「Cross-ministerial Strategic Innovation Promotion Program (SIP)/Automated Driving for Universal Services/ Technical study and evaluation of automated driving control using lane-specific probes」

FY 2019 Report

Pacific Consultants Co., LTD

March, 2020

1. Outline of research

1.1. Business goals

In the case of automatic driving on expressways, the system may not be able to smoothly change lanes from the traveling lane to the deceleration lane if the information obtained in advance is insufficient, inaccurate, or inaccurate, such as when there is a stopped vehicle or falling objects ahead or when there is a traffic jam. One of the ways to solve these possible cases is for the automatic driving vehicle to obtain traffic information for each lane of the road, so that it can change lanes in advance to enable safe and smooth automatic driving.

1.2. Business summary

In this study and evaluation work, in order to put these measures into practical use, we will study technologies to collect and provide information on traffic congestion by lane, information on parked vehicles, information on falling objects, and information on event regulations (hereinafter referred to as " lane-specific information") to automated vehicles. Specifically, a demonstration experiment will be conducted on the Metropolitan Expressway Route No.1 Haneda Line and Bayshore Route. These measures will be considered not only for automated driving systems, but also for Level 1 and Level 2 driving support systems.

The following research and development items will be implemented to achieve the above research and development objectives.

a. Technical examination of each element
   1) Study on technology to generate lane-specific information
   2) Examination and evaluation of lane-specific probe processing technology required to generate lane-specific information
   3) Study and evaluation of data integration technology for lane-specific information generation
   4) Study and evaluation of lane-specific information distribution technology
b. Demonstration experiment
c. Examination and verification of elemental technology utilizing pre-read information at the semi-dynamic level

In FY2019, among the R & D items, R & D was conducted for part of "a. Technical examination of each element" and "b. Demonstration experiment".

1.2. Business summary

Flow of this R & D study

Examination of requirements and specifications
(a. Technical examination of each element ① Technical examination)

a1) Study on technology to generate lane-specific information

Probe data information acquired from the vehicle

Event information (regulation information, falling objects, broken cars)

→ Examination of data processing technology requirements
- Lane-specific information generation technology
- probe processing technology
- Data integration technology

a2) Examination and evaluation of lane-specific probe processing technology required for lane-specific information generation

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

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

Link with high-precision 3D map
- Position Reference Point (CRP) Installation
- Data generation based on lane-level position reference method

c Examination and verification of elemental technology using pre-reading information at quasi-dynamic level

