Cross-ministerial Strategic Innovation Promotion Program (SIP)
Automated Driving System / Large Scale Field Operation Test

Next Generation Transportation

ART operational data aggregation and storage of operation, construction of mechanism for providing information to ART users, and implementation and management of large scale field operation test

FY 2017 Annual Report (Summary)

Hitachi, Ltd., Pacific Consultants Co., Ltd.
and The Institute of Behavioral Sciences

1．Backgrounds, Goals and Intents

【Goal】Next Generation Transportation

We realized followings by appealing effectiveness of PTPS (Public Transportation Priority System) that improves speediness of ART (Advanced Rapid Transit) and the pedestrian support system in their field operational test.

- Promoting of social receptivity towards social implementation of Next step ART technologies
- Improving convenience and accessibility (physical and information) for realizing public transportation for wide range of users including the elderly and people with disabilities, and promoting the conversion from other transportations

【Achievements】

a. ART operational data aggregation and storage, and construction of mechanism for providing information to ART users

① Development and feasibility study on ART Information Center
② Field operational test of improving the speediness of ART with advanced PTPS
③ Investigation of measures of traffic congestion forecasting and guiding to avoid congestion, Demonstrative experiment
④ Pedestrian Transfer Support System

c. Management of large scale field operational test

① Organizing large scale field operational test
② Organizing the achievement experience session for stakeholders
③ Development and feasibility study on ART Information Center
④ Field operational test of improving the speediness of ART with advanced PTPS
⑤ Pedestrian Transfer Support System

2．Milestones and Goals

「a. ART operational data aggregation and storage, and construction of mechanism for providing information to ART users」

Item	Goal
①Development and feasibility study on ART Information Center	<Milestones> Complete the optimization of the priority mediation information (adjustment of the priority mediation parameter) providing from the ART information center to the PTPS on-board equipment and verification of the service function (API and application) provided for large scale field operational test (in FY2018)
	<Goals> Perform the following effectiveness evaluation on the PTPS priority mediation support function and service functions (API and application) provided for large-scale feasibility study, and show the usefulness of data collected and provided by the ART information center • ART speediness improvement by Advanced PTPS • Promotion of bus (ART) by providing connection guidance service • Provide user information such as bus crowdedness and on / off boarding
②Field operational test of improving the speediness of ART with advanced PTPS	<Milestones> • Complete the development of the Advanced PTPS on-board equipment • Verify its performance from the technical point of view by a preliminary test • Complete planning of the field operational test of FY2018
	<Goals> • Confirm effectiveness and technical feasibility of Advanced PTPS through the field operational test. • Extract technical and practical issues in implementing Advanced PTPS in a bus route.

2．Milestones and Goals

「a. ART operational data aggregation and storage, and construction of mechanism for providing information to ART users 」

Item	Goal
③Investigation of measures of traffic congestion forecasting and guiding to avoid congestion, Demonstrative experiment	<Milestones> ・Considering case examples of measures of traffic congestion forecasting and guiding to avoid traffic congestion, experimental survey will be conducted to estimate effects of measures to avoid congestion. ・Based on the results, traffic condition during a large event will be simulated. ・Based on these knowledge, draft plan of demonstrative experiment will be drawn up.
	<Goals> Based on the results of demonstrative experiment, effective measures guiding to avoid traffic congestion will be developed.
④Pedestrian Transfer Support System	<Milestones> For large scale field operational test , we prototype walking route collection application and information posting application, and collected GPS track information and barrier free information. Based on these information and on-site survey, we develop walking network data.
	<Goals> Through the large scale field operation test, we evaluate the effectiveness and acceptability (easy to understanding delivery method and information presentation to users' smartphone) of pedestrian transfer support system.

2．Milestones and Goals

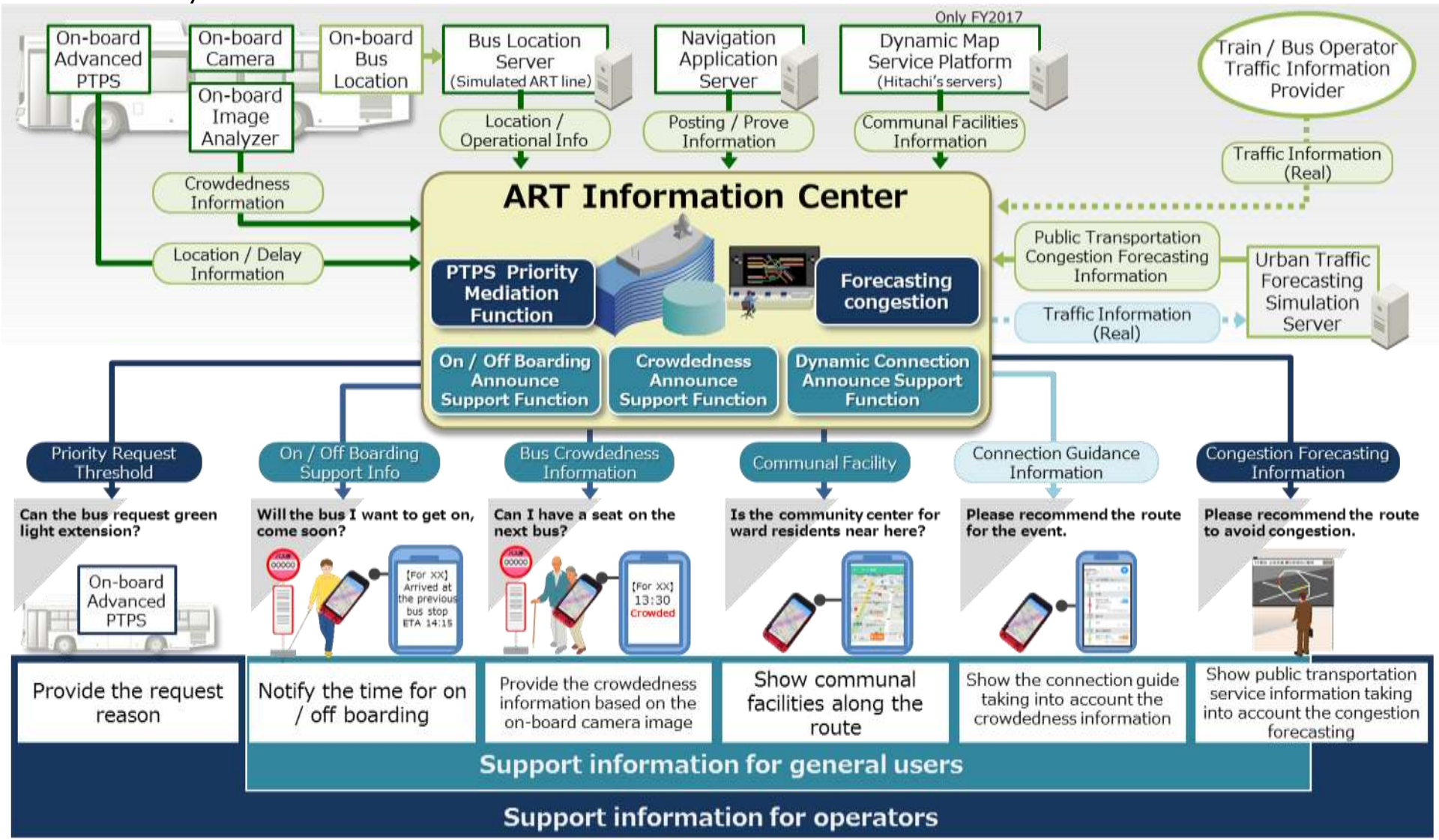
「c. Management of Field Operational Test」

Goals
<Milestones> ・Support various arrangements including equipment procurement, planning, and stakeholder arrangement to conduct the field operational test and the demonstration event in FY 2018.
<Goals> ・Complete the field operational test and the demonstration event at the Tokyo bay area without traffic accident. ・Raise people’s awareness of ART for fostering social acceptability through the test and the demonstration.

