Ascent
Toward Railway Innovation

Railway Technical Research Institute

R&D for the Future of Railways

R&D for the Future of Railways

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On behalf of the Railway Technical Research Institute (RTRI), I would like to extend my sincere greetings to our readers.

Guided by its vision, "We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society," RTRI has advanced its activities through a five-year master plan designed to realize this vision. Under its master plan, "Research and Development for Creating the Future of Railways—RESEARCH 2025," launched in FY2020, RTRI has focused its research and development (R&D) on improving railway safety, particularly by bolstering resilience against intensifying natural disasters, developing innovative railway systems that make full use of digital technologies, and decarbonizing railways toward achieving carbon neutrality by 2050.

To effectively utilize its resources and advance its R&D activities, RTRI has established three pillars of R&D: (1) R&D for the future of railways, (2) development of practical technologies, which provides immediate benefits for railway operation, and (3) basic research for railways, which serves as the driving force for addressing different railway issues and as a source of innovative technologies.

"R&D for the future of railways" targets technologies for practical applications approximately a decade ahead. It addresses themes that respond to the evolving needs of railway operators and changes in society while fully utilizing the high research capabilities, distinctive facilities, and collective technical strength of RTRI. Within this framework, six major R&D themes have been established: (1) enhancement of resilience against intensifying natural disasters, (2) autonomous train operation, (3) labor saving through digital maintenance, (4) building low-carbon power-feeding networks by coordinated power control, (5) increasing the speed of

Shinkansen trains in a manner suitable for their wayside environment, and (6) sophistication of simulation technologies. These six major themes comprise 22 associated projects and 51 research topics, conducted through cross-disciplinary collaboration. The current issue of this journal features the outcomes of these R&D efforts.

Since its inception, the master plan of RTRI has faced considerable challenges due to the COVID-19 pandemic, which placed severe constraints on our operations. Even under these challenging circumstances, we undertook a careful reassessment of the importance and urgency of all of our activities and worked to reprioritize our operations. In parallel, we have made every effort to secure R&D funding wherever possible and have strived to manage our R&D operations with a well-balanced and targeted approach. Consequently, we believe that we have largely accomplished our anticipated R&D goals.

In recent years, changes in the social, economic, and industrial environments surrounding railways in Japan have been accelerating. The railway sector now faces pressing challenges such as labor shortages, aging infrastructure, and the business continuity of regional railway companies. Addressing these challenges requires continuous technical innovation. To achieve this goal, it is vital to promote collaboration and data sharing among different technical fields and organizations, thereby creating new values, enhancing the quality of R&D outcomes, and shortening development timelines.

Under its new master plan, RESEARCH 2030, which commenced in FY2025, RTRI will continue to play a significant role in promoting collaboration for technical innovation and will contribute to the realization of sustainable railway systems for the future.

Front cover photo: **Upper left:** Airflow analysis results and a predicted wind speed map along a railway line generated based on forecast data from the Japan Meteorological Agency and other sources
Lower left: Display screen of the integrated analysis platform
Right: Test train equipped with a front obstacle detection system

R&D Achievements under RESEARCH 2025 and Future Initiatives of RTRI

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AIntroduction

This article highlights the outcomes of the master plan for research and development (R&D), "RESEARCH 2025—R&D for Creating the Future of Railways" (FY2020-FY2024), implemented at the Railway Technical Research Institute (RTRI), and introduces the new master plan, "RESEARCH 2030—Creating Sustainable Railway Systems" (FY2025-FY2029), launched in FY2025.

Achievements under RESEARCH 2025

In accordance with its basic policy for activities, RTRI has made extensive efforts to produce high-quality outcomes. A total of 660 R&D projects were implemented in a cross-disciplinary manner under our three core pillars for R&D: (1) R&D for the Future of Railways; (2) Development of Practical Technologies; and (3) Basic Research for Railways. Despite the challenges posed by the COVID-19 pandemic, most objectives were successfully met by substituting simulations for certain experiments and conducting in-house analyses to reduce external resource costs.

R&D for the Future of Railways

This pillar addresses R&D aimed at the practical implementation of technologies expected ten years ahead in the future, in line with evolving railway operator needs and social trends. It draws on the advanced research capabilities and distinctive facilities of RTRI and comprehensive expertise. This pillar includes six major research themes, comprising 22 sub-themes and 51 R&D projects (*Figure 1*), which were adopted as five-year initiatives forming the core of RESEARCH 2025. The details of some of these activities are presented in the related articles in this issue.