Reflection on experiments and development ⇔ Feedback

b. Demonstration experiment

Proof of experiment plan →

1) Creation of node link maps at demonstration test sites

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

3) Demonstration experiment

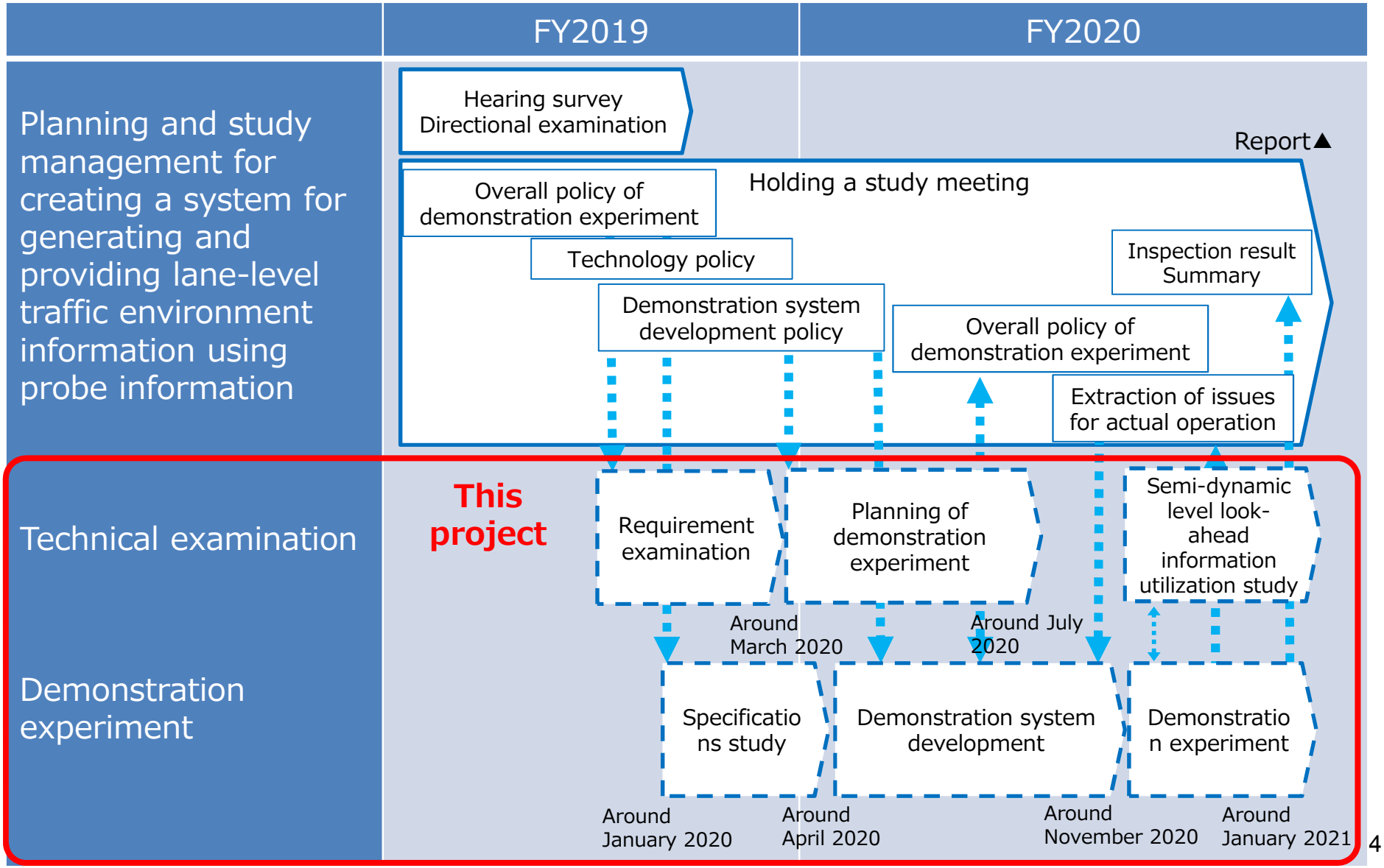
②Technical evaluation

- Lane-level road traffic information use case-based evaluation
- Evaluation of certainty of information content and position expression

※It is assumed that the main operation of the verification experiment will be handled by the verification experiment consortium.

1.2. Business summary

Implementation schedule of this research and development



2. Technical examination of each element

2.1. Study on technology to generate lane-specific information

- Targeting highways and motorways,
  - ① Statistical data of probes (travel speed by link, etc.) collected from vehicles of each company
  - ② Each piece of data that classifies falling object information, event regulation information, etc. by lane

  investigate a method to generate more lane-specific information.

- It should be noted that in this work, in order to aim for early commercialization, available data (meaning data obtained from already-sold vehicles that are not automated vehicles) will be used.

