TF3-20-182Ⅲ6

Outline and analysis result of the FOTs in the Tokyo Waterfront area

MITSUBISHI ELECTRIC CORPORATION
YOSHIAKI TSUDA

10th,November,2020

SIP Cabinet Office

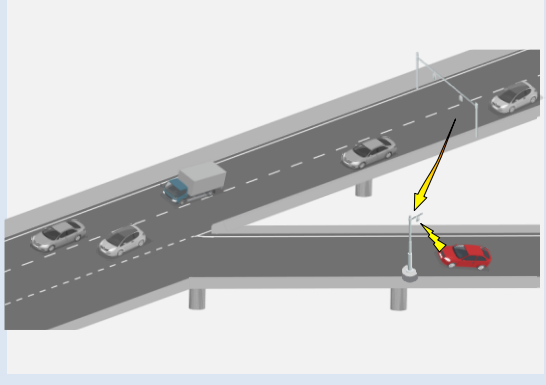
1. Overview of the FOTs in the Tokyo Waterfront area

(1) Implementation contents for each testing area

Transmitting traffic signal information to **implement advanced automated driving on ordinary roads**

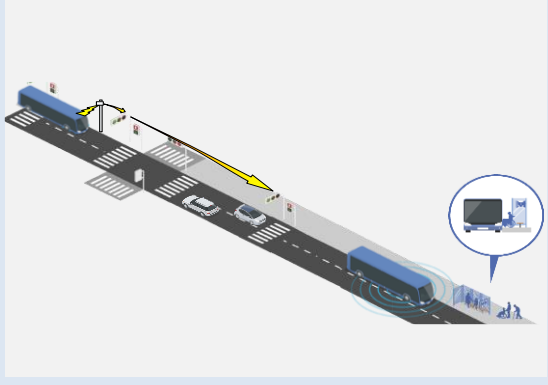
① Waterfront City Area
③ Haneda Airport area

Transmitting driving support information and lane-level traffic environment information to **implement advanced automated driving on highways**



②Expressway routes connecting Haneda Airport and the Waterfront City, etc.

Defining ODDs and using infrastructure facilities such as advanced PTPS in mixed traffic environments to **implement ART using automated driving technology**

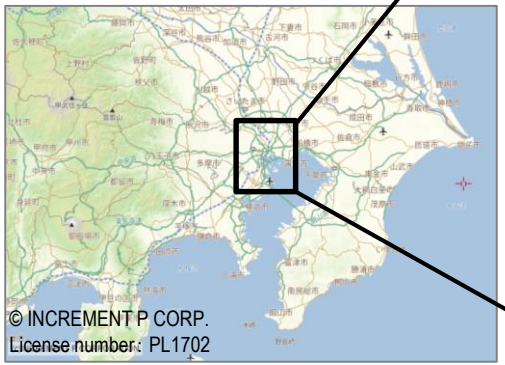


③Haneda Airport area

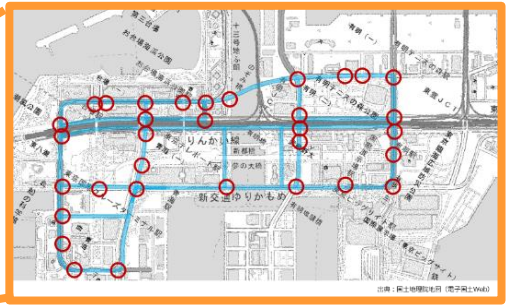
1. Overview of the FOTs in the Tokyo Waterfront area

(2) Testing areas

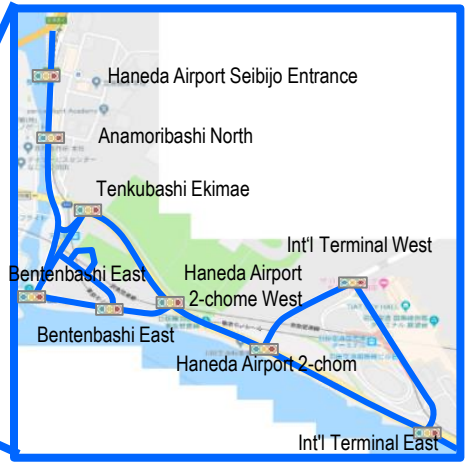
② Expressway routes connecting Haneda Airport and the Waterfront City, etc.



① Waterfront City Area



③ Haneda Airport area



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1. Overview of the FOTs in the Tokyo Waterfront area

(3) Organization of the FOTs in the Tokyo Waterfront area WG

Cabinet Office /
New Energy and Industrial Technology Development Organization(NEDO)

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FOTs in the Tokyo Waterfront area TF

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FOTs in the Tokyo Waterfront area WG

FOTs in the Tokyo Waterfront Area Consortium＊

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FOTs Participants

FOTs in the Tokyo Waterfront Area Consortium

Mitsubishi Electric Corporation (representative)

