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

FY2022 Annual Report

Summary

Pacific Consultants Co., Ltd.

March 2023

<Contents>

1. Study Outline

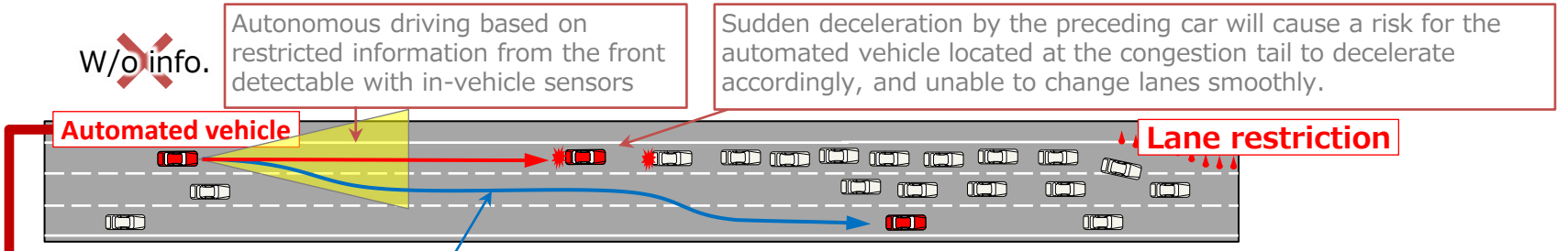
1.1. Project Goals

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

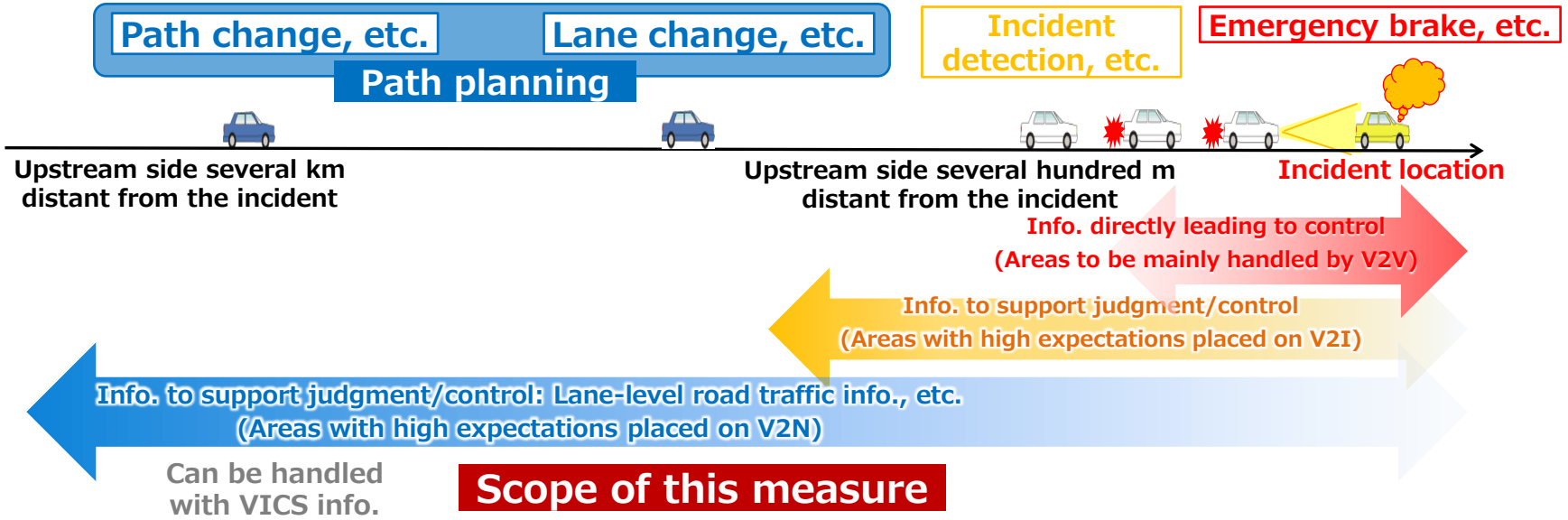
Effectively generating information by combining information from various sources

- ○ **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

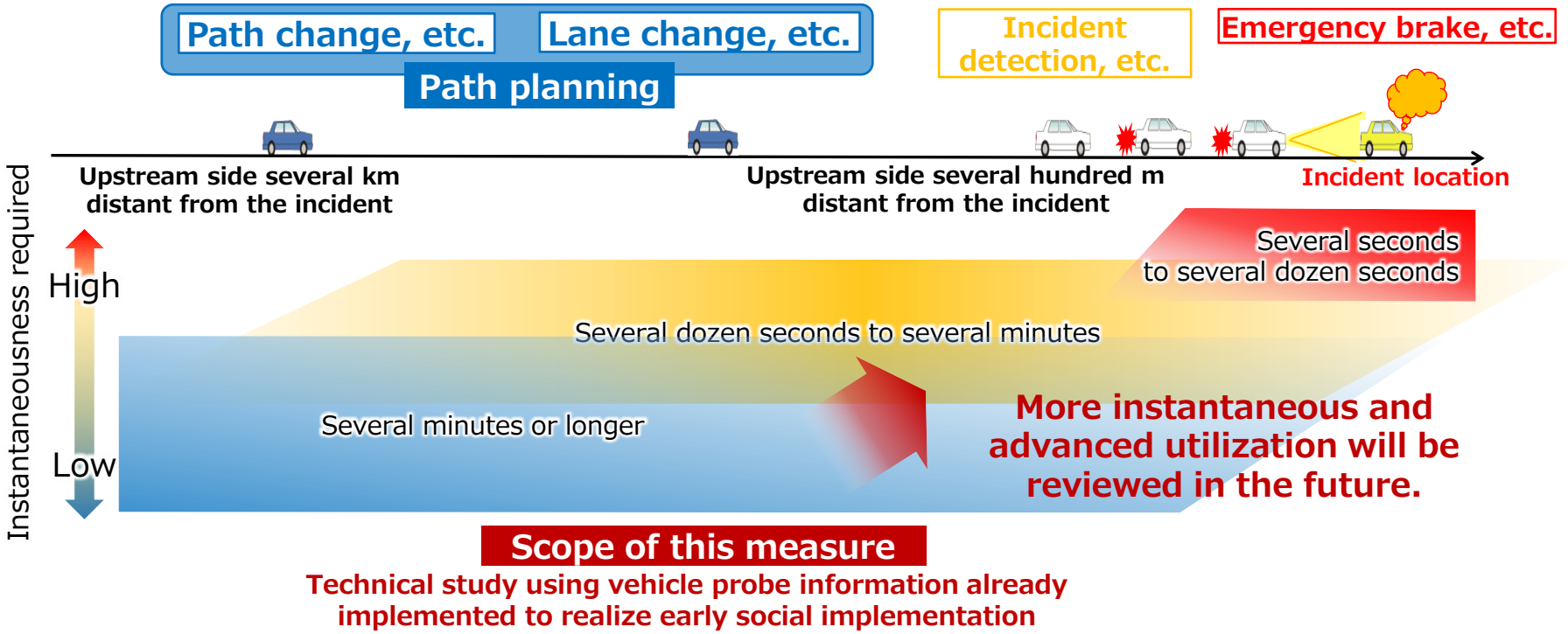
- There are multiple stages for automated vehicles to appropriately control or make judgment, depending on the distances to the point to perform controls necessary for individual scenes. Thus lane-level information is required for each stage.
- It is important to use various communication measures depending 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.

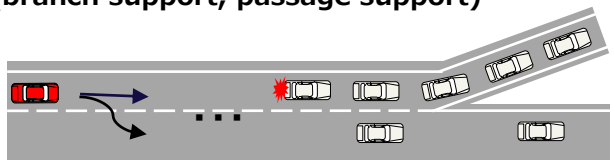


1.1. Project Goals

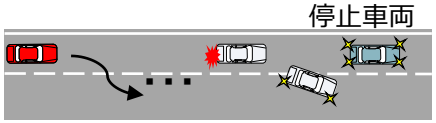
Target Use Cases and Advantage of Information Provision

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

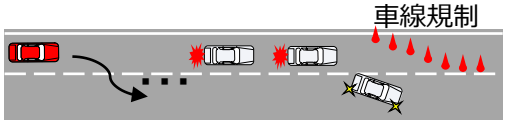
A: Congestion tail (branch support, passage support)



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)

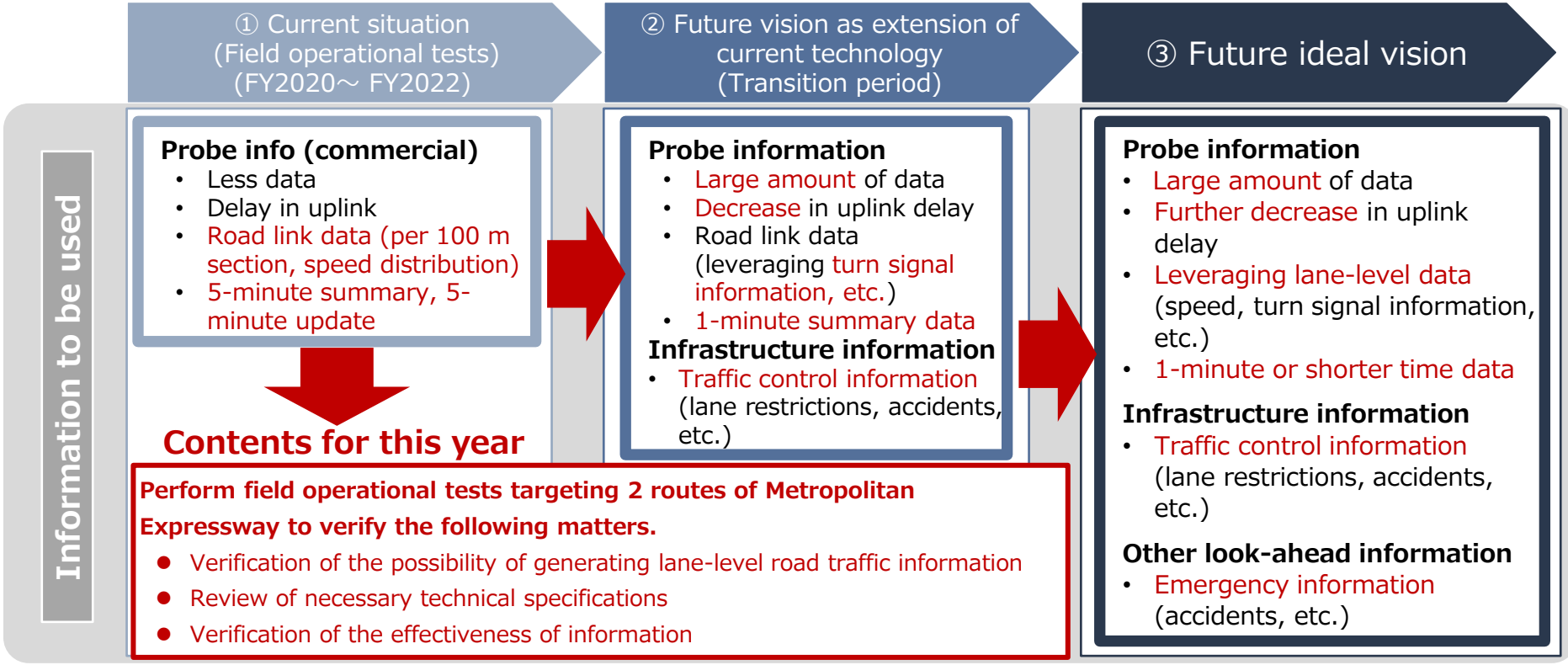
Advantages of info provision

- **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 demonstration experiment on the Metropolitan Expressway Haneda Line and Bayshore Route (hereinafter referred to as "demonstration experiment") in the course of the Tokyo Bay Area 2020 Demonstration Experiment. 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. Demonstration experiment

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

d. Study on the use and validation of vehicle probe data for the detection of bad weather and road surface conditions

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

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. Demonstration experiment

Demonstration experiment planning

1) Creation and update of node link maps of the demonstration experiment sections

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

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

* The demonstration experiment is assumed to be conducted mainly by the Demonstration Experiment Consortium.

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

d. Study on the use and validation of vehicle probe data for the detection of bad weather and road surface conditions

1.2. Project Outline

Examination of elemental technologies

This research aims to generate alert information on the location of congestion trails and obstacle lanes from commercial probe vehicle information, etc., and to provide this information to automated vehicles.

The scope of this project includes data aggregation and integration from data providers, information generation, location representation, and distribution to OEMs, etc., as part of a series of steps up to the distribution of information to user vehicles, which is a cooperative area.

Based on the effectiveness verification and technological evaluation through demonstration experiments, this project aims to develop specific technical specifications (information resolution, delivery frequency, delivery format, etc.) for the practical application of lane-level road traffic information.

Technical specifications for generating and providing lane-level road traffic information

Technical Specifications

①Data sharing (aggregation) specifications
Data sharing specifications (data items, format, collection frequency, etc.) between centers when probe data, etc. are shared from the provider's server to the information integration/generation server.

②Data integration specifications for multiple information sources
Specifications for integrated processing of data collected from multiple information providers

③Specifications for generating lane-by-lane road traffic information
Technical specifications for generating road traffic information by roadway from available data

④Conversion specification to location-expressible data
Data format and conversion specifications (e.g., conversion to CRP and dynamic maps) to enable representation (distribution) of generated lane-by-lane road traffic information
※ Consideration of whether or not this functionality is required.

⑤Data sharing (distribution) specifications
Data sharing specifications (data items, format, frequency of distribution, etc.) between centers when distributing generated information from information integration/generation servers to OEM and other servers

Assumptions and conditions to be considered

Related specifications, etc.
○Data sharing specifications between centers
- JASPAR Specifications

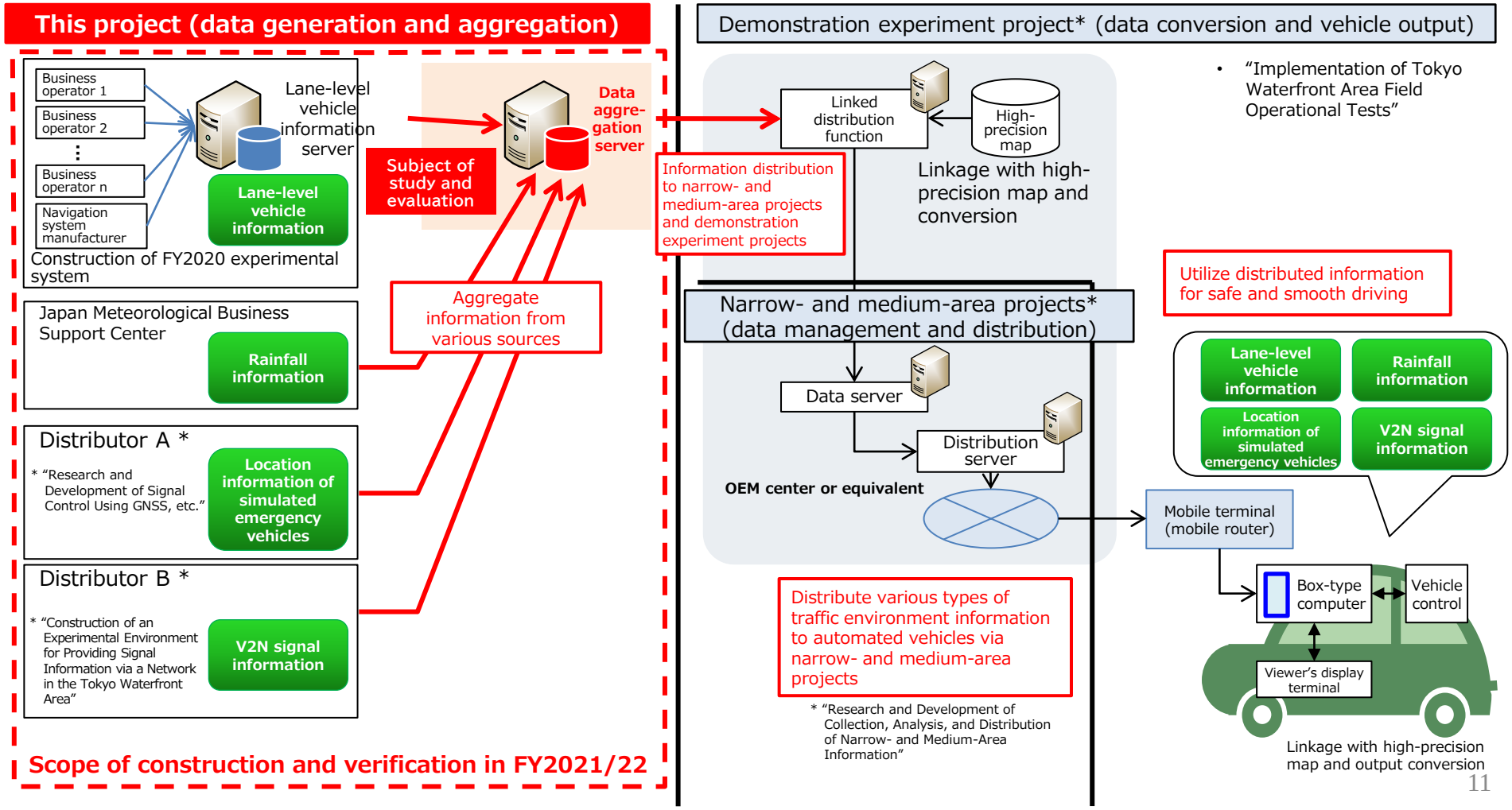
○Location Expression Specifications
- Extended DRM-DB
- CRP

Data that can be utilized for early commercialization
- Probe information available from commercial-based vehicles
  → Roadway-level travel time information, event information, etc.

1.2. Project Outline

Demonstration experiment system configuration

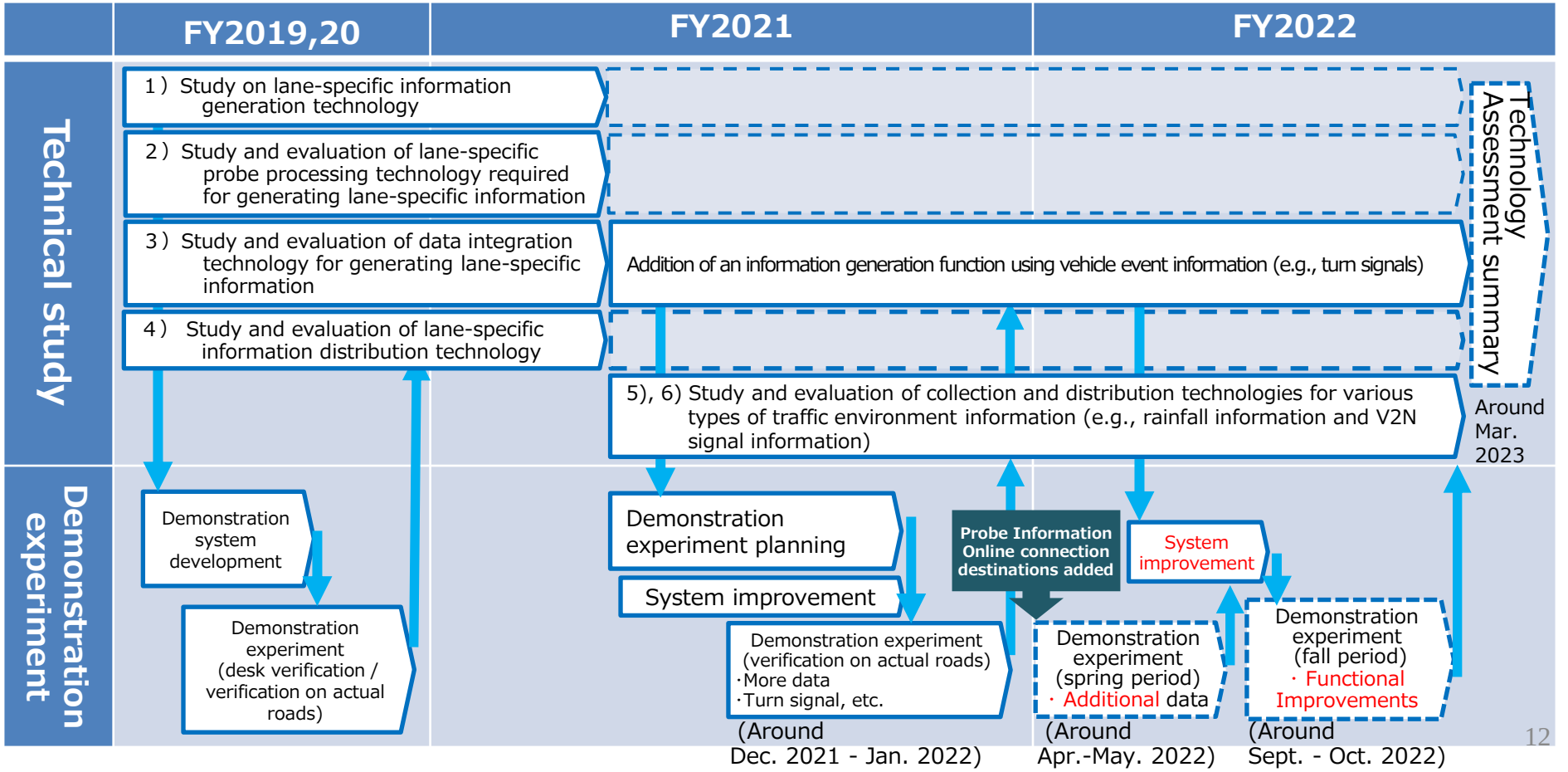
- Construct an experimental environment in which various types of traffic environment information useful to appropriately determine and control automated vehicles can be centrally aggregated with lane-level vehicle information, for which a demonstration experiment system has been constructed since FY2020,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



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.
- In FY2022,In addition to the addition of probe providers (further increase in data volume), verification experiments were conducted twice a year, in spring and fall, and technical verification was conducted using the PDCA cycle.



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.

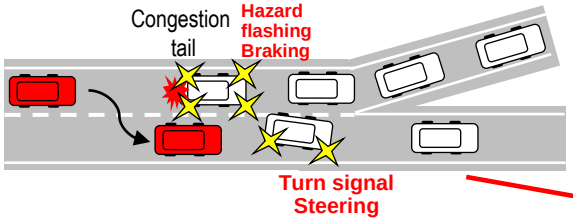
2.1. Study on Lane-specific Information Generation Technology

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

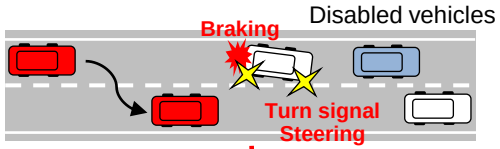
■ Target use case incidents and concept of detection based on probe information

- 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.

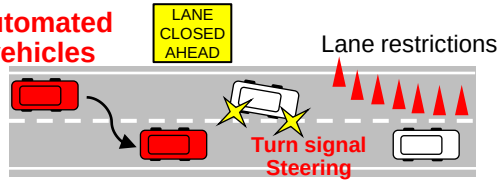
A: Congestion tail (branch support, passage support)



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

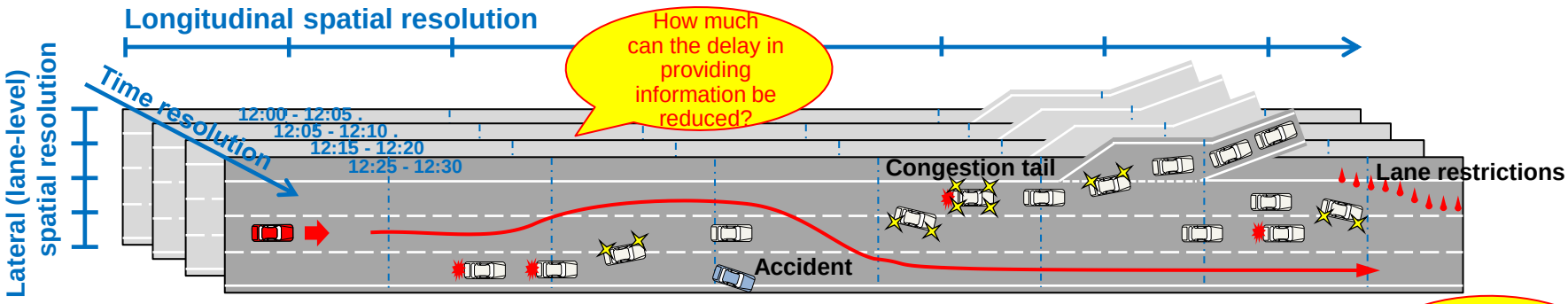


Image of the (lane-specific) probe information to be collected

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) 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 demonstration experiment
- The cost, contract method, and coordination required to cooperate with this project, and more

2.1. Study on Lane-specific Information Generation Technology

(2) 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.

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

2.2.1 Technical Study

■ Basic technology for generating lane-specific probes

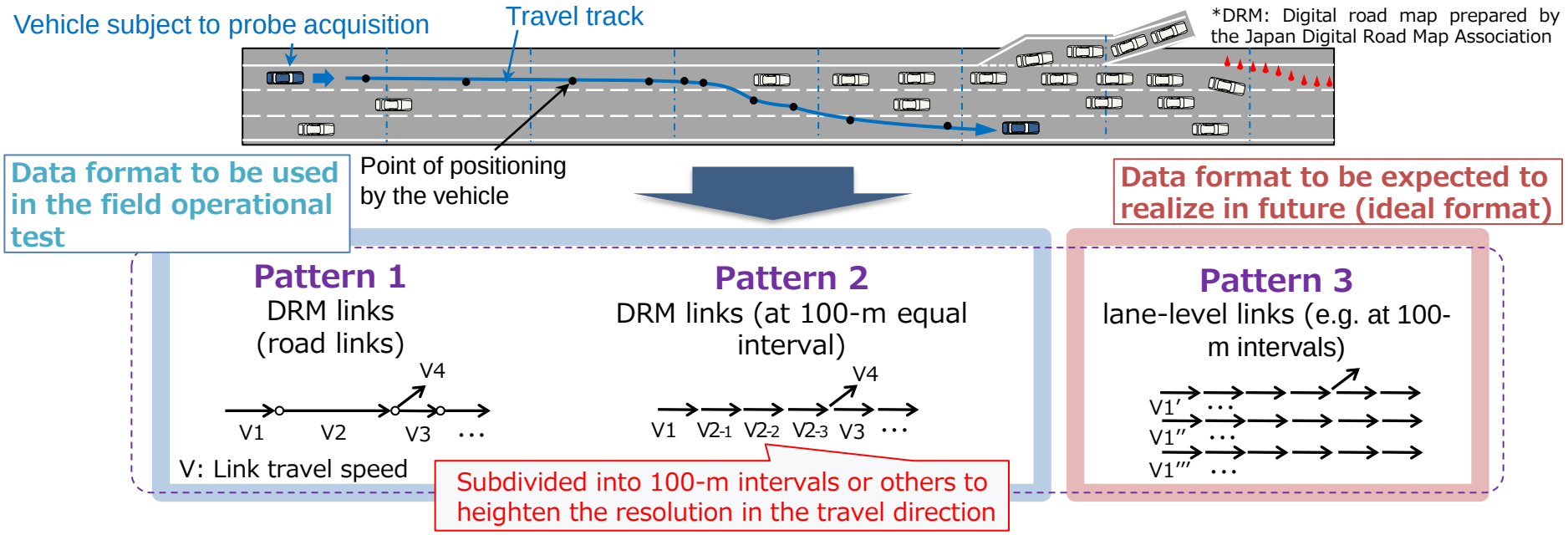
- Among the methods discussed in 2.1, probe processing technology will be examined for those that are feasible to conduct demonstration experiments.
- In FY2019, the data format and information items were organized regarding the available information obtained from vehicles and required for generating 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.

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	

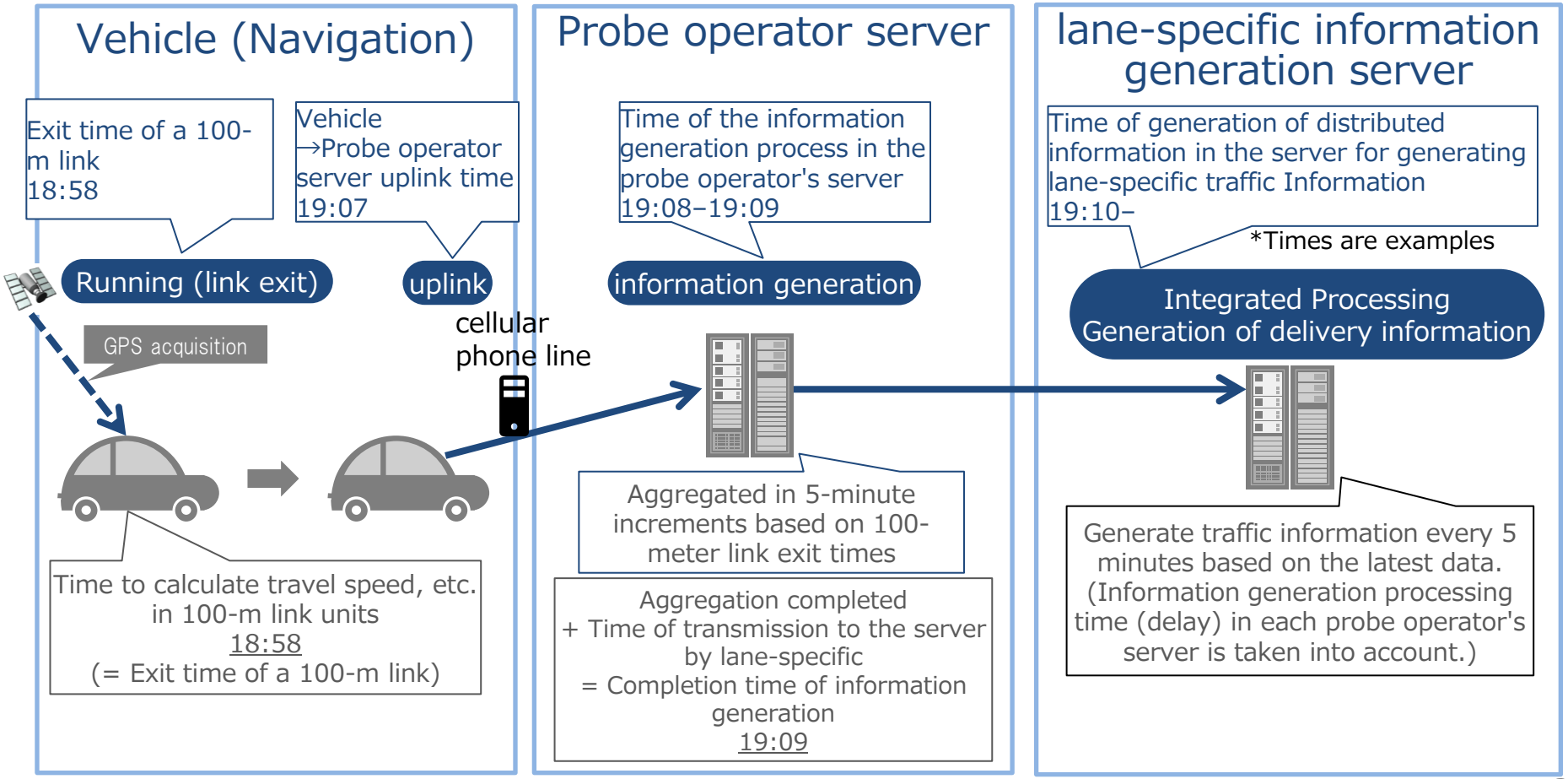
Note 2) Not used in the FY2020 demonstration system

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)

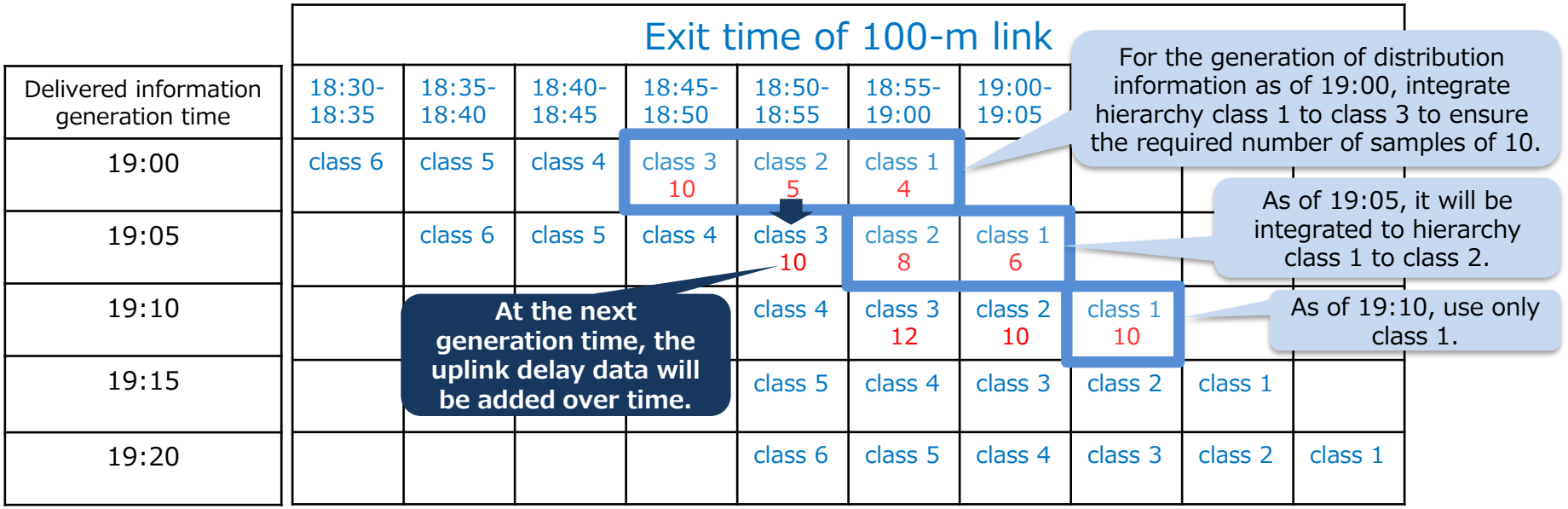


Image of data integration to ensure the required number of samples

***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 demonstration experiment.
- 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

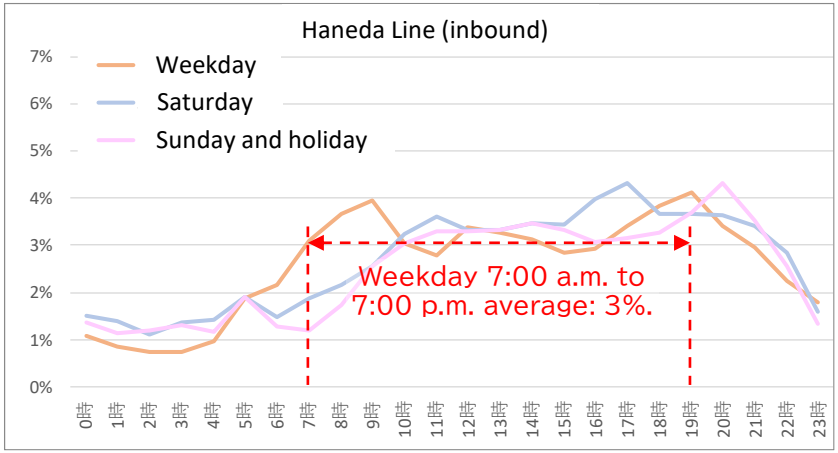
2.2.2 Technical evaluation

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

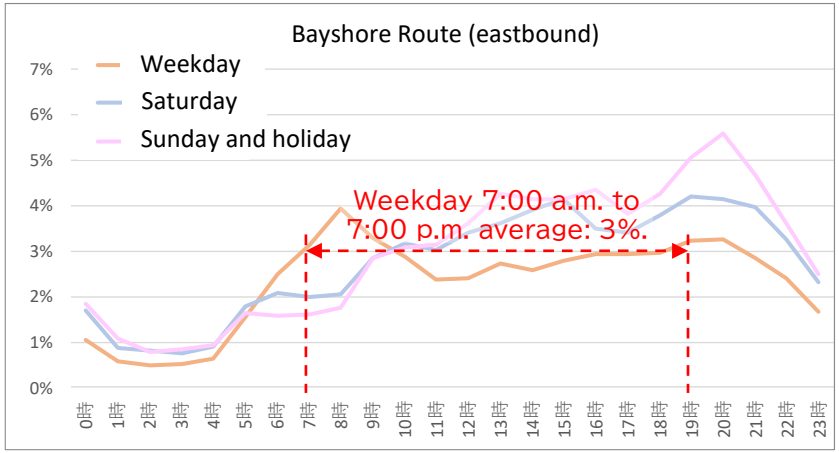
- The contamination rate of probe information (number of vehicles by speed stratification) that can be collected at present is about 3% on the Metropolitan Expressway (Route No.1 Haneda Line and Bayshore Route) (weekdays/daytime).
- Equivalent to 6 cars/5 minutes on Route No.1 Haneda Line (inbound) and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

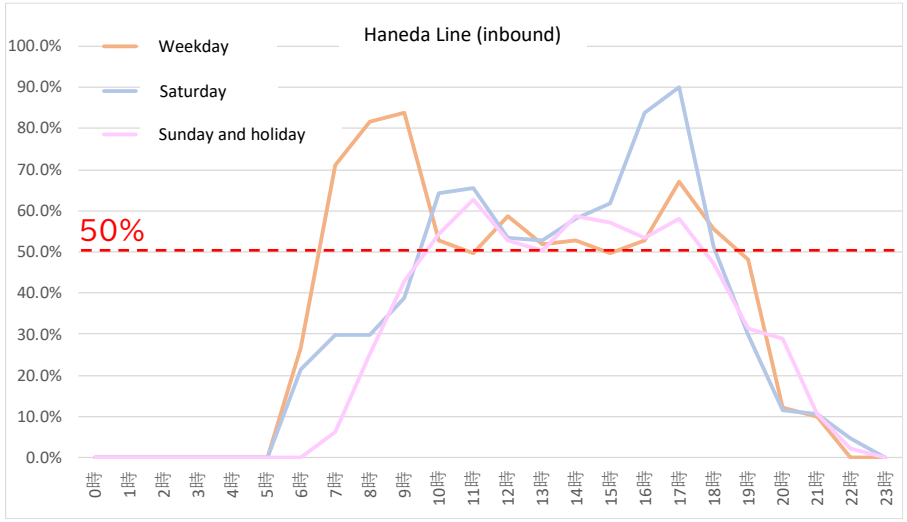
- On Route No.1 Haneda Line, regardless of the day of the week, generally more than 50% of the sections have 5 cars/5 minutes or more* during the daytime.
- On the Bayshore Route, generally more than 80% of the sections have 5 cars/5 minutes or more* during the daytime, regardless of the day of the week.
- 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.

