戦略的イノベーション創造プログラム

Cross-ministerial Strategic Innovation Promotion Program (SIP) Phase 2
- Automated Driving for Universal Services/
Operations of Planning and Deliberation Council for the Creation of Systems for Generating and Providing Lane-level Road Traffic Information Using Probe Information

FY2019 to 2022 Results Report

Overview

Mitsubishi Research Institute, Inc.

March, 2023

Background and Objectives

Background

Lane-level road traffic information holds promise for use in predicting upcoming conditions which cannot be recognized by vehicle sensors. This can assist with automated driving and safe driving assistance. Roadside sensors can only perform fixed-point measurement, so there is a pressing need to consider systems for generating and providing lane-level road traffic information using vehicle probe information, which can assess traffic conditions over entire areas.

In order to tackle these issues, during SIP Phase 2, in 2019, technology specifications for FOTs related to lane-level road traffic information were created. From 2020 to 2022, FOTs were conducted in which information from private-sector vehicle probes from motor vehicle and navigation system manufacturers was processed and supplied as lane-level road traffic information. Furthermore, the technology specifications are being reviewed and revised based on the issues and necessary improvements discovered through these FOTs, with the aim of establishing specifications for the provision of lane-level road traffic information.

Objectives

In this study, we investigated the current state of vehicle probe information through deliberation council meetings of public and private sector stakeholders. The aim of the study is the creation of a system for generating and providing lane-level road traffic information using vehicle probe information to contribute to automated driving and safe driving assistance. We also deliberated regarding the direction to be taken in the future.

Study Items

This study was performed over the course of four years, 2019 to 2012, and consisted of the following four study items.

Table. Study items

Item	Overview
1. Interview study	We conducted interviews with motor vehicle manufacturers and navigation system manufacturers that handle vehicle probe information. We confirmed the current state of affairs and the vehicle probe information that could be collected in the future. (1) Method of collecting data from vehicles (2) Statistical processing technologies (3) Method of providing generated road traffic information (4) Data usage conditions, licensing, and privacy protection
2. Deliberation regarding future direction	Through discussions with related government agencies (Cabinet Office; National Police Agency; Ministry of Land, Infrastructure, Transport and Tourism, etc.) and major related organizations (Japan Automobile Manufacturers Association, Japan Road Traffic Information Center, Vehicle Information and Communication System Center), we deliberated on the future direction of systems for generating and providing lane-level road traffic information. (1) Method of use and future vision of lane-level road traffic information (2) Deliberation regarding the generation and provision of lane-level road traffic information created using probe information (3) Confirmation of the benefits of and issues involved in lane-level road traffic information (4) Deliberation of system for practical application
3. Holding of deliberation council meetings	Meetings of the deliberation council, which was composed of related government agencies and major related organizations, were held with the aim of deliberating implementation plans for lane-level road traffic information FOTs, evaluation methods, and the issues involved in the use of this information, based on the results of the tests *When the term "deliberation council meetings" is used in the text of this report or in the description of sources, etc., without any special note, it refers to this deliberation council meetings.
4. Deliberation regarding the provision of merging support information	We have investigated the Day 2 system, a service that provides merging support information being deliberated by NILIM, with the aim of improving lane-specific traffic flow information. • Administration of meetings • Study of merging area road alignment • Creation of vehicle trajectory data for the area upstream from the East Ikebukuro Entrance • Simulation results and recommendations for further analysis and future project developments

Item 1. Interview Study

Interview Study

We conducted interviews with motor vehicle manufacturers, navigation system manufacturers, etc., regarding the domestic and overseas measures related to the collection of vehicle probe information and the use of this information in automated driving. **Our objective was to assess current conditions and gather basic information for use in deliberations regarding future direction,** with the ultimate aim of generating and providing lane-level road traffic information based on information from private-sector probes.

Table. Interview items

Item	Interview item
(1) Hopes for lane-level road traffic information. Possibility of collaboration in FOTs.	• Needs and expectations for lane-level road traffic information • Content of possible collaboration in FOTs
(2) Method of collecting data from vehicles	• Content of data collected and gathered from vehicles • Frequency and conditions applying to the collection of data from vehicles by OEM centers (uplink) • Positioning accuracy • Transmission method
(3) Statistical processing technologies	• Contents of information generated through statistical processing • Processing contents and processing frequency • Existence of technologies for generating lane-level road traffic information
(4) Method of providing generated road traffic information	• Method for providing information generated at OEM centers to vehicles (transmission method, provision frequency) • Data items
(5) Data usage conditions, licensing, and privacy protection	• Data usage conditions and terms (data usage purposes, restrictions regarding whom data can be provided to, rights, etc.) • Privacy protection (technical measures and systems for anonymizing data, etc.) • Provision cost

Interview Study Results

- We conducted interviews with four companies collecting and using probe information: three motor vehicle manufacturers and one navigation system manufacturer.
- We asked each company about their expectations for lane-level road traffic information. We confirmed that the information currently being collected from commercially sold vehicles, which could be provided for use in FOTs, is carriageway-level (not lane-level), statistically processed information.

■ Needs and expectations for lane-level road traffic information
- Respondents had high hopes for the use of information in reliable automated driving control and improved route guidance accuracy (one step before automated driving).

■ Possibility of collaboration in FOTs
- The information currently being collected from commercially sold vehicles, which could be provided for use in FOTs, is, as a rule, carriageway-level information.
- From the perspective of protecting personal information as specified in agreements between service users and individual companies, the data that could be used would be statistically processed data*.

  * Statistically processed data: Anonymized data such as (1) link-specific average travel time, (2) the number of probe vehicles used to generate the data in (1), (3) the number of vehicles in each speed range, etc.
- Map matching processing is performed by each company using propriety maps. To integrate data, it will be necessary to make advance arrangements regarding which map to use as the base map.

Issues to be considered based on the actual state of probe information collection, processing, and use by individual OEMs and other companies

Technologies for processing and integrating probe information in order to generate lane-specific information

Methods of processing probe information necessary for generating lane-specific information

Methods of integrating information collected by multiple OEMs, etc.

Technologies for delivering lane-specific information

Methods for delivering generated lane-specific information

Item 2. Deliberation Regarding Future Direction

Outline of the Deliberation

In cooperation with the entity that conducted the technical study work, we summarized the issues and discussed the direction of the project with regard to the ideal form and functions to be provided in order to realize the generation and provision of lane-level road traffic information using private sector probe information.

1. Method of Use and Future Vision of Lane-level Road Traffic Information

1.1. Need for Lane-level Road Traffic Information (Significance of Initiative)

1.2. Scope of These Initiatives

1.3. Target Use Cases and Benefits of Information Provision

1.4. Future Vision and Investigative Scope of These Initiatives

2. Deliberation Regarding the Generation and Provision of Lane-level Road Traffic Information Created Using Probe Information

2.1. Overview of Information Generation and Provision and Scope of Investigative Subject

2.2. Deliberation of Elemental Technologies

3. Confirmation of the Benefits and Issues of Lane-level Road Traffic Information

3.1. Plans for Technical Verification and Effectiveness Verification

3.2. Verification Results

4. Deliberation of Systems for Practical Application

4.1. Deliberation Steps and Approach to Use to Achieve Practical Application (Draft)

4.2. Summary of Discussion Points Involved in Practical Application

4.3. Overview of Proposals for Systems for Practical Application

4.4. Summary of Existing Road Traffic Information Provision Process

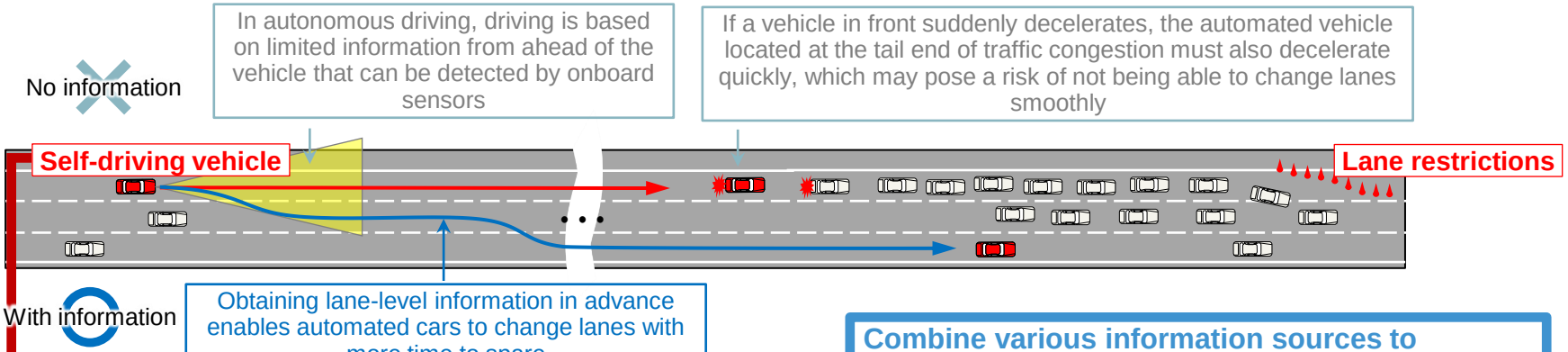
4.5. Lane-specific Road Traffic Information Provision Process (Proposal)

4.6. Overview of Information Delivered via V2N (Proposal)

1. Method of Use and Future Vision of Lane-level Road Traffic Information

1.1. Need for Lane-level Road Traffic Information

- Lane-level road traffic information is necessary for achieving safe and smooth driving, such as by identifying conditions ahead of the vehicle, which cannot be detected by onboard sensors, and changing lanes in advance.
- The use of vehicle probe information that allows for the assessment of traffic conditions over areas is effective for generating lane-level road traffic information and functionality is anticipated to be enhanced by combining with information from road and traffic administrators.



What the vehicle needs to know

- Which lane to drive in
- When to make a lane change

→ **Lane-level road traffic information is necessary** for making the above decisions.

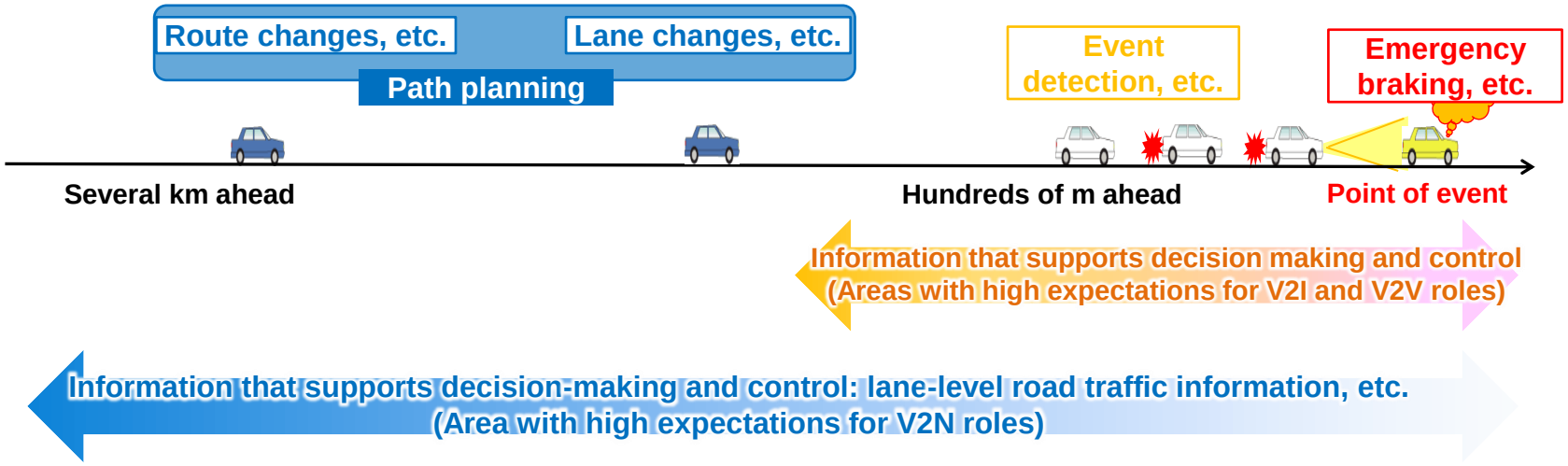
To meet these needs

Combine various information sources to generate information effectively.

- ○ **Vehicle probe information**
  Enables precise assessment of traffic conditions and position over areas.
- ○ **Information from road and traffic authorities**
  Provides an understanding of information such as the causes of incidents that cannot be determined by the vehicle.
- ○ **Other (emergency report information, etc.)**
  Immediate assessment of emergency information.

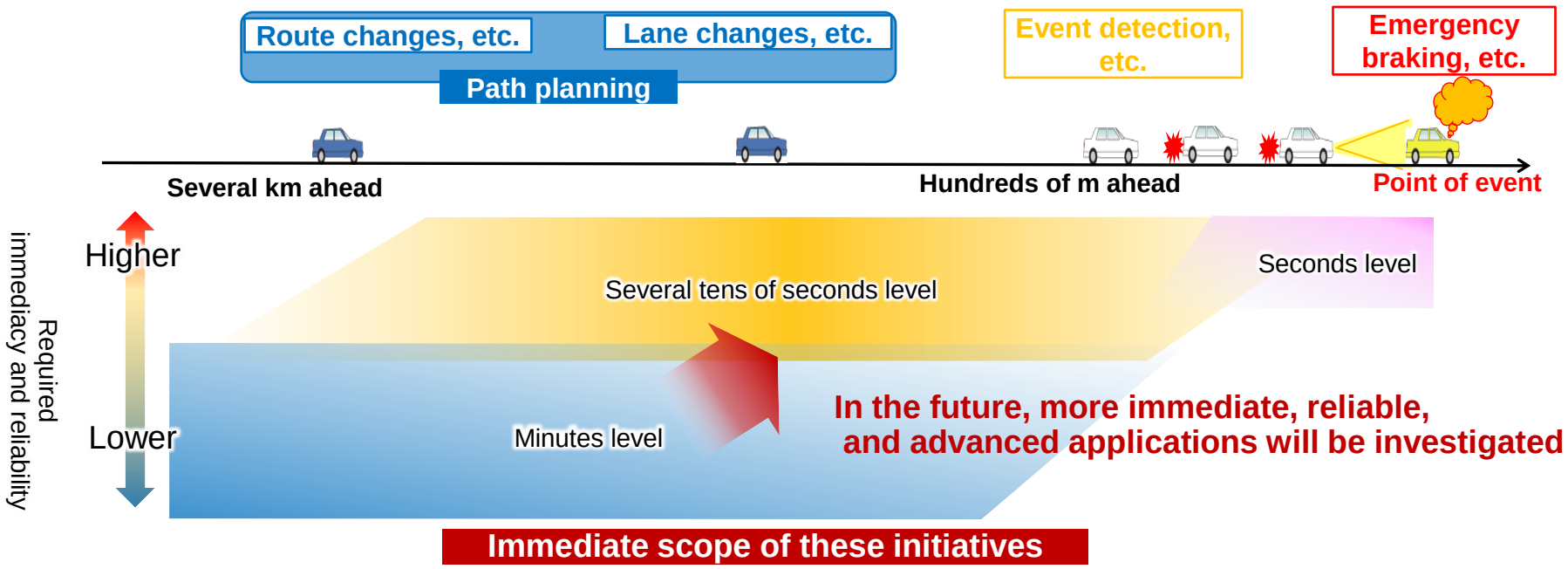
1.2. Scope of These Initiatives

- In order for a self-driving vehicle to make appropriate judgments and provide appropriate control, there are stages of control depending on the distance to where said control will be needed in individual situations. Lane-level information is needed for each stage.
- It is important to combine information obtained using various communication means in a comprehensive manner based on the characteristics of each stage.
- We are investigating the usefulness and usage of lane-level road traffic information that corresponds to the characteristics of various situations. Through these initiatives, we are investigating the use of lane changes in path planning with a focus on lane changing.



1.2. Scope of These Initiatives

- We have started initiatives through which we are investigating technologies for generating and providing information with a level of real-time correspondence equivalent to the timeliness of conventional road traffic information. This is being done using vehicle probe information that has already been put into practical application, with the aim of being able to put these technologies into practical application in the near future.
- In the future, we aim to generate and provide more immediate information.