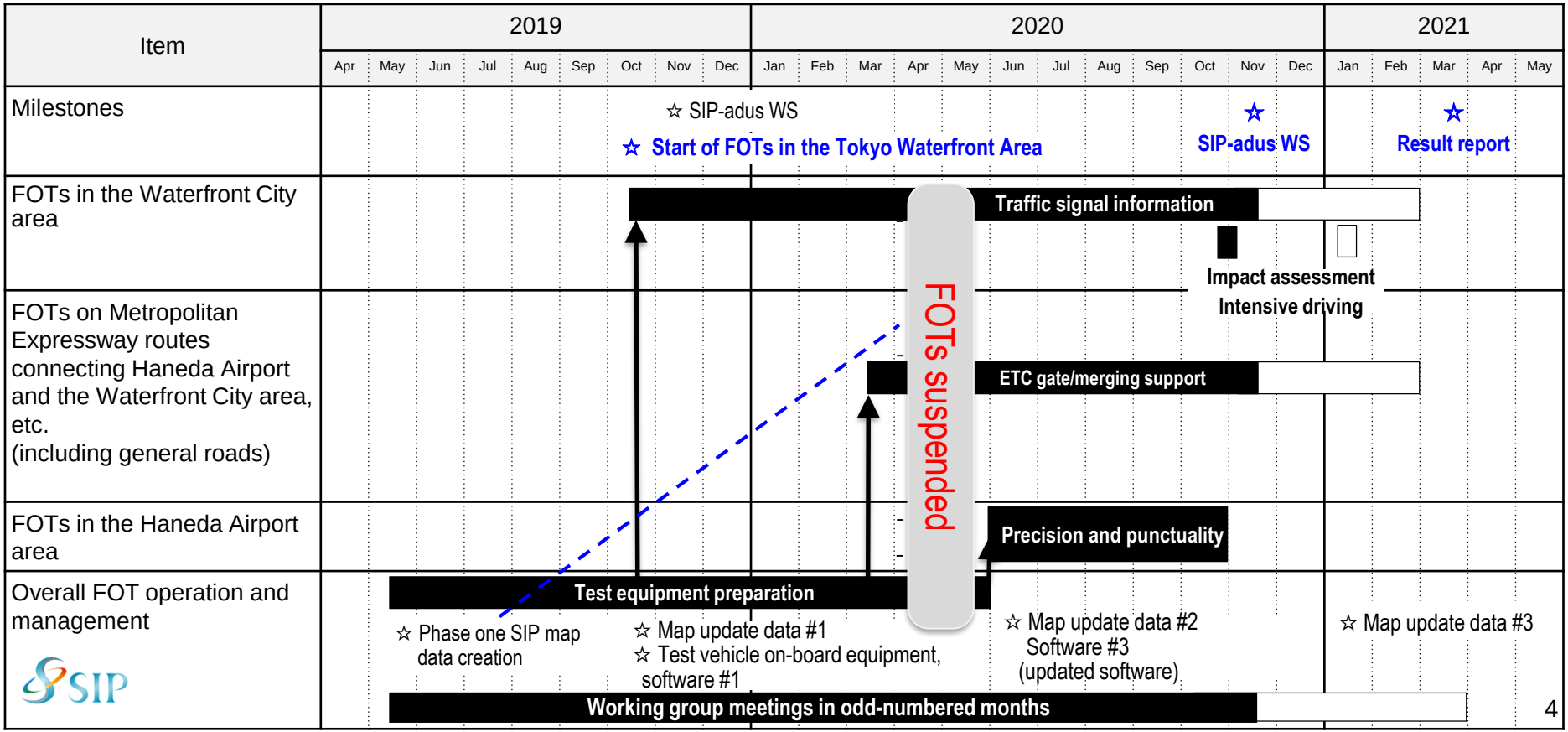
Aisan Technology Co., Lt
Increment P Corporation
Toyota Mapmaster Incorporated
Pacific Consultants Co., Ltd.
Zenrin Co., Ltd.
Pasco Corporation
Nippon Koei Co., Ltd.
Sumitomo Electric Industries, Ltd.

Stakeholders of the FOTs

	JPN	Overseas
OEMs	9	4
Overseas	3	2
Universities	5	—
Others	4	2
Total	29 parties	

1. Overview of the FOTs in the Tokyo Waterfront area

(4) FOTs in the Tokyo Waterfront area schedule



2. Contents of tests performed in each area

(1) Waterfront City area

Issues

- **Ensure reliability of signal recognition by vehicle**
- **Presence of dilemma zones* interfering with smooth traffic flow**

Hypotheses regarding effectiveness of cooperative infrastructure technologies

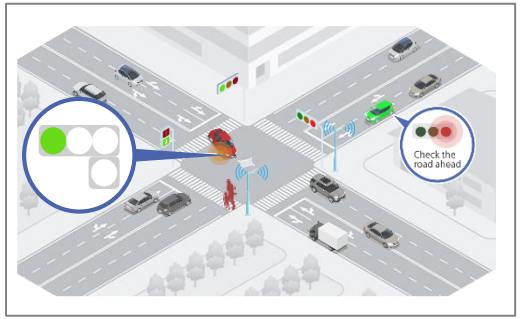
- Recognition improved by use of dual information systems
- Avoidance of dilemma zones* through use of predictive traffic signal information (number of remaining seconds)

Verification items

- Infrastructure information effectiveness and conditions for traffic signal intersections
  - Confirmation of received data Confirmation of traffic signal state information
  - Comparison of vehicle driving status and traffic signal information
  - Confirmation of traffic signal and route information, etc., at each location
- Assessment of impact of autonomous vehicle driving on traffic flow and factors causing this impact
  - Verification of safety and acceptability of dilemma avoidance model
  - Comparison of vehicle driving status and traffic signal information

Target

- **Verify effectiveness of distributing traffic signal information**
- **Confirm specifications aimed at standardization and consensus by test participants**
- **Identify environmental conditions required for traffic signal information distribution**
- **Clarify issues to be addressed in order to cultivate a sense of acceptability in society**



Dilemma zone definition
Region in which, when the traffic light turns yellow, the vehicle would not be capable of stopping before the stop line when decelerating at the normal deceleration rate but the vehicle would not be able to traverse the intersection (stop line) while the traffic light was still yellow if maintaining the same pace

2. Contents of tests performed in each area

(2) Metropolitan Expressway routes connecting Haneda Airport and the Waterfront City area, etc.