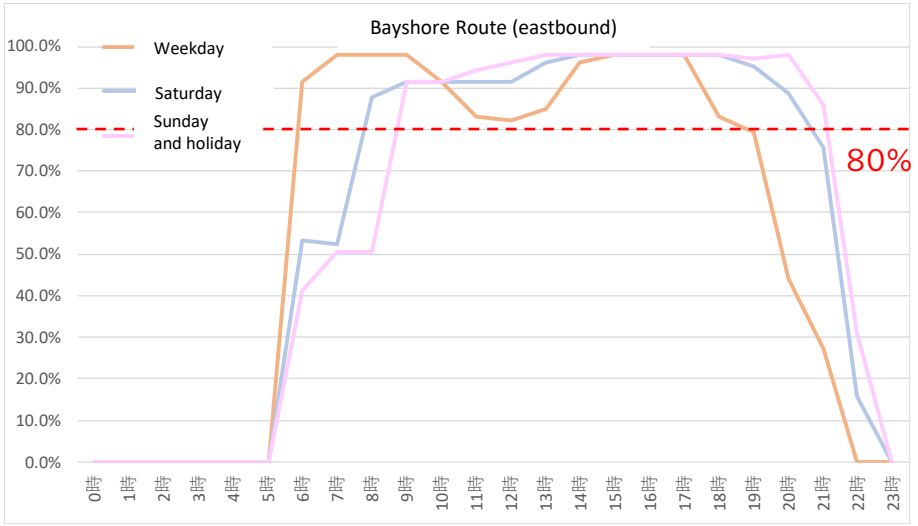
July 8, 2020 - August 7, 2020 Weekday average

Haneda Line (inbound)



Time

Bayshore Route (eastbound)



Time

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

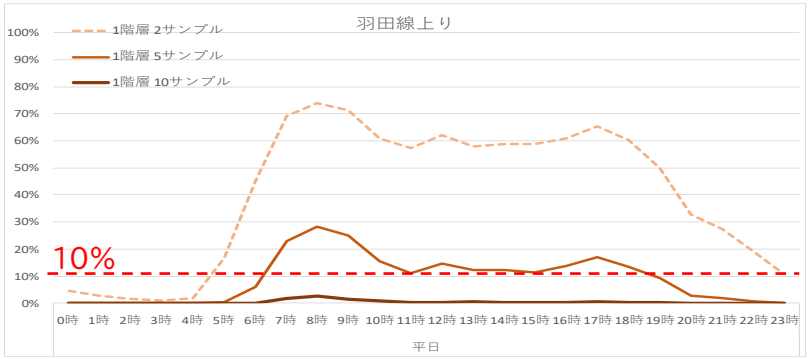
2.2.2 Technical evaluation

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

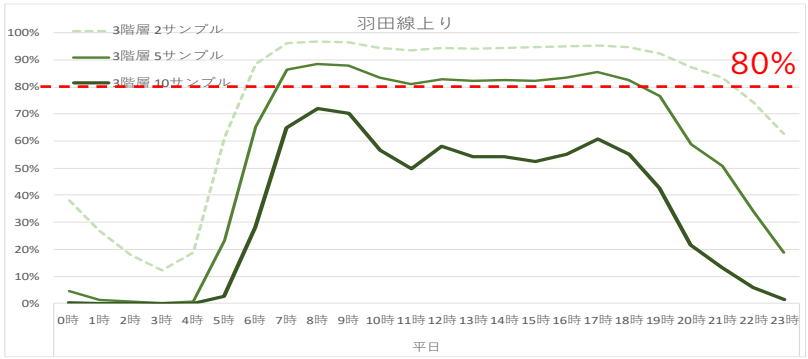
- Since there is a delay in the uplink when collecting probe information for each OEM, etc., data will be collected in 5-minute units up to 30 minutes in the past so that data collected late can be utilized.
- When trying to secure data for more than 5 units, the percentage of sections that can be collected 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

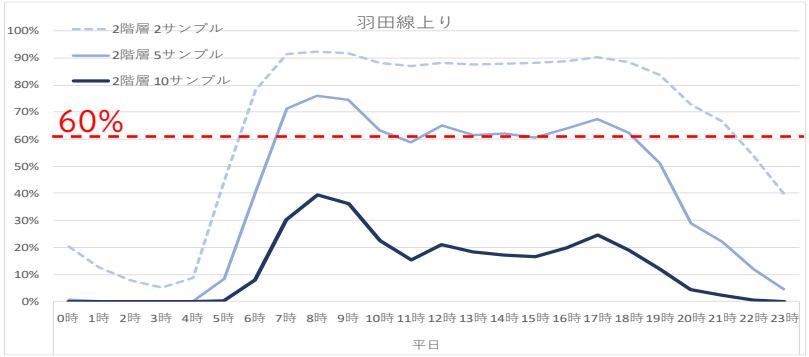
class 1 (Last 5 minutes)



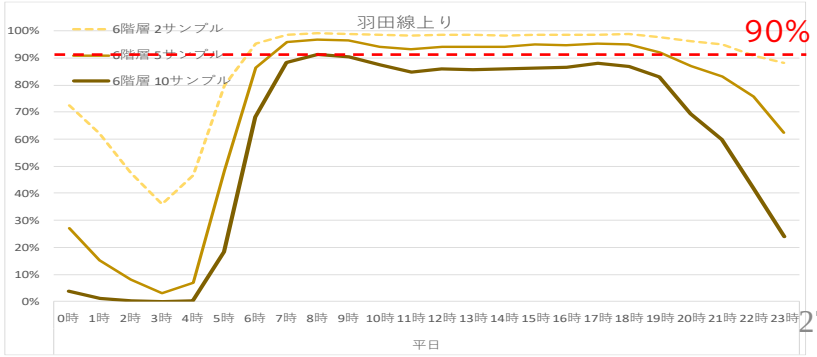
class 3 (Last 15 minutes)



class 2 (Last 10 minutes)



class 6 (Last 30 minutes)



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

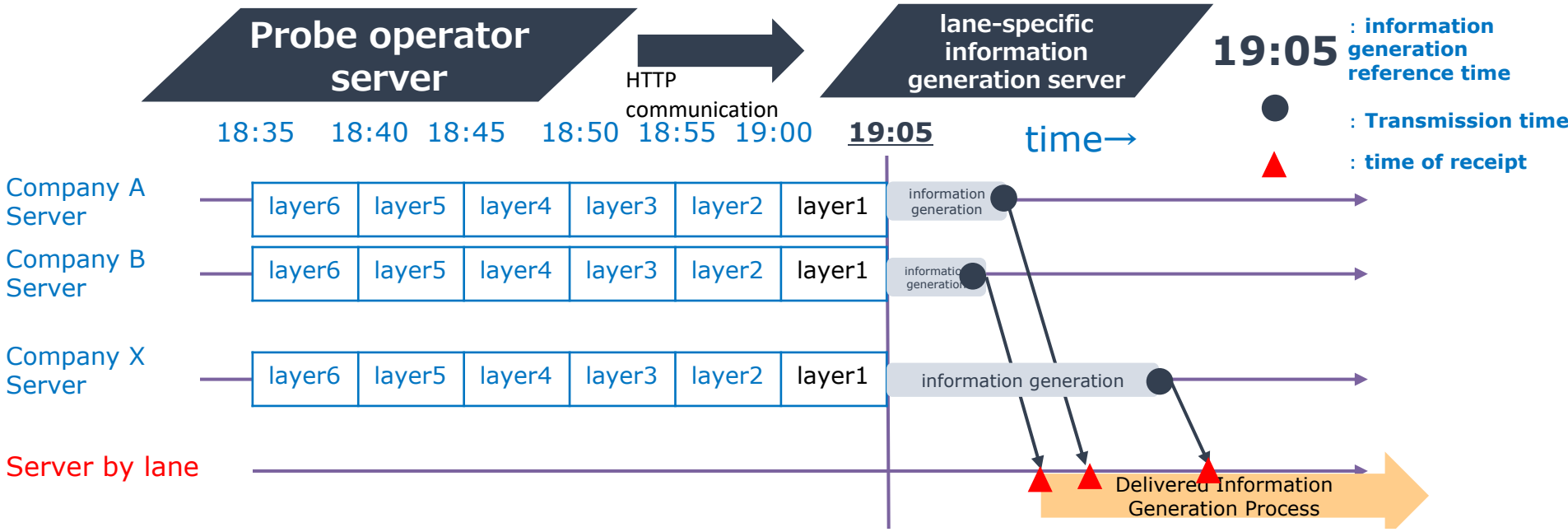
2.3.1 Technical Study

- 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 demonstration experiment server, a logic that also uses vehicle event information (e.g., turn signal count) for generating lane-specific information was studied.

2.3.1 Technical Study

■ Data integration and information generation that takes into account variations in the time information is received from each company's servers

- In the experiment using real-time online data, the time at which the server can receive the data will vary depending on the processing time for data generation, etc. at each probe provider.
- Therefore, in generating information, we set the specification that data integration and information generation based on the latest aggregated data is updated every minute, taking into account the delay in the time when probe information can be received by the server of this experiment and the variation of each probe provider with respect to the reference time for information generation.



Data integration and information generation based on the latest aggregate data updated every minute

Data integration and information generation that takes into account variations in the time information is received from each company's servers

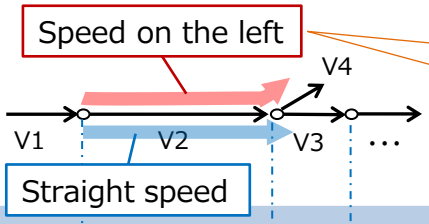
2.3. Study and evaluation of data integration technology for generating lane-specific information

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

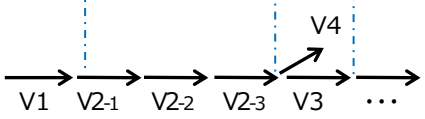
Pattern 1
DRM links (road link)
- Speed by direction at links before junction



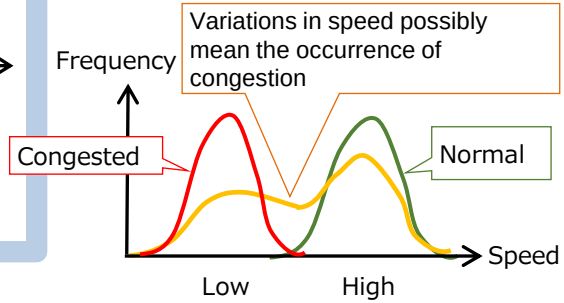
Speed by direction at links before junction

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.

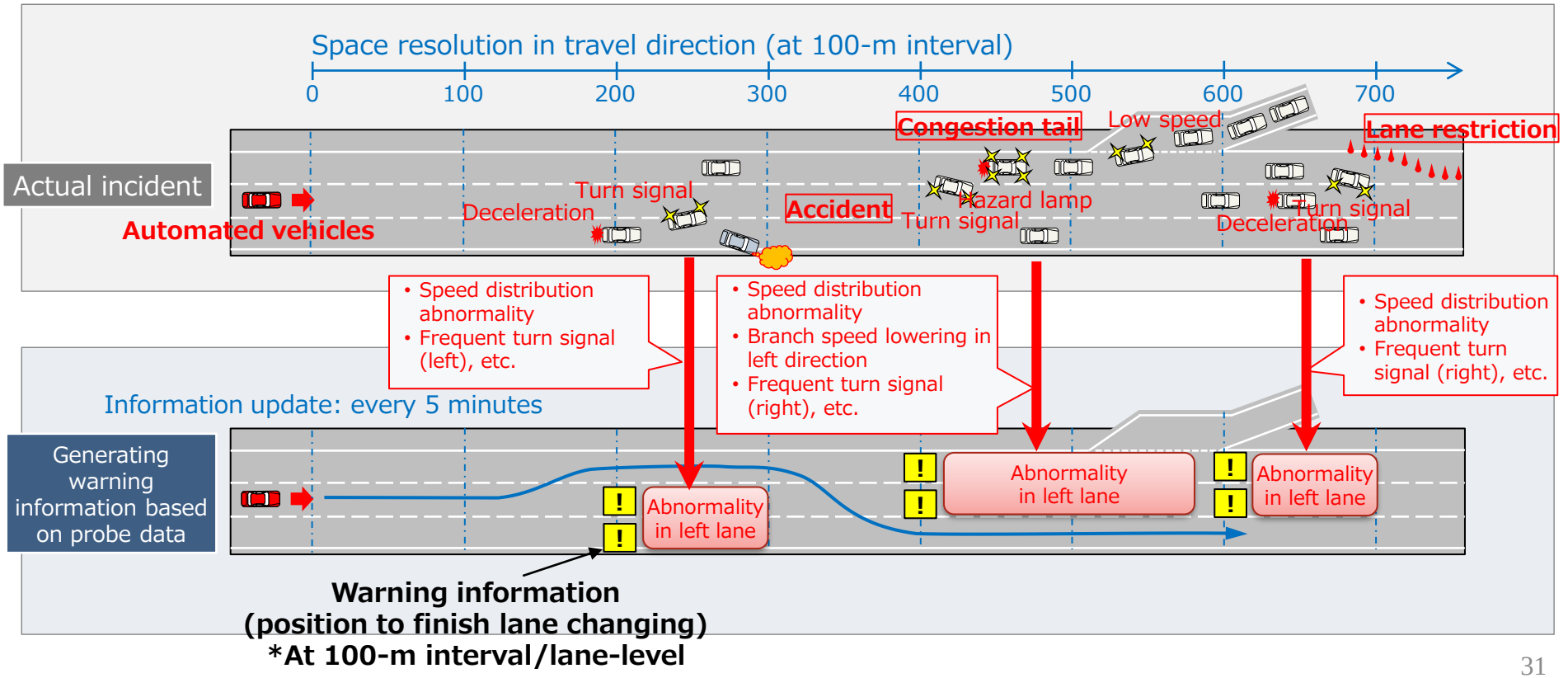
- Identifies a position where an abnormality occurs in the traveling direction at 100-m intervals from information on number of vehicles by speed range in Pattern 2.
- For lane-level abnormality, the direction (left or right) of the lane having the trouble is judged from turn signal information or the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

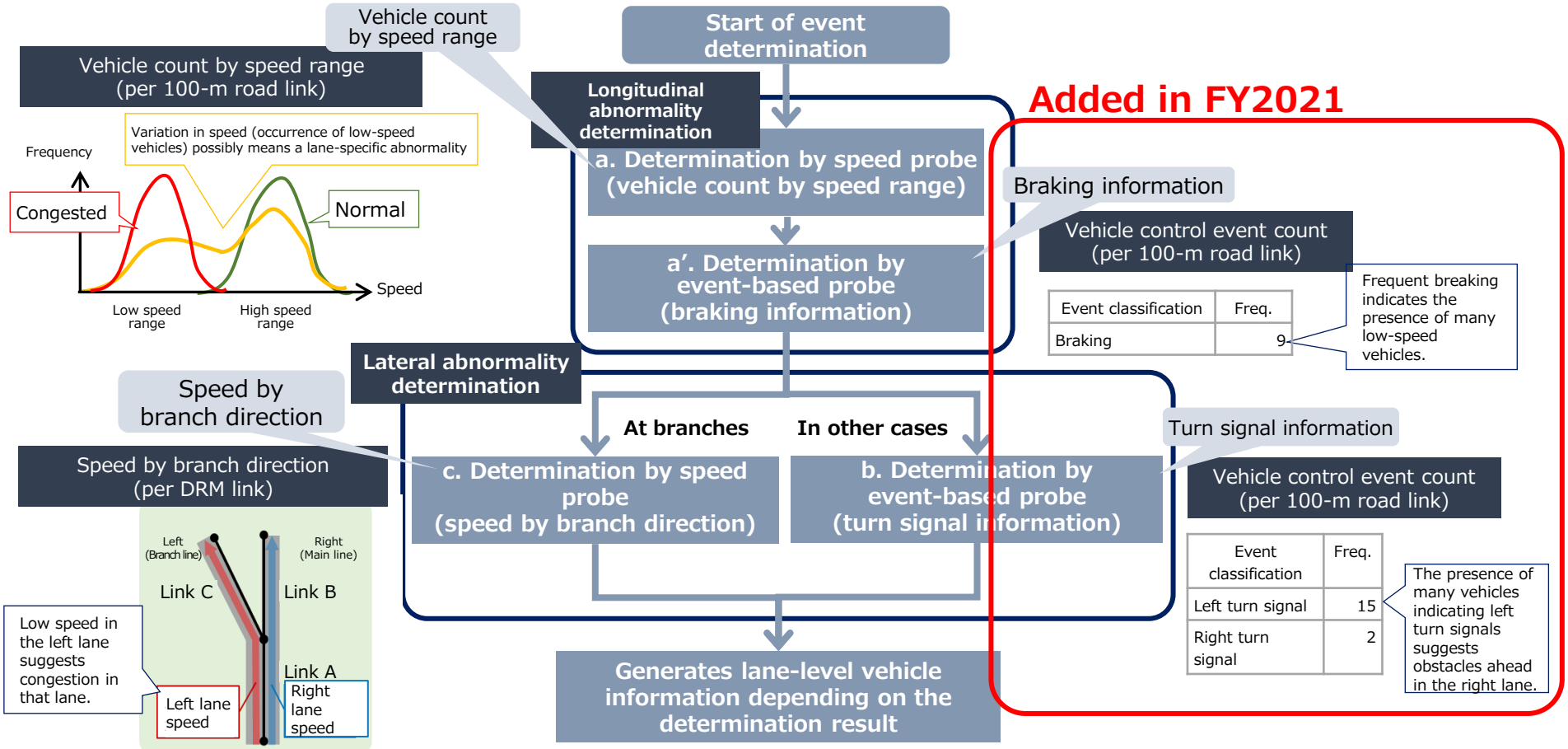
- Generation of the following warning information applicable to target use cases is studied.
- Since vehicle event information processing functions are not implemented in the experiment system for verification, use cases for congestion tails at the junction will be mainly verified.



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

2.3.2 Technology Assessment

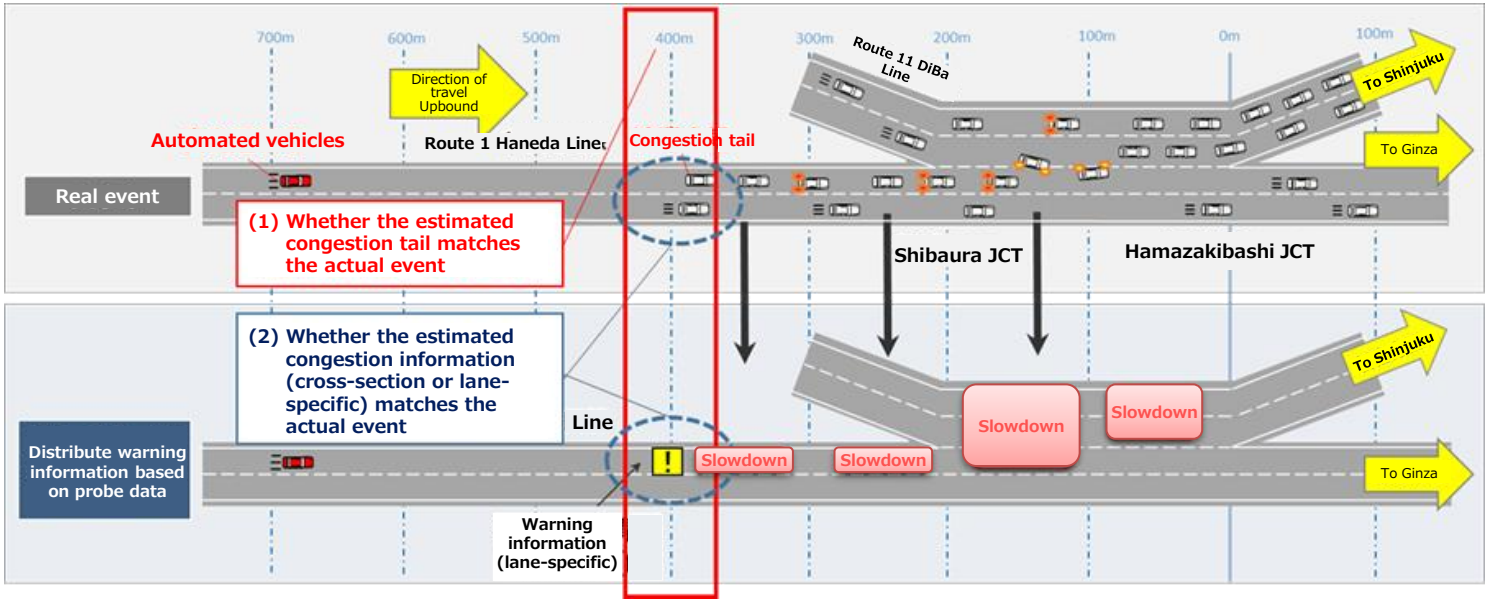
- Build a data integration server and create lane-specific information using a statistical processing method based on the technical study described in the previous section. Analyze the issues for practical use such as information accuracy of the created lane-specific information, and make necessary improvements.
- 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 Technology Assessment

■ 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.

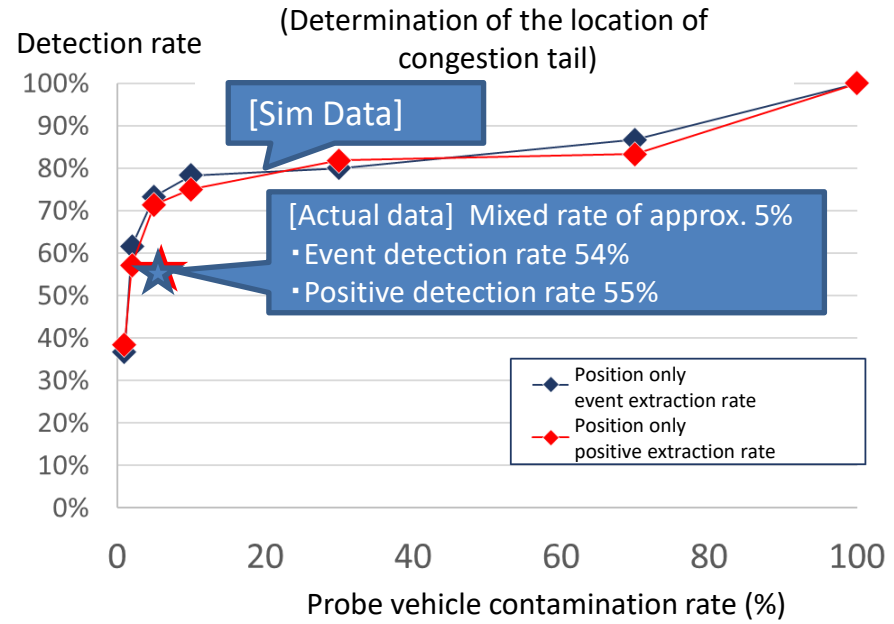
Image of validation of event detection method using speed information

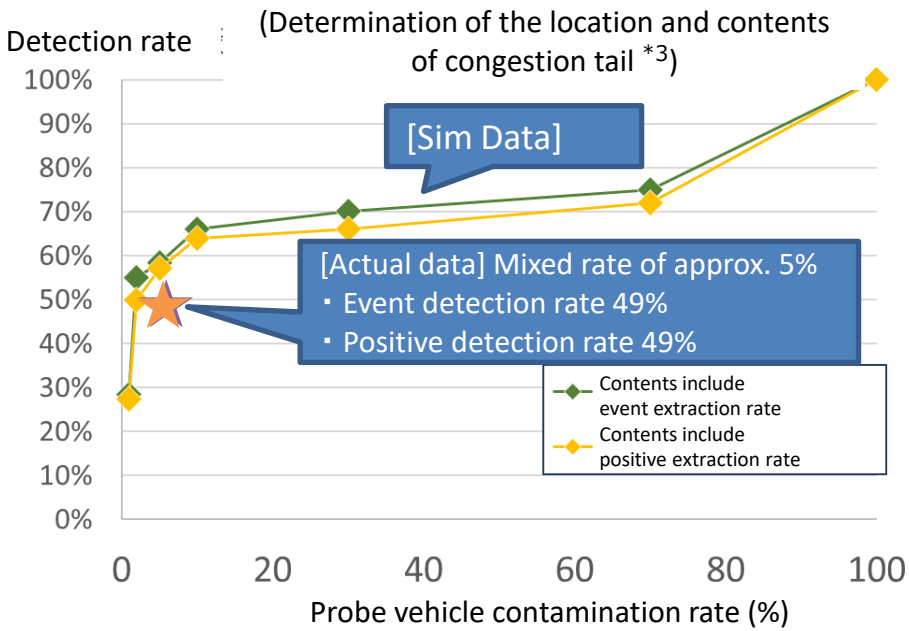


2.3.2 Technology Assessment

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.

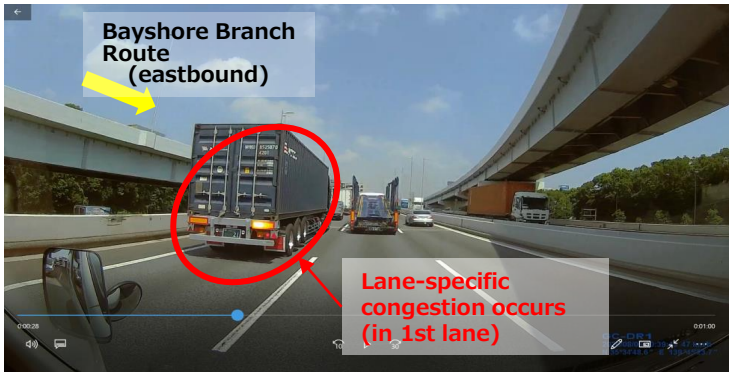
- Event extraction rate = Percentage of congestion events detected by estimation out of actual congestion events
- Positive extraction rate = Proportion of congestion events detected by the estimation that are exactly on target

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

2.3.2 Technology Assessment

■ 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.

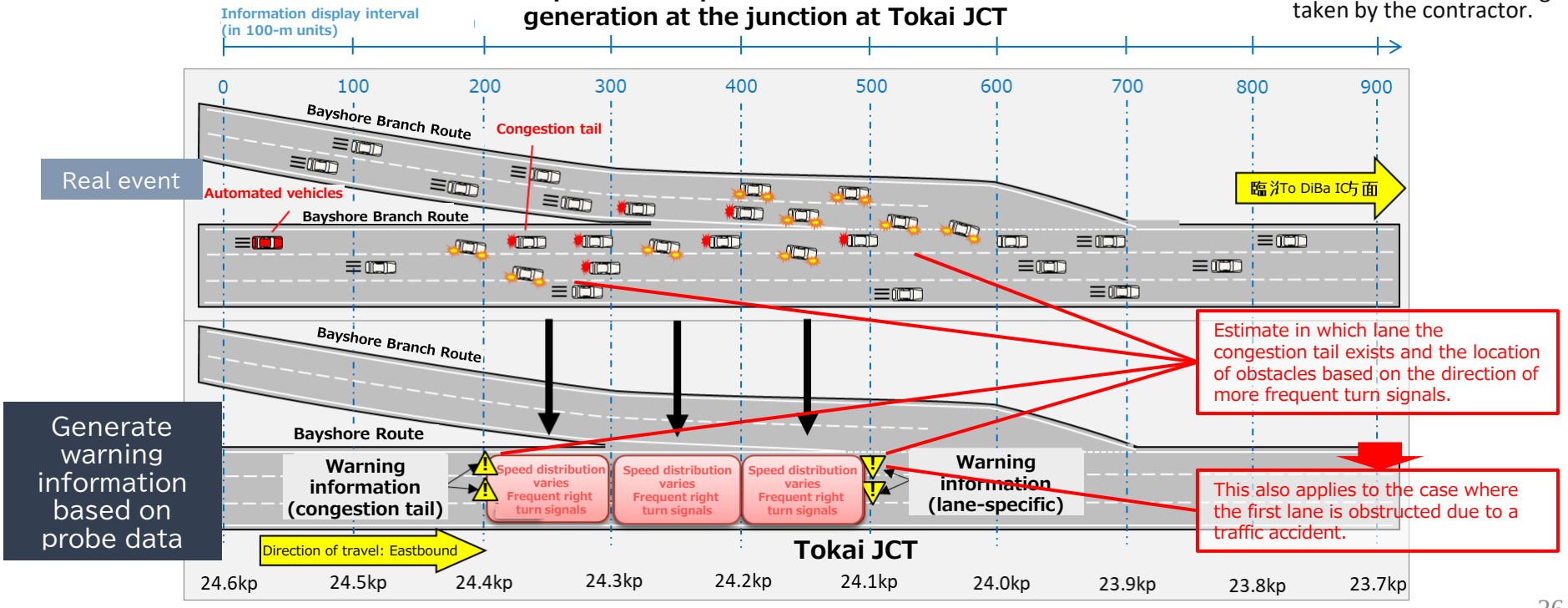


Lane-specific congestion in front of a junction
(captured around 10:39 on August 6, 2020, during preliminary verification)

210928_review meeting

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

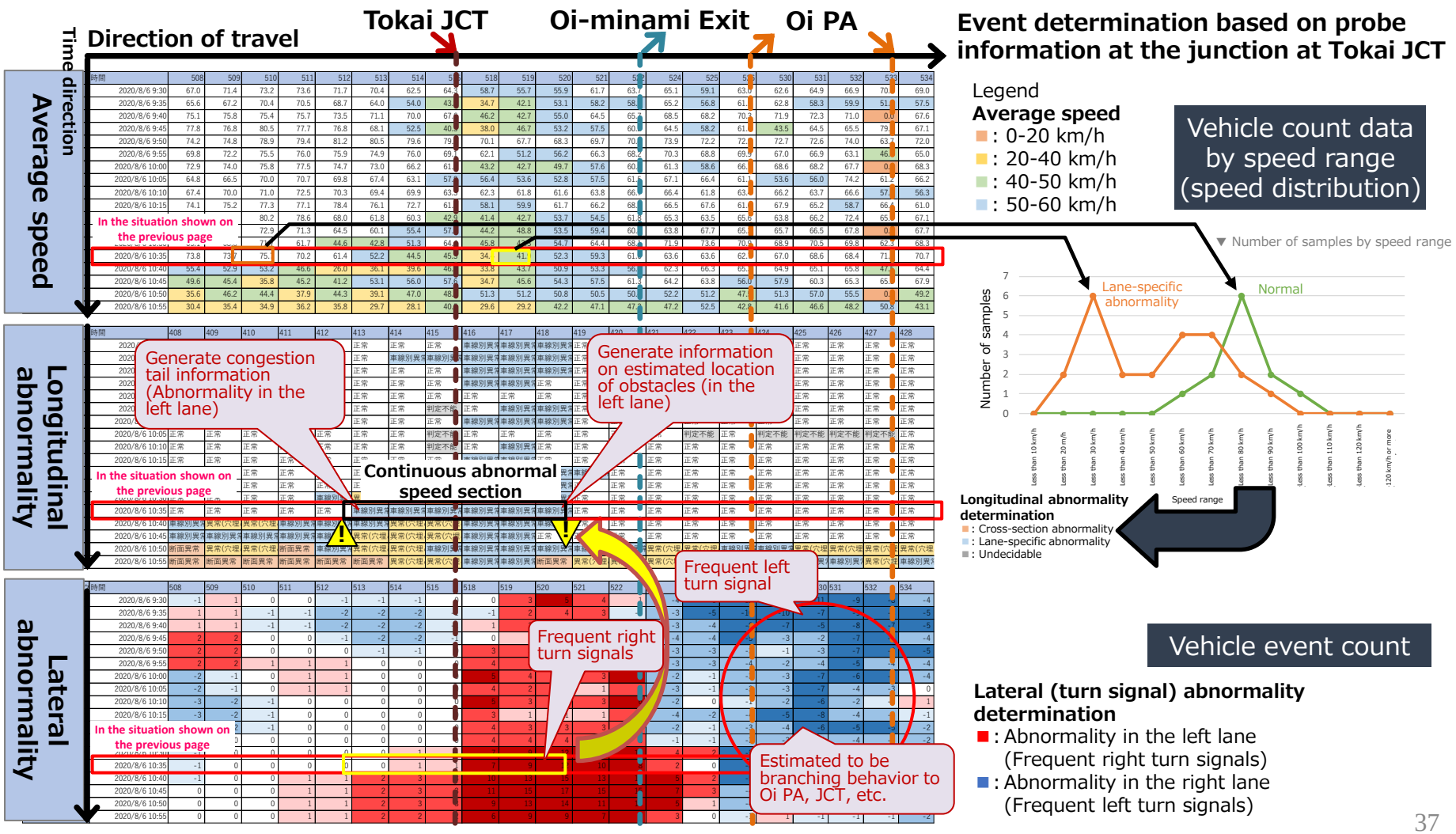
Source: Add to the footage taken by the contractor.



