessary extended DRM and CRP maps.



Flow of conversion to positionally representable data

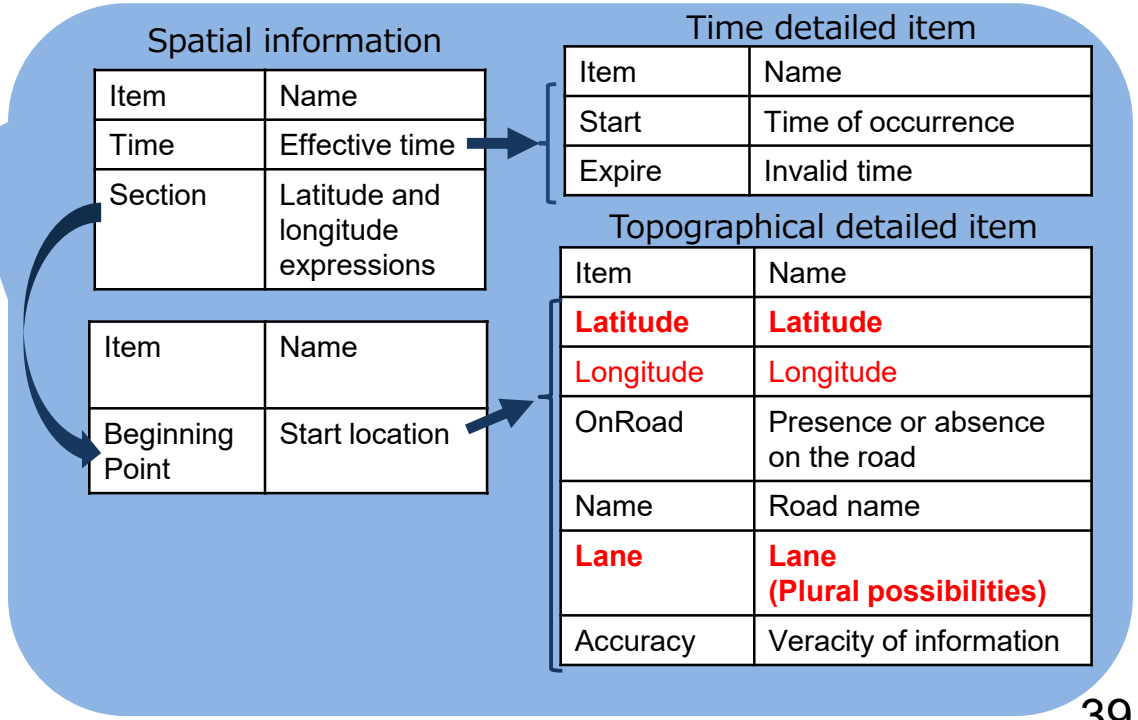
2.4.2 Technology Assessment

■ Data sharing (distribution) (Data Sharing Specification (Draft))

- JASPAR specification standards will be applied for data sharing between the centers when the generated information is distributed from the information integration and generation server to the servers of the Tokyo Waterfront Area Operational Test Consortium (assuming future OEM telematics centers, etc.).
- The message set referenced between servers consists of "spatial information" and "content body," where the spatial information includes valid time and latitude/longitude expressions.
- The point and lane classification for displaying the generated alert information is described by the latitude/longitude and lane of the point details item.

Image of message structure

Administration		**Management information**
Container	**Basic**	**Spatial information**
	Contents	Content body



2.4. Study and Evaluation of Lane-specific Information Distribution Technology

2.4.2 Technology Assessment

- Based on the results of the technology study, information by lane will be created using data expressions based on the definitions of the location reference method determined, and an interface will be implemented to exchange information between the probe data integration server for the verification experiment and the server for the experiment prepared by the Tokyo Waterfront Area Operational Test Consortium, and the appropriateness of using the technology will be evaluated. The details of the interface to be implemented will be decided in consultation with the Consortium.
- In FY2020, information by lane was created using data expressions based on the definition of the location reference method in accordance with the upgraded DRM, and an interface was implemented on the probe data integration server to exchange information with the server for the experiment of the Tokyo Waterfront Area Operational Test Consortium.

■Conversion to positionally representable data

○ Development of data infrastructure for representing lane level road traffic information

- For the process of integrating and generating lane-specific traffic information, the road level map (DRM-DB in the FOT) and the high-precision 3D map are used as the source data to generate the data that organizes the number of lanes in the section every 100 meters.
- It is necessary to develop a data infrastructure capable of representing lane-specific positions and to establish a system for continuous updating.

2.4. Study and Evaluation of Lane-specific Information Distribution Technology

2.4.2 Technology Assessment

■ Data sharing (distribution)

○Data distribution specification

- Through the FOT, we clarified the issues with the current JASPAR specifications when distributing alert information.
- Although the current specifications do not specify the "congestion tail" as alert content, the "99: Others" marker number is used in the FOT to explicitly distribute information on the congestion tail.

→ Consideration will be given to assigning a special marker number for congestion tail information as needed.

○Data delivery processing time

- The server side of the Tokyo Waterfront Area Operational Test Consortium acquires lane-specific road traffic information in arbitrary one-minute cycles and distributes it to the experiment participants.
- To achieve 1-minute delivery, an API that can be processed in about 3 seconds must be implemented.

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

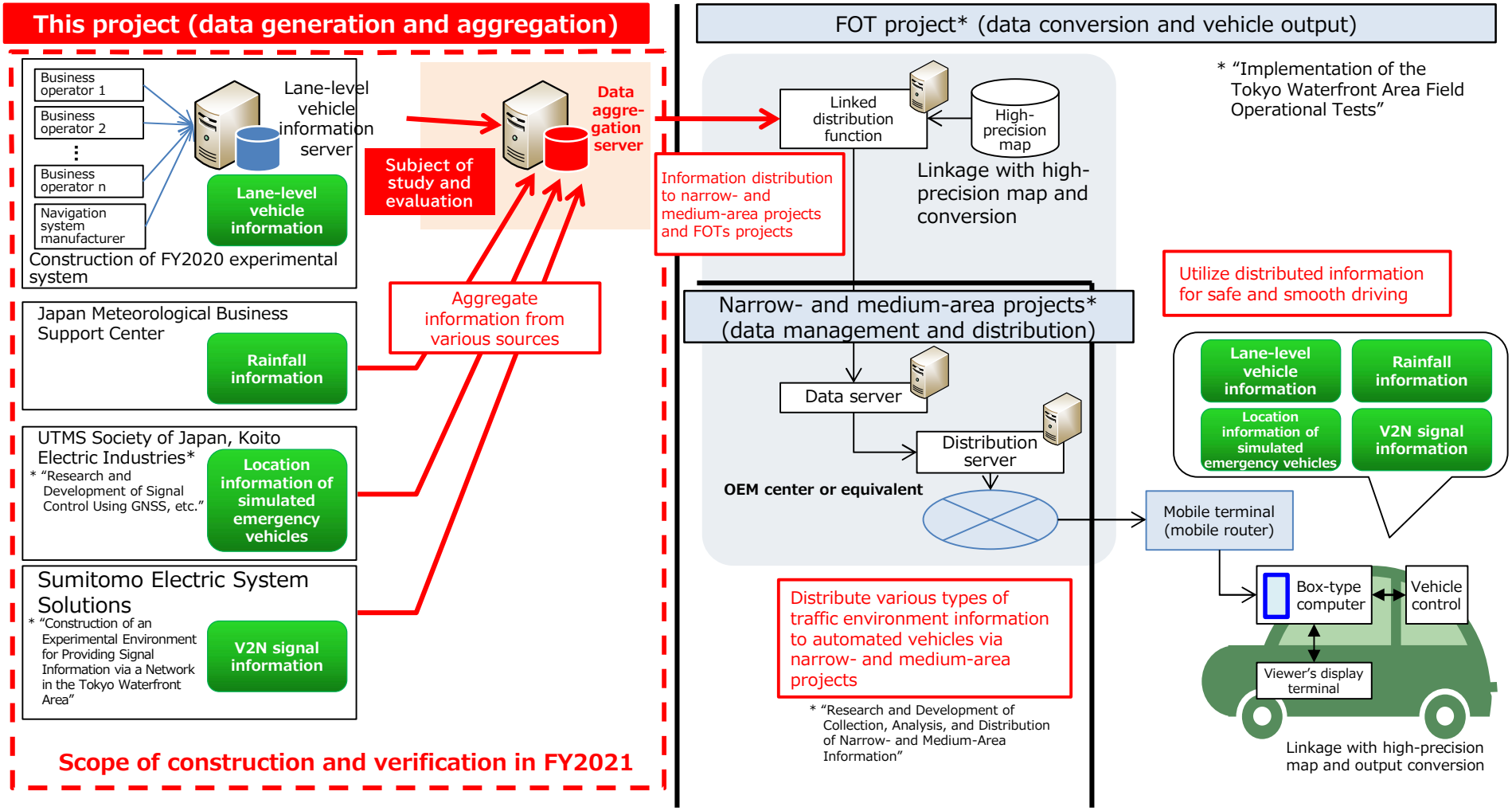
- Based on 2.1 through 2.4 above, technology for collecting lane-level vehicle information and other traffic environment information (see table below) from information sources was studied.

Traffic environment information	Information source	Notes
Lane-level vehicle information	Lane-level vehicle information server	Generated and distributed in this project
Rainfall information	Japan Meteorological Business Support Center	Generated in the information source side business and distributed in this project
Location information of simulated emergency vehicles	UTMS Society of Japan, Koito Electric Industries * "Research and Development of Signal Control Using GNSS, etc."	Generated in other SIP project and distributed in this project
V2N signal information	Sumitomo Electric System Solutions * "Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area"	Generated in other SIP project and distributed in this project

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

- Technologies for collecting and distributing various types of traffic environment information that are to be implemented in the data aggregation server shown in the figure below are studied and evaluated in 2.5 and 2.6.



2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

- Based on the interface specifications of the information source, study and organize the distribution cycles, information representation formats, and communication methods of various types of traffic environment information.

Traffic environment information	Information source	Collection cycle	Information representation format	Communication method
Lane-level vehicle information	Lane-level vehicle information server	1-minute cycle	JASPAR: JSON data Contents: attention	HTTP
Rainfall information	Japan Meteorological Business Support Center	5-minute cycle	GRIB2 (International Synoptic Code FM92 GRIB Binary Lattice Point Data Weather Report Format (Version 2))	SFTP
Location information of simulated emergency vehicles	UTMS Society of Japan, Koito Electric Industries	As needed	Proprietary binary data	UDP
V2N signal information	Sumitomo Electric System Solutions	As needed	Proprietary binary data	UDP

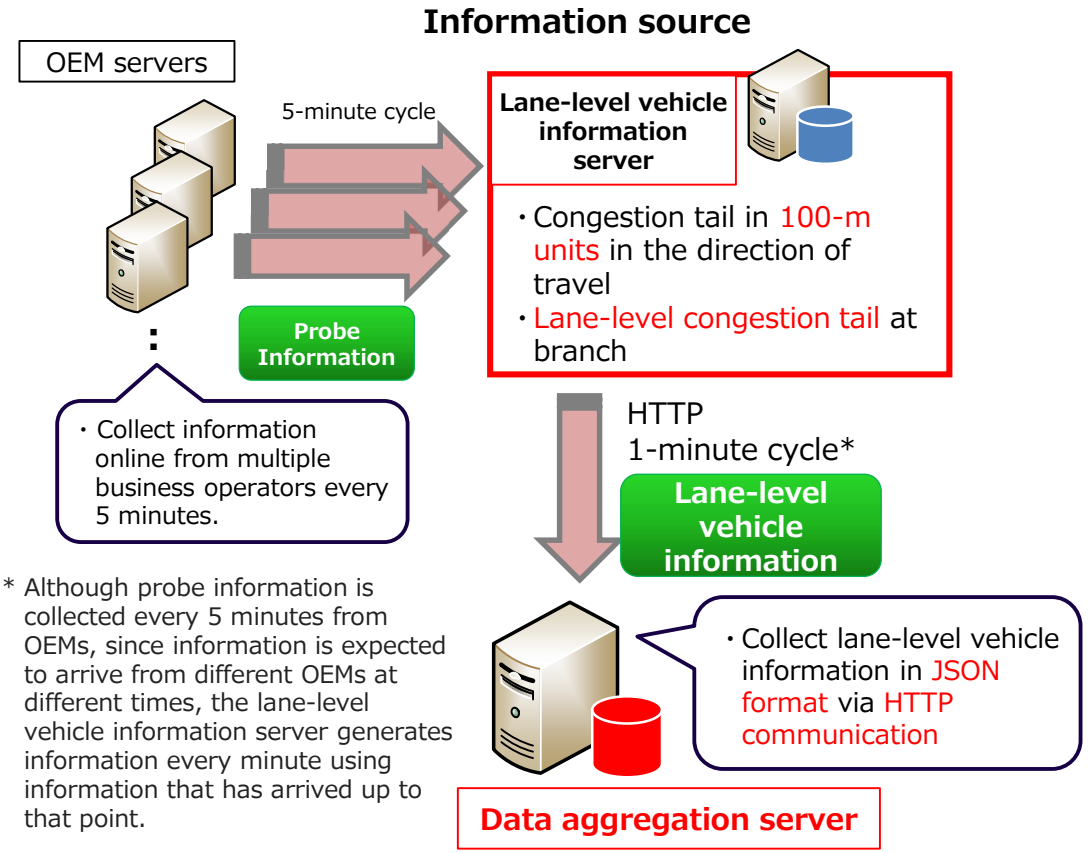
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(1) Study on technology for collecting lane-level vehicle information

■ Information collection specifications overview

- Collect lane-level vehicle information according to the interface specifications (JASPAR specifications) on which information was generated and distributed by the lane-level vehicle information server constructed in this project in FY2020.
- As warning information of JASPAR specifications, collect data in JSON format every minute via HTTP communication.
- The information items of lane-level vehicle information conform to those defined in 2.1 through 2.4.



* Although probe information is collected every 5 minutes from OEMs, since information is expected to arrive from different OEMs at different times, the lane-level vehicle information server generates information every minute using information that has arrived up to that point.

JSON format in accordance with the warning information of JASPAR specification (Contents: attention)

```
"container":[
 {"basic":{
  "time":{
   "start":"2020-10-01T13:30:00.000",
   "expire":"2020-10-01T13:35:00.000"
  },
  "section":{
   "beginningPoint":{
    "latitude":36.1234567,"longitude":139.1234567,
    "onRoad":"on","name":"Metropolitan Expressway Haneda Line"
    "lane":["1","2"],"accuracy":"1"
   }
  }
  "contents":{
   "attention":{"sequence":"1","subject":"50"}
  }
 }
]
```

Marking number
50: Congestion tail
60: Obstacles

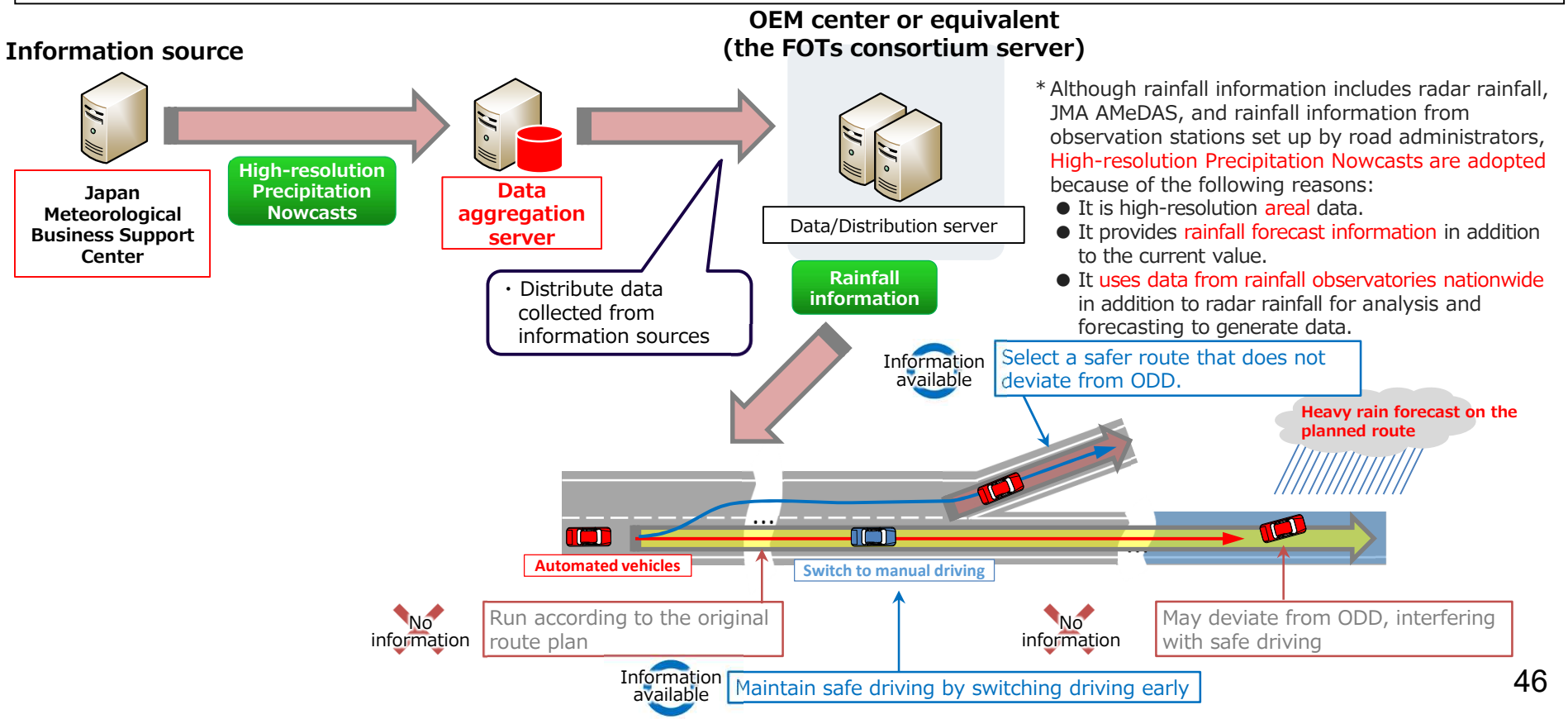
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(2) Study on technology for collecting rainfall information

■ Empirical hypothesis about information collection and distribution

- Use high-definition rainfall information to expect deviations from ODD, then issue TOR to drivers and change the route plan with time to spare.
- Use the existing High-resolution Precipitation Nowcasts distribution service to distribute rainfall forecast information expressed by the latitude and longitude of the center coordinates of 250-meter grids at five-minute intervals to the FOTs project side.