Issues

- **Smooth expressway gate pass support**
- **Main roadway merging support based on actual main roadway vehicle speeds**

Hypotheses regarding effectiveness of cooperative infrastructure technologies

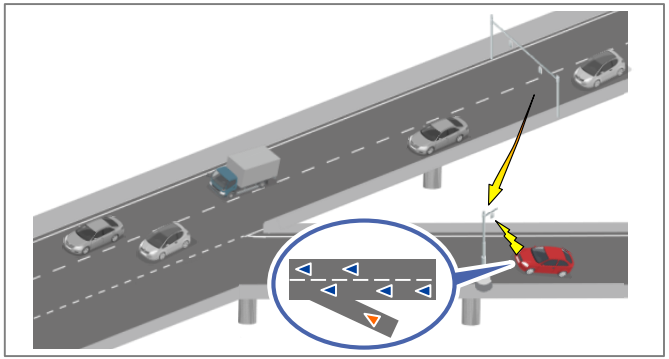
- Support gate selection and passing by providing information
- Support adjustment of vehicles speeds in order to merge into main roadways by providing information

Verification items

- Appropriateness of operation of cooperative infrastructure system
  - Confirmation of the data received from roadside unit for expressway experiments and the data output to vehicle control
  - Measurement of transmission time between roadside unit for expressway experiments and test vehicle on-board equipment
- Effectiveness of provision of support information to autonomous vehicles, etc.
  - Presence/absence of expressway gate passing support information/merging support information and confirmation
  - Confirmation of automated driving using merging support information
- Impact on ordinary vehicles (assessment)
  - Confirmation of automated driving using expressway gate passing support information

Target

- **Consider infrastructure specification improvements**
- **Identify infrastructure installation conditions for airport west exit/entrance**
- **Clarify issues in order to define specifications based on FOT**
- **Identify infrastructure need and prioritization requirements**



2. Contents of tests performed in each area

(3) Haneda Airport area

Issues

- **Clarification of environment conditions required for practical implementation of level 4 ART in mixed transportation environments**

Verification items

- Analysis of factors necessitating driver involvement in mixed transportation environments
- Effectiveness of cooperative infrastructure in regularly scheduled transport
- Comfort when boarding/exiting
- Assessment of impact of autonomous vehicle driving on traffic flow, and factors causing this impact

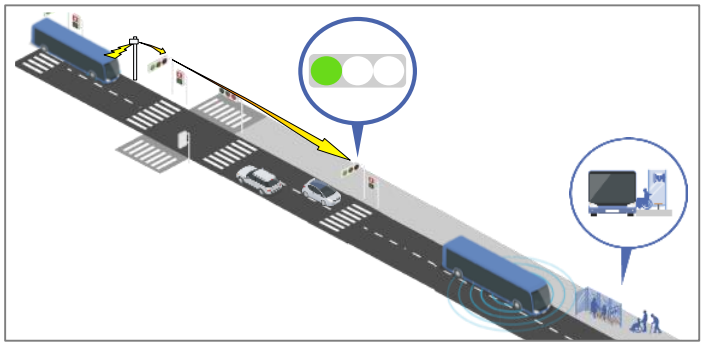
ODD：Operational Design Domain
ART：Advanced Rapid Transit

Hypotheses regarding effectiveness of cooperative infrastructure technologies

- Implement automated driving which does not require driver involvement
- Implement regularly scheduled transport
- Improve comfort
  (Bus stop curb docking, gradual acceleration and braking)

Target

- **Clarification of which infrastructure is required for expansion of ODD**
- **Identify what infrastructure conditions are required for the improvement of ART service**
- **Clarify issues to be addressed in order to cultivate a sense of acceptability in society**



2. Contents of tests performed in each area

(4) Confirmation of social acceptability (Impact assessment)

Issues

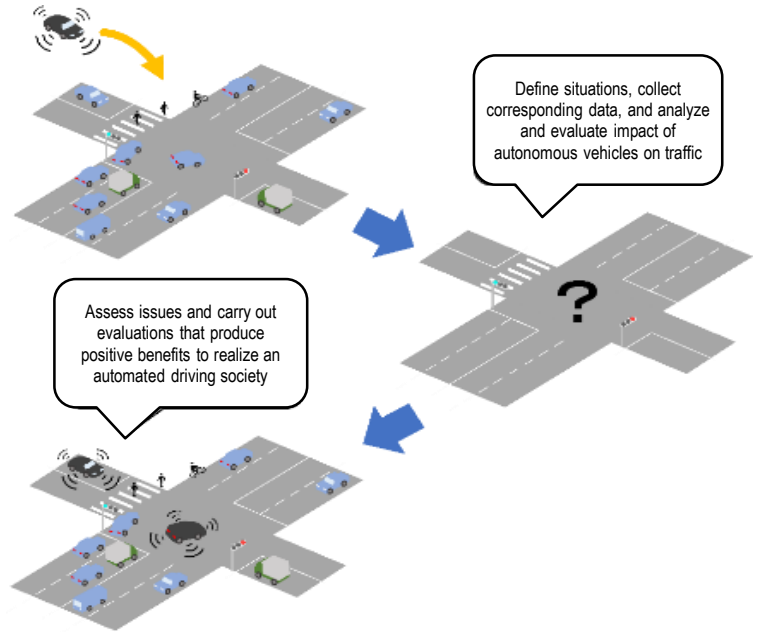
- **Assessment of impact of autonomous vehicles on surrounding environment (ordinary vehicles, crosswalk pedestrians, etc.)**

