

Infrastructure Development Institute - JAPAN

DEVELOPMENT OF THE AUTONOMOUS TRAFFIC SIGN VEHICLE USING THE QUASI-ZENITH SATELLITE SYSTEM AND THE VEHICLE-TO-VEHICLE COMMUNICATION SYSTEM ON EXPRESSWAYS IN JAPAN

Michibiki, the
quasi-zenith
satellite

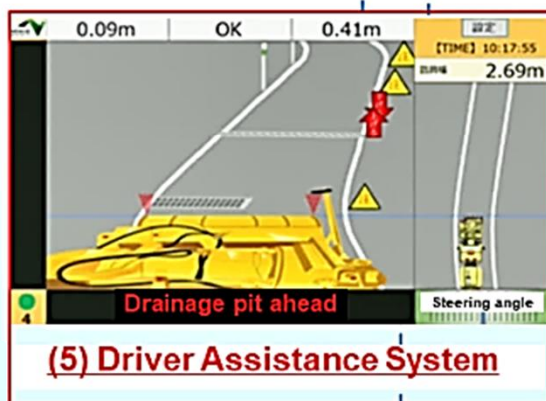


(1) Obtain position
information.



(2) Create high-accuracy maps

(3) Correct the position
information.



(5) Driver Assistance System

(4) Monitor for display
and warning



(6) Vehicle control



Driver Assistance System

Vehicle control

【 Overview of snow blower automation 】

Source: East Nippon Expressway Co., Ltd.

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Development of the Autonomous Traffic Sign Vehicle Using the Quasi-Zenith Satellite System and the Vehicle-to-Vehicle Communication System on Expressways in JAPAN

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ABSTRACT

East Nippon Expressway Company Limited (hereafter referred to as NEXCO-East) has developed an autonomous traffic sign vehicle that automatically follows a rotary snow blower on expressways without manual operation. In Hokkaido, heavy snowfall and a declining, aging workforce make snow removal operations increasingly difficult and technical skills harder to pass on. To address this, we integrated the Quasi-Zenith Satellite System (QZSS) and high-precision expressway maps. The traffic sign vehicle, equipped with a variable message sign (VMS), uses vehicle-to-vehicle (V2V) communication to adjust its distance from the snow blower based on road geometry and visibility. Positioning accuracy is exceptionally high, with discrepancies of less than a few tens of centimeters, allowing the driver to focus on monitoring the surroundings rather than operating the vehicle.

INTRODUCTION

A significant portion of Japan's expressways are in heavy snowfall regions, where poor visibility and obscured lane markings make winter maintenance dangerous. These conditions increase the risk of collisions with roadside structures like guardrails. Operators must rely on limited cues, such as snow poles, while remaining alert to traffic, making the task highly demanding. However, an aging workforce makes securing experienced operators difficult. Consequently, NEXCO East is developing autonomous technologies, including convoy control. Following the 2023 deployment of autonomous rotary snow blowers, the focus has shifted to autonomous traffic sign vehicles that alert users and ensure safety through high-precision satellite data and V2V communication.

PREVIOUS RESEARCH: DEVELOPMENT OF AUTONOMOUS SNOW BLOWER VEHICLE

NEXCO East previously developed a driver assistance system and autonomous capabilities for rotary snow blowers. Using QZSS (MICHIBIKI) and 1-meter interval 3D high-accuracy maps, the system achieves centimeter-level positioning via the Centimeter Level Augmentation Service (CLAS). This technology allows for safe operations even when road markings are completely invisible due to snow. Autonomous driving on snow was successfully verified in 2020, and after trial runs on in-service expressways, the technology was finalized by the winter of 2022.