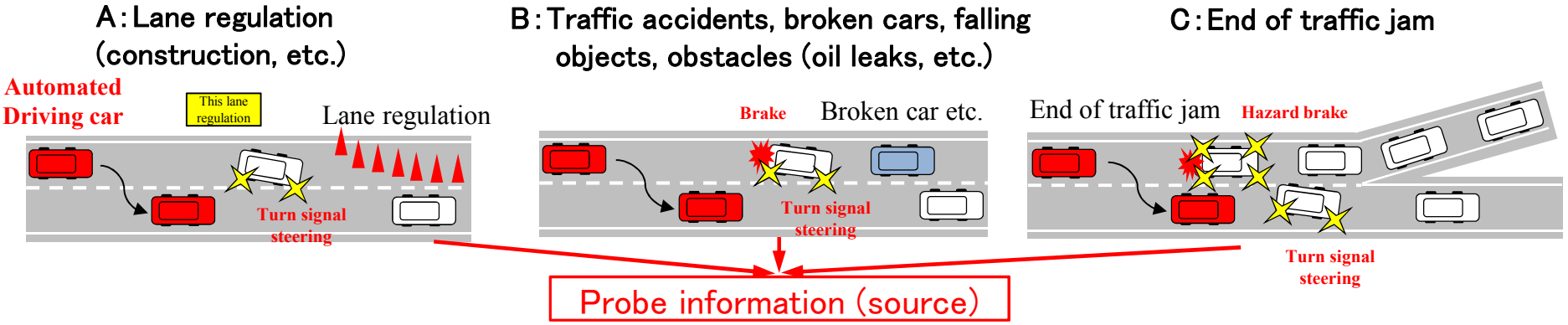
- In addition, in FY2019, a basic study was conducted on a method of generating lane-specific information. In addition, we conducted a hearing survey with probe providers regarding available data.

2.1. Study on technology to generate lane-specific information

2.1.1 Basic Study on Method of Generating Lane-Specific Information

(1) Target use case event and detection concept based on probe information

- There are three use cases in which autonomous vehicles utilize lane-level road traffic information.
- Depending on the use case, consider using available probe information to detect events.



Target use case and detection method of the event by probe information

Use Case	A: Lane regulation (construction, etc.)	B: Sudden event (traffic accident, broken car, falling object, obstacle (oil leakage, etc.))	C: Congestion end (congestion by direction, etc.)
Information obtained by automated vehicles	Road traffic information by lane * Semi-dynamic information (Every 1 minute)		
Lane level event detection method (Source)	● Frequent blinkers ● Frequent steering	● Frequent blinkers ● Frequent steering ● Frequent occurrence of brakes	● Position where the speed is reduced by lane-specific probes (direction at branch) ● Frequent occurrence of hazards and brakes ● Frequent blinkers and steering
Behavior of automated vehicles	Early avoidance (lane change, etc.)		Avoid early (lane change, etc.) or follow the end of traffic jam

2.1. Study on technology to generate lane-specific information

2.1.1 Basic Study on Method of Generating Lane-Specific Information

(2) Concept of generating road traffic information for each lane required for automated driving

- Depending on the use case, the available probe information is used properly to identify the event occurrence position (point where the lane change should be completed) and provide it to the automated vehicles.

Image of Road Traffic Information for Each Lane Provided to automated vehicles and Challenges

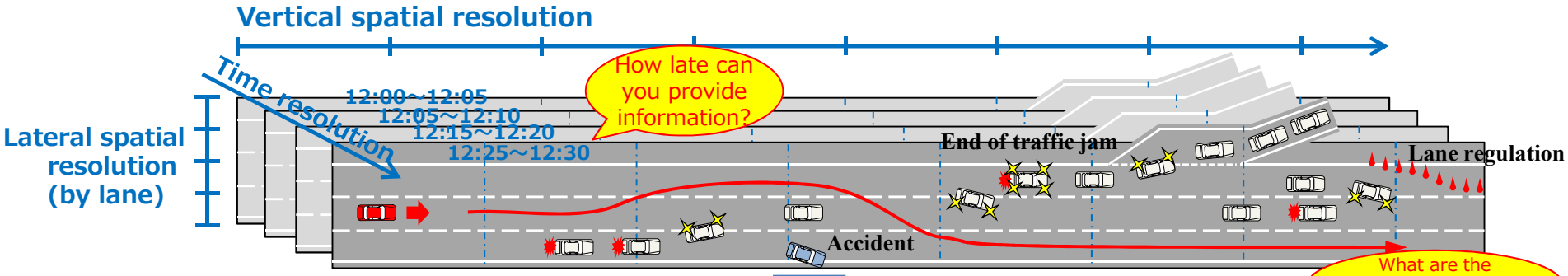


Image of collected probe information (by road)

