12th Japan ITS Promotion Forum

Automated Driving System

Next Generation Transport

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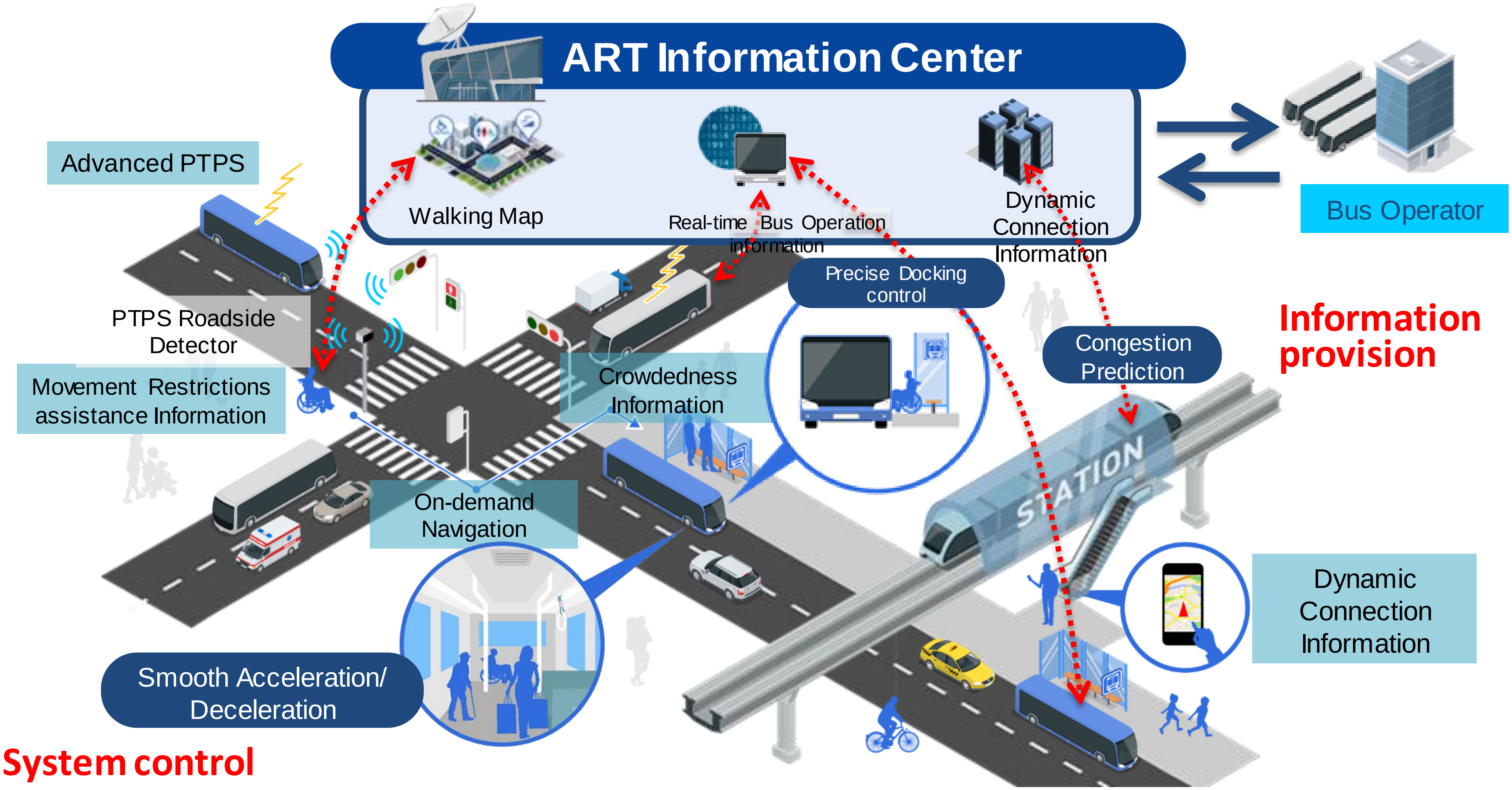
SIP

Cabinet Office

<Translated Version>

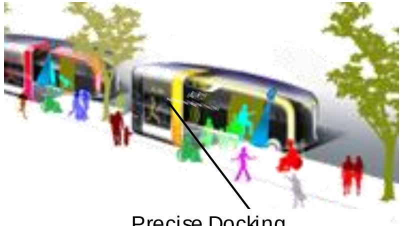

ART Information Center
Walking Map
Real-time Bus Operation information
Dynamic Connection Information
Bus Operator
Advanced PTPS
PTPS Roadside Detector
Movement Restrictions assistance Information
Precise Docking control
Crowdedness Information
Congestion Prediction
Information provision
On-demand Navigation
STATION
Dynamic Connection Information
Smooth Acceleration/ Deceleration
System control

Improvements in Accessibility through Information and Control

Pedestrian travel support system (Walking support)

Pedestrian Information and Communication Systems PICS

Improved accessibility for boarding/exiting (shortening of stopping time)



Precise Docking, smooth acceleration/deceleration

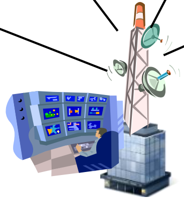
Stress-free travel using public transport (ensured speed during travel)

Signal system that prioritizes public transport Advanced PTPS

Transportation system using mobile terminals

Provision of transport support information for disabled persons

ART Information Center



Open platform for providing information on using ART and its surroundings

・Congestion prediction
・Dynamic connection guidance

Organic combination of information based on ART Information Center

Needs for Precise Docking

The distance and difference in level between the bus stop edge and bus step hinders the independent actions of wheelchair users

People with impaired vision cannot see the depth or height of the distance between the bus stop edge and bus step

Expectations towards Precise Docking are common throughout the world

Cleveland, Ohio
United States

Grand Rapids, Michigan
United States

1. **Adaptation of laws for guiding lines for precise docking control and verification of impact on general road users**

2. Precise docking guidance using magnetic markers

3. Precise docking guidance based on sensor fusion using existing features
   Improvement of precise docking guidance under unfavorable conditions such as a narrow bus stop, etc.