【 Operation in March 2024 (winter) 】

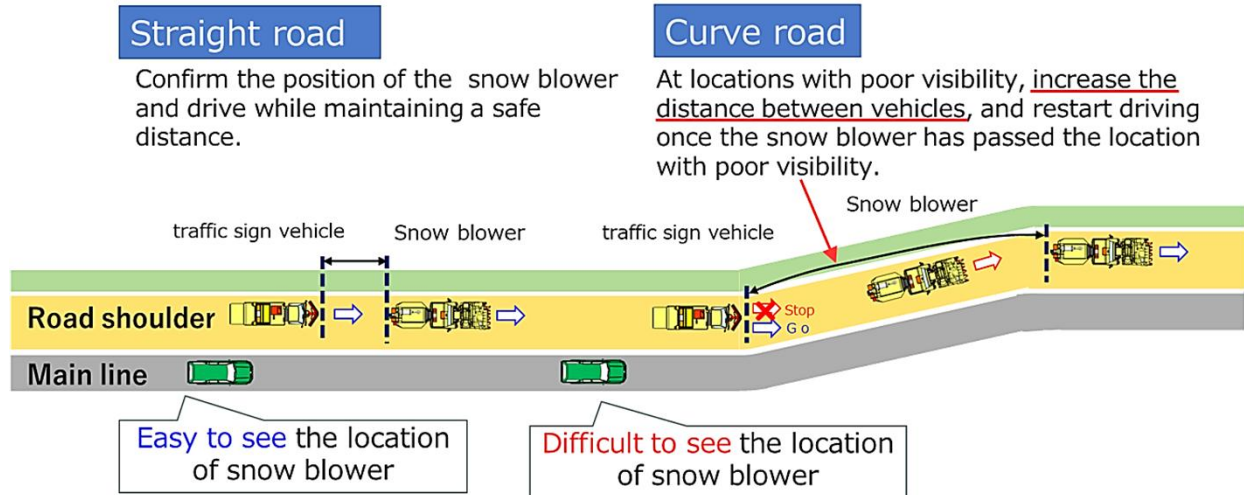
NEW SYSTEM DEVELOPMENT

1. Background

In Hokkaido's severe winter conditions, traffic sign vehicles are essential to protect slow-moving snow blowers from general traffic. The distance between the snow blower and the traffic sign vehicle varies depending on road geometry and conditions, such as curves or areas with limited visibility, and must be adjusted accordingly. Currently, operators must coordinate via radio, manage signage, and monitor surroundings while driving, which is a high-workload task. This automation aims to reduce that burden.

【V2V communication】

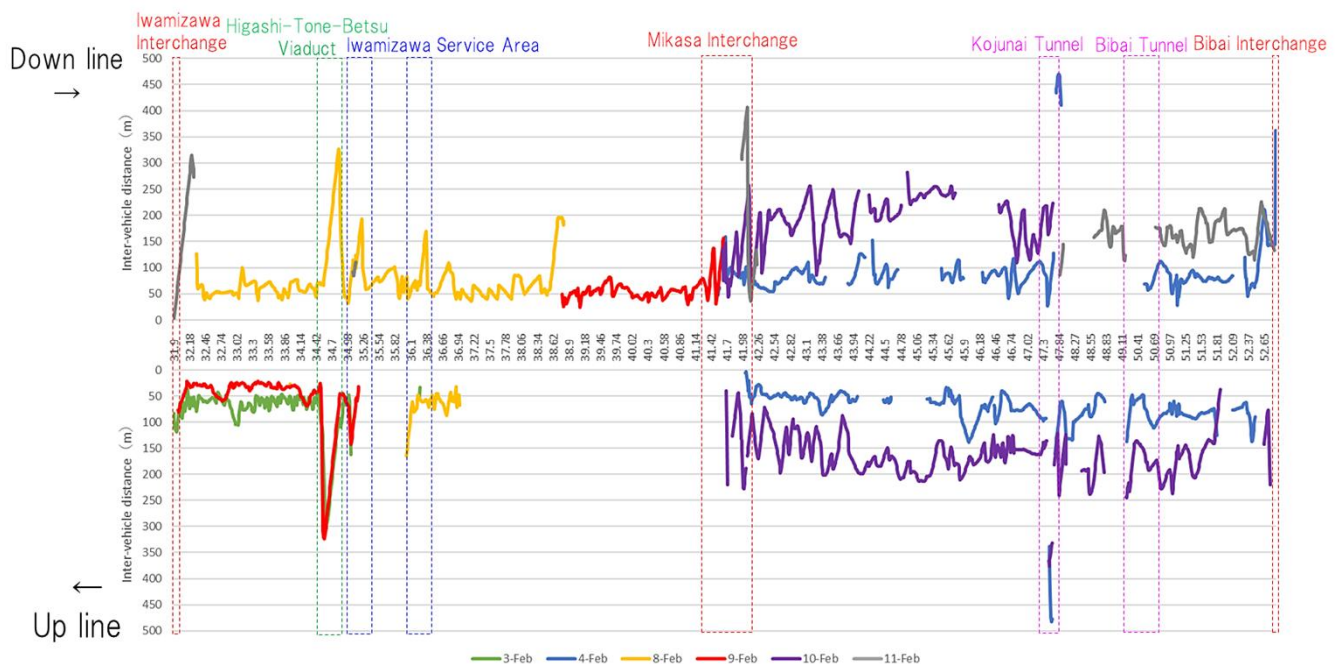
Vehicle spacing is adjusted according to road conditions.