2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(2) Study on technology for collecting rainfall information

■ Information collection specifications overview

- Use the existing High-resolution Precipitation Nowcasts distribution service to collect High-resolution Precipitation Nowcasts provided in accordance with the online distribution specifications of the Japan Meteorological Business Support Center.
- According to the above distribution specifications, collect precipitation intensity in GRIB2* format and 5-minute accumulated precipitation via SFTP communication every 5 minutes (see the next page for details of data items).

* GRIB2: International Synoptic Code FM92 GRIB Binary Lattice Point Data Weather Report Format (Version 2)

Information source

Japan Meteorological Business Support Center

■ **High-resolution Precipitation Nowcasts**

- Created based on the observation data from the JMA weather radar and MLIT XRAIN, data from ground observation stations, etc.
- Distributes 5-minute instantaneous precipitation intensity and 5-minute accumulated precipitation in 250-m grids (1-km grids at sea).
- Distributes the real-time value and forecasts per 5 minutes for up to the next 30 minutes.

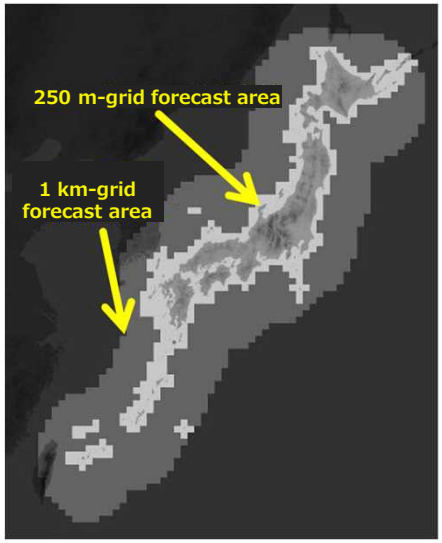
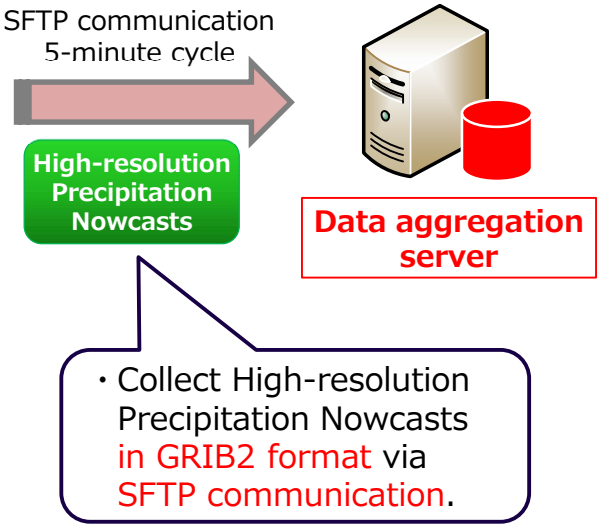


Image Source: Technical Information on Distribution Materials (Weather Edition) No. 398 Launch of High-resolution Precipitation Nowcasts (Forecast Department, Japan Meteorological Agency, May 30, 2014 (partially revised on August 5, 2014))
https://www.data.jma.go.jp/suishin/jyouhou/pdf/398.pdf



2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(2) Study on technology for collecting rainfall information

■ Information collection specifications overview

Data specifications in High-resolution Precipitation Nowcasts (example of rainfall intensity)

Section No.	Section name / Applicable template	Octet	Details	Table	Value	Notes
0	Index section	1-4	GRIB		"GRIB"	International Alphabet No. 5 (CCITT IA5)
		5-6	Reserved		missing	
		7	Material field	Code table 0.0	0	Meteorological field
		8	GRIB version number		2	
		9-16	Overall length of GRIB report		******	
1	Identification section	1-4	Section length		21	
		5	Section number		1	
		6-7	Identification of the creation center	Common code table C-1	34	Tokyo
		8-9	Sub creation center		0	
		10	GRIB master table version number	Code table 1.0	10	Current operational version number (the latest version is
		11	GRIB regional table version number	Code table 1.1	1	Regional table version 1
		12	Meaning of reference time	Code table 1.2	1	Forecast start time
		13-14	Material reference time (year)		*1	
		15	Material reference time (month)		*1	
		16	Material reference time (day)		*1	
		17	Material reference time (hour)		*1	
		18	Material reference time (minute)		*1	
		19	Material reference time (second)		*1	
		20	Creation status	Code table 1.3	T	0: Current product, 1: Current test product
		21	Type of material	Code table 1.4	2	Analysis and forecast products
2	Locally used section	Not used			Omitted	
3	Grid system definition section	1-4	Section length		72	
		5	Section number		3	
		6	Source of grid system definition	Code table 3.0	0	See code table 3.1.
		7-10	Number of materials		*2	Variable
		11	Number of octets in the list that defines the number of grid points		0	
		12	Description of the list that defines the number of grid points		0	
		13-14	Grid system definition template number	Code table 3.1	0	Latitude/longitude grid
	From here Template 3.0	15	Shape of the earth	Code table 3.2	4	GRS80 spheroid
	↓	16	Scale factor for the radius of the earth sphere		missing	
	↓	17-20	Scaled radius of the earth sphere		missing	
	↓	21	Scaled factor for the major axis of the earth spheroid		1	
	↓	22-25	Scaled length of the major axis of the earth spheroid		63781370	
	↓	26	Scaled factor for the minor axis of the earth spheroid		1	
	↓	27-30	Scaled length of the minor axis of the earth spheroid		63567523	
	↓	31-34	Number of grid points along the latitude line		*2	Variable
	↓	35-38	Number of grid points along the longitude line		*2	Variable
	↓	39-42	Basic angle of the original creation area		0	
	↓	43-46	Subdivisions of the basic angle used to define the longitude and latitude of the endpoint and the directional increment		missing	
	↓	47-50	Latitude of the first grid point	In 10-6 degree units	*2	
	↓	51-54	Longitude of the first grid point	In 10-6 degree units	*2	
	↓	55	Resolution and component flags	Flag table 3.3	0x30	
	↓	56-59	Latitude of the last grid point	In 10-6 degree units	*2	
	↓	60-63	Longitude of the last grid point	In 10-6 degree units	*2	
	↓	64-67	Increment in i-direction	In 10-6 degree units	*	3125[1/80/4] for 250 m area, and 12500[1/80] for 1 km area
	↓	68-71	Increment in j-direction	In 10-6 degree units	*	2083[(2/ 3)*(1/80)/4] for 250 m area, and 8333[(2/ 3)*(1/80)] for 1 km area
	To here Template 3.0	72	Scanning mode	Flag table 3.4	0x00	

Source: Technical Information on Distribution Materials (Weather Edition) No. 398 Launch of High-resolution Precipitation Nowcasts (Forecast Department, Japan Meteorological Agency, May 30, 2014 (partially revised on August 5, 2014))
https://www.data.jma.go.jp/suishin/jyouhou/pdf/398.pdf

[Reference time]
- Time of the dataset provided
- Described in Coordinated Universal Time (UTC)

[Lattice system definition, earth shape, etc.]
- Defines the coordinate system and ellipsoid with the codes in the GRIB2 code table.

[Number of grid points, latitude and longitude of endpoints, etc. (definition of grid points)]
- The High-resolution Precipitation Nowcasts provide information by dividing entire Japan into multiple regions.
- For each divided region, defines the latitude and longitude of the northwest and southeast end grid points (center of the grid) and the number of grid points included, etc.

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(2) Study on technology for collecting rainfall information

■ Information collection specifications overview

Data specifications in High-resolution Precipitation Nowcasts (example of rainfall intensity)

Section No.	Section name / Applicable template	Octet	Details	Table	Value	Notes
4	Product definition section	1-4	Section length		82	
		5	Section number		4	
		6-7	Number of coordinate values immediately after the template		0	
		8-9	Product definition template number	Code table 4.0	50011	Predictive product using X-band radar (Extended version of Template 4.8)
	From here Template 4.50011	10	Parameter category	Code table 4.1	1	Humidity
	↓	11	Parameter number	Code table 4.2	*	203: Precipitation intensity level (analysis, forecast) 214: Factors of precipitation intensity error
	↓	12	Type of creation process	Code table 4.3	2	0: Analysis / analysis error, 2: Forecast
	↓	13	Background creation process identifier	Code table JMA4.1	151	Precipitation Nowcasts
	↓	14	Forecast creation process identifier		missing	
	↓	15-16	Deadline from the observation data reference time (hour)		0	
	↓	17	Deadline from the observation data reference time (minute)		5	
	↓	18	Duration unit indicator	Code table 4.4	0	minute
	↓	19-22	Forecast time		*1	
	↓	23	Type of first fixed surface	Code table 4.5	1	Ground or water surface
	↓	24	Scale factor of the first fixed surface		missing	
	↓	25-28	Scaled value of the first fixed surface		missing	
	↓	29	Type of second fixed surface	Code table 4.5	missing	
	↓	30	Scale factor of the second fixed surface		missing	
	↓	31-34	Scaled value of the second fixed surface		missing	
	↓	35-36	End of all time intervals (year)		*1	
	↓	37	End of all time intervals (month)		*1	
	↓	38	End of all time intervals (day)		*1	
	↓	39	End of all time intervals (hour)		*1	
	↓	40	End of all time intervals (minute)		*1	
	↓	41	End of all time intervals (second)		*1	
	↓	42	Number of period specifications that describe the time interval used to calculate the statistics		1	
	↓	43-46	Total number of missing data in the statistical process		0	
	↓	47	Type of statistical processing	Code table 4.10	196	196: Representative value (analysis, forecast)
	↓	48	Type of time increment for statistical processing	Code table 4.10	2	Has the same forecast start time and is added to the forecast time
	↓	49	Indicator of the time unit for statistical processing	Code table 4.4	0	minute
	↓	50-53	Length of statistically processed period		*	5 (Analysis, error information, forecast)
	↓	54	Indicator of the time unit for increments between successive material fields		0	
	↓	55-58	Time increments between successive material fields		0	Result of continuous processing
	↓	59-66	Radar and other operational information 1		*3	
	↓	67-74	Radar and other operational information 2		*3	
	To here Template 4.50011	75-82	Radar and other operational information 3		*3	

[Parameter number]
・Defines the type of data (precipitation intensity, error factors of precipitation intensity, accumulated precipitation, etc.)

[Forecast time]
・Difference from the reference time (time of provided data) to the forecast start time

[At the end of all time intervals]
・Time of forecast value

[Length of statistically processed period]
・Period of statistical processing of forecast values
・5 minutes for High-resolution Precipitation

Source: Technical Information on Distribution Materials (Weather Edition) No. 398 Launch of High-resolution Precipitation Nowcasts (Forecast Department, Japan Meteorological Agency, May 30, 2014 (partially revised on August 5, 2014))
https://www.data.jma.go.jp/suishin/jyouhou/pdf/398.pdf

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(2) Study on technology for collecting rainfall information

■ Information collection specifications overview

Data specifications in High-resolution Precipitation Nowcasts (example of rainfall intensity)

Section No.	Section name / Applicable template	Octet	Details	Table	Value	Notes
5	Material representation section	1-4	Section length		******	
		5	Section number		5	
		6-9	Number of all material points		*2	Variable
		10-11	Material expression template number	Code table 5.0	200	Grid point data - Run length compression
	From here Template 5.200	12	Number of bits per data		8	
	↓	13-14	Maximum value of the level used for this compression		V	V is variable (<= M)
	↓	15-16	Maximum level		M	
	↓	17	Scale factor for the representative value of data		*	2: (Analysis, forecast) The representative value to be reported is multiplied by 10**2. 0: (Error information) The representative value is the category number.
	To here Template 5.200	16 + 2 x m to 17 + 2 x m	Data representative value corresponding to level m			m = 1 to M, level 0 is a missing value, unit is mm/h (forecast, analysis) or category (error)
6	Bitmap section	1-4	Section length		6	
		5	Section number		6	
		6	Bitmap indicator		255	Bitmap not applied
7	Material section	1-4	Section length		******	
		5	Section number		7	
	Template 7.200	6-nn	Run-length compressed octet sequence		D	Format described in document template 7.200
8	Termination section	1-4	7777		"7777"	International Alphabet No. 5 (CCITT IA5)

[Material representation template, etc.]
- Data values, data compression method, parameters required for decompression and conversion, etc.

Source: Technical Information on Distribution Materials (Weather Edition) No. 398 Launch of High-resolution Precipitation Nowcasts (Forecast Department, Japan Meteorological Agency, May 30, 2014 (partially revised on August 5, 2014))
https://www.data.jma.go.jp/suishin/jyouhou/pdf/398.pdf

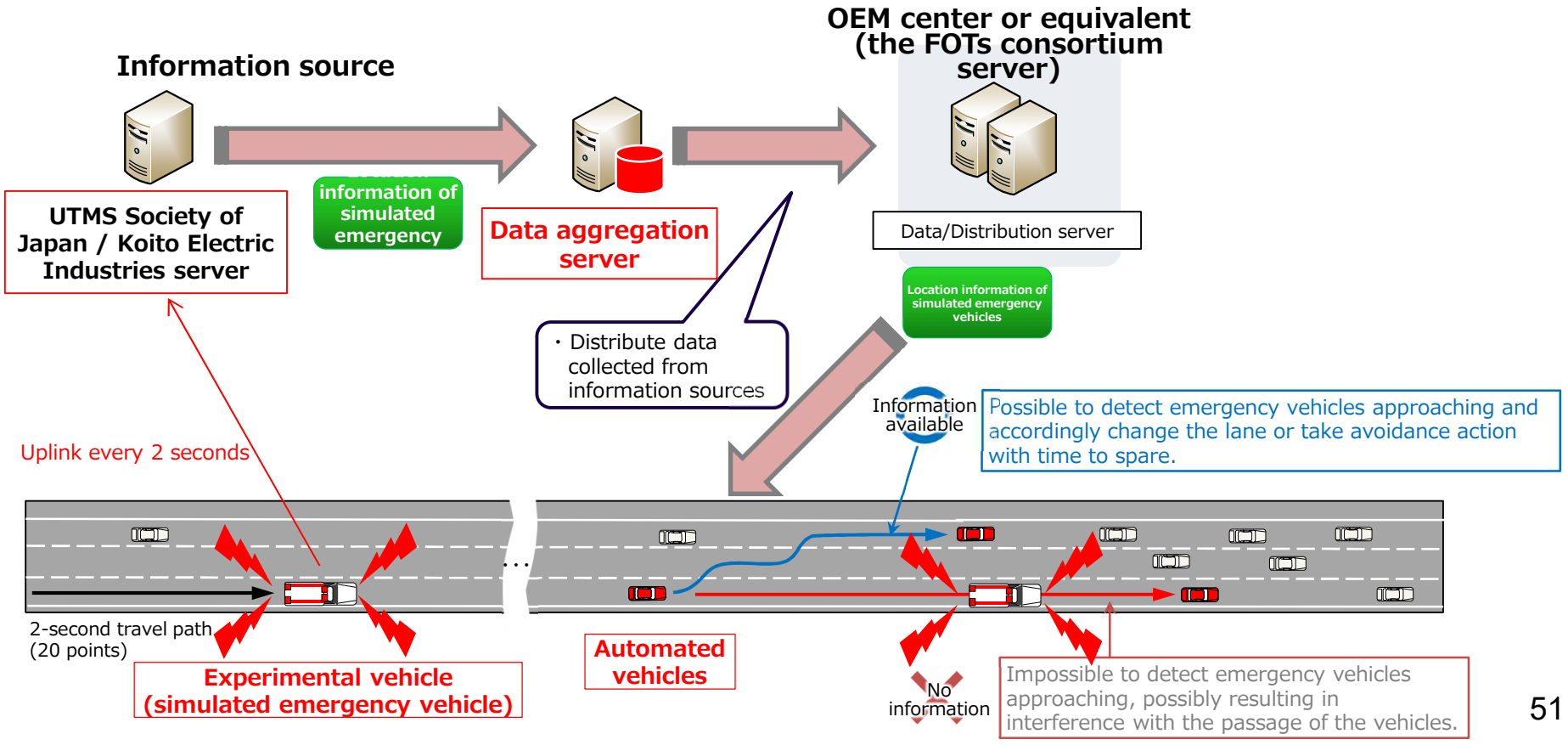
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(3) Study on technology for collecting location information of simulated emergency vehicles

■ Empirical hypothesis about information collection and distribution

- By acquiring the location information of approaching simulated emergency vehicles, achieve appropriate alerting, lane changes, avoidance action, etc.
- By using the model system facilities constructed in the SIP project “Research and Development of Signal Control Using GNSS (Location Information), etc.”, drive an experimental vehicle equipped with a simulated on-board unit, simulating an actual emergency vehicle, collect the latitude and longitude information indicating the vehicle’s position, and distribute it to the FOTs project side.