Mock bus stop

Guiding lines
for precise docking
control

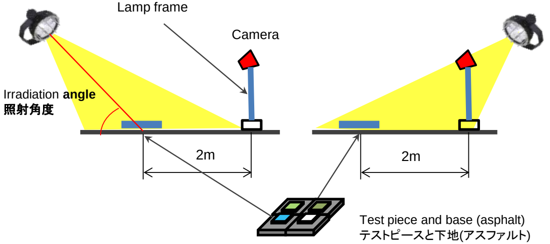
Experiment at Japan Automobile Research Institute (Tsukuba)

Verification of System Recognition Performance in a Laboratory

- The contrast ratio recognized through the camera upon changing conditions such as the color used for the guiding lines, lighting, etc. is measured
- From the experiment results, “system recognizability” is confirmed, and the color, etc. used for the guiding lines is selected

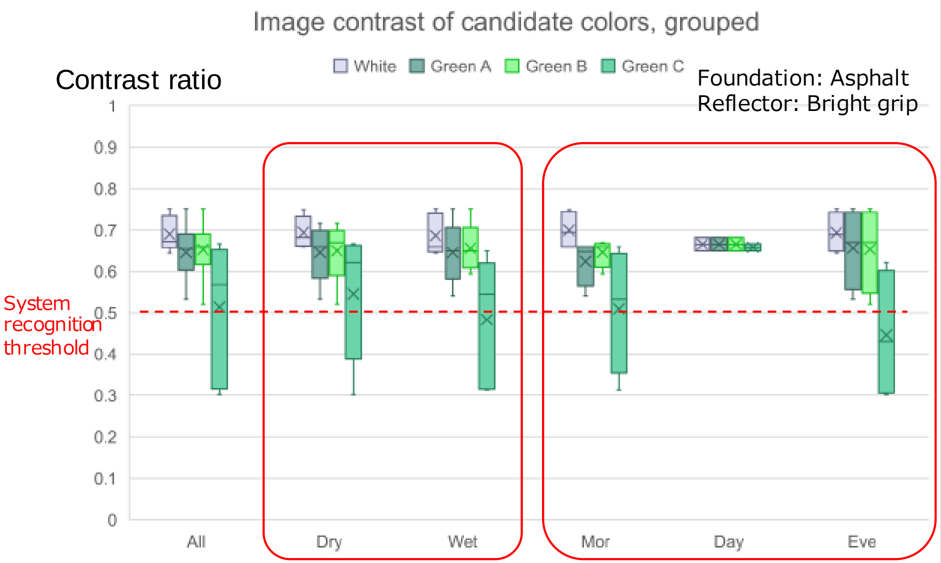
■ Combination of laboratory experiment conditions

Test pieces		Colors	White, Green A, Green B, Green C, Orange, Pink, Purple, Blue
		Reflectors	Glass beads, AWT, bright grip
		Foundation	Asphalt, rough, heat insulating pavement
Measurement conditions	Day	Sunlight	Morning, daytime, evening (reproduced using light)
		Light source direction	Front, backward irradiation, angled
		Humidity	Dry, wet
	Night	Street light	Street light, no street light



Evaluation Results of System Recognition Performance

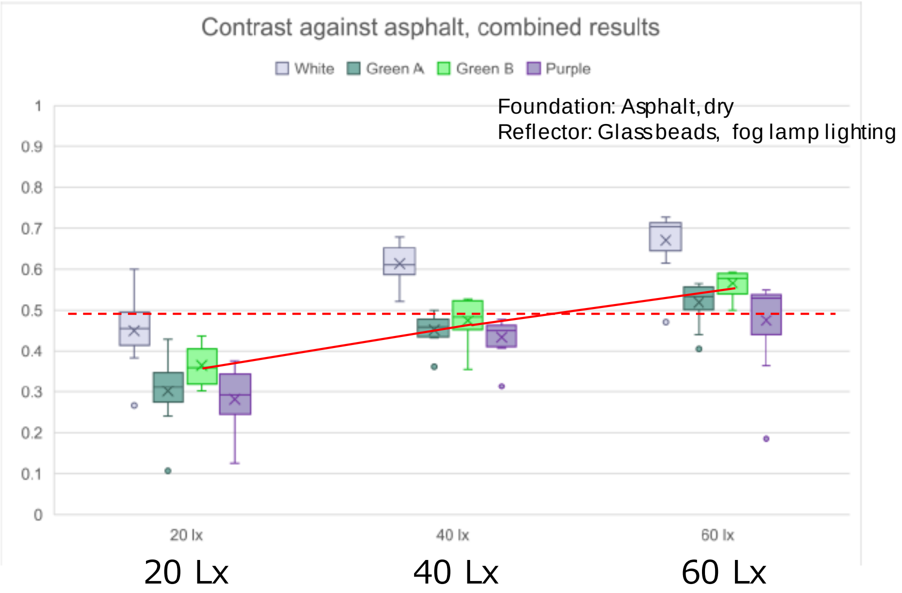
Basic performance evaluation: Morning/Daytime/Evening + Dry/Wet