【 Automatic follow-up driving function required for traffic sign vehicle 】

2. Pre-Studies

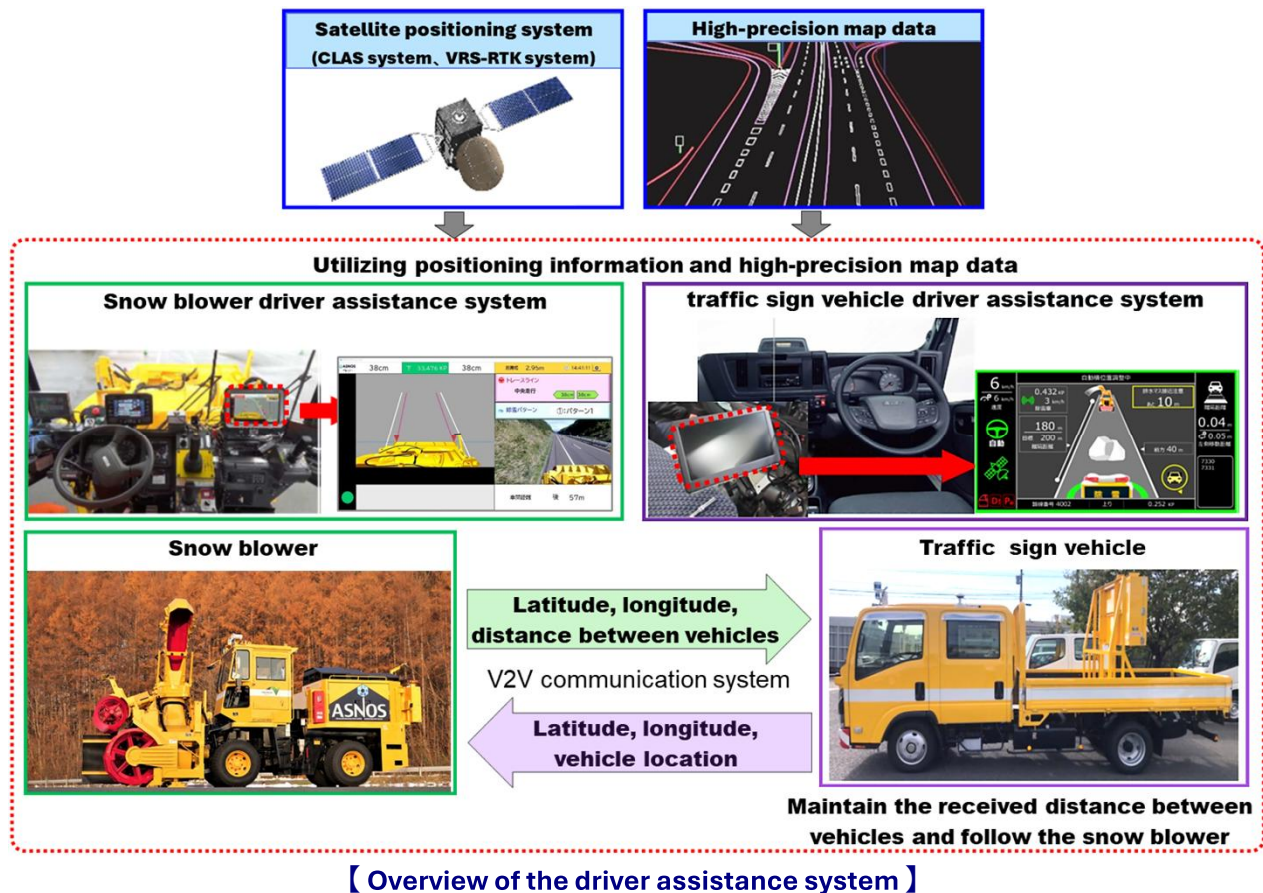
A 2022 investigation found that manual following distances range from 50 to 250 meters, varying at bridges and junctions. A 2023 prototype confirmed the system could communicate in real time, handle automatic steering along curves, and stop for detected obstacles. A prototype for public roads was completed in FY2024.



【 Results of inter-vehicle distance during manual operation (February 2022) 】

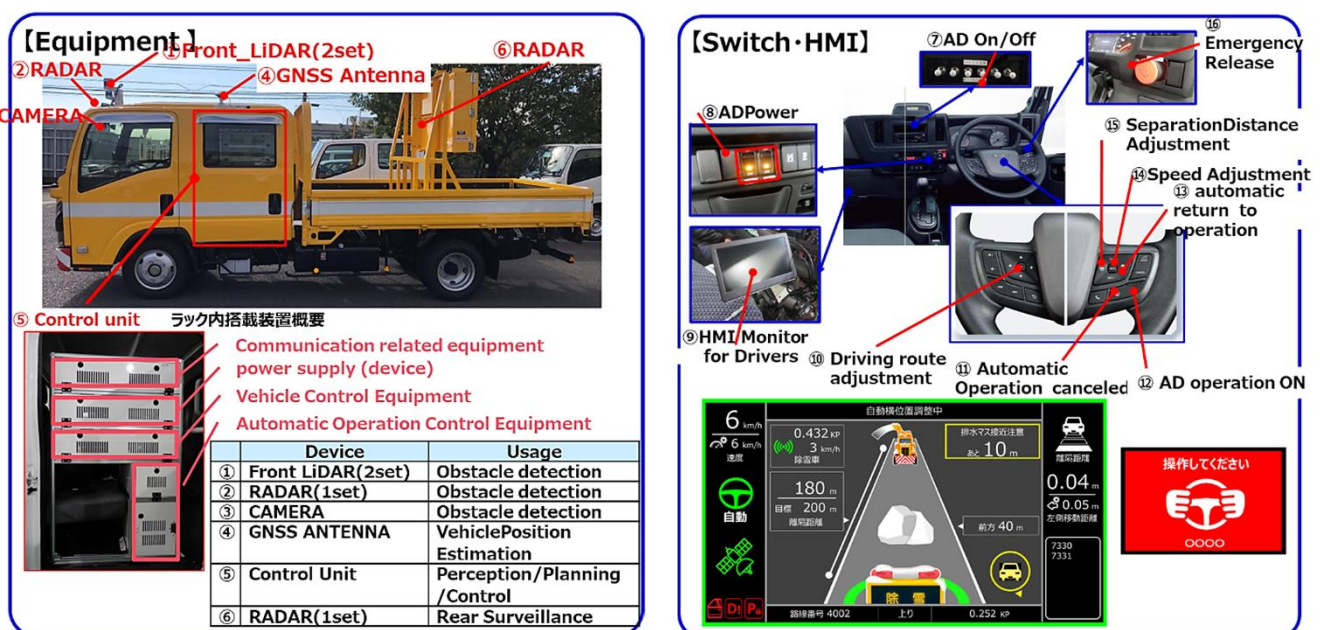
3. Development of Autonomous Driving Support System