3． Achievement

Item a① Development and verification of ART information center

- The ART information center receives and stores in-vehicle crowdedness information, and provides necessary information to the user



3． Achievement

Item a① Development and verification of ART information center

Item		FY 2017
ART Information Center function	**Data receiving / publishing infrastructure**	①Define the data format and communication method for exchanging data with multiple cooperation partners and create usage guide ②Provide API and develop the operating environment ③Verify basic operations with each partner
Bus operation support / user support function	**Advanced PTPS priority mediation support function**	①Design range of priority setting and implementation method (decision logic) ②Verify the decision logic and ART information center cooperation using PTPS roadside unit in Daiba
	On / Off boarding guidance support function	①Consider input-output information and prototyping ②Prototype on / off boarding guidance API and verify on smartphone sample screen
	Dynamic connection guidance support function	①Design the input-output information and function for traffic forecasting simulation ②Confirm data acquisition by designing cooperation method and prototyping
	Bus information provision such as crowdedness	①Prototype the image analysis on-board device and consider camera position and number (analyze images of passenger on / off boarding in bus) ②Prototype the bus crowdedness notification API and verify on smartphone sample screen
Cooperation with Dynamic Map Service Platform (DM-SPF) [Other SIP project]		①Consider cooperation with information providing service function for the personal navigation ②Confirm the communal facility information stored in ART Information Center by prototyped function
Basic business investigation		①Consider information to be stored in ART Information Center

3． Achievement

Item a① Development and verification of ART information center

➢ Bus crowdedness information: Videoing for analysis

・Take videos about on / off boarding of cooperative passengers in 22 scenarios that are assumed 4 step predefined crowdedness

◆Date and Time: From 12:30 to 16:00,
Thursday January 25, 2018

◆Place: Keisei Bus Co., Ltd. Shintoshin Business Office

◆Bus: 1 Non-step type large route bus

◆Experiment Cooperator: 34 persons

◆Data handled by on-board image analysis device (extraction)

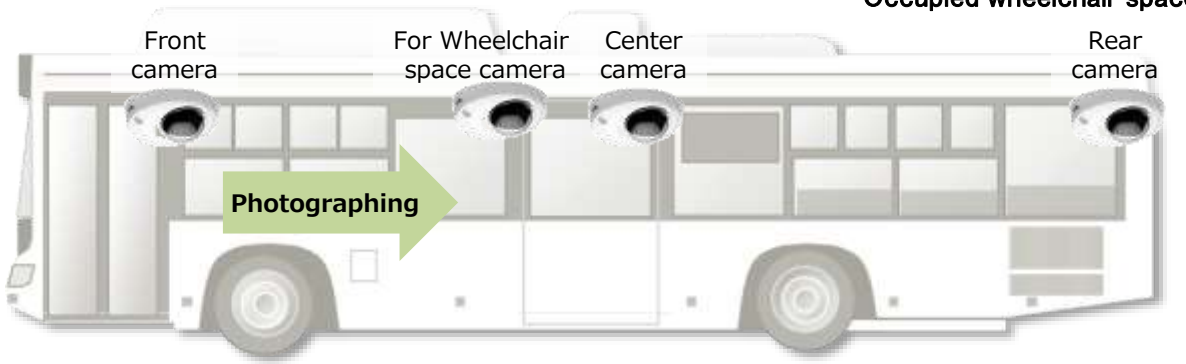
Bus and cooperators

Full occupied seats

Item	Value
Crowded level	1～4 (1 : unoccupied seat、2 : All seat occupied、3 : Space on Aisle、4 : Full crowded)
Crowdedness Information	Analyzed headcount (countable)
Wheelchair space occupancy	0 : unoccupied、1 : occupied

Occupied wheelchair space

◆Camera position



3． Achievement

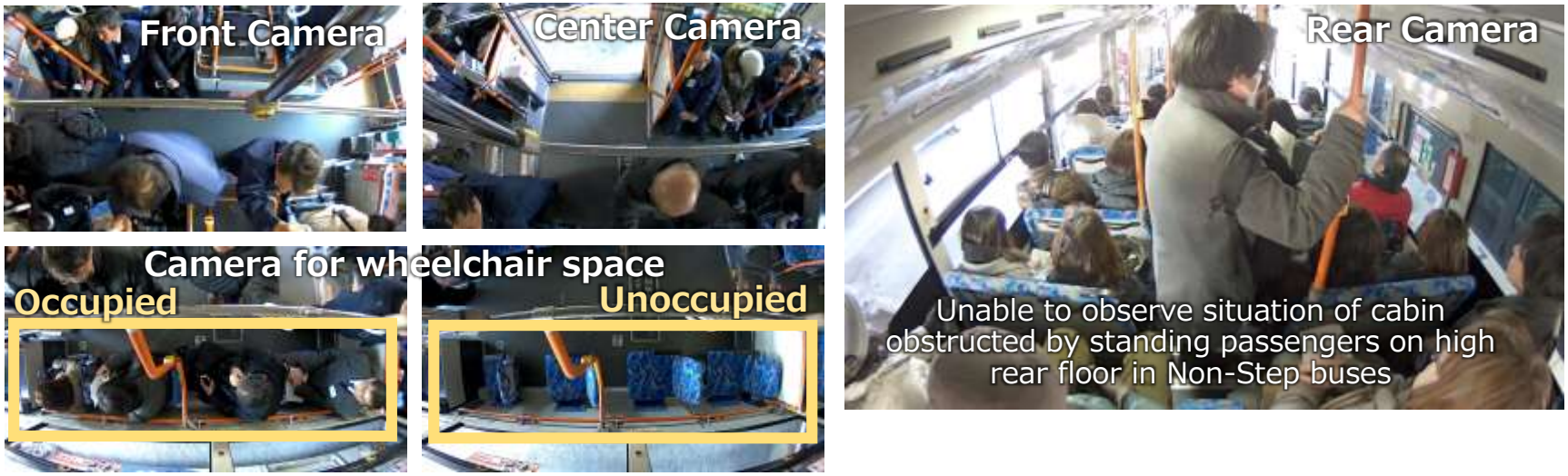
Item a① Development and verification of ART information center

➢ Bus crowdedness information : Analysis of Recorded video

・Evaluation: Analysis of on-board video camera（Video Analysis Technology), comparison and verification with visual inspection

- ◆Camera for Wheelchair space : Almost able to recognize occupied/unoccupied without errors
- ◆Front camera, Center camera : Almost able to recognize crowdedness
- ◆Rear camera : Almost able to recognize passengers within camera view, but difficult to recognize crowdedness in front area
  →Unable to recognize crowdedness of whole cabin only with rear camera

⇒ Combination of information from 3 cameras (Front, Center and Rear) is required to decide crowdedness level of whole cabin



Samples of vision of four on-board cameras

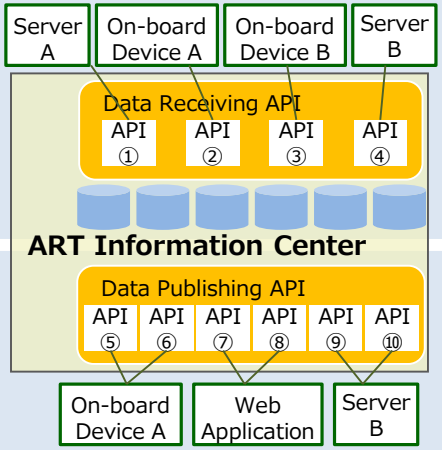
・2018FY Plan: Additional proto-typing of functions to indicate crowdedness Level of whole cabin situation with combination of information from 3 cameras, and verification the functions

3． Achievement

Item a① Development and verification of ART information center

➢ **ART Information Center Function** :

・Adjust data types and data frequencies sending and receiving with the target devices and systems, prototype and confirm (completed)