No difference between dry and wet

For morning and evening, there are performance differences dependent on color

Nighttime headlight evaluation: Confirmation of effects of street light illumination



- Contrast ratio improves with illumination
- Possibility that system recognition is not possible depending on illumination

Selection of Guiding Lines with which to Conduct Field Operational Tests on a Proving Ground

Based on the results of preliminary reviews, Proposal 1 (reference), 2 and 4 were selected as guiding line designs to test on a Proving Ground

No	Characteristic	Compliance with laws	System recognizability	Construction workability	Possibility of erroneous recognition (preliminary survey)
1 Reference	White	×	◎	◎	
2	Green: Green B	○	○	○	△
3	Green: Green A	○	△	○	
4	Note: For buses	○	○	○	△
5	Note: Symmetric line	○	○	△	
6	Arrow feather lines	◎	×	△	×

Verification of Impact on General Road Users

Overview of verification

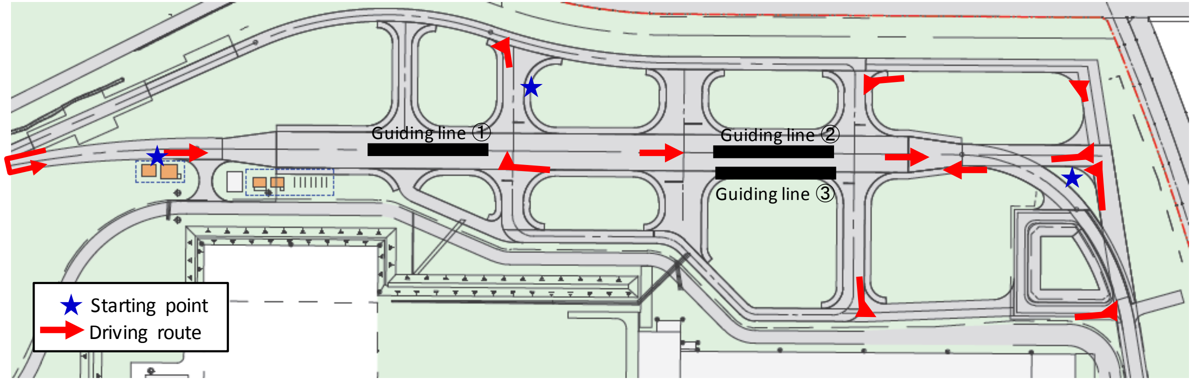
・Recruit test subjects, and have them drive on the proving ground unassisted to verify influence of guiding lines on the driving state of general drivers.

・Since it is plausible that the effect of guiding lines on driving conditions **differs depending on driving experience and physical capabilities**, test subjects are recruited across a wide variety of attributes.

　－20s (male and female), 30s to 50s (male and female), 60s (male and female), etc.

・Since it is **anticipated that the impact of guiding lines on general drivers differs greatly depending on practice and preliminary information**, **considerations are made so as not to convey the original intent of the field operational test before the driving experiment**.

・The 30 total test subjects were divided into 3 groups of 10, **and the type of guiding line that appears first was changed for each group.**



Outline JARI's V2X urban course (Tsukuba) and driving pattern

Field Operational Tests on JARI's Proving Ground

Evaluation from perspective of general road users

Actual precise docking experiment using green (Green B) guiding lines

Gap during precise docking (fulfills required precision)

Testing of boarding/exiting using a wheelchair

1. Adaptation of laws for guiding lines for precise docking control and verification of impact on general road users

2. **Precise docking guidance using magnetic markers**

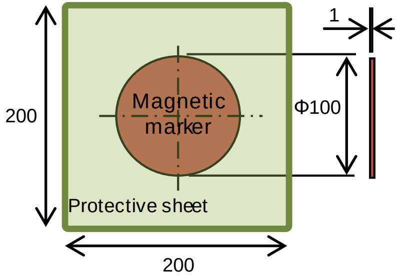
3. Precise docking guidance based on sensor fusion using existing features
Improvement of precise docking guidance under unfavorable conditions such as a narrow bus stop, etc.

2. Precise Docking Guidance Using Magnetic Markers

Implemented as a theme for field operational tests for automated driving buses in Okinawa by the Cabinet Office