2.3.2 Technology Assessment

■ 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

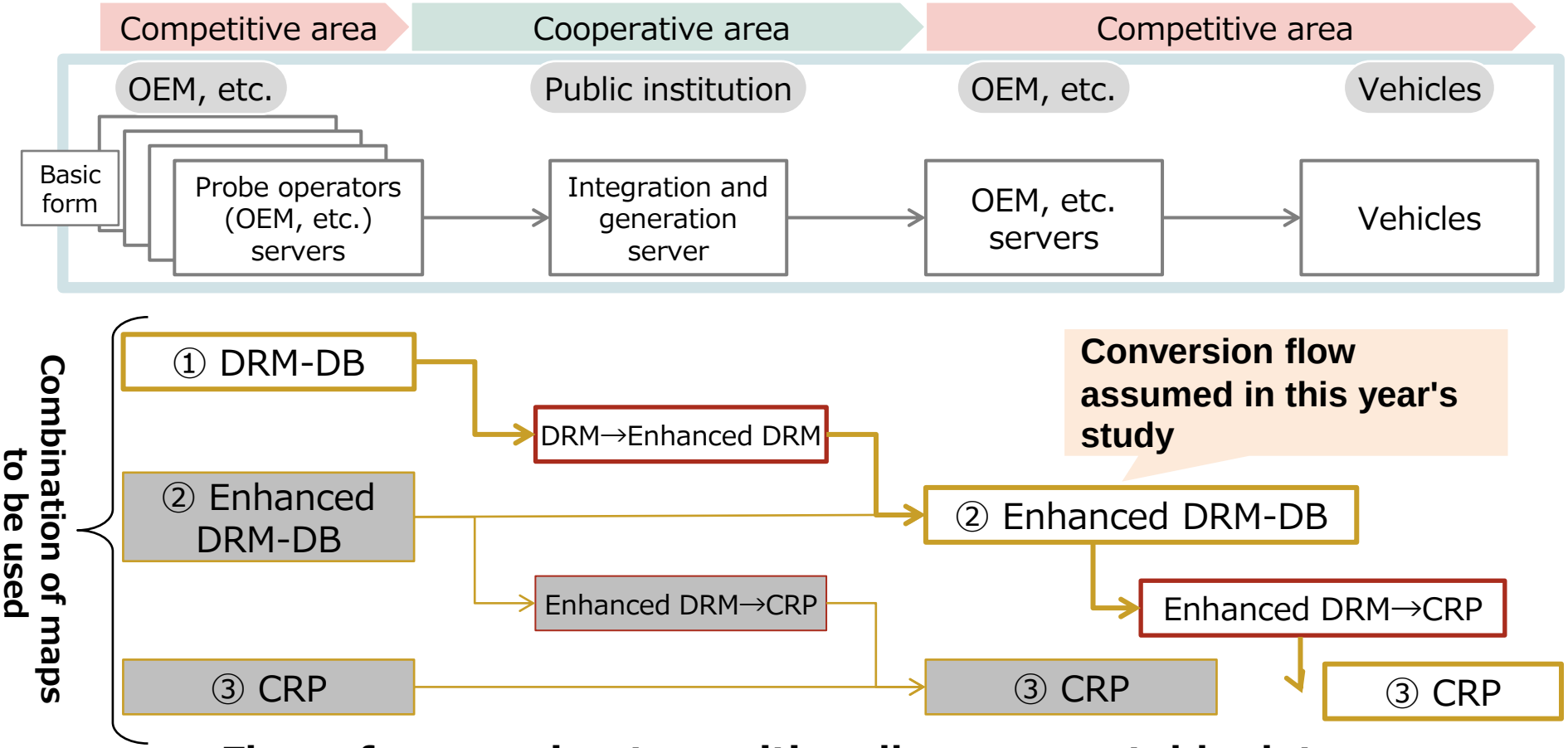
2.4.1 Technical Study

- 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.

2.4.1 Technical Study

■ 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

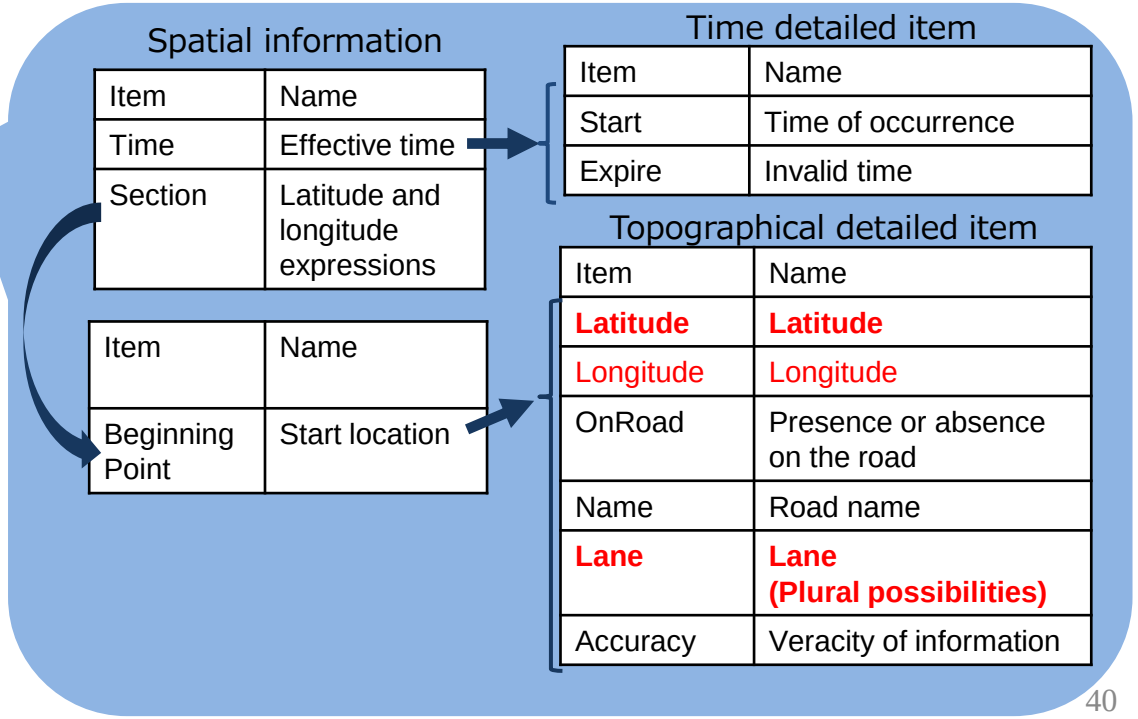
2.4.1 Technical Study

■ 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 FOTs 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



2.4.1 Technical Study

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

- The generated alert information was positioned in "5 alert event".
- For the items Subject and Accuracy, we conducted empirical tests using the definitions shown in the figure below.

Image of message composition

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

item number	Content Type	Definition
1	traffic flow conditions (e.g. heavy traffic)	Information on average speed and number of vehicles in the section
2	Regulatory Status	Traffic Regulation Information
3	Environmental conditions	Information on temperature, weather, estimated road surface conditions, solar radiation, regulations, etc.
4	obstacle	Information on falling objects, stopped vehicles, etc.
5	**alert event**	**Information on emergency vehicles, road work, vehicles requiring attention, etc.**
6	Vehicle Events	Information such as the point of activation of ABS and ESC
7	Parking position	Locations where parking is possible/impossible and information about them
8	Road structure change	Information on road geometry changes, paint changes, ancillary equipment changes, cracks and sinkholes, etc.

Detailed alert event items

item	name
Sequence	Number to segregate/manage
Subject	Targets that should be alerted [Additional items "50: Traffic jam end" and "60: Obstacle location" were used in the demonstration experiment].
Accuracy	Veracity of information [In the demonstration experiment, information was used as "5: information generated by data up to hierarchy 1," "4: up to hierarchy 2," "3: up to hierarchy 3," "2: up to hierarchy 4," and "1: after hierarchy 5"].

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

2.4.2 Technical Evaluation

- 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 FOTs 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 FOTs 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 demonstration experiment) 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 Technical Evaluation

■ Data sharing (distribution)

○Data distribution specification

- Through the demonstration experiment, 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 demonstration experiment 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 FOTs 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 7 seconds must be implemented.

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

2.5.1 Technical Study

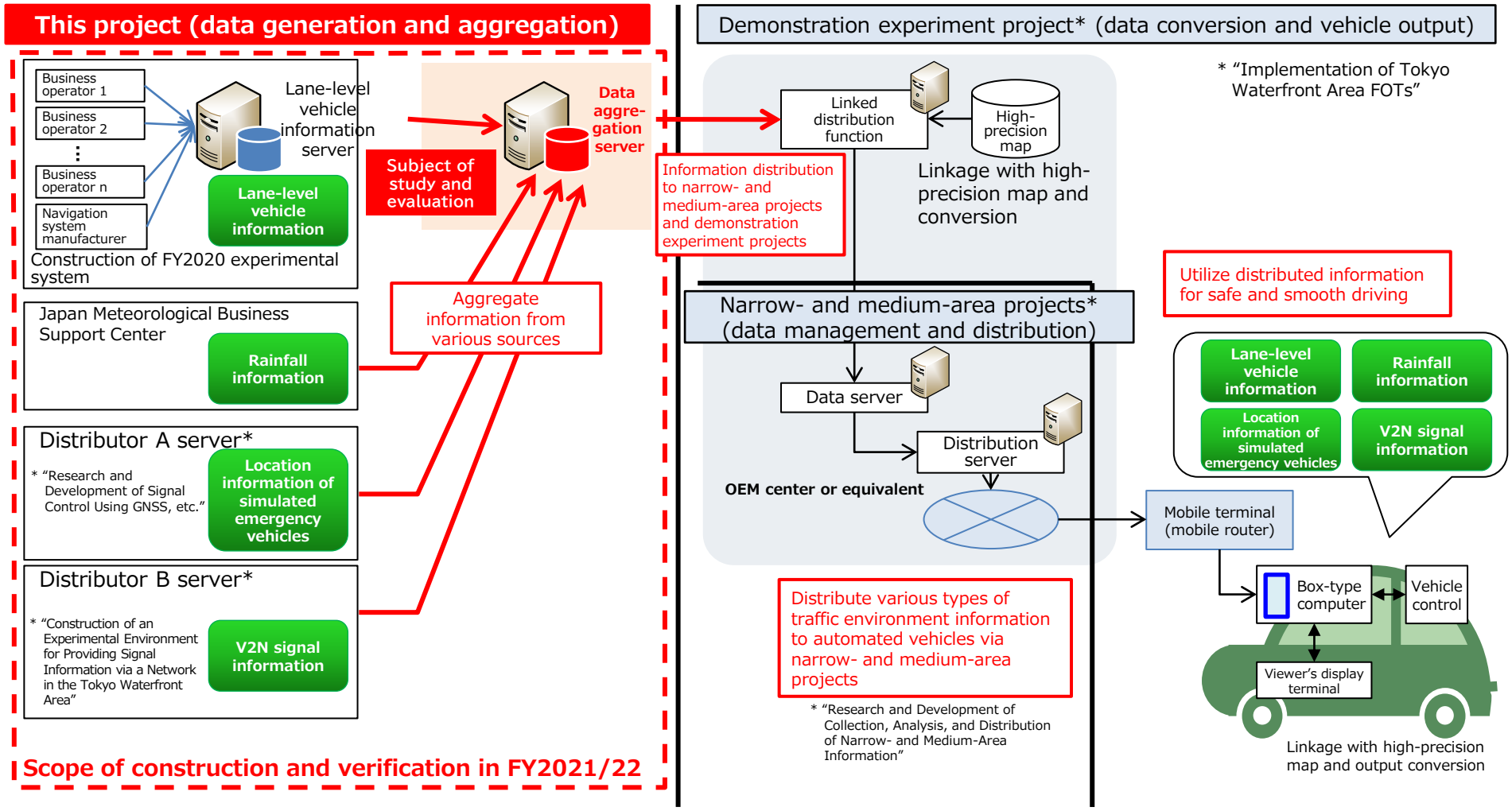
- Based on 2.1 through 2.4 above, technology for collecting lane-level vehicle information and other traffic environment information (see table below) from information sources was studied.

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	Distributor A *1 *1 "Research and Development of Signal Control Using GNSS, etc."	Generated in other SIP project and distributed in this project
V2N signal information	Distributor B *2 *2 "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	Distributor A *1 *1 "Research and Development of Signal Control Using GNSS, etc."	As needed	Proprietary binary data	UDP
V2N signal information	Distributor B *2 *2 "Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area"	As needed	Proprietary binary data	UDP

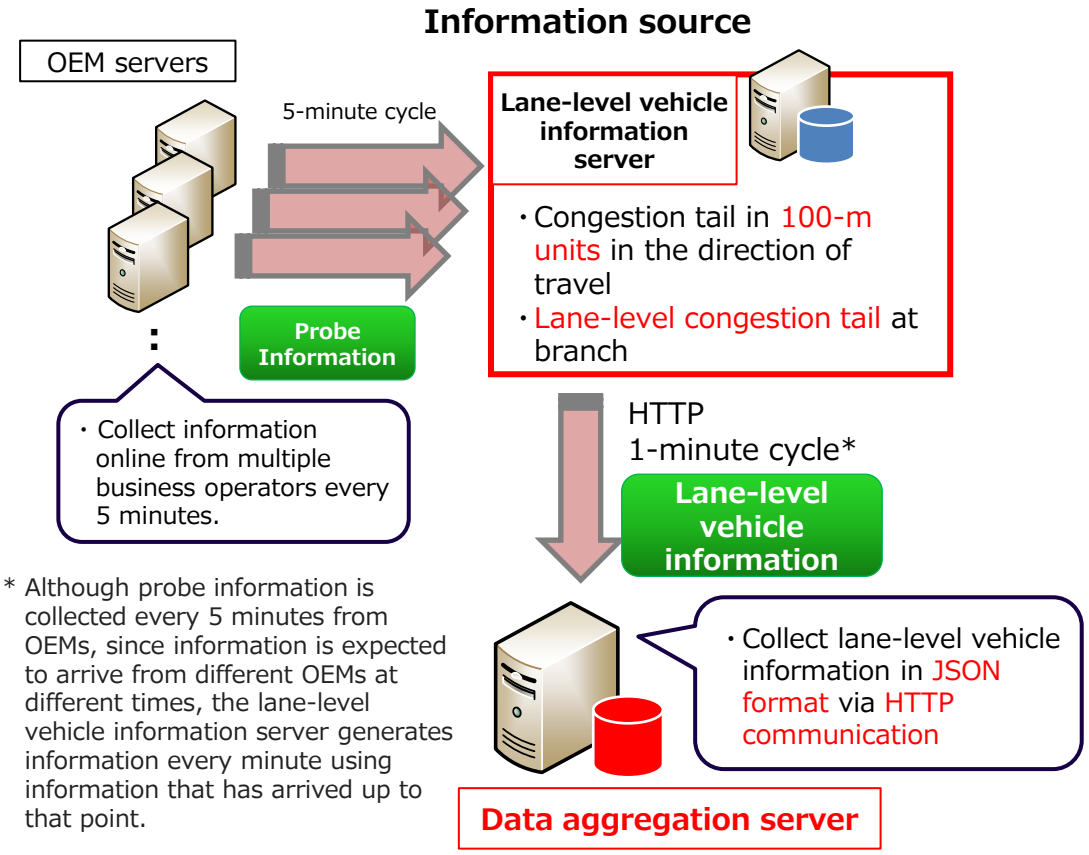
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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

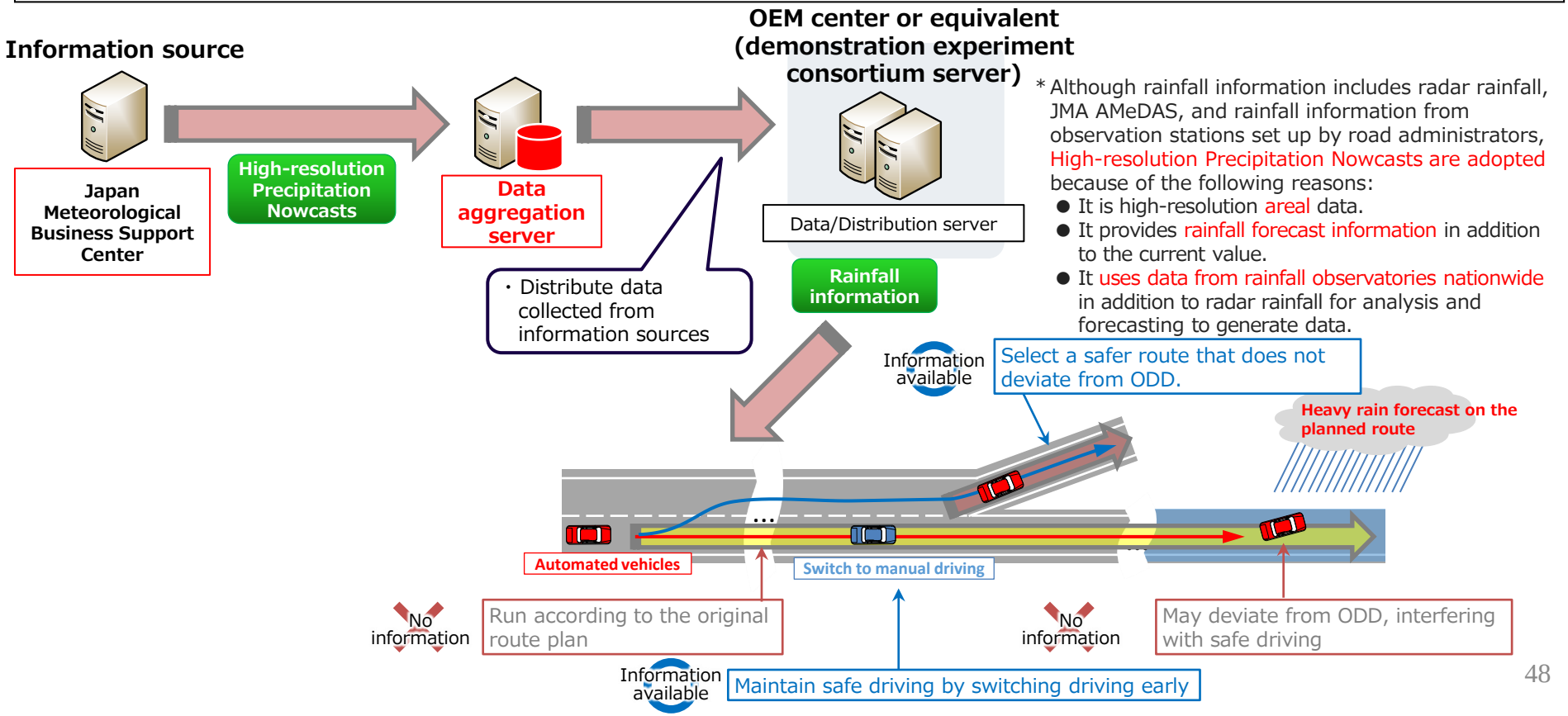
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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 demonstration experiment 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.

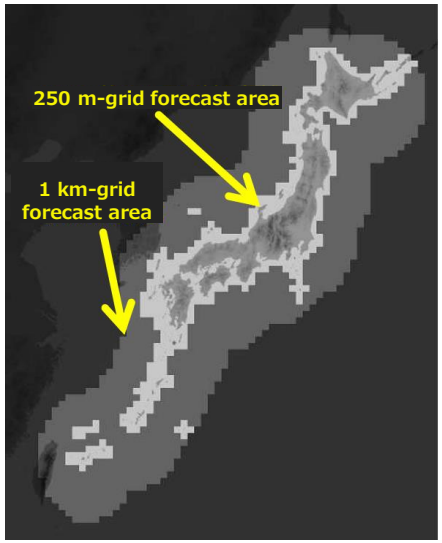


Image Source: Technical Information on Distribution Materials (Weather Edition) No. 398 Launch of High-resolution Precipitation Nowcasts (Forecast Department, Japan Meteorological Agency, May 30, 2014 (partially revised on August 5, 2014))
https://www.data.jma.go.jp/suishin/jyouhou/pdf/398.pdf

SFTP communication
5-minute cycle

High-resolution Precipitation Nowcasts

Data aggregation server

- Collect High-resolution Precipitation Nowcasts in GRIB2 format via SFTP communication.

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

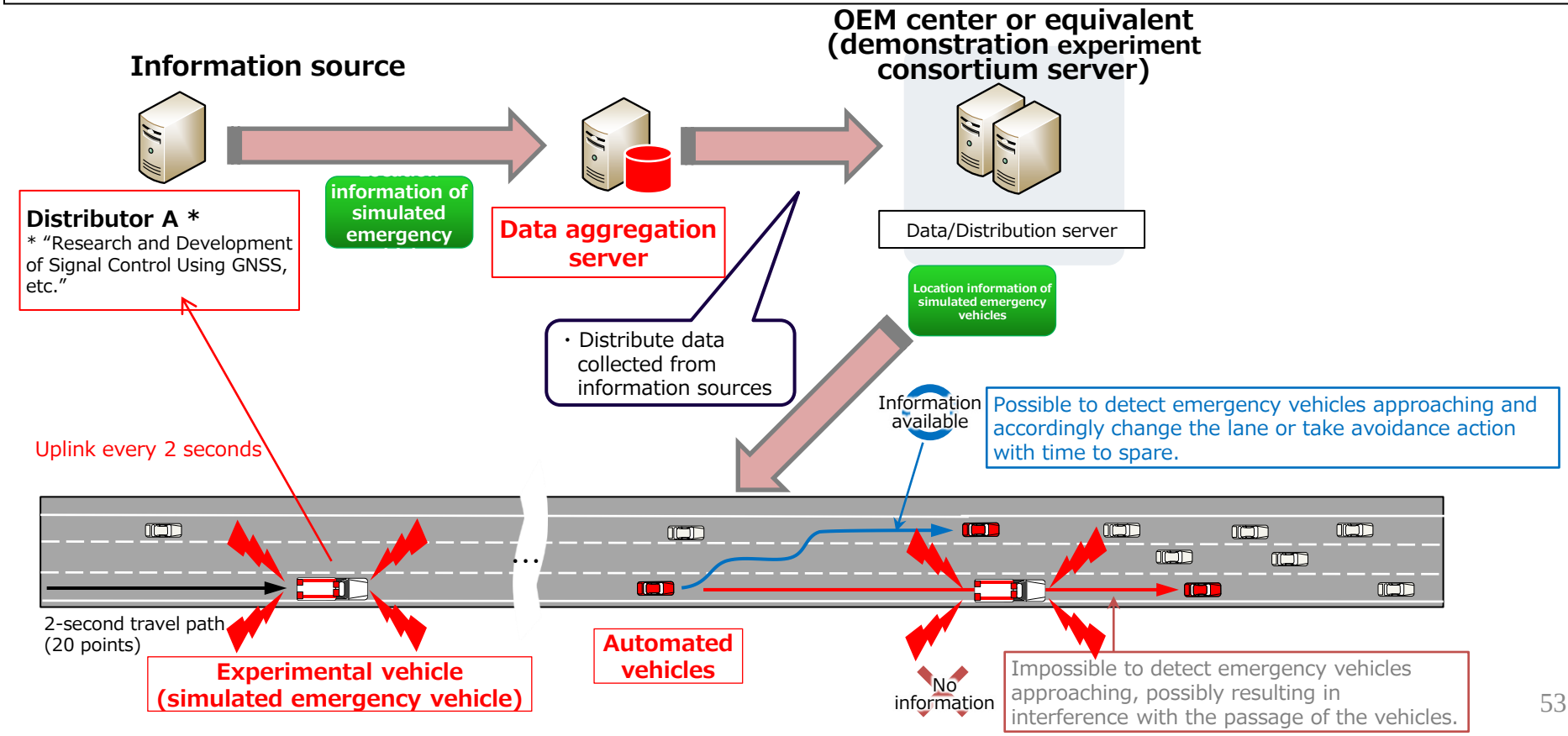
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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 demonstration experiment 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

Distributor A※ 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)

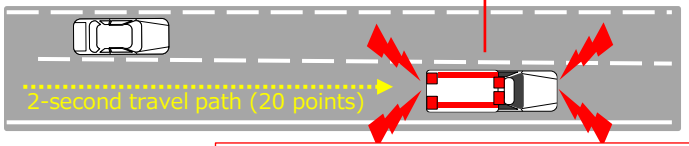
UDP communication
As needed

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)

* "Research and Development of Signal Control Using GNSS, etc."

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						(1)
≀	(16 bytes)						≀
	Latest latitude information						(2)
≀	(4 bytes)						≀
	Latest longitude information						
≀	(4 bytes)						≀
	Continuous GNSS information						(3)
≀	(up to 480 bytes)						≀

(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.

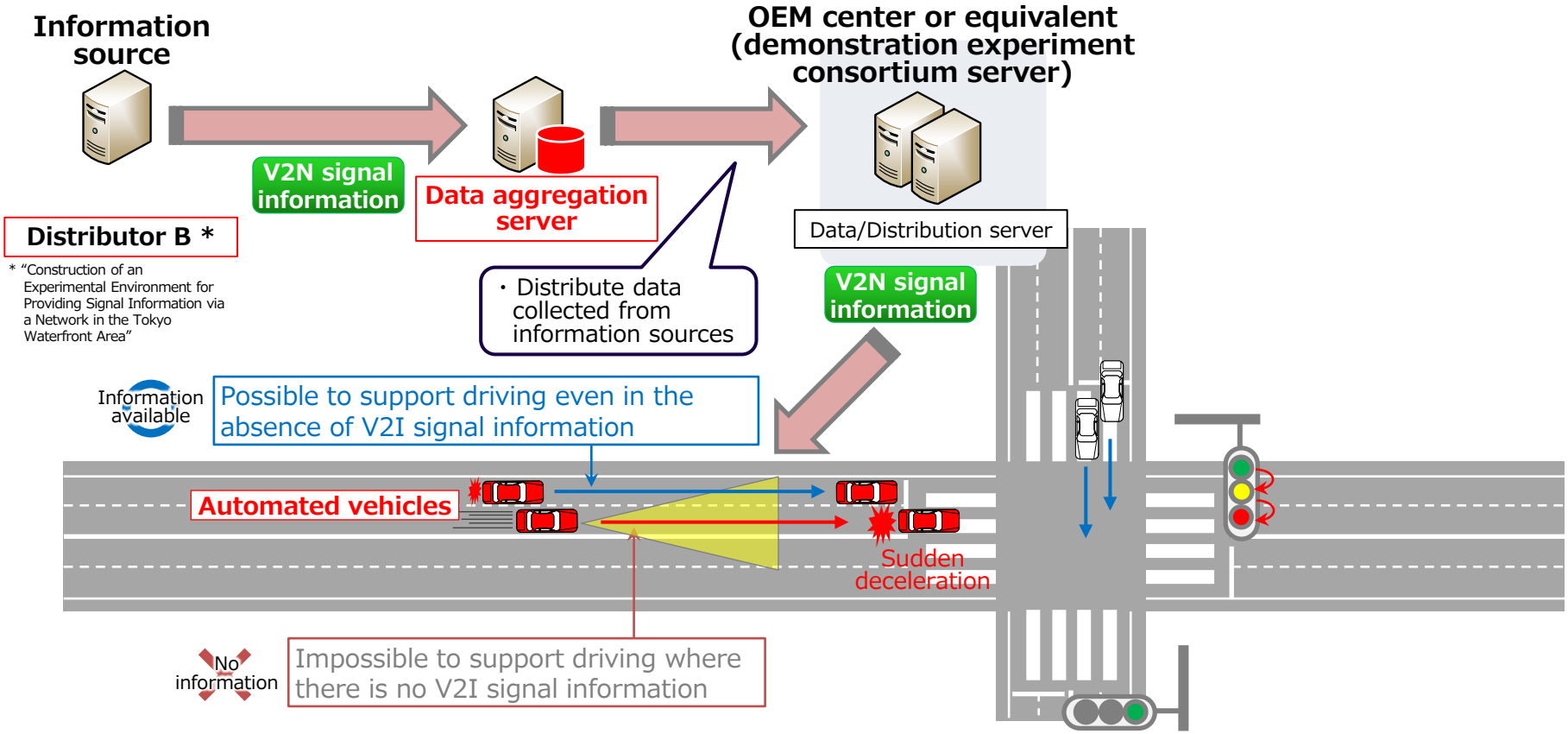
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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 demonstration experiment 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

Distributor B※ 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).

* "Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area"

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

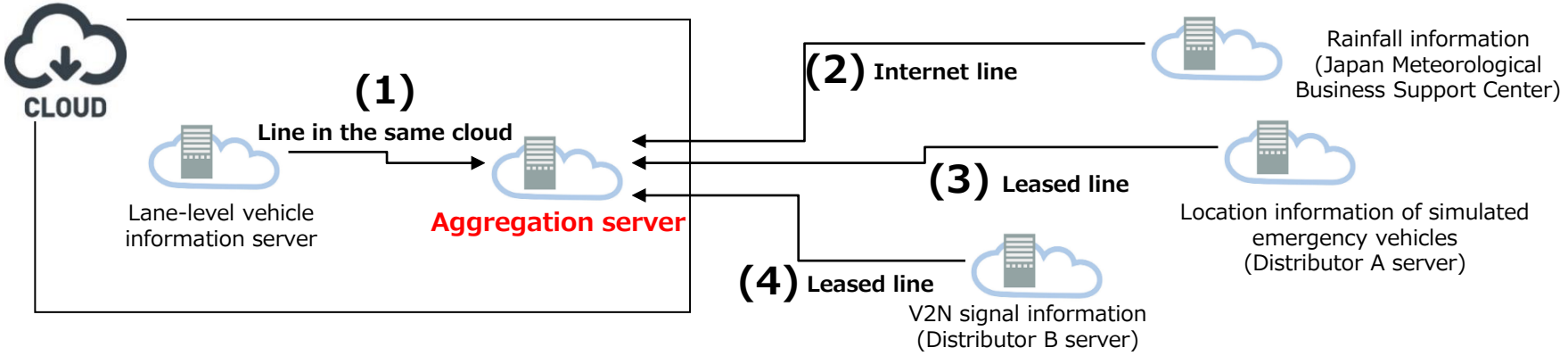
2.5.2 Technical Evaluation

- Based on the results of study described in 2.5.1, a data aggregation server (with a collection function) was constructed for the demonstration experiment, 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	Distributor A 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	Distributor B server	

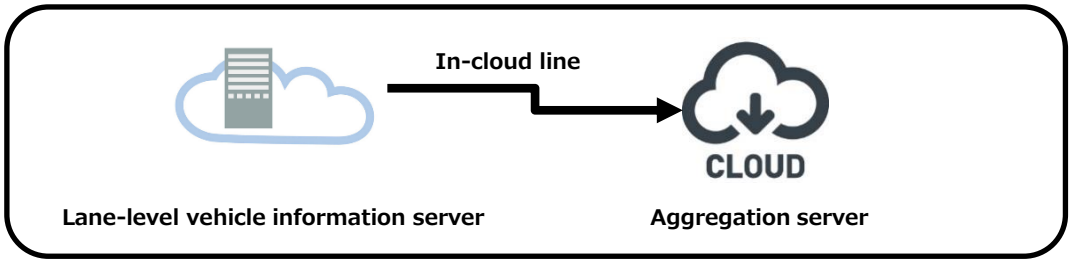
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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.

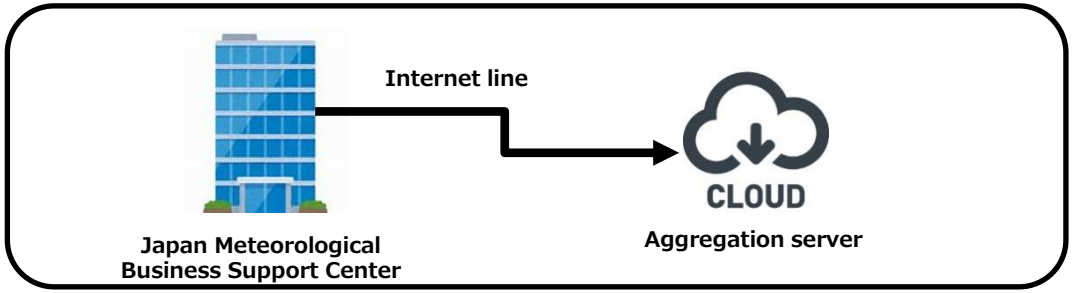
2.5. Study and evaluation of technology for collecting various types of traffic environment information

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.

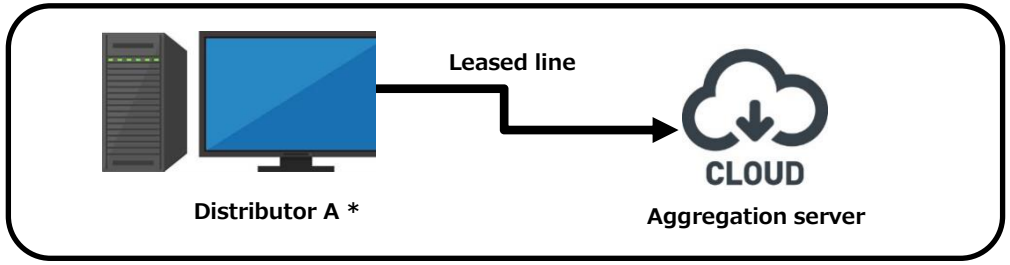
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

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

■ Verification method for information collection

- Location information of simulated emergency vehicles(Distributor A server), which distributes the location information of simulated emergency vehicles, and the aggregation server via a leased line.



* "Research and Development of Signal Control Using GNSS, etc."

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.

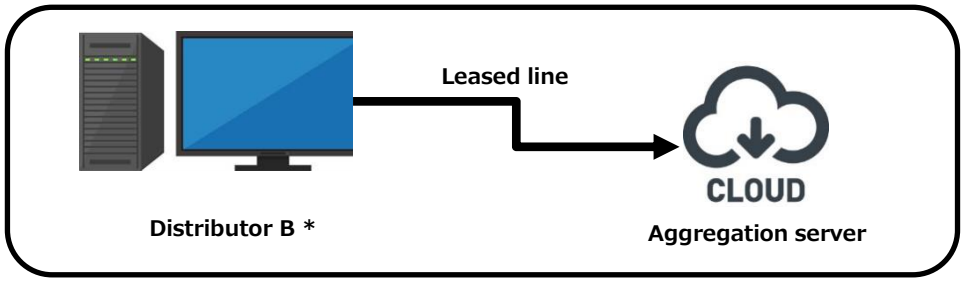
2.5. Study and evaluation of technology for collecting various types of traffic environment information

2.5.2 Technical Evaluation

(4) Evaluation of technology for collecting V2N signal information

■ Verification method for information collection

- V2N signal information(Distributor B server), which distributes V2N signal information, and the aggregation server via a leased line.