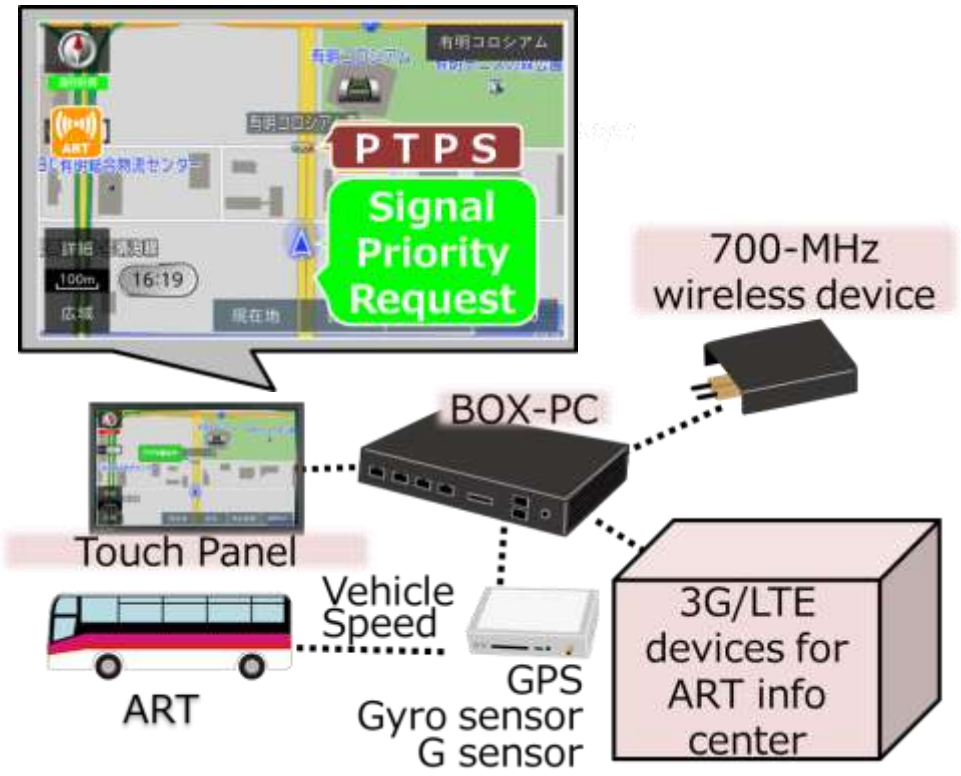
Type	Prototype API	Information	Target Devices and Systems
Data Receiving 	Bus Location Data Receiving API	Bus Master Information (Timetable, Bus Stop, Vehicle Info)	Bus Location Server (Simulated: ART1 Line)
	Bus Delay Info Receiving API	Bus Location, Delay Information	PTPS On-board Equipment
	Bus Crowdedness Info Receiving API	Bus Crowdedness Info (Crowdedness Level etc.)	Bus inner Camera Image Analysis On-board Device
	Posted Text Info Receiving API	Collecting Application Posting Information	Navigation Application Server
Data Publishing	Bus Location Data Providing API	Management Info, Bus Stop , Timetable	PTPS On-board Equipment
	PTPS Priority Decision Providing API	Bus Crowdedness Info (Crowdedness Info) PTPS Control Info (Priority Request Threshold, Direction Info)	PTPS On-board Equipment
	Target Bus ETA Providing API	On-Off Boarding Support Information (Bus Stop, Delay)	Web Application (Sample)
	Bus Crowdedness Providing API	Crowdedness Information (Crowdedness Level)	Web Application (Sample)
	Traffic Forecasting Providing API	Traffic Simulation Frediction Result Information	Navigation Application Server
	Posted Text Info Providing API	Information Collecting Application Posting Information	Navigation Application Server

3． Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

➢ Development of Advanced PTPS on-board equipment

- Developed three equipment based on the study results in past fiscal year



▲ **Structure of Advanced PTPS on-board equipment**

Transmission from the on-board equipment to a roadside unit :

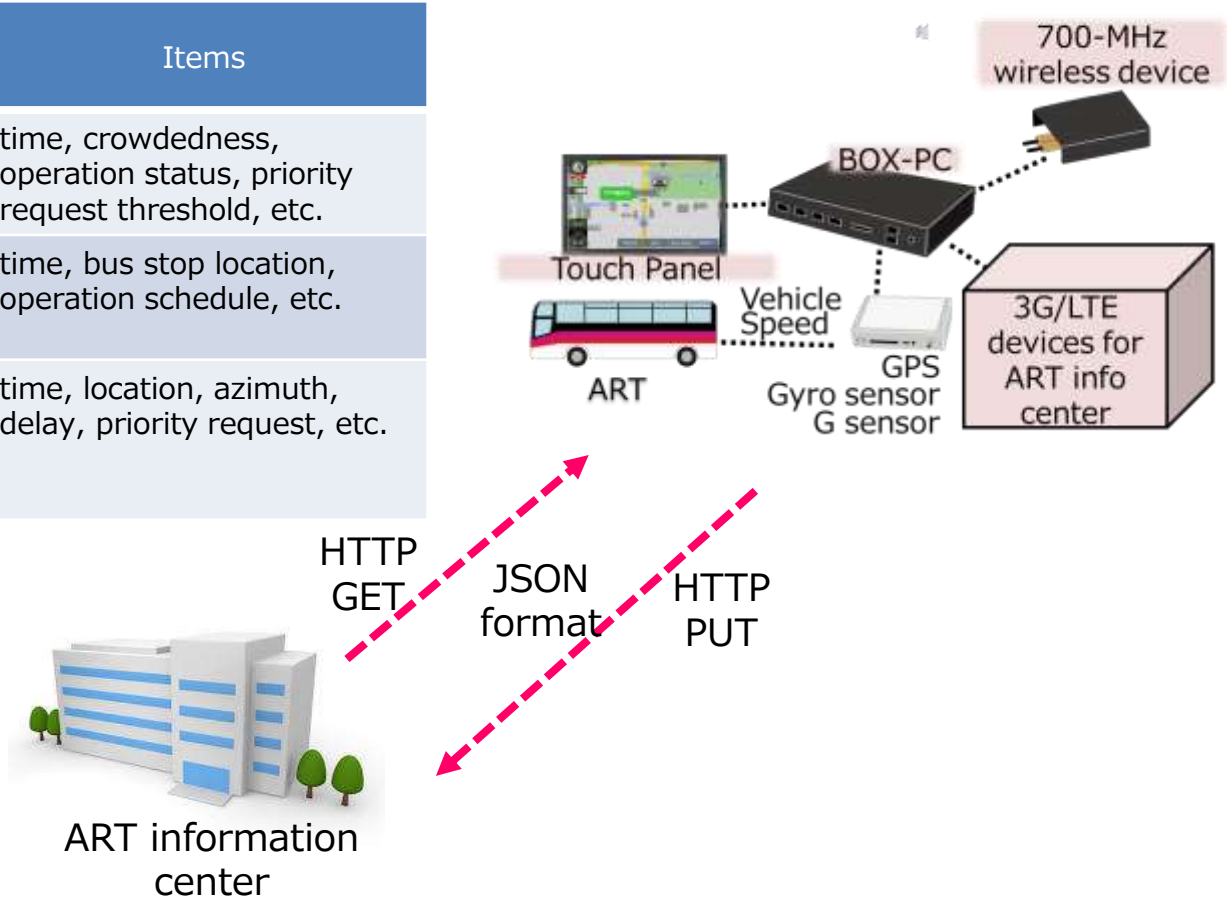
Item	About
Time	Basic information that utilizes common app data
Location	Specifying vehicle position
Status	Specify the running state such as speed and azimuth angle
PTPS priority request	Information on priority request such as bus company number, line number, operation state and priority request(yes/no)

3．Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

- Connecting Advanced PTPS on-board equipment with ART information center
  - Adjust information items and transmission methods with the ART information center and install in the on-board equipment

Direction		Frequency	Items
from	to		
ART information center	PTPS on-board equipment	Any time	time, crowdedness, operation status, priority request threshold, etc.
ART information center	PTPS on-board equipment	Once before operation	time, bus stop location, operation schedule, etc.
PTPS on-board equipment	ART information center	Any time	time, location, azimuth, delay, priority request, etc.



▲PTPS on-board equipment – ART Information Center connection

3． Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

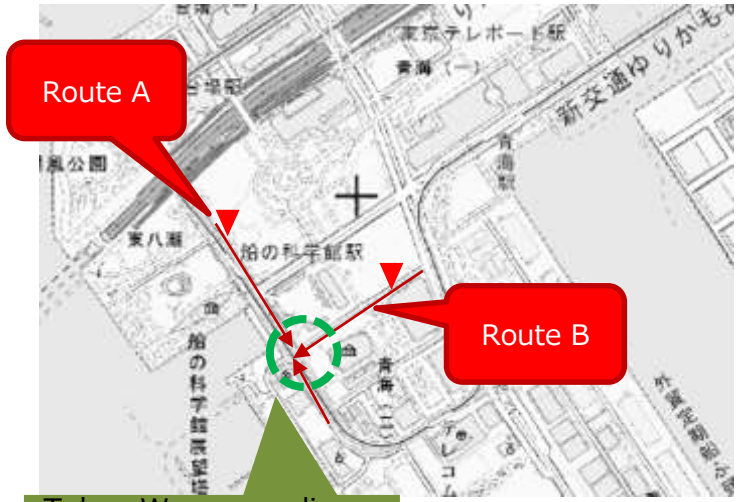
➢ Preliminary test

- Conducted a basic technical verification test of the developed Advanced PTPS on-board equipment using a PTPS roadside unit in Daiba