2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(3) Study on technology for collecting location information of simulated emergency vehicles

■ Information collection specifications overview

- In accordance with the interface specifications (Emergency Vehicle Location Information Distribution Server Communication Application Standards) specified in the SIP project "Research and Development of Signal Control Using GNSS (Location Information), etc.", collect the location information of simulated emergency vehicles that is uplinked every 2 seconds from the vehicles.
- According to the above interface specifications, collect the (1) on-board unit information, (2) latest latitude and longitude, and (3) 2-second travel path of simulated emergency vehicles at any time via UDP communication (see the next page for details of data items).

Information source

UTMS Society of Japan / Koito Electric Industries server

■ Location information of simulated emergency vehicles

Collect the following information as binary data every 2 seconds.

(1) Basic on-board unit information (transmission time, vehicle ID, operating status (normal / emergency travel), etc.)

(2) Latest latitude and longitude

(3) 2-second travel path (measurement time, latitude/longitude, speed, etc., up to 20 points)

If no information is available, sends heartbeat only with a header (data length: 0).

<Data section (up to 504 bytes)>

D7	D6	D5	D4	D3	D2	D1	D0	
Basic on-board unit information (16 bytes)								(1)
Latest latitude information (4 bytes)								(2)
Latest longitude information (4 bytes)								
Continuous GNSS information (up to 480 bytes)								(3)

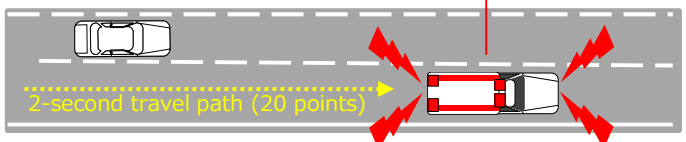
UDP communication
As needed

Location information of simulated emergency vehicles

Data aggregation server

・Collect simulated emergency vehicle information as proprietary binary data via UDP communication.

Uplink every 2 seconds



Experimental vehicle (simulated emergency vehicle)

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(3) Study on technology for collecting location information of simulated emergency vehicles

■ Information collection specifications overview

Data items in accordance with Emergency Vehicle Location Information Distribution Server Communication Application Standards

D7	D6	D5	D4	D3	D2	D1	D0
Type of information							
Serial number							
Data length							
- Data section (up to 504 bytes) -							

[Information header]
If there is no data, sends heartbeat only with a header.

<Data section (up to 504 bytes)>

D7	D6	D5	D4	D3	D2	D1	D0	
Basic on-board unit information								(1)
≀	(16 bytes)						≀	
Latest latitude information								(2)
≀	(4 bytes)						≀	
Latest longitude information								
≀	(4 bytes)						≀	
Continuous GNSS information								(3)
≀	(up to 480 bytes)						≀	

(1) Basic on-board unit information

Basic information such as the ID number of the on-board unit.

D7	D6	D5	D4	D3	D2	D1	D0
On-board unit time							
≀	(8 bytes)						≀
Vehicle ID information							
≀	(5 bytes)						≀
Spare							
Operating status							
Total number of continuous information data stored							

Data item	Description	Format
On-board unit time	Date and time of sending on-board unit information	BCD
Vehicle ID information	ID number unique to the on-board unit	Binary data
Operating status	Normal: 0 Emergency travel: 1	Binary data
Number of continuous GNSS information data stored	Number of travel path data stored (0 to 20)	Binary data

(2) Latest latitude/longitude information

Latest latitude/longitude (in World Geodetic System).

Code form: Signed binary (4 bytes each for latitude and longitude)
Unit form: Decimal (coefficient: 10^7)
Numerical range: [Latitude] -90.0000000 to 90.0000000
[Longitude] -180.0000000 to 180.0000000

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(3) Study on technology for collecting location information of simulated emergency vehicles

■ Information collection specifications overview

Data items in accordance with Emergency Vehicle Location Information Distribution Server Communication Application Standards

D7	D6	D5	D4	D3	D2	D1	D0
Type of information							
Serial number							
Data length							
- Data section (up to 504 bytes) -							

[Information header]
If there is no data, sends heartbeat only with a header.

<Data section (up to 504 bytes)>

D7	D6	D5	D4	D3	D2	D1	D0
Basic on-board unit information (16 bytes)							(1)
Latest latitude information (4 bytes)							(2)
Latest longitude information (4 bytes)							
Continuous GNSS information (up to 480 bytes)							(3)

(3) Continuous GNSS information

Data item for each travel path data.

D7	D6	D5	D4	D3	D2	D1	D0
GNSS measurement time (5 bytes)							
Spare							
Latitude (4 bytes)							
Longitude (4 bytes)							
Travel speed							
Spare							
Altitude above sea level (2 bytes)							
Geoid height (2 bytes)							
HDOP value (2 bytes)							
Number of positioning satellites							
Positioning status							

Data item	Description	Format
GNSS Measurement time	Time when the GNSS receiver module made the measurement.	BCD
Longitude/ latitude	Specifications for the unit, range, and others are the same as for the latest latitude and longitude information.	Signed Binary data
Travel speed	Unit: km/h Numerical range: 0 to 255	Unsigned Binary data
Altitude above sea level	Unit: m (coefficient: 10) Numerical range: -3276.8 to 3276.8	Signed Binary data
Geoid height	Unit: m (coefficient: 10) Numerical range: -3276.8 to 3276.8	Signed Binary data
HDOP* value	GNSS positioning quality Unit: None (coefficient: 10^2) Numerical range: 0 to 99.99	Unsigned Binary data
Number of positioning satellites	Unit: None Numerical range: 0 to 12	Unsigned Binary data
Positioning status	0: Not positioned 1: Independently positioned 2: DGPS-positioned 3: - 4: RTK Fix 5: RTK Float	Unsigned Binary data

* HDOP: Horizontal Dilution of Precision
A value that indicates the approximate measurement error of the position in the horizontal plane.

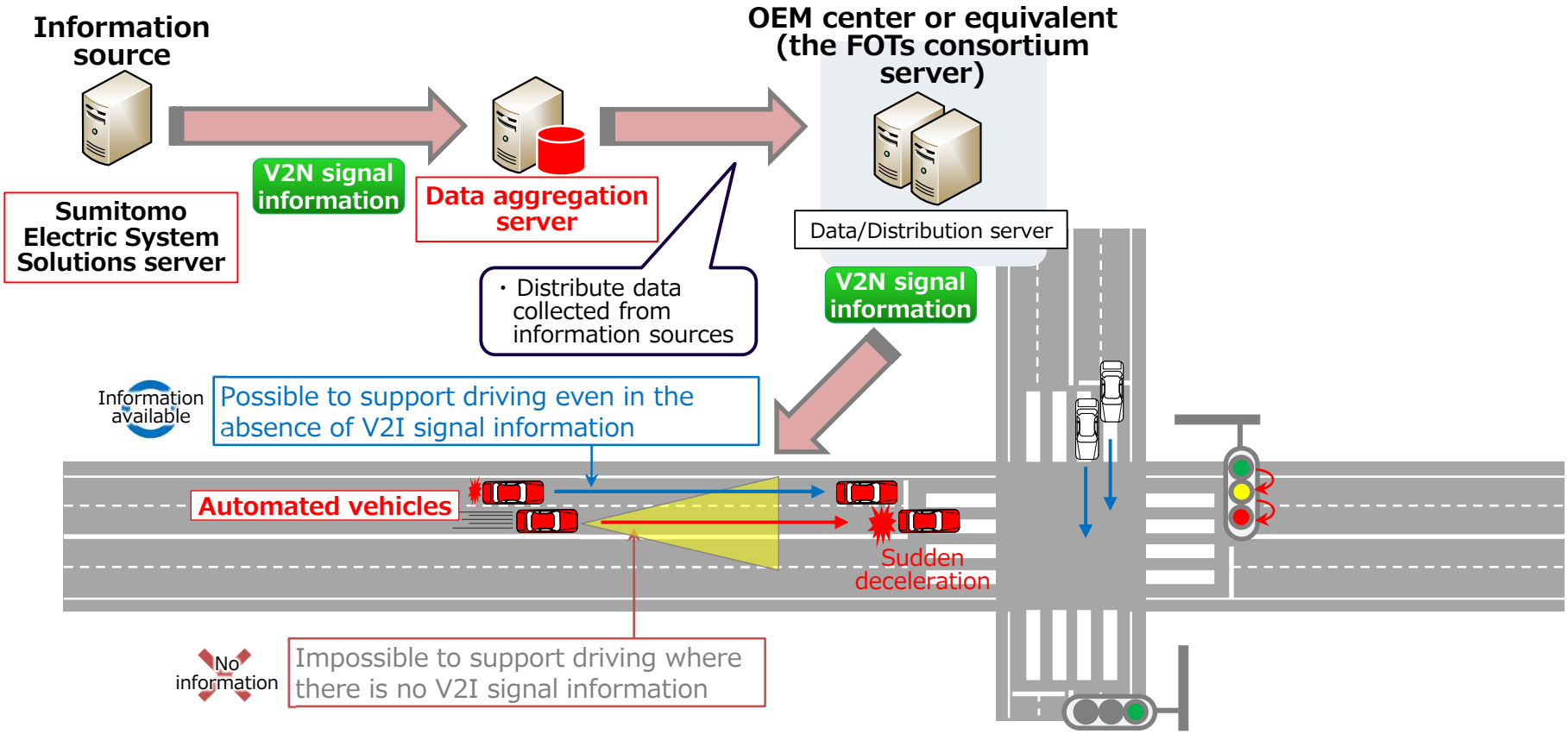
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(4) Study on technology for collecting V2N signal information

■ Empirical hypothesis about information collection and distribution

- By supplementing signal information sent via a network that is expected to be delayed in distribution through the absolute time synchronization with the signal phase table, effectively use automated vehicles and drivers.
- Collect V2N signal information from the system constructed in the SIP project “Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area” and distribute it to the FOTs project side.



2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(4) Study on technology for collecting V2N signal information

■ Information collection specifications overview

- Collect V2N signal information provided in accordance with the interface specifications specified in the SIP project "Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area."
- According to the above interface specifications, collect the (1) management information on the point of information provision and (2) signal schedule information at any time via UDP communication (see the next page for details of data items).
- The management information on the intersection where traffic lights are installed is defined in the interface specifications, but in this experiment, it is not distributed from the information source, so intersection management information is not collected.

Information source

Sumitomo Electric System Solutions server

■V2N signal information

Distributes the following information:

(1) Management information on the point of information provision
Static information on the point of information provision, including the intersection ID, number of lights, and directions.

(2) Signal schedule information
Predicted signal light color change pattern and duration seconds.

(3) Intersection management information
Static information including the name, latitude, and longitude of the intersection where traffic lights are installed (not collected in this study, data length: 0).

UDP communication
As needed

V2N signal information

Data aggregation server

・Collect V2N signal control information as proprietary binary data via UDP communication.

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.1 Technical Study

(4) Study on technology for collecting V2N signal information

■ Information collection specifications overview

Data items in accordance with interface specifications for V2N signal information

Configuration		Representation form	Code
Information provision point management number			
	Prefecture code	bin (8)	E-1
	Information provision point type code	bin (1)	E-2
	Intersection ID / Single-lane road ID	bin (15)	C-1
	Spare	bin (8)	D-8
	Spare	bin (8)	D-8
	Version number (standard)	bin (8)	C-3
	Version number (definition information)	bin (8)	C-4
	Spare	bin (8)	D-8
	Spare	bin (8)	D-8
Creation date and time			
	Year	bin (8)	A-1
	Month	bin (8)	A-2
	Day	bin (8)	A-3
	Time (hour)	bin (8)	A-4
	Time (minute)	bin (8)	A-5
	Time (second)	bin (8)	A-6
	Time (10 ms)	bin (8)	A-7
Signal status information		bin (8)	E-1
Flag during specific control		bin (8)	D-8
System status		bin (8)	F-1
Event counter		bin (8)	F-2
Number of vehicle lights		bin (8)	C-5
Number of pedestrian lights		bin (8)	C-6
Number of connection routes (I)		bin (8)	D-9
Number of service routes (J)		bin (8)	D-10
Service route signal information: 1			
	Route ID	bin (8)	C-2
	Signal traffic direction information flag	bin (1)	F-3
	Spare	bin (7)	D-7
	Signal traffic direction information	bin (8)	F-4
	Vehicle light information pointer: 1	bin (16)	F-5
	:		
	Vehicle light information pointer: I	bin (16)	F-5
	Pedestrian light information pointer: 1	bin (16)	F-5
	:		
	Vehicle light information pointer: I	bin (16)	F-6
:			
Service route signal information: J			

*No intersection management information provided.

Vehicle light information (x number of vehicle lights)

Vehicle light ID	bin (4)	C-5
Number of light color changes (K)	bin (4)	F-7
Vehicle traffic light information (1)		
Round signal light color	bin (8)	F-8
Green arrow signal direction	bin (8)	F-9
Countdown stop flag	bin (1)	F-10
Minimum number of seconds remaining	bin (15)	F-11
Maximum number of seconds remaining	bin (16)	F-12
:		
Vehicle light information: K		

Pedestrian light information (x number of pedestrian lights)

Pedestrian light ID	bin (4)	C-6
Number of light color changes (L)	bin (4)	F-7
Pedestrian signal information: 1		
Pedestrian signal display	bin (8)	F-13
Countdown stop flag	bin (1)	F-10
Minimum number of seconds remaining	bin (15)	F-11
Maximum number of seconds remaining	bin (16)	F-12
:		
Pedestrian light information: L		

Information items enclosed by red frames are not defined in V2I.
→ Fixed to “0” or regarded as indefinite (see below).

Version:	Fixed to “0”
Creation date and time:	Next cycle start time (seconds and after are undefined)
Signal status information:	Fixed to “0”
Flag during specific control:	Undefined (0)

2.5. Study and evaluation of technology for collecting various types of traffic environment information

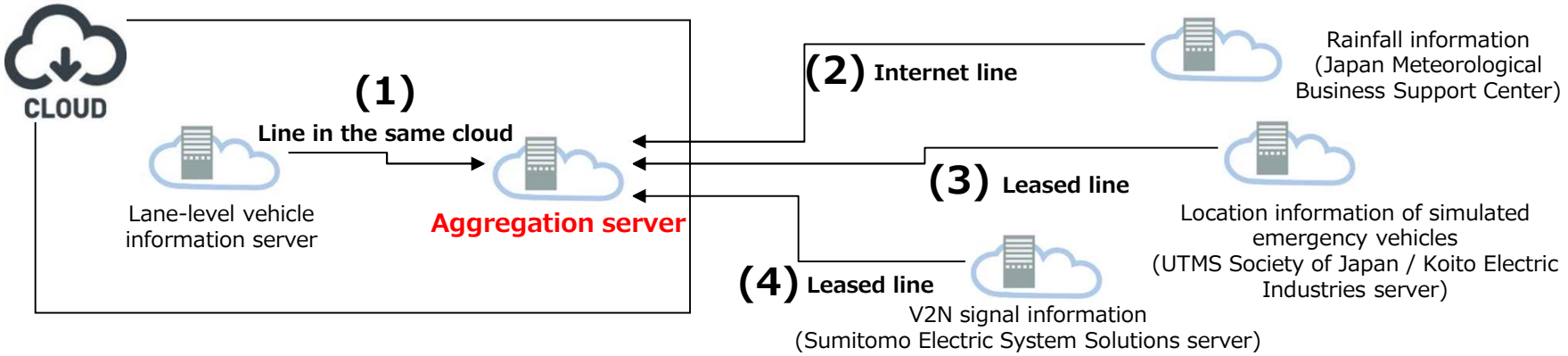
2.5.2 Technical Evaluation

- Based on the results of study described in 2.5.1, a data aggregation server (with a collection function) was constructed for the FOT, and it was confirmed that it can collect traffic environment information from information sources using the data collection method based on the results of technical study described in the previous section. In addition, the collected traffic environment information was analyzed for issues, such as collection frequency and processing time, for practical application.

2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

- Verify the communication between each information source and the aggregation server after taking appropriate information security measures according to the interface specifications and other characteristics of the information to be collected.



No.	Traffic environment information	Target server	Security measures
(1)	Lane-level vehicle information	Lane-level vehicle information server	■ Adopt peering connection of communication service between AWS ・Information is encrypted and never passes through the public Internet, reducing threats such as general exploits (vulnerability-based malicious programs) and DDoS attacks (attacks that interfere with services).
(2)	Rainfall information	Japan Meteorological Business Support Center	■ Adopt Internet gateway connection of AWS communication service 1) Packet filtering by inbound rules (IP filtering) 2) Communication port restrictions 3) User authentication by SFTP protocol
(3)	Location information of simulated emergency vehicles	UTMS Society of Japan / Koito Electric Industries server	■ Adopt a closed network that combines Cloud Gateway Cross Connect (NTT East Japan connection service) and business ether network ・Connect directly to AWS from a secure network that does not use the Internet
(4)	V2N signal information	Sumitomo Electric System Solutions server	

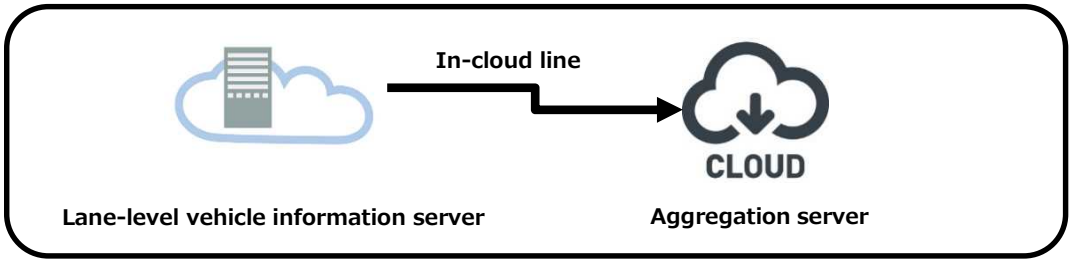
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

(1) Evaluation of technology for collecting lane-level vehicle information

■ Verification method for information collection

- Connect the lane-level vehicle information server, which generates lane-level vehicle information, and the aggregation server via an in-cloud line.