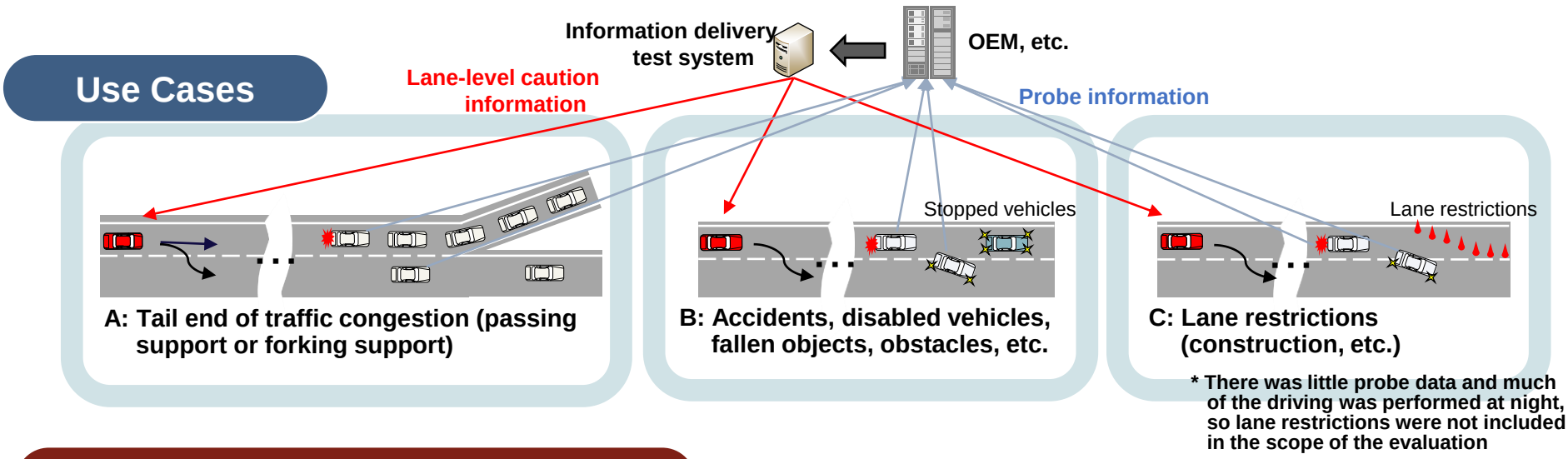


Technical deliberation using vehicle probe information that is already in practical use with the aim of putting technologies into practical application in the near future

1.3. Target Use Cases and Benefits of Information Provision

- In this initiative, we investigated the following three use cases where lane-level information for the area ahead of the vehicle would be effective in controlling lane changes, etc., when performing path planning.

Use Cases



* There was little probe data and much of the driving was performed at night, so lane restrictions were not included in the scope of the evaluation

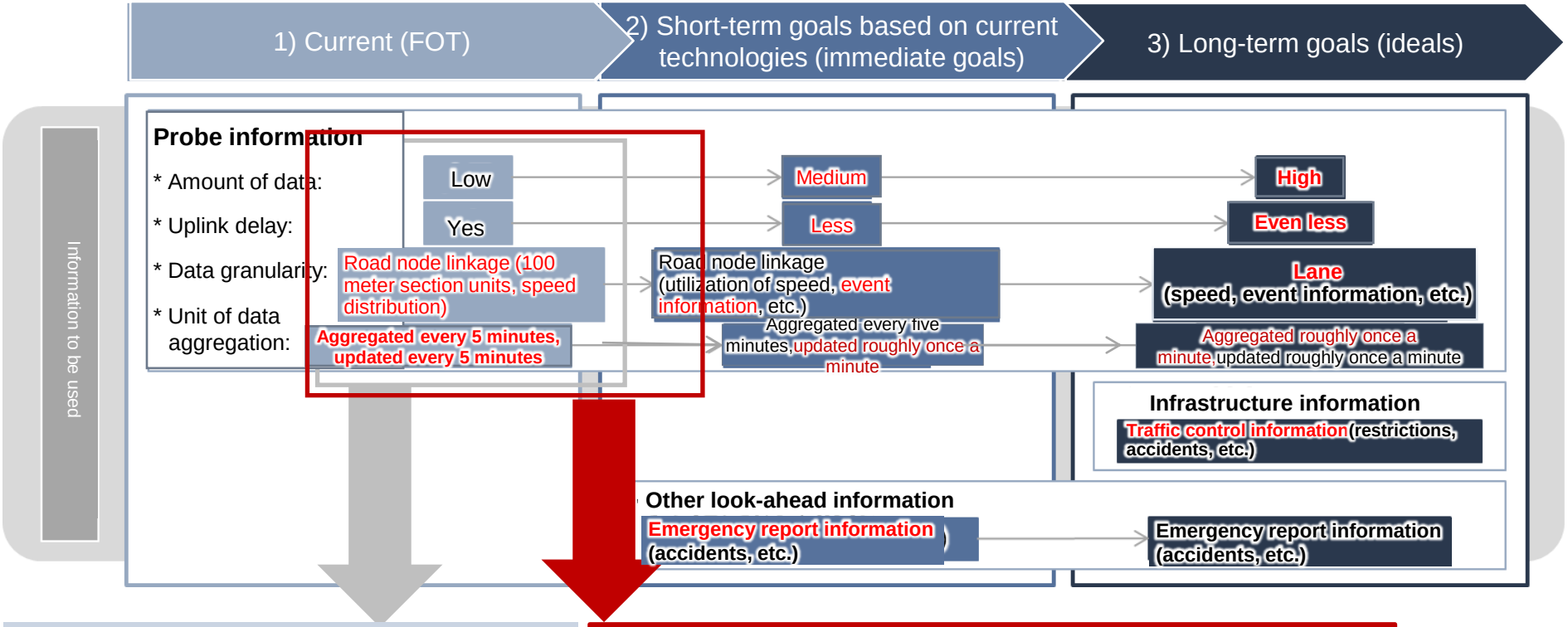
Benefits of Information Provision

- This information has the **potential to improve safety and make driving smoother** by preventing automated vehicles from having to decelerate quickly, etc., preventing rear-end collisions, and enabling lane changes to be performed at leisure when situations such as the indicated use cases occur. These outcomes can be prevented by decelerating and changing lanes, etc., far in advance based on conditions ahead of the vehicle.
- **It is also effective as support information for vehicles performing level 1 or 2 automated driving.**

Source: FY2021 4th deliberation council meeting material (created by Pacific Consultants)

1.4. Future Vision and Investigative Scope of these Initiatives

- The investigation is based on the assumption that in the future, as connected cars become more widespread, the quantity and quality of data will improve, making it possible to provide more accurate information with no uplink delay.



FY2020:

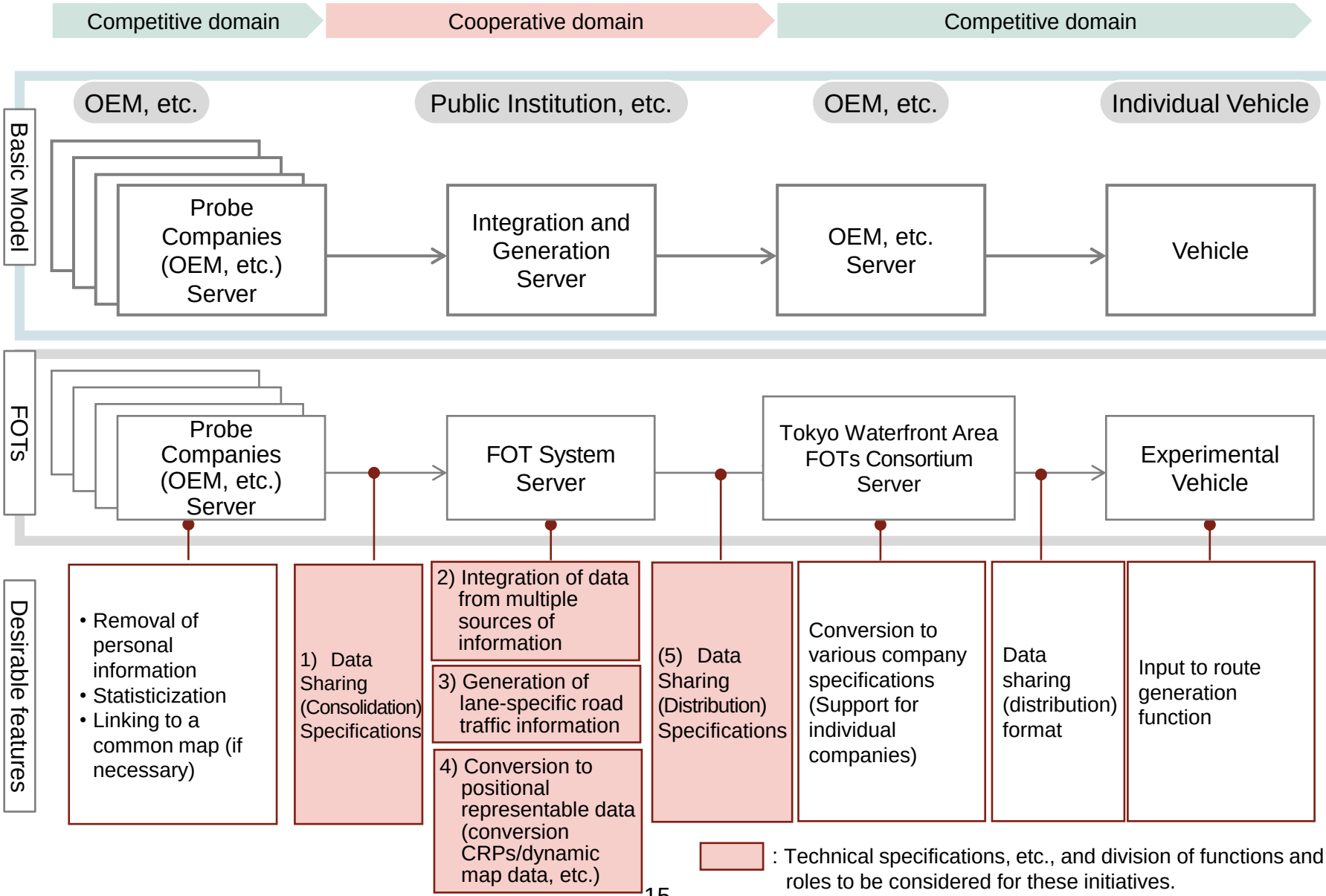
- **Deliberation and collection of acquirable probe information**
- **Deliberation of essential technical specifications and development of testing system**
- **Verification of technologies for generating lane-level information using direction-specific speed information for fork areas**

FY2021: Deliberation and verification of technologies for generating information in areas other than fork areas using vehicle control event information (turn signal information, etc.)

FY2022: Addition of probe information providers, system improvements, and verification of ability to generate information using the amount of data that can currently be acquired and given the current level of information precision, etc.

2. **Deliberation Regarding the Generation and Provision of Lane-level Road Traffic Information Created Using Probe Information**

2.1. Overview of These Initiatives and Scope of Deliberation



2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Purpose

- **Consideration of technical specifications and data formats for each function related to the cooperative domain**
- **Clarification of the roles and functions of each function**

Technical Specifications

1) Specifications for data sharing (aggregation)
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 and generation server

2) Specifications for data integration from multiple sources of information
Specification for integrated processing of data collected from multiple information providers

3) Specifications for generation of lane-specific road traffic information
Technical specifications for generating lane-specific road traffic information from available data.

4) Specifications for conversion to positional representable data
Data format and conversion specifications (conversion to CRP, dynamic map, etc.) that can express (deliver) the generated road traffic information on a per-lane basis. * The deliberation also looked at the need for this function

(5) Specifications for data sharing (distribution)
Data sharing specifications (data items, format, distribution frequency, etc.) between centers when distributing the generated information from the information integration and generation server to the OEM, etc. servers.

Structure

Division of functions and roles
Which of the functions described above can be considered as part of the cooperative domain for future implementation
Consideration of how the system should be set up, such as how responsibilities and roles should be separated

Assumptions and conditions to be considered

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

○ Position expression specifications
- Extended DRM-DB
- CRP

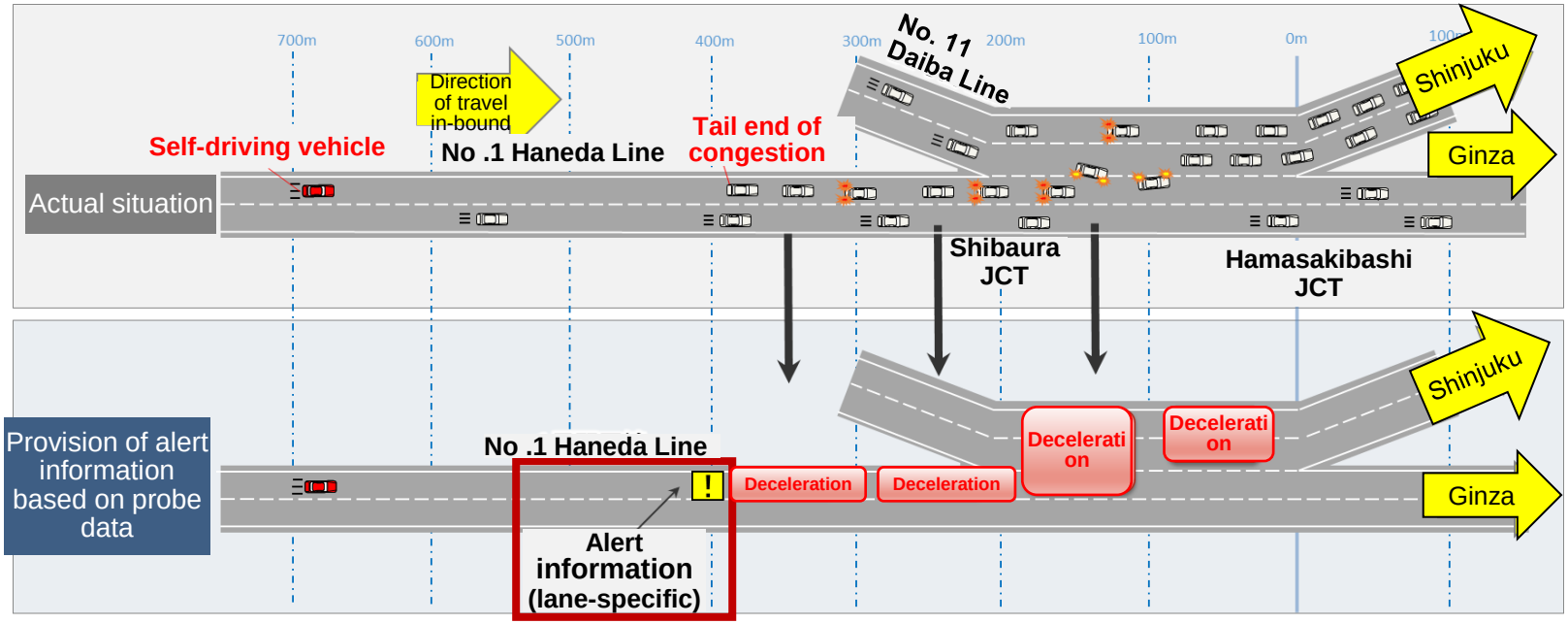
Data that can be utilized for early practical application
- Probe information available from commercial vehicles
  → Travel time information, event information, etc. on the roadway level

*Technical specifications will be investigated regarding both:
(1) Goals for early practical application by extending current technologies
(2) Goals of an ideal future

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Information to be generated and provided: congestion tail end information

- The first initiative with respect to lane-level road traffic information was the implementation of technical deliberation aimed at generating and supplying information regarding the **tail ends of traffic congestion**
- Congestion information was generated in 100 m units in the direction of travel



Information to be generated and provided

Source: Eighth Deliberation Council Meeting Materials (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation on data sharing (aggregation)

- The data collection format used when aggregating data from probe providers was designed so that information for the 30 minutes before the collection deadline can be aggregated in five-minute increments, taking uplink delays into account.

Format Structure when Collecting Data from Probe Providers

Configuration Information			Main Information
Basic Information			Geodetic system, time zone, time of information generation
Probe information	DRM basic information		DRM link version, secondary mesh code, link number
	Layers 1 to 6		Information for the 30 minutes prior to the collection deadline is aggregated in 5-minute increments.
		DRM link unit information	Average travel speed in each direction
	Layers 1 to 6		Information for the 30 minutes prior to the collection deadline is aggregated in 5-minute increments.
		Link unit information in 100 m segments	Segment serial number, segment link distance Average speed information, information by speed range, other vehicle information, average travel speed in each direction

*The data is collected from the probe provider in JSON format and collected by file transfer using the HTTP protocol.