1. Basic operation
Accuracy of information transmission in V2V and V2I communication

2. Priority arbitration function verification (with/without ART information center)
Accuracy of transmission when multiple vehicles approach at the same time

3. Verification of display function
Accuracy of HMI of the on-board equipment that provide the priority status of the vehicle to the driver



Tokyo Wangan police station intersection

▲Test site

3．Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

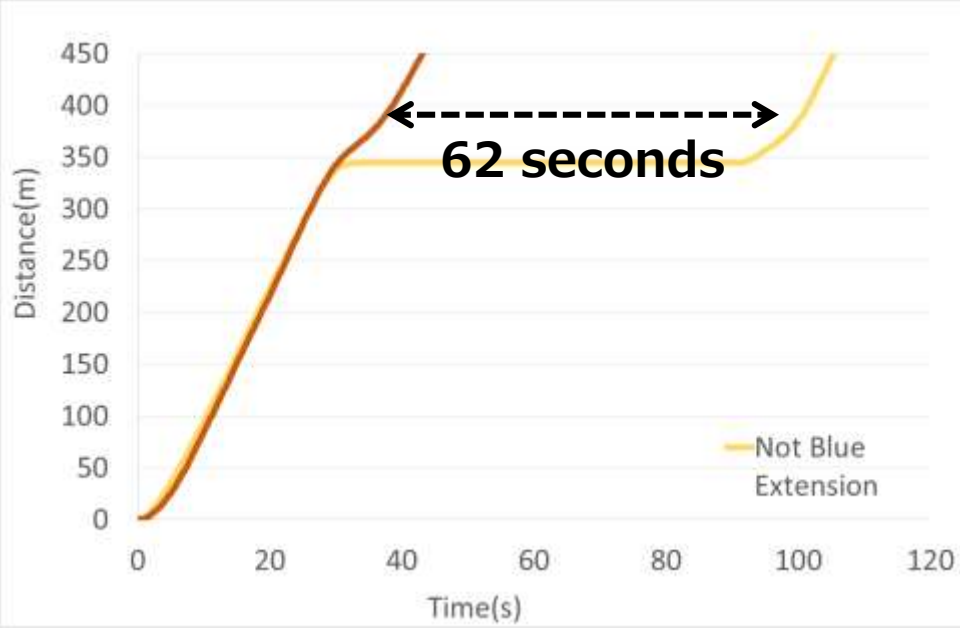
➢ Result of the preliminary test①: Basic operation

The on-board equipment accurately worked and communicated with the PTPS roadside unit in V2V and V2I communication.

➢ Effect of PTPS (green time extension)

Comparison with and without green time extension by PTPS

⇒The test vehicle could pass through the intersection without stopping by the green time extension and it was able to shorten the time taken to pass through the intersection by 62 seconds.



3．Achievement

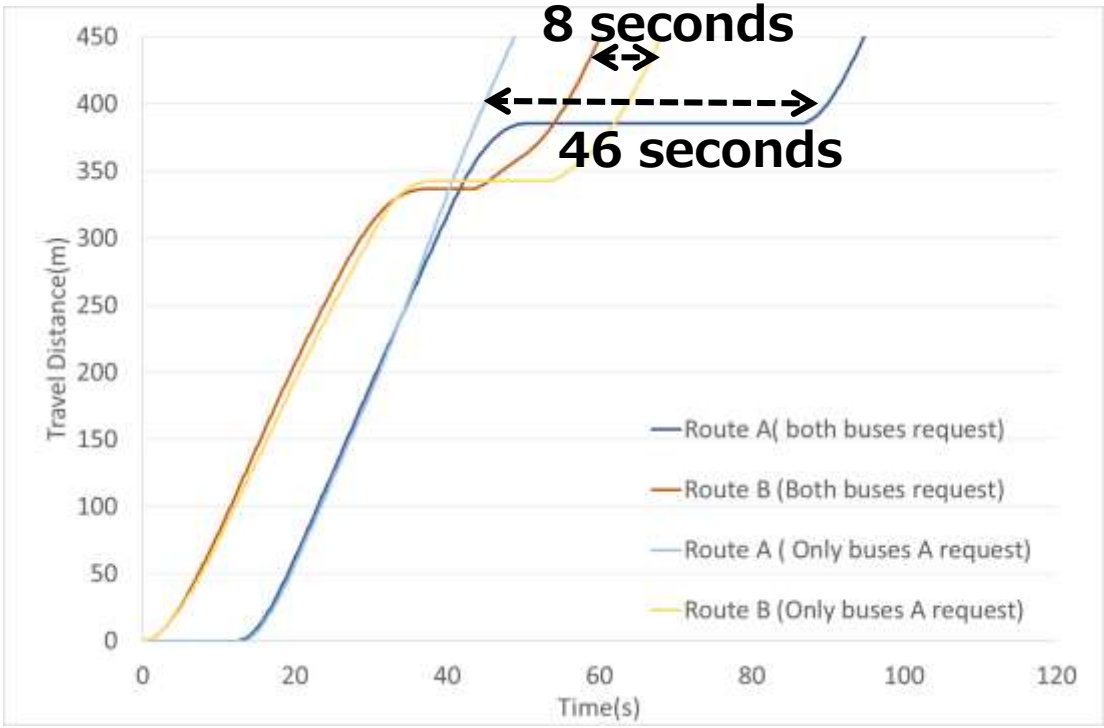
Item a② Field operational test of improving the speediness of ART with advanced PTPS

➢ Result of the preliminary test② : Priority arbitration function verification

- The on-board equipment could judge the presence or absence of the priority request of the own vehicle based on the threshold value and transmitted the request to the roadside unit.
- By connecting with ART Information Center, the on-board equipment could set the threshold value for the judgement of the priority request in considering the condition of other test vehicle (e.g. Delay time, Congestion).

Comparison with and without priority arbitration function

⇒By the priority arbitration, only the test vehicle on Route A (we assumed that the vehicle is more crowded than the test vehicle on Route B) requested the priority control and it was able to shorten the time taken to pass through the intersection of the test vehicle on Route A.

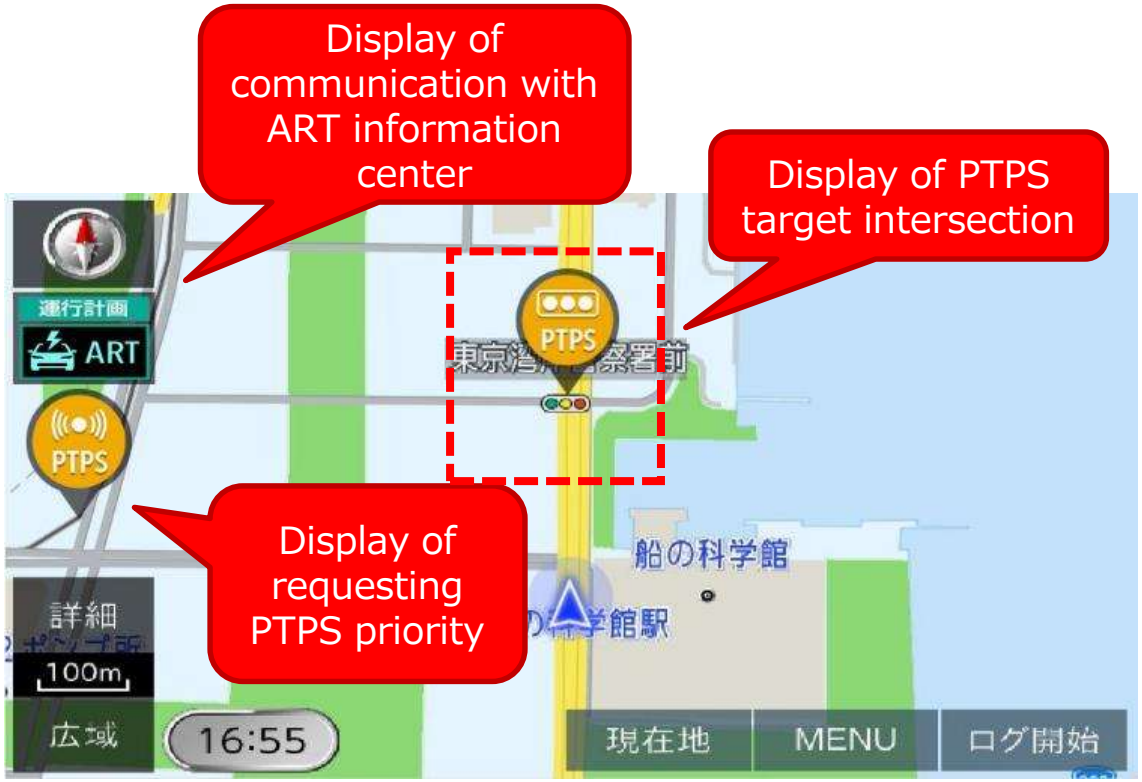


3． Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

➢ Result of the preliminary test③ : Verification of display function

- Concerning HMI, the on-board equipment was able to display the information correctly on the screen.