Verification items

- Evaluation approach
  - Define situations in which autonomous vehicles driving in actual roadway traffic environments influence traffic, collect information about these situations, and analyze situations when autonomous vehicles are in actual roadway traffic environments and when they are not
- Areas of focus in evaluations
  - When autonomous vehicle are in traffic
    - ✓ Whether traffic flows as normal
    - ✓ Whether the environment is safer than normal
    - ✓ Whether the flow of traffic gets better/worse
    - ✓ Whether there are changes in the behavior of vehicles near the autonomous vehicle
  - When encountering pedestrians/bicycles at intersections, etc.
    - ✓ Whether traffic flows as normal, etc.

Target

- **Assess evaluations and points to note as automated driving gradually becomes more prevalent in society**

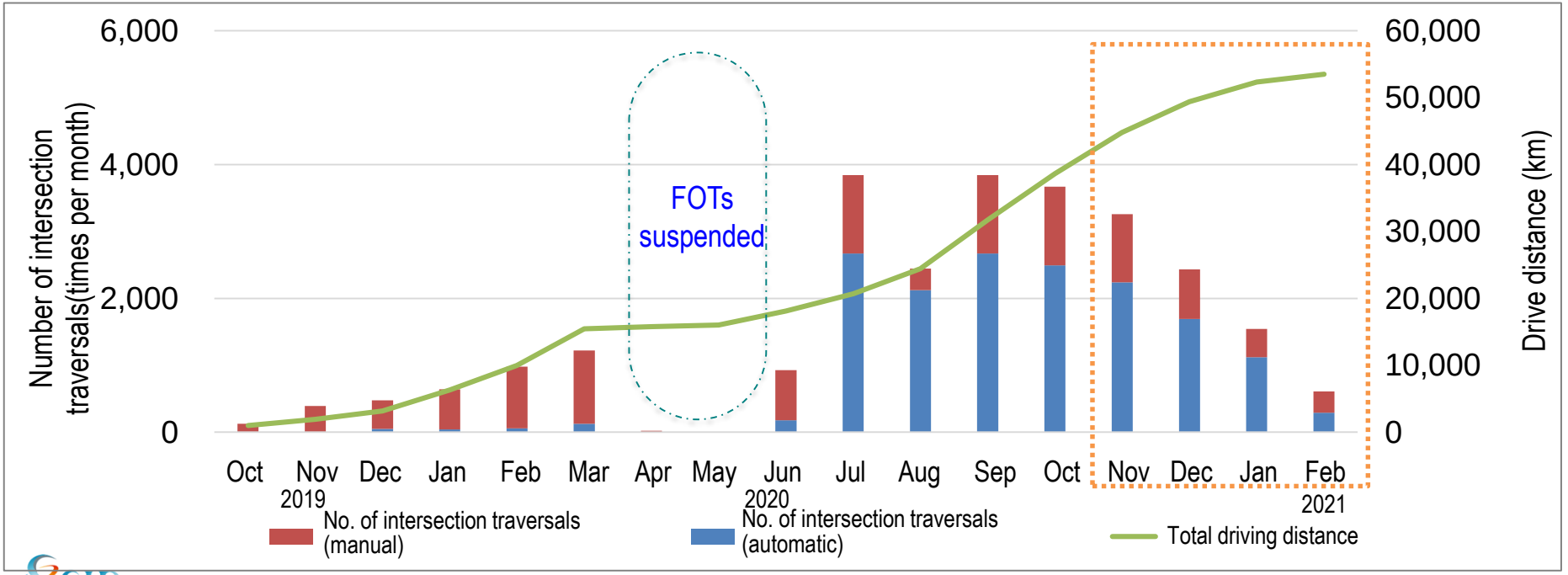


3. Test participant submission data, analysis results, and forecasts

(1) Total distance driven by test participants

October 15, 2019, to October 31, 2020 (approx. 12 months)
: Approx. **40,259km** (figures collected via movement management system)

Estimated from driving plans
: Approx. 54,000 km expected (by end of February 2021)



Driving results to date + future driving expectations (as of September 30, 2020)

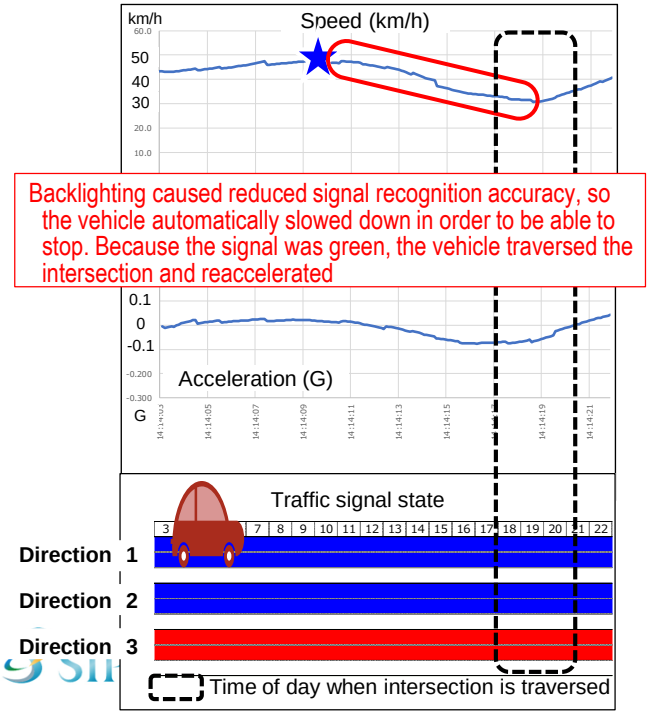
3. Test participant submission data, analysis results, and forecasts