Source: Sixth Deliberation Council Meeting materials(created by Pacific Consultants)

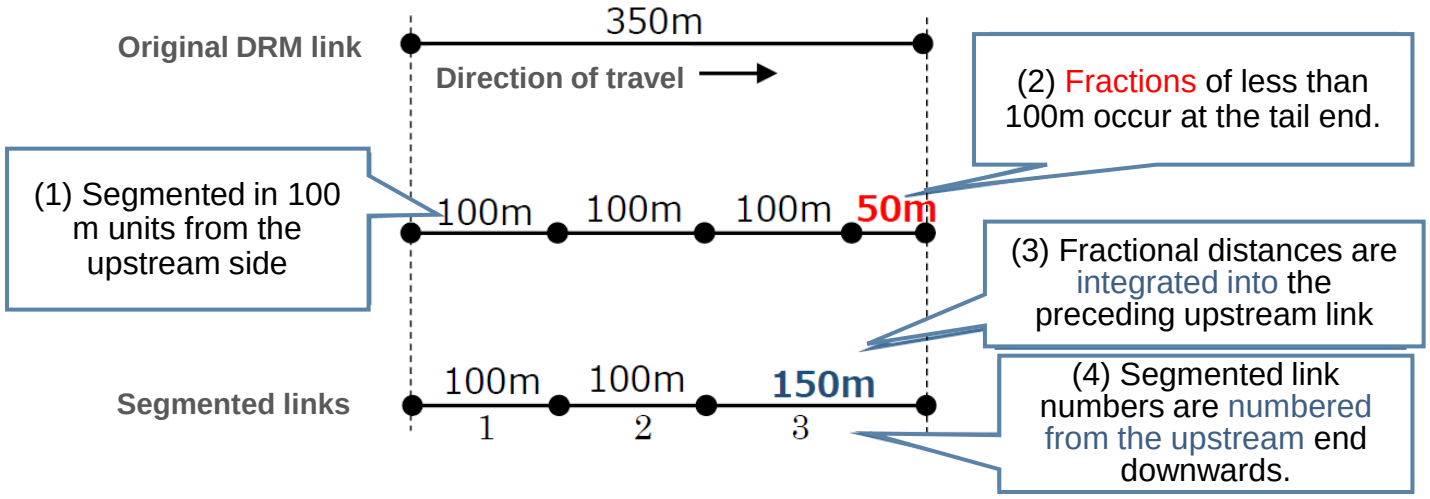
2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation on data sharing (aggregation)

- The unit of data aggregation used when aggregating data from probe providers is based on DRM links, and the specifications are defined such that each link is segmented into 100 m units.

◆ How the DRM link is segmented

- The map is segmented into 100 m link units based on the link numbering system of the map databased published by the Japan Digital Road Map Association (Edition: DRM · DB3203A (March 2020 edition)).
- DRM links with a link length of 200 m or more are targeted for segmentation, and the DRM links are segmented into 100m units starting from the upstream side of the original DRM link. The fractional distance links of less than 100m that are furthermost downstream are integrated into the preceding upstream link.
- The segmented link is assigned a branch number from the upstream side in relation to the original DRM link number (see the figure below).



Source: Sixth Deliberation Council Meeting Materials (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

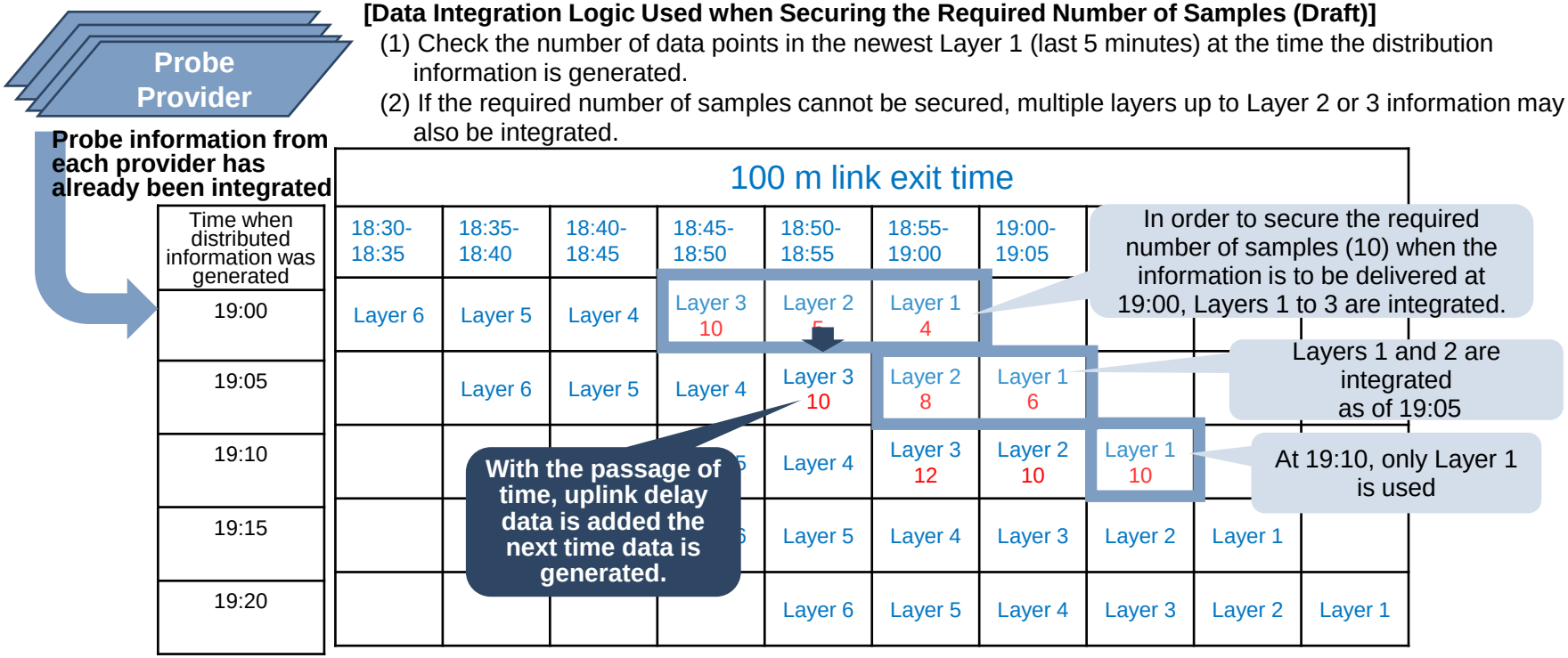
Technical deliberation on integrating data from multiple information sources

- Since it may not be possible to secure the required number of samples using only the most recent five minutes of data (Layer 1) due to the effects of uplink delays, the most recent historical data (Layers 2 to 6) is used due to the need to balance the freshness of the information.
  → In order to maintain a good balance of the amount of information that is generated and the freshness of the data, the maximum amount of historical data is is limited to the immediately preceding 15 minutes (Layer 3).

[Data Integration Logic Used when Securing the Required Number of Samples (Draft)]

(1) Check the number of data points in the newest Layer 1 (last 5 minutes) at the time the distribution information is generated.

(2) If the required number of samples cannot be secured, multiple layers up to Layer 2 or 3 information may also be integrated.



Concept of data integration approach used to secure the required number of samples

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

Source: Eighth Deliberation Council Meeting Materials (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation regarding the generation of lane-specific road traffic information

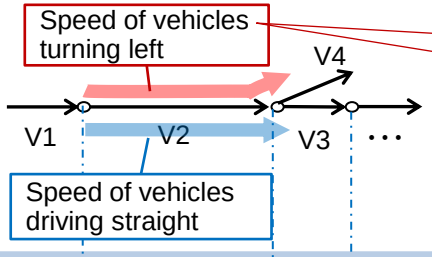
(1) **Lane-specific traffic congestion conditions for the direction of travel** were determined in **100 m units** using **information regarding the number of vehicles in each speed range** using Pattern 2

(2) **When there was lane-specific traffic congestion**, the direction of the lane with the traffic impediment (such as whether it was a left turn lane or a straight-facing lane) were determined for **fork areas** using Pattern 1 **speeds for individual link directions before the fork area**

(3) **For areas other than fork areas**, Pattern 2 **turn signal information** was used to determine the direction of the lane with the traffic impediment (left or right)

<Information provided by probe information (links)>

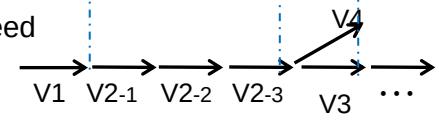
<Pattern 1>
DRM link (road node links)
- Speed in each link direction before the fork area



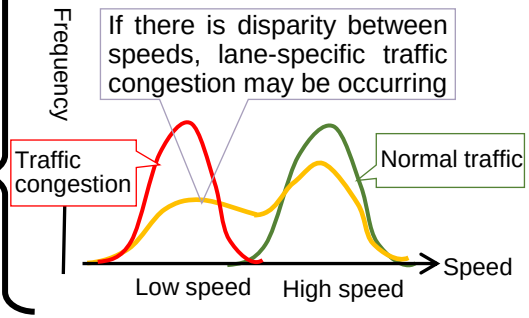
Speed in each link direction before the fork area

If the speed of the vehicles turning left is low, traffic congestion may have occurred in the left lane

<Pattern 2>
100 m segment links
- No. of vehicles by speed range
- No. of vehicle events (turn signals, etc.)



No. of vehicles by speed range (speed distribution)



No. of vehicle events

Turn signal	No. of events
Left turn signals	15
Right turn signals	0

When a large number of vehicles engaging their left turn signals is detected, this is inferred to indicate an impediment in the right lane further ahead

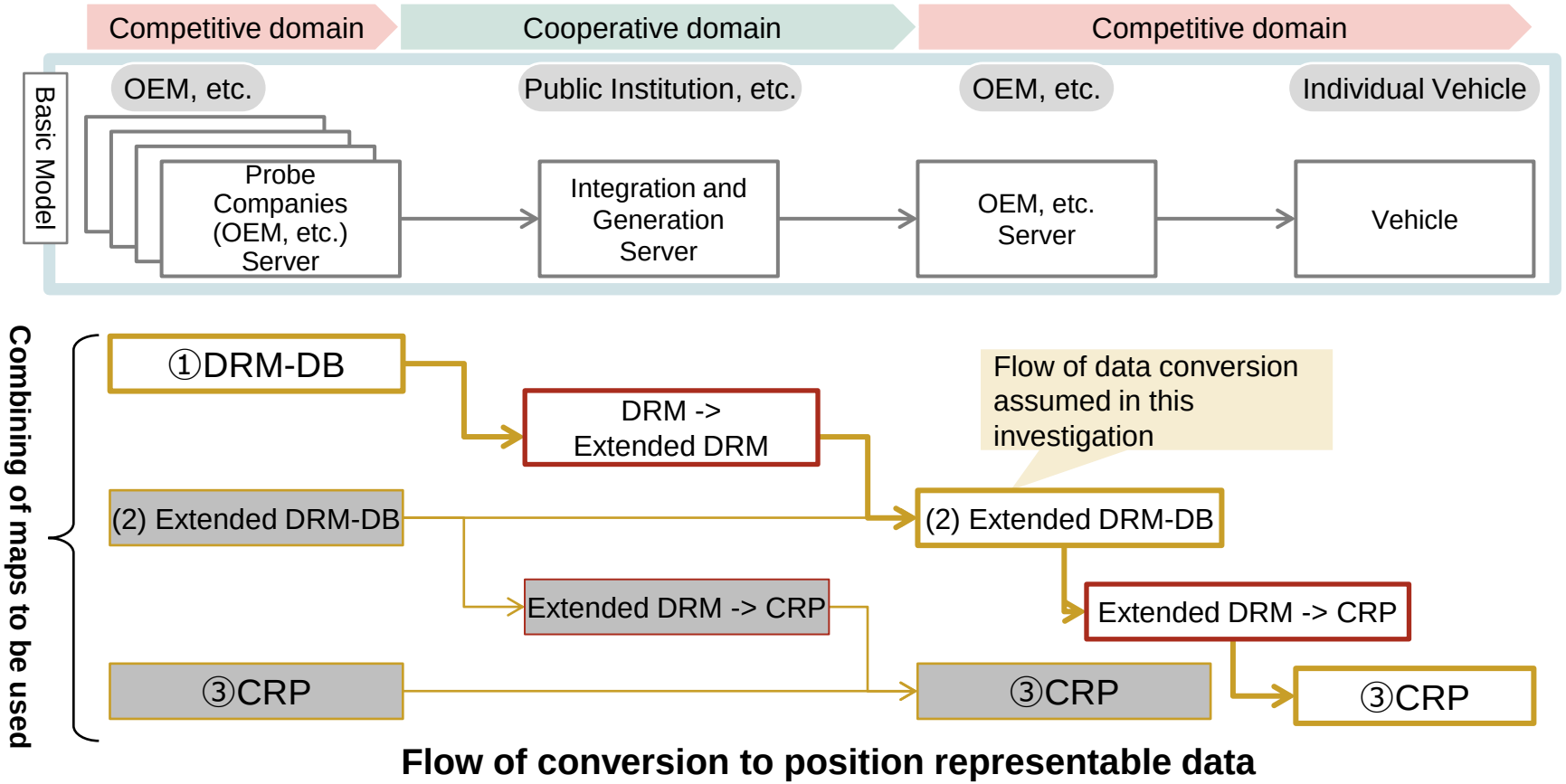
- ✓ The specific lane number of the lane with an impediment cannot be determined, so when a left or right side impediment direction has been determined for a route with three or more lanes, for safety purposes, caution information is displayed for all lanes from the left or right side impediment, excluding the furthest lane.
- ✓ When there is not enough data to determine the left or right side impediment direction, or it cannot be determined because it cannot be detected, then for safety purposes traffic congestion information is displayed for all lanes.

Source: FY2022 final deliberation council meeting material (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation on conversion to position representable data

- In the flow of data from the probe provider to the vehicle, the combination of maps to be used is assumed to be as shown in the figure below. This presents an organized view of the issues involved in future practical application with respect to generating the necessary extended DRM and CRP system maps.



Flow of conversion to position representable data

Source: Fifth Deliberation Council Meeting Materials (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation on data sharing (distribution)

- JASPAR specification standards are applied for data sharing between the centers when generated information is distributed from the information integration and generation server to the servers of the Tokyo Waterfront Area FOT Consortium (assuming future OEM telematics centers, etc.).
- The message set referenced between servers consists of “spatial information” and the “content body,” where the spatial information includes valid time and latitude/longitude expressions.
- The point and lane sections where the generated alert information is displayed are described using the point detail items of latitude, longitude, and lane.

Message structure concept

Administration		**Administrative Information**
Container	**Basic**	**Spatial information**
	Contents	Content body

Spatial information

Item	Name
Time	Effective time
Section	Latitude and longitude expressions

Item	Name
Beginning Point	Starting point

Time details

Item	Name
Start	Time of occurrence
Expire	Information expiration time

Geographical detail item

Item	Name
Latitude	**Latitude**
Longitude	**Longitude**
OnRoad	Presence or absence on the road
Name	Road name
Lane	**Lane(s)**
Accurancy	Accuracy of information

Source: Sixth Deliberation Council Meeting Materials (created by Pacific Consultants)

2.2. Deliberation of Elemental Technologies (Scope of Deliberation of This Project)

Technical deliberation regarding data sharing (distribution)

- Generated caution information was delivered and positioned within the content itself as information regarding "5. Caution phenomena."
- FOTs were performed using the definitions shown below for "Subject" and "Accuracy."

Conceptual image of message structure

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

Item no.	Content type	Definition
1	Traffic conditions	Information regarding average vehicle speeds, number of vehicles, etc. for the section
2	Restriction conditions	Information about traffic restrictions
3	Environmental conditions	Information regarding temperature, weather, estimated road surface conditions, amount of solar radiation, regulations, etc.
4	Impediments	Information regarding fallen objects, stopped vehicles, etc.
5	**Caution phenomena**	**Information regarding emergency vehicles, road work, vehicles requiring special caution, etc.**
6	Vehicle events	Information such as ABS and ESC operation locations
7	Parking locations	Locations where parking is/is not possible and related information
8	Road structure changes	Information regarding changes to road geometry, changes to painting, changes to ancillary facilities, cracking, subsidence, etc.