Verification system configuration

■ Verification Results

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Confirmation of received data accumulation status	The lane-level vehicle information file must be stored in the storage folder every 5 minutes.	Visually confirmed that the collected lane-level vehicle information files are stored in the storage folder.
3	Format of received data	There must be no reading error (format violation) in the process of importing lane-level vehicle information using the aggregation server application.	Visually confirmed that there is no import error message in the operation log of the information import process of the aggregation server application.

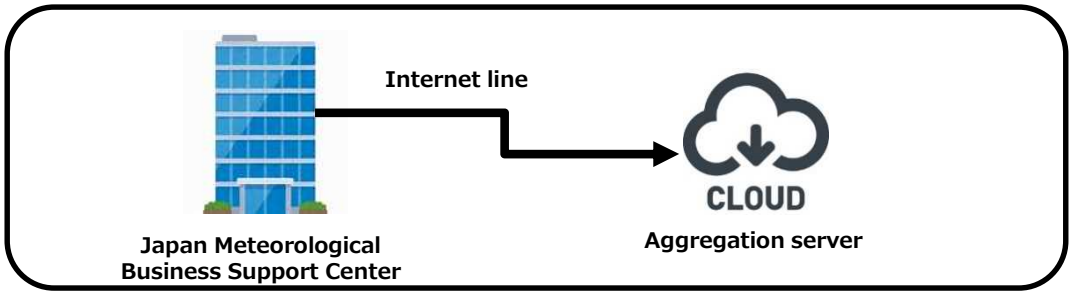
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

(2) Evaluation of technology for collecting rainfall information

■ Verification method for information collection

- Connect the Japan Meteorological Business Support Center, which distributes rainfall information, and the aggregation server via an Internet line.



Verification system configuration

■ Verification Results

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Confirmation of received data accumulation status	The rainfall information file must be stored in the storage folder every 5 minutes.	Visually confirmed that the collected rainfall information files are stored in the storage folder.
3	Format of received data	There must be no reading error (format violation) in the process of importing rainfall information using the aggregation server application.	Visually confirmed that there is no import error message in the operation log of the information import process of the aggregation server application.

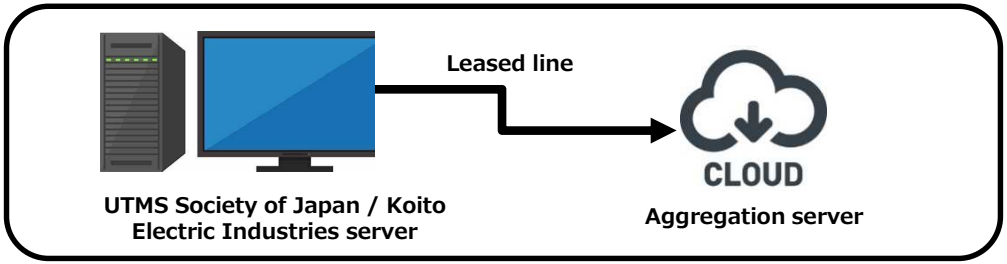
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

(3) Evaluation of technology for collecting location information of simulated emergency vehicles

■ Verification method for information collection

- Connect the UTMS Society of Japan / Koito Electric Industries server, which distributes the location information of simulated emergency vehicles, and the aggregation server via a leased line.



Verification system configuration

■ Verification Results

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Reception log (date, time, data size)	The date, time, and data size of the collected location information of simulated emergency vehicles must be the same as those obtained by the aggregation server application.	Visually confirmed that the date, time, and data size recorded in the information collection log of the aggregation server application are the same as those stored in the collected location information of simulated emergency vehicles.

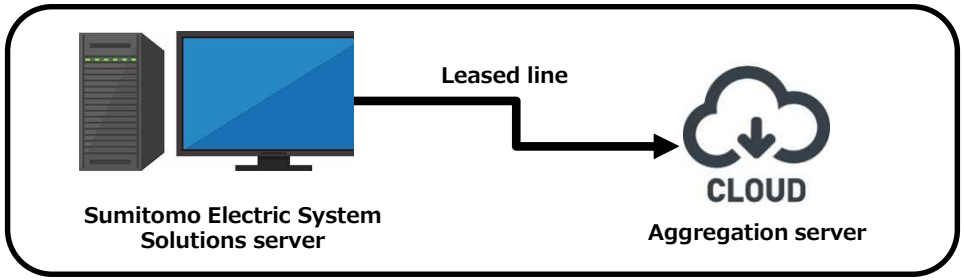
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

(4) Evaluation of technology for collecting V2N signal information

■ Verification method for information collection

- Connect the Sumitomo Electric System Solutions server, which distributes V2N signal information, and the aggregation server via a leased line.



Verification system configuration

■ Verification Results

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Reception log (date, time, data size)	The date, time, and data size of the collected V2N signal information must be the same as those obtained by the aggregation server application.	Visually confirmed that the date, time, and data size recorded in the information collection log of the aggregation server application are the same as those stored in the collected V2N signal information.

2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

- The technology to convert and distribute the traffic environment information collected and accumulated in 2.5 to the server that relays the information to the vehicles participating in the experiment (this relay server is expected to be replaced by the telematics center of each automobile manufacturer in future stages of social implementation) was studied.

2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

- For distribution to the OEM center or equivalent (the FOTs consortium server), study and organize the distribution cycles, information representation formats, and communication methods of various types of traffic environment information considering their characteristics.

Traffic environment information	Distribution cycle	Information representation format	Communication method	Notes
Lane-level vehicle information	1-minute cycle	JASPAR: JSON data Contents: attention	HTTP	Distributed upon request from the OEM center or equivalent (the FOTs consortium server)
Rainfall information	1-minute cycle	JASPAR: JSON data Contents: environment	HTTP	Distributed upon request from the OEM center or equivalent (the FOTs consortium server)
Location information of simulated emergency vehicles	As needed	Proprietary binary data	WebSocket	
V2N signal information	As needed	Proprietary binary data	WebSocket	

2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

- Basically, the information representation format specified in the JASPAR specifications (Vehicle Information Sharing Specifications) should be adopted, but the format is to be determined from the following perspectives.
  - Since JASPAR data is in JSON format, the data volume is larger than binary data.
  - For information that is highly urgent and volatile and therefore requires immediacy, for example, use the data format of the information source as it is taking into account the amount of data after conversion, etc.

Determination factor	JASPAR data (in JSON format)	Binary data
Data characteristics	○: The format is easy to understand for humans. ▲: Agreement is required on the (alphanumeric) data representation format.	○: The format is easy to understand for computers. ▲: Definitions and handling arrangements are required to eliminate CPU dependency.
Immediacy	▲: Takes time to interpret and process information.	○: Fast in interpreting and processing information (adopted in cases requiring communication speed).
Data volume	▲: Requires 1 byte to represent 1 one-byte character (the data volume increases in proportion to the number of characters).	○: Represents a lot of data in a small size (represents numerical values from 0 to 255 in 1 byte).
Scalability	○: Highly compatible with extensions such as addition of data items (possible to continue processing with unrecognized items discarded).	▲: Has a problem with compatibility with expansions such as addition of data items (needs to modify the specifications or program, in principle).
Evaluation	**Adopted for distribution of information that relatively does not require immediacy, such as periodic distribution.**	**Adopted for distribution of information that is highly urgent and volatile and therefore requires immediacy.**

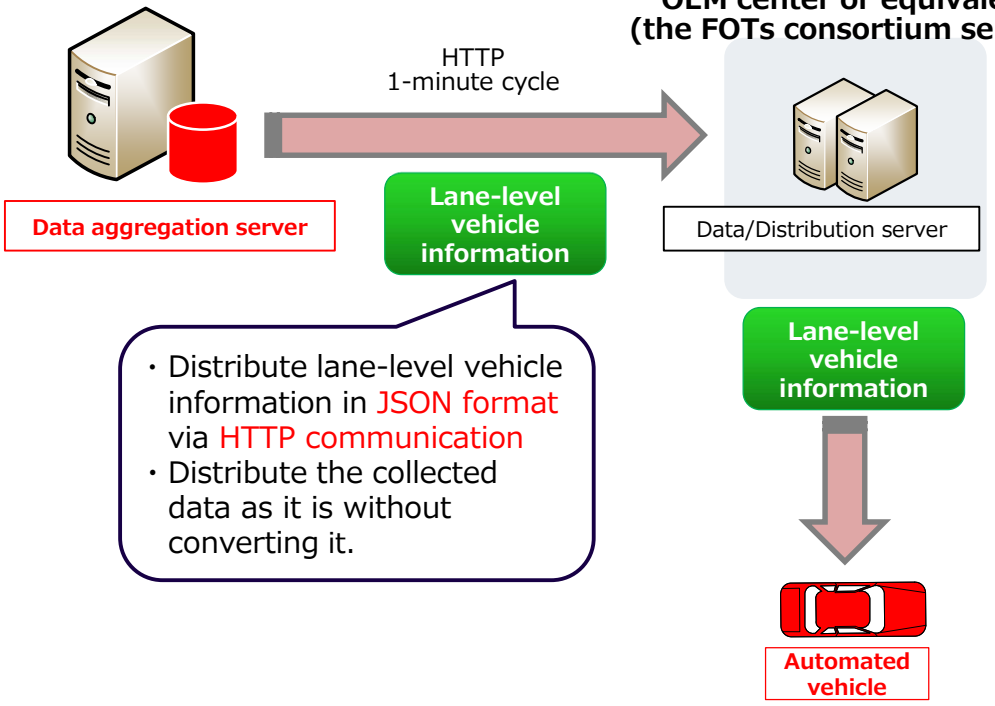
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

(1) Study on technology for distributing lane-level vehicle information

■ Information distribution specifications overview

- Since lane-level vehicle information is collected from lane-level vehicle information servers every minute as warning information of JASPAR specification, distribute data in JSON format in accordance with the JASPAR specifications without applying any conversion or other processing upon request received every minute via HTTP communication.
- The information items of lane-level vehicle information conform to those defined in 2.1 through 2.4.



JSON format in accordance with the warning information of JASPAR specification (Contents: attention)

```
"container":[
 {"basic":{
  "time":{
   "start":"2020-10-01T13:30:00.000",
   "expire":"2020-10-01T13:35:00.000"
  },
  "section":{
   "beginningPoint":{
    "latitude":36.1234567,"longitude":139.1234567,
    "onRoad":"on","name":"Metropolitan
Expressway Haneda Line"
    "lane":["1","2"],"accuracy":"1"
   }
  }
  "contents":{
   "attention":{"sequence":"1","subject":"50"}
  }
 }
]
```

Marking number
50: Congestion tail
60: Obstacles

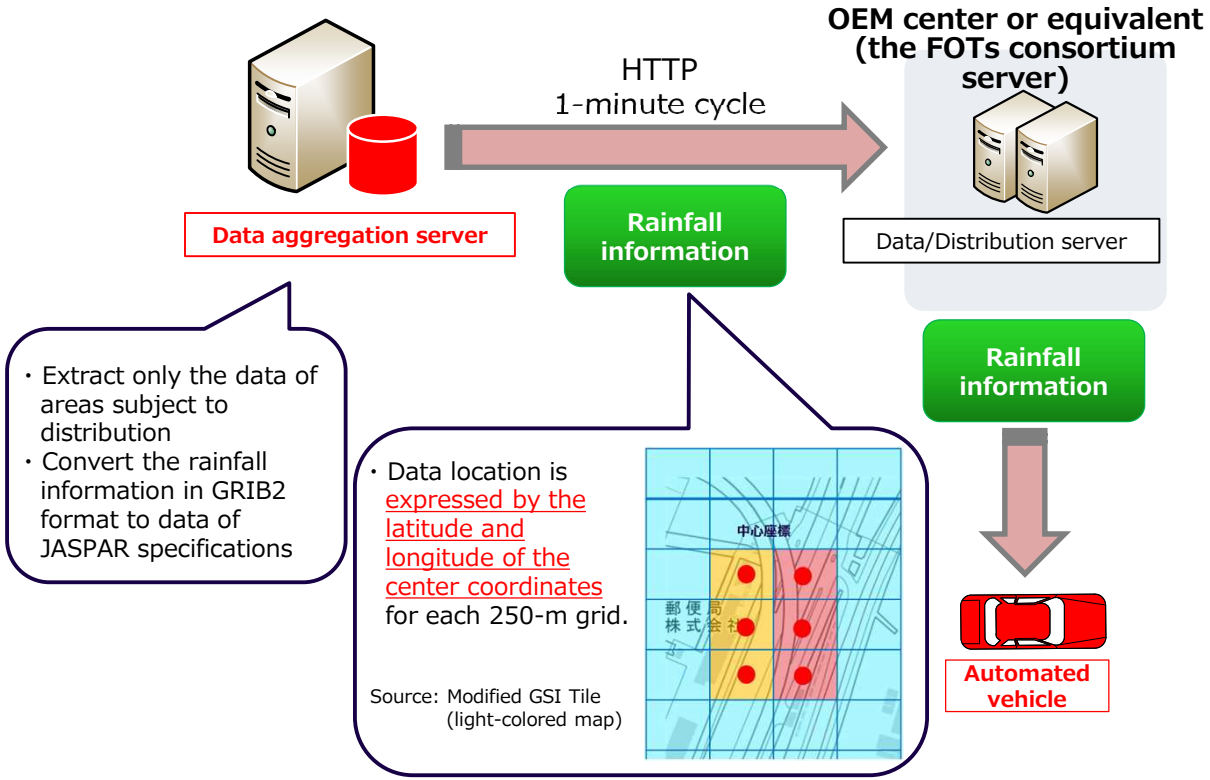
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

(2) Study on technology for distributing rainfall information

■ Information distribution specifications overview

- Since rainfall information is collected at regular intervals of 5 minutes, convert the data format as environmental information of JASPAR specification, and distribute data in JSON format without applying any conversion or other processing upon request received every minute via HTTP communication in conjunction with the lane-level vehicle information cycle (see the next page for data format).
- The rainfall information to be collected is data for the whole country and an enormous amount of information is distributed, so in order to reduce the information volume, extract the area corresponding to the FOT area and convert it.



Areas subject to distribution and data description order

Source: Modified GSI Tile (light-colored map)

2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

(2) Study on technology for distributing rainfall information

■ Information distribution specifications overview

- Rainfall intensity and 5-minute accumulated precipitation are collected from the information source as rainfall information. However, since instantaneous rainfall intensity is expected to be more effective for automated driving control, rainfall intensity is distributed as rainfall information.
- Since vehicles are constantly moving and therefore real-time analysis value alone may be not “real-time,” rainfall forecast information (per 5 minutes for up to the next 30 minutes) is distributed in addition to the real-time analysis value.

JSON format in line with JASPAR specification environment


```
“container”:[
 {“basic”:{
  “time”:{“start”:”2020-10-01T13:30:00.000”,”expire”:”2020-10-01T13:35:00.000”},
  “section”:{“beginningPoint”:{“latitude”:36.1234567,”longitude”:139.1234567,“accuracy”:”3”}}
  “contents”:[
   “environment”:{“sequence”:”1”,“rain”:[”20.00”,”25.00”,”25.00”,”30.00”,”35.00”,”35.00”,”40.00”],”accuracy”:”3”},
   “environment”:{“sequence”:”2”,“rain”:[”20.00”,”25.00”,”25.00”,”30.00”,”35.00”,”35.00”,”40.00”],”accuracy”:”3”}
  ]
 },
 {“basic”:{
  “time”:{“start”:”2020-10-01T13:30:00.000”,”expire”:”2020-10-01T13:35:00.000”},
  “section”:{“beginningPoint”:{“latitude”:36.5671234,”longitude”:139.5671234,“accuracy”:”3”}}
  “contents”:[
   “environment”:{“sequence”:”1”,“rain”:[”20.00”,”25.00”,”25.00”,”30.00”,”35.00”,”35.00”,”40.00”],”accuracy”:”3”},
   “environment”:{“sequence”:”2”,“rain”:[”20.00”,”25.00”,”25.00”,”30.00”,”35.00”,”35.00”,”40.00”],”accuracy”:”3”}
  ]
 }
]
```


Distributes the real-time analysis value and predicted values of rainfall intensity in an array.