Turn signal			Left frequent		Right frequent		Right frequent	
Brake		Frequent	Frequent		Frequent		Frequent	
Hazard		p13※1 See supplementary explanation		p13※2 See supplementary explanation	Frequent			
Steering			Left frequent		Right frequent		Right frequent	
Number of samples by velocity layer		Low speed zone generation	Low speed zone generation		Low speed zone generation		Low speed zone generation	
Speed by branching direction					Left slow down	Left slow down		

What resolution is effective as support information?

Image of generated road traffic information by lane — Data integration

Road traffic information by lane			Right lane obstacle		Left lane end of traffic jam		Left lane obstacle	

2.1. Study on technology to generate lane-specific information

2.1.1 Basic Study on Method of Generating Lane-Specific Information

(3) Pre-verification method of information generation method (draft)

○ Verification method using actual data

- Among the target use cases, lane regulations (construction, etc.) that can be understood in advance, and congestion caused by traffic lanes at Route No.1 Haneda Line inbound Hamasakibashi JCT verify accuracy.
- The occurrence status of the target event and vehicle behavior will be confirmed by CCTV video recording.

○ Verification method using dummy data

- It is desirable to verify the accuracy of the generated information based on the probe information that is actually acquired, but it is difficult to obtain 100m units of roadway-specific probes and turn signal information at an early stage, and the video recording used for verification is limited. Therefore, it is also used to create and verify dummy data by reproducing the use case event by traffic simulation and assuming the acquisition amount of probe information.
- In the verification, we will clarify the spatial variation of the place where the blinker is generated with respect to the lane obstacle, the amount of acquisition at 100 m intervals, etc., and the relationship with the number of samples by speed layer.

2.1. Study on technology to generate lane-specific information

2.1.1 Interview survey with probe providers

- In order to organize the data format and information items for the information from the vehicles that can be used, which is necessary for generating information by lane, we conducted a hearing survey with multiple probe providers.

<Hearing survey implementation period>

- Late February to early March 2019

<Survey method>

- Hearing sheet will be sent in advance and interview will be conducted on the day of the survey

<Hearing items for probe providers>

- Regarding cooperation in providing probe information in the desired data format for this project
- About cooperation of provision by online connection at the time of demonstration experiment
- Regarding costs, contract methods, adjustment items, etc., if you can cooperate with this effort

2.2. Examination and evaluation of lane-specific probe processing technology required for lane-specific information generation

2.1.1 Technical examination

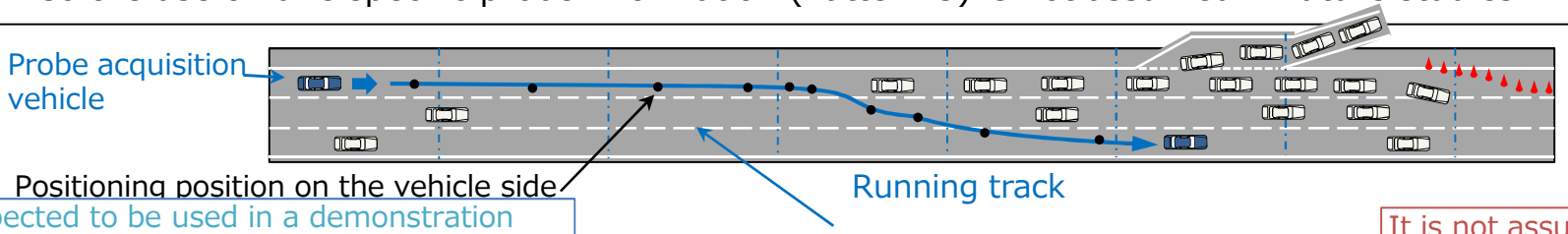
- Among the methods examined in 2.1, the probe processing technology will be examined for those that can be used for verification tests.
- In FY2019, the data format and information items of the available vehicle information necessary for the lane-specific information generation were organized.