Caution phenomena details

Item	Name
Sequence	Classification/management number
Subject	Phenomenon necessitating caution [In the FOTs, "50: Traffic congestion tail end" and "60: Impediment location" were added and used]
Accuracy	Accuracy of information [In the FOTs, "5: Information generated using data from up to level 1," "4: Up to level 2," "3: Up to level 3," "s: Up to level 4," "1: Level 5 and beyond," were used]

Source: Created based on 6th deliberation council meeting material (created by Pacific Consultants)

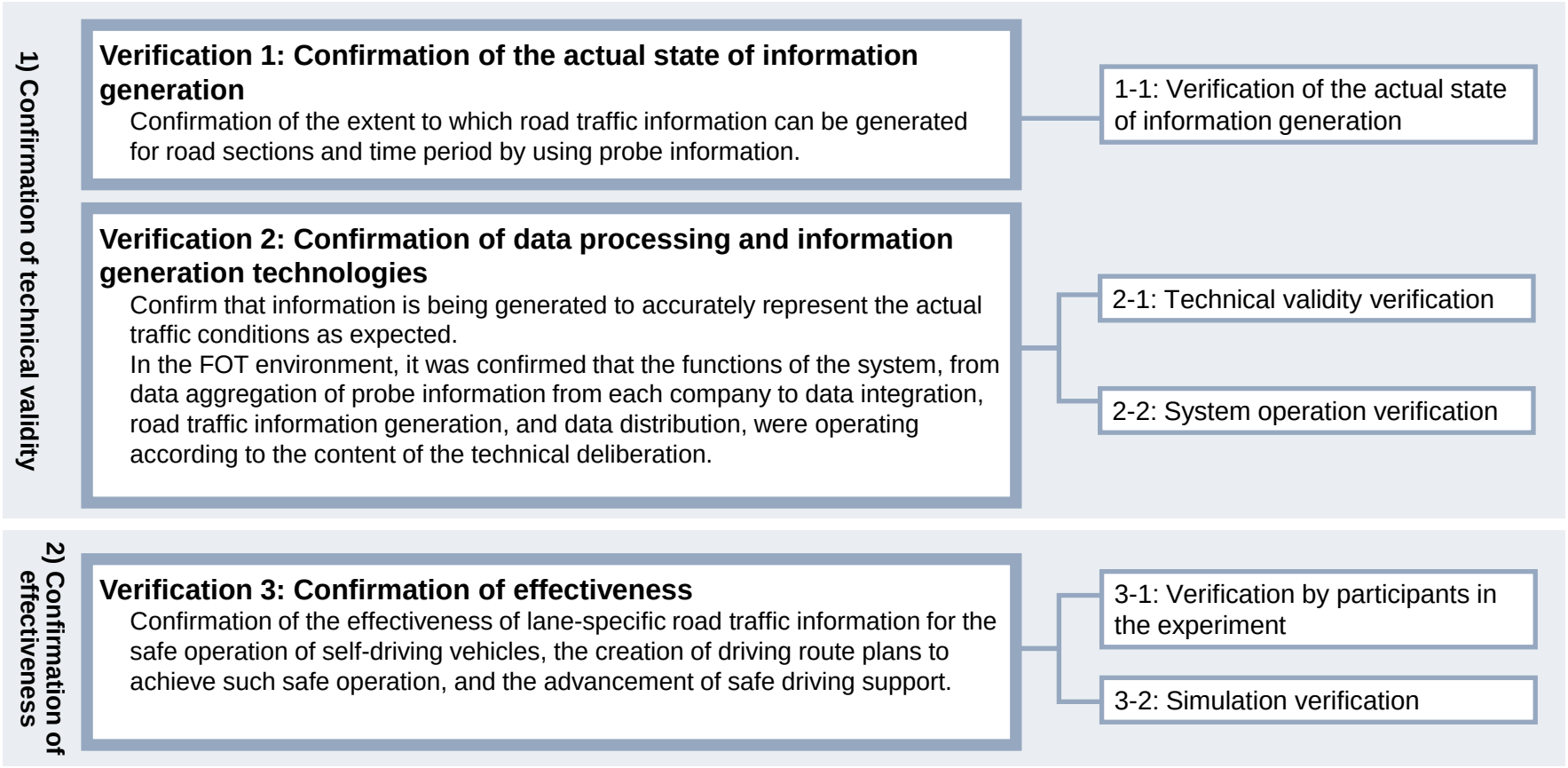
3. Confirmation of the Benefits and Issues of Lane-level Road traffic information

3.1. Approach Used in Technical Verification and Effectiveness Verification

The FOTs for this fiscal year will be conducted with the following two verification objectives.

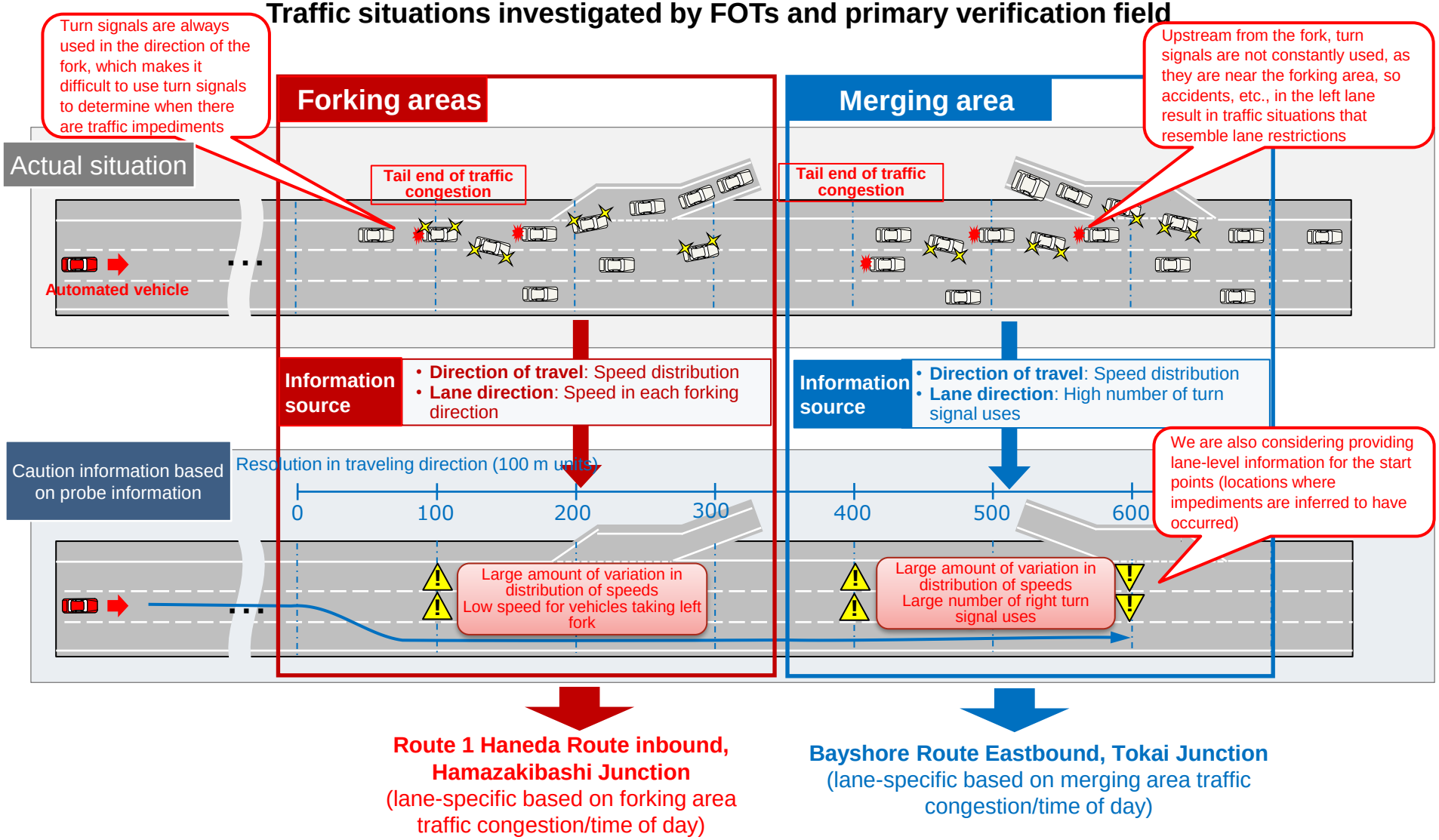
(1) **Verify the effectiveness of lane-specific road traffic information.**

(2) **Confirm the technical validity of each elemental technology** under investigation for the practical application of generating and providing lane-specific road traffic information.



3.1. Approach Used in Technical Verification and Effectiveness Verification

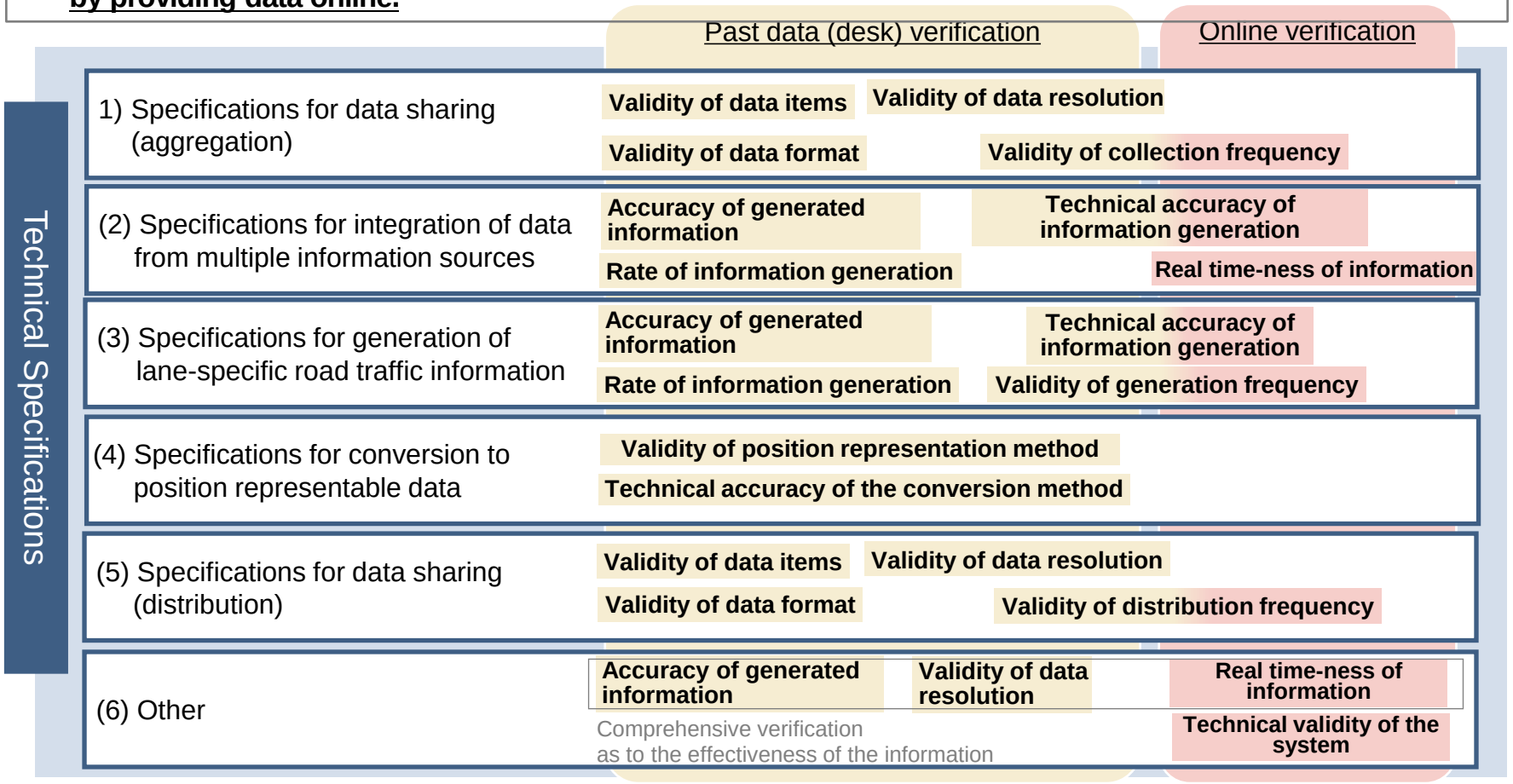
Traffic situations investigated by FOTs and primary verification field



Source: Created based on FY2021 2nd deliberation council meeting material (created by Pacific Consultants)

3.1. Approach Used in Technical Verification and Effectiveness Verification:
Verification Items and Verification Methods for FOTs in FY2020

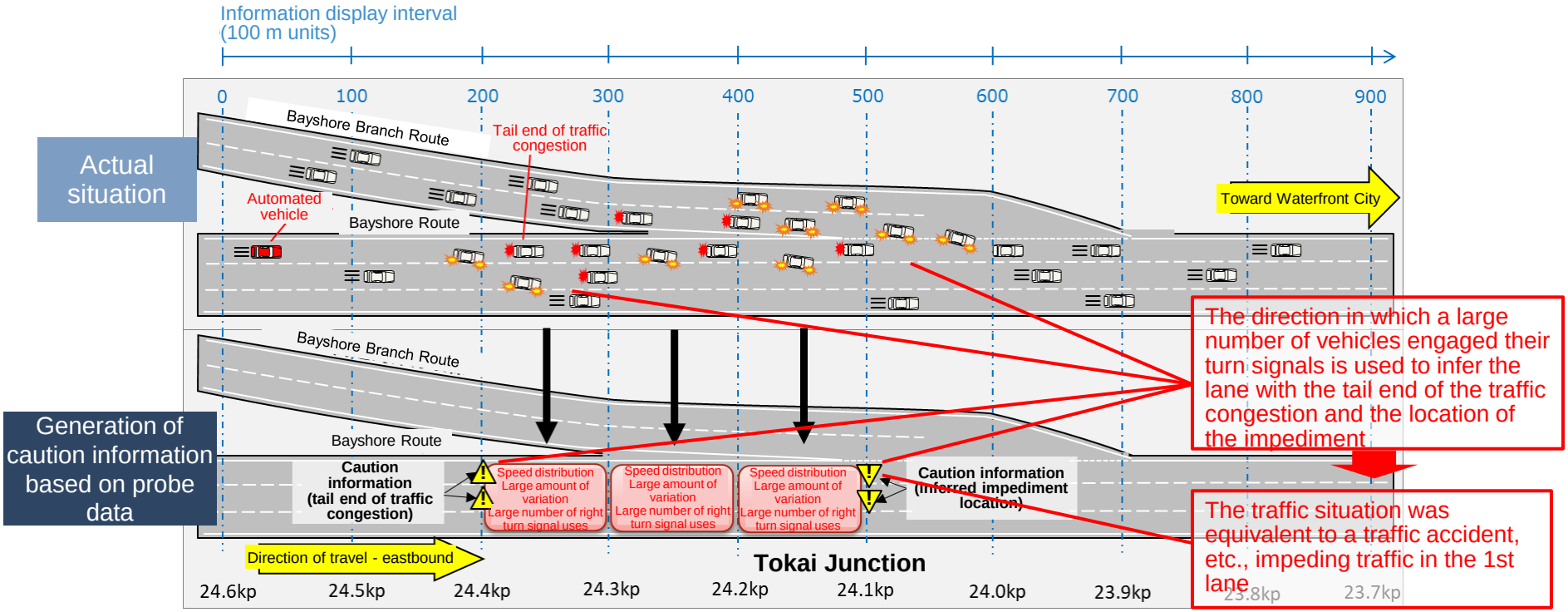
- In the FOTs for fiscal year 2020, the **technical specifications for data transfers between related entities and the specifications for generating lane-specific road traffic information will be mainly verified using past data (desk verification). In addition, confirmation of the amount of delay, the validity of the frequency with which data is provided, and verification of the effectiveness of the information resolution will be achieved by providing data online.**



3.1. Approach Used in Technical Verification and Effectiveness Verification:
Verification Items and Verification Method for FOTs in FY2021

In the FY2021 FOTs, we verified the **generation of more stable and accurate information due to the increase in the number of probes from which data was collected online from two providers,** we verified the **provision of information in the directions of lanes where there were impediments, other than forks, based on the number of turn signals used,** and we **added a type of caution information indicating the location of inferred impediments.**

Conceptual image of traffic situations in Tokai Junction merging area and generation of information



Source: Created based on FY2021 2nd deliberation council meeting material (created by Pacific Consultants)

3.1. Approach Used in Technical Verification and Effectiveness Verification:
Verification Items and Verification Method for FOTs in FY2002

In the FY2022 FOTs, **additional probe information providers were added** (further increasing the amount of data), **FOTs were performed twice, in spring and in fall**, and the **PDCA cycle was used in technical verification**.

■ **Status of increase in data from FY2022 spring FOTs**

The number of probe information providers was increased from two to four companies. This increased the overall volume of information approximately 1.4-fold , but there were no major changes in data with high levels of freshness, namely information from within the past 5 minutes (level 1) to 10 minutes (level 1 + 2).

■ **System improvements during the FY2022 spring FOTs (latter half)**

In the test system, when level 1 data alone did not provide sufficient amounts of data, level 2 and further data were successively added to generate data, but this caused the information to be less fresh. To minimize the impact of this, improvements were made to reduce the weighting of data from level 2 and beyond.

■ **FY2022 fall FOTs** Based on the results of the spring tests, further function improvements and adjustments were made, and a final evaluation was conducted.