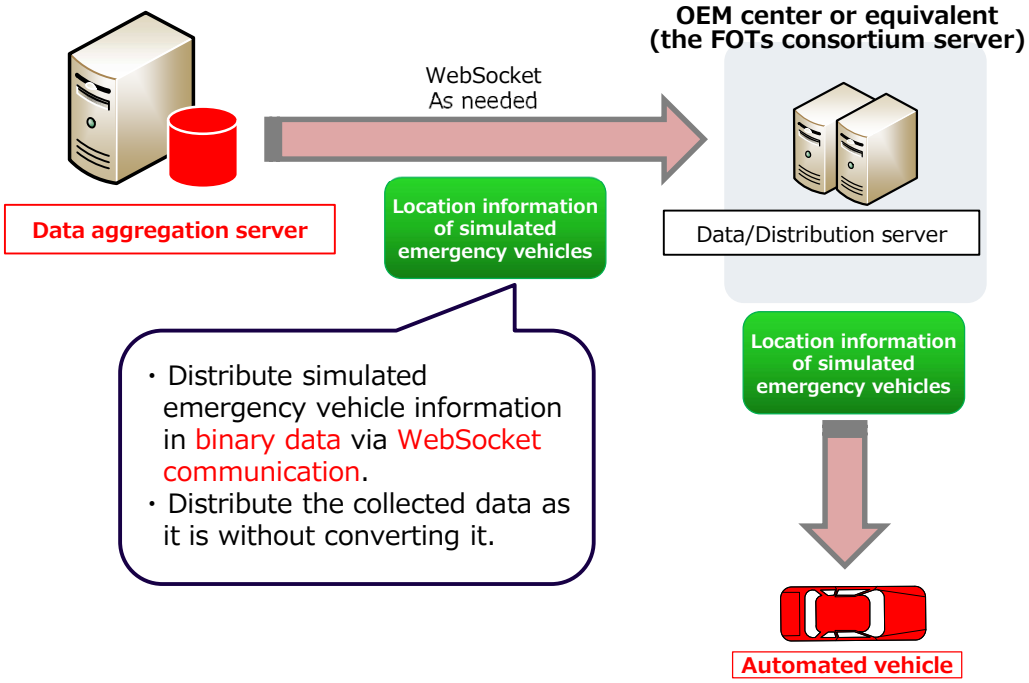
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

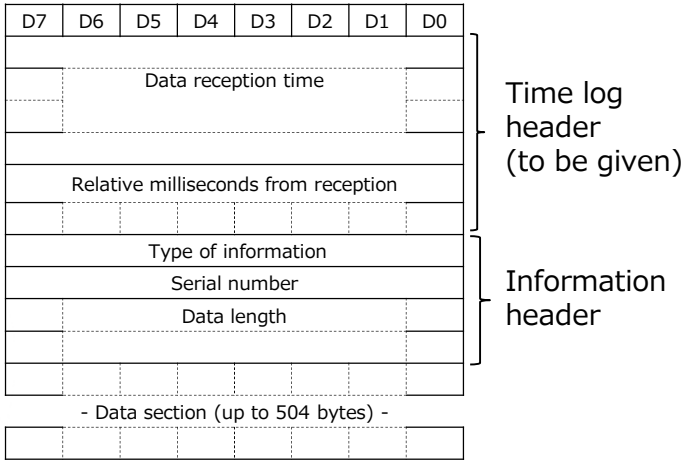
(3) Study on technology for distributing location information of simulated emergency vehicles

■ Information distribution specifications overview

- The location information of simulated emergency vehicles is highly urgent and volatile in nature, and therefore for which immediacy is considered to be the highest priority. Accordingly, distribute the collected binary data as it is without applying any conversion or other processing.
- Since information is collected at any time (irregularly), distribute information via WebSocket communication, which can distribute data at any time and has a simple communication protocol procedure.
- To make it possible to measure distribution delays in the FOT, the collected information is given the time it was received by the data aggregation server (time log header).



Data structure of location information of simulated emergency vehicles



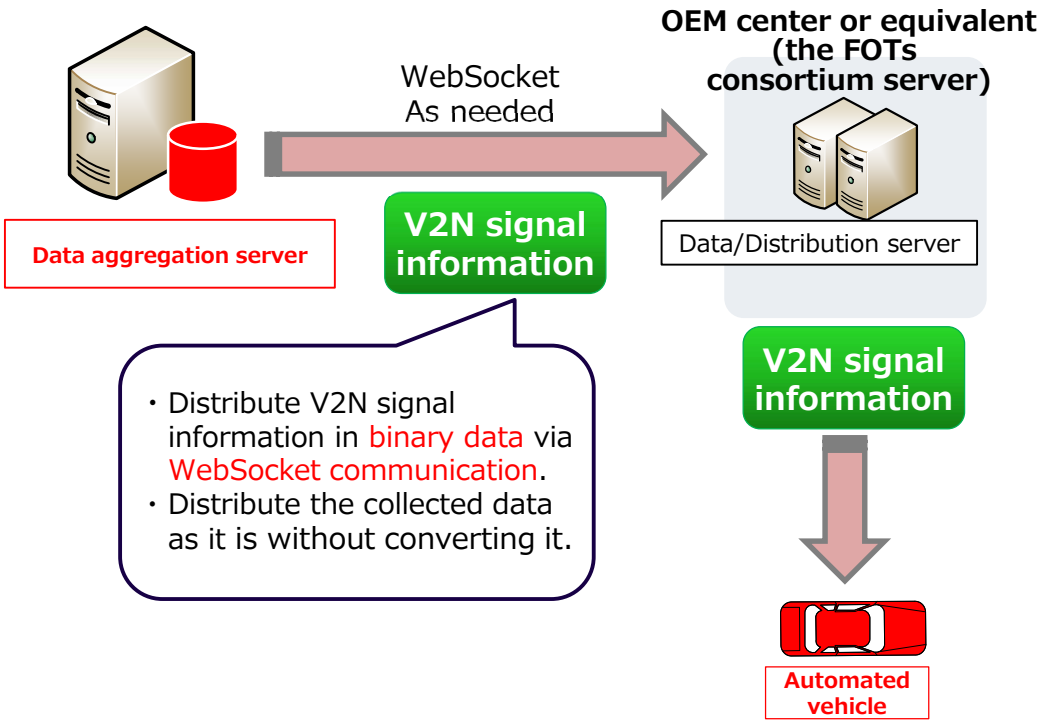
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

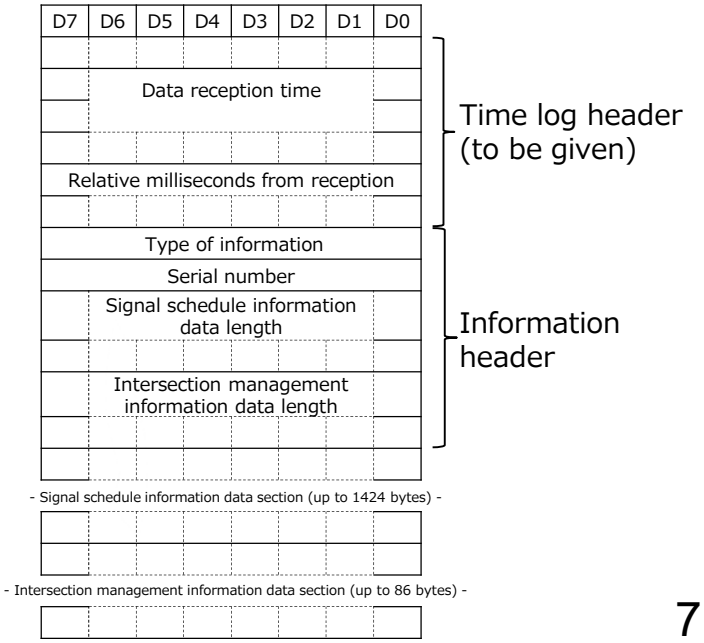
(4) Study on technology for distributing V2N signal information

■ Information distribution specifications overview

- V2N signal information is highly urgent and volatile in nature, and therefore for which immediacy is considered to be the highest priority. Accordingly, distribute the collected binary data as it is without applying any conversion or other processing.
- Since information is collected at any time (irregularly), distribute information via WebSocket communication, which can distribute data at any time and has a simple communication protocol procedure.
- To make it possible to measure distribution delays in the FOT, the collected information is given the time it was received by the data aggregation server (time log header).



Data structure of V2N signal information



2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

- Based on the results of study described in 2.6.1, a data aggregation server (with conversion and distribution functions) was constructed for the FOT, and it was confirmed that it can convert and distribute traffic environment information to the experimental server prepared by the Tokyo Waterfront Area FOTs Consortium using the data distribution method based on the results of technical study described in the previous section. In addition, the converted and distributed traffic environment information was analyzed for issues, such as the time required for conversion and distribution, for practical application.

Traffic environment information	Continuity evaluation/ verification item	Verification result	Distribution delay verification result
Lane-level vehicle information	PING command connectivity	○	・It depends on whether the probe collection is in time to launch the information generation application.
	Distribution data accumulation status	○	
	Distribution data format	○	
Rainfall information	PING command connectivity	○	・Almost independent of weather (sunny or rainy) ・Possible to distribute information with a delay of about 155 seconds.
	Distribution data accumulation status	○	
	Distribution data format	○	
Location information of simulated emergency vehicles	PING command connectivity	○	・Transmission time error: 10 ms max.
	Distribution log (date, time, data size)	○	
V2N signal information	PING command connectivity	○	・Transmission time error: 10 ms max.
	Distribution log (date, time, data size)	○	

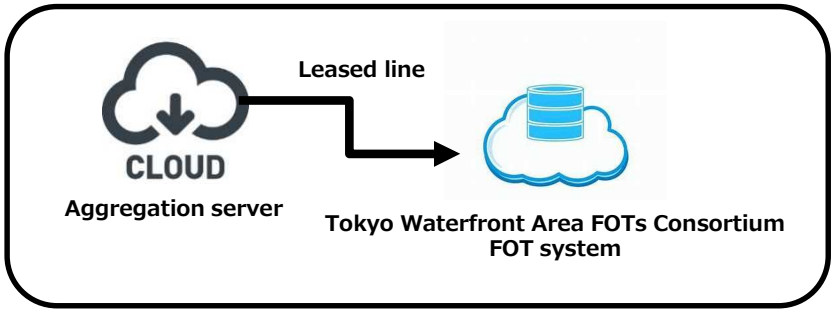
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

(1) Evaluation of technology for distributing lane-level vehicle information

■ Verification method for information distribution

- Connect the aggregation server, which distributes lane-level vehicle information, and the Tokyo Waterfront Area FOTs Consortium FOT system via a leased line.



■ Distribution delay verification result

- In the lane-specific vehicle information server, the information generation application normally starts in 1 minute + 10 seconds, and takes about 5 seconds to generate the information.
- The time required to generate information depends on whether the probe collection is in time to launch the information generation application.

Probe collection

In time	Not in time
Delayed for **15 sec.**	Delayed for **75 sec.**

■ Continuity evaluation/verification result

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Distribution data accumulation status	The lane-level vehicle information file distributed must be stored in the storage folder every minute.	Visually confirmed that the distributed lane-level vehicle information files are stored in the storage folder.
3	Distribution data format	There must be no reading error (format violation) in the process of importing lane-level vehicle information distributed by the Tokyo Waterfront Area FOTs Consortium FOT system application.	Confirm that there is no import error message in the operation log of the information import process of the Tokyo Waterfront Area FOTs Consortium FOTs system application.

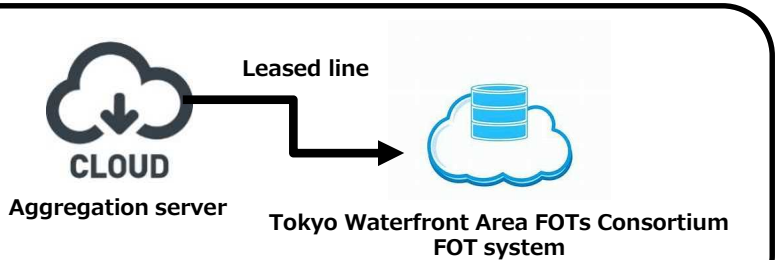
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

(2) Evaluation of technology for distributing rainfall information

■ Verification method for information distribution

- Connect the aggregation server, which distributes rainfall information, and the Tokyo Waterfront Area FOTs Consortium FOT system via a leased line.



■ Distribution delay verification result

- Analyzed rainfall information (High-resolution Nowcasts) ⇒ Takes about 8 seconds on average to generate information in JSON format (transmission format).
- Confirmed that the time required to generate information is almost independent of weather (sunny or rainy).
- Possible to distribute information with a delay of about 155 seconds (normally every 5 minutes).

■ Continuity evaluation/verification result

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Distribution data accumulation status	The distributed rainfall information file must be stored in the storage folder every minute.	Visually confirmed that the distributed rainfall information files are stored in the storage folder.
3	Distribution data format	There must be no reading error (format violation) in the process of importing rainfall information distributed by the Tokyo Waterfront Area FOTs Consortium FOT system application.	Confirm that there is no import error message in the operation log of the information import process of the Tokyo Waterfront Area FOTs Consortium FOT system application.

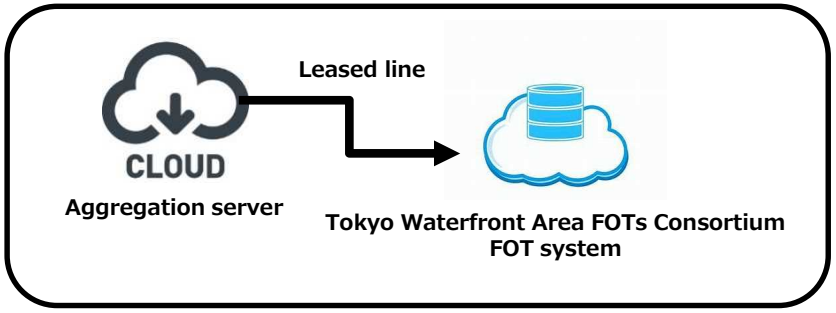
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

(3) Evaluation of technology for distributing location information of simulated emergency vehicles

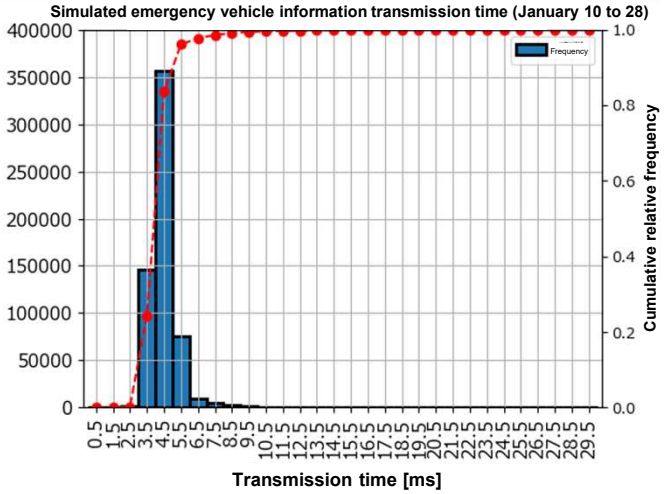
■ Verification method for information distribution

- Connect the aggregation server, which distributes location information, of simulated emergency vehicles and the Tokyo Waterfront Area FOTs Consortium FOT system via a leased line.



■ Distribution delay verification result

- Transmission time error: 10 ms max.
- Confirmed that it hardly affects the distribution delay because the transmitted information volume is small.



■ Continuity evaluation/verification result

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Distribution log (date, time, data size)	The date, time, and data size of the distributed location information of simulated emergency vehicles must be the same as those obtained by the aggregation server application.	Visually confirmed that the date, time, and data size recorded in the information distribution log of the aggregation server application are the same as those stored in the collected location information of simulated emergency vehicles.

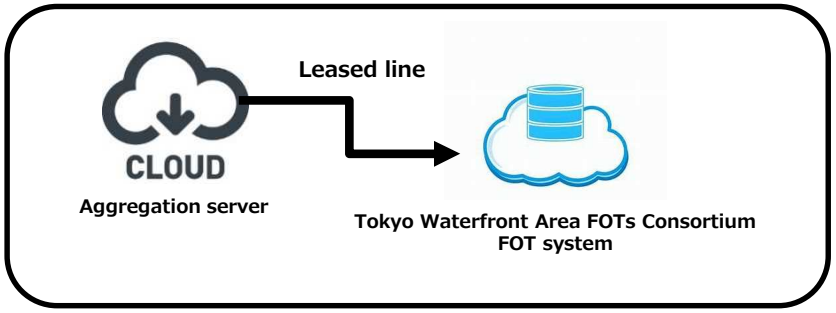
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

(4) Evaluation of technology for distributing V2N signal information

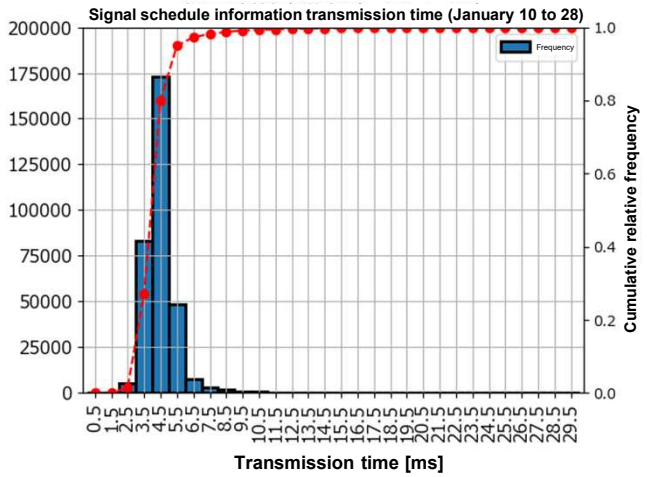
■ Verification method for information distribution

- Connect the aggregation server, which distributes V2N signal information, and the Tokyo Waterfront Area FOTs Consortium FOT system via a leased line.



■ Distribution delay verification result

- Transmission time error: 10 ms max.
- Confirmed that it hardly affects the distribution delay because the transmitted information volume is small.



■ Continuity evaluation/verification result

- All verification items met the evaluation criteria.

No.	Evaluation item	Evaluation criteria	Evaluation results
1	PING command connectivity	The PING command response time must be on the order of ms.	All response times met the criteria.
2	Distribution log (date, time, data size)	The date, time, and data size of the distributed V2N signal information must be the same as those obtained by the aggregation server application.	Visually confirmed that the date, time, and data size recorded in the information distribution log of the aggregation server application are the same as those stored in the collected V2N signal information.