Verification system configuration

* "Construction of an Experimental Environment for Providing Signal Information via a Network in the Tokyo Waterfront Area"

■ 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 (demonstration experiment 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 (demonstration experiment consortium server)
Rainfall information	1-minute cycle	JASPAR: JSON data Contents: environment	HTTP	Distributed upon request from the OEM center or equivalent (demonstration experiment 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.**

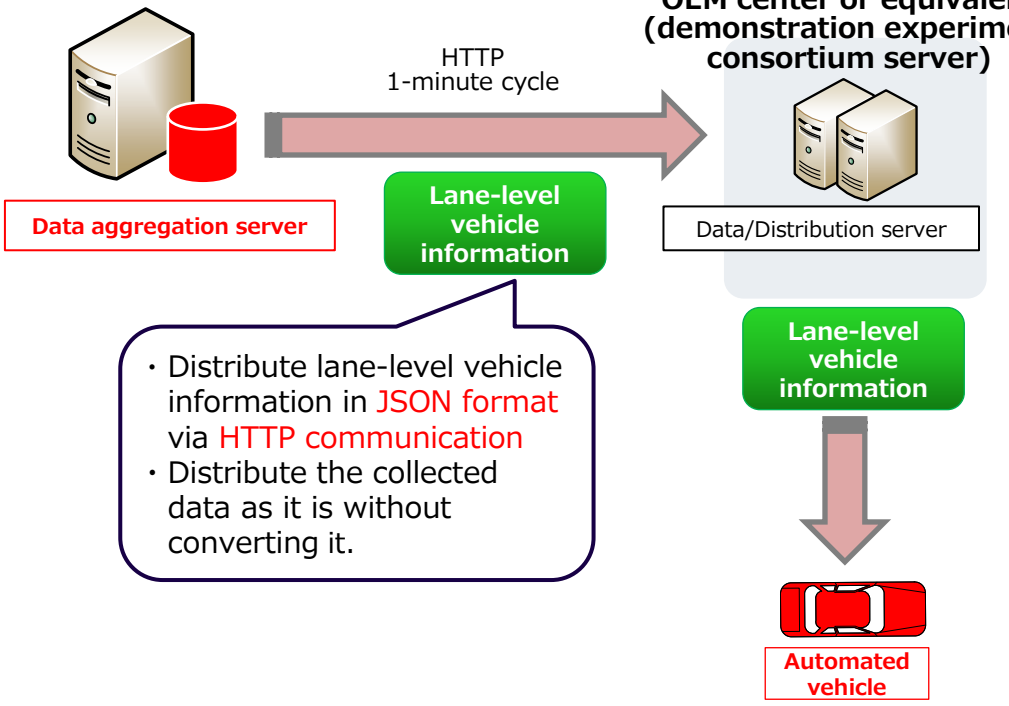
2.6. Study and evaluation of technology for distributing various types of traffic environment information

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

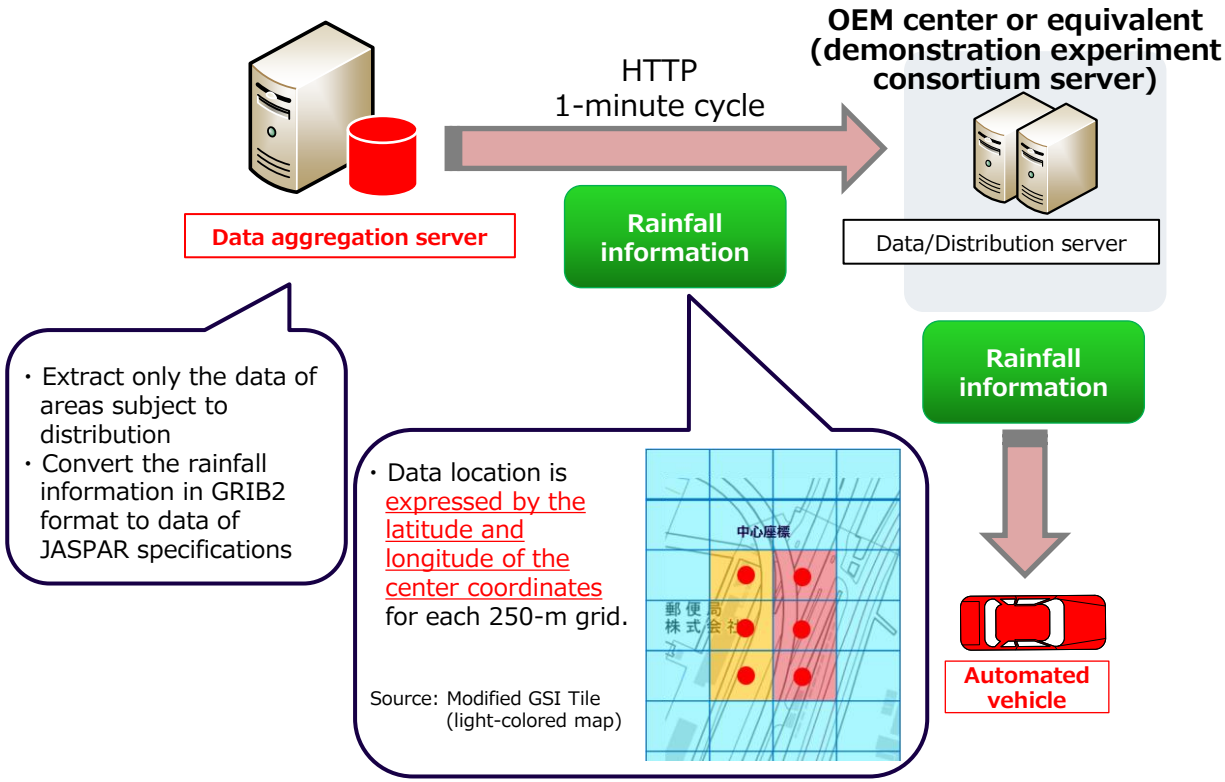
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.1 Technical Study

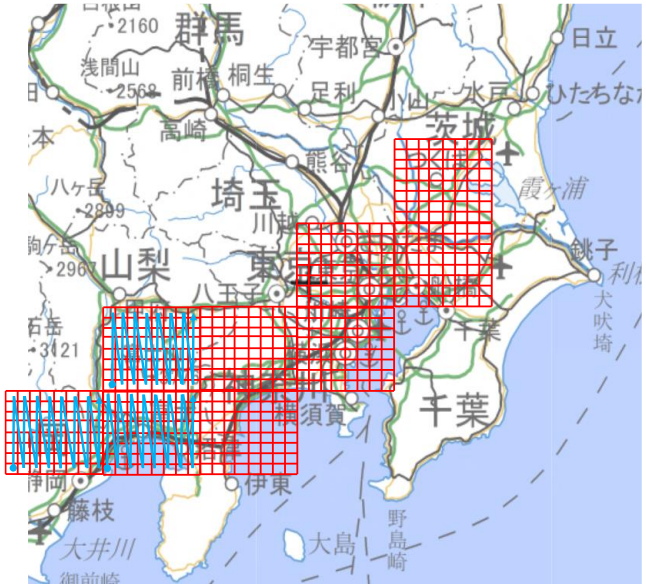
(2) Study on technology for distributing rainfall information

■ 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 demonstration experiment 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.

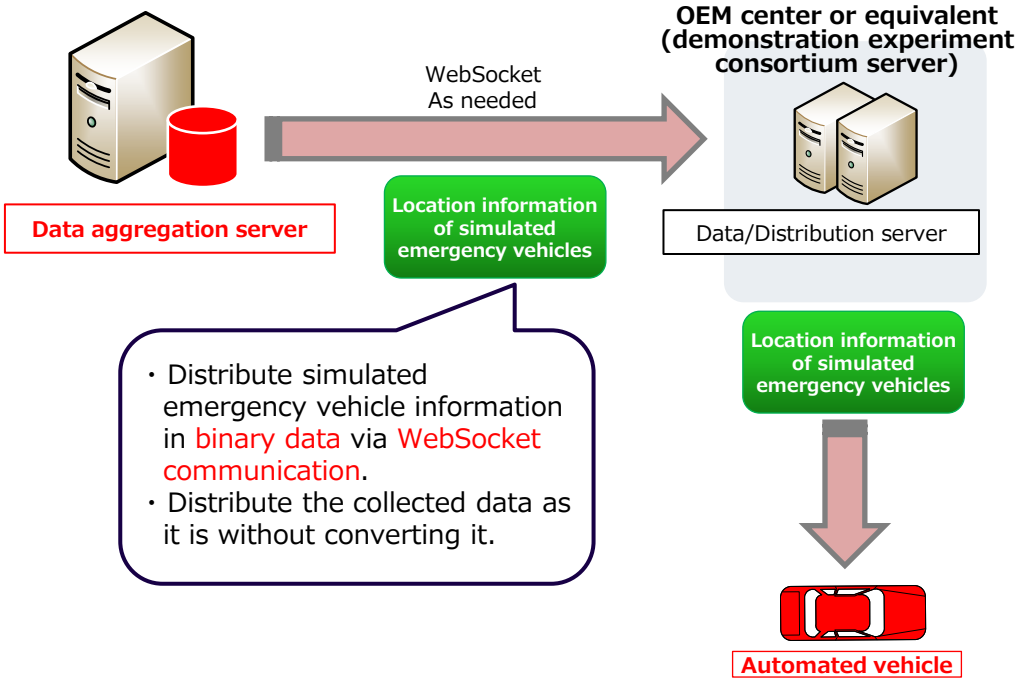
2.6. Study and evaluation of technology for distributing various types of traffic environment information

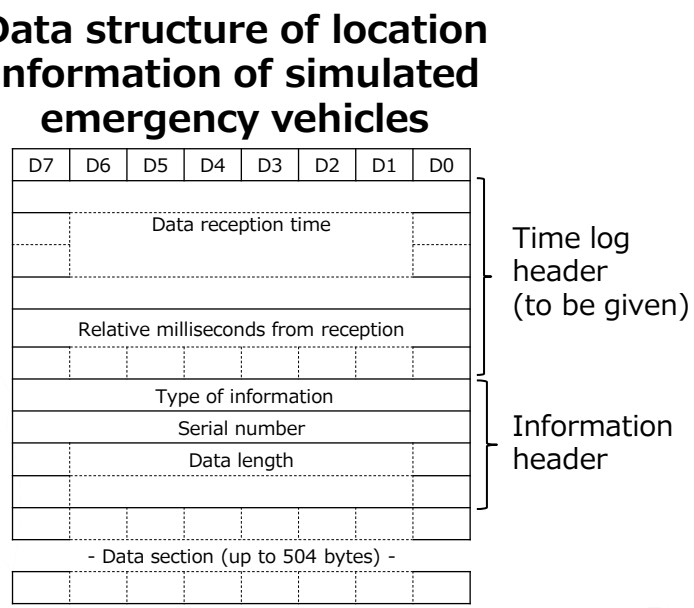
2.6.1 Technical Study

(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 demonstration experiment, the collected information is given the time it was received by the data aggregation server (time log header).





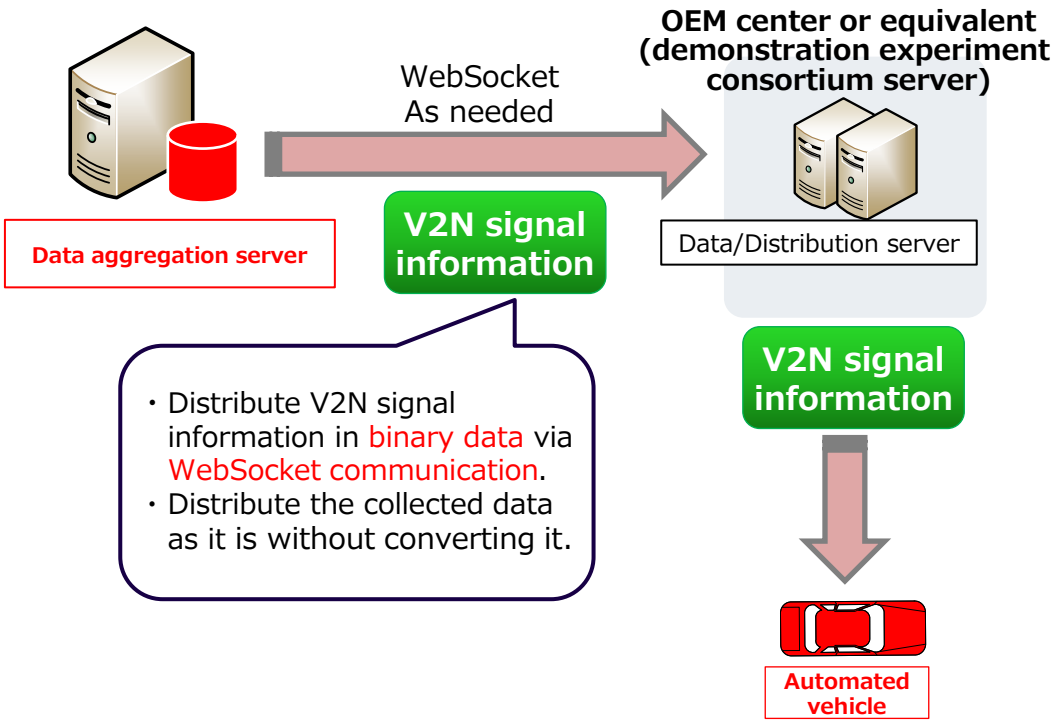
2.6. Study and evaluation of technology for distributing various types of traffic environment information

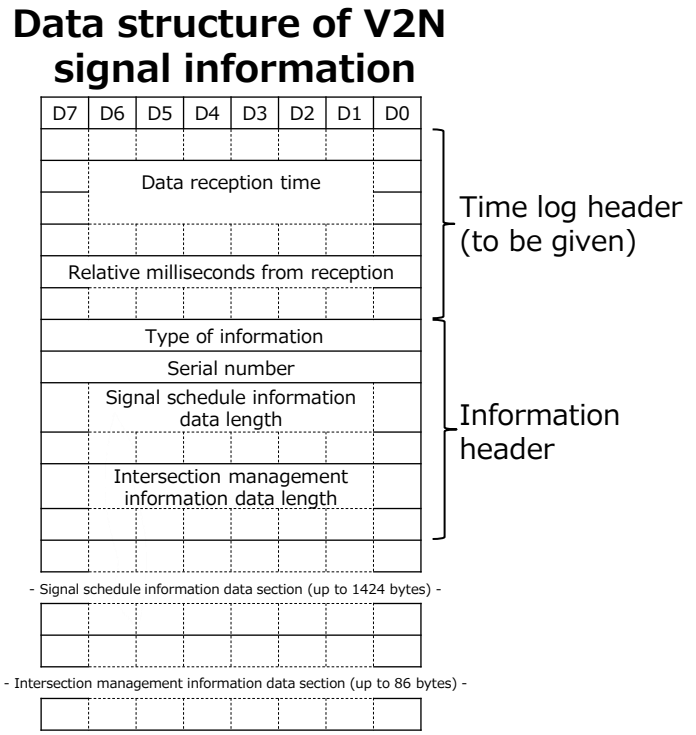
2.6.1 Technical Study

(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 demonstration experiment, the collected information is given the time it was received by the data aggregation server (time log header).





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 demonstration experiment, 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)	○	

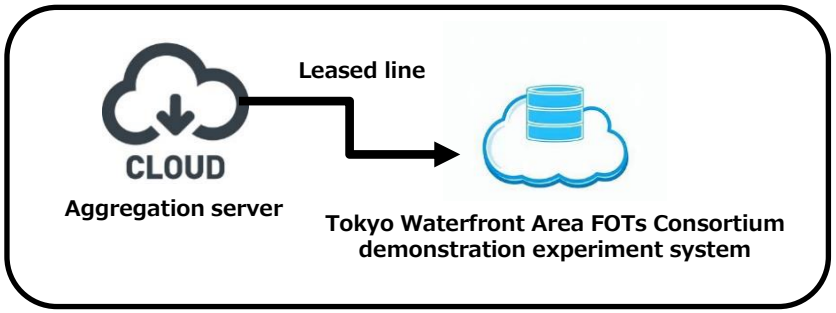
2.6. Study and evaluation of technology for distributing various types of traffic environment information

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 demonstration experiment 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 demonstration experiment 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 demonstration experiment system application.

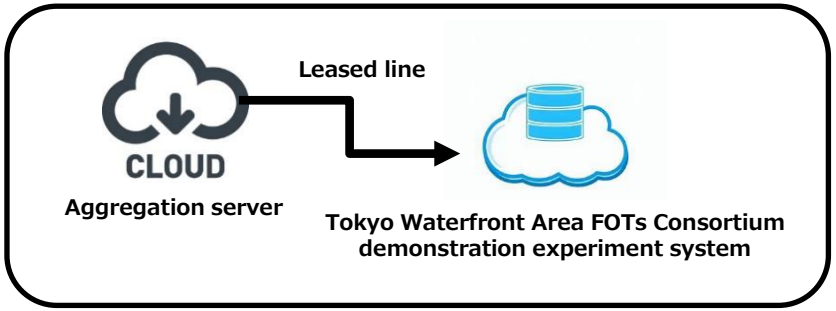
2.6. Study and evaluation of technology for distributing various types of traffic environment information

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 demonstration experiment 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 demonstration experiment 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 demonstration experiment system application.

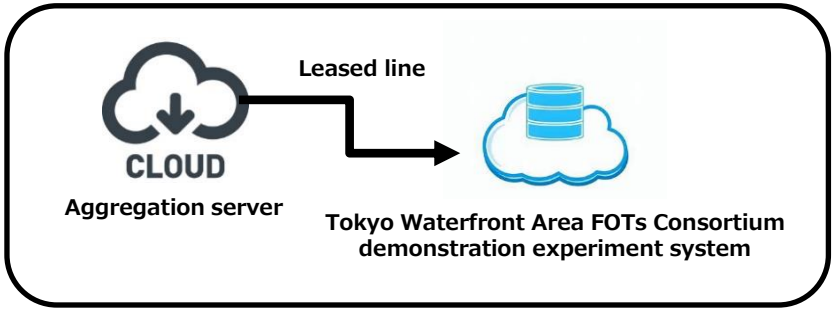
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

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

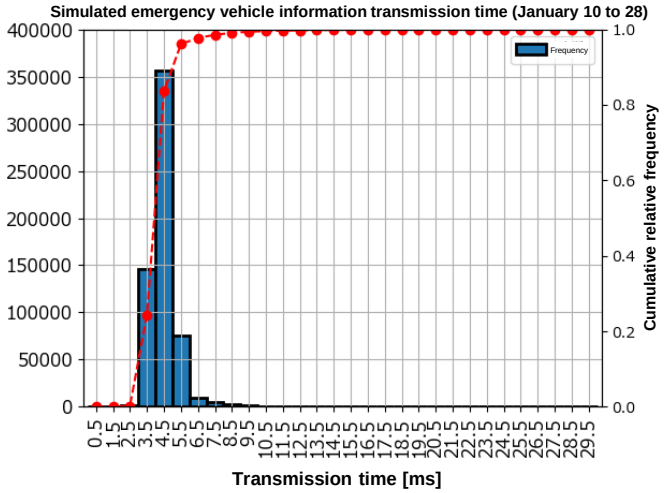
■ Verification method for information distribution

- Connect the aggregation server, which distributes location information, of simulated emergency vehicles and the Tokyo Waterfront Area FOTs Consortium demonstration experiment 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.

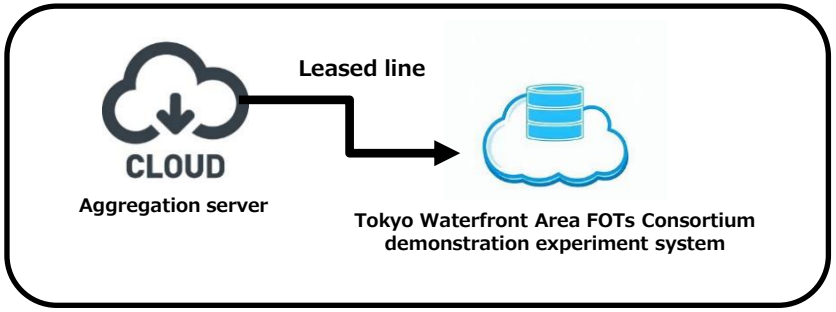
2.6. Study and evaluation of technology for distributing various types of traffic environment information

2.6.2 Technical Evaluation

(4) Evaluation of technology for distributing V2N signal information

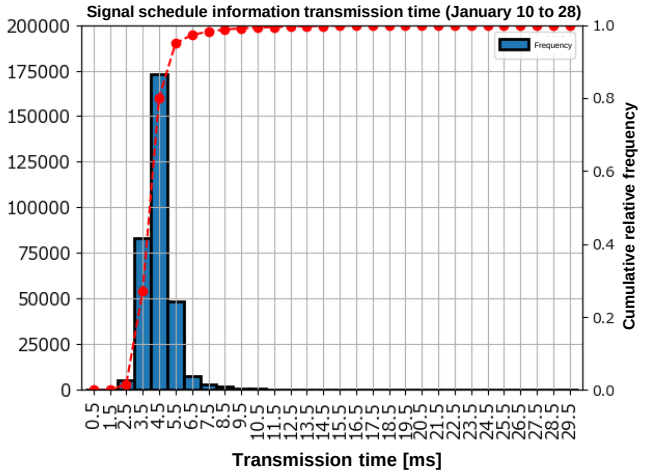
■ Verification method for information distribution

- Connect the aggregation server, which distributes V2N signal information, and the Tokyo Waterfront Area FOTs Consortium demonstration experiment 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. Demonstration Experiment

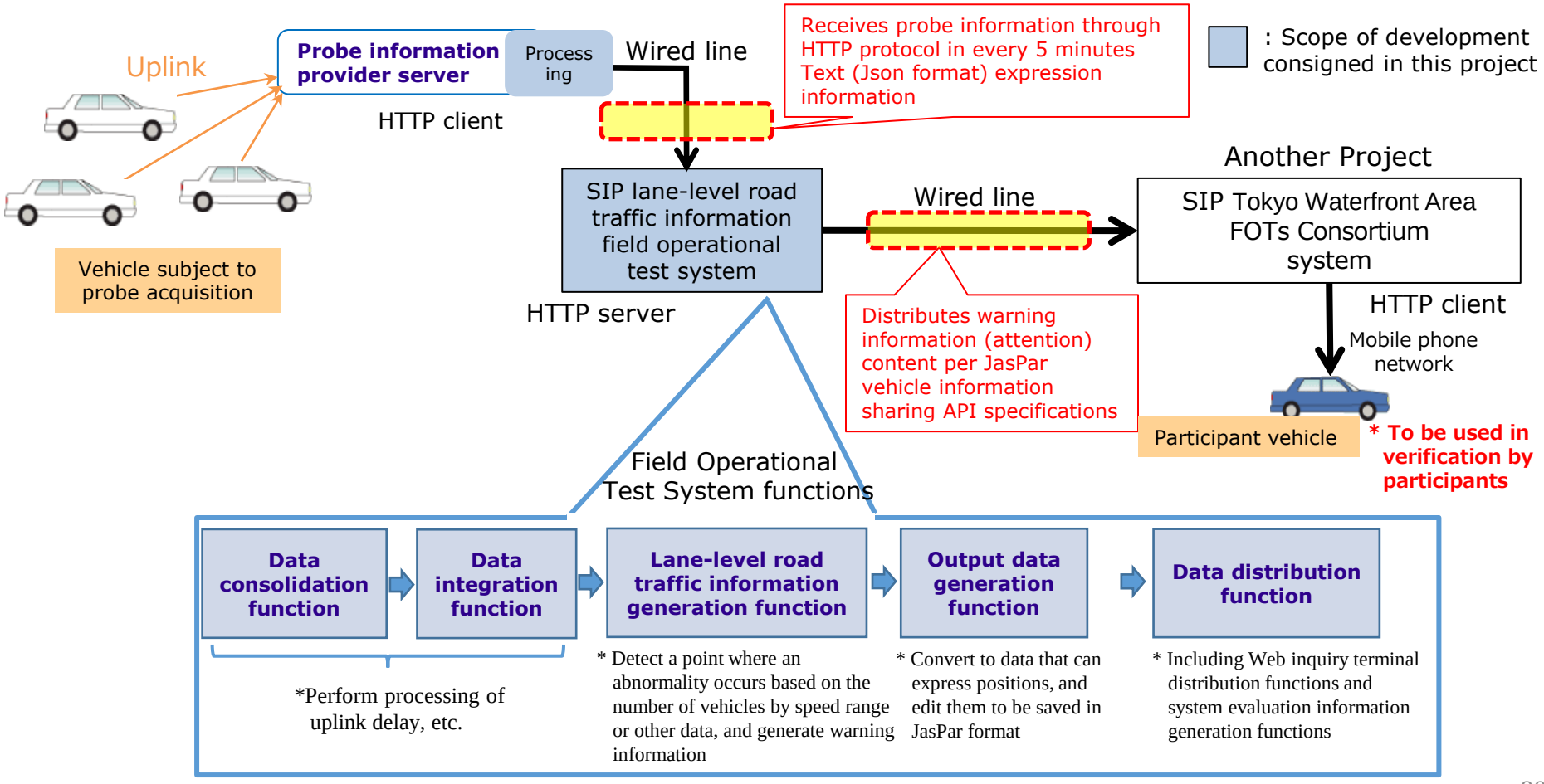
3.1. Demonstration Experiment Implementation Policy

- A demonstration experiment 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 demonstration experiment 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 FOTs 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 demonstration experiment, 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 demonstration 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.
- In FY2022, we accumulated various kinds of traffic environment information in the Data Integration Server with the demonstration experiment environment constructed in the previous fiscal year maintained, and distributed the information to the data server for another business ①. For the lane-specific information of the above information, we conducted the demonstration experiment by dividing the experiment period into the spring period (conducted from April to May) and the autumn period (conducted from around September to October) with the objective of repeating such PDCA cycle as experiment ⇒ technical assessment ⇒ review and improvement ⇒ experiment as well as by increasing the probe providers for online connection from two to four.

3.1. Demonstration Experiment Implementation Policy

Configuration of Field Operational Test System

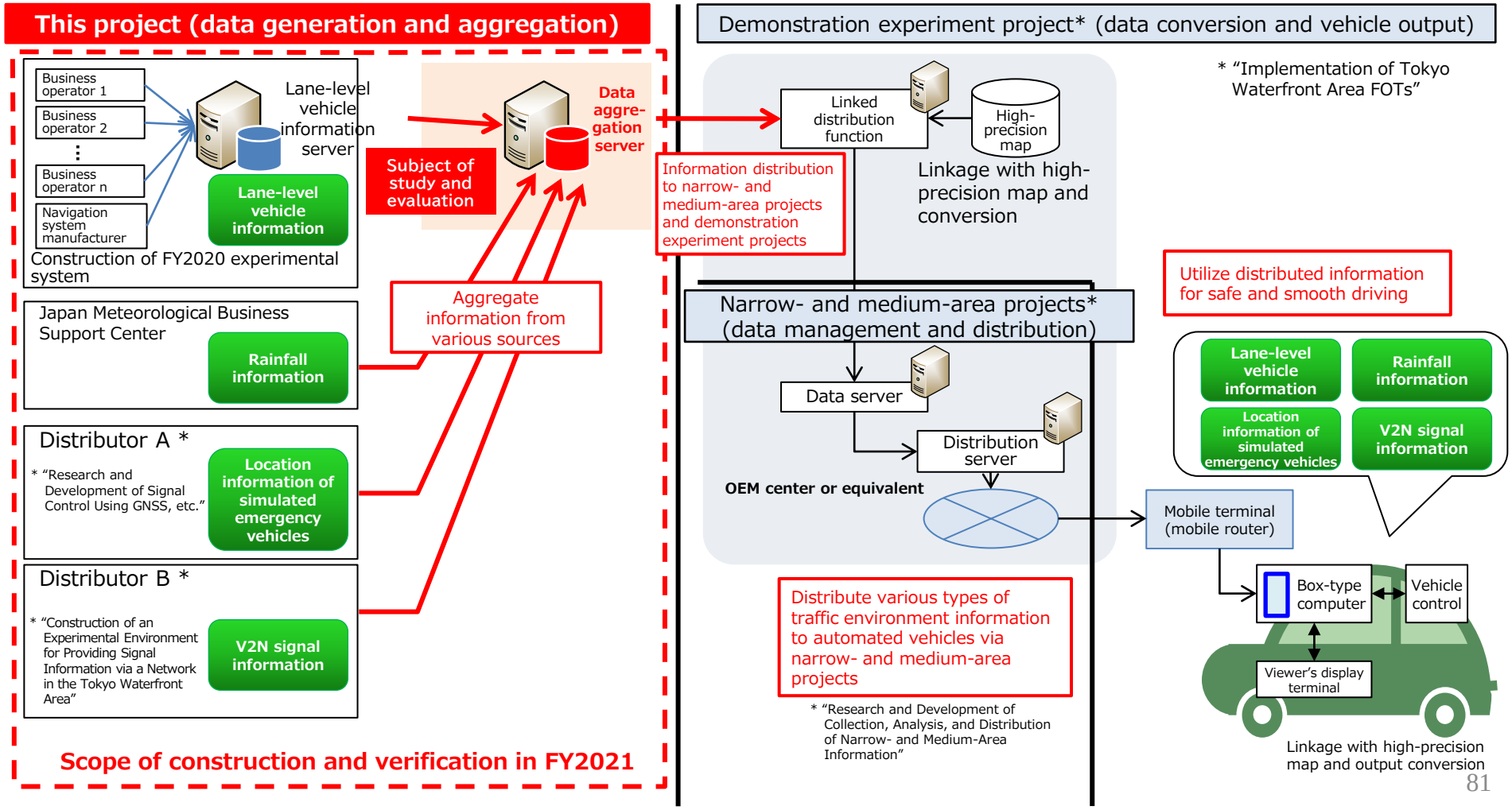
- Verify system operation, processing time, etc., and compile technical specifications.
- Participants in the experiment experienced delivery of information, and were asked to answer questions about the effectiveness and issues.



3.1. Demonstration Experiment Implementation Policy

Demonstration experiment 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 demonstration experiment system has been constructed since FY2020, and then provided to the vehicle side (OEM center or equivalent), and implement the demonstration experiment.

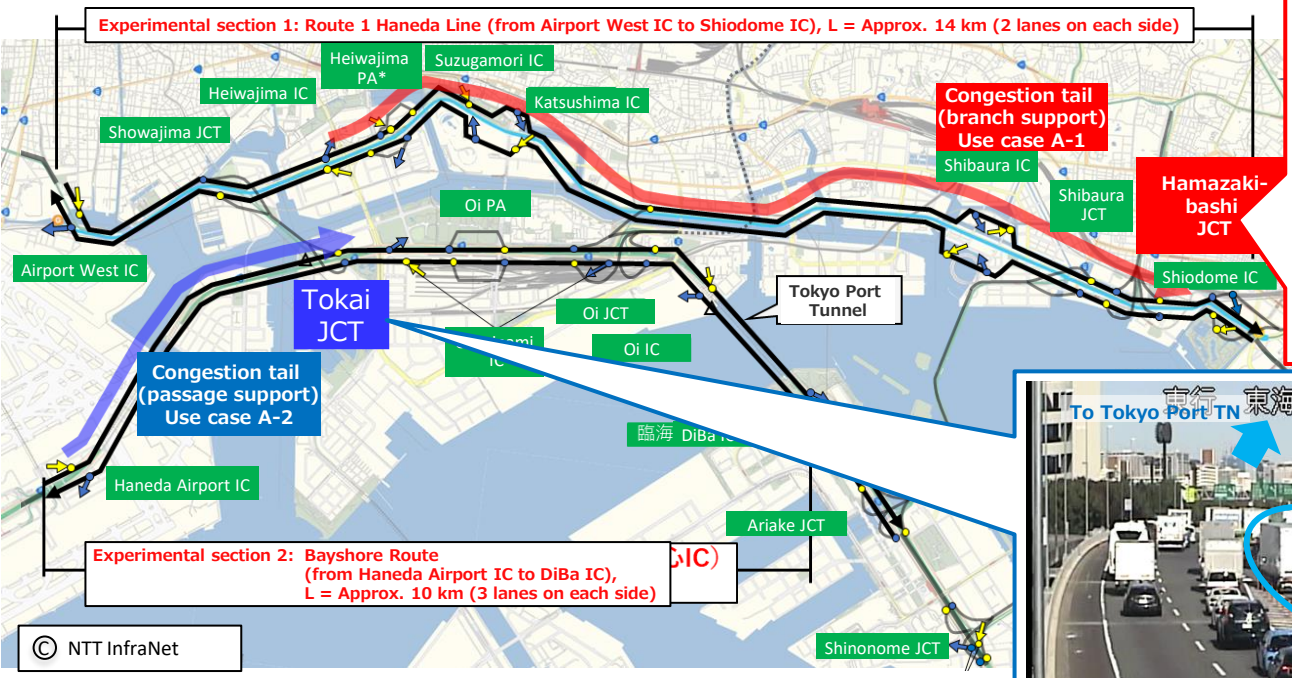


3.1. Demonstration Experiment Implementation Policy

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

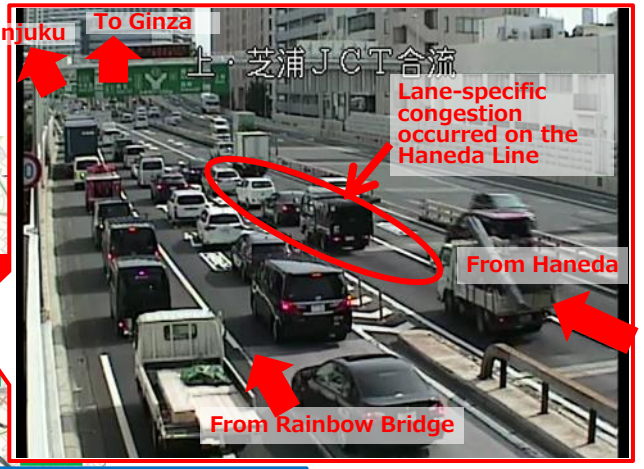
- The demonstration experiment of information generation is conducted in the sections shown below on the Metropolitan Expressway Haneda Line and Bayshore Route.
- The main verification fields for the target use cases are as follows:
  - **A-1: Congestion tail (branch support)**: Branch at Hamazakibashi 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 demonstration experiment

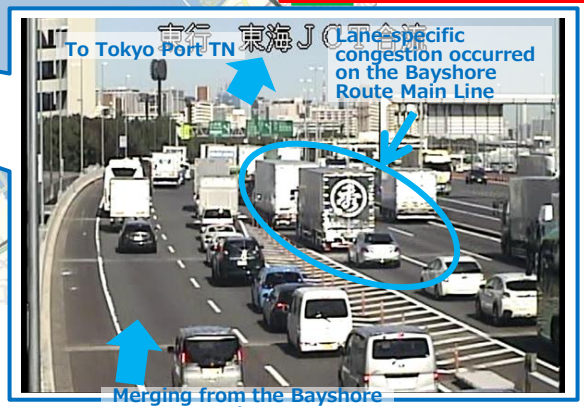


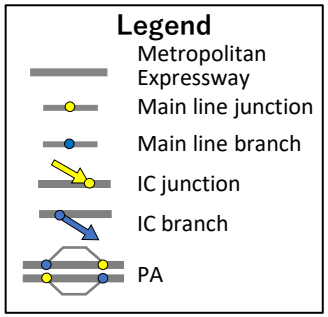
Information provision period:
Weekdays between December 13, 2021 and January 28, 2022 (9 a.m. to 5 p.m.)