Enhancement of Railway System Resilience against Intensifying Meteorological Disasters

To shorten the service downtime caused by disasters, RTRI conducted R&D on methods such as setting of operation regulation thresholds during rainfall using radar precipitation data, forecasting wind speeds along railway lines using publicly available data, and introducing low-cost restoration techniques for rain-damaged embankments (*Figure 2*).

Autonomous Train Operation

The research efforts at RTRI focused on developing technologies for forward obstacle detection, creating the railway dynamic map, and facilitating onboard decision-making and control systems, all
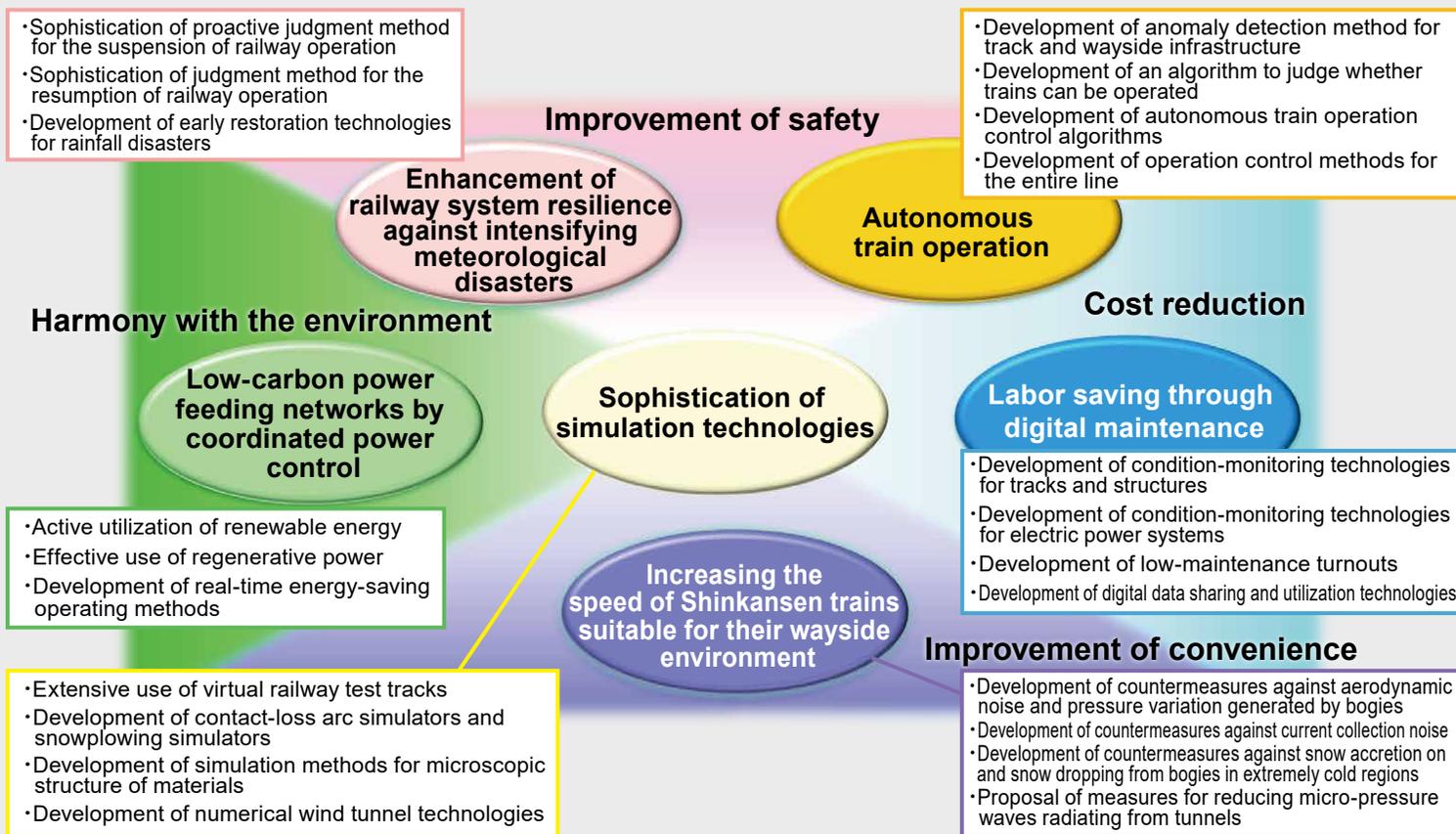
Improvement of safety