▲Display while the vehicle is running

▲Display of settings

3． Achievement

Item a② Field operational test of improving the speediness of ART with advanced PTPS

➢ Field Operational Test in FY 2018 (draft)

- Period : 2-3 days
  (pre-test by small car will be conducted if necessary)
- Test vehicle : 2 buses

→Verify the effectiveness of the speediness of bus with advanced PTPS in about 1.5 km section of Tokyo bay area.

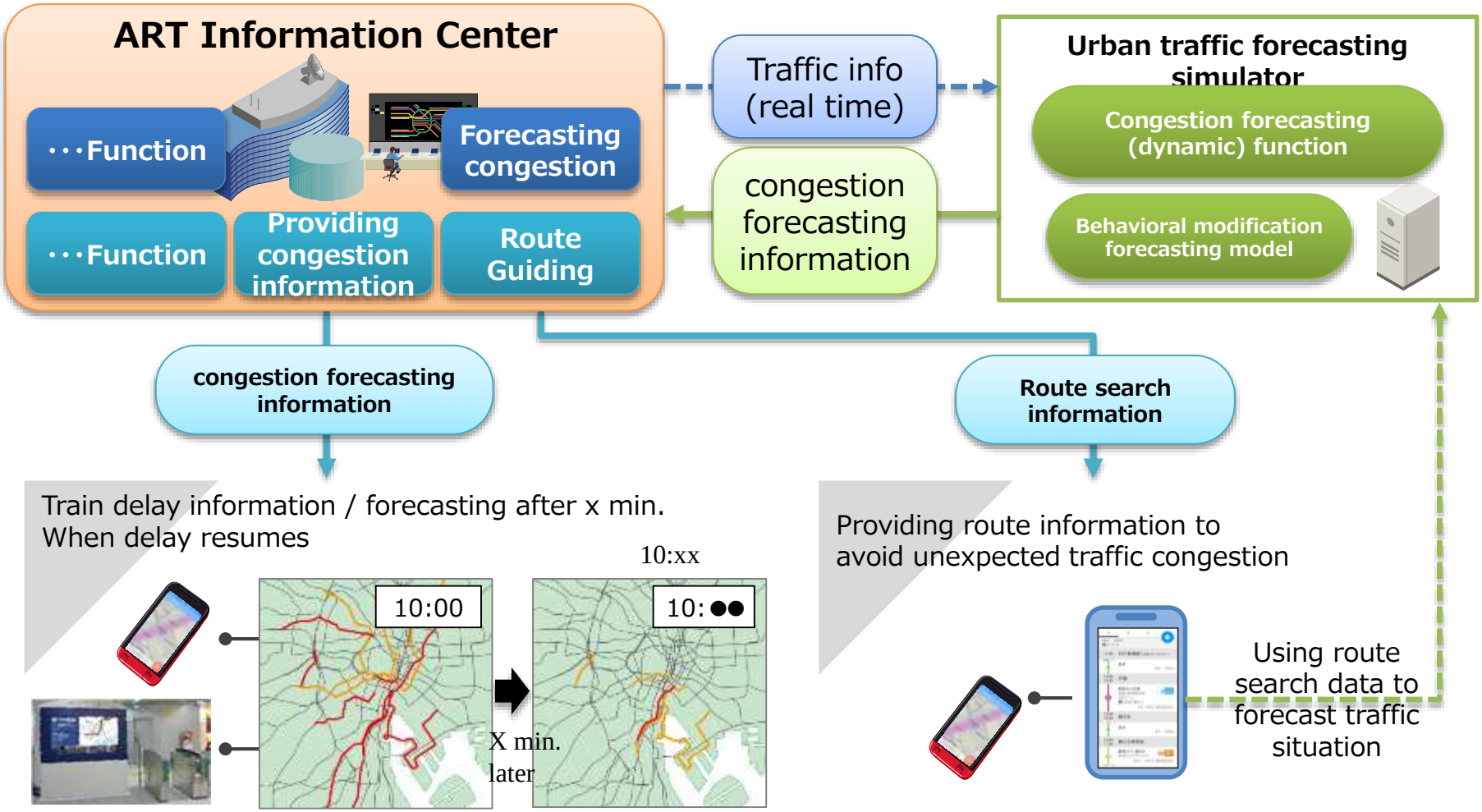
▼verification items

Item	Content
I. when a bus stop is close to an intersection	After departing the bus stop, the PTPS priority request is transmitted to a roadside unit, and the crossing of an intersection of a bus is supported
II. multiple buses approach at the same time	Priority arbitration function when multiple buses simultaneously approach an intersection
III. Effect of advanced PTPS on bus operation	Effectiveness of improving the speediness of bus with multiple PTPS roadside units on entire section
IV. Effect on a bus arriving/departing at a bus terminal	Including the possibility of departure support by providing signal information to a bus at a terminal

Item a③ Investigation of measures of traffic congestion forecasting and guiding to avoid congestion, Demonstrative experiment

■Outline of traffic congestion forecasting and guiding to avoid congestion

- Conducting dynamic traffic congestion forecasting
- Guiding to avoid traffic congestion based on the behavioral modification process, providing the appreciate information depending on the individual attribute and situation as well as dynamic congestion forecasting in cooperation with ART Info. Center