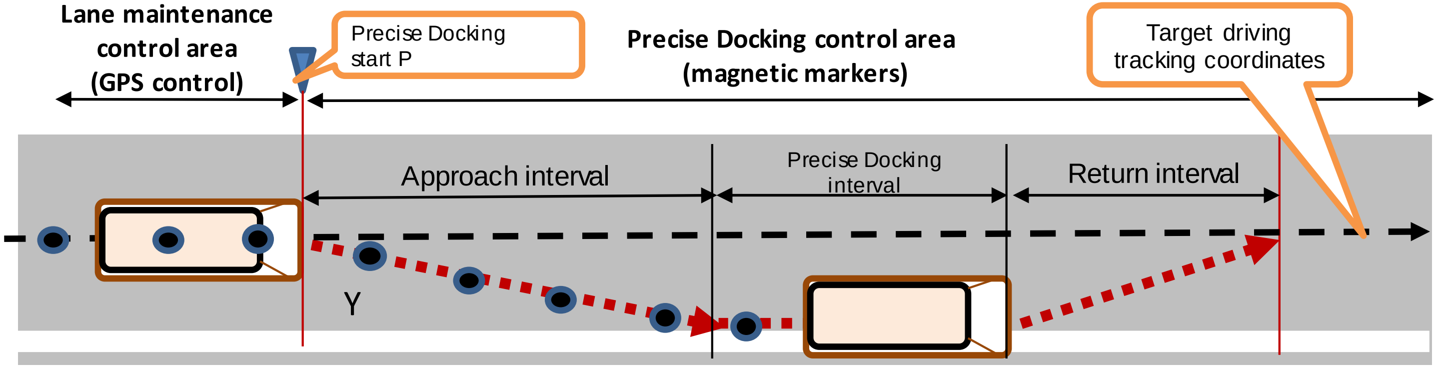
Types and Layout of Magnetic Markers

Magnetic markers with a thickness of 1 mm are affixed to the road surface (temporary)



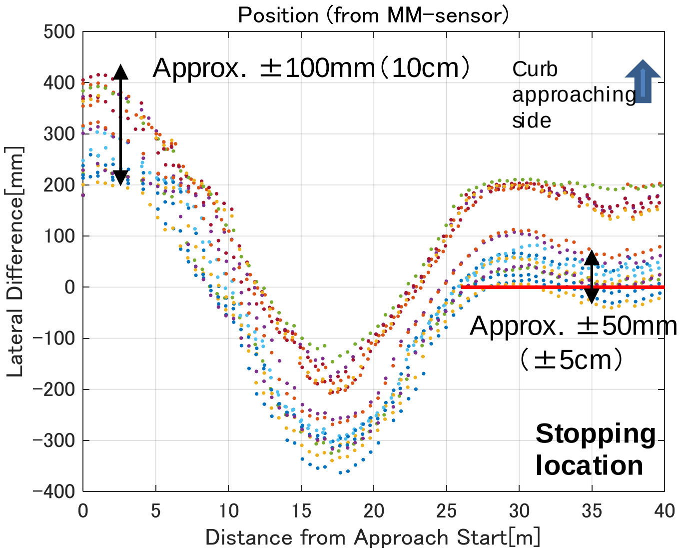
- Magnetic marker: Flat markers
- Laying method: Bonded
- Laying intervals: 50 cm

- **The target distance for precise docking(from curb to bus)** was set to **20 cm**.

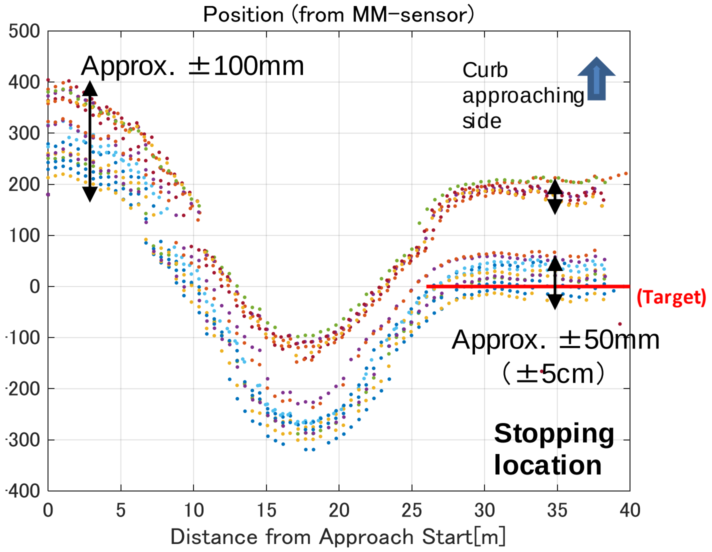


Results of Precise Docking using Magnetic Markers

- In this experiment, magnetic markers were used as RTK-GPS position correction
- Adjustment to target value (40±20 mm) set by the Next-Generation Transport Working Group was not possible; further reviews are necessary



Front axle side (18 times)



Rear axle side (18 times)

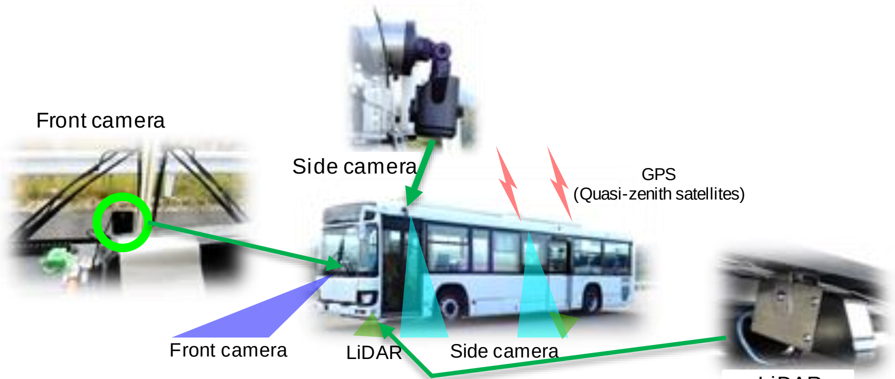
1. Adaptation of laws for guiding lines for precise docking control and verification of impact on general road users