2.2. Examination and evaluation of lane-specific probe processing technology required for lane-specific information generation

2.1.1 Technical examination

(1) Available probe information

- The probe data is generally spatially aggregated by link aggregation such as DRM.
- Although lane specific probe information (Pattern 3) is necessary to generate lane specific road traffic information needed for automatic driving, it is unlikely to be used in the demonstration tests in FY2020, so the use of lane specific probe information (Pattern 3) is not assumed in future studies.

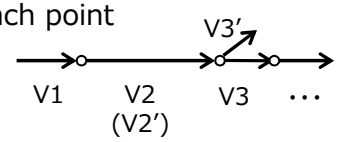


Expected to be used in a demonstration experiment in FY 2020 (some adjustments are being made)

It is not assumed that it will be used in a demonstration experiment in fiscal 2020.

<Pattern 1>

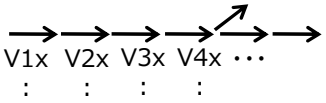
- Link speed by road (DRM link unit)
- Speed by direction in front link at branch point



- In the route direction, the average travel speed V is calculated for each DRM link
- The average link length of DRM is about 300m, but there are some that are extremely long, in which case the resolution of traffic condition determination based on the link travel speed decreases.
- If the link speed corresponding to the direction after branching at the branch front link can be obtained, it may be possible to analogize the speed for each lane corresponding to the branching direction.

<Pattern 2>

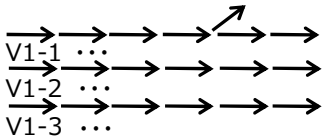
- Link speed by road (100m interval, etc.)
- Number of samples by velocity layer
- Turn signal, number of brakes, etc.



- The average travel speed V is calculated not at the DRM link but at 100m intervals along the route.
- Since the vertical resolution is constant, it is useful to identify the lane selection judgment position.
- By using it together with the number of winkers, it may be possible to infer the lane in which the obstacle is occurring (right or left).

<Pattern 3>

- Link speed by lane (100m interval, etc.)



- In Pattern 2 on the left, speeds are aggregated by lane
- Most desirable data format for generating traffic information by lane

Data format of probe information that is expected to be used to generate road traffic information by lane

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

2.3.1 Technical examination

- Regarding the statistical data of each company's lane probes, the statistical processing method to integrate as lane-specific information based on the difference in the number of probe data and accuracy, etc. is assumed and examined.
- In addition, when generating the lane-specific information by the above-mentioned integration processing, a method of referring to and utilizing data obtained by classifying falling object information and event regulation information by lane will be examined.
- In FY2019, we conducted a basic study on statistical processing methods for integrating statistical data of probes as lane-specific information.

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

2.3.1 Technical examination

(3) Basic study of statistical processing method integrated as road traffic information by lane

- In the future, based on this generation method (draft), it will be studied to improve the analogy accuracy of the obstacle occurrence position at the lane level by supplementing it with the number of speed stratified samples and the velocity information for each direction.

【※1 : Analogy of obstacle lanes due to the number of winkers, etc. and supplementation by the number of samples by speed layer】

Proposal of analogy method for lane-based information based on turn signal
From the turn signal occurrence information (direction of the turn signal), the position of the left and right lanes of the obstacle and the position of occurrence in the traveling direction are estimated. Considering the accuracy of analogy by considering the number of samples by velocity layer, which has a large amount of data

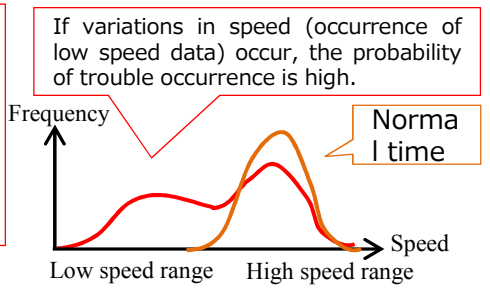
Occurrence information such as turn signal