(2) Waterfront City area: Evaluation by test participants

a. Effectiveness of infrastructure traffic signal information in automated driving
(Reduces the impact when it is difficult to judge the color of a traffic light)

Expected output
Even when vehicle sensor recognition rates decline, traffic signal information can be used to traverse intersections

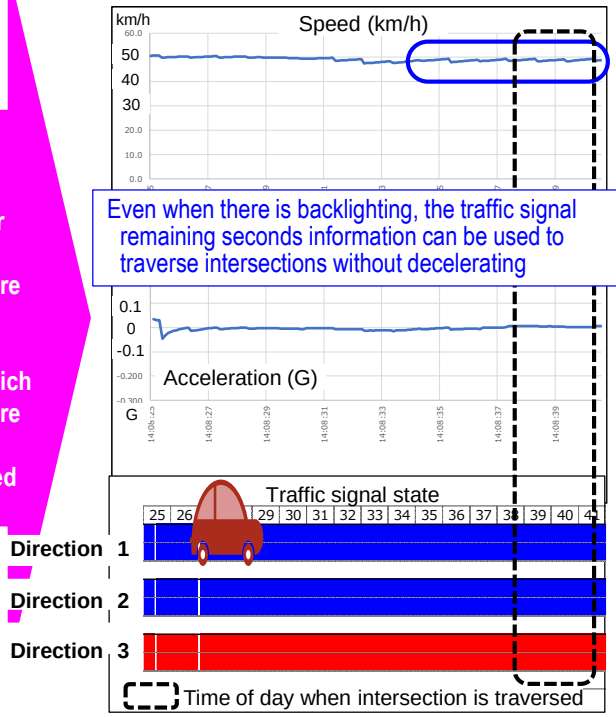
When not using infrastructure information (actual measurement data)



Backlighting caused reduced signal recognition accuracy, so the vehicle automatically slowed down in order to be able to stop. Because the signal was green, the vehicle traversed the intersection and reaccelerated

Changes in vehicle behavior for use of infrastructure information based on cases in which infrastructure information was not used

When using infrastructure information (actual measurement data)



Even when there is backlighting, the traffic signal remaining seconds information can be used to traverse intersections without decelerating

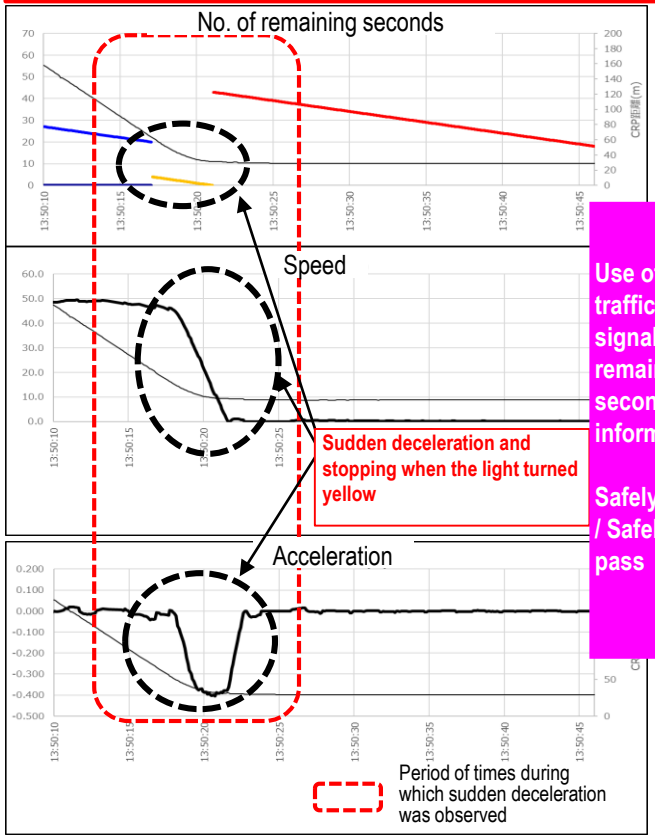
On-board camera image (with backlighting)

On-board camera image (without backlighting)

3. Test participant submission data, analysis results, and forecasts

b. Effectiveness of predictive traffic signal information (number of remaining seconds)