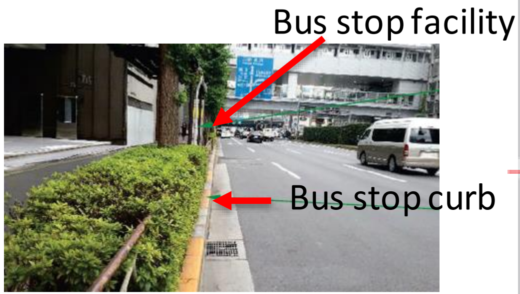
2. Precise docking using magnetic markers

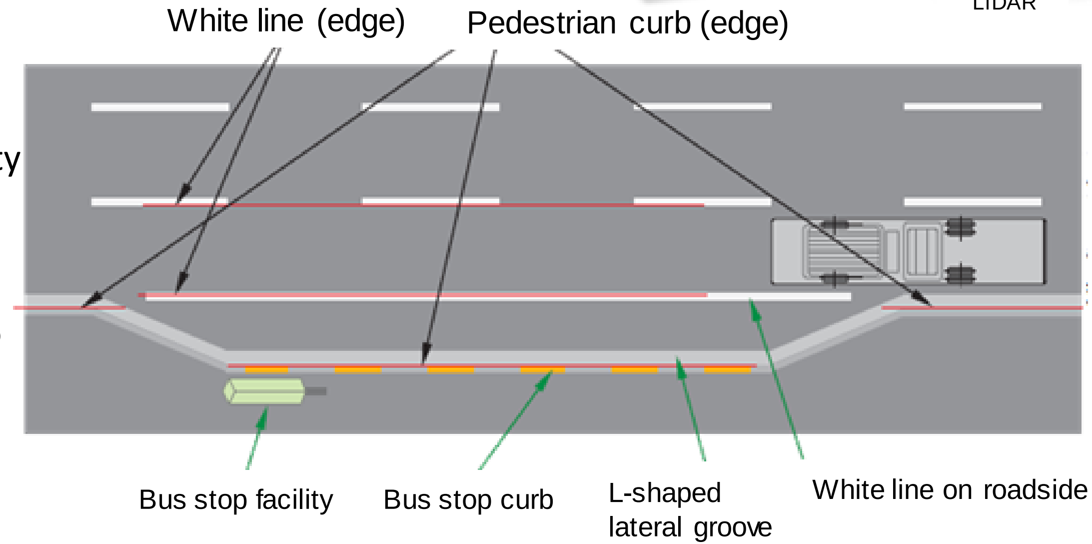
3. **Precise docking guidance based on sensor fusion using existing features Improvement of precise docking guidance under unfavorable conditions such as a narrow bus stop, etc.**

3. Sensor Fusion Technology that is Not Dependent on Guiding Lines

Guidance for precise docking is implemented based on multiple sensors on the bus that utilize the existing infrastructure around bus stops

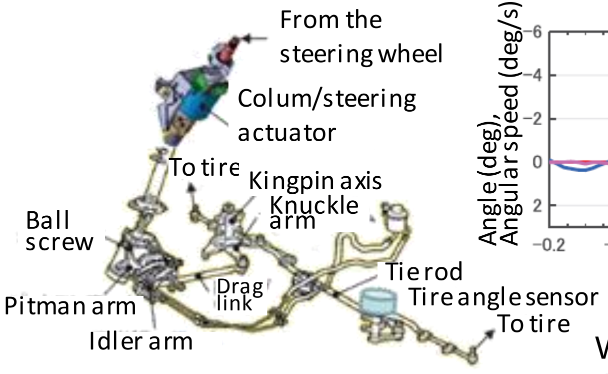


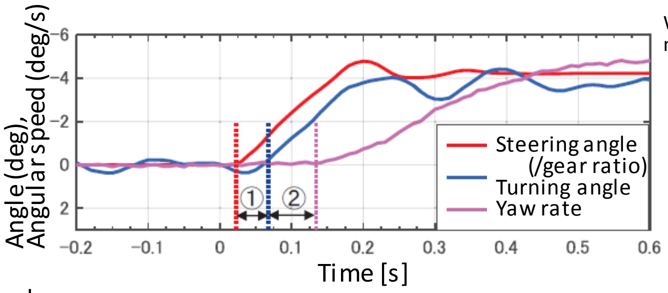


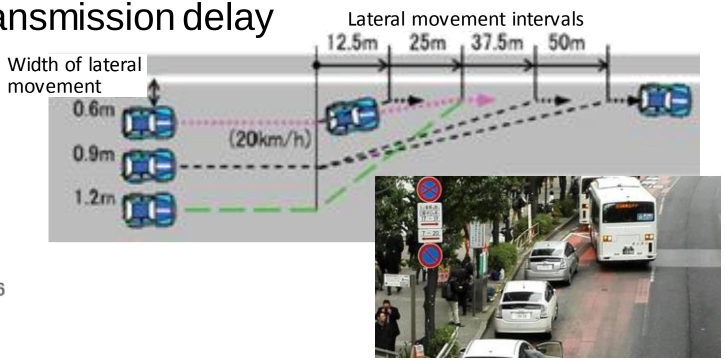


Improved Control Performance of Steering System (Improved Performance of Precise Docking under Unfavorable Conditions)