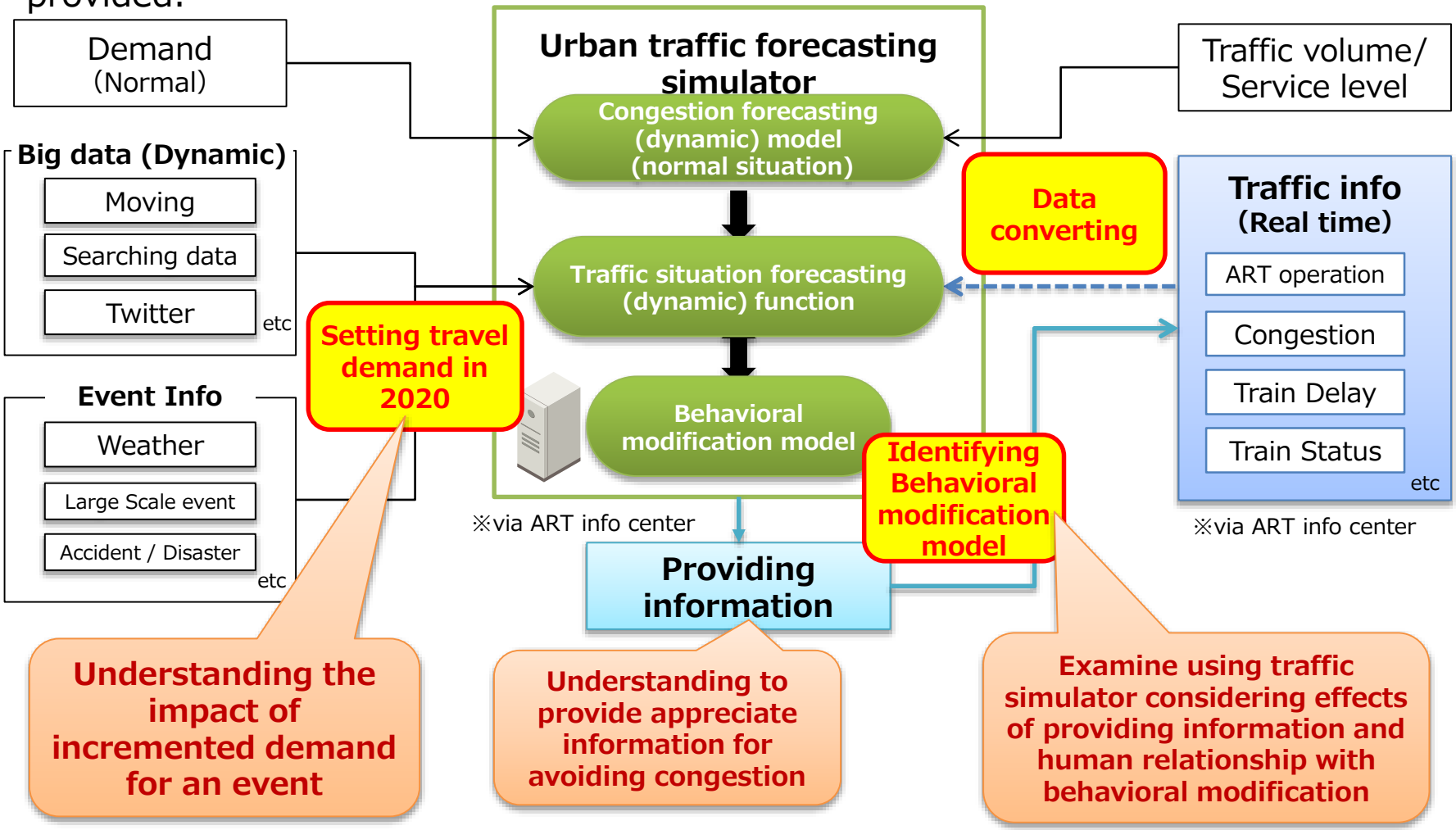


3．Achievement

Item a③ Investigation of measures of traffic congestion forecasting and guiding to avoid congestion, Demonstrative experiment

■Outline of traffic congestion forecasting and guiding to avoid congestion

- In FY 2017, we simulated traffic situation using traffic simulator (applying agent modelling), integrated with behavioral modification based on the information provided.



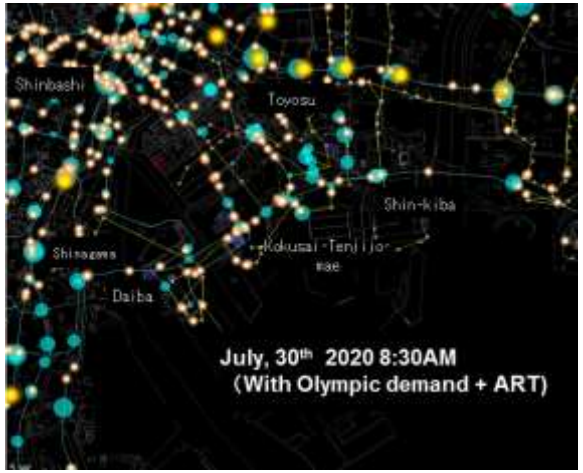
3．Achievement

Item a③ Investigation of measures of traffic congestion forecasting and guiding to avoid congestion, Demonstrative experiment

■ Building urban traffic forecasting simulator (using agent modelling)

- Reproduce the movement (route) of each public transport user【Agent modelling】
- Searching most suitable route of each agent【Route searching function】
- Setting output (evaluation index)
  - ✓ Travel time (delay time) of public transport user
  - ✓ Congestion avoidance rate（Percentage of people who avoids congestion)
  - ✓ Variety of congestion situation depends on the providing information

■ Simulation output (example)



<Legend>
● Num. of people at station
● Train (location and their degree of congestion)

■ Output: Congestion rate
(Shibaura-Futo⇒Odaiba-Kaihin-Kouen : Yurikamome)

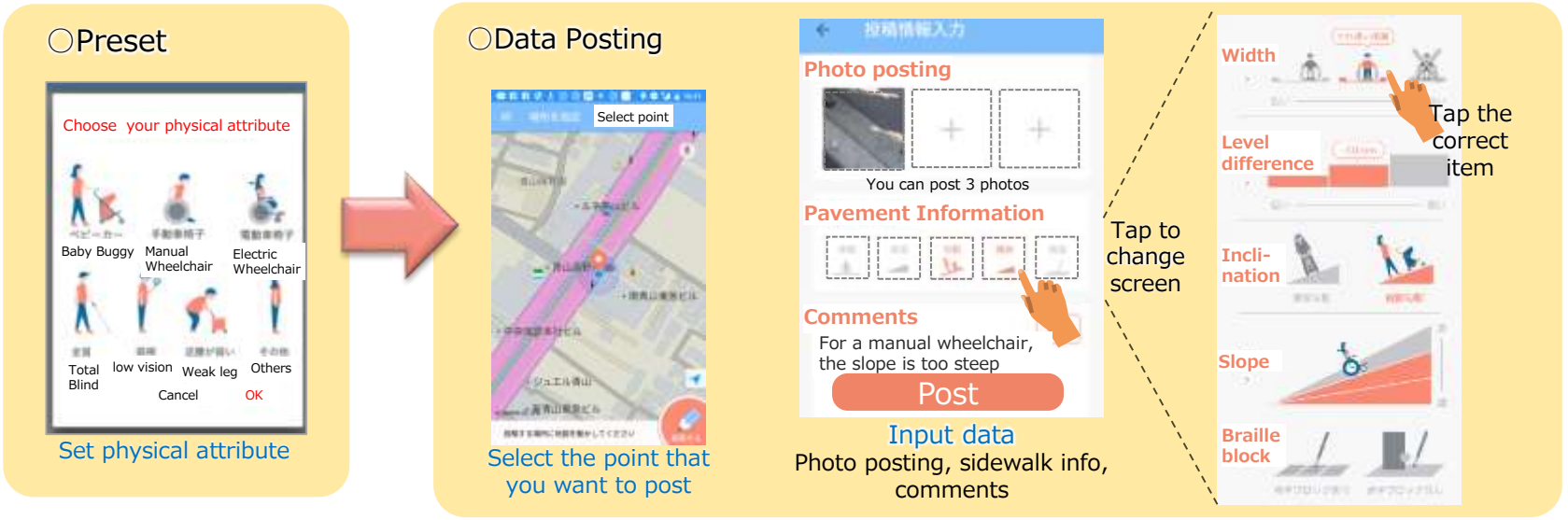
ケースの概要			6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
case1	Normal + Olympic demand		69%	160%	160%	87%	46%	64%	201%	51%	28%	67%	203%	41%
case2-1	Request to enter into Coastal area(Reduce)	-20%	69%	160%	160%	87%	46%	64%	201%	51%	28%	67%	202%	40%
case2-2		-30%	69%	160%	160%	87%	46%	64%	201%	51%	28%	67%	202%	39%
case2-3		-40%	69%	160%	160%	87%	45%	64%	201%	51%	27%	66%	202%	39%
case3-1	Request Visitors to enter into Coastal area (Reduce)	-10%	69%	160%	160%	86%	43%	62%	201%	49%	26%	65%	202%	39%
case3-2		-20%	68%	160%	160%	83%	40%	60%	201%	47%	24%	63%	202%	38%
case3-3		-30%	68%	160%	160%	82%	38%	57%	201%	44%	22%	61%	200%	36%
case4-1	Request commuters to commute earlier (Retime)	10%	120%	157%	161%	69%	45%	64%	201%	51%	28%	67%	203%	41%
case4-2		20%	120%	157%	161%	69%	45%	64%	201%	51%	28%	67%	203%	41%
case4-3		30%	132%	156%	162%	60%	45%	64%	201%	51%	28%	67%	203%	41%
case5-1	Request commuters to go home earlier (Retime)	10%	69%	160%	160%	87%	46%	64%	201%	51%	28%	70%	203%	44%
case5-2		20%	69%	160%	160%	87%	46%	64%	201%	51%	28%	73%	204%	45%
case5-3		30%	69%	160%	160%	87%	46%	64%	201%	51%	28%	78%	205%	46%
case6-1	Request commuters to detour to commute (Reroute)	20%	67%	158%	141%	64%	45%	64%	201%	51%	28%	67%	203%	41%
case6-2		40%	64%	129%	112%	52%	43%	64%	201%	51%	28%	67%	203%	41%
case7-1	Request commuters to detour to go home (Reroute)	20%	69%	160%	160%	87%	46%	64%	201%	51%	28%	67%	203%	40%
case7-2		40%	69%	160%	160%	87%	46%	64%	201%	51%	28%	67%	203%	35%
case8-1	With ART	All passengers can choose ART	69%	173%	171%	74%	45%	63%	201%	44%	28%	67%	204%	37%
case8-2		All Olympic spectators use ART	69%	152%	103%	67%	45%	24%	18%	24%	28%	30%	28%	35%
case8-3		All Olympic spectators and commuters use ART	69%	165%	93%	67%	45%	24%	17%	24%	28%	29%	28%	35%
case9-1	Request spectators to go to venue earlier (Retime)	40%	69%	160%	160%	88%	68%	103%	154%	42%	50%	116%	144%	39%
case9-2		60%	69%	160%	160%	90%	102%	101%	121%	44%	86%	113%	113%	39%
case9-3	Request spectators to detour to go to venue (Reroute)		69%	160%	160%	87%	46%	49%	58%	40%	28%	54%	51%	39%