Turn signal	number
Left turn signal	15 cases
Right turn signal	0 cases
Left steering	15 cases
Brake	9 cases

Example: Number of winkers, etc. during 5 minutes from 12:00 to 12:05

If there are many left turn signal vehicles etc., it is estimated that obstacles will occur in the front right lane

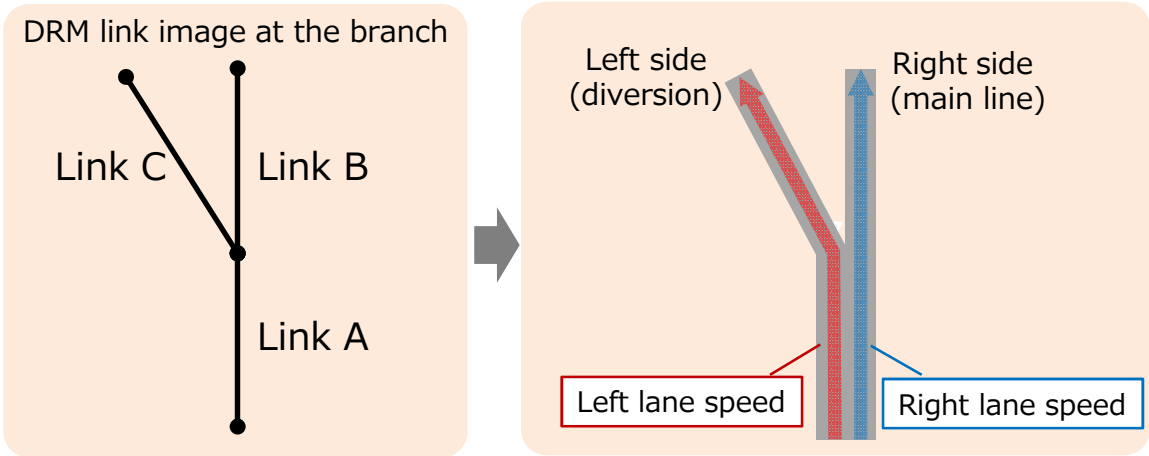
Distribution of sample numbers by velocity layer



Example: Number of samples by velocity layer for 5 minutes from 12:00 to 12:05

【※2 : Supplement for identifying the end position of traffic congestion by the direction-specific probe linked to the direction information at the branch destination】

Proposal of analogy method for lane-specific information
If further speeds by direction can be obtained with the front link at the branch point, each speed is used as the speed of the lane for each direction to reinforce the end of congestion judgment.
[Example]
- Average speed of link A for vehicles traveling from link A to link C
  =Left lane speed
- Average speed of link A for vehicles traveling from link A to link B
  =→Lane speed



2.4. Study and evaluation of lane information distribution technology

2.4.1 Technical examination

- Providing lane-specific information integrated in 2.3 to the vehicle participating in the experiment or a server that relays it (assuming that the telematics center of each automobile manufacturer will correspond to this relay server at the stage of social implementation in the future) Consider the technology.
- Specifically, we will examine the message format after examining the location reference method for superimposing lane-specific information on a high-precision three-dimensional map and the information items of lane-specific information provided according to the location. The examination will be based on other SIP measures and examinations conducted by other entities.
- After that, the position reference method, the description contents of the information items of the lane-specific information to be provided, the encoding format, and the like are examined, and the encoding method is embodied.
- In FY2019, A method for creating a no-drink map based on a position reference method for superimposing lane specific information on a high-precision three-dimensional map is studied.