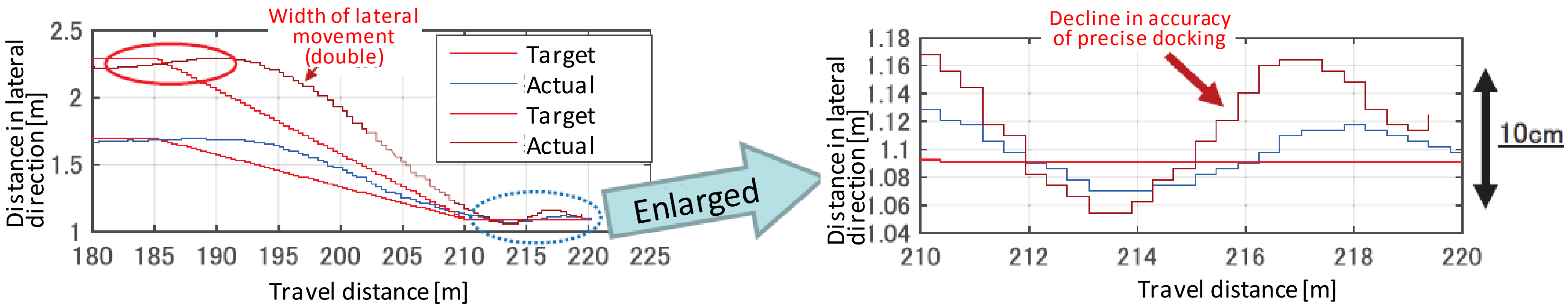
The steering system of large buses is complex, with a mechanical transmission delay







When the angle of approach to the bus stop during precise docking is large, the required accuracy for precise docking (40±20mm) cannot be produced



⇒ Delay in the mechanical system is compensated through steering control, etc.

Basic performance confirmed through precise docking experiments using a mock platform on a proving ground

Travel route: Straight → Reduce speed → Pull over → Stop
Travel speed: From constant speed of 30 km/h, reduce speed and stop
Method of precise docking:
Straight line (orange line in photos below) is detected using on-board camera (detection of curb will be implemented in the future)
Steering and braking through automated control

⇒ Check robustness of control under more conditions

(1) Straight ↑ Mock platform (2) Pull over (3) Stop

Summary of approaches toward Precise Docking through activities

Technological development phase
・Concept verification
・Accuracy verification

Practical application review phase
・Robustness, cost
・Commercialization scenario, supply system

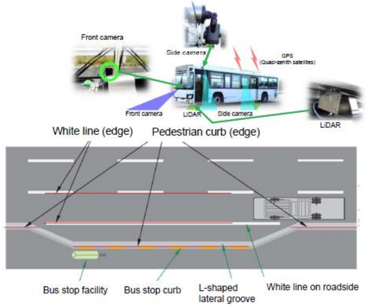
Social implementation phase
・Mass production, infrastructure development
・Foster receptivity in preparation for implementation

Guiding line method →

With the Olympics as the turning point, aim for social implementation by 2020
(Issue) Maintenance costs to avoid fading (whitening) and deterioration of guiding lines

Magnetic marker method →

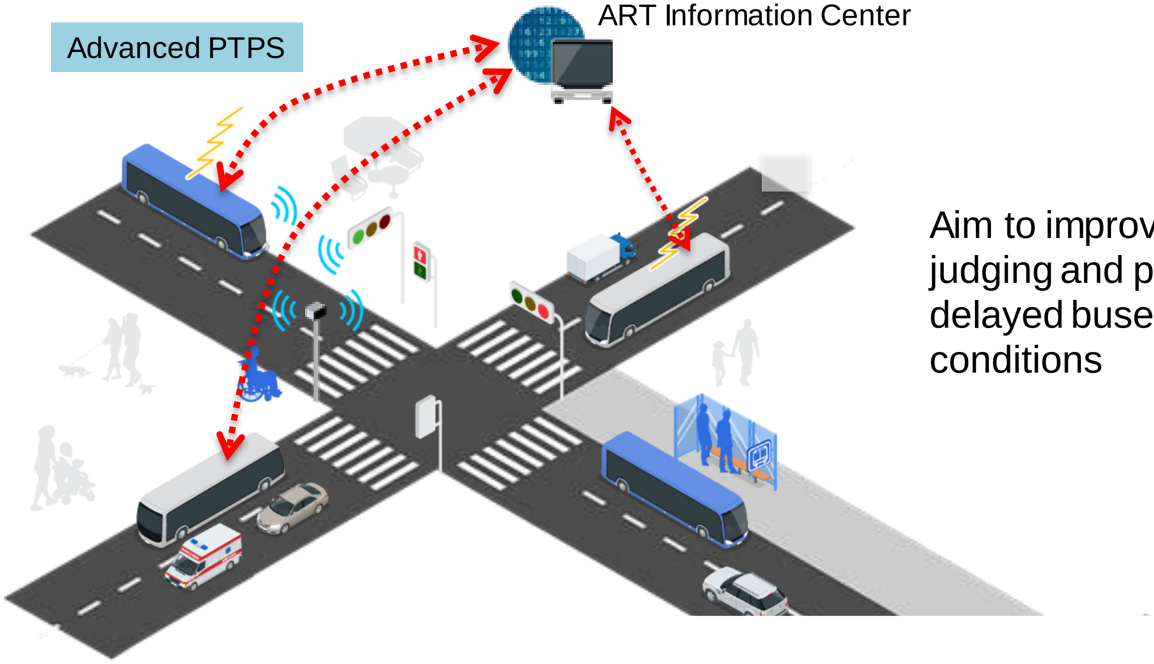
Eliminate impacts on surface road users by matching the protective sheets for magnetic sensor s to the road surface color
(Issues) Complementation with magnetic markers through GPS, etc. is necessary
Installation/maintenance costs for magnetic markers