3． Achievement

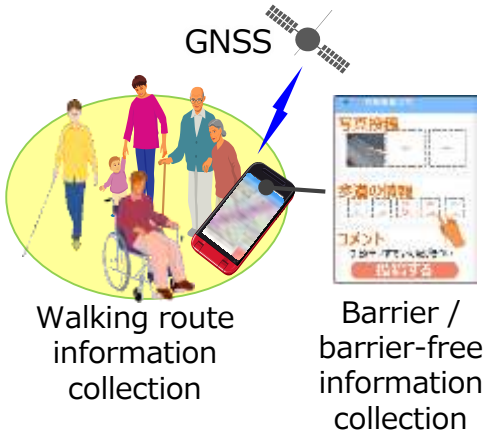
Item a④ Pedestrian Transfer Support System

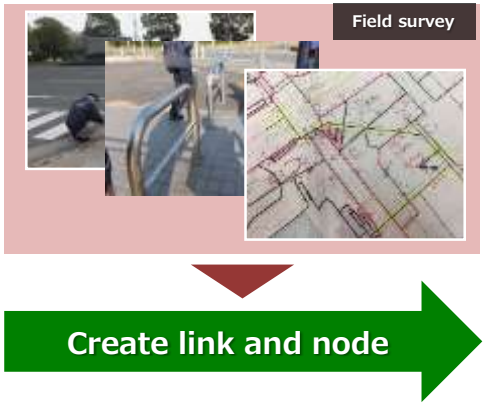
(1) Collect necessary information for pedestrian transfer support

- Prototype data collection application for constructing network for pedestrians



- Improve network data for pedestrians by field survey





3．Achievement

Item a④ Pedestrian Transfer Support System

(2) Feasibility study on construction of network for pedestrians using data collection application

Date: From November 1 to 30, 2017 (Rehearsal: October 30)

Target Area: Toyosu Area, Ariake Area

Participants: 63 persons (wheelchair 22, elderly adult 10,
total blind 10, low vision 10, Baby buggy 10)

Feasibility study outline :

- ✓ At total 14 meetings, we have explained this feasibility study purpose and application operation, after that, cooperators walked around in the area.
  - Cooperators posted barrier and barrier-free information by using the data collection application.
  - GPS moving route information was collected (background).
  - Staff accompanied visually impaired people and some elderly people (for security reasons)
- ✓ In each area, each cooperators walked 3 or 4 different routes from start to goal, and we surveyed the route which was easiest and the reason by using the questionnaire.

3． Achievement

Item a④ Pedestrian Transfer Support System

(2) Feasibility study on construction of network for pedestrians using data collection application

Visually impaired people

- “I do not have a clue so I do not know which way to go.”
- ” There was a telephone pole on a narrow sidewalk, and there was an obstacle, I felt the danger.”
- ” When there are landing in the stairs, I want to know that.”

Wheelchair user

- ” When crossing the road (when going up to the sidewalk), it is inclined and hard to pass.”
- ” The sidewalk has a slope to the roadway and the wheelchair tire slips to the roadway.”
- ” There is no guide of the elevator. It is hard to use it.”

Elderly people

- ” It was easy to walk with uncrowded.”
- ” There are few guidance boards of building, and road guidance.”
- ” Watching the surrounding scenery, I chose a road that is wide and easy to walk.”

Baby buggy user

- ” I was surprised that the green light of the pedestrian crossing was short (with respect to the width of the road).”
- ” It is difficult for baby buggy user with upper child to walk narrow sidewalk.”
- ” At a pedestrian crossing, it is difficult to judge because some level differences are easy to walk and other level differences are not easy to walk.”

Item a④ Pedestrian Transfer Support System

HITACHI
Inspire the Next

(2) Feasibility study on construction of network for pedestrians using data collection application

Result of collection of information posts classified by attributes

Attributes	Number of Posts	Information of Walkway				
		Bump	Road Width	Slope	Slant	studded paving block
Total Blind	467	4	4	5	4	17
Low Vision	503	6	3	9	10	50
Electric Wheel Chair	223	67	74	85	80	73
Manual Wheel Chair	221	50	52	74	93	63
Baby Buggy	242	62	96	36	47	69
Elderly people	45	11	12	9	13	3
Total	1701	200	241	218	247	275

Trends of posted data classified by attributes

Visually impaired people (Total Blind/Low Vision)

- Many posts with pictures and comments (Posts about clueing landmarks on walking)
- Many posts about studded paving block in walkway information

Wheelchair (Manual／Electric)

- Many posts about information of walkway by both manual and electric
- Many posts about slope and slant by Manual, and Many posts about all subjects by Electric

Baby Buggy

- Posted about lower bump where buggy is not easy to go through
- Prefer to wilder walkway to consider safety

Elderly People (Weak legs)

- Not only posts about information related to their own attributes, but also many posts to consider about useful information for people in other

➢ Planning to publish data collection application after improvement of its UI, to collect more comments and data, and to apply to 2017FY field operation test

Item a④ Pedestrian Transfer Support System

HITACHI
Inspire the Next

(2) Feasibility study on construction of network for pedestrians using data collection application

Study of correlation between posted data and measured value (example: slope and slant)

➢ Toyosu Area
- Almost plain and no long slopes
- Slants are everywhere in walkway

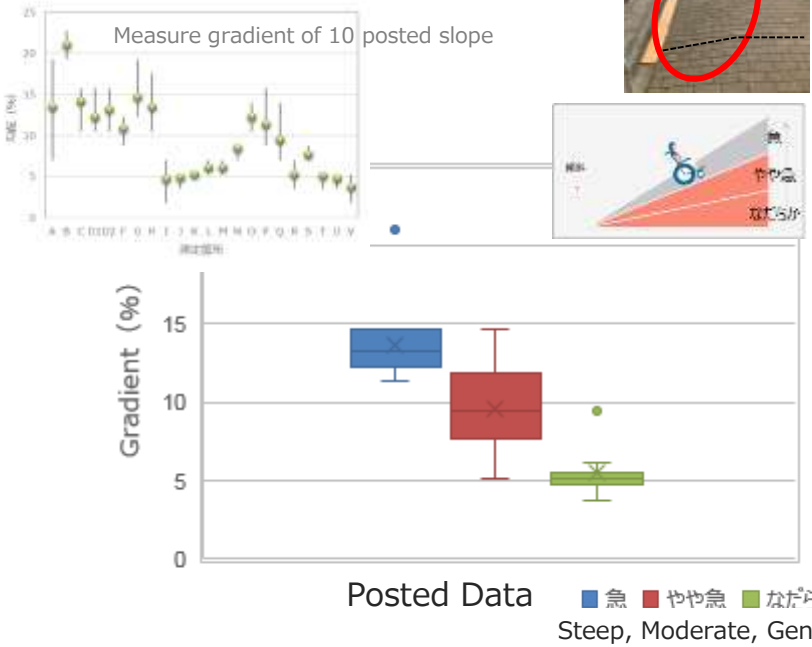
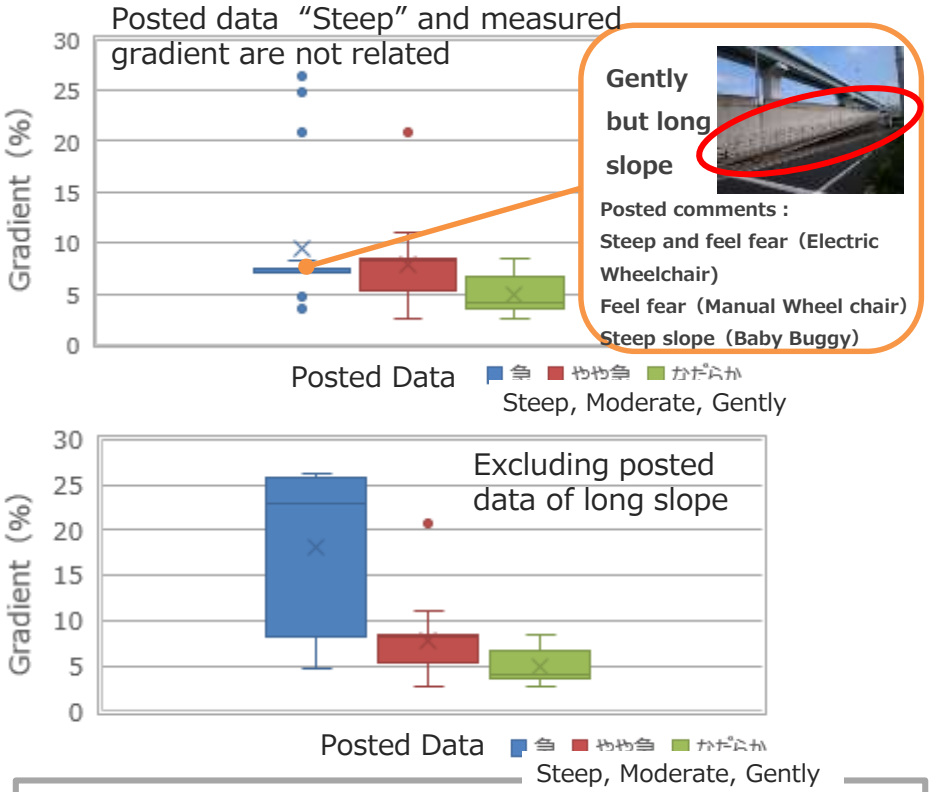