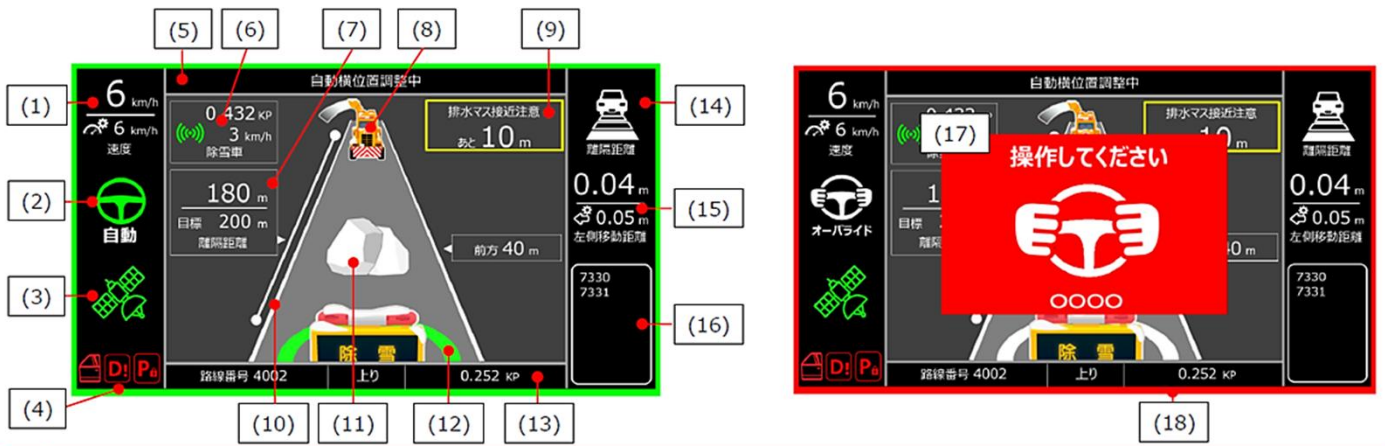
The system uses satellite positioning and V2V communication to share position data between vehicles. Target following distances are transmitted from the snow blower for dynamic adjustment based on location. Multi-access Edge Computing (MEC) ensures secure, low-latency communication. The vehicle performs automatic acceleration, steering, and obstacle detection (e.g., snow chunks) to ensure safety.



4. Development of Test Vehicle

Equipped with GNSS, LiDAR, RADAR, and cameras, the vehicle detects obstacles of 30 cm or larger. Since the vehicle's minimum creep speed (6 km/h) is often faster than the snow blower, a "creep-and-stop" cycle was adopted. The vehicle moves to the target distance, stops, and resumes once the blower has moved 10 meters ahead, mimicking manual operation.





No.	Name	Description
(1)	Vehicle Speed	Displays actual vehicle speed above and target speed below.
(2)	Autonomous Driving Status	Indicates autonomous driving status with an icon.
(3)	Vehicle Positioning Mode	Indicates vehicle positioning mode in three stages (green: stable, yellow: unstable, red: abnormal).
(4)	Vehicle Preparation Status	When the icon is lit, it indicates "door open," "shift not in D," and "parking brake engaged" from left to right.
(5)	Autonomous Driving Status Notification	Displays "stop hold" during stop hold, "instruction lateral movement" during route change, and "automatic lateral adjustment" during route auto-adjustment.
(6)	Snowplow Information	Displays reception status (green: normal, yellow: warning, red: abnormal), snowplow KP number, and snowplow speed.
(7)	Separation Distance	Displays actual separation distance above and target separation distance below.
(8)	Snowplow	Indicates the snowplow. The display position changes according to the distance between vehicles.
(9)	Work Attention Information	Displays the name and distance to "drainage basin," "bridge," and "bridge joint" when approaching.
(10)	Driving Lane	Indicates the driving lane. Changes from white to red when lane departure occurs.
(11)	Other Vehicles/Obstacles	Displays an icon and distance to other vehicles or obstacles when detected.
(12)	Vehicle Status	Indicates vehicle status in three stages (white: autonomous driving OFF, green: autonomous driving ON).
(13)	Road Information	Displays "route number," "up/down line," and "KP number" from left to right.
(14)	Target Separation Distance Adjustment	Indicates driver adjustment of target separation distance (three stages).
(15)	Left Lateral Movement Distance	Displays actual movement distance above and driver-set distance below. Negative values indicate right direction.
(16)	Developer Diagnostic Code	Displays code during abnormal conditions.
(17)	Authority Transfer Notification	Displays notification prompting driver to transfer authority during abnormal conditions.
(18)	Screen Frame Color	Indicates autonomous driving status with screen frame color. Gray
(19)	Rear Monitoring Information	Indicates that another vehicle is approaching from behind when the icon is lit.