Source: Created based on FY2022 1st deliberation council meeting material (created by Pacific Consultants)

3.2. Verification Results

(1) Results of technical feasibility verification

Study contents	Objective of the technical study	Results of the technical study
1) Data sharing (collection)	* Investigate specifications for sharing data between centers when sharing information between servers of probe information providers and information integration and generation servers	**[Technical specifications]** ● Types of data to collect, tabulation definitions, and collection format (json) ● Collection frequency (5 minutes intervals) and method of handling data when there are uplink delays ● Method for segmenting information from DRM links to 100 m links **[Technical evaluation]** ◆ Collect data from four probe information providers from which information can currently be collected online and confirm data acquisition trends ⇒ The average amount of data that could be collected for the preceding five minutes was data for 6.0 vehicles for two lane sections (the Haneda Route) and 7.3 vehicles for three lane sections (the Bayshore Route)
2) Integration of data from multiple information sources	* Deliberate regarding specifications for integrating data collected from multiple information providers	**[Technical specifications]** ● Methods of handling numerical data during integration and of securing sufficient samples of data ● Measures to address the disparities in the information provision times of multiple probe information providers. **[Technical evaluation]** ◆ Confirmed the relationship between the number of backtracked levels and the information generation ratio (percentage of sections) ⇒ Data could be created approximately 60% of the time using information for the past five minutes alone (level 1) and approximately 95% of the time using information for the past 10 minutes (level 1 + level 2) ⇒ However, for long tunnels which interfere with uplinking, the information generation ratio when using data from the past 10 minutes fell to 72%

Source: Created based on FY2022 final deliberation council meeting materials (created by Pacific Consultants)

3.2. Verification Results

(1) Results of technical feasibility verification

Study contents	Objective of the technical study	Results of the technical study
3) Generation of lane-specific road traffic information	* Deliberation regarding the technical specifications involved in the generation of lane-specific road traffic information from carriageway-specific probe information	**[Technical specifications]** ● Developed logic for determining lane-specific traffic congestion conditions in the direction of travel (in 100 m units) based on information regarding the number of vehicles in each speed range ● When there was lane-specific traffic congestion, logic was created for determining the direction of the lane with the traffic impediment (such as whether it was a left turn lane or a straight-facing lane) for fork areas using speeds for individual link directions before the fork area. For areas other than fork areas, logic was created for determining the direction of the lane with the traffic impediment (left or right) based on turn signal information. **[Technical evaluation]** ◆ See "Results of evaluation and analysis performed through the FOTs" on page 34 of this document.
4) Conversion of data that can be used to express locations	* Deliberation regarding the data format that can be used to express (share) generated lane-level road traffic information and the conversion specifications involved	**[Technical specifications]** ● Method for creating node link maps that can express locations for lane directions ● Location referencing method for superposing information on high-accuracy maps **[Technical evaluation]** ◆ Reflected insights produced through actual data prototyping in technical specifications (draft)
5) Data sharing (distribution	* Deliberated regarding specifications for data sharing between centers when distributing generated information to OEM and other servers	**[Technical specifications]** ● Applied JASPAR specifications (organized information regarding issues with current JASPAR specifications) ● Implemented API for performing startup processing in one minute intervals in order to minimize information delays **[Technical evaluation]**API processing time of approximately 3 seconds

Source: Created based on FY2022 final deliberation council meeting materials (created by Pacific Consultants)

3.2. Verification Results

(2) Results of effectiveness verification

(1) Verification by participants in the Tokyo Waterfront Area FOT 2020: received responses from 11 companies.

Effectiveness of information

- The majority of organizations responded that lane-specific information regarding tail end of traffic congestion was effective.
  Reasons cited for the effectiveness of the system include “smooth driving by implementing lane changes, etc. in advance.”
- The majority of organizations also responded that congestion tail information that is not lane-specific was also effective.

Timing of providing information

- Participants indicated that information was provided 200 m to 2 km ahead for intra-city highways and 500 m to 5 km ahead for inter-city highways.

Positional accuracy of information

- The most common accuracy indicated in responses was 100 m. Some participants indicated that high positioning accuracy is necessary for intra-city highways due to the large number of curves and diverging/merging areas.

Information distribution cycle

- The most common indicated cycle length was 1 min.

Necessity of information

- About 80% of respondents answered that information regarding tail end of congestion is necessary.
- About 70% of respondents answered that information regarding congested sections (starting and end points) is also necessary.

(2) Verification by traffic simulation

Traffic facilitation

- Confirmed that the presence of automated vehicles in traffic has a rectifying effect and also has the effect of reducing journey time by providing lane-level road traffic information.

Safety improvement

- Confirmed that the provision of lane-level road traffic information reduces the rate of hazardous event occurrences.

Source: Prepared based on Tenth Deliberation Council Meeting Materials (prepared by Pacific Consultants)

3.2. Verification Results

<Findings regarding practical application feasibility>

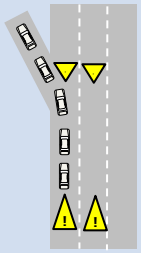
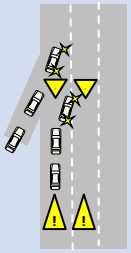
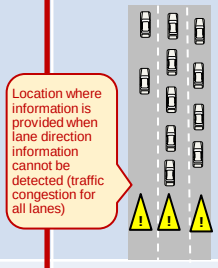
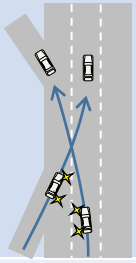
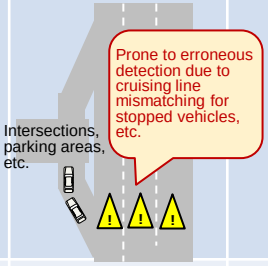
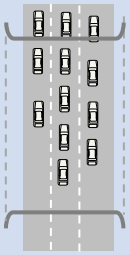
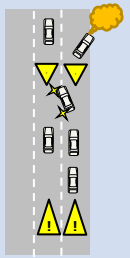
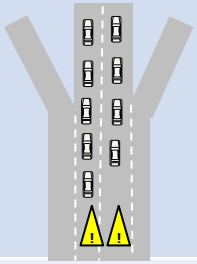
1. **It was confirmed that the current information generation method** could be used to **generate lane-level traffic information from carriageway-level probe information** for **certain road environment conditions**.
2. **In particular,** because traffic volume (which correlates to the number of probes from which information could be collected) was high **in fork areas (including exits) where there is chronic lane-specific traffic congestion, there is a high likelihood that the provision of lane-level traffic congestion information could be practically implemented quickly**.
3. **For other sections (such as non-intersection sections)**, as well, when it is possible to provide traffic congestion tail end information, etc., for traffic congestion affecting all lanes (across the roadway), it was confirmed that existing services **could provide more detailed and granular traffic congestion information for the direction of travel**.
4. **The amount of probe information that is currently available is not sufficient** for generating highly detailed information in various roadway traffic environments and under various traffic flow conditions. However, **we can expect improvements to be made as the amount of probe data that is collected increases** due to the more widespread use of connected cars in the future.
5. **To improve the accuracy of information,in addition to shortening information update intervals**, suggestions have been made regarding **further improving the methods used to process and deliver data**. Consideration will need to be given to the commercial factors involved, including cost effectiveness, taking into consideration increased transmission costs.
6. As **high-accuracy 3D maps, etc., become more common, lane-specific probe information** which is expected to become usable in the future will also have a great deal of promise for **further improving information accuracy**.

Source: Created based on FY2022 final deliberation council meeting materials (created by Pacific Consultants)

3.2. Verification Results

- **At fork areas (including exits) and merging areas where there is high traffic volume and chronic lane-specific traffic congestion**, there is a high feasibility of providing lane-level information **within the near future**. For non-intersection sections, **traffic congestion tail end information could be provided for traffic congestion across all lanes in the direction of travel with a higher degree of detail than is possible using conventional methods.**
- For long tunnels, areas near frontage roads, etc., and weaving sections, the accuracy of the information may decline.

Applicability of this method to determination of lane-specific traffic congestion based on current probe information collection conditions for each of the major road traffic environments

		① Forking areas (including exits)	② Merging areas	③ Non-intersection sections	④ Weaving sections	⑤ Areas near frontage roads	⑥ Long tunnels	⑦ Lane-specific traffic congestion due to lane closures	⑧ Forking areas (both sides)
Road traffic shape and examples of generated information ▲ Tail end of traffic congestion ▼ Impediment locations				 Location where information is provided when lane direction information cannot be detected (traffic congestion for all lanes)		 Intersections, parking areas, etc. Prone to erroneous detection due to cruising line mismatching for stopped vehicles, etc.			
Locations where verification was performed during the FOTs		Haneda Route inbound, Hamazakibashi Junction fork area	Bayshore Route Eastbound, Tokai Junction merging area	All lanes within FOTs area	Bayshore Route Oi Parking Area to Oi Junction, etc.	Haneda Route, Shibaura Interchange Bayshore Route Oi Parking Area, etc.	Bayshore Route, Tokyo Port Tunnel, etc.	Haneda Route inbound, Oi Junction merging area rear-end collision, etc.(see reference material)	(Hakozaki Junction) * Not included within FOTs area
Applicability of this information generation method*1		○ Forking area logic	○	○	○	○	○	○	○ Forking area logic * Not tested
Applicability under current data collection conditions *1	**Direction of movement**	○	○	○	○	△ Prone to erroneous detection due to cruising line mismatching for stopped vehicles, etc.	△ Large amount of deviation due to decreased amount of acquired data as a result of uplink interference	○	○
		65% traffic congestion tail end encounter rate and 60% likelihood of deviation distance being 800 m or less when generating information ⇒ Improvement possible by shortening information update cycle length				10 erroneous determinations per day (50 minutes)*2	Information generation ratio when using data from the past 10 minutes fell to 72%*3		
	Lane direction	○ Fork direction information can also be assigned to traffic congestion tail end information	○ Large number of merging vehicles and high frequency of turn signal usage in merging areas	△ Turn signals are not detected in some cases	△ Both left and right turn signals are used, making determination difficult	△	△	○ Statistical verification has not been performed	○
		Left-right determination possible 100% of the time	Left-right determination possible 77% of the time	Left-right determination possible 31% of the time					
Improvement proposals		**Highly feasible within the near future**		* Improve accuracy of lane direction determination through use of lane-specific probe information	* Improve accuracy of lane direction determination through use of lane-specific probe information	* Reduce amount of erroneous matching by using longer link lengths * Improve accuracy of lane direction determination through use of lane-specific probe information	* Improve communication environment within tunnel * Increase volume of vehicle -side data collection		

Source: Created based on FY2022 final deliberation council meeting materials (created by Pacific Consultants)

*1)○:Information can be generated if sufficient data can be acquired, △: Large amounts of information error may occur
*2) Values from the Haneda Route inbound , near the Shibaura Interchange (winter test, December 20, 2021) *3) Values from the Tokyo Port Tunnel (morning and evening peak hours)

4. Deliberation of Systems for Practical Application

4.1. Investigative Steps and Procedures Toward Practical Application

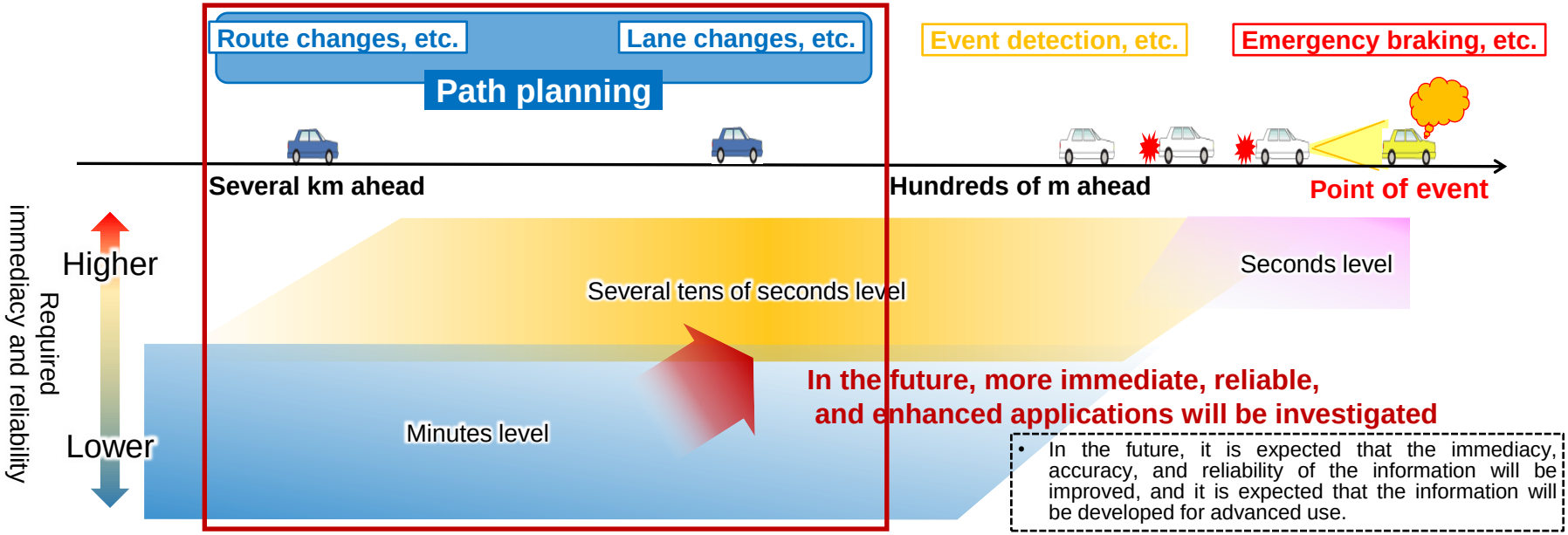
In preparation for practical application, various deliberations were made in parallel with the technical deliberation focused on the generation and provision of lane-specific road traffic information through this technical verification project.

	FY2020 Step1	FY2021/FY2022 Step2	FY2022 Step3
Technical	**Investigation and verification of elemental technologies** • Confirmation of data processing and information generation techniques based on past data • Confirmation of system function operation through online FOTs	**Technology improvements through FOTs** • Verification of real-time information distribution through online FOTs • Improvement of information generation technologies through FOTs	**Deliberations regarding evaluation and improvements aimed at achieving practical application** • Evaluation and verification of accuracy of information produced by information generation technology and of the applicability of this technology under different road traffic conditions, aimed at achieving practical application • Investigate feasibility of practical application and organize information regarding improvement proposals
Structural	**Confirm investigation steps** • Confirm investigative steps and procedures toward practical application • Recognition of issues for investigation	**Investigation in division of roles and functions** • Investigation of systems for division of roles and functions towards practical application • Specifying issues towards practical application	**Proposals for systems for practical application** • Organize information regarding existing process used to provide information and propose process for providing lane-specific road traffic information. • Conduct discussions of proposal contents among stakeholders and reach a consensus through ongoing discussions aimed to deployment in society.

Practical application (deployment in society)

(Reference) Immediate Service Scope for Practical Application

- In the SIP research and development project, initiatives were launched with the aim of **achieving early social implementation.** These initiatives investigated technologies for generating and providing information with a level of **real-time correspondence equivalent to the timeliness of conventional road traffic information using vehicle probe information that has already been put into practical application.**
- In order to put these technologies into **practical application quickly** after the completion of the SIP project **and to make them more effective as the use of self-driving vehicles increases**, the service scope for the time being is assumed to be **use in path planning such as route changes and lane changes** for **both self-driving and non-self-driving** vehicles.



Current scope of services (immediately after the end of SIP)

- During the transitional period as the use of self-driving vehicles becomes widespread, information will be provided to both self-driving and non-self-driving vehicles with the aim of making it more effective and beneficial (information will be provided to a wider range of road users).
- Considering the immediacy of the lane-level road traffic information that can be generated, etc., it is assumed that this information will be used for path planning such as route changes and lane changes.

4.2. Summary of Discussion Points Involved in Practical Application

For practical application, it is necessary to clarify the division of functions and roles, build a sustainable operation system, establish a system for developing and maintaining the data infrastructure, and clarify the roadmap for service expansion.

(1) Clarifying the division of functions and roles

- The current scope of services consists of the enhancement of current road traffic information provision services. It is considered possible and feasible to follow and utilize existing organizations and conventional information provision frameworks for early practical application.

(2) Clarification and detailing of needs

- Have envisioned users (OEMs, road administrators, members of the private sector, etc.) indicated an intent to use lane-specific road space information? (Conduct deep investigation of needs compared to other V2X and investigate effectiveness in usage situations)

(3) Establishment of a sustainable operation system

- Based on the envisioned services, what value do we see in the information and what business model should be built?
  (Clary who would benefit from the services, what added value they provide, and how costs should be shared)
- How should data from probe providers be priced?

(4) Establishment of a system to develop and maintain data infrastructure

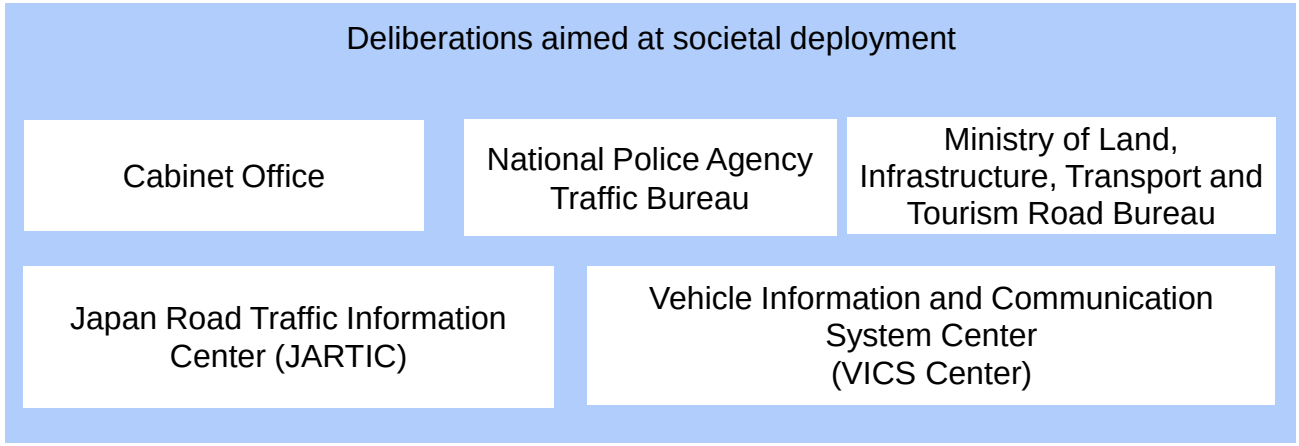
- What kind of system will be used to construct and maintain road network data (link node maps) for providing lane-level road traffic information?