Fig Correlation between posted data and measured gradient

＊Line in box is median ● Outlier (far out from others)

Correlation is found between qualitative posted data and measured gradients

➢ Ariake Area
- Many ups and downs
- Long slops, Elevators and pedestrian bridges



Not only gradient of slope but also efforts such as length of slopes are considered in posted comments

3． Achievement

Item a④ Pedestrian Transfer Support System

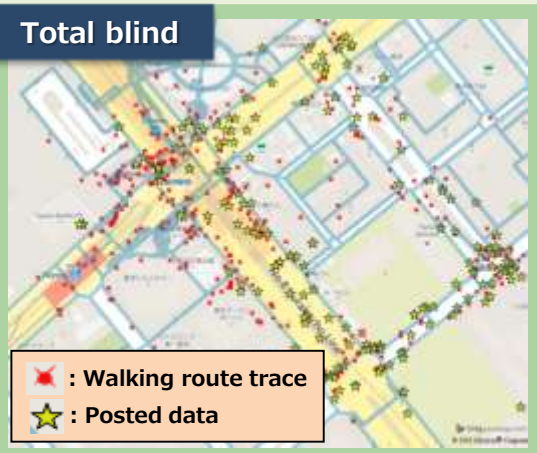
(3) Recommended route for each attribute considered from the information from the data collection application and the questionnaire

Information obtained from the data collection application (Walking route trace and posted data)

Route which it felt as "easy to move" from the questionnaire

Recommended route for each attribute (draft)

Total blind



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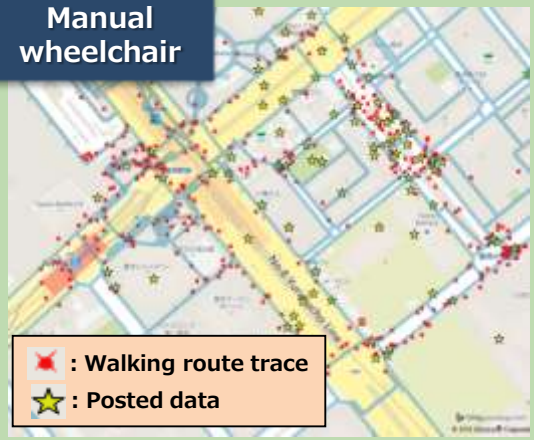
Manual wheelchair



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3． Achievement

Item a④ Pedestrian Transfer Support System

(4) Preliminary verification for advanced PICS cooperation

➢ I/F design for advanced PICS terminal application cooperation

1 **Move using route guidance of Personal Navigation application**

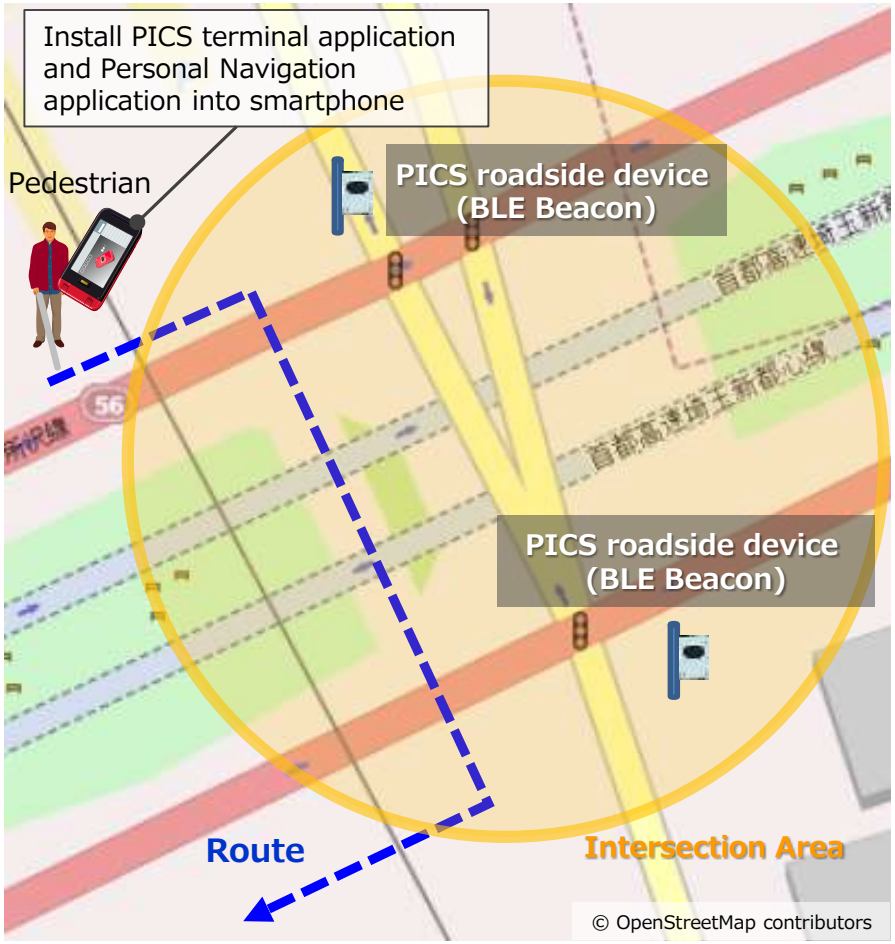
2 **The PICS terminal application send push notification to the personal navigation system when it detects entering intersection area (within the PICS terminal communication range).**

OK

3 **Switch to PICS terminal application**

4 **Push the green light extension button of the PICS terminal application (Press while this signal is red light)**

5 **Green light is extended**



※Route guidance is suspended in the intersection area and resumes guidance when it goes outside the area.

3． Achievement

Item a④ Pedestrian Transfer Support System

(4) Preliminary verification for advanced PICS cooperation

- Evaluation of acceptability of advanced PICS cooperation

A look of the preliminary verification and participant's voice


Briefing


Explanation of the application


Crossing according to the notification from the application


Interviewing after the preliminary verification

Visually impaired people (total blind)

- ” I want you to provide voice guidance including the address of the intersection that I am about to cross over and the direction of the direction of the crosswalk by linking advanced PICS with route guidance a little more.”
- ”I understand that there are two types of guidance (advanced PICS terminal application and personal navigation), but I cannot distinguish them.”
- ” When it is raining, I often get lost even around my house. It might be useful to use in neighborhood.”

Visually impaired people (low vision)

- ”It guides about signals of two intersecting directions. Since it is only one signal in the direction that I am about to cross, I want only one guidance in the direction that I am about to cross.”
- I‘m surprised that you are developing this kind of system It is very helpful for vulnerable road users..

⇒We believe that acceptability of navigation application cooperation with advanced PICS is high.

3．Achievement

Item c Management of Field Operational Test

➢ <u>Objective of the field operational test and the demonstration event</u>

- Field operational test is conducted on actual roads to verify each technology
- Demonstration event provides opportunity of experiencing the technologies in one place