[System configurations]

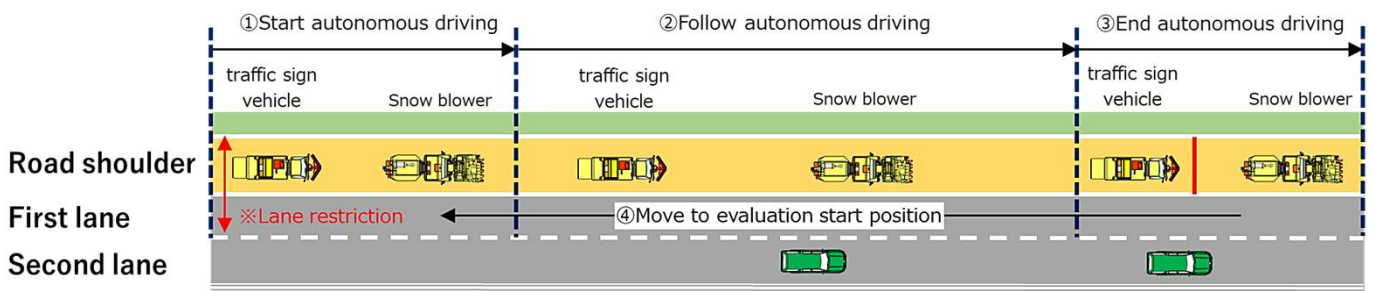
5. Communication Environment

The MEC platform enables low-condition, high-security V2V communication by eliminating internet routing. Testing in 2022 showed a maximum latency of 2.0 seconds at high speeds and 0.5 seconds at low speeds. This was deemed sufficient for the system's 1 Hz communication cycle.