Sensor fusion method →

Future technology where stable, precise docking is possible even in relation to obstacles, etc. near bus stops, using existing infrastructure
(Issue) Still in the concept verification stage; continued reviews are necessary until social implementation

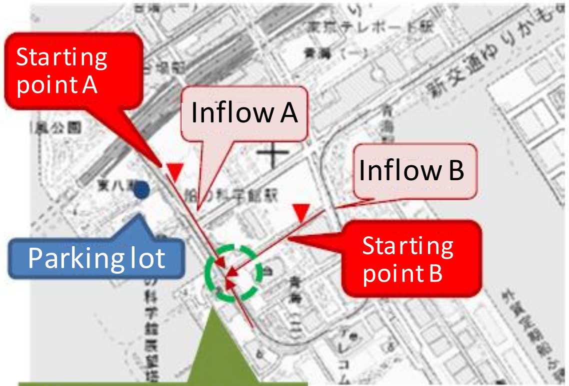
The way in which priority passage request signals generated from buses, etc. are emitted is adjusted at the ART Information Center by using Advanced PTPS (Public Transportation Priority System) based on 700MHz band radio waves



Aim to improve overall rapidness by flexibly judging and prioritizing crowded buses, delayed buses, etc., depending on the conditions

Experiment on 2 inflow roads using roadside unit installed at the Tokyo Wangan Police Station-Mae Intersection