Cases of sudden deceleration and stopping in traversal area

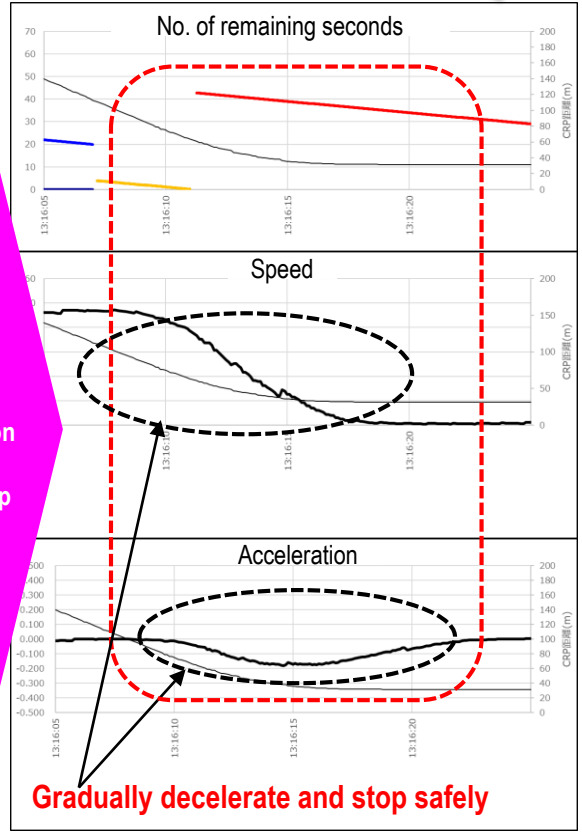


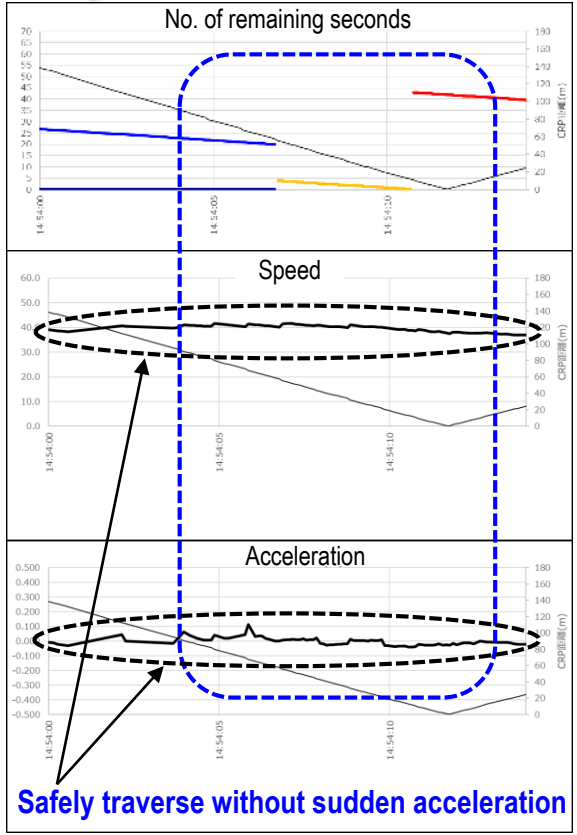
Use of traffic signal remaining seconds information

Safely stop / Safely pass

Use of traffic signal remaining seconds information for vehicle control (actual measurement data)

Stopping determined possible in advance ⟷ **Traversal** determined possible in advance