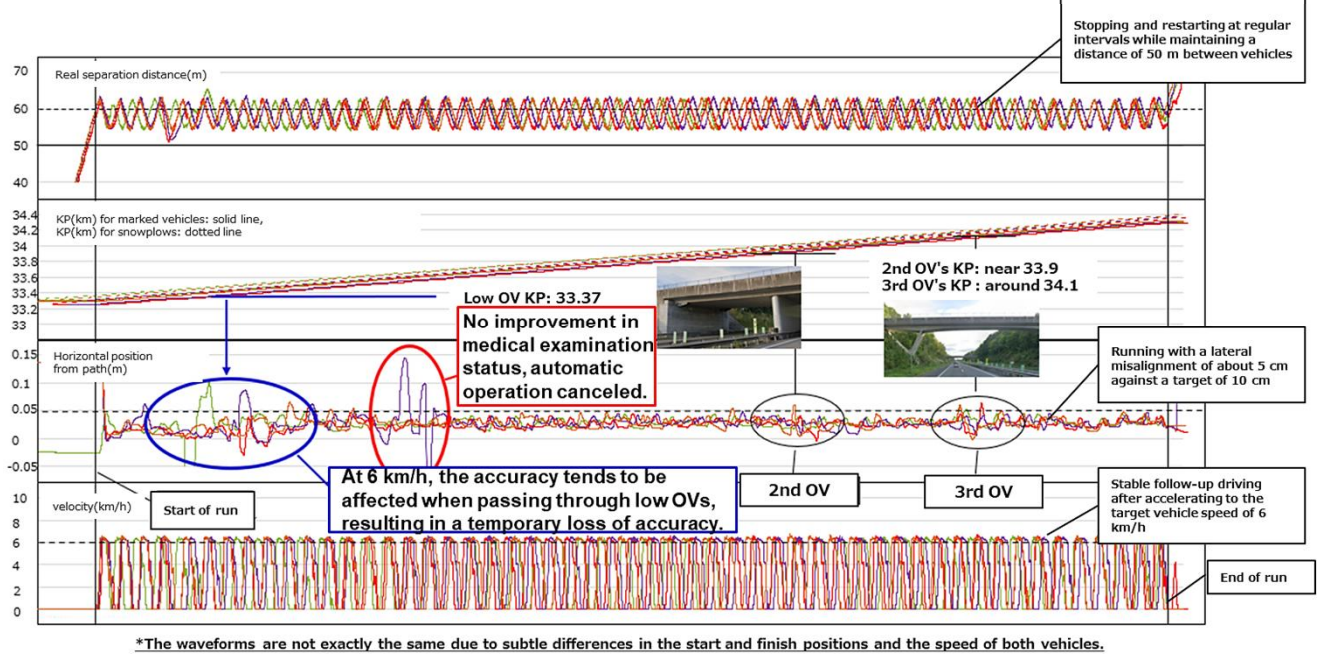
EVALUATION OF TEST RUN

1. Expressway: Summer (September 2024)

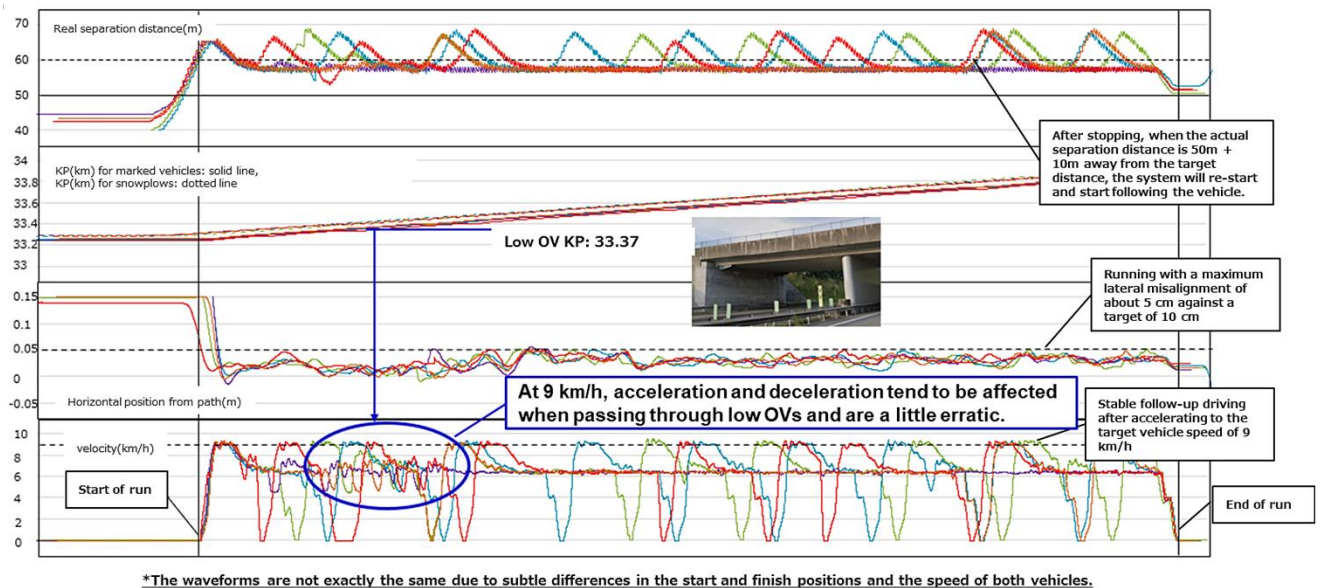
Tests on the DO-O Expressway verified the vehicle could follow a blower at 3 or 6 km/h while maintaining a 50-meter distance. The lateral deviation was only 5 cm, demonstrating high precision. However, positioning accuracy dropped under overbridges, necessitating the system to stop and wait for driver intervention for safety.



[Verification image on the demonstration road]



【 Test result of test run (summer) 3km/h 】



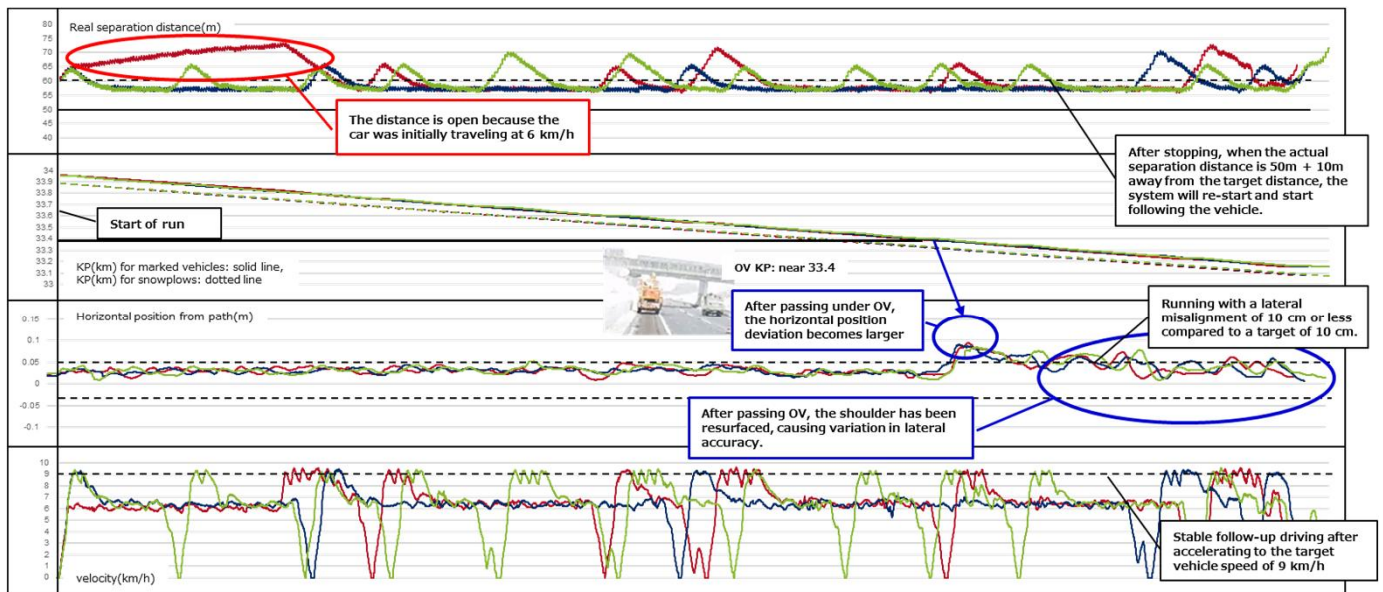
【 Test result of test run (winter) 6km/h 】