(5) Clarification of the roadmap for service expansion

- In the FOTs, technical deliberation was conducted using the Tokyo Metropolitan Expressway. How should the scope of providing information be expanded and the conditions for providing information be considered, considering the differences between motorable roads and public roads and the differences in road structure?

4.3. Overview of Proposals for Systems for Practical Implementation

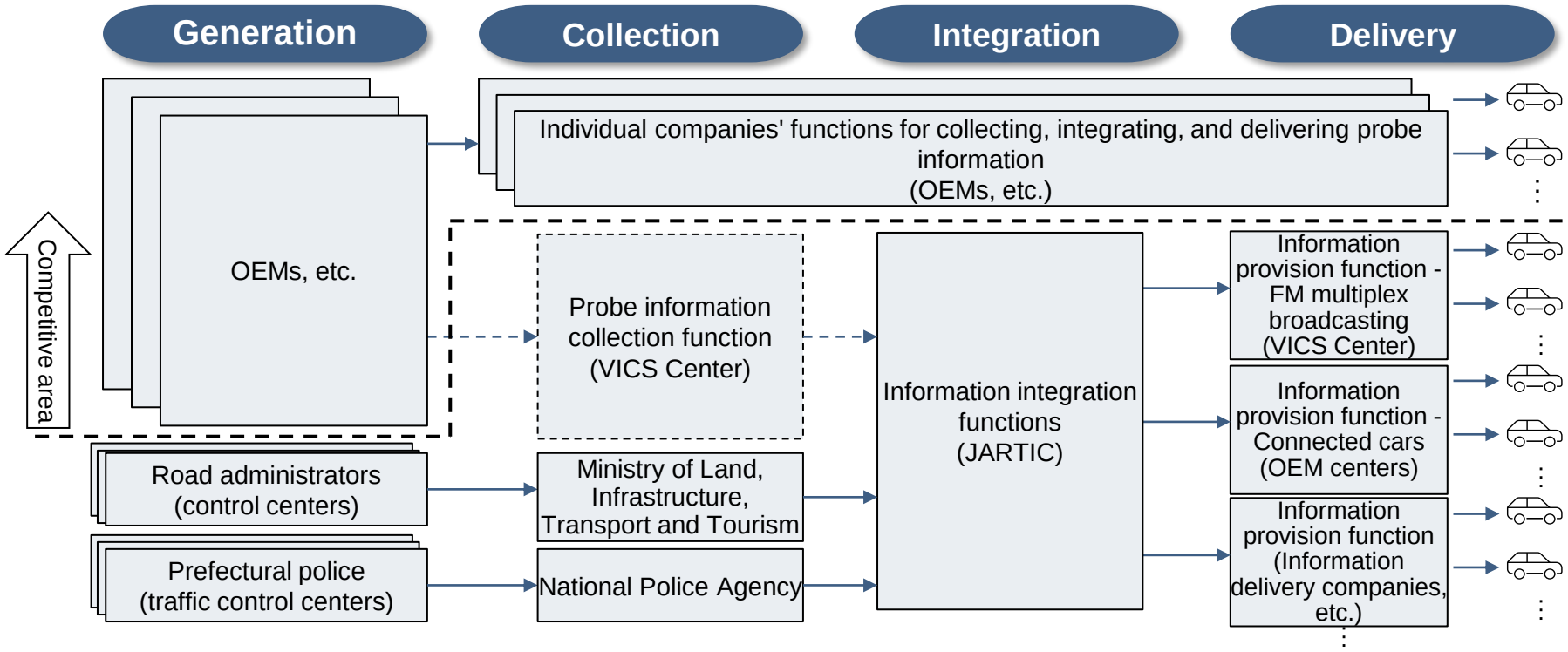
- Separate from this deliberation council meeting, the Cabinet Office has also led the development of a **proposal for a system for distributing information, with the aim of deploying this technology in society**, based on the FOTs results
- Discussions have been conducted among stakeholders responsible for the provision of road traffic information, **such as the Japan Road Traffic Information Center (JARTIC) and the Vehicle Information and Communication System Center (VICS Center)**, and **the participants have reached an agreement to continue discussions aimed at societal deployment.**



- Based on the results of the FOTs, **organize information regarding the existing process used to provide information** and **propose necessary functions and divisions of roles**.
- Conduct discussions of proposal contents among stakeholders and **reach a consensus through ongoing discussions aimed to deployment in society**.

4.4. Summary of Existing Road Traffic Information Provision Process

- OEMs, etc. provide services in which **each uses its own in-house methods to collect, integrate, and deliver probe information** (competitive area)
- Information generated by prefectural police and road administrators is aggregated and integrated and delivered via FM multiplex broadcasting, etc. to vehicles (**VICS service**)
- From FY2020, public and private sector probe information has been integrated by JARTIC, and field tests are being carried out of expanding the area in which **carriageway level traffic congestion and travel time information** is supplied (arrows with dotted lines)



* Probe information integration is indicated within the dotted line, as it is part of the current FOTs

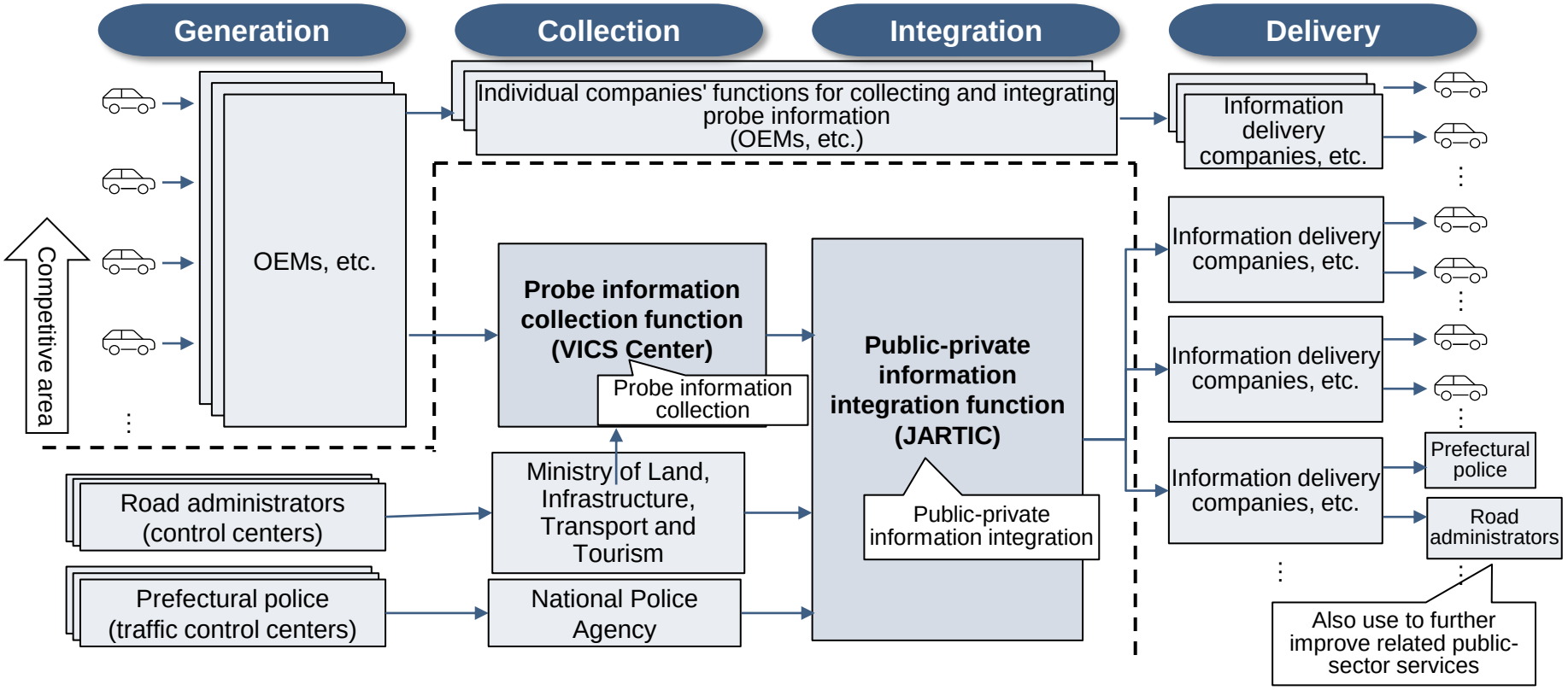
OEMs, etc., generate lane-specific traffic congestion information

4.5. Lane-specific Road Traffic Information Provision Process (Proposal)

Normal font thickness — Existing organization/function

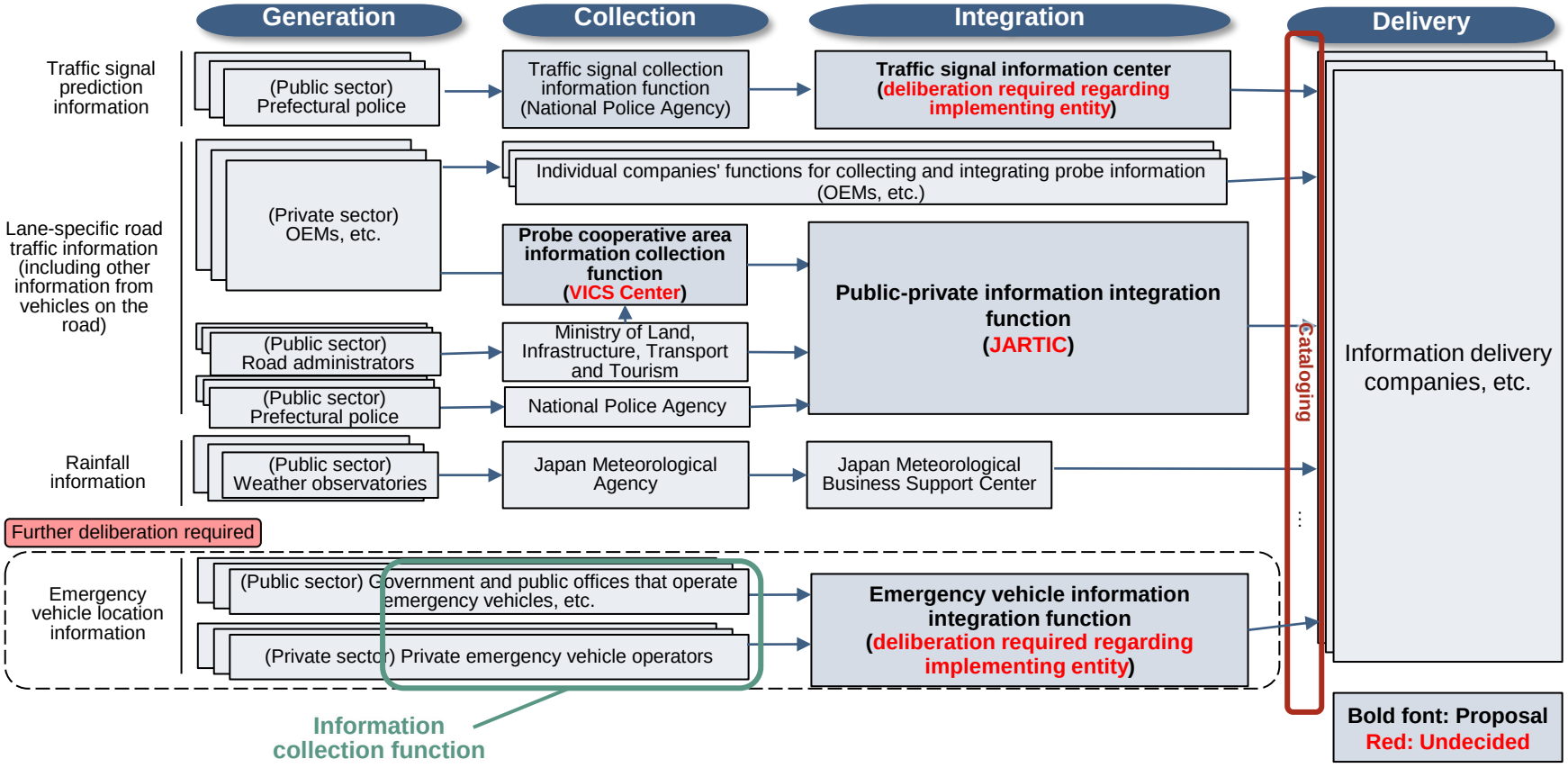
Bold font — **Further consideration required (implementing entity)**

- Traffic information collected from public-sector infrastructure and cooperative area traffic information collected from private-sector probes are **integrated as public-private sector traffic information and delivered** to make road traffic safer and smoother.
- In order to deploy this technology in society, it would probably be best to **leverage the existing FOTs framework**, having the VICS Center take over the probe information collection functions and having JARTIC take over the public-private information integration functions.



4.6. Overview of Information Delivered via V2N (Proposal)

- Based on the results of the FOTs in the Tokyo Waterfront area, in addition to lane-specific road traffic information, deliberation should be conducted of how to deliver other types of information as well, including traffic signal prediction information, rainfall information, and emergency vehicle location information.
- Information will come from diverse information sources, so in order to improve information distribution efficiency, it would be best to **deploy collection functions** as necessary.
- **Catalogue functions should also be deployed** for traffic environmental information as a whole to expand data distribution by making it easier to identify information at a glance.



Item 3. Holding of Deliberation Council Meetings, etc.

Status of Deliberation Council Meetings

A deliberation council was established and deliberation council meetings were held with the aim of discussion and coordination between **related government agencies** (Cabinet Office; National Police Agency; Ministry of Land, Infrastructure, Transport and Tourism) **and major related organizations** (Japan Automobile Manufacturers Association, Japan Road Traffic Information Center, Vehicle Information and Communication System Center) with the ultimate aim of generating and providing lane-level road traffic information based on information from probes.

Table. Status of deliberation council meetings (FY2019)

Session	Agenda
First meeting June 26, 2019	• Implementation plan • Issues to consider in preparation for the 2020 FOTs • Implementation approach for interviews regarding vehicle probe information collection and processing
Second meeting August 6, 2019	• Reporting on the results of interviews • Handling approach and requirement approach for issues to consider in preparation for the 2020 FOTs
Third meeting December 25, 2019	• Data that can be used in the 2020 FOTs • Overall 2020 FOTs approach (draft)
Fourth meeting March 26, 2020	• Status of technology deliberations in preparation for the 2020 FOTs • 2020 FOTs implementation approach and system development approach (draft)

Status of Deliberation Council Meetings

Table. Status of deliberation council meetings (FY2020)

Cession	Agenda
Fifth meeting May 28, 2020	• Deliberation regarding elemental technologies for the generation and provision of lane-specific road traffic information • Technology verification approach by simulation • Approach for FOTs (draft) / Status of deliberation and coordination in the development of the FOTs system
Sixth meeting August 6, 2020	• Deliberation regarding elemental technologies for the generation and provision of lane-specific road traffic information • Implementation approach and details of the FOTs; policy on technology evaluation • How to proceed toward practical application of generation and provision of lane-specific road traffic information (draft)
Seventh meeting October 13, 2020	• Status of technical deliberations in the FOTs • Policy on technology evaluation in the FOTs (draft); policy on effectiveness evaluation (draft)
Eighth meeting December 15, 2020	• Status of implementation of technical validity verification • Details of effectiveness verification • Outline of the summary (draft)
Ninth meeting February 5, 2021	• Progress of the FOTs • Status of technical deliberation for generation and provision of lane-specific road traffic information
Tenth meeting March 18, 2021	• Implementation status of the FOTs • Summary of deliberation results

Status of Deliberation Council Meetings

Table. Status of deliberation council meetings (FY2021)

Session	Agenda
First meeting of FY2021 June 30, 2021	• Results of the FY2020 FOTs • Contents of measures implemented in FY2021 FOTs
Second meeting of FY2021 September 28, 2021	• Contents of new technical deliberations in FY2021 • Approach used in deliberations of the use of information other than probe information • Contents of measures implemented in FY2021 FOTs and evaluation approach
Third meeting of FY2021 December 14, 2021	• Contents of issues pointed out in deliberation council meetings, working group sessions, and task force meetings • Status of technology deliberations regarding lane-level road traffic information • Contents of measures implemented in FY2021 FOTs and technology evaluation approach
Fourth meeting of FY2021 February 18, 2022	• Status of measures implemented in FY2021 FOTs • Approach used in summarizing results of FY2021 measures

Table. Status of deliberation council meetings (FY2022)

Session	Agenda
1st session of FY2022 November 29, 2022	• Approach used in summarizing implementation status and results of FY2022 FOTs • Deliberations regarding use of probe information related to inclement weather and road surface conditions
Final session March 16, 2033	• Summary of results of deliberation regarding the generation and provision of lane-level road traffic information created using probe information • Summary of results of deliberations regarding use of probe information related to inclement weather and road surface conditions

Item 4. Deliberation Regarding the Provision of Merging Support Information

Outline of Deliberations

We have investigated the Day 2 and Day 3 systems, services that provide merging support information being deliberated by NILIM, with the aim of improving lane-specific traffic flow information.