3. FOT

3.1. Examination of Field Operational Test Implementation Policy

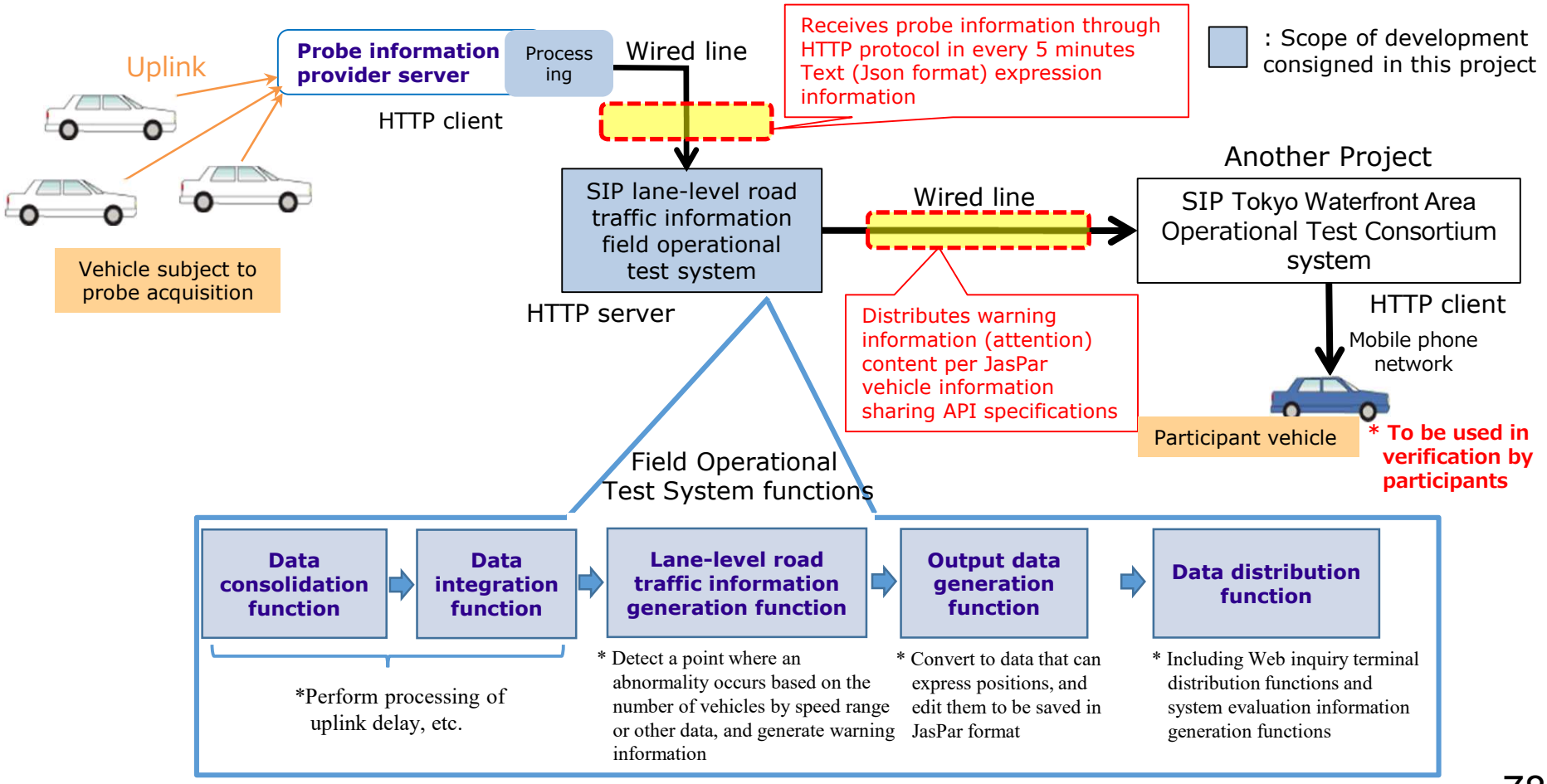
- A FOT is conducted to verify the technical study and evaluation of each element mentioned in 2 above.
- Create two types of node link maps for the FOT sections (Metropolitan Expressway Bayshore Route (from DiBa to Haneda Airport) and Metropolitan Expressway Haneda Line (from Shiodome to Airport West)), based on the definition of the position reference method representing the link map provided by the Japan Digital Road Map Association (hereinafter referred to as "DRM Association") and that provided by the Vehicle Information and Communication System Center (hereinafter referred to as "VICS Center") by lane and the definition of the position reference method based on the CRP setting specifications, which is being examined in the SIP Second Phase "Investigation and study on the Role of Common Reference Points (CRP) in High-precision 3D Maps."
- In FY2020, real-time probe information was procured through online connections from probe providers, and in cooperation with the Tokyo Waterfront Area Operational Test Consortium, a verification experiment was conducted to distribute lane by lane information to vehicles participating in the experiment in the above section. Two types of node-linked maps were prepared for the locations of the FOT, and the node-linked map based on the definition of the location reference method, which expresses the link map by lane, of the DRM Association and the Road Traffic Information and Communication Systems Center was used for the field operational test. In addition, a questionnaire survey was conducted on the participants of the experiment to verify the effectiveness of lane-specific information.
- In FY2021, a new data aggregation server was constructed and connected with the information provider, and various types of traffic environment information were stored in the data aggregation server, converted to the prescribed communication specifications, and then distributed to the data server of another project (1). Of these, regarding lane-specific information, probe providers with online access increased from one to two, and provided lane-specific information also in cases other than branches by using turn signal information.

3.1. Examination of Field Operational Test Implementation Policy

Conducted in FY2020

Configuration of Field Operational Test System

- Verify system operation, processing time, etc., and compile technical specifications.
- Participants in the experiment experienced delivery of information, and were asked to answer questions about the effectiveness and issues.

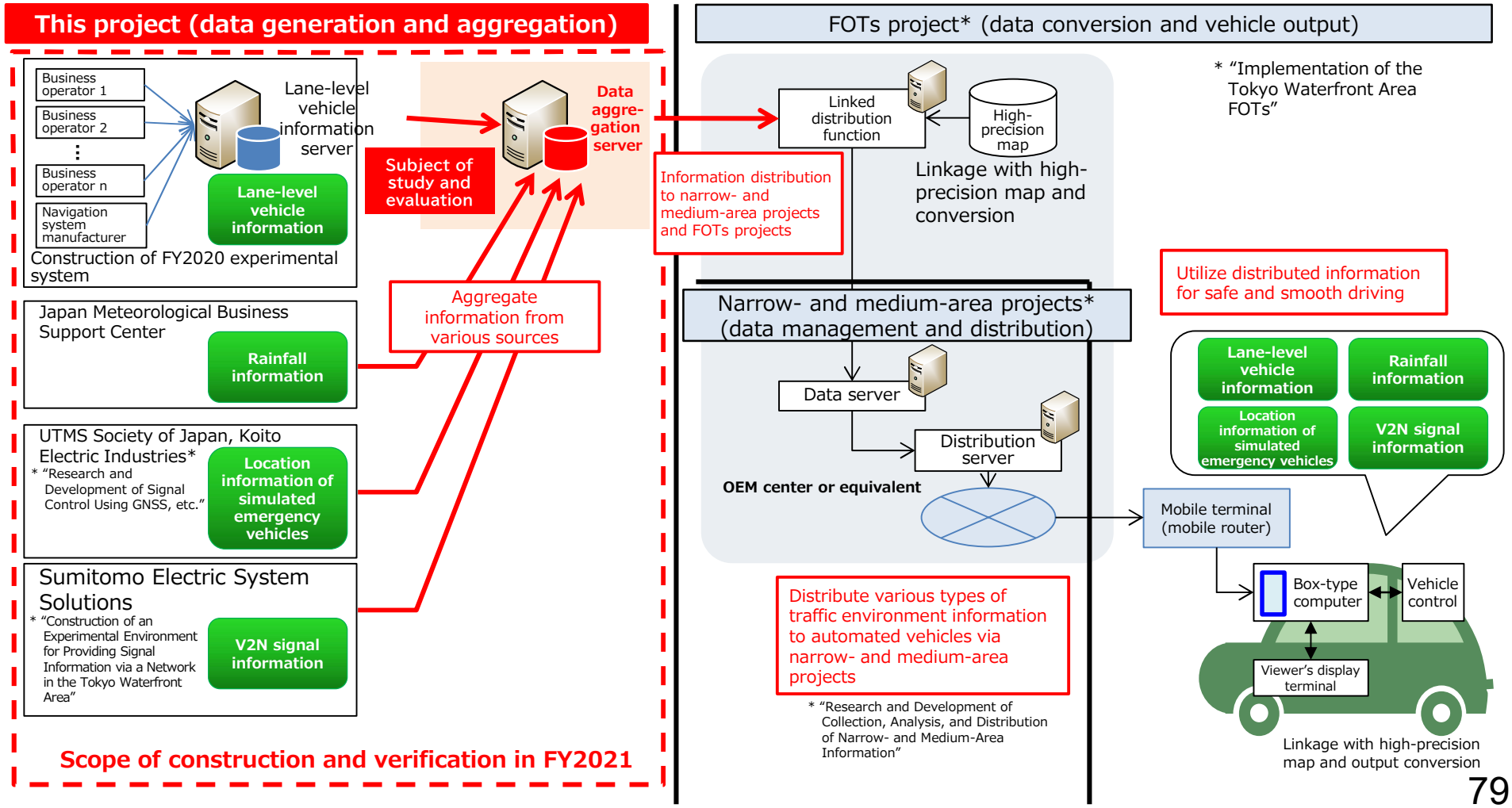


Conducted in FY2021

3.1 Field Operational Test Implementation Policy

FOT system configuration

- Construct an experimental environment in which various types of traffic environment information useful to appropriately determine and control automated vehicles can be centrally aggregated with lane-level vehicle information, for which a FOT system has been constructed since FY2020, and then provided to the vehicle side (OEM center or equivalent), and implement the FOT.



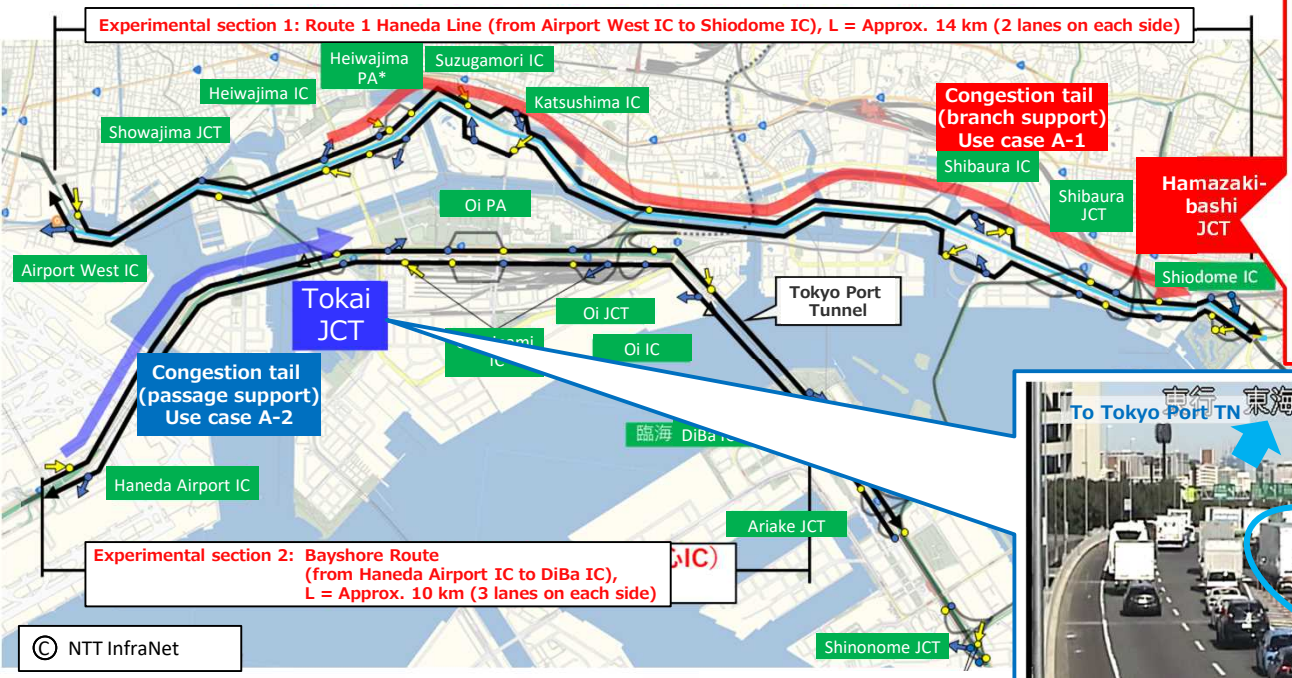
3.1 Field Operational Test Implementation Policy

Conducted in FY2021

■ Sections subject to information generation and main verification fields in the FOT

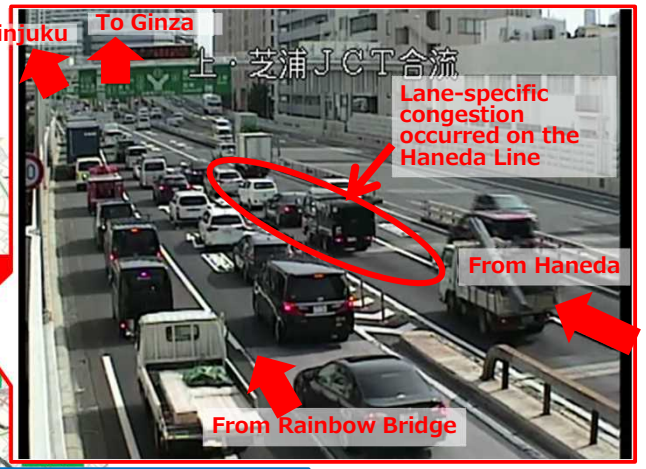
- The FOT of information generation is conducted in the sections shown below on the Metropolitan Expressway Haneda Line and Bayshore Route.
- The main verification fields for the target use cases are as follows:
  - **A-1: Congestion tail (branch support)**: Branch at Hamazakibashi JCT where lane-specific congestion occurs constantly
  - **A-2: Congestion tail (passage support)**: Junction at Tokai JCT where lane-specific congestion occurs constantly
  - **B: Accidents**: Appropriate ones that occurred in the target section for which data is available

Sections subject to information generation and the main verification field for each use case in the FOT

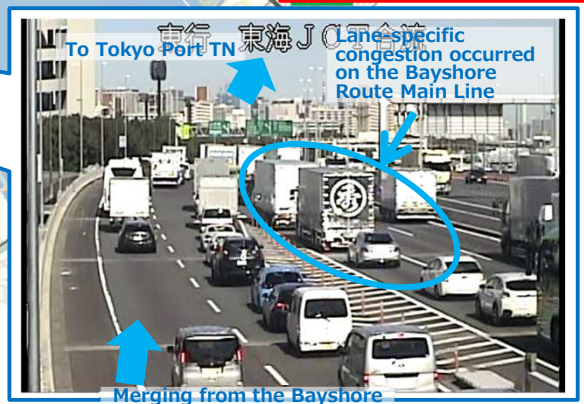


Information provision period:
Weekdays between December 13, 2021 and January 28, 2022 (9 a.m. to 5 p.m.)

To the branch at Hamazakibashi JCT on the upbound Haneda Line



Junction at Tokai JCT on the eastbound Bayshore Route



Legend
- Metropolitan Expressway
- Main line junction
- Main line branch
- IC junction
- IC branch
- PA

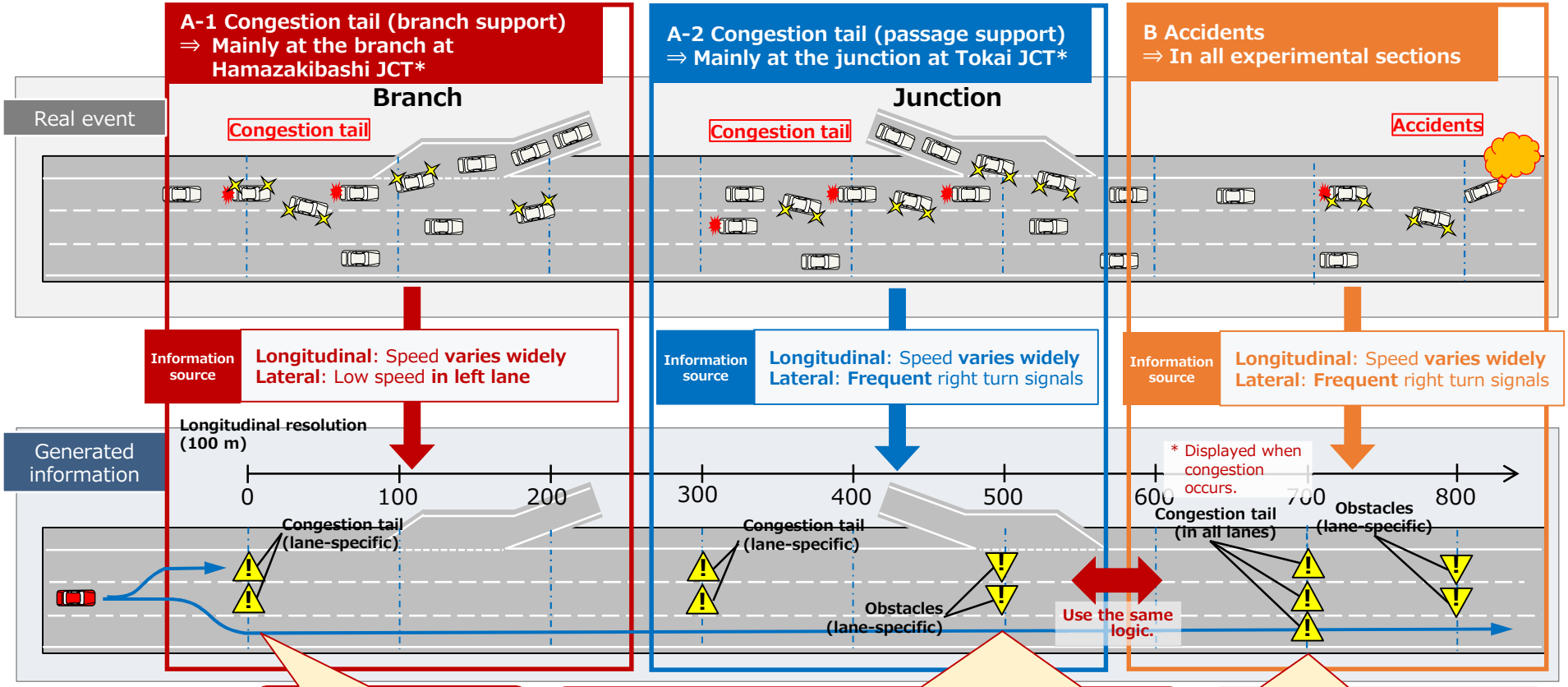
*From Metropolitan Expressway CCTV

3.1 Field Operational Test Implementation Policy

Conducted in FY2021

■ Overview of information generation in target use cases

- Generate warning information about the congestion tail and location of obstacles (in 100-m units in the longitudinal direction) every 5 minutes.
- If lane-specific congestion is determined in a section with three or more lanes, the obstructed lane cannot be identified, so warning information is displayed in all lanes except the farthest lane from the left or right where the obstructed lane exists.