To the branch at Hamazakibashi JCT on the upbound Haneda Line



Junction at Tokai JCT on the eastbound Bayshore Route



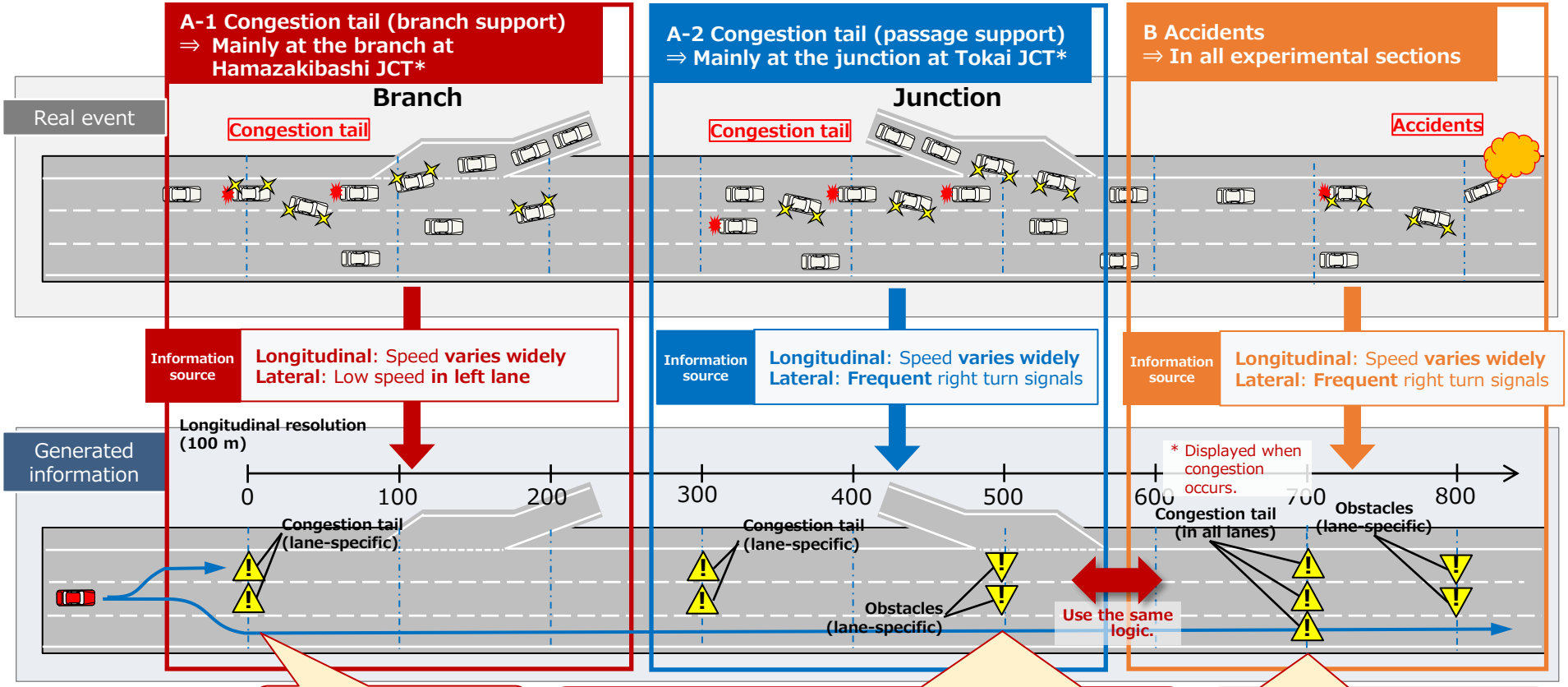


*From Metropolitan Expressway CCTV

3.1. Demonstration Experiment Implementation Policy

■ 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).

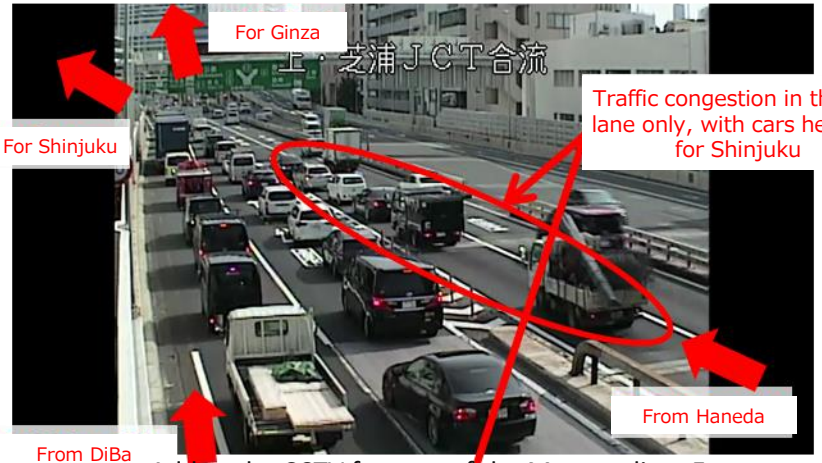
If the amount of information for lane direction determination is not sufficient to determine whether the congested lane is on the left or right, the congestion tail is displayed in all lanes.

3.1. Demonstration Experiment Implementation Policy

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

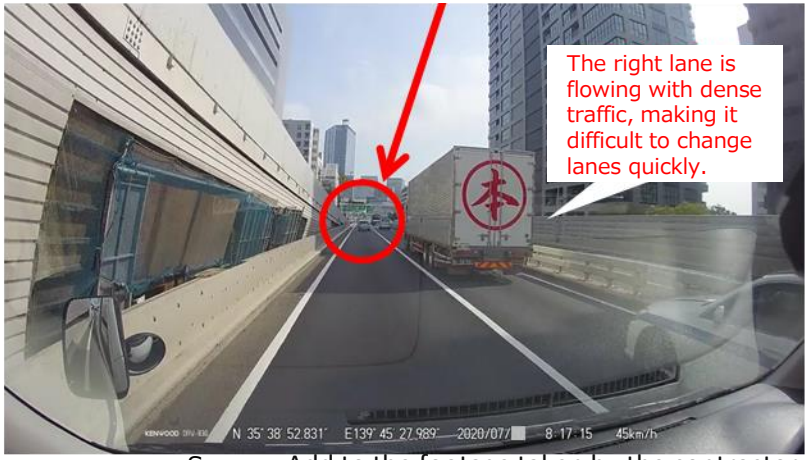
- When there is lane by lane congestion in the first lane of Route No.1 Haneda Line, the second lane is flowing with dense traffic and it is difficult to change lanes quickly when going straight toward Ginza.
- If you know the lane ahead of you in advance, you can change lanes in plenty of time.

Lane-specific traffic congestion near Shibaura JCT confluence



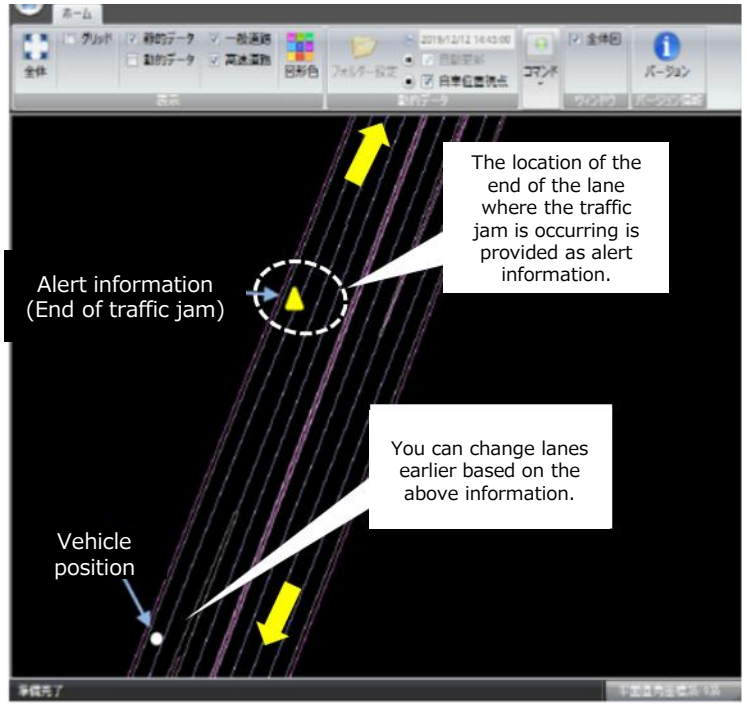
Source: Add to the CCTV footage of the Metropolitan Expressway

Running image



Source: Add to the footage taken by the contractor.

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



Source: Display high-precision 3D map data prepared by the demonstration experiment consortium using viewer software prepared by the same consortium.

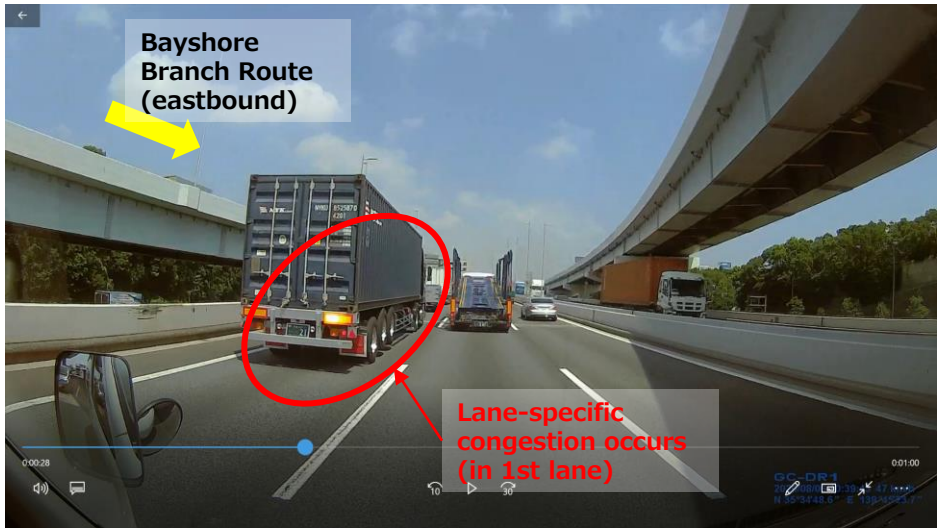
3.1. Demonstration Experiment Implementation Policy

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.

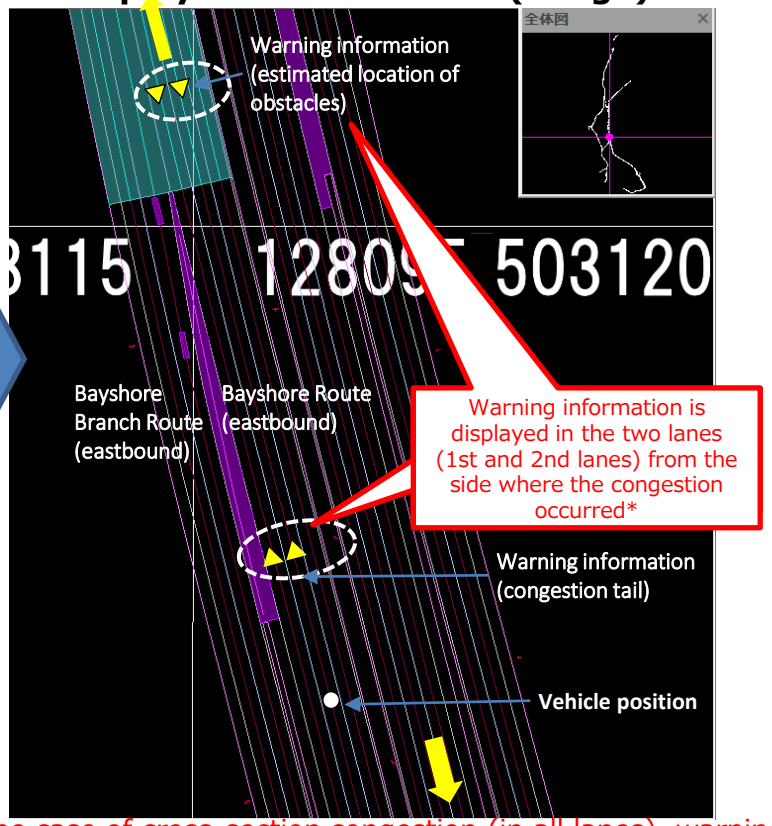
Video of driving eastbound Bayshore Route



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

Source: Add to the footage taken by the contractor.

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.

Source: Display high-precision 3D map data prepared by the demonstration experiment consortium using viewer software prepared by the same consortium.

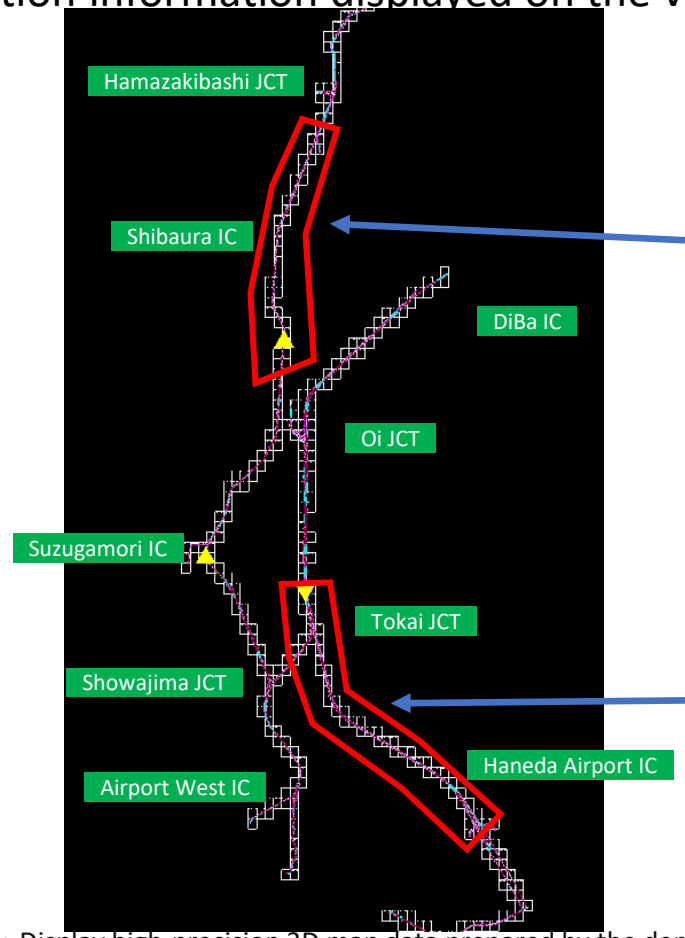
3.2. Outline of Implementation of Demonstration Experiment

Distribution of warning information during demonstration experiment

- 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

Source: Display high-precision 3D map data prepared by the demonstration experiment consortium using viewer software prepared by the same consortium.

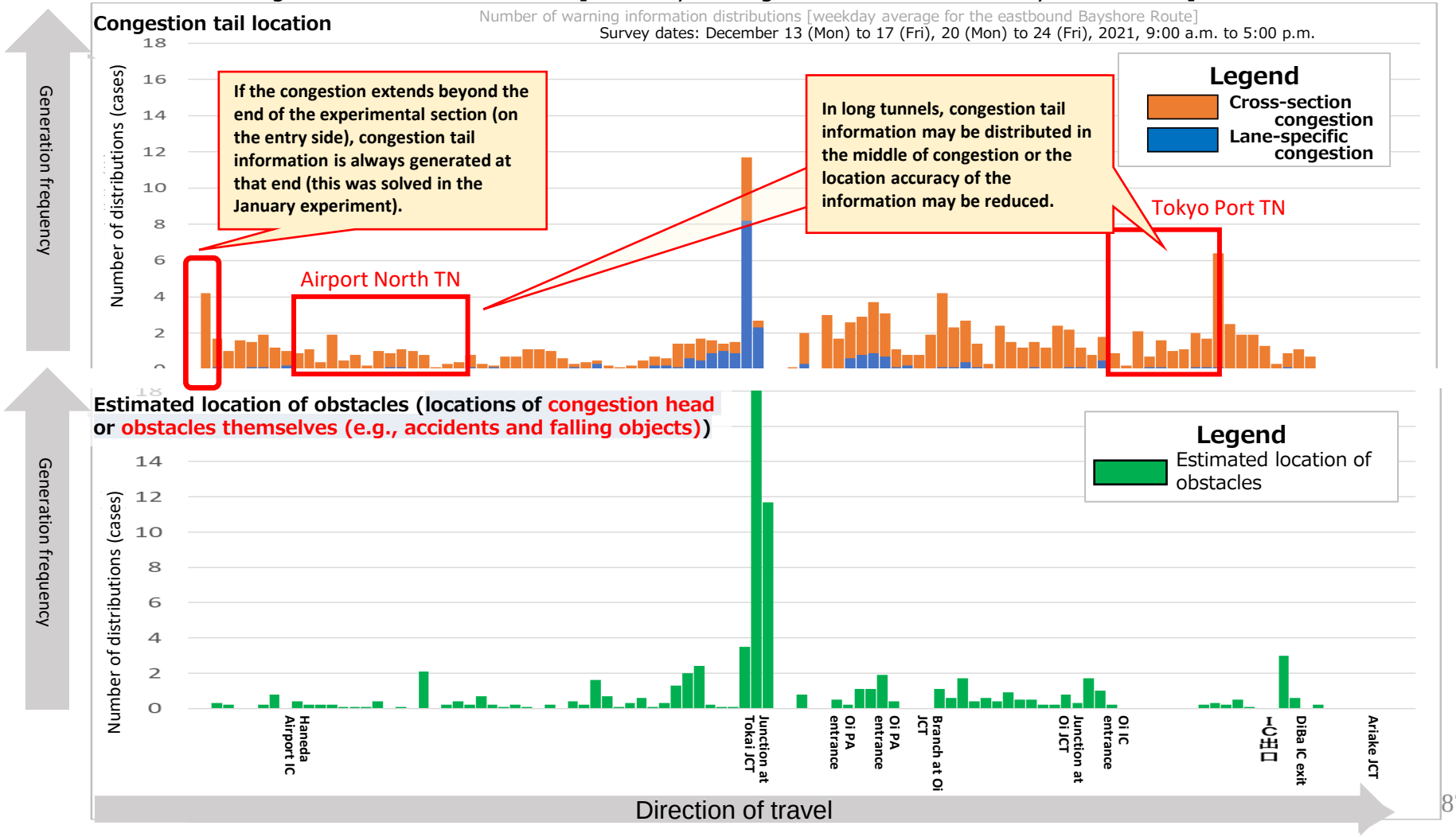
*From JARTIC website

3.2. Outline of Implementation of Demonstration Experiment

Distribution frequency of warning information (by content) during the demonstration experiment

- 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.

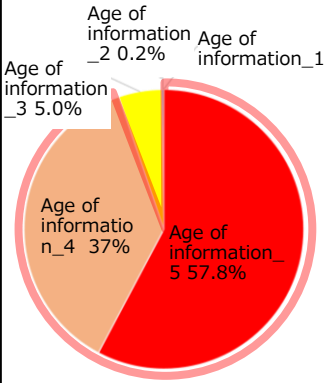
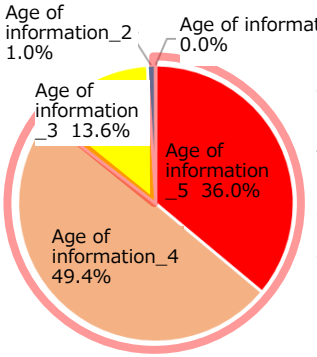
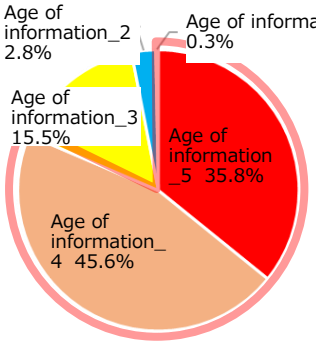
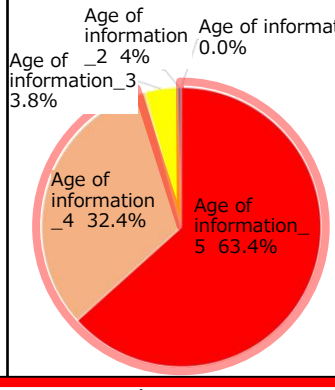
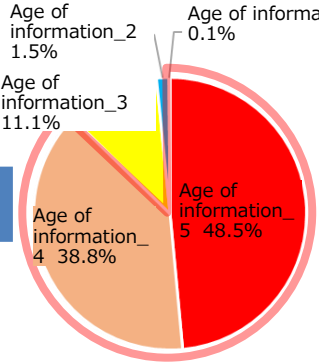
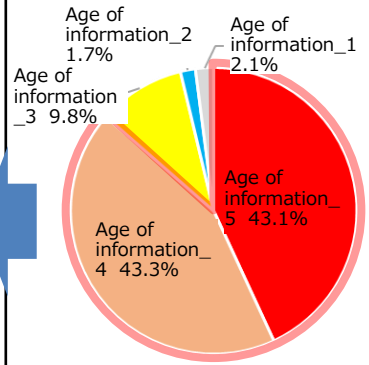
Number of warning information distributions [weekday average for the eastbound Bayshore Route]



3.2. Outline of Implementation of Demonstration Experiment

Age of information calling for attention during the demonstration experiment period

- In terms of the breakdown of the distribution number of information items calling for attention in the order of the age of information, the age of the distributed information improved with the increase of the fresher data distributed within the latest 5 minutes (Layer 1) and within the latest 10 minutes (Layers 1 + 2).

	September 2022 (FY2022 autumn)	April 2022 (FY2022 spring)	December 2021 (FY2021 winter)
	Online connection (four providers)	Online connection (four providers)	Online connection (preceding two providers)
Weekday average on Haneda Route inbound	 **→The rate of information up to the latest 10 minutes in age was approximately 95%** * Actual value	 →The rate of information up to the latest 10 minutes in age was **approximately 85%** * Actual value	 →The rate of information up to the latest 10 minutes in age was **approximately 81%** * Actual value
Weekday average on Bayshore Route eastbound	 **→The rate of information up to the latest 10 minutes in age was approximately 96%** * Actual value	 →The rate of information up to the latest 10 minutes in age was **approximately 87%** * Actual value	 →The rate of information up to the latest 10 minutes in age was **approximately 86%** * Actual value

* Survey period
9:00 to 17:00, from December 13 (Mon) to 17 (Fri), from December 20 (Mon) to 24 (Fri), 2021
9:00 to 17:00, from April 18 (Mon) to 22 (Fri), from April 25 (Mon) to 28 (Thu), 2022
9:00 to 17:00, from September 15 (Thu) to 30 (Fri), 2022 *Except 27 (Tue)
* The age of information as of the time of information generation (by minutes) was aggregated

Age of information 5	The data of the latest 5 minutes (Layer 1) was used
Age of information 4	The data of the latest 10 minutes (Layer 1 + Layer 2) was used
Age of information 3	The data of the latest 15 minutes (Layers 1 to 3) was used

3.3. Efficacy Evaluation by Experiment Participants

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

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 demonstration experiment 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.

3.3. Efficacy Evaluation by Experiment Participants

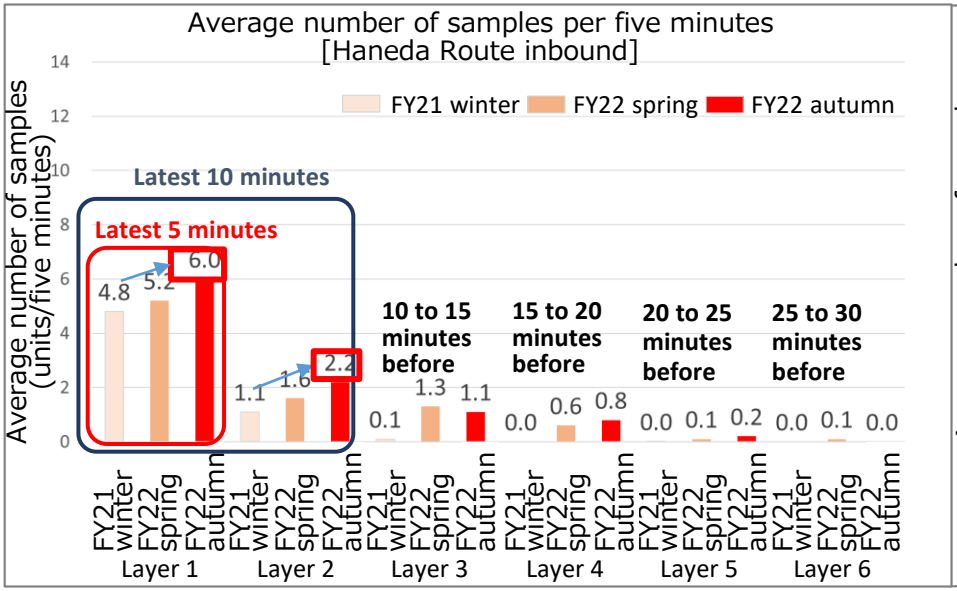
■Findings obtained through the demonstration experiment

Primary evaluation items	Findings obtained through the demonstration experiment
①Probe amount acquired and real-timeliness	- **The average data amount acquired within the latest 5 minutes** increased from 5.2 to 6.5 units in the spring experiment to **6.0 to 7.3 units in the autumn experiment (1.1 times)**. - **The information was able to be generated from the data up to the latest 5 minutes for approximately 60% and from the data up to the latest 10 minutes for 95%.** - **In large long tunnel sections**, however, the rate of the information generated from the data up to the latest 10 minutes **decreased to 72%*** due to the hindrance of the uplink.

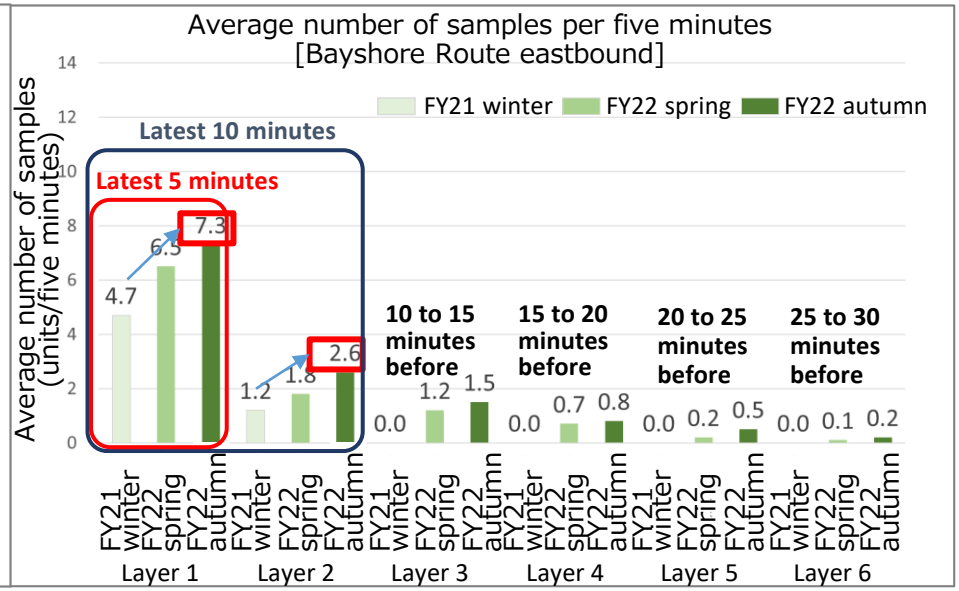
■Average number of probes per five minutes (FY2021 winter, FY2022 spring and autumn)

* A value at the peak hours in the morning and the evening on September 29, 2022 (from 7 to 9 and from 17 to 19) in the autumn experiment at the Tokyo Port Tunnel on the Bayshore Route

Haneda Route inbound



Bayshore Route eastbound



<Survey period>
- FY21 winter: 9:00 to 17:00 on 15 weekdays from January 10 (Mon) to 28 (Fri), 2022
- FY22 spring: 9:00 to 17:00 on five weekdays from April 4 (Mon) to 8 (Fri), 2022
- FY22 autumn: 9:00 to 17:00 on 11 weekdays from September 15 (Thu) to 30 (Fri), 2022

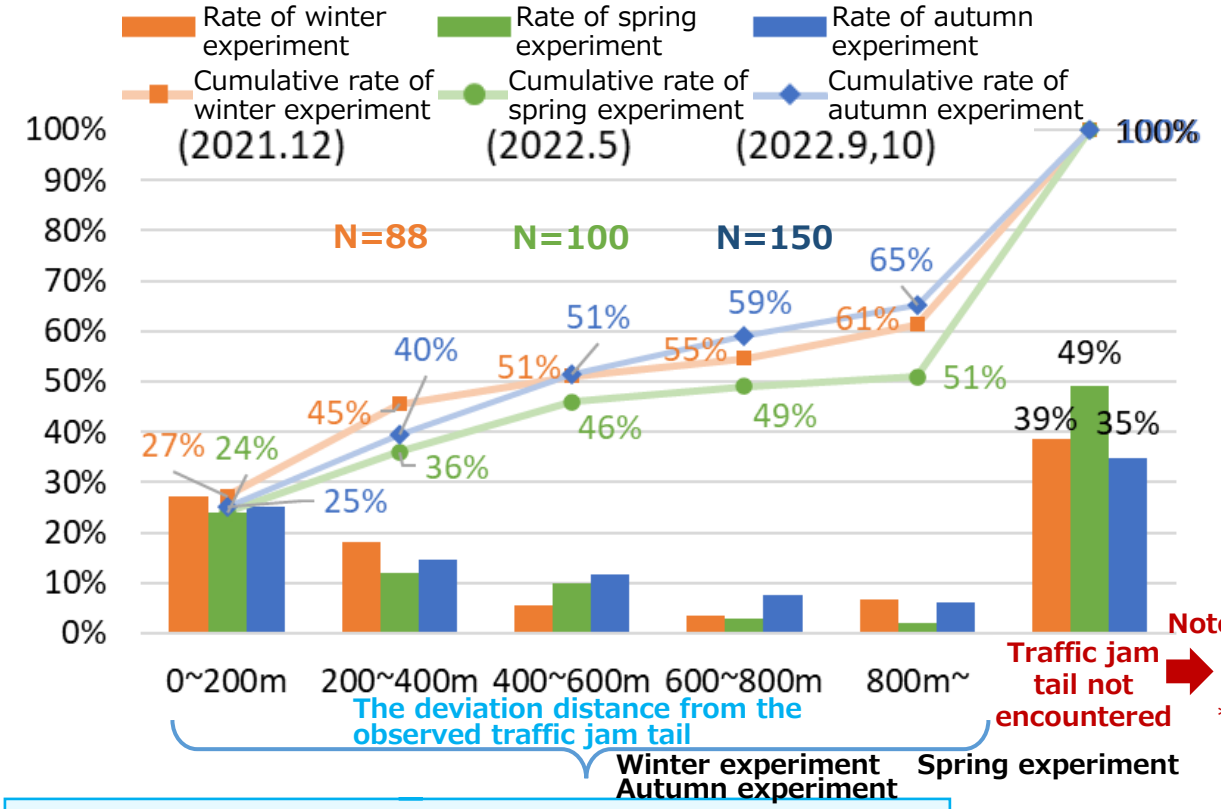
*Except 27 (Tue)

3.4. Summary of the demonstration experiment evaluations

■Findings obtained through the demonstration experiment

Primary evaluation items	Findings obtained through the demonstration experiment
②Information accuracy in the traveling direction	- **The traffic jam tail encounter rate** at the time of information provision **is 65%**, **60% of which is within the deviation distance of 800 m.*** * Given that, in the five-minute assessment, deviation of 500 m to 1000 m may be generated due to the extension or shortening of the traffic jam, the deviation distance was set at 800 m or less as a guideline. - In the five-minute assessment, **an error will be observed according to the changes of the traffic condition**.

■The deviation distance between the provided information on traffic jam tail and the observed traffic jam tail, etc.



<Total of the Bayshore Route and the Haneda Route>

Note 1) **Traffic jam tail not encountered**: A case where a corresponding traffic jam tail was not observed, such as where the test vehicle did not encounter traffic jam although traffic jam tail information had been displayed

Note 2) **Traffic jam tail encounter rate**: Rate of the observed traffic jam tail of the traffic jam tail information generated

Note 1)
Achieved approximately 35% through the experiment
* In the spring experiment, the error likely had been increased due to the small traffic volume and the frequent occurrence of slight traffic jam (the error was improved by the process improvement in the autumn experiment).

[Traffic jam tail encounter rate at the time of information generation Note 2)] 61%⇒51%⇒65%
Achieved approximately 65% through the experiment

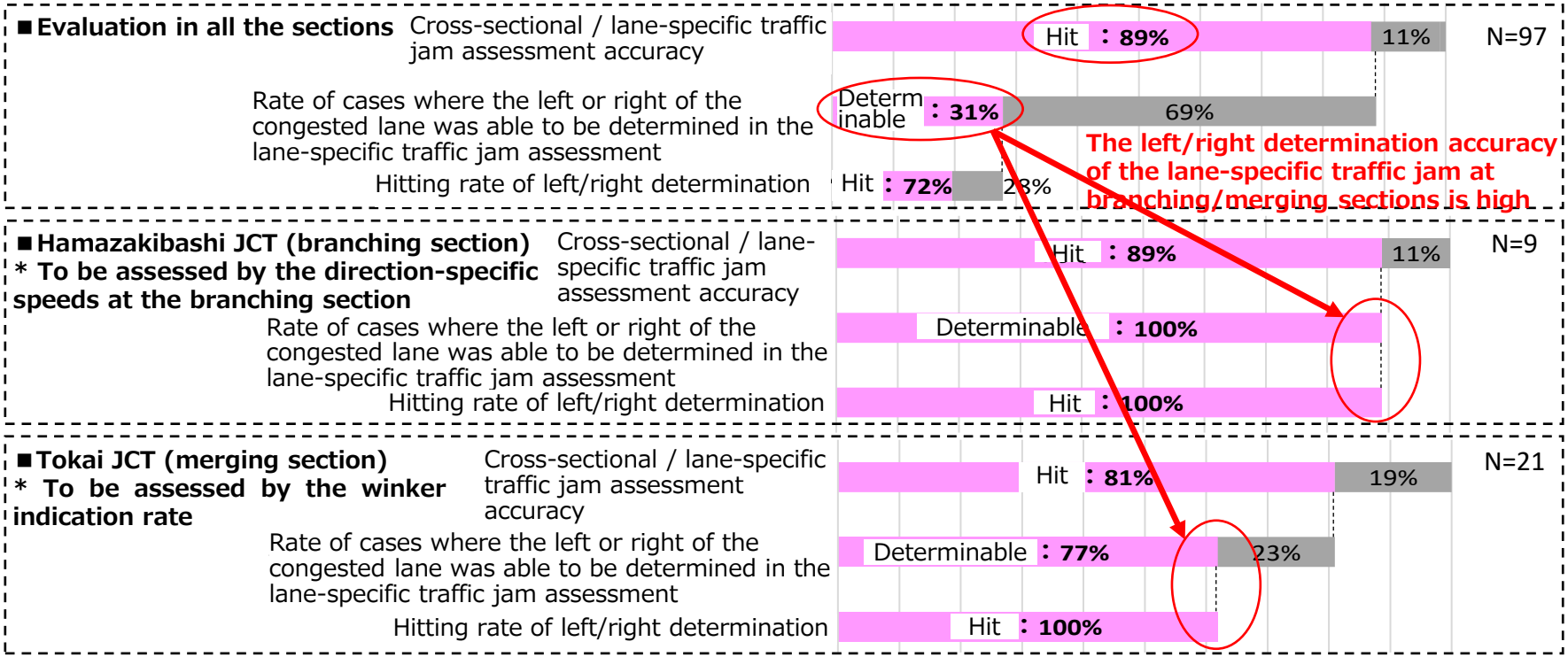
[Rate of deviation distance within 800 m] 55%⇒49%⇒59%
Achieved approximately 60% through the experiment

3.4. Summary of the demonstration experiment evaluations

■Findings obtained through the demonstration experiment

Primary evaluation items		Findings obtained through the demonstration experiment
③Information accuracy in the lane direction	All experiment sections	- **While the cross-sectional / lane-specific assessment of traffic jam was properly performed for 90%, the left or right of the congested lane was able to be determined** with the winker indication detected only **in 30% of the cases**. Winker indication was not detected in most cases.
	Branching/ merging sections	- However, in terms of the **major validation fields (Hamazakibashi JCT, Tokai JCT) only,** where a lane-specific traffic jam frequently occurs, the rate **of the cases where the left or right of the congested lane was able to be determined was high at 77% to 100% and the hitting rate was 100%.**

Comparison of the information accuracy in the lane direction at a certain section with the evaluation results in all the sections



Note) Evaluation of all the sections: The difference between the traffic jam observed by the survey vehicle and the provided traffic jam tail information was assessed.