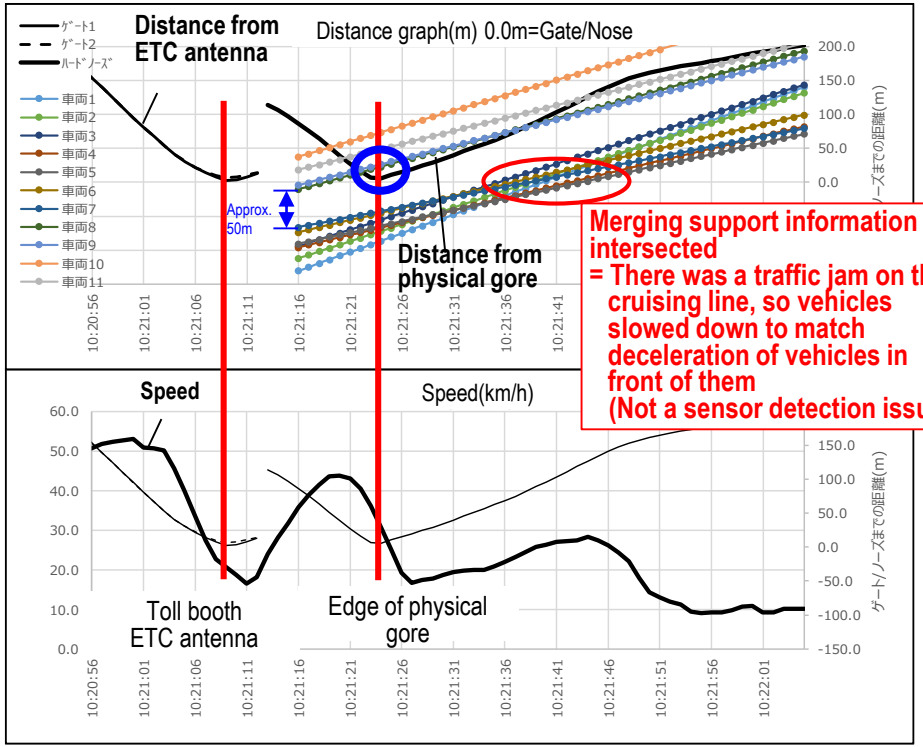


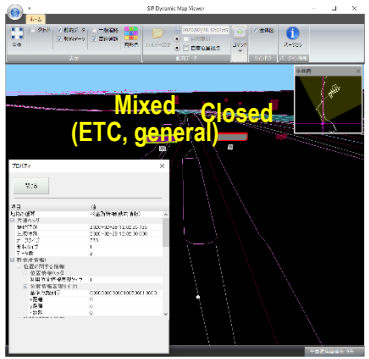


3. Test participant submission data, analysis results, and forecasts

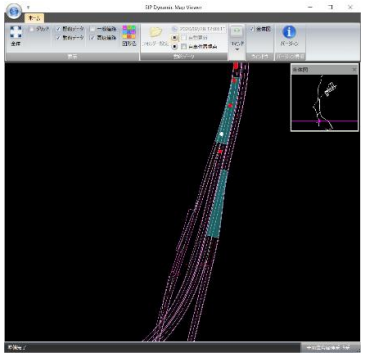
(3) Metropolitan Expressway

Example of data provided by infrastructure and vehicle behavior





ETC gate passing support information
(comparison of viewer display and test video data recording device image)
Feb 28, 2020 12:02:49



Merging support information
(comparison of viewer display and test video data recording device image)
Feb 28, 2020 12:03:11

SIP [Findings]
- Merging support information received and vehicle merging into cruising line vehicle gap
- Cruising line vehicles driving at low speed, approx. 20 to 30 km/h after cruising line merging

3. Test participant submission data, analysis results, and forecasts

(4) Haneda Airport area

① Evaluation approach

Use driving data obtained from the Haneda Airport FOTs to evaluate the feasibility, arrival speed, punctuality, comfort, etc., of automated driving using the cooperative infrastructure automated driving ART system

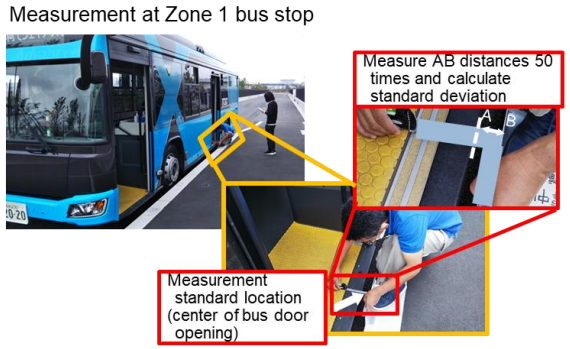
Evaluation perspectives

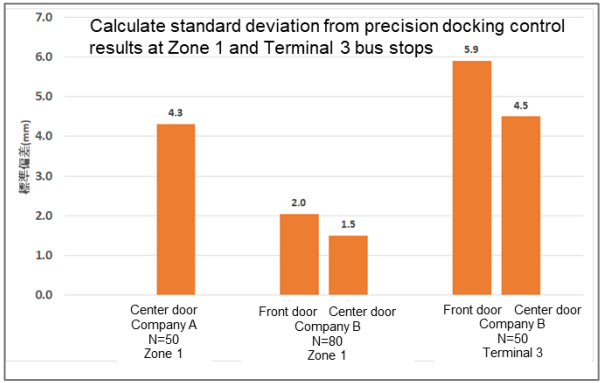
1. Was automated driving possible in mixed transportation environments?
2. Did arrival speed and punctuality improve?
3. Was automated driving comfortable?
   * Were stopping and acceleration gradual?
   * Was precision docking at bus stops achieved with a high level of reproducibility?

Consider the following regarding the cooperative infrastructure automated driving ART system
* Effectiveness * Effective conditions * Infrastructure operation issues * Approach, etc.

② Evaluation of reproducibility of precision docking control

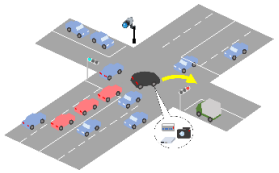
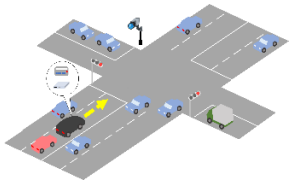
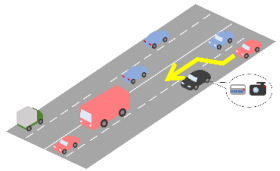
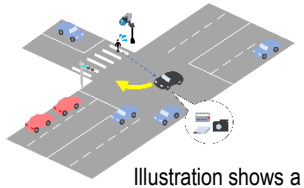
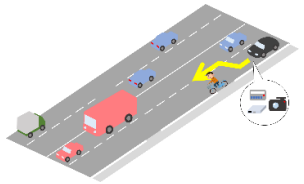
- Confirm degree of autonomous bus precision docking control reproducibility based on standard deviation between bus stop and bus when using precision docking control





3. Test participant submission data, analysis results, and forecasts

(5) Impact assessment

	① Impact and issues in mixed transportation environments			② Evaluation of impact on and issues related to pedestrians, etc.
Evaluation item	①-1 Processing evaluation (Right turn/Left turn)	①-2 Vehicle behavior (Red light stop)	①-3 Vehicle behavior (Behavior when cutting in occurs and driving straight)	②-1 Handling of pedestrians (Right turn/Left turn/Straight)
Evaluation points	• Changes in no. of vehicles processed and processing time • Differences from ordinary vehicles when turning right when there are oncoming vehicles driving straight • Congestion with following vehicles • Contribution to safe/smooth traffic flow	• Changes in the behavior of vehicles near the autonomous vehicle • Contribution to safe and smooth traffic flow	• Sudden braking, cutting in, or passing when there are autonomous vehicles, and the causes of this behavior	• Behavior of pedestrians, encountered vehicles, and following vehicles when encountering pedestrians • Contributions to safe driving when autonomous vehicle are in traffic • Impact of presence of bicycles on surrounding vehicles • Impact on following vehicles when encountering bicycles
Conceptual image	 Illustration shows a right turn situation			 Illustration shows a right turn situation 