▼ Driving course used in experiment

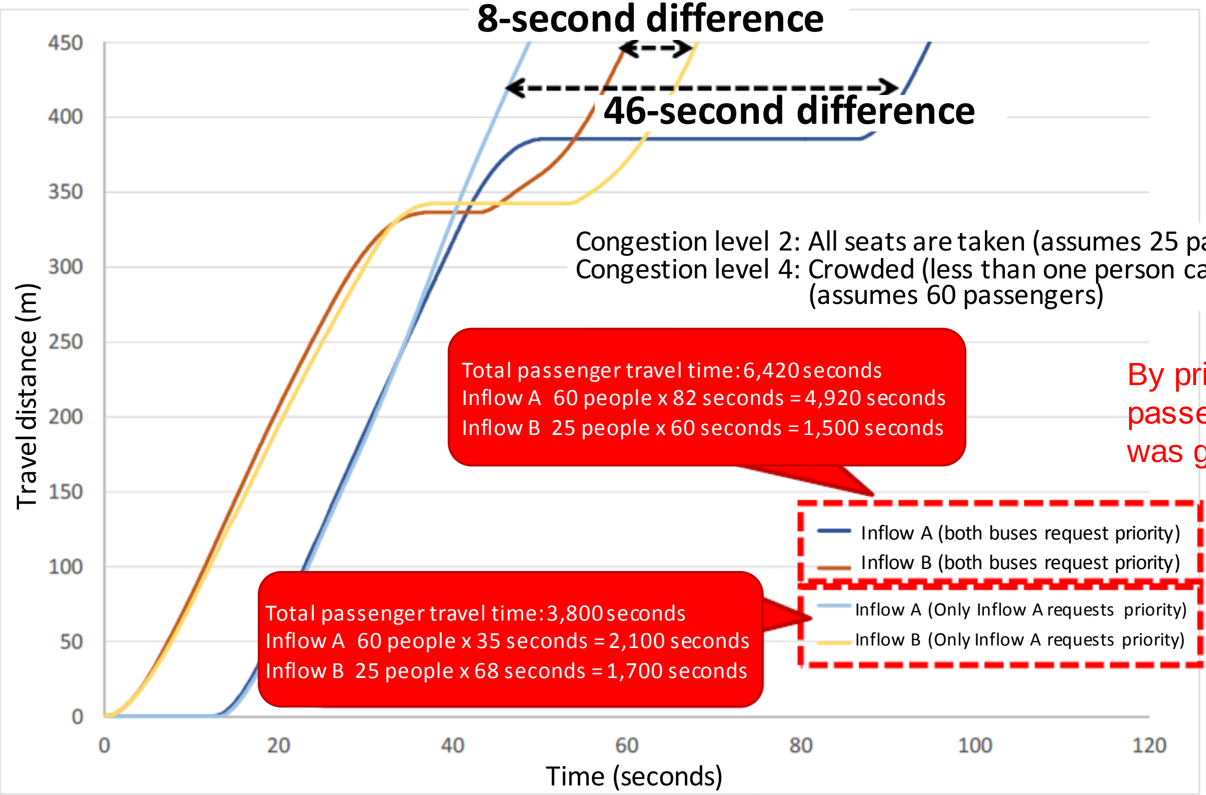


Tokyo Wangan Police Station-Mae Intersection

▼ Tokyo Wangan Police Station-Mae Intersection as seen from Inflow A

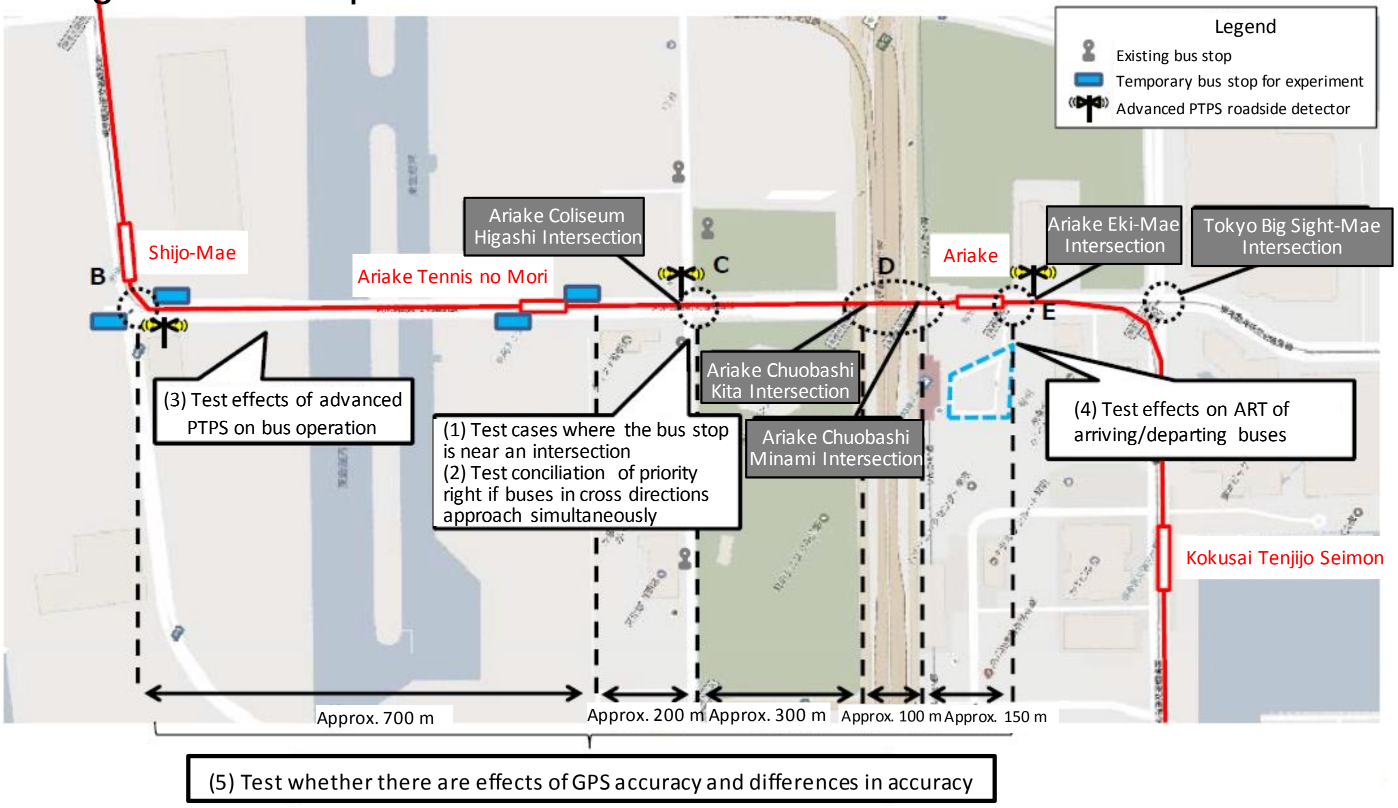
▼ Tokyo Wangan Police Station-Mae Intersection as seen from Inflow B

Experiment conducted based on premise of "prioritizing buses that are crowded (with many passengers)"
After organizing priority rights, the time required for passing through an intersection was shortened by 46 seconds for inflow road A and lengthened by 8 seconds for inflow road B



By prioritizing crowded buses, passengers' total travel time was greatly reduced

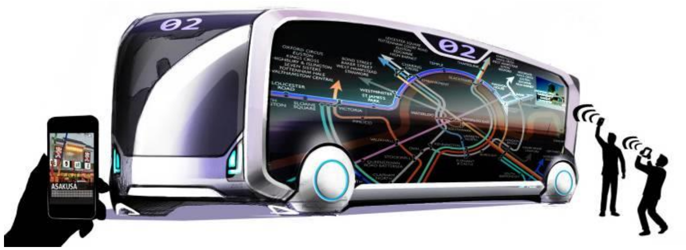
Test using advanced PTPS roadside detector (Intersections B, C and E in map below) installed along Odaiba Loop Road No. 2



Approaches toward next generation public transport is considered as being polarized

1. Large buses: Mass transport, drive support (LRT, BRT)
2. Small shuttles: Automated operation (automated driving + autonomous operation management)

Recently, approaches toward automated operation of small shuttles in particular have been carried out in various regions around the world



Evolution of Public Transport Throughout the World (Mass Transport within Urban Areas)

Europe


LRT
Nancy, France


LRT
Amsterdam, Netherlands


LRT
Strasbourg, France


BRT
Metz, France


BRT
Eindhoven, Netherlands


Future Bus demo
Amsterdam, Netherlands

Japan


BRT
Niigata


LRT
Toyama

Automated Operation of Small Shuttles (Automated Driving + Automated Operation Management)

Although testing of automated driving of small shuttles is carried out throughout the world, there are no major differences in test contents

Navya's Arma (France)

EasyMile's EZ-10 (France)

BESTMILE
THE MISSING LINK

Operation management system
BestMile (Switzerland)

LocalMotors' Olli (United States)

A transport system accessible to all

Thank you

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