*The road structures shown above are not the actual ones at Hamazakibashi JCT or Tokai JCT.

If the left lane is congested, the congestion tail is displayed in all lanes except the rightmost lane.

- If frequent turn signals are detected at the congestion head at branch, the location of obstacles is displayed in the lane opposite to the turn signal direction.
- However, if frequent turn signals are not detected, the location of obstacles is not displayed (the same applies to the head of natural congestion in single-lane sections).

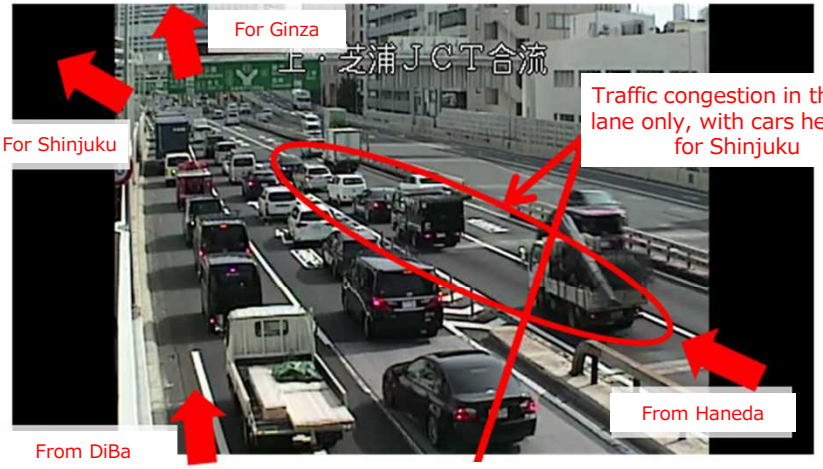
If the amount of information for lane direction determination is not sufficient to determine whether the congested lane is on the left or right, the congestion tail is displayed in all lanes.

3.1. Examination of Field Operational Test Implementation Policy

Traffic congestion by lane at Hamazakibashi JCT and image of information distribution

- When there is lane by lane congestion in the first lane of Route No.1 Haneda Line, the second lane is flowing with dense traffic and it is difficult to change lanes quickly when going straight toward Ginza.
- If you know the lane ahead of you in advance, you can change lanes in plenty of time.

Lane-specific traffic congestion near Shibaura JCT confluence



Running image

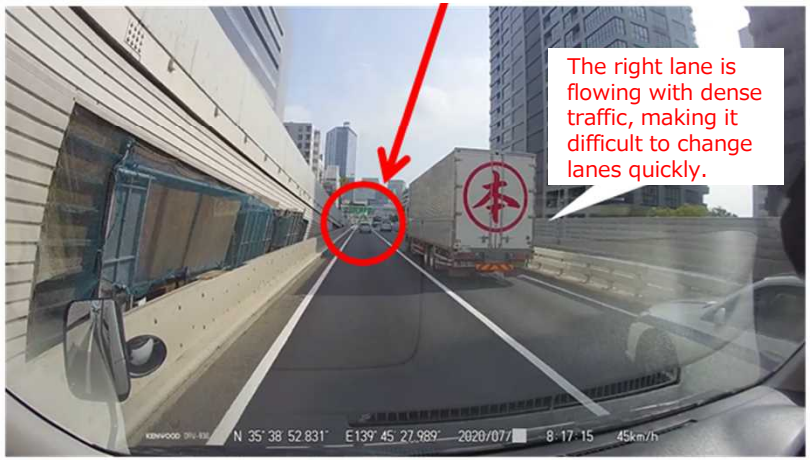
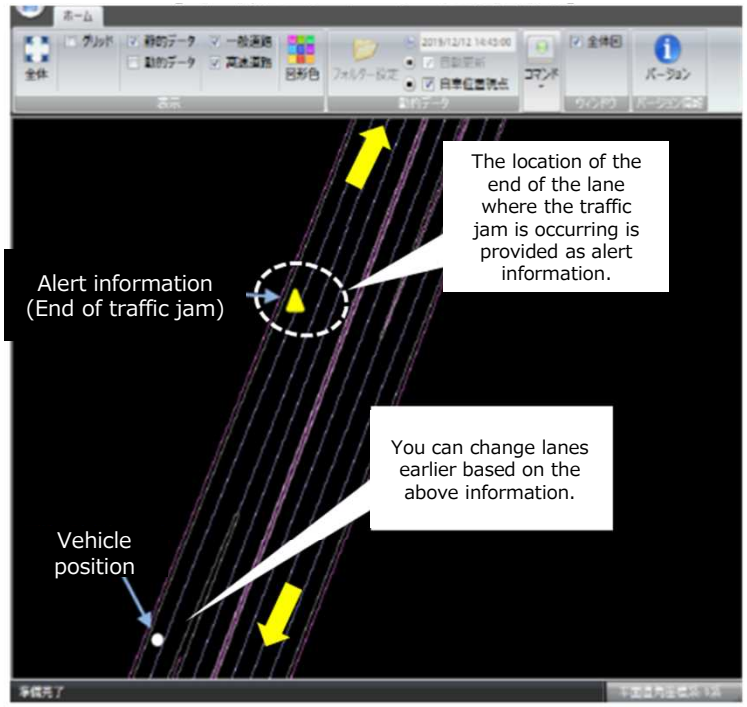


Image of displaying lane level road traffic information on a high-precision 3D map (example of in-vehicle viewer display)



Conducted in FY2021

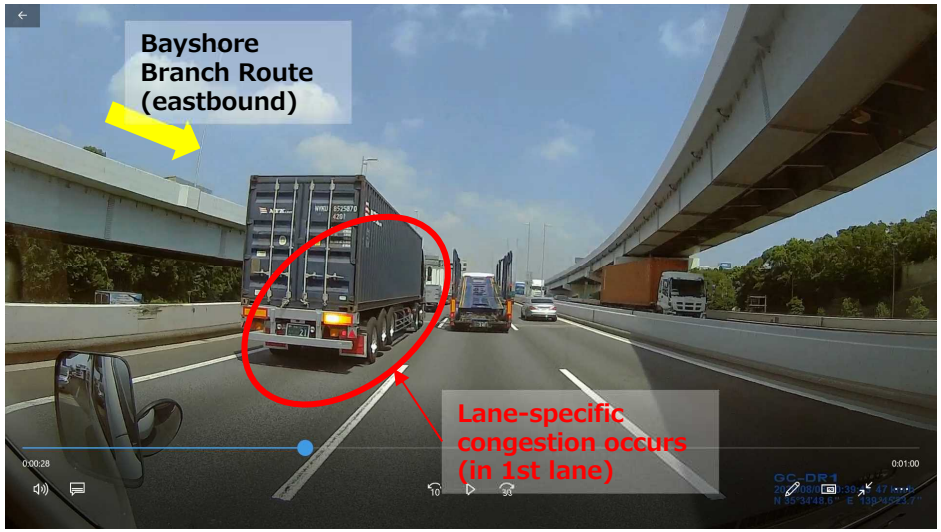
3.1 Field Operational Test Implementation Policy

Occurrence of lane-specific congestion at Tokai JCT and image of information distribution

Image of display of warning information in case of lane-specific traffic congestion (in a specific lane)

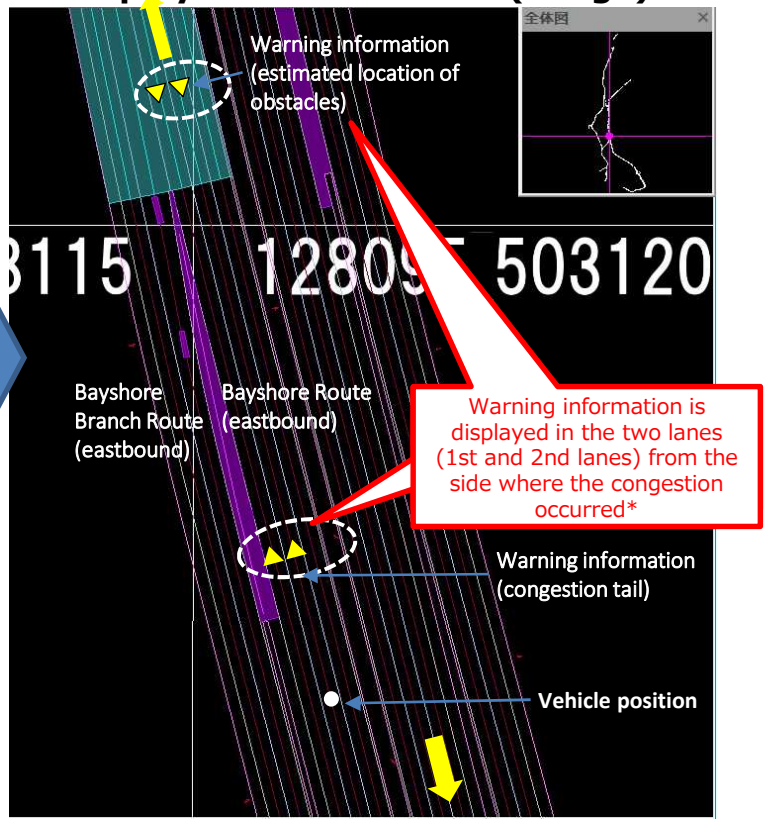
- ○ If vehicles merging from the Haneda Line increases, it interferes with the travel of vehicles in the first lane of the Bayshore Route, generating congestion starting from the junction.
- ○ Lane-specific congestion occurs in the first lane of the Bayshore Route, then if traffic is heavy, the second lane also becomes congested.

Video of driving eastbound Bayshore Route



Traffic between Haneda Airport IC and Tokai JCT on the Bayshore Route (eastbound)
(weekday, August 2020, around 10:39)

Example of distributed information displayed on the viewer (image)



* In the case of cross-section congestion (in all lanes), warning information is displayed in all three lanes.

3.2 Outline of Implementation of FOT

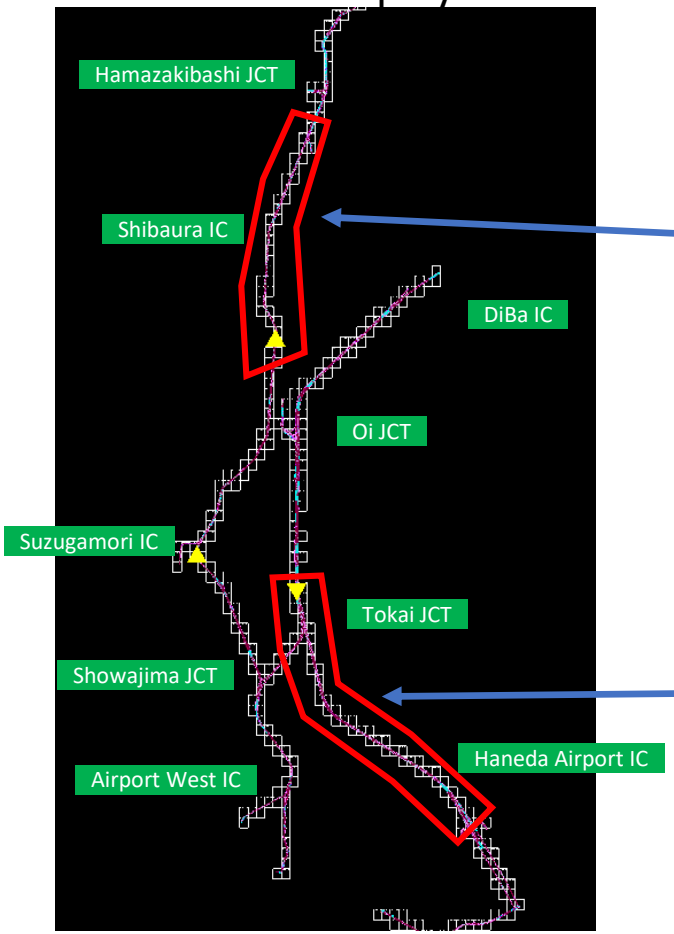
Conducted in FY2021

Distribution of warning information during FOT

- The viewer display at 10:00 a.m. on December 20 (Monday) shows warning information (congestion tail) around Hamazakibashi JCT to Shibaura IC (upbound Haneda Line), and warning information (estimated location of obstacles) at Tokai JCT (eastbound Bayshore Route), which almost corresponds to the traffic situation on that day.

December 20, 2021 (Monday) 10:00 a.m.

Distribution information displayed on the viewer



JARTIC congestion information

*From JARTIC website

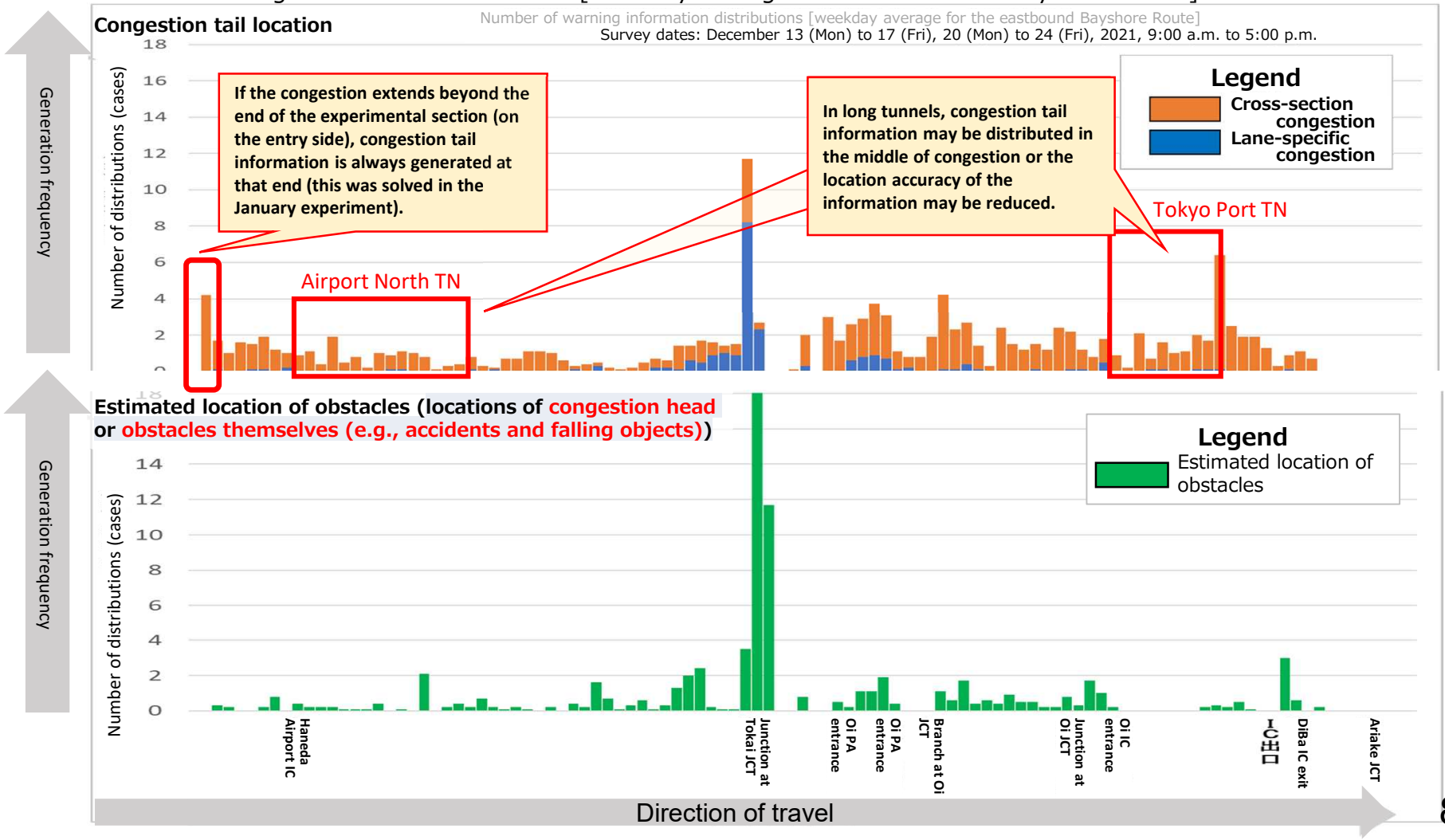
3.2 Outline of Implementation of FOT

Conducted in FY2021

Distribution frequency of warning information (by content) during the FOT

- On the Bayshore Route (eastbound), the generation frequency of warning information was particularly high around Tokai JCT during the period. In this connection, lane-specific congestion information was generated around Tokai JCT and Oi PA entrance/exit.