1. Administration of meetings

1.1. Background and objectives

1.2. Deliberation scope

1.3 Status of meetings

2. Study of merging area road alignment

2.1. Study scope and study items

2.2. Features of merging areas on Metropolitan Expressways and positioning of East Ikebukuro verification

2.3. Examples of study items

3. Creation of vehicle trajectory data for the area upstream from the East Ikebukuro Entrance

3.1. Overview of creation of vehicle trajectory data

4. Simulation results and recommendations for further analysis and future project developments

4.1. Overview of simulation verification results

4.2. Recommendations for further analysis and future project developments

1. Administration of Meetings

1.1. Background and Objectives of the Merging Support Day 2 System Simulation

Background

- **The Ministry of Land, Infrastructure, Transport and Tourism and NILIM are conducting joint public and private sector cooperative research regarding cooperative systems. One type of service offered by these systems that has been selected as being of particular note is merging support services.**
- **A technology study was performed from the perspective of the technical feasibility of merging support services. This study consisted of the following two steps.**

  (1) Day 1, which can be rapidly realized by combining existing technologies: Spot sensing + information provision

  (2) Day 2, which is expected to be feasible in the future: Planar sensing + information provision

- **Within the Cabinet Office's SIP-adus program, in FY2019 and FY2020 a Day 1 system was set up at the Metropolitan Expressway Haneda Airport West Entrance for the FOTs in the Tokyo Waterfront Area. Test driving and evaluation were performed. There were high expectations for the Day 2 system, as indicated below.**

<Primary evaluation results>

- The tests showed potential for merging support services (test participant that received information and performed HMI evaluation)
- The Day 1 system method of performing spot sensing and inferring merging point arrival times did not offer a sufficient level of inference accuracy when there is traffic congestion or heavy traffic
- Given the expectations for the Day 2 system, in FY2020, the NILIM's cooperative public and private sector research performed a technical evaluation of infrastructure sensors used to perform planar sensing

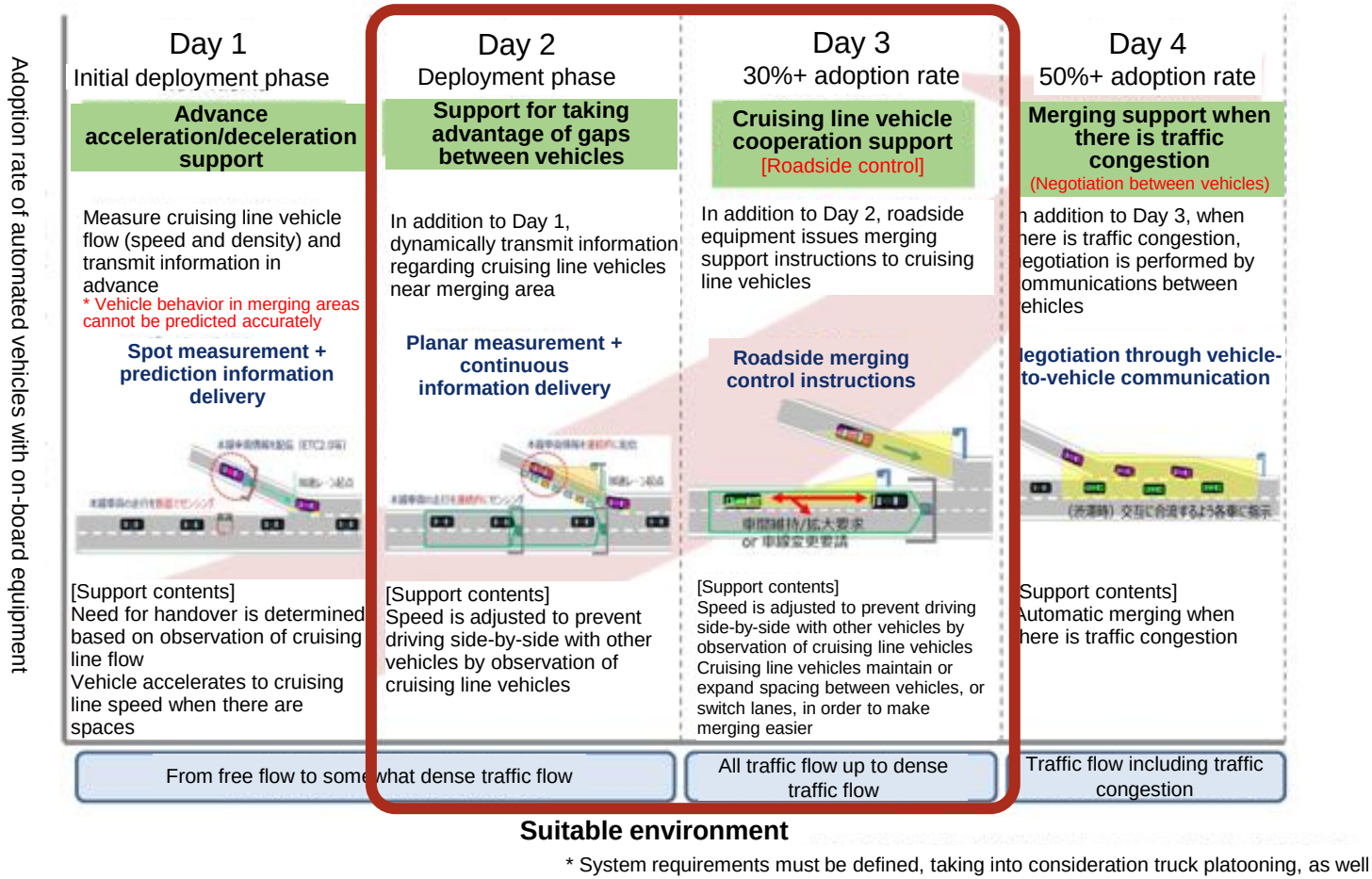
Source: SIP Phase 2 / Innovation of Automated Driving for Universal Services (SIP-adus) / Reports of FOTs in the Tokyo Waterfront Area

Objectives

- **Through the FY2021 and FY2022 Cabinet Office SIP-adus project, perform verification through the use of simulations in order to confirm the effectiveness of merging support services and identify issues involved in their real-world deployment with the aim of quickly deploying these services.**

1.2. Deliberation Objectives and Scope

- **Verification of Day 2 and Day 3 systems was performed using simulations in order to confirm the effectiveness of merging support services and identify issues involved in their real-world deployment with the aim of quickly deploying these services.**



* System requirements must be defined, taking into consideration truck platooning, as well

1.3. Status of Meetings

Creation of the merging support system simulation deliberation council

- **A deliberation council for deliberations regarding merging support system simulations was established and met to enable discussions and coordination between related government agencies (the Cabinet Office, Ministry of Land, Infrastructure, Transport and Tourism, NILIM, etc.) and major related organizations (JAMA, the Metropolitan Expressway, etc.).**

Session no.	Date	Agenda
1st	June 10, 2021	• Day 2 system deliberation schedule • Merging support system measures • Future deliberation schedule
2nd	August 5, 2021	• Day 2 system deliberation schedule (update) • Merging simulation specifications (proposed) • Plan for study of merging area road alignment (proposed)
3rd	October 7, 2021	• Explanation of proposal contents by contractor responsible for simulation operations • Merging simulation requests (proposed) • Report of results of study of merging area road alignment
4th	December 9, 2021	• Merging simulation results interim report (1)
5th	February 10, 2022	• Merging simulation results interim report (2)
6th	March 24, 2022	• Merging simulation results report of the FY2022
7th	July 28, 2022	• Merging simulation results interim report (3)
8th	October 17, 2022	• Merging simulation results interim report (4)
9th	January 12, 2023	• Merging simulation results final report

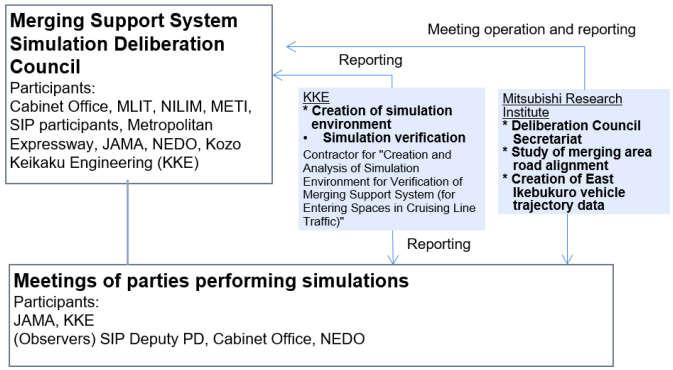


Fig. Positions of meeting bodies

Holding of meetings of parties performing simulations

- **Weekly operation meetings attended by related parties were held while merging support simulations were being conducted.**

Activities conducted in FY2021

2. Study of Merging Area Road Alignment

Activities conducted in FY2021

2.1. Study Scope and Study Items

- **In order to organize information about the characteristics of the merging area at the East Ikebukuro Entrance, where the merging support simulation was performed, a study was performed of the merging area's** road alignment**.**

[Study scope]

- **182 merging areas on Metropolitan Expressway routes for which distances were measurable using aerial photographs**
  - Interchanges: 108, Junctions: 63, Parking area exits: 11
  - Some parts of the Bayshore Route were excluded

[Study items]

- **Road alignment**
  - Acceleration lane length (from physical gore to edge of taper)
  - Section where merging is possible (from theoretical gore to edge of taper)
  - From ETC toll booth to physical gore
  - Distance from point where merging lane width is 2 m to edge of taper
  - Distance between edge of obstacle such as wall to theoretical gore, separating cruising line from merging lane
  - Visibility from cruising line/merging lane (* Envisioned as being visibility from driver's perspective)
  - No. of cruising line lanes
  - No. of merging lanes
- **Traffic restrictions**
  - Cruising line speed limit
  - Merging lane speed limit
- **Cruising line/merging lane traffic volume**
  - Daily traffic volume

2.2. Features of Merging Areas on Metropolitan Expressways and Positioning of East Ikebukuro Verification [1/2]

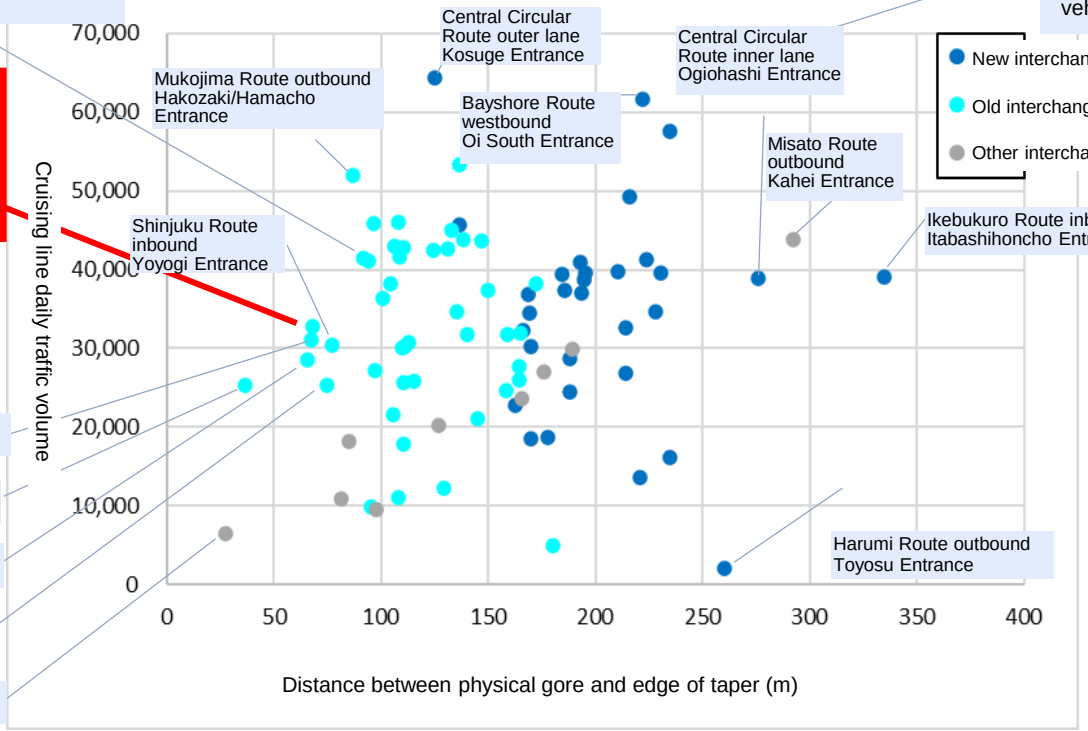
Activities conducted in FY2021

- **A study was conducted of the road alignment of merging areas in Metropolitan Expressway entry points and merging lane lengths and cruising line traffic volume were investigated**
- **It was confirmed that the East Ikebukuro Entrance had a merging area with a particularly short merging lane, even among merging points designed under old road standards**

Haneda Route inbound Airport West Entrance
Merging lane length 91.5 m
Cruising line traffic volume 41,440 vehicles/day

Ikebukuro Route outbound - East Ikebukuro Entrance
Merging lane length 68.17 m
Cruising line traffic volume 32,840 vehicles/day

Tomei inbound Yokohama Machida Entrance (reference)
Merging lane length 298 m
Cruising line traffic volume 21,948 vehicles/day

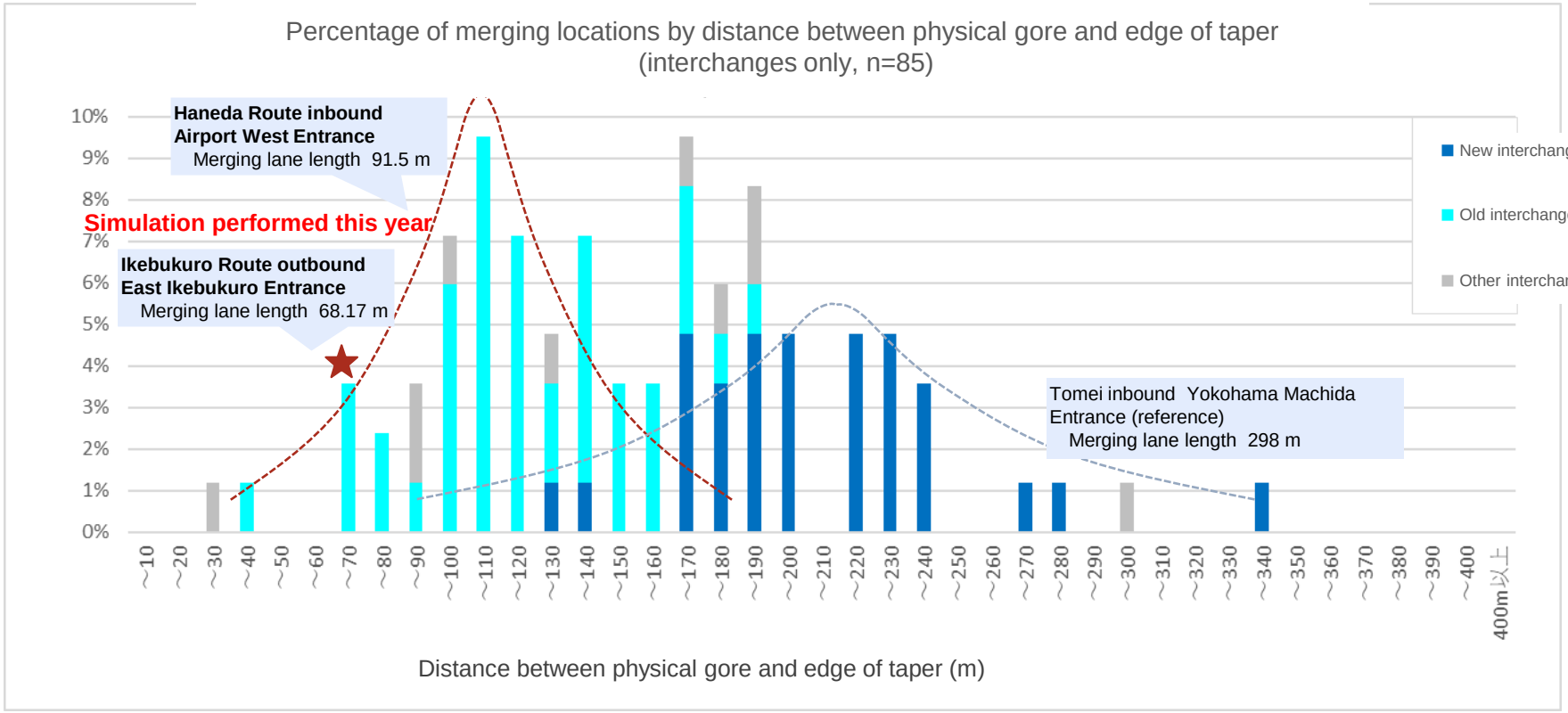


* Analysis was performed for locations where distances could be measured based on aerial photographs.