3. Demonstration experiment

3.1 Examination of verification experiment implementation policy (draft)

- A verification experiment will be conducted to verify the technical examination and evaluation of each element of 2.
- In the verification test, the definition of the position reference method that represented the link maps of the Japan Digital Road Map Association (Hereinafter "DRM Association") and the Road Traffic Information and Communication Systems Center (Hereinafter "VICS Center") for each lane, and the SIP Phase 2 “Location reference in high-precision 3D maps” Two types of node link maps based on the definition of the position reference method based on the CRP setting specifications, which was examined in "Survey and examination of the way of points (CRP)", are used for verification tests (Metropolitan Expressway Bayshore Route (Daiba-Haneda Airport IC) and Route No.1 Haneda Line (Shiodome-Airport West IC)) and make a demonstration test.
- As for the collection of fallen objects in the section, the existing system is in operation, so another system will be separately developed and necessary personnel will be allocated for the experiment so as not to affect the existing system.
- In FY2019, the outline implementation policy of the demonstration experiment was examined.

3.1 Examination of verification experiment implementation policy (draft)

- The results of the examination of the proposed implementation policy regarding the demonstration experiment scheduled to be implemented between October and December 2020 are shown below.

<Content of implementation>

- In the demonstration test, data will be collected from the probe providers, and road traffic information at the lane level will be actually distributed to the participating vehicles.

<Preconditions>

- Period: From October to December 25 (Friday)
- Experiment participants: 15 companies (highway experiment participants)

<Matters that require detailed examination in the future>

- Implementation content
  - Verify the reliability / effectiveness of information
  - It is carried out separately by the trustee side (information reliability evaluation) and by the experiment participants running (information effectiveness evaluation).

3.1 Examination of verification experiment implementation policy (draft)

<Image of technology evaluation in the demonstration experiment>

- The evaluation in the demonstration experiment is performed from the two viewpoints of reliability of generated information and effectiveness of information.
- Since the occurrence of a sudden event cannot be foreseen in advance, evaluations involving the running of the vehicles participating in the experiment will be performed at Route No.1 Haneda Line inbound Hamasakibashi JCT, where traffic congestion by lane can be foreseen.

Evaluation frame for proof experiment (draft)

Division	Evaluation index	Evaluation method / use data, etc.	Target use case event (implementation location)	Implementation period
Information reliability → Conducted by trustee	● Reliability of obstacle lane judgment ● Information reproduction delay time	● CCTV image, in-vehicle camera image ● Collation with event occurrence record	Lane regulation (regulation enforcement point) Sudden event (location of occurrence) End of traffic jam (congestion by lane of Hamasakibashi JCT)	Early October About 3 days * Assuming system adjustments each time, discontinuous 3 days are assumed
Effectiveness of information (safety of autonomous driving) → Driving by the test participants	● Appropriateness of information granularity ● Effectiveness for avoiding obstacle lanes (changing lanes)	● Experiment participant opinions (questionnaire)	End of traffic jam (congestion by lane of Hamasakibashi JCT) Assessing lane restrictions and sudden events based on driving at Hamasakibashi JCT Note 1)	**1st time: Late October About 3 days ↓ Note 2) Second time: late November About 3 days**

Note 1) If the participants are allowed to drive during the lane regulation hours (mainly at night), lane regulation evaluation is also assumed.