Collect, analyze, and evaluate data for traffic consisting only of ordinary vehicles and traffic which includes autonomous vehicles

4. Experiment implementation status

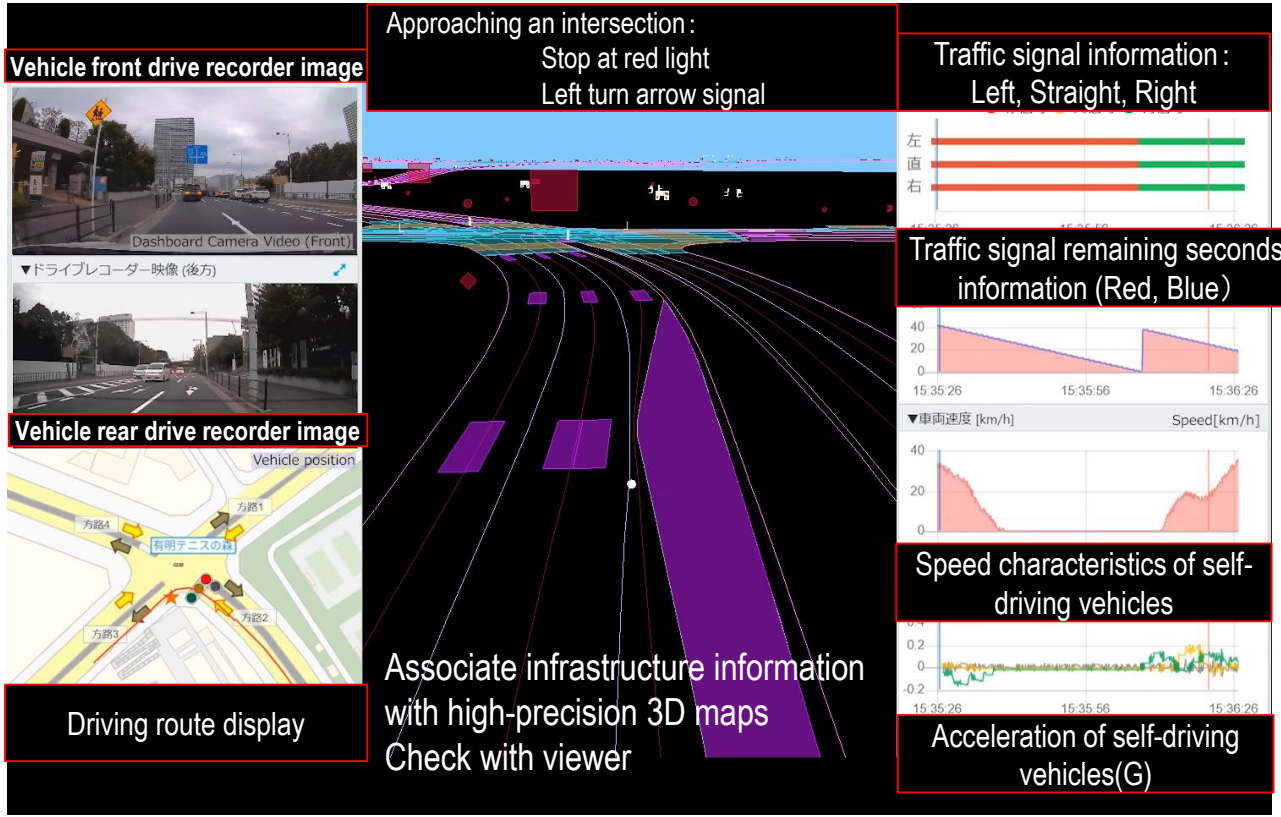
◆ Waterfront City Area: Vehicle running status

Evaluation item		Evaluation item	Intersection no.	Name of intersection
Processing evaluation	Right turn	①-1	25	Aomi 1-chome
			26	Tokyo Big Sight-mae
			C	Ariake Coliseum East
	Left turn		10	Telecom Center-mae
			25	Aomi 1-chome
			26	Tokyo Big Sight-mae
			C	Ariake Coliseum East
Handling of pedestrians	Right turn	②-1 ②-2	26	Tokyo Big Sight-mae
	Left turn		10	Telecom Center-mae
			25	Aomi 1-chome
			26	Tokyo Big Sight-mae
			C	Ariake Coliseum-mae
	Straight		A	Aomi 2-chome
Vehicle behavior	Red light stop	①-2	5	Daiba Ekimae
			21	Tokyo Big Sight Front Entrance
	Behavior when cutting in occurs	①-3	–	(Evaluate with the video of the drive recorder)
	Behavior when driving straight	①-3	B	Ariake 3-chome

※FLECT CO., LTD. Real-time vehicle management system “Cariot”

4. Experiment implementation status

◆ Waterfront City Area：Experimental status of signal information effectiveness



4. Experiment implementation status

◆ Waterfront City Area : Experimental status of Impact assessment

Fixed point camera image

Location information

Traffic signal information

Traffic signal remaining seconds information

Vehicle speed

Vehicle acceleration

Telecom Center-mae intersection: Two self-driving vehicles turn left

Thank you