2.2. Features of Merging Areas on Metropolitan Expressways and Positioning of East Ikebukuro Verification [2/2]

Activities conducted in FY2021

- **It was confirmed that the distribution of Metropolitan Expressway merging lane lengths had two peaks, corresponding to the old and new standards**
  - Locations with short merging lanes (old standard), including East Ikebukuro, had short distances between merging start points and merging completion points, so there appear to be many potential situations in which merging support would be effective
  - For locations with relatively long merging lanes (new standard), merging may be possible during automated driving without merging support

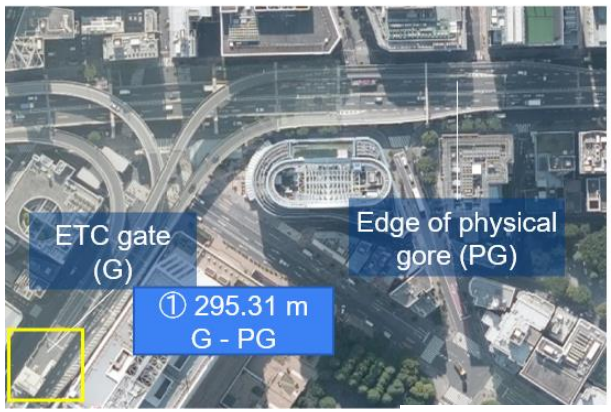


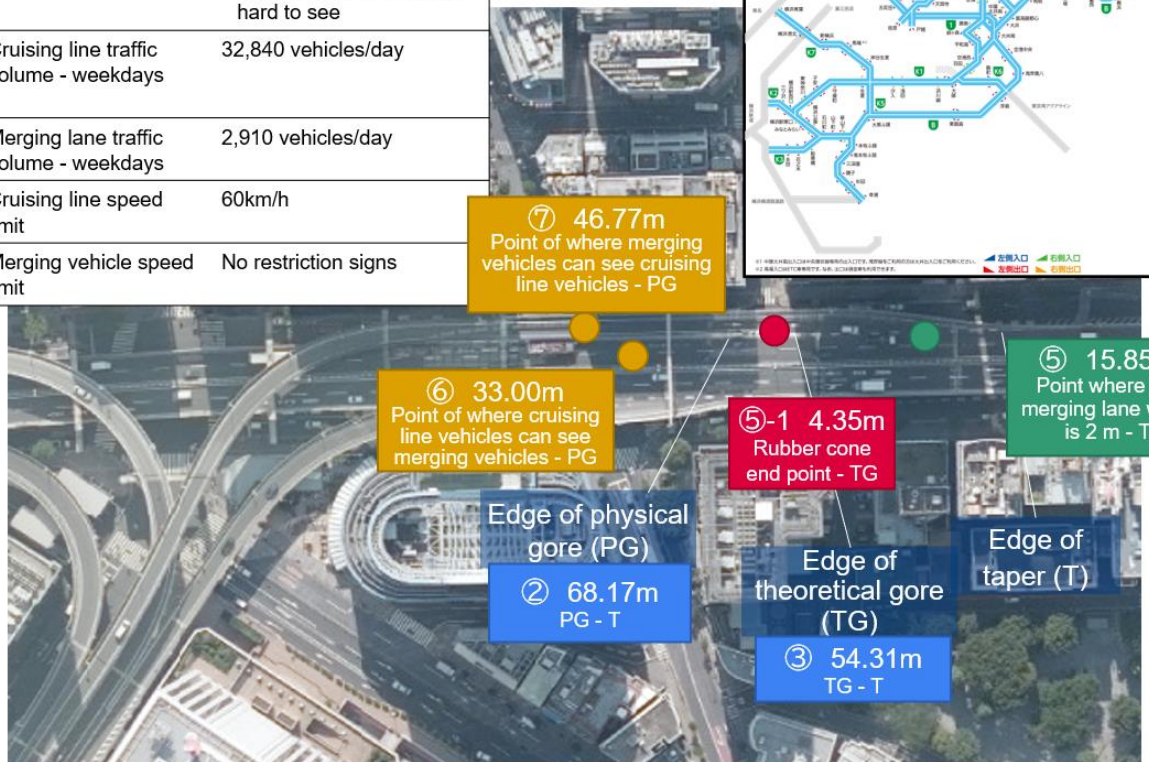
* Analysis was performed for locations where distances could be measured based on aerial photographs.

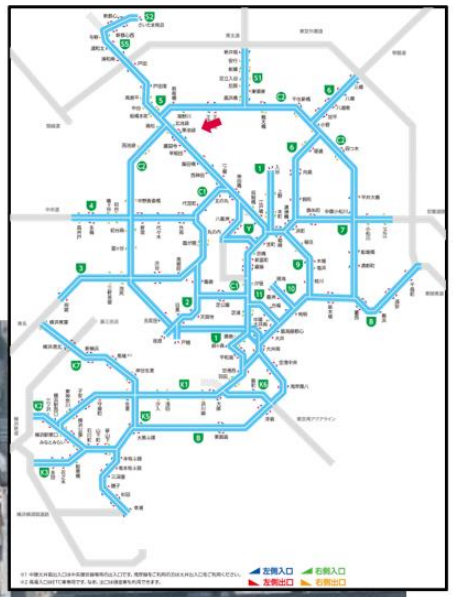
Activities conducted in FY2021

2.3. Examples of Study Items (East Ikebukuro Entrance (Route 5 Ikebukuro Route, Outbound))

①	ETC gate to physical gore	295.31m	⑥	Point where merging vehicles can be seen from cruising line	33.00 m to PG
②	Physical gore to edge of taper	68.17m	⑦	Point where cruising line vehicles can be seen from merging lane	46.77 m to PG
③	Theoretical gore to edge of taper	54.31m	⑧	Visibility from merging lane/cruising line	• The merging lane is higher than the cruising line, so both cruising line vehicles and merging vehicles are hard to see
④	Point where the merging lane width is 2 m	15.85 m to T	⑨	Cruising line traffic volume - weekdays	32,840 vehicles/day
⑤-1	Rubber cone start and end points	4.35 m to 15.22 m to TG	⑩	Merging lane traffic volume - weekdays	2,910 vehicles/day
⑤-3	Concrete wall end point	32.72 m to TG	⑪	Cruising line speed limit	60km/h
	(only curb between concrete wall and rubber cones)		⑫	Merging vehicle speed limit	No restriction signs







Photographs courtesy of the Geospatial Information Authority of Japan
Metropolitan Expressway map: Metropolitan Expressway website, Metropolitan Expressway Mikata - Metropolitan Expressway Entrance and Exit Map
https://www.shutoko.jp/ss/mikata/map/index.html

Activities conducted in FY2022

3. Creation of Vehicle Trajectory Data for the Area Upstream from the East Ikebukuro Entrance

Activities conducted in FY2022

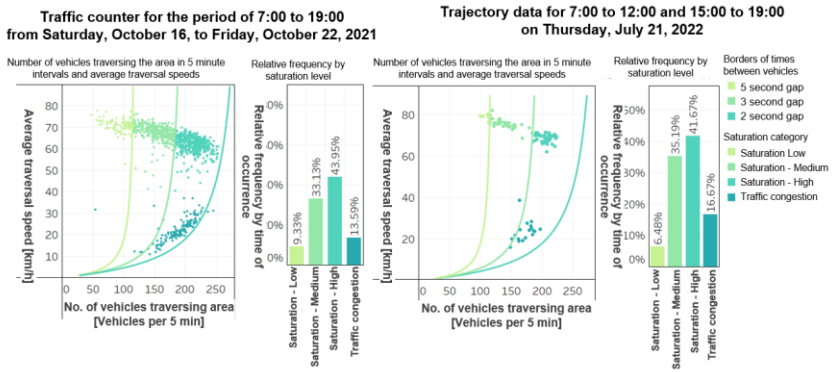
3.1. Overview of Creation of Vehicle Trajectory Data

- **In order to create more detailed models of the cruising line upstream area for the Day 2 support system simulation, video was taken of the cruising lines upstream from the East Ikebukuro Entrance and used to create vehicle trajectory data**
- **Data for nine hours of video was analyzed, and the behavior of vehicles driving on cruising lines upstream from the East Ikebukuro Entrance was analyzed**
- **It was confirmed that typical traffic conditions could be determined for the area near the East Ikebukuro Entrance**

[Study scope]

- **From roughly 200 meters upstream from the physical gore to the physical gore**

Photographs courtesy of the Geospatial Information Authority of Japan



Traffic counter data for the East Ikebukuro area, provided by the Metropolitan Expressway Company Limited (left) was compared against trajectory data obtained through this project (right), and it was confirmed that the saturation frequencies of both followed the same trend.

Source: Materials supplied by KKE, the contractor for "Creation and Analysis of Simulation Environment for Verification of Merging Support System (for Entering Spaces in Cruising Line Traffic)"

Activities conducted in FY2022

4. Simulation Results and Recommendations for Further Analysis and Future Project Developments

Activities conducted in FY2022

4.1. Overview of Simulation Verification Results

- **Verification of Day 2 and Day 3 systems was performed using simulations**
  - **Support system physical conditions and saturation were changed and the Day 2 support results were measured**
  - **The effectiveness of switching to the Day 3 system was measured and analyzed**

<table>
<tr><th>Implementation category</th><th>Contents of implemented measures</th><th>Conclusions</th></tr>
<tr><td rowspan="3">Day 2 system</td><td>Verification of the concept feasibility of the Day 2 system</td><td>• Confirmed that the Day 2 system produced merging improvements based on the fact that evaluation scores rose for over half of the merging AD vehicles
• Using the Day 2 system reduced the amount of last-minute merging by roughly half, so the Day 2 system's concept was confirmed to be effective</td></tr>
<tr><td>Verification of the concept feasibility when physical system conditions change</td><td>• When physical system conditions were favorable (as shown in the table below), the concept was confirmed to be effective
<table>
<tr><th>Transmission area length</th><th>Sensing area length</th><th>Information delivery time</th><th>Speed information deviation</th><th>Location information deviation</th></tr>
<tr><td>80 m or more</td><td>130 m or more</td><td>0.8 seconds or less</td><td>Within 6 km/h</td><td>None</td></tr>
</table></td></tr>
<tr><td>Verification of the concept feasibility when traffic flow conditions change</td><td>• The concept was confirmed to remain effective for everywhere from low to high traffic flow saturation levels
• In particular, when saturation levels were low, the system reduced the level of last-minute merging for merging AD vehicles, for which evaluation scores were low, to roughly 5%, demonstrating a high level of effectiveness</td></tr>
<tr><td>Day 3 system</td><td>Verification of the concept feasibility of the Day 3 system</td><td>• When the Day 3 system was tested in an environment with limited testing conditions, it had the same level of merging effectiveness and reduced the amount of last-minute merging by roughly the same amount as the Day2 system
→However, in this analysis, the conditions under which testing was performed did not cover all Day 3 conditions, so to confirm effectiveness, additional deliberation must be performed with the aim of further improving the effectiveness of the Day 3 system by performing additional verification under more diverse conditions.</td></tr>
</table>

Source: Materials supplied by KKE, the contractor for "Creation and Analysis of Simulation Environment for Verification of Merging Support System (for Entering Spaces in Cruising Line Traffic)"

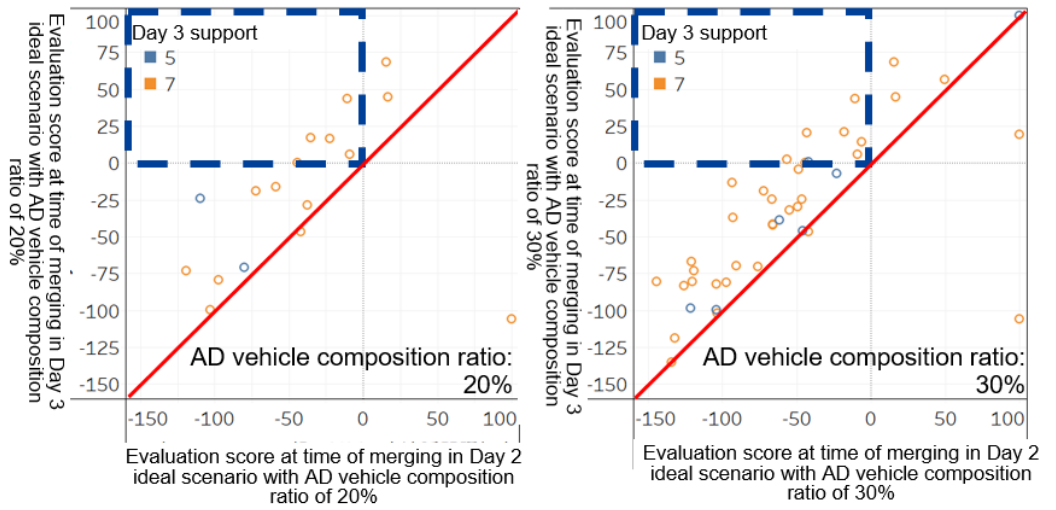
Activities conducted in FY2022

4.1. Overview of Simulation Verification Results

- **The degree of change in the effectiveness of support was measured when switching from the Day 2 system (with cruising line AD vehicle gaps of 2 seconds) to the Day 3 system (with cruising line AD vehicle gaps of 2.5 seconds)**

Hypotheses and expectations	In addition to providing support to merging vehicles, cruising line vehicle support (maintaining 2.5 second gaps) would further improve merging
Verification results	For many merging AD vehicles to which the Day 3 system provided cruising line vehicle support, there were improvements at the merging evaluation point (the area above the red line in the figures below) However, there were few examples of last-minute merging being eliminated (the area outlined in blue below)
Findings	Lengthening the cruising line vehicle gaps maintained through Day 3 system support could eliminate the issue of last-minute merging (Securing larger gaps between vehicles on cruising lines could reduce cruising line vehicle speeds and result in longer periods of traffic congestion, so verification will be necessary)

Comparative scatter plot of evaluation scores when providing Day 2 and Day 3 support



Day 2 support: Evaluation score below 0 (last-minute merging)
Day 3 support: Evaluation score of 0 or higher

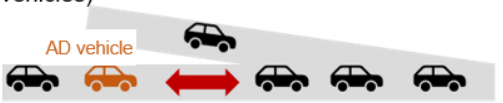
Source: Materials supplied by KKE, the contractor for "Creation and Analysis of Simulation Environment for Verification of Merging Support System (for Entering Spaces in Cruising Line Traffic)"

4.2. Recommendations for Further Analysis and Future Project Developments

Activities conducted in FY2022

- **When there were groups of cars in the cruising line merging area, there were times when merging was not performed smoothly even when support was provided**
  → This could be addressed by providing support such that a vehicle on the cruising line could open up a gap in advance for use when the merging area was reached.
- **The findings from this project are being shared with related parties**
- **Continued collaborative discussions will be carried out by members of the public and private sectors in order to improve the product feasibility of merging support systems, and expectations are high for further advances in initiatives aimed at societal deployment through infrastructure improvements and the development of on-board systems, etc.**

Appropriate vehicle gap instructions will be issued to AD vehicles on cruising lines depending on the cruising line density
➡ Maintain appropriate vehicle group lengths and vehicle group spacing
(creating gaps that can be easily entered by merging vehicles)

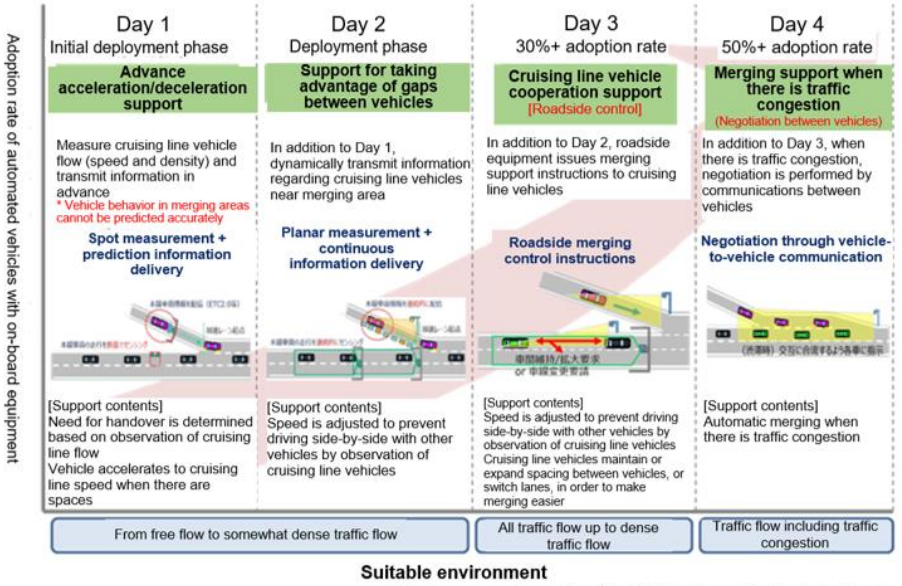


Creating cruising line traffic flow that is easy to merge into

- Install sensors that measure cruising line traffic flow and provide cruising line density information to vehicles on the cruising line
- Configure appropriate vehicle spacing tables based on traffic density and provide vehicle gap estimate information

Vehicles driving on the cruising line will create gaps before reaching merging areas **that can be easily entered by merging vehicles**

Support to merging vehicles (automated vehicle)



* System requirements must be defined, taking into consideration truck platooning, as well

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.