2. Expressway: Winter (March 2025)

Winter tests evaluated performance with snow walls and uneven surfaces. The vehicle successfully adjusted its following distance between 25, 50, and 100 meters. Lateral deviation remained around 10 cm, and V2V communication delays were negligible, confirming stable autonomous performance in winter conditions.

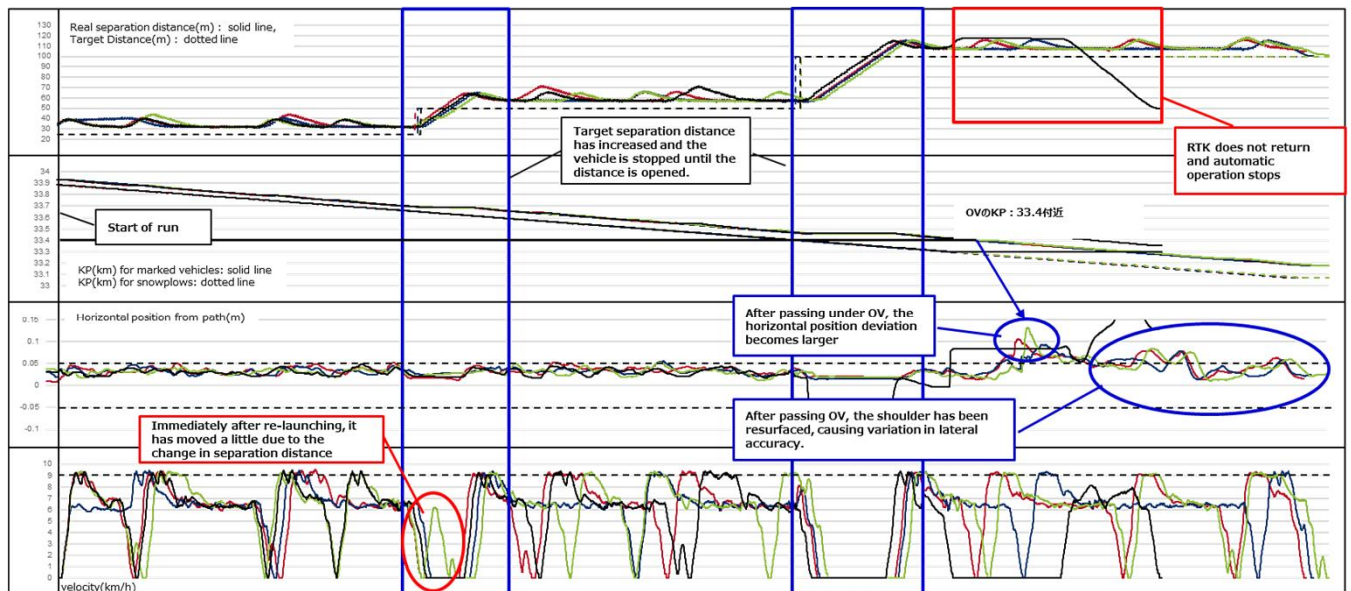


【 Test run under winter condition 】



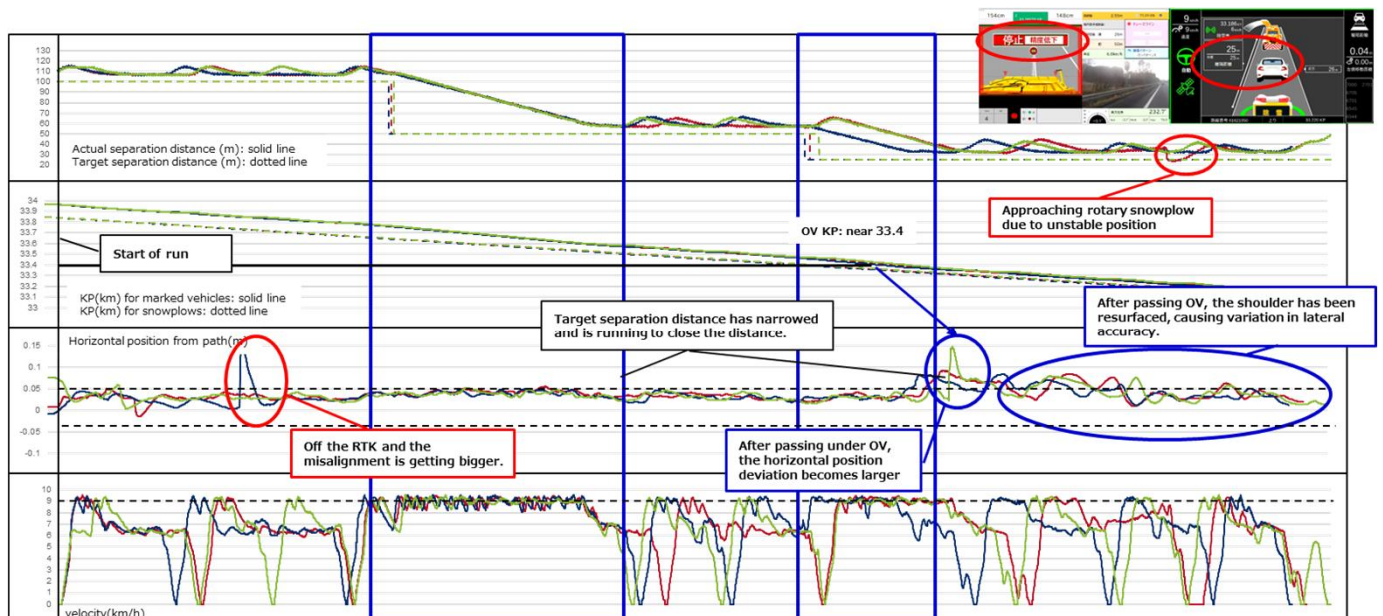
*The waveforms are not exactly the same due to subtle differences in the starting and finishing positions and the speeds of the two vehicles. *

【 Result data of the winter test (the following distance 50m) 】



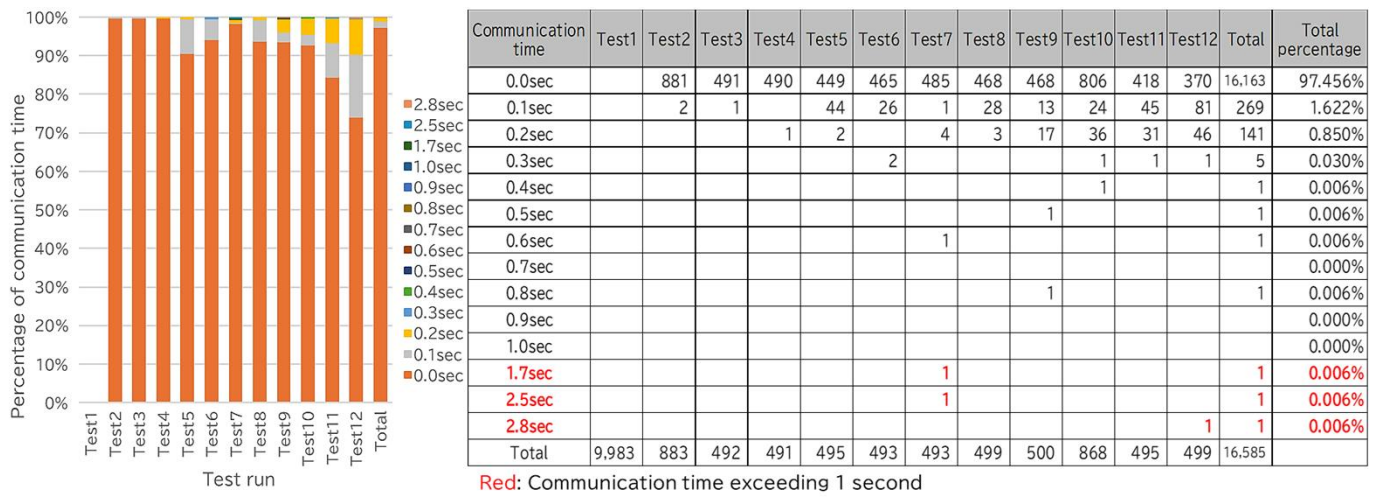
*The waveforms are not exactly the same due to subtle differences in the start and finish positions and the speed of both vehicles.

【 Result data of the winter test (the following distance 25m to 50m to 100m) 】



*The waveforms are not exactly the same due to subtle differences in the start and finish positions and the speed of both vehicles.

【 Result data of the winter test (the following distance 100m to 50m to 25m) 】



【 Vehicle-to-vehicle communication status 】

FURTHER VALIDATION ISSUES

Several challenges remain: satellite signal degradation under overbridges and slow recovery after passing them. The system sometimes misidentifies snow walls or vehicle spray as obstacles, and LiDAR performance can degrade when snowmelt dries on the sensors. Future work must also evaluate the physical load on the vehicle and operators during repeated start-stop cycles.

CONCLUSION

This research confirmed the feasibility of autonomous traffic sign vehicles using satellite positioning and V2V communication. Trial runs on in-service expressways will begin next winter, incorporating operator feedback for further refinement. NEXCO East will continue developing automation for high-speed snow removal trucks to improve efficiency in Japan's aging society.

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