Harmony with the environment

Cost reduction

Improvement of convenience

- Sophistication of proactive judgment method for the suspension of railway operation
- Sophistication of judgment method for the resumption of railway operation
- Development of early restoration technologies for rainfall disasters

Enhancement of railway system resilience against intensifying meteorological disasters

- Development of anomaly detection method for track and wayside infrastructure
- Development of an algorithm to judge whether trains can be operated
- Development of autonomous train operation control algorithms
- Development of operation control methods for the entire line

Autonomous train operation

Low-carbon power feeding networks by coordinated power control

Sophistication of simulation technologies

Labor saving through digital maintenance

- Active utilization of renewable energy
- Effective use of regenerative power
- Development of real-time energy-saving operating methods

- Development of condition-monitoring technologies for tracks and structures
- Development of condition-monitoring technologies for electric power systems
- Development of low-maintenance turnouts
- Development of digital data sharing and utilization technologies

Increasing the speed of Shinkansen trains suitable for their wayside environment

- Extensive use of virtual railway test tracks
- Development of contact-loss arc simulators and snowplowing simulators
- Development of simulation methods for microscopic structure of materials
- Development of numerical wind tunnel technologies

- Development of countermeasures against aerodynamic noise and pressure variation generated by bogies
- Development of countermeasures against current collection noise
- Development of countermeasures against snow accretion on and snow dropping from bogies in extremely cold regions
- Proposal of measures for reducing micro-pressure waves radiating from tunnels

Figure 1   Six major research themes and 22 sub-themes for R&D aimed at the future of railways

aimed at reducing workforce requirements and achieving cost-efficient autonomous operation. These systems were demonstrated using test vehicles and internal test tracks (*Figure 3*).

Labor Saving Through Digital Maintenance

To promote efficiency in railway maintenance, RTRI developed an integrated analytics platform that consolidates inspection and condition-monitoring data across multiple technical domains. The system modules include (i) anomaly detection for tracks and structures using portable information terminals, including smartphones, and (ii) anomaly detection for Shinkansen overhead contact lines and pantographs using cameras and LiDAR sensors (*Figure 4*).

Priority R&D

Under RESEARCH 2025, RTRI conducted 276 R&D projects for the development of practical technologies, which included projects commissioned by Japan Railway companies as well as those independently initiated, and 333 projects as basic research addressing railway-specific issues and serving as the source for innovative technologies (*Figure 5*).

Enhancement of Safety and Resilience Against Natural Disasters

In its research on earthquake disaster management, RTRI focused on advancing vehicle behavior analysis during earthquakes, upgrading early earthquake warning systems utilizing ocean-bottom seismometers, and developing seismic reinforcement methods for railway structures and electrical equipment. The research projects for rainfall-induced disasters included emergency diagnosis and temporary restoration techniques for scoured bridges. These research outcomes have been applied to the investigations of damage and development of restoration and countermeasure strategies following events such as the Fukushima offshore earthquakes (February 2021 and March 2022), torrential rains of July 2020, and heavy rainfall due to the 2023 rainy season front.