Number of warning information distributions [weekday average for the eastbound Bayshore Route]



3.2 Outline of Implementation of FOT

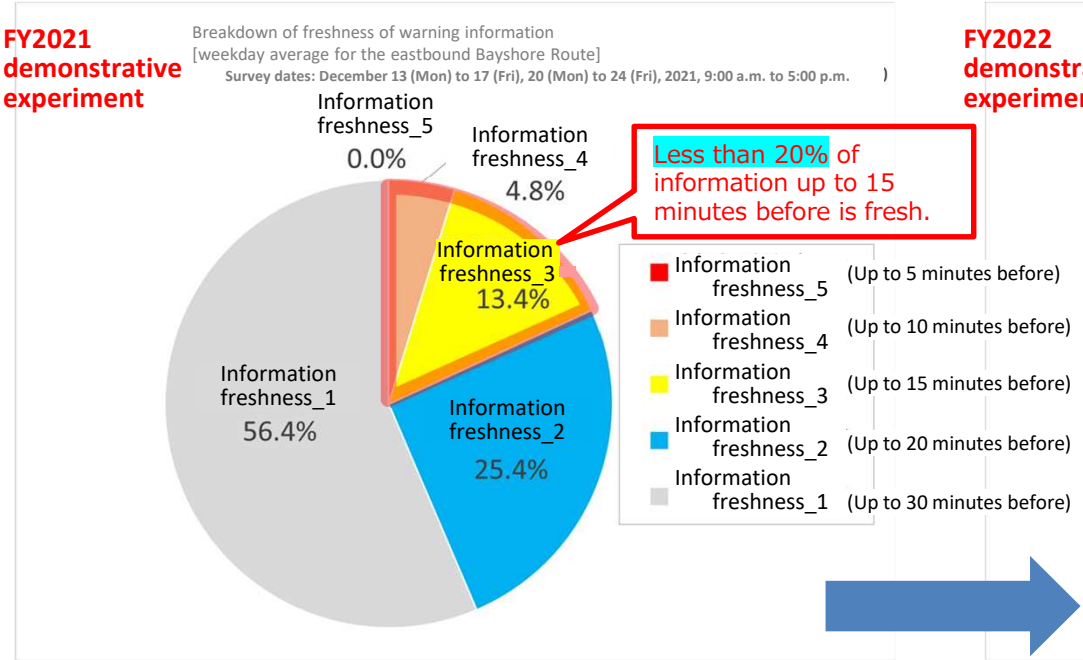
Conducted in FY2021

Comparison of information generation status with that in the FY2021 FOTs

- Compared to the results of the FY2021 FOTs, since probe providers with online access increased (from one to two), the freshness of warning information was greatly improved.
- In addition, information such as turn signal information has become available, making it possible to detect lane-specific congestion even in cases other than branches.

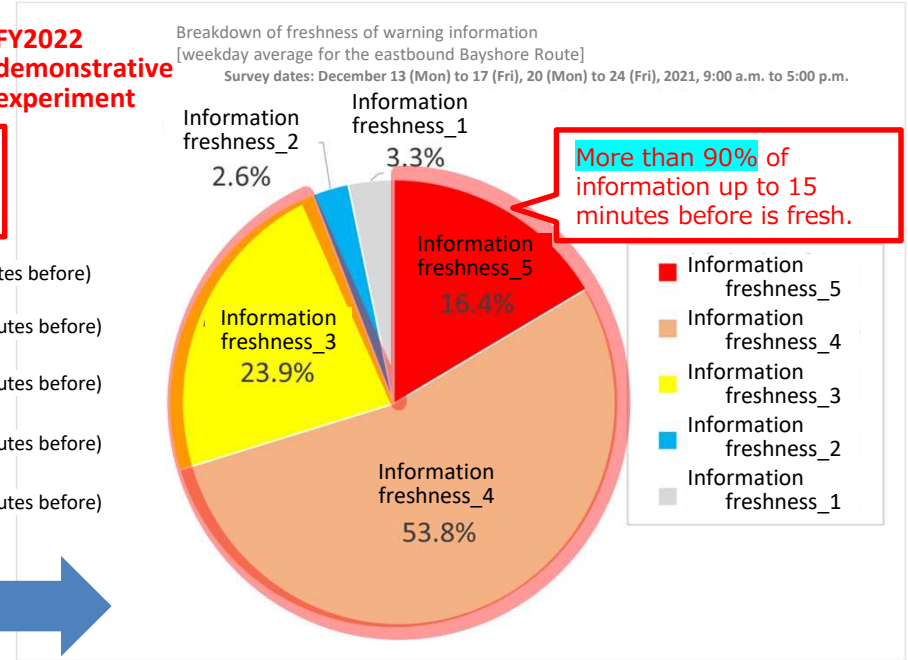
◆ Details of freshness of congestion tail information generated (percentage distribution): Bayshore Route (eastbound)

FY2021 demonstrative experiment



Less than 20% of information up to 15 minutes before is fresh.

FY2022 demonstrative experiment



More than 90% of information up to 15 minutes before is fresh.

◆ Number of warning information (congestion tail) generated (daily average): Bayshore Route (eastbound)

FY2021 demonstrative experiment
- Cross-section congestion: 40 cases/day
- Lane-specific congestion: 0 cases/day

Impossible to identify lane-specific congestion due to unavailability of turn signal information

FY2022 demonstrative experiment
- Cross-section congestion: 116 cases/day
- Lane-specific congestion: 22 cases/day

The availability of turn signal information made it possible to detect lane-specific congestion near Tokai JCT.

3.2 Outline of Implementation of FOT

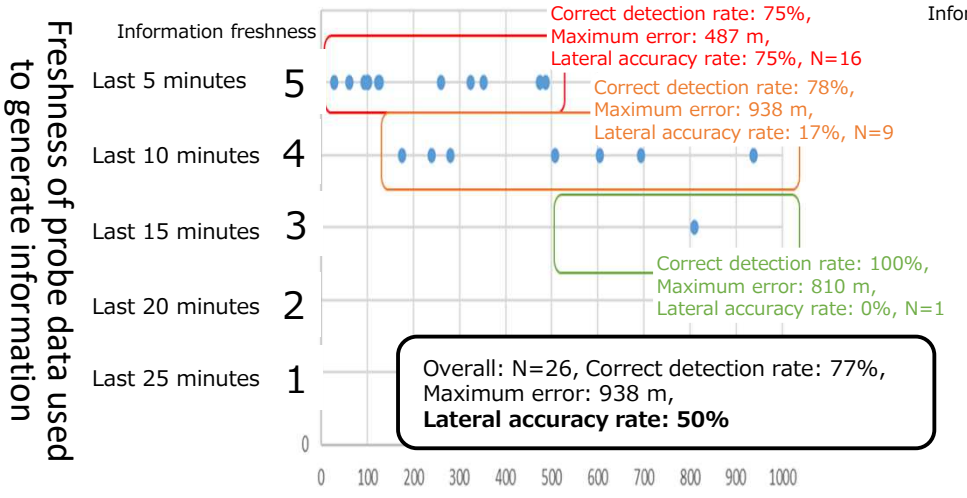
Conducted in FY2021

◆Verification of the accuracy of lane-level vehicle information generated

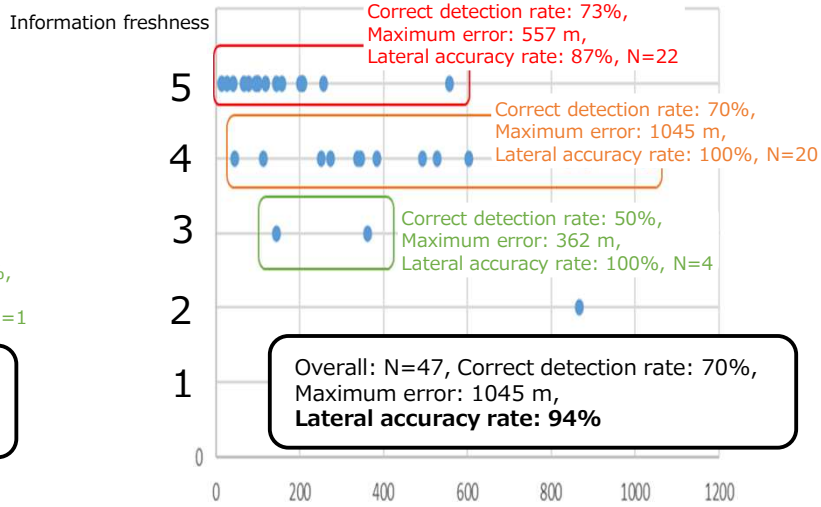
- Comparing the information generated with the actual location of the congestion tail, the correct detection rate was about 70 to 80%.
- Even information with a freshness of 5 (using probes up to the last 5 minutes) shows an error of about 500 m at the maximum, which tends to increase as the freshness decreases.
  (OEMs often require a location accuracy deviation (in the longitudinal direction) of 100 to 300 m (according to the results of the FY2020 questionnaire).)
- The accuracy of determining whether the congested lane is on the left or right is 94% for the upbound Haneda Line (2 lanes), and 50% for the eastbound Bayshore Route (3 lanes).

Accuracy verification results of warning information (congestion tail) generation locations
<Relation between information freshness and location errors>

[Bayshore Route (eastbound)]



[Haneda Line (upbound)]



Deviation (m) of the information provision location from the slowdown location

Survey method: Speed measurement of survey vehicles and video surveys (determined as congestion below 20 km/h, and as recovered above 40 km/h)

Verification route: Bayshore Route (eastbound), Haneda Line (upbound)
Verification period: December 20 to 24, 2021

Bayshore Route (eastbound): 26 data provided during 21 runs among a total of 40 runs in which congestion tail information was distributed
Haneda Line (upbound): 47 data provided during 26 runs among a total of 36 runs in which congestion tail information was distributed

Conducted in FY2020

3.3. Efficacy evaluation by experiment participants

Mode of participation in the experiment by experiment participants (questionnaire respondents)

- A total of 11 companies responded to the questionnaire regarding the evaluation of the effectiveness of delivered information.
- Five respondents received the delivered information during actual driving, and two received it in the laboratory.
- The number of times each company drove the actual route ranged from 2 to 13 times. Of these, the number of times that the delivered information could be compared with actual traffic conditions ranged from 1 to 8 times.

Participation of survey respondents in the experiment

Form of participation		Number of participants
①	Participation in online distribution experiment (Receiving during actual driving on the expressway)	5 companies
②	Participation in online distribution experiments (Reception in the laboratory)	2 companies
③	Viewing of handout video materials only	3 companies
④	Answered questionnaire only	1 companies
Total		11 companies

Driving conditions in the experimental section

Participants in the experiment	Number of days traveled	Number of trips	Number of times of checking delivered information	Number of times compared to actual traffic conditions
A	2 days	9 times	8 times	8 times
B	1 day	2 times	1 time	1 time
F	3 days	9 times	4 times	4 times
G	4 days	13 times	9 times	6 times
H	2 days	2 times	2 times	2 times

*Traveling sections were Route No.1 Haneda Line inbound and outbound.

3.3. Efficacy evaluation by experiment participants

Conducted in FY2020

Summary of questionnaire contents and results (preliminary report)

*In the future, the reasons for the responses will be confirmed, cross-analyzed, and cross-checked with the driving images.

Questionnaire A
(Answer for each trip)

- Date and time of travel
- Degree of agreement between delivered information and actual event

Congestion tail with lane-specific location information
⇒Match + Slight match = 44%

Questionnaire B
(Answer based on all runs)

- Regarding questions that contribute to path planning for automated vehicles (level 3 and above)
- Regarding questions that contribute to path planning for drivers (automatic driving level 2 and below)

Comparison

① Validity of information

① Valid + Somewhat valid
= 54% (I'm not sure, 27%)

⑧ Validity of information

Service requirements (by intra-city/inter-city expressway)
② Timing
③ Positional accuracy
④ Update cycle

② How far in advance do you need the information?
⇒200m–2km
③ Location accuracy of required information (direction of travel)
⇒100–300m
④ Update cycle for necessary information
⇒1–2 minutes

Comparison

Service requirements
⑨ Timing
⑩ Positional accuracy
⑪ Update cycle

*All of these answers are for intra-city highways.

Information needed and why
⑤ Congestion tail
⑥ Traffic accident
⑦ Lane regulation

⑤⑥⑦ Congestion tail position
⇒Necessary + Somewhat necessary= 82–91%
⑤⑥⑦ Congested traffic section
⇒Necessary + Somewhat necessary= 72–81%
⑤⑥⑦ Location of obstacle itself
⇒Necessary + Somewhat necessary= 63–73%

⑨ How far in advance do you need the information?
⇒200m–2km
⑩ Location accuracy of required information (direction of travel)
⇒50–500m
⑪ Update cycle for necessary information
⇒1–5 minutes

⑫ Improvements for practical use

*All answers are for intra-city highways.

Questionnaire structure and summary of results

3.3 Efficacy Evaluation by Experiment Participants

Conducted in FY2020

Summary of questionnaire items and results

(1) Degree of agreement between the distributed information and the actual event

*Confirmed by comparing the participant's dashcam video with the information distribution log.

- The percentage of actual encounters with congestion tails to the cases of passing through the warning information location was a little less than 40%.
- It was confirmed that the probe information used was often not current in cases of no encounter with congestion tails.
- The number of allowable retroactive levels is considered to be at least up to the third level (the last 15 minutes).
  ⇒ This target is considered to be attainable if more probe providers with online access participate.

(2) Effectiveness of distributed information

*As information that contributes to path planning for automated vehicles (Level 3 and above)

- Majority of participants answered "Effective" or "Somewhat effective" for lane-specific information.
- In the FOT on the actual road, the participants who had experienced a high degree of matching between the distributed information and the actual event tended to highly evaluate the effectiveness.
  ⇒ It is expected that the effectiveness will be evaluated more highly by improving the information accuracy.
- Majority of participants answered "Effective" or "Somewhat effective" even for non-lane-specific information.
  ⇒ Possibility of early social implementation

(3) Service requirements *Answers for urban expressways

- Required information update cycle: 1 to 2 minutes
  ⇒ May be improved if restrictions on probe providers are eliminated.
- At how far forward is the information required? : 200 m to 2 km
  ⇒ Assuming 60 km/h, this matches the update cycle.
- Location accuracy required for information (in the longitudinal direction): 100 to 300 m
  ⇒ An error of less than 300 m is considered to be attainable if more probe providers participate.

(4) Other necessary information *As information that contributes to path planning for automated vehicles (Level 3 and above)

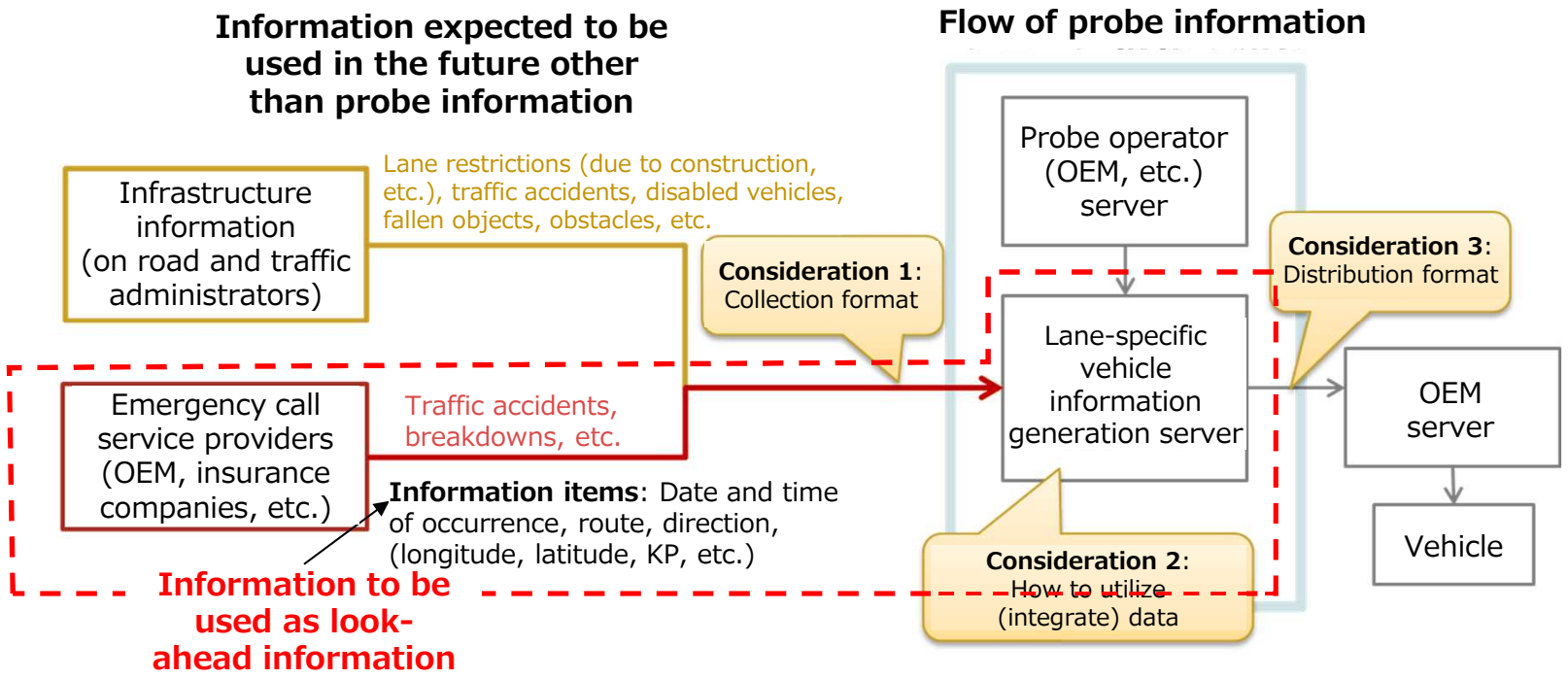
- In any use case, there is a high need for information on "congested sections" and "the location of obstacles themselves." ⇒ Referred to as a priority for future development.

(5) Improvements for practical use

- 2/3 of participants answered "Effective" or "Somewhat effective" as information that benefits drivers.
  ⇒ Possibility of early social implementation
- Participants requested improvements in location accuracy and update cycle as points to be improved for realization. ⇒ May be improved if restrictions on probe providers are eliminated.

4. Investigation and verification of elemental technologies using quasi-dynamic level look-ahead information

- The following is a summary of the information sources that may be utilized as quasi-dynamic level look-ahead information, as well as a study of the applicability to lane-specific information generation.
- In FY2020, the sources of warning information (operators) and available information items were organized.



Information expected to be used in the future other than probe information and issues to be considered regarding its use

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.