Assessment of branching/merging sections: The difference between the provided traffic jam tail information and the traffic jam condition observed from the CCTV images was assessed for the traffic jam conditions on May 19 and May 31 that were able to be grasped from the CCTV images (evaluated according to the apparent time).

3.4. Summary of the demonstration experiment evaluations

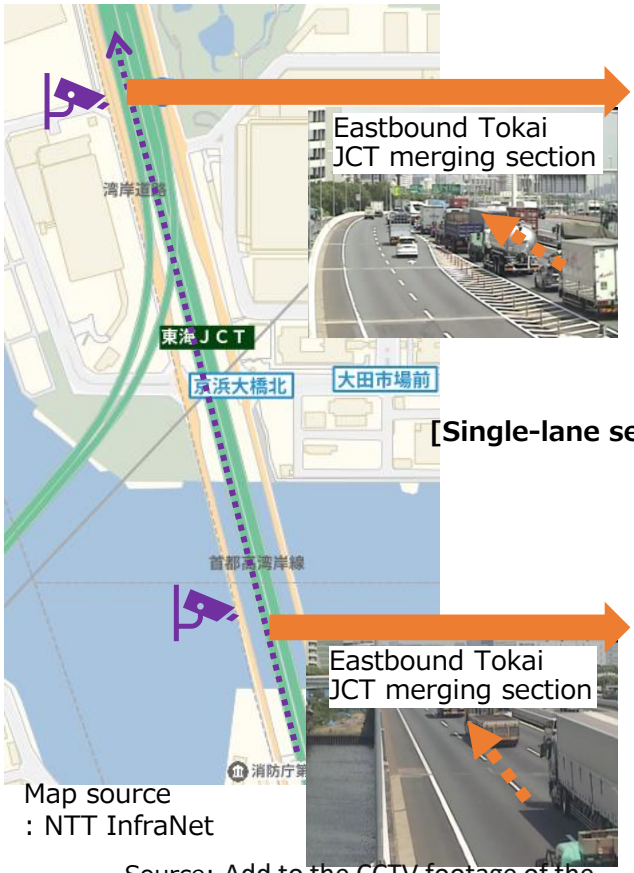
■Findings obtained through the demonstration experiment

Primary evaluation items	Findings obtained through the demonstration experiment
④Amount of data required to obtain a certain level of assessment accuracy	- **Accurate traffic jam assessment will be obtained if data is obtained from 15 units or more per five minutes for a merging section** with complicated traffic behaviors and **10 units or more per five minutes for a single-lane section**.

■Comparison between the lane-specific traffic jam assessment indicator (rate of vehicles traveling at lower than 30 km/h) probe data and the results observed from CCTV (actual time)

Bayshore Route eastbound (Tokai JCT)

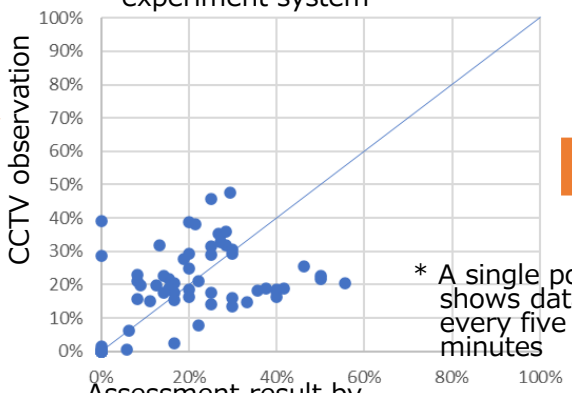
Note) Observed from 7:30 to 10:00 on May 19 (Thu) and from 10:30 to 13:00 on May 31 (Tue), 2022



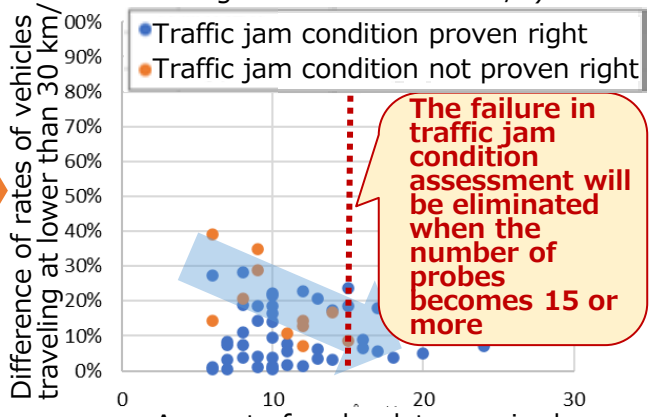
Map source : NTT InfraNet

Source: Add to the CCTV footage of the Metropolitan Expressway

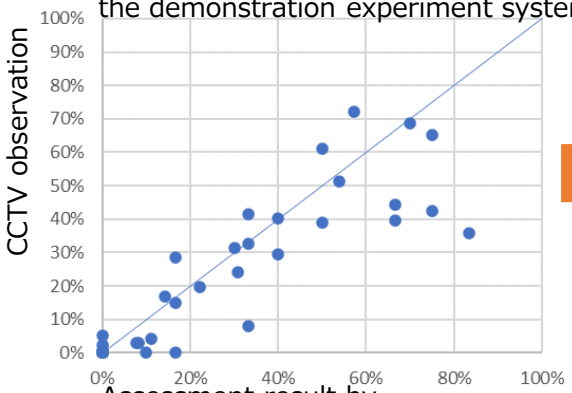
[Merging section] Relationship between the CCTV observation and the aggregate results of the demonstration experiment system



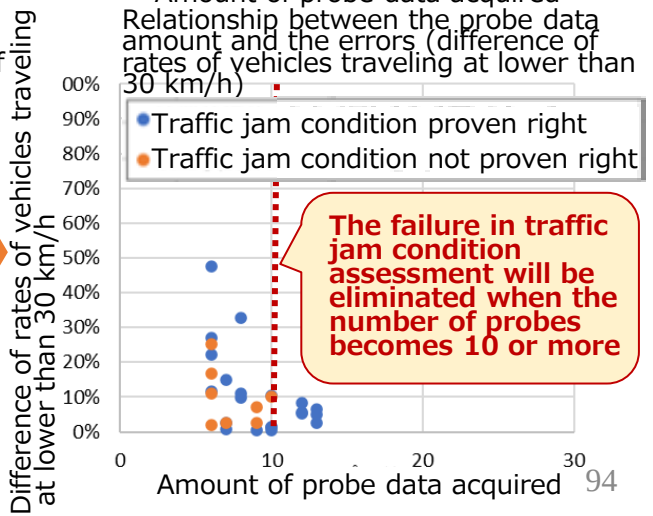
Relationship between the probe data amount and the errors (difference of rates of vehicles traveling at lower than 30 km/h)



[Single-lane section] Relationship between the CCTV observation and the aggregate results of the demonstration experiment system



Relationship between the probe data amount and the errors (difference of rates of vehicles traveling at lower than 30 km/h)



3.4. Summary of the demonstration experiment evaluations

■Findings obtained through the demonstration experiment

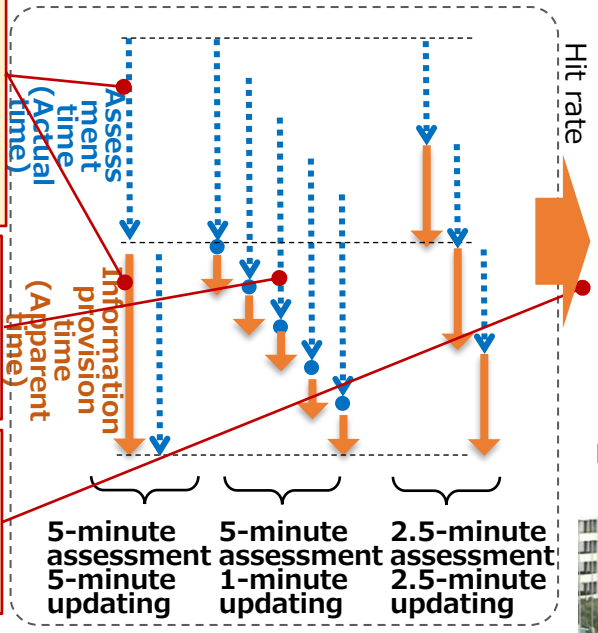
Primary evaluation items	Findings obtained through the demonstration experiment
⑤Analysis of the assessment time*1 and the information updating interval shortening effect	- It is effective to **shorten the assessment time and the information updating interval** for increasing the **hit rate of the provided information**. - **During the changes of traffic condition where the hit rate of the provided information lowers, shortening the information updating interval to one minute** with the current 5-minute assessment time maintained **increases the hit rate of the generated information to approximately 1.1 times** - **It is effective to preferentially shorten the information updating interval** that does not need an increase of probe data.

Estimation of the event hit rate expected to be improved when the event assessment time*1 and the information updating interval are shortened
(Estimation only during the changes of traffic condition at the merging section)

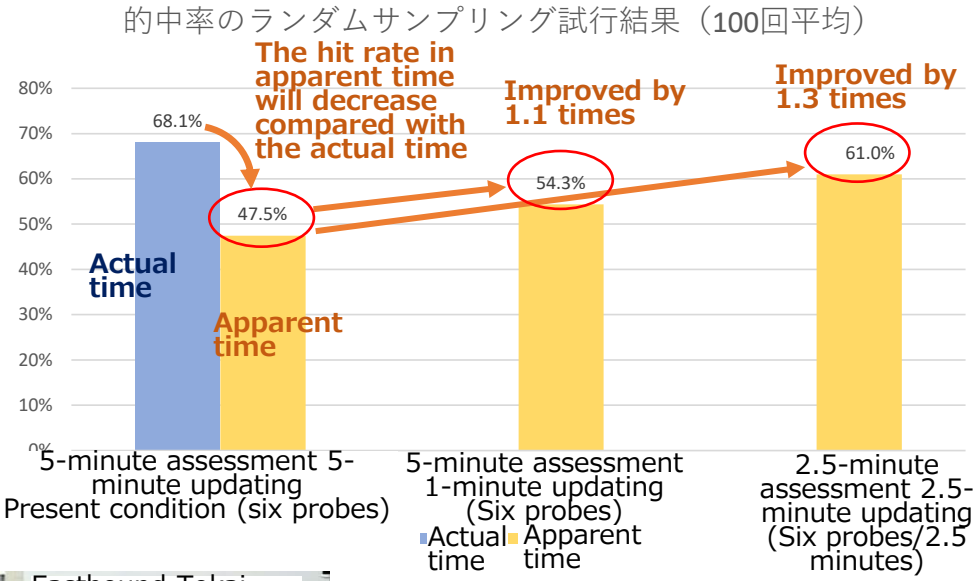
The provided information will not be proved right if the traffic condition has been changed during the information provision time (apparent time) even if the assessment for the previous five minutes (actual time) had been right.

Updating at one minute interval will improve the hit rate with the information updated as needed even at 5-minute assessment time

Shortening the assessment time will improve the hit rate but the probe data needs to be increased correspondingly



Relationship between the assessment time*1 and the information updating interval



■Used data: Measured from the CCTV images at the Tokai JCT (merging section) (7:40 to 8:15 on May 19 (Thu) 2022 * The time zone when the traffic condition changes)

■Method: Comparative errors in traffic jam condition assessment were validated between the random sampling of speed measurement data of all vehicles and all samples (average value of 100 assessments)

*1 This assessment time includes the time to collect and accumulate the probe data. For reference, the actual time required for the assessment itself is several seconds.

Source: Add to the CCTV footage of the Metropolitan Expressway

3.4. Summary of the demonstration experiment evaluations

■Findings obtained through the demonstration experiment

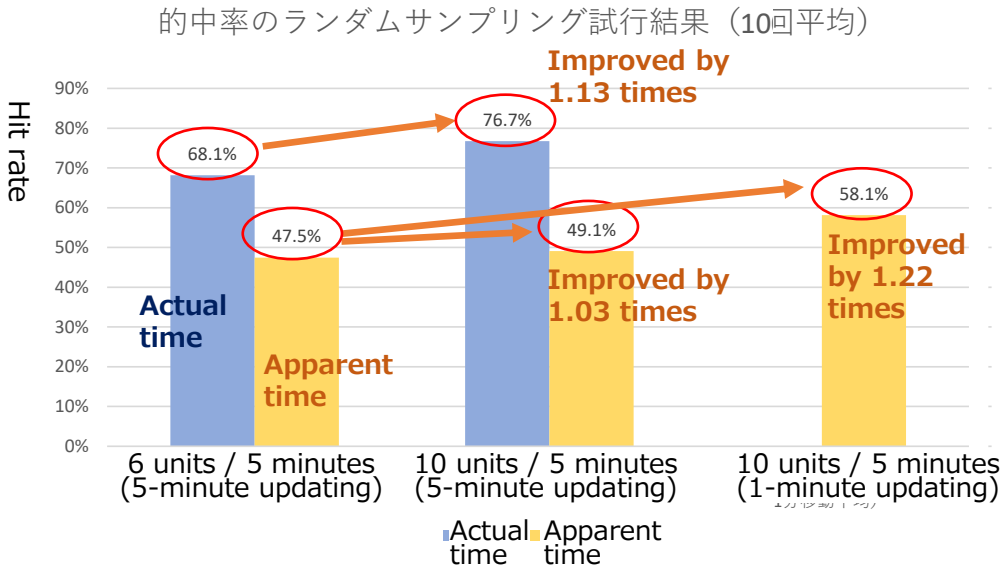
Primary evaluation items	Findings obtained through the demonstration experiment
⑥Analysis of the accuracy improvement effect in the case that the data amount is increased in future	- The disseminated number of connected cars is estimated to be **1.24 times the present level in 2025 and 1.59 times the present level in 2030** - Based on the present number of probe acquisition, data will be possibly **acquired from approximately 10 units per five minutes in 2030**. - In that case, the **actual time hit rate** of the information generated at the merging section **during the changes of the traffic condition** is estimated to **increase by 1.13 times (hit rate 77%) and the apparent time hit rate during the changes of the traffic condition by 1.03 times (hit rate 49%)**

Estimation of the event hit rate to increase in the case that the probe data amount increases (During the changes of the traffic condition at the merging section)

Setting of information hit rate estimation cases based on the estimated number of disseminated connected cars

	2022 (Present condition)	2025	2030	2035
Increase rate of disseminated connected cars*	1.00	1.24 times	1.59 times	1.82 times
Estimated number of probes from which data can be acquired per five minutes	6.0 to 7.3 units	7.4 to 9.1 units	9.2 to 11.2 units	11.4 to 13.9 units
Estimated case unit	6 units	10 units		15 units

* Calculated from the estimated number of disseminated connected cars in Fuji Keizai "Future perspective 2020 of the markets relating to connected cars, V2X, and autonomous cars"



■Used data: Measured from the CCTV images at the Tokai JCT (merging section) (7:40 to 8:15 on May 19 (Thu) 2022 * The time zone when the traffic condition changes)

■Method: Comparative errors in traffic jam condition assessment were validated between the random sampling of speed measurement data of all vehicles and all samples (average value of 100 assessments)

Source: Add to the CCTV footage of the Metropolitan Expressway

3.4. Summary of the demonstration experiment evaluations

■Discussions on the practical use

a. **This information generation method demonstrated that it is possible to generate lane-level traffic information from the lane-level probe under certain road traffic conditions.**

b. **In particular, given that, at branching sections (including exits) and merging sections where the lane-specific traffic jam constantly develops, it is highly possible to put the provision of the lane-level traffic jam information into practical use in an early stage** because the traffic volume (obtainable probe data) is also large in those sections.

c. **It was also demonstrated that more detailed information about the traffic jam in the traveling directions can be provided** than in the existing services **in other sections (such as single-lane sections)** as well for provision of traffic jam tail information as congestion of all lanes (cross-section).

d. **Although the present amount of probe data is not enough** to generate information with high accuracy under various traffic environment and traffic flow conditions, the **accuracy is expected to be improved with the increase of the collected probe data** associated with the future dissemination of connected cars.

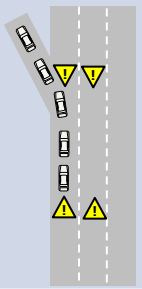
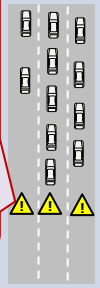
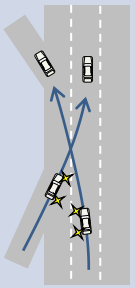
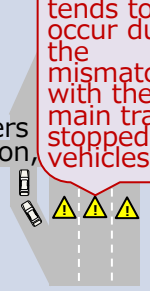
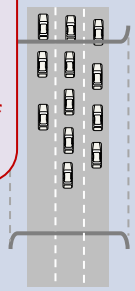
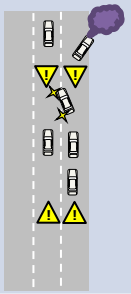
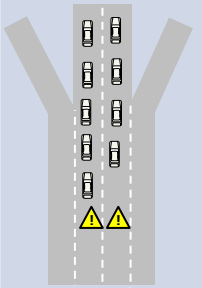
e. **In order to enhance the accuracy, while there is an idea to further improve the data processing and distribution method such as shortening of the information updating interval, study on the business aspect including the cost effectiveness associated with the increase of communication cost** is also required.

f. In addition, the **accuracy is expected to be further improved by the lane-specific use of probe information** likely to be enabled in future associated with the **dissemination of high-precision 3D maps**.

Applicability of this information generation method for respective road traffic conditions

- **At branching sections (including exits) and merging sections where the traffic volume is large and the lane-specific traffic jam constantly develops, it is highly possible to realize** the provision of the lane-level information **in an early stage**. More detailed **information about the traffic jam tail in the traveling directions as all-lane congestion can be provided** than in the existing services for single-lane sections as well.
- In large long tunnel sections, vicinities such as byways, and weaving sections, the information accuracy may be lowered.

Applicability of this method to respective major road traffic conditions in the present probe acquisition condition in lane-specific traffic jam assessment

	①Branching section (including the exit)	②Merging section	③Single-lane section	④Weaving section	⑤Vicinities such as byways	⑥Large long tunnel section	⑦Lane-specific traffic jam due to lane occlusion	⑧Branching sections (both sides)
△Traffic jam tail ▽Interference position / **Examples of road traffic patterns and information generation**		 Information provision position in the case that the information in the lane directions is not detected (when all lanes are congested)			 Intersection, PA, etc. Erroneous assessment tends to occur due to the mismatching with the main track of stopped vehicles, etc.			
Validation sections in the demonstration experiment	Hamazakibashi JCT (branching section) on the Haneda Route inbound	Tokai JCT on the Bayshore Route eastbound	All section lines targeted for experiments	Between the Oi PA and the Oi JCT on the Bayshore Route	Shibaura IC on the Haneda Route Oi PA on the Bayshore Route	Tokyo Port Tunnel on the Bayshore Route	Rear-end collision at the Oi JCT merging section on the Haneda Line inbound (see the reference material)	(Hakozaki JCT) * Out of the scope of the demonstration experiment
Applicability of this information generation method*1	○Branching section logic	○	○	○	○	○	○	○Branching section logic * Not demonstrated
Applicability in the present data acquisition condition*1 — **Traveling direction**	○	○	○	○	△Erroneous assessment tends to occur due to the mismatching with the main track of stopped vehicles, etc.	△The hindrance of the uplink will result in decrease of acquired data and cause significant error	○	○
Lane direction	○The information in the branching direction can be added to the traffic jam tail information	○When many vehicles merge and winker indication frequently develops at the merging section	△Winker indication may not be detected	△The congestion side is difficult to assess as the winker indication develops left and right	△ Erroneous assessment develops 10 times/day (50 minutes)*2	△ The information generation rate from the latest 10-minute data decreased to 72%*3	○Not verified statistically	○
Improvement idea	The rate of assessment of both left and right: 100%	The rate of assessment of both left and right: 77%	The rate of assessment of both left and right: 31% - Improvement of the information accuracy in the lane direction by the use of lane-specific probes	- Improvement of the information accuracy in the lane direction by the use of lane-specific probes	- Inhibition of mismatching by the extension of the link length - Improvement of the information accuracy in the lane direction by the use of lane-specific probes	- Improvement of the communication environment within tunnels - Increase of cumulative data volume		

The traffic jam tail encounter rate at the time of information provision is 65%, 60% of which is within the deviation distance of 800 m
⇒The traffic jam tail encounter rate can be improved by shortening the information updating cycle

Highly possible to realize in an early stage

*1) ○: Information generation is possible if a certain data amount can be acquired, △: Significant information error may develop
*2) The value in the vicinity of the Shibaura ICT on the Haneda Route inbound (winter experiment on December 20, 2021)
*3) The value at the Tokyo Port Tunnel (at the morning and evening peak hours)

3.5. Technical study results based on the demonstration experiment

■Outlook of the technical study results for the respective element technologies (2/2)

Study item	Purpose of technological study	■Outlook of the technological study results
①Data sharing (aggregation)	- The inter-center data sharing specifications will be studied in sharing the probe data between the provider server and the information integration/generation server	**[Technical specifications]** ●Definition of collected data items and aggregation, collection format (json format) ●Collection frequency (five minutes), uplink delay data handling method ●Method to split from the DRM link to the 100-m link **[Technical evaluation]** ◆The data of four probe providers from whom data can be collected online at present and the data acquisition tendency will be assessed ⇒The average data amount obtainable in the latest five minutes is 6.0 units for the 2-lane sections (Haneda Route) and 7.3 units for the 3-lane sections (Bayshore Route)
②Data integration of several information sources	- The data integration and processing specifications for the data collected from several information providers will be studied	**[Technical specifications]** ●How to handle the numerical data in integration and to secure required number of samples ●Response to the variation in the information provision time by several probe providers **[Technical evaluation]** ◆The relationship between the number of retrospective layers and the information generation rate (section rate) will be studied ⇒Approximately 60% of information can be generated from the data up to the latest 5 minutes (Layer 1) and approximately 95% from the data up to the latest 10 minutes (Layer 1 + Layer 2) ⇒In large long tunnel sections, however, the rate of the information generated from the data up to the latest 10 minutes decreased to 72%* due to the hindrance of the uplink

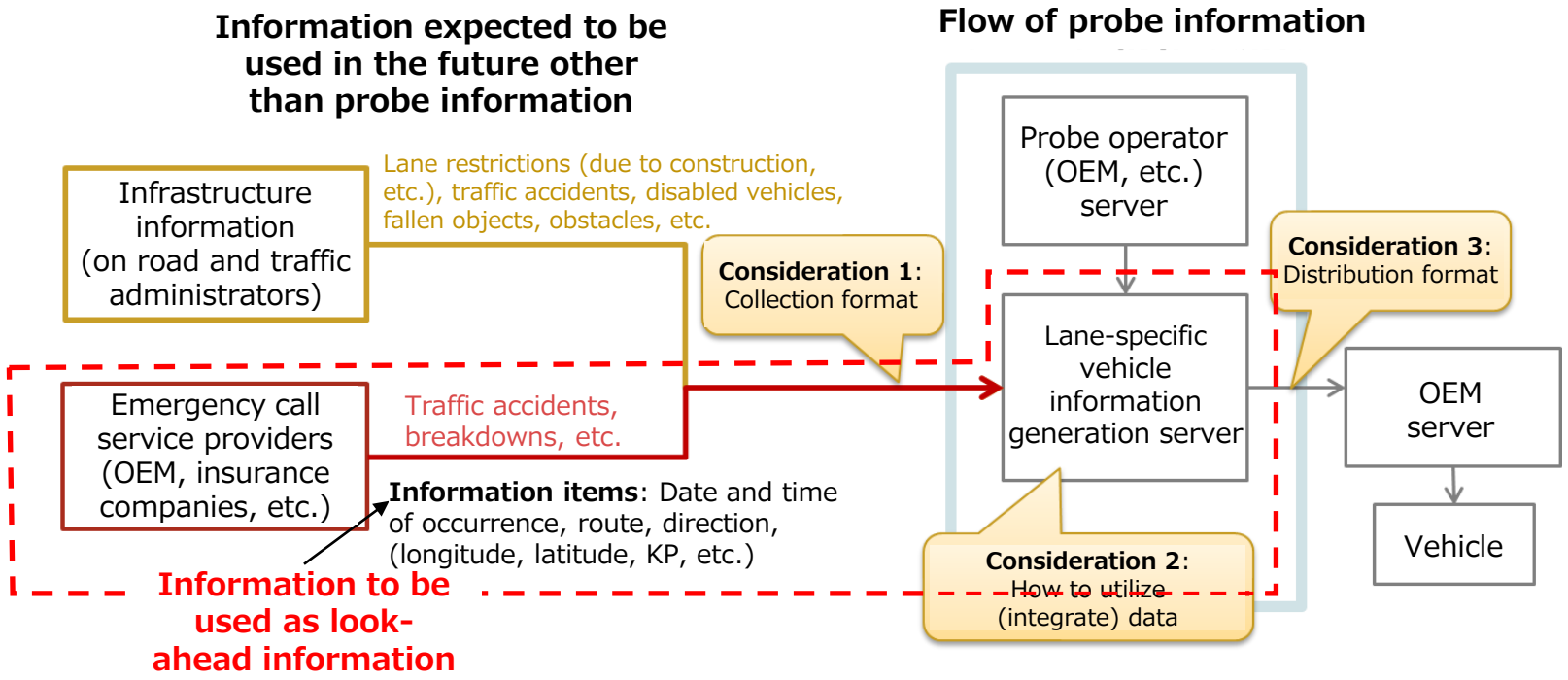
3.5. Technical study results based on the demonstration experiment

■Outlook of the technical study results for the respective element technologies (1/2)

Study item	Purpose of technological study	Technical study results
③Generation of lane-specific road traffic information	- The technical specifications to generate the lane-level road traffic information from the lane-specific probe will be studied	**[Technical specifications]** ●A logic will be constructed to assess the lane-specific traffic jam condition in the traveling distance (hundreds of meters) from the information about the number of units by speed layers ●In the case of the lane-specific traffic jam, a logic will be constructed to assess the direction of the interference lane (left or straight) from the speed for each direction at the link before the branching section for branching sections and to assess the direction of the interference lane (left or right) from the winker information for sections other than branching sections **[Technical evaluation]** It was demonstrated that it is possible to generate lane-level traffic information from the lane-level probe under certain road traffic conditions
④Conversion to data that can express locations	- Data format and conversion specifications will be studied that can express (distribute) the generated lane-level road traffic information	**[Technical specifications]** ●Method to prepare a node-link map that can express the locations in the lane direction ●Location reference method to superimpose on a high-precision map **[Technical evaluation]** ◆The matters noted through the actual data prototyping will be reflected in the technical specifications (draft)
⑤Data sharing (distribution)	- The data sharing specifications between the centers in distributing generated information to the OEM server will be studied	**[Technical specifications]** ●The Jaspar specifications will be applied (the issues of the present JASPAR specifications will be organized) ●A start process of every one minute will be realized to minimize the information delay Implementation of API **[Technical evaluation]** ◆The API processing time is approximately seven seconds

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

4.1. Information sources and information-gathering specifications for emergency call service information

- The emergency call service is provided by OEM and insurance companies and those providers are candidates for the information sources.
- Guidelines have been established for the information items that the related organizations can obtain from the emergency call service toward the acceleration of their dissemination and it is anticipated that information items will be gathered according to those guidelines.
- The information items do not include the information regarding closed lanes.

Examples of information sources of emergency notification information

Service example	Service outline
(1) Service example of OEM (HELPNET*1)	- The HELPNET service has been employed for the emergency call service provided by automobile manufacturers for their users. - The emergency information will be automatically reported to the HELPNET Center through the airbag-interlocking device or by simple operation. Communication will be made with the reporter to grasp the situation to call an ambulance or the police as needed. - Data will be transmitted simultaneously with the communication. Accurate location and vehicle information allows an ambulance and a patrol car to quickly arrive at the accident site.
(2) Service example of an insurance company (GK Automobile insurance *Mimamoru*2)	- The dedicated dashboard camera will detect an impact of a given level and, if vehicle traveling cannot be detected for approximately 30 seconds, it will judge that the vehicle has encountered a traffic accident and will transmit the location information, the "event records" at the impact detection, etc. - An operator at the dedicated safety confirmation desk will make a safety confirmation call to the driver through the dedicated dashboard camera.

***1 Source: Mechanism and flow of HELPNET (https://www.helpnet.co.jp/about/flow/)**

***2 Source: GK Automobile insurance Mimamoru (Mitsui Sumitomo Insurance) (https://www.msins.com/personal/car/gk/mimamoru-dr.html#anc-06)**

***3 Source: Guidelines on the handling of emergency call from automobiles by service providers (May 2018, National Police Agency, Fire and Disaster Management Agency, Ministry of Land, Infrastructure, Transport and Tourism)**

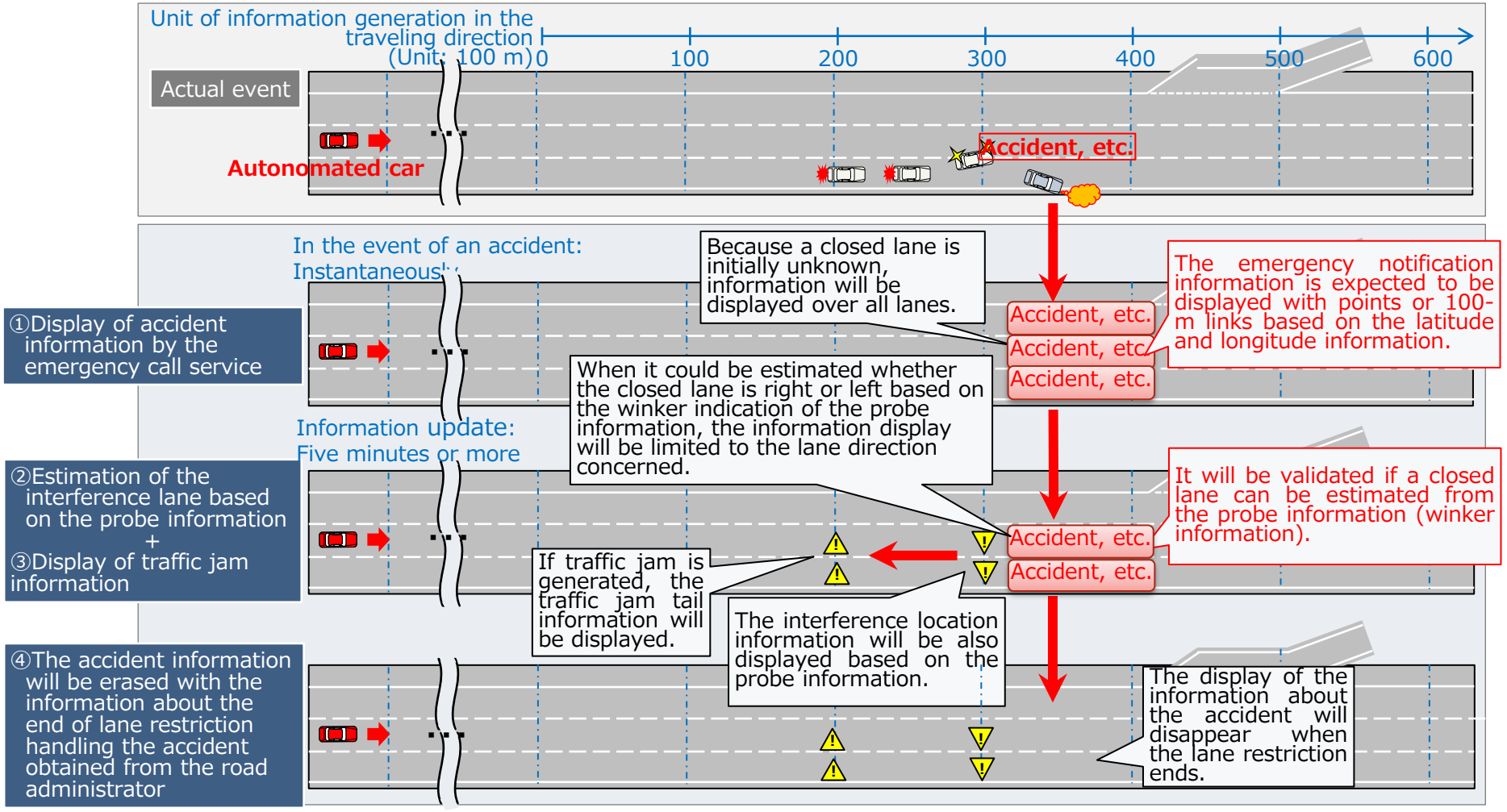
Information items expected to be provided in the emergency notification information (traffic accidents, etc.)*3

Item No.	Notification Item	Details
1	Automatic/manual reporting	Automatic reporting or manual reporting
2	Latitude and longitude	Latitude and longitude information (The datum and expression form (degree representation) must comply with the conditions designated by the rescue organization)
3	Location accuracy	Radius errors of latitude and longitude (unit: meters)
4	Vehicle traveling direction	Orientation representing the vehicle traveling direction
5	Traveling track	Track information representing the route where a vehicle has traveled to the accident site (Track information at several points acquired at a certain interval (2 to 4 above) approximately 10 points (*1))
6	Vehicle type	Vehicle type such as large-sized vehicle, bus, etc.
7	Vehicle identification number	Vehicle identification number or a unique number given to the reporting device used to identify a vehicle
8	Fuel species (*2)	Fuels such as gasoline, light oil, LPG, electricity, and hydrogen
9	Accident time	The time when the reporting was made
10	Telephone number for call back	The telephone number of an automatic reporting device or mobile phone that can be used for communication with the reporter
11	Name of contractor	Name of vehicle owner (user) (including legal entity)
12	Registration No.	Vehicle registration number (e.g. Nagoya 123 *A* 1234)
13	Provider ID	An identifier used to identify the service provider
14	Telephone number of the sender	Sender telephone number of the service provider
15	Cause for reporting	Reporting classification that the operator of the service provider confirmed in the communication with the reporter (e.g. traffic accident resulting in property damage, no response)

4.2. Study on the generation of lane-level emergency notification information through the integrated use of probe information

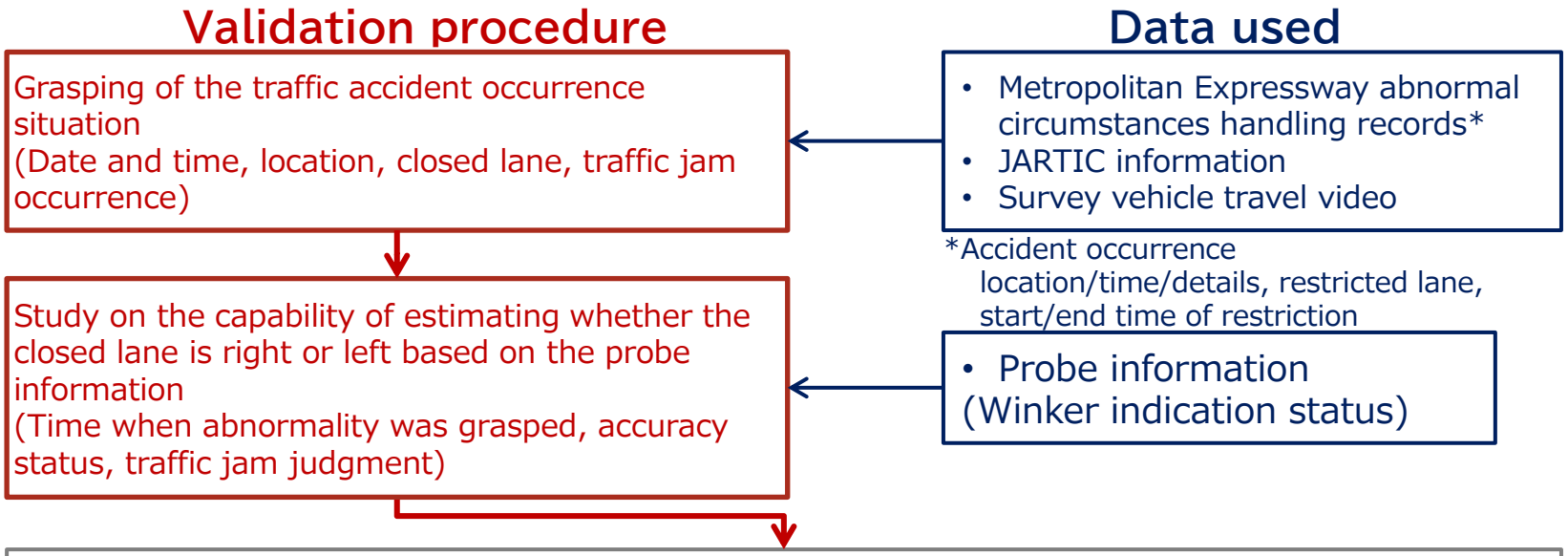
- The image of the information generation through the integrated use of emergency notification information and probe information is as shown below.
- While a lane closed by an accident, etc. is initially unknown, instantaneous information calling for attention can be provided. Then, it will be validated if a closed lane can be estimated from the probe information.