Innovation of Railway Systems Through Digital Technology

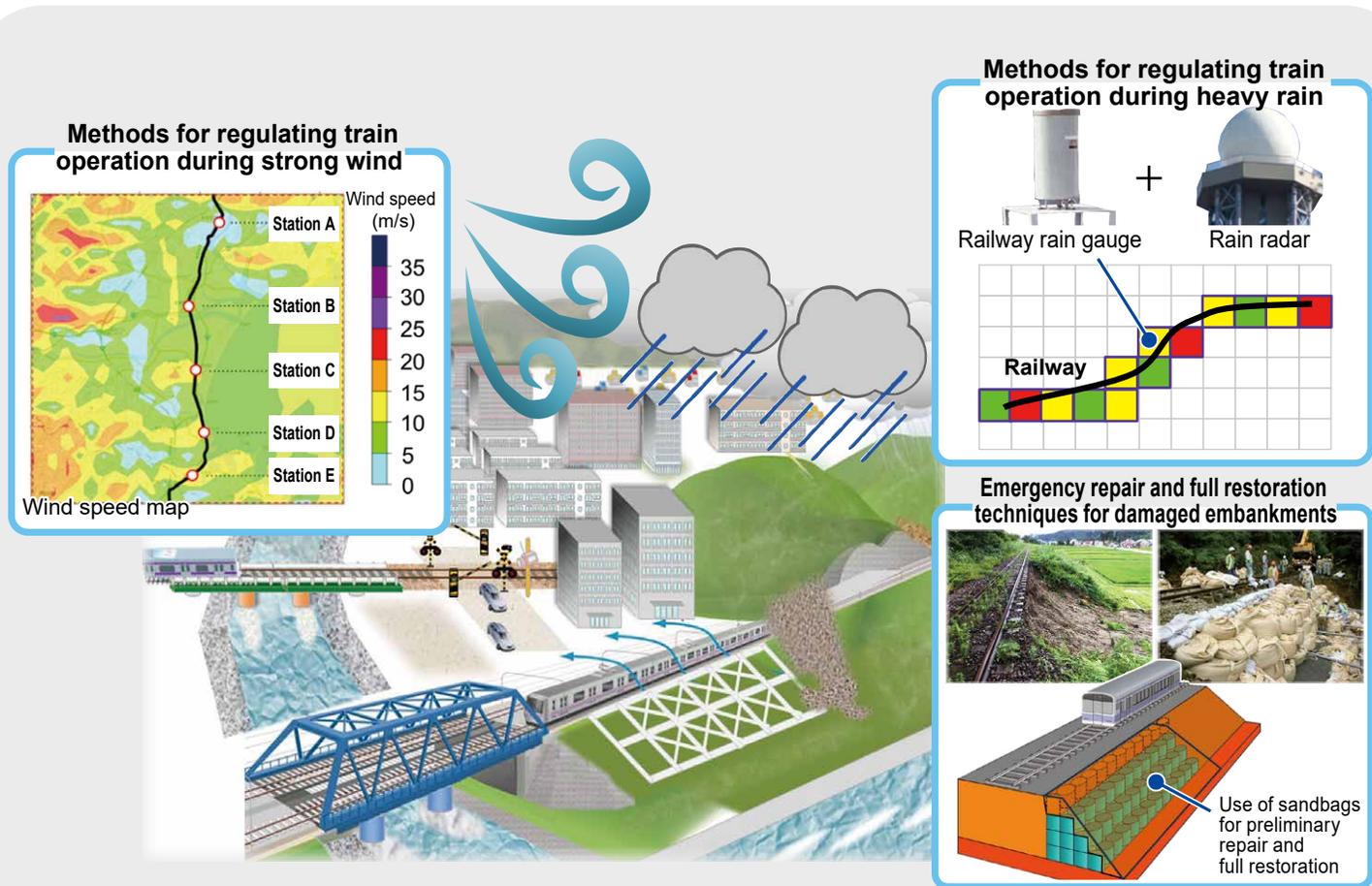Driven by deepening labor shortages owing to the declining working-age popula-

Methods for regulating train operation during strong wind

Wind speed (m/s)

Station A
Station B
Station C
Station D
Station E

Wind speed map

Methods for regulating train operation during heavy rain

Railway rain gauge + Rain radar

Railway

Emergency repair and full restoration techniques for damaged embankments

Use of sandbags for preliminary repair and full restoration

Figure 2   Enhancement of railway system resilience against intensifying meteorological disasters

tion, the focus of R&D among railway operators has shifted from improving the work efficiency to achieving substantial labor saving. RTRI supported the development of GOA2.5 automated train operation and conducted advanced research into workforce reduction in vehicle and equipment maintenance, accompanied by increased adoption of artificial intelligence across many R&D projects.

Realization of Carbon Neutrality by 2050

In line with the declaration by the Japanese government in October 2020 to achieve carbon neutrality by 2050, decarbonization has become a pressing issue in the railway sector.

RTRI has actively conducted R&D focusing on reducing railway CO_2 emissions and promoted R&D in new fields such as preventing hydrogen leakage in fuel-cell-powered vehicles and evaluating the performance of biodiesel-powered diesel engines while supporting their social implementation.

Urgent Issues Requiring Prompt Action

RTRI has responded rapidly to challenges requiring immediate resolution, as requested by railway operators, including the development of next-generation tilt control systems and assessing the effectiveness of opening windows for improved vehicle ventilation as a COVID-19 mitigation measure.

Overview of R&D under RESEARCH 2030

The following is an overview of our R&D initiatives under the new master plan launched in FY2025.

Creating Sustainable Railway Systems

Since the COVID-19 pandemic, the Japanese social, economic, and railway environment has been undergoing rapid changes. Social issues, including frequent climate change and large-scale natural disasters, the goal of realizing carbon neutrality by 2050, heightened geopolitical risks, and a shrinking working-age population due to