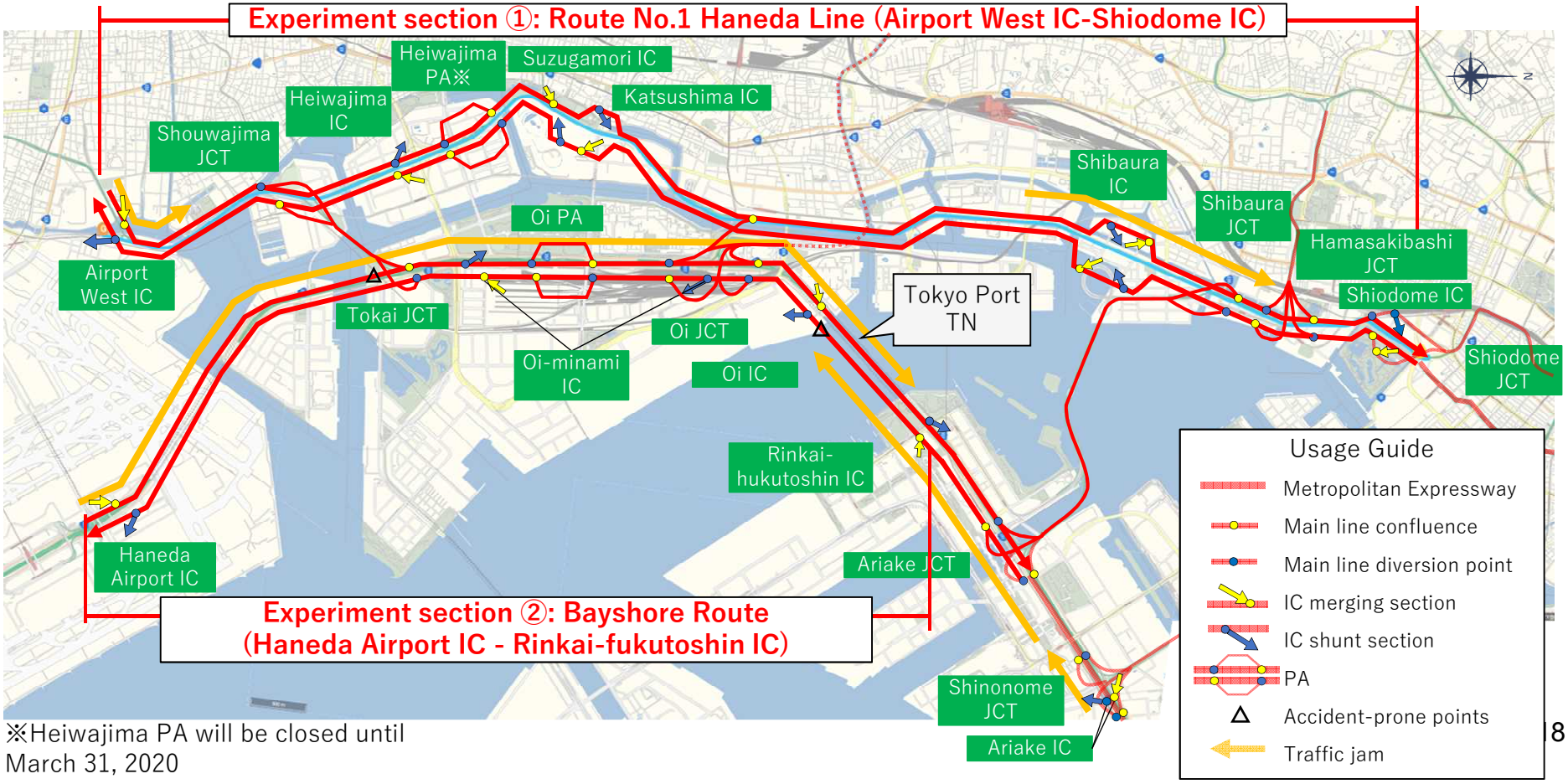
Note 2) It is assumed that the evaluation by the test participants' running will be divided into two parts so that it can be carried out again after the experimental method has been modified and the system has been adjusted based on the opinion of the questionnaire. The number of implementation days will be determined based on future coordination with the probe provision business.

3.1 Examination of verification experiment implementation policy (draft)

<Target section of demonstration experiment>

- The sections subject to the demonstration test are the two sections of the Metropolitan Expressway ① Haneda Line (Airport West IC - Shiodome IC) and ② Bayshore Route (Haneda Airport IC - Rinkai-fukutoshin IC)
- Demonstration tests will be conducted within this section

Location map of target section



※Heiwajima PA will be closed until March 31, 2020

3.1 Examination of verification experiment implementation policy (draft)

<Image of experimental system configuration>

- In the demonstration test, an experimental system will be constructed, and information will be distributed to the participating vehicles by connecting to the probe provider and the system of the Tokyo coastal area demonstration experiment consortium.