Image of the integrated use of emergency notification information and probe information



4.3. Validation of lane-level emergency notification information generation capability

- More instantaneous information calling for attention will be provided from the probe information and then it will be validated if a closed lane can be estimated based on the later probe information.
- The validation procedure and the data used are as shown in the chart below.



Validation method of lane-level emergency notification information generation capability

4.3. Validation of lane-level emergency notification information generation capability

- Regarding a rear-end collision in the vicinity of the head of the Oi Junction merging section on the Haneda Line (inbound), ①whether the closed lane is right or left was estimated based on the winker indication status and ②the lane-level traffic jam due to congestion was detected.
- It was validated that a closed lane can be estimated and the information calling for attention can be provided from the probe information.

<Example of detecting accidental traffic congestion at the merging lane in the vicinity of the head of the Oi Junction merging section on the Haneda Line (inbound)>

- A rear-end collision by a truck occurred on the merging lane in the vicinity of the head of the Oi Junction merging section
- Information calling for attention was generated on the right-side lane of the accident site (interference location) (many left winkers were detected), the traffic jam tail information was generated approximately 300 m behind the interference location (right lane). (10:45)
- Since then, the information calling for attention was continuously displayed and the traffic jam was extended.
- The "abnormal circumstances handling records" of the Metropolitan Expressway showed the following information.

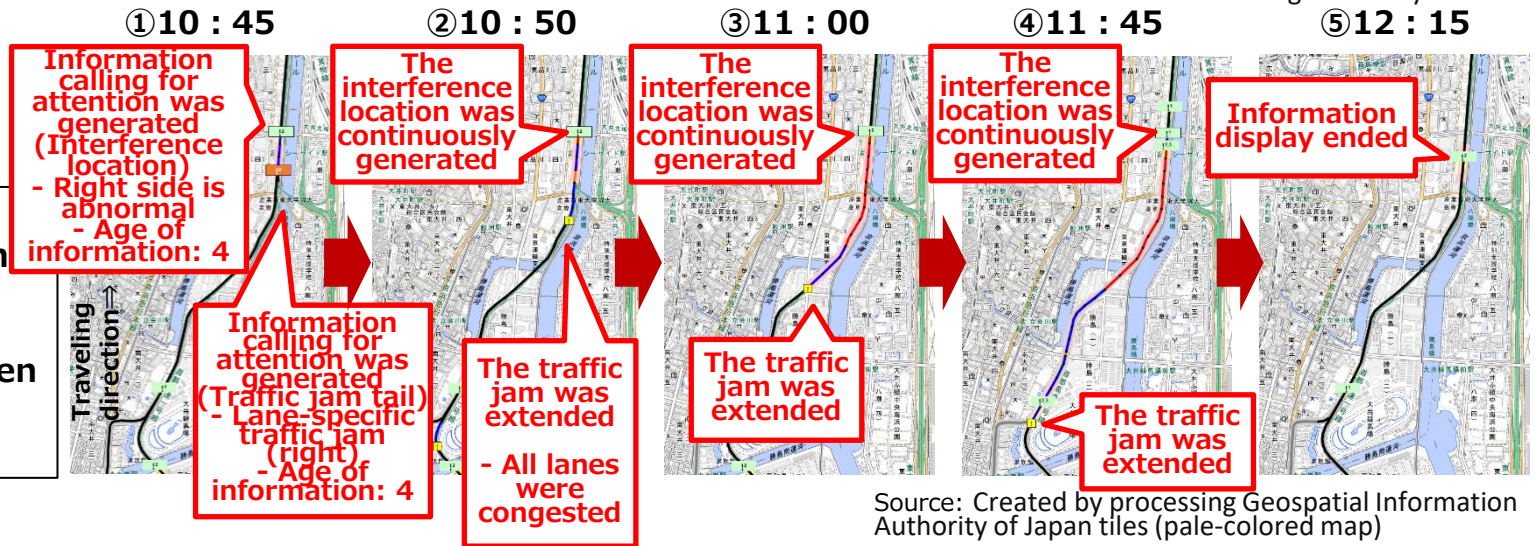
(Event type: accident, occurred at 10:46, ended at 12:15, type: minor collision, interference lane: Lane 1)

Video sent from the survey vehicle

Source: Add to the footage taken by the contractor.

Changes of event detection by the probe

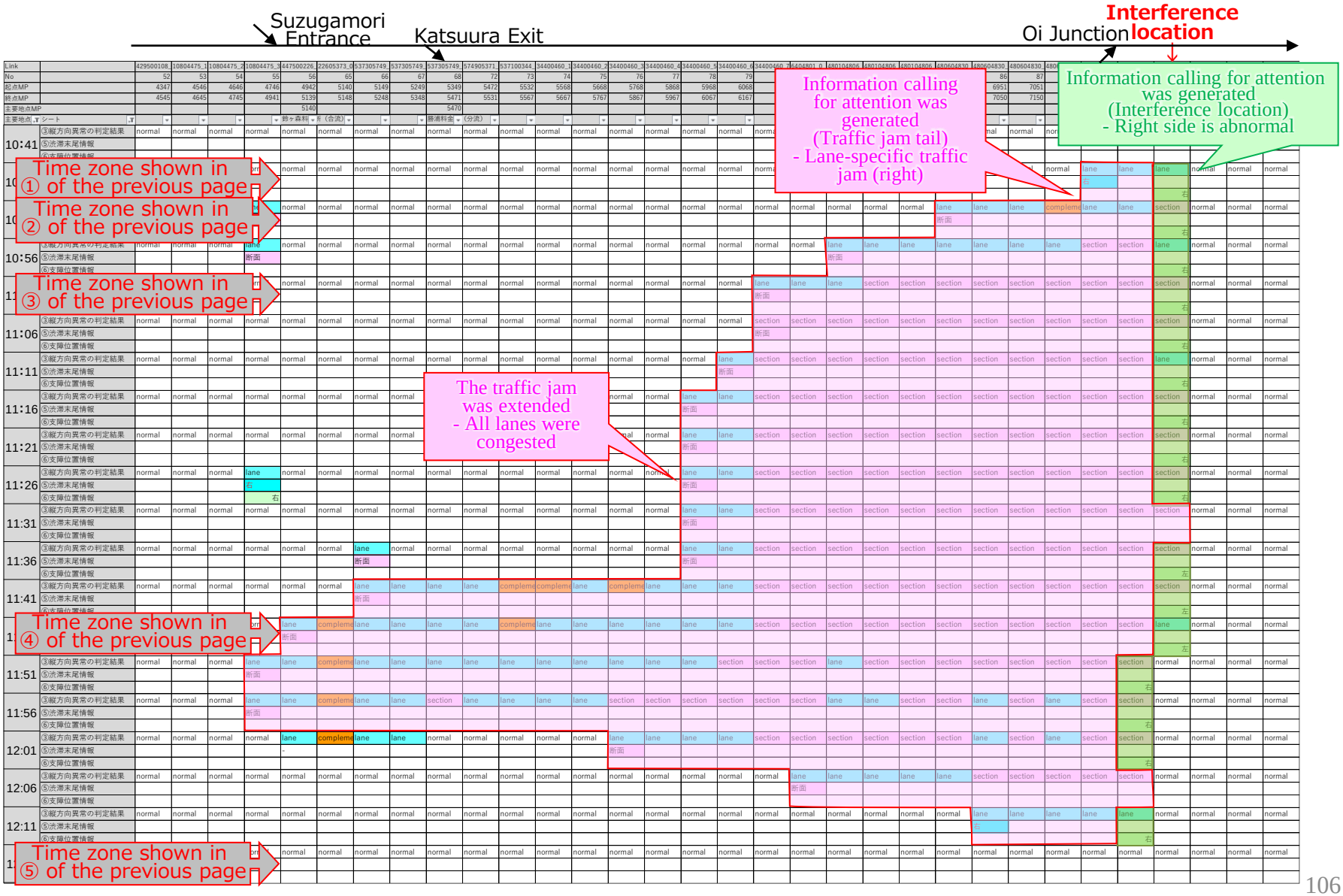
*** Internal screen of the probe system**



Source: Created by processing Geospatial Information Authority of Japan tiles (pale-colored map)

4.3. Validation of lane-level emergency notification information generation capability

[Reference] Mosaic plot of the interference location, Haneda Line (inbound)



4.4. Study on the information distribution specifications

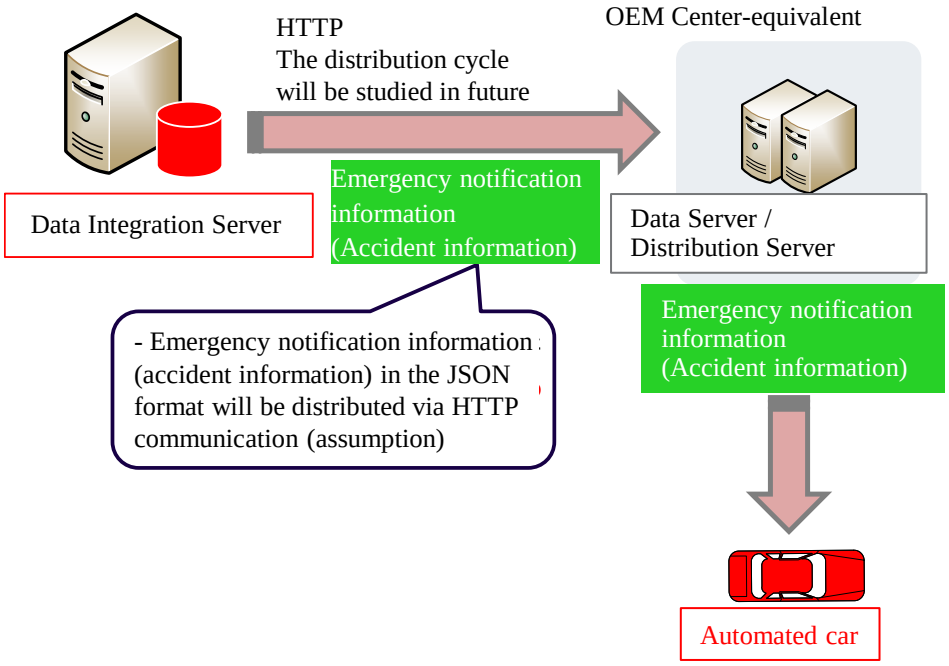
- The emergency notification information can be distributed as obstacle information (contents: obstacle) in the JASPAR specifications.
- Accordingly, the information distribution specifications will be assumed to be an interface according to the JASPAR specifications (HTTP protocol, JSON format information expression). The information distribution cycle needs to be studied in future based on the cycle at which the information can be gathered from the information sources.

Example of data in the JSON format according to the obstacle information in the JASPAR specifications


```
"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":"首都高速羽田線"
    " lane":["1","2"]
    "accuracy":"1"
   }
  }
  "contents":{
   "obstacle":{
    "sequence":"1","size":"L","move":"1","object ":"停止車両"
   }
  }
 }
]
```


Locations to which lane-level information relating to the closed lane will be provided

Distribution image of the emergency notification information



5. Study on the use and validation of vehicle probe data for the detection of bad weather and road surface conditions

- We studied and evaluated/validated the techniques to detect the bad weather such as torrential rain and the associated road surface conditions such as water film formation by use of vehicle probe data with the objective of the safety improvement of automatic driving and the efficiency improvement/enhancement of road management.

1) Study on elemental technologies

- We studied the applicability of vehicle probe data and technologies to automatic driving and road management after organizing available vehicle probe data and technologies.

2) Collection and evaluation of vehicle probe data

- We collected the available vehicle probe data organized in 1) for a certain period and then conducted the comparative evaluation with the weather and road surface conditions and the collected vehicle probe data during that period. We also collected the data of the weather and the road surface conditions required for the comparative evaluation.

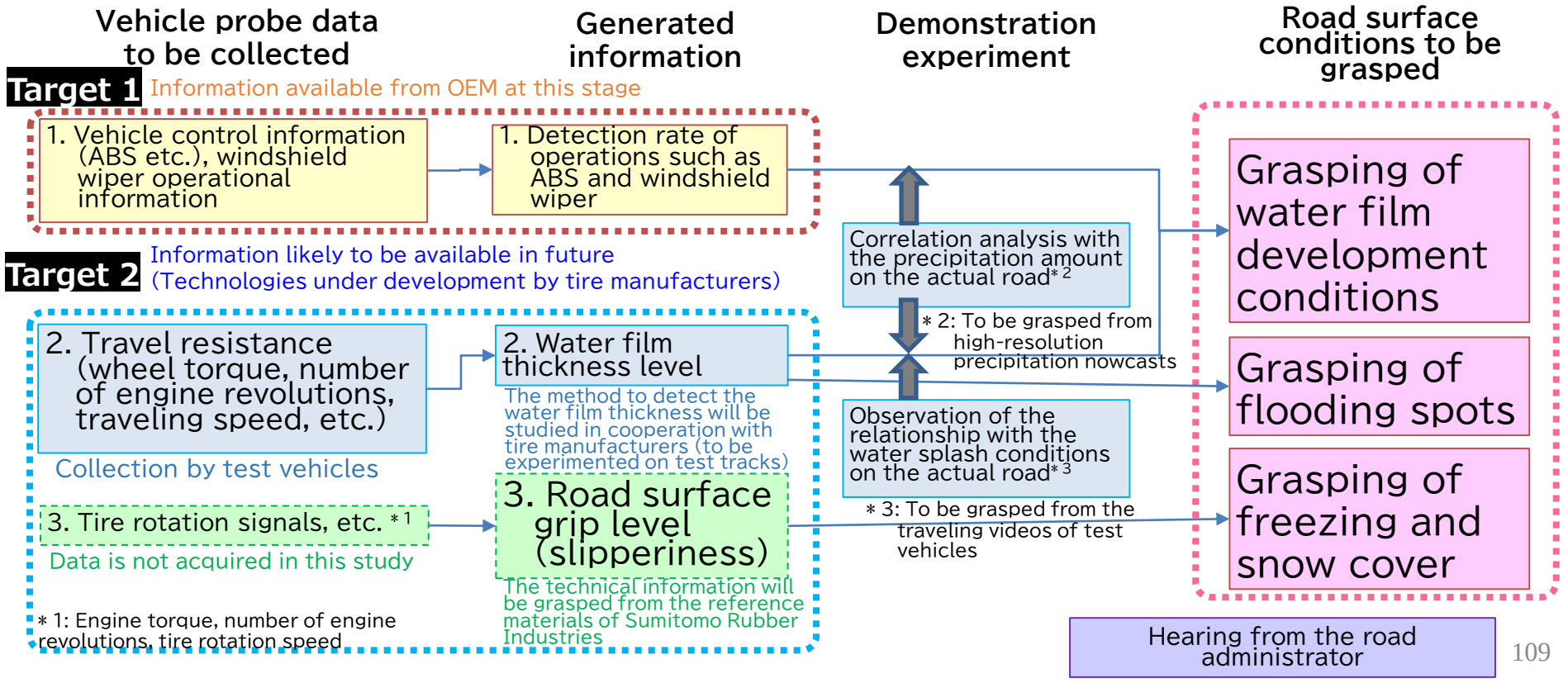
3) Study on the application methods to autonomous cruising and road maintenance

- We studied the method to apply the vehicle probe data to autonomous cruising and road maintenance and the possibility to put it into practical use by grasping the rainfall and road surface water film conditions from the vehicle probe data based on the studies 1) and 2).

5. Study on the use and validation of vehicle probe data for the detection of bad weather and road surface conditions

5.1. Study on elemental technologies

- We studied the applicability of the probe data to the detection of road surface conditions such as the water film development and flooding with the objective of effective information service to road management and drivers/automated cars
- We targeted the following vehicle probe data for the study of detectability:
  Target 1: **vehicle control information (operational information such as ABS)** and **windshield wiper operational information** as probe data associated with the grasping of road surface conditions that can be presently collected from OEM
  Target 2: **tire rotation signals and travel resistance** that are likely to be available in future from tire manufacturers as input data for **road surface grip levels**, **water film thickness levels**



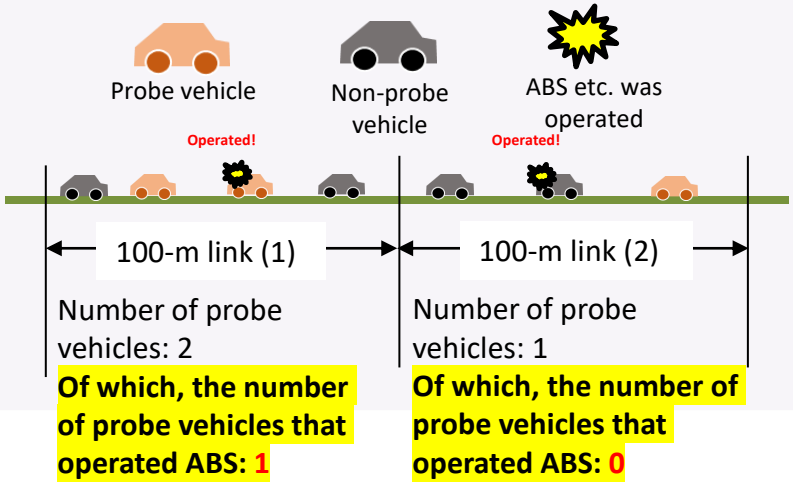
5.1. Study on elemental technologies

Target 1: Summary of the use of vehicle control information and windshield wiper information

- **Vehicle control information (ABS etc.)** and **windshield wiper operational information (high-speed, low-speed, intermittent)** will be acquired as from OEM as **statistic information (number of operated vehicles) per 100-m link section by five minutes** (the same type as the one used for the demonstration experiment of the lane-level road traffic information) in off-line form.
  - Since **the water film formation is attributable to the precipitation amount** in general, it will be validated assuming that the water film thickness can be estimated from **the relationship between the development of the vehicle control such as ABS or the windshield wiper operational information and the precipitation amount** for each section.

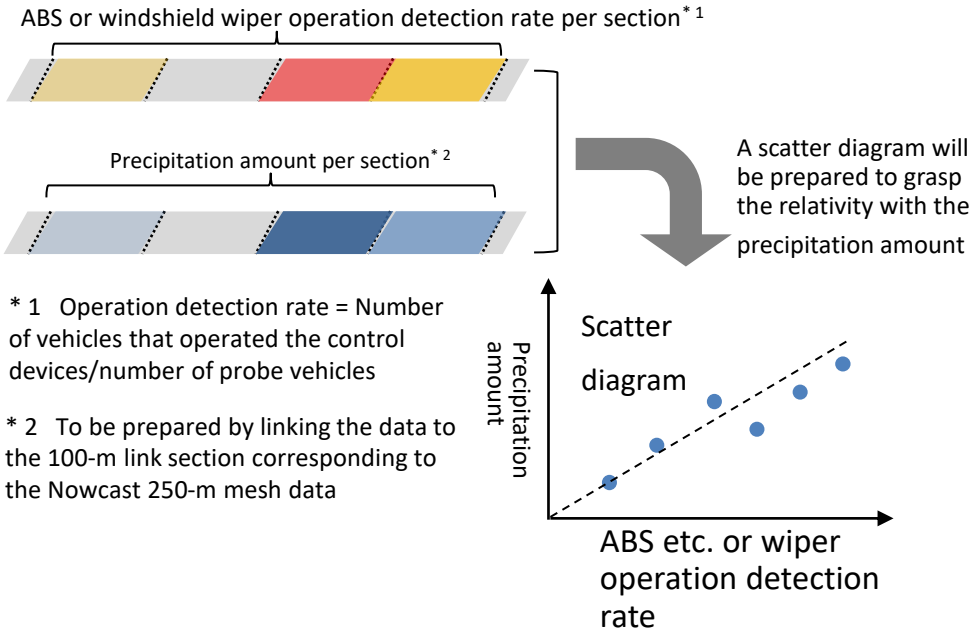
<Image of data aggregation by 100-m link section>

●From OEM, the number of probe vehicles that passed such 100-m link section during such 5 minutes and the number of vehicles that operated ABS or the like in the section will be collected as statistical information



<Image of the analysis of the water film formation estimability>

Collate the data acquired for each 100-m link section in the same time zone



* 1 Operation detection rate = Number of vehicles that operated the control devices/number of probe vehicles

* 2 To be prepared by linking the data to the 100-m link section corresponding to the Nowcast 250-m mesh data

5.1. Study on elemental technologies

Target 2: concept of the method to estimate the road surface grip level and the water film thickness level

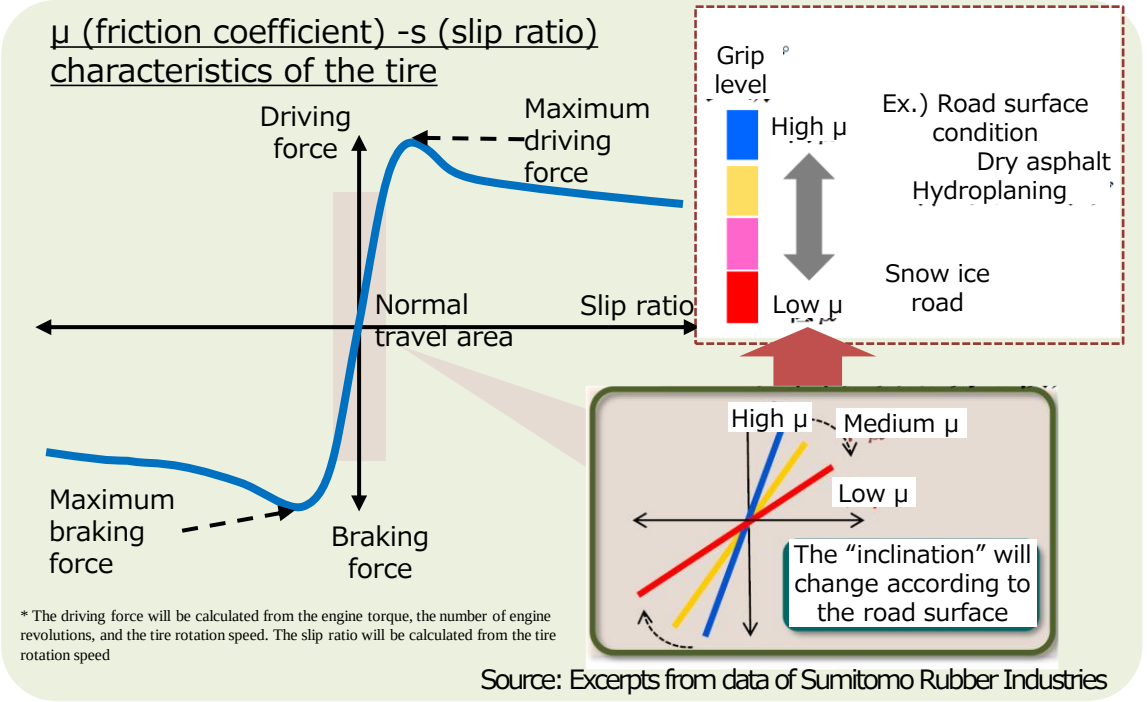
[Road surface grip level]

- **The relationship (inclination) between the slip rate and the driving force, etc. depends on** the slipperiness of the road surface. This inclination will be derived from **the tire rotation signals** (engine torque, number of engine revolutions, tire rotation speed, etc.) to detect the road surface slipperiness (**road surface grip level⇒4 levels**) (the technology will be developed in advance by tire manufacturers)

[Water film thickness level]

- A method will be studied to **estimate the water film thickness from the changes in travel resistance during traveling on water-filmed roads** based on the vehicle driving force information during traveling
- **After the validation on the test tracks (up to 10mm of water film thickness)**, the water film thickness will be estimated by **driving test vehicles mounted with a device** capable of acquiring necessary data such as driving force and travel resistance **on actual roads in wet weather**.

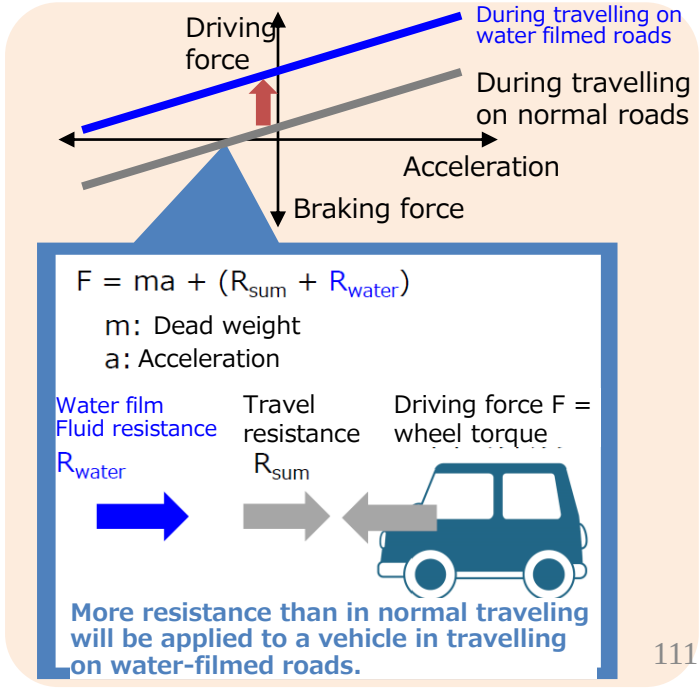
Concept of road surface grip level detection



* The driving force will be calculated from the engine torque, the number of engine revolutions, and the tire rotation speed. The slip ratio will be calculated from the tire rotation speed

Source: Excerpts from data of Sumitomo Rubber Industries

Concept of water film thickness detection



5.2. Collection and evaluation of vehicle probe data

Target 1: Collection of vehicle control information (August to November 2022)

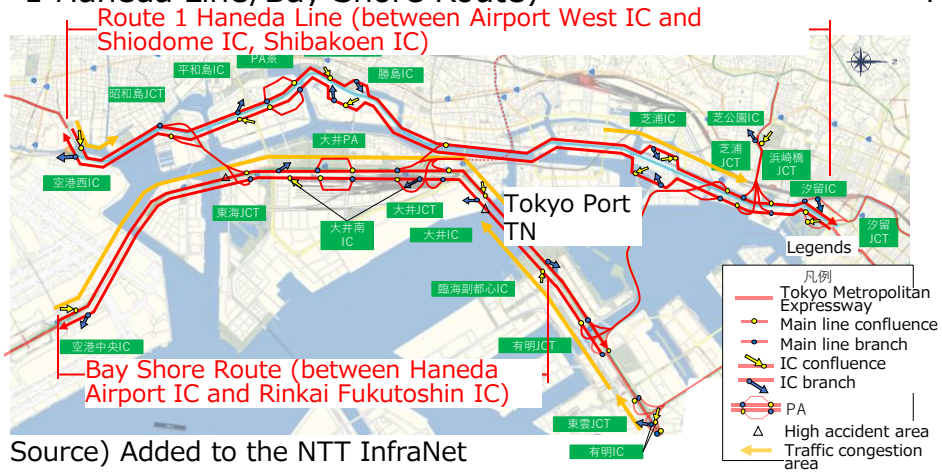
- **Area**: Route 1, Haneda Line/Bay Shore Route, Metropolitan Expressway (same as in the demonstration experiment of the lane-level road traffic information)

Target 2: Acquisition of the tire rotation signals and travel resistance information (August to September 2022)

- **Area**: Same as in Target 1 + general roads (Route 357 between Shinkiba and Funabashi)

Probe data acquisition area

[Target 1・2] Metropolitan Expressway section (Route 1 Haneda Line/Bay Shore Route)



Source) Added to the NTT InfraNet

[Target 2] Route 357 section (between Shinkiba and Funabashi)

Target 2: number of days taken for the acquisition of the traveling data (water film thickness measurement on actual roads)

Travel area \ Rainfall category	Slight rainfall	Rainfall (5 mm or more /12 h daytime)	Considerable rainfall (25 mm or more /12 h daytime)	Total number of days traveled
Haneda Line /Bay Shore Route	3 days	2 days	2 days	4 days
Route 357	8 days	4 days	1 day	8 days

Test vehicle and instrumentation device used for the measurement of the water

Source: Add to the footage taken by the contractor(vehicle and instrument provided by: Sumitomo Rubber Industries)

5.2. Collection and evaluation of vehicle probe data

The correlation analysis with the precipitation amount on the actual roads will use the "high-resolution precipitation nowcasts"

High-resolution precipitation nowcasts

- Weather information provided by the **Japan Meteorological Business Support Center**
- Detailed and high-precision radar image and precipitation amount forecast will be provided
- The service aims to **strengthen the monitoring/forecasting capability of local heavy rain**
- Two types of weather information (1) **high-resolution precipitation nowcasts** (represents instantaneous precipitation intensity) and (2) **high-resolution precipitation nowcasts (5-minute precipitation amount)**
- The weather will be forecasted in the details of **250 square meters** (1 square km up to 30 minutes forward and 1 square km up to 35 minutes to 60 minutes forward for the weather on the sea) and will be updated **every five minutes**
- The weather will be forecasted using the meteorological phenomenon doppler radar data from 20 stations all over Japan; observational data from approximately 10,000 rain gauges possessed by the Japan Meteorological Agency, Ministry of Land, Infrastructure, Transport and Tourism, and local authorities; high-story observational data from wind profilers and radiosondes; and the radar rain gauges of the Ministry of Land, Infrastructure, Transport and Tourism

Data name	**High-resolution precipitation nowcasts** * Instantaneous precipitation intensity	**High-resolution precipitation nowcasts (5-minute precipitation amount)** * 5-minute integrated precipitation amount
Definition	It represents the rainfall in millimeters when it continues to rain for 1 hour at the present precipitation intensity (instantaneous rainfall intensity). (Unit: mm/h)	It represents the precipitation amount in millimeters for five minutes. (Unit: mm)
Mesh spacing	Up to 30 minutes forward: 250 m × 250 m, 35 minutes to 60 minutes forward: 1 km × 1 km	
Update interval	Every 5 minutes (the present condition and the predictive value up to 30 minutes later will be delivered every five minutes)	
Applicability	Suitable to know the rain intensity felt by the skin	Suitable to know the actual precipitation amount.
Major applications	Continuous use	Used as precipitation amount
Summary of characteristics	To be used as **detailed forecast**	To be used as **detailed records**

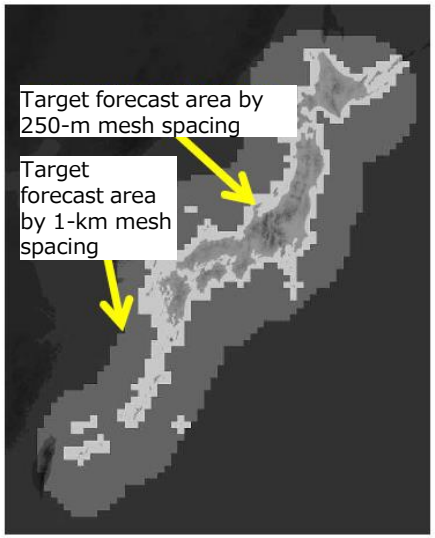


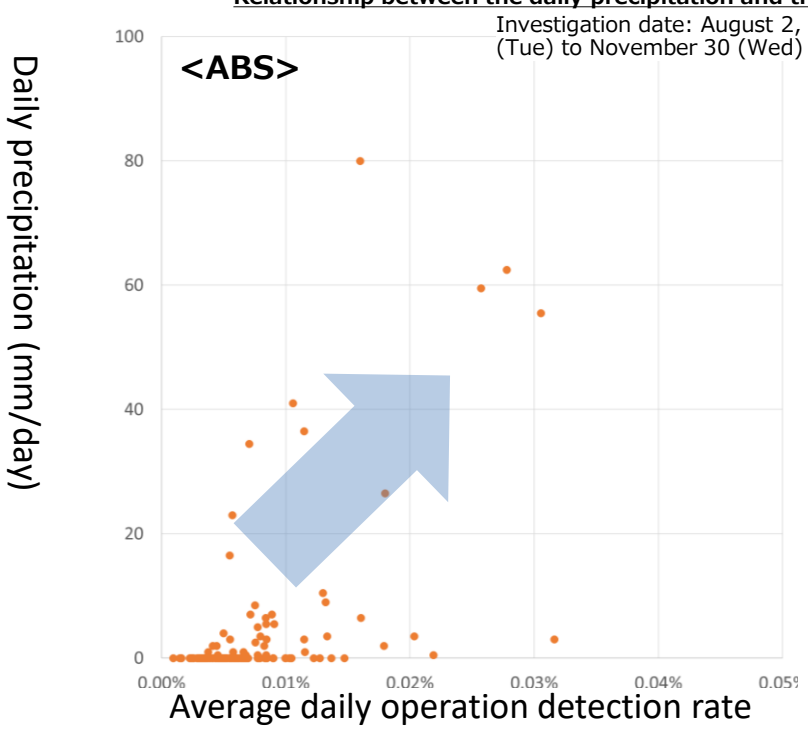
Image Source: Japan Meteorological Business Support Center http://www.jmbsc.or.jp/jp/index.html/

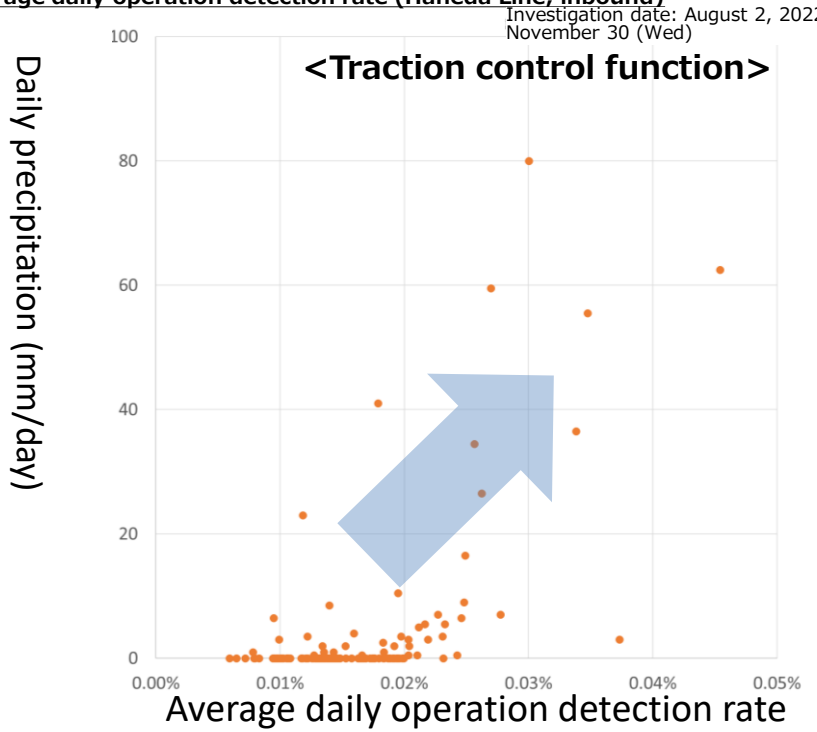
5.2. Collection and evaluation of vehicle probe data

Target 1: Demonstration experiment result using OEM probe data (ABS etc.)

- **The operation detection rate of ABS or other control devices tends to increase with the increase of the precipitation amount**
  - Since the **water film formation is attributable to the precipitation amount** in general, **the operation detection rate of ABS or other control devices is considered to be related to the road surface water film formation.**
  - However, the **operation detection rate of ABS or other control devices was small** for the present data and the effects need to be observed at a shorter data acquisition cycle in future
  - Since the **probe data specifications from which the data of ABS or other control devices may differ among OEMs**, the specifications need to be checked for other OEMs in future

Relationship between the daily precipitation and the average daily operation detection rate (Haneda Line, inbound)





* Aggregation target period: August 2, 2022 to November 30, 2022

5.2. Collection and evaluation of vehicle probe data

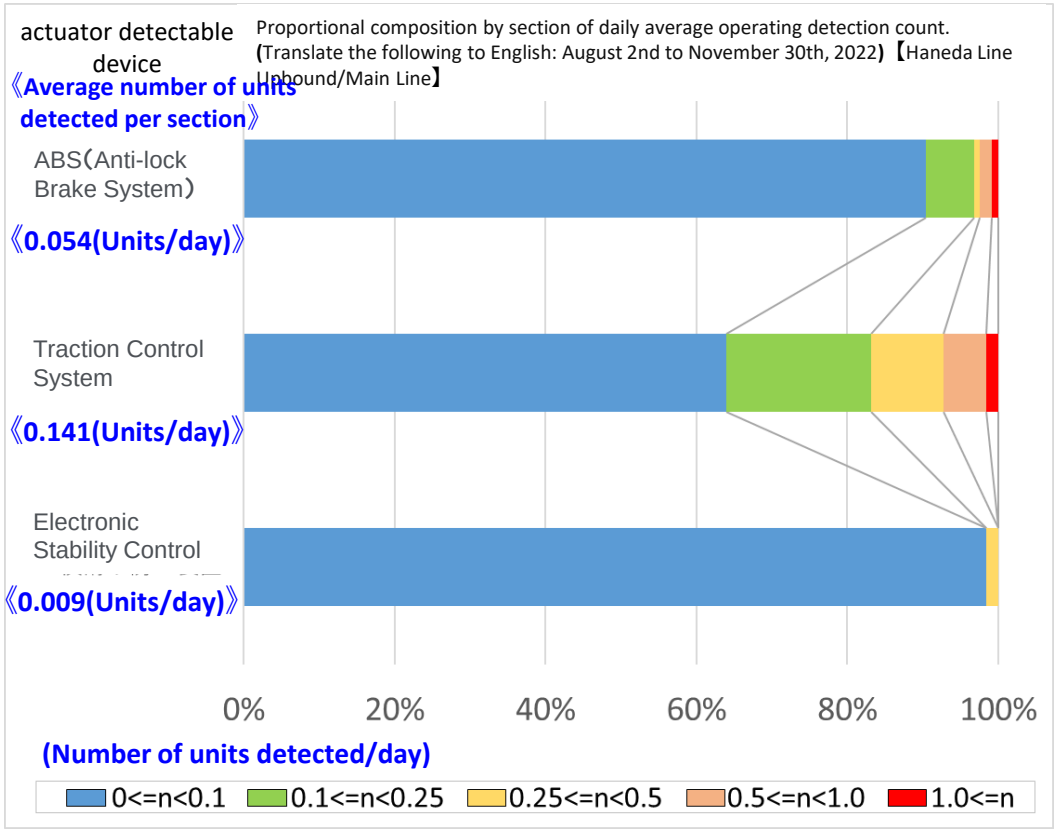
Target 1: Demonstration experiment result using OEM probe data (windshield wiper)

- Number of activated ABS and other devices detected on the Haneda Line (uplink) from probe vehicles, organized by 100-meter link.

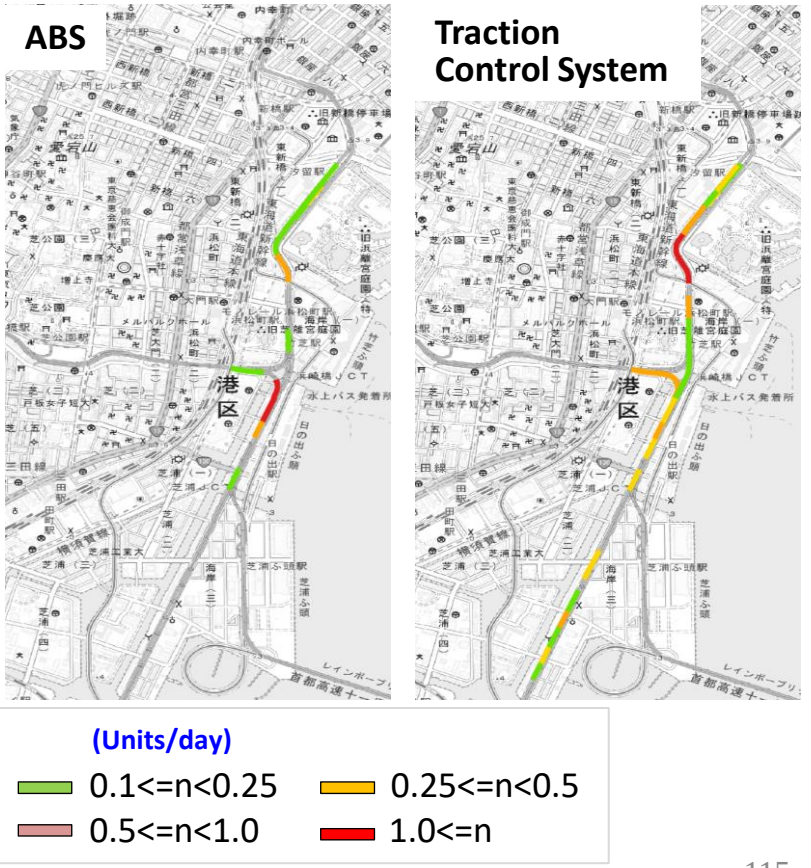
⇒The percentage of sections where the number of activated vehicles detected is less than 0.1 vehicles/day accounts for about 90% in ABS.

⇒The detection tends to occur at curves and the sections before and after curves, at mergers, and at JCTs.

【Composition of sections by daily average number of activated vehicles detected: Haneda Line up】



【Daily average number of detected activations by section: Haneda Line up】



Date of survey：2022/8/2（Tue）～2022/11/30/（wed）

Source: Created by processing Geospatial Information Authority of Japan tiles

5.2. Collection and evaluation of vehicle probe data

Target 1: Demonstration experiment result using OEM probe data (windshield wiper)

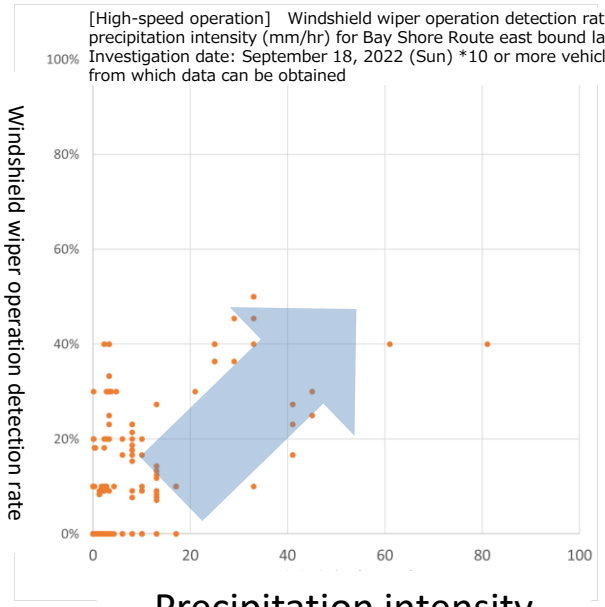
- The relationship between the **windshield wiper operation detection rate** for all the 100-m links on the east bound lanes of the Bay Shore Route and the **precipitation intensity every five minutes at the Nowcast 250-m mesh corresponding to the above links was organized in a scatter diagram** using the same data as in the previous page.
  - ➢ **A certain correlation** is observed between the ratio of vehicles **operating the windshield wiper at a high speed and the precipitation intensity**.

Relationship between the windshield wiper operation detection rate and the 5-minute precipitation intensity (mm/hr) (scatter diagram)

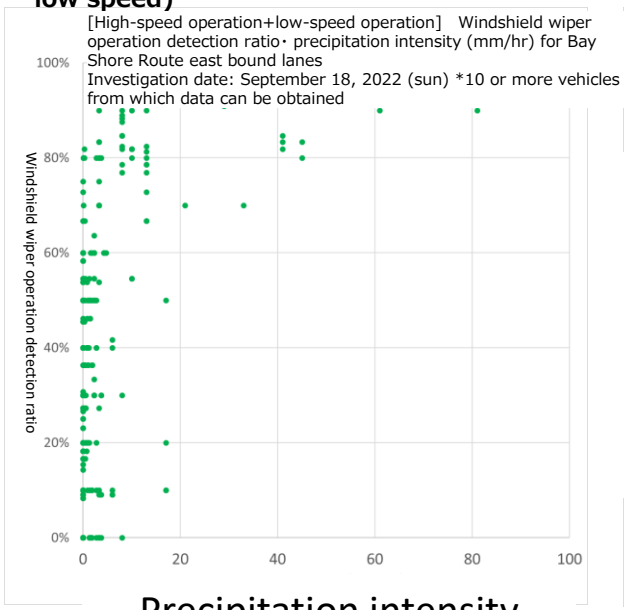
○ Bay Shore Route east bound lanes: September 18, 2022 (Sun)

* Only the 100-m links with the number of probes of 10 pcs/5 minutes or more from which windshield wiper information can be obtained were plotted

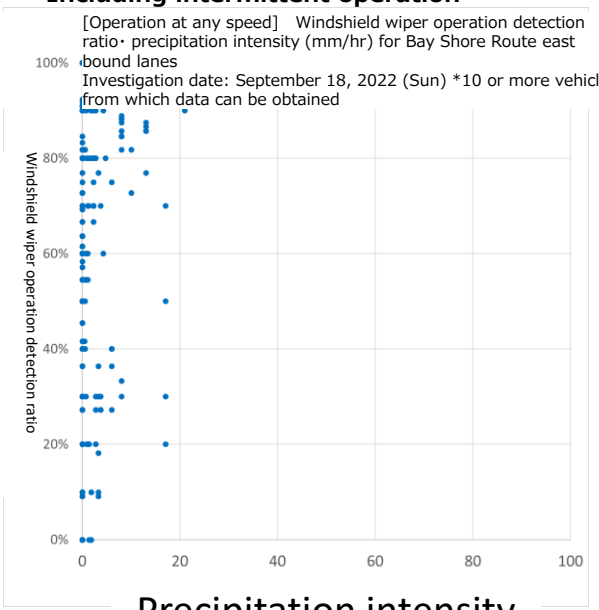
(Windshield wiper operated at a high speed)



(Windshield wiper operated at a high speed + low speed)



(Windshield wiper operated at any speed) * Including intermittent operation



5.2. Collection and evaluation of vehicle probe data

Summary of evaluation results (Target 1)

<Discussions on the possibility of commercialization>

① It was observed that the **operation frequency of the probe data associated with the vehicle control (ABS, etc.) will increase on days with high precipitation amount**. Since the **water film formation is attributed to the precipitation amount**, the **operation detection rate of ABS or other control devices is considered to relate to the water film formation on the road surface**.

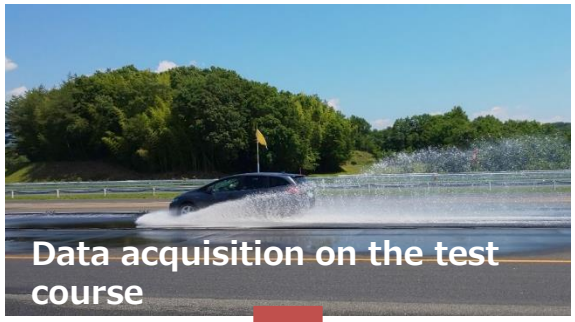
② In the meantime, the **operation detection rate of ABS or other control devices was small** for the present data and the effects need to be observed at a shorter data acquisition cycle in future

③ For the constraints of the business period and scale, **no validation has been conducted during the snowfall or freezing season**. In addition, the **validation has been conducted for vehicle probe data of only one OEM**. Accordingly, **data specifications or accuracy validation including the threshold value of ABS or other control devices have not been conducted** yet. These need to be verified and validated in future.

5.2. Collection and evaluation of vehicle probe data

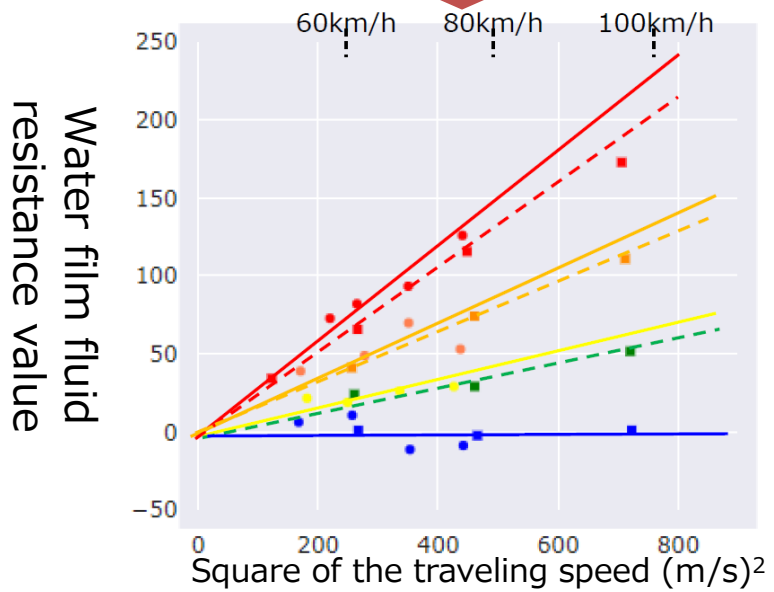
Target 2: Study results on the water film thickness level detection method (preparation of a calibration curve)

- Because the "water film thickness" is linearly related to the square of the **"resistance value of the water film / traveling speed (hereinafter referred to a new indicator),"** we assumed that it can be obtained from the "resistant value of the water film" and the "traveling speed" (based on the knowledge of tire manufacturers)
  - We found from the measurement results on the test course (up to 10 mm of water film thickness) that **a linear approximate equation (calibration curve) can be prepared**
  - Theoretically, **flooding (such as 20 cm of water film thickness) may be detected (future validation is needed)**

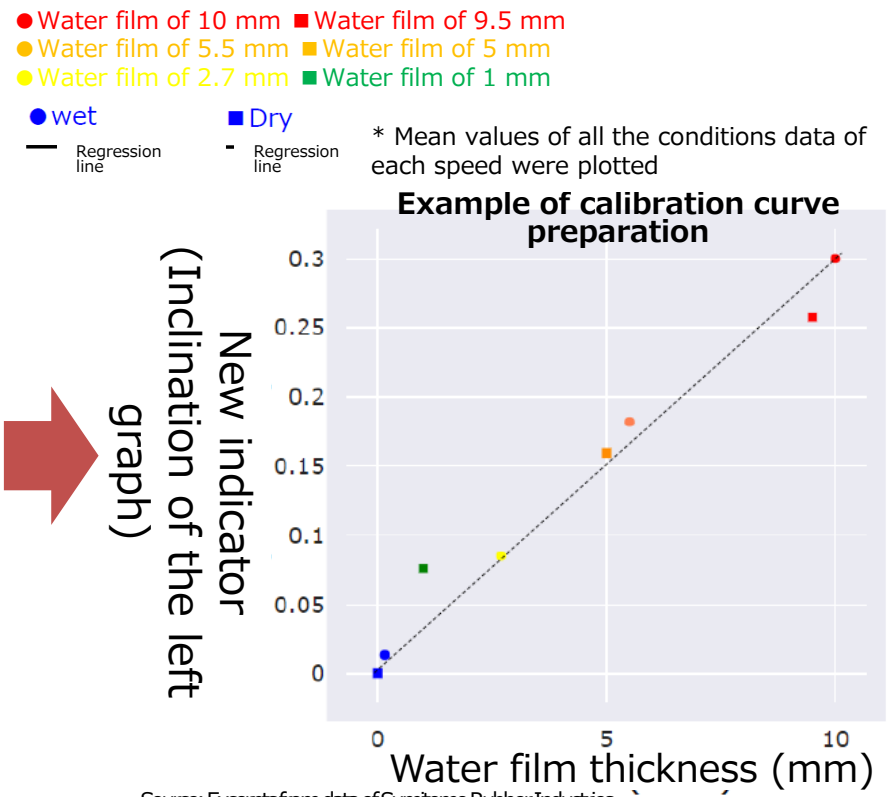


Source: Photographed by Contractor

Course of action to prepare a calibration curve for estimation of water film thickness



Source: Excerpts from data of Sumitomo Rubber Industries



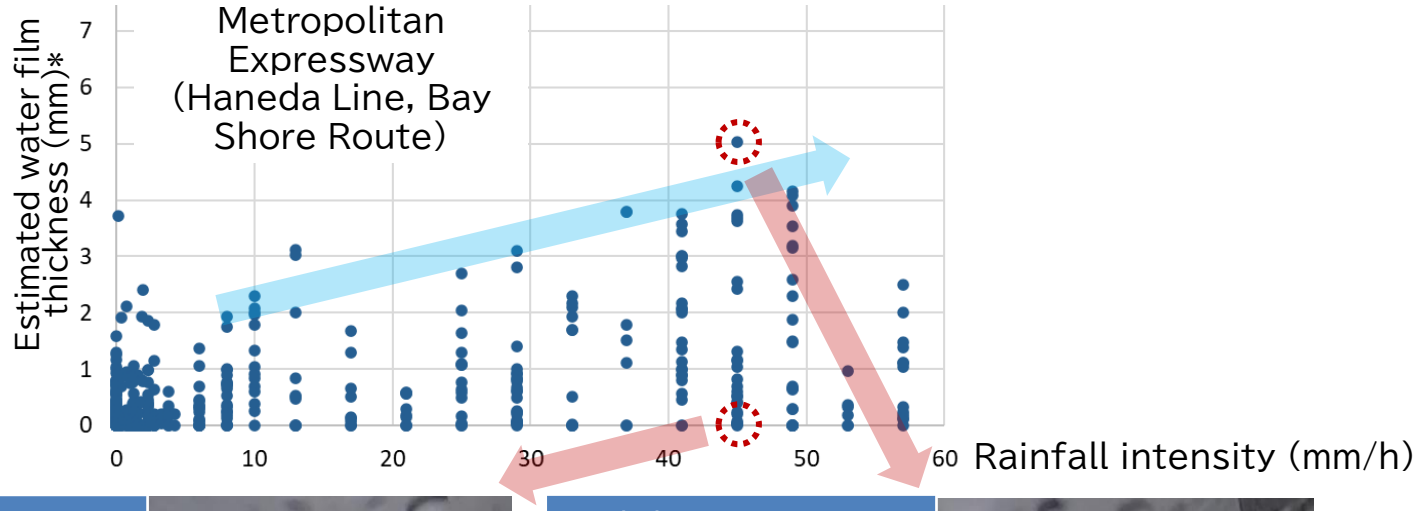
Source: Excerpts from data of Sumitomo Rubber Industries

5.2. Collection and evaluation of vehicle probe data

Target 2: Results of the water film thickness level detection trial on actual roads

- **Sections with a higher estimated water film thickness appeared at higher rainfall intensity**
- We observed sections with the same rainfall intensity and different estimated water film thickness in the travelling video and found difference of the water film thickness condition from the water splash conditions of surrounding vehicles. ⇒ It shows that the **water film thickness levels have been correctly detected.**

Relationship between the rainfall intensity and the estimated water film thickness and the actual condition

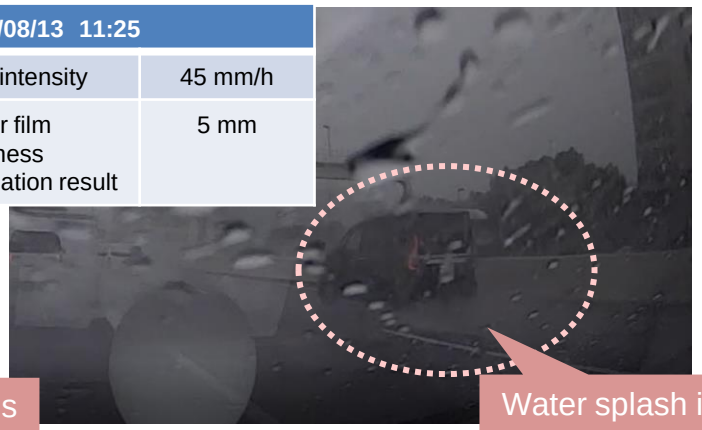


* 5-minute mean value for 100-m section

■ The water splash condition from surrounding vehicles varies when the water film thickness is different even at the same rainfall intensity

2022/08/13 11:12	
Rain intensity	45 mm/h
Water film thickness estimation result	0.1 mm

2022/08/13 11:25	
Rain intensity	45 mm/h
Water film thickness estimation result	5 mm



Source: Photographed by Contractor

5.2. Collection and evaluation of vehicle probe data

Target 2: Issues and possibility of water film thickness level detection based on the trial result

- As one issue of the water film thickness estimation based on the calibration curve, **1 mm to 2 mm of water film thickness may be estimated even on a dry road surface and the error may become significant when the vehicle travels at a slow speed (40 km/h or slower)**
  - In light of the above findings, the **estimation of water film thickness levels may be possible for larger categories (e.g. three levels)**.

Issues in the estimation of the water film thickness

- There are conditions where the water film thickness cannot be estimated (when the vehicle is turning, braking, changing gears, accelerating rapidly)
- Even on dry road surface, the water film thickness may be estimated at 1 mm to 2 mm due to estimation error.
- The estimation error is significant at a slow speed (40 km/h or slower) and a significantly large water film thickness may be estimated even on a dry road surface.

Detection conditions and detectability

[Conditions] Constant traveling at a speed of 40 km/h or more

[Detectability] The water film thickness level can be estimated according to the following categories (in the case of 3 levels*)

① The road may not have been covered with water film (the water film thickness will be estimated to be 0 mm to 4 mm)

② The road may have been covered with a thin water film (the water film thickness will be estimated to be 5 mm to 9 mm)

③ The road may have been covered with considerable water film (the water film thickness will be estimated to be 10 mm or larger)

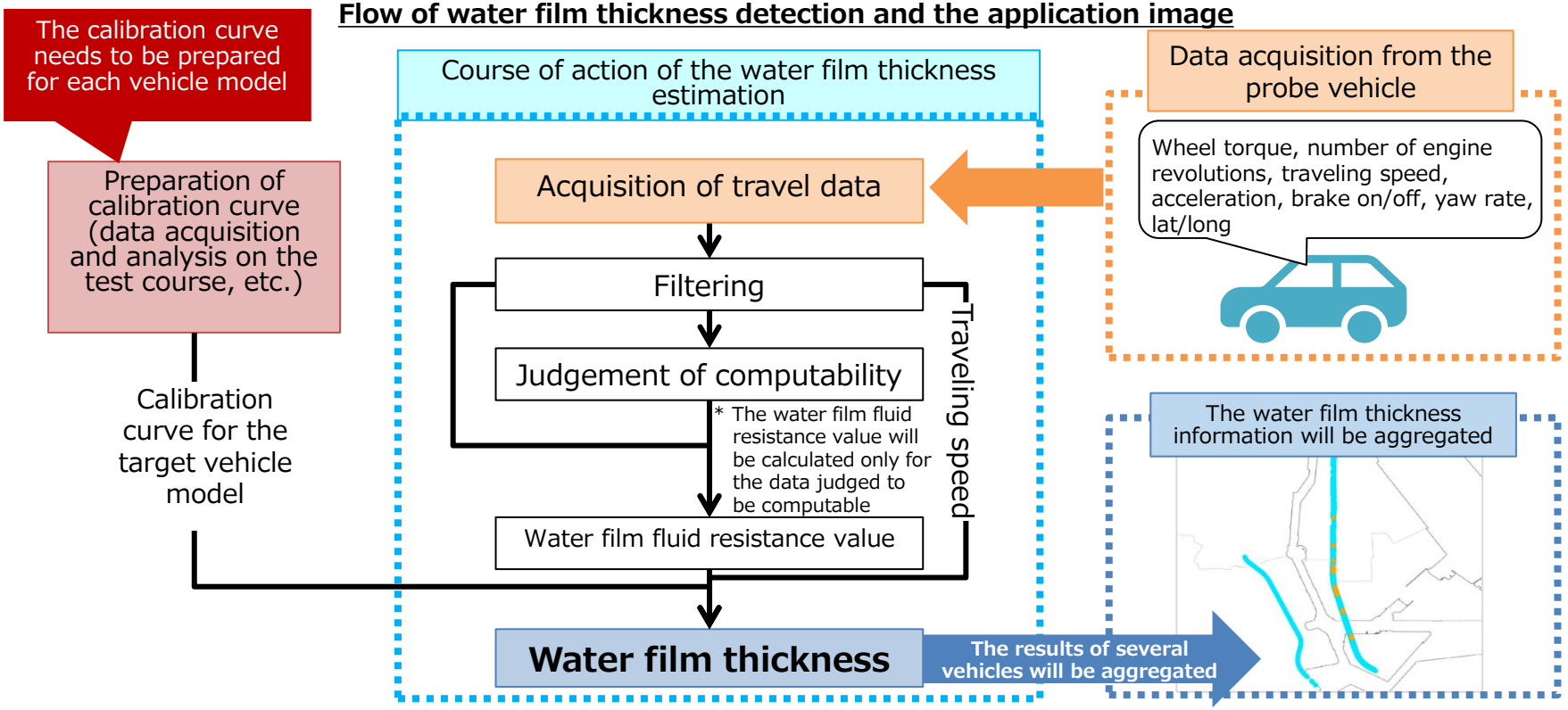
* The number of levels and the threshold values need to be validated in future

5.2. Collection and evaluation of vehicle probe data

Target 2: Future issues toward the practical creation of the water film thickness level information

- While the calibration curve needs to be prepared for each vehicle model at present, **prior preparation of the calibration curve will enable the water film thickness level information only from the data obtainable from the vehicle.**
  - **The load of passengers, the inner tire pressure, and the remaining tire groove** (as long as the drainage performance is secured) **have little impact** on the estimation.
  - However, **the calibration curve may vary according to the vehicle model and the tire type** (difference between the summer tire and the studless tire).
  - In order to generalize the calibration curve, **the factors for the difference of the calibration curve need to be identified and the countermeasures** need to be studied in future.

Flow of water film thickness detection and the application image



5.2. Collection and evaluation of vehicle probe data

Summary of evaluation results (Target 2)

<Discussions on the possibility of practical use>

① As for **the water film thickness level**, it has been confirmed by the validation on the test tracks that **the calibration curve can be prepared based on the travel resistance value detection technology** of tire manufacturers, and **the water film thickness can be measured**. **The calibration curve may be also able to detect flooding by further application**.

② At the **measurement on actual roads (during wet weather)**, it has been visually checked that the **water film thickness level can be detected correctly**.

③ However, the demonstration experiment results show that **the measurement error is significant at a low speed, and water film thickness of several millimeters may be detected even when the road surface is dry**. Accordingly, **it may be realistic to estimate the water film thickness level in large categories**.

④ On the other hand, there is a possibility that **the calibration curve may vary among vehicle types and tire types**. Accordingly, **the factors for the difference of the calibration curve need to be identified and the countermeasures need to be studied** in future.

5.3. Study on the method to use for autonomous cruising road maintenance

- The road surface grip level and the water film thickness level estimated from the vehicle probe data enables **road surface freezing/snow cover**, **water film development**, and **flooding** events to be grasped and provided to road management, drivers, and automated cars.
- **A hearing survey** was conducted based on the validation results on the applicability of the vehicle probe data with the **road administrators** (expressway companies and national highway offices).
- We **extracted 10 expected use cases** from the hearing survey results.

Use cases extracted concerning the grasping of road surface conditions

Road surface condition	Grasping of freezing and snow cover	Grasping of water film development	Grasping of flooding areas
Expected use case	(1) Support for judgement of road closing (2) Provision of slipperiness information to drivers*1 (3) Monitoring of effect duration of antifreezing agents (4) Use for elaborate spraying of antifreezing agents (5) Judgement of antifreezing pavement sections	(6) Grasping of sections prioritized for measures against pavement deterioration (water splash prevention)	(7) Identification of abnormal flooding areas (8) Real-time detection of flooding (heat map, etc.) (9) Detection of flooding signs (10) Provision of flooding information to drivers*1

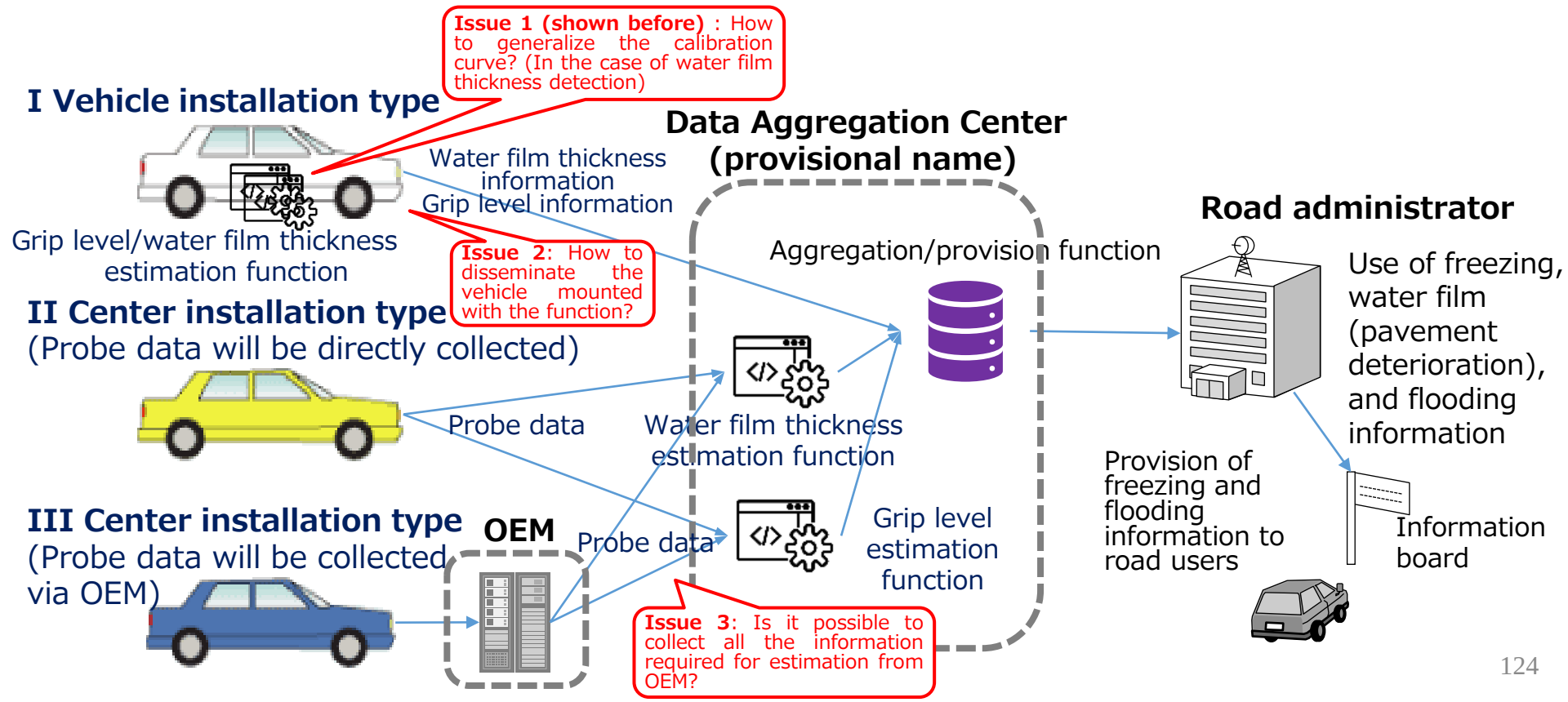
*1: The use cases for drivers may be applicable to automatic driving and driving support.

5.3. Study on the method to use for autonomous cruising road maintenance

Concept and issues of function allocation expected in practical use

- When collecting and using the grip level and the water film thickness information examined this time, **three cases** are considered. **The first case is to mount the information creation function on the vehicle, the second case is to collect the necessary probe data directly from the vehicle or via OEM, and the third case is for the center to create information.**
- An issue in the case of mounting the function on the vehicle is **how to disseminate it.** Regarding the method of mounting the function on the center, **whether the necessary probe data can be collected** is an issue, and if not, the countermeasures against the unavailability needs to be studied in future.

Concept and issues of function allocation expected in practical use



This report presents the results of the Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase 2: Automated Driving (Expansion of Systems and Services) (NEDO management number: JPNP18012), which was carried out by the Cabinet Office and for which the New Energy and Industrial Technology Development Organization (NEDO) served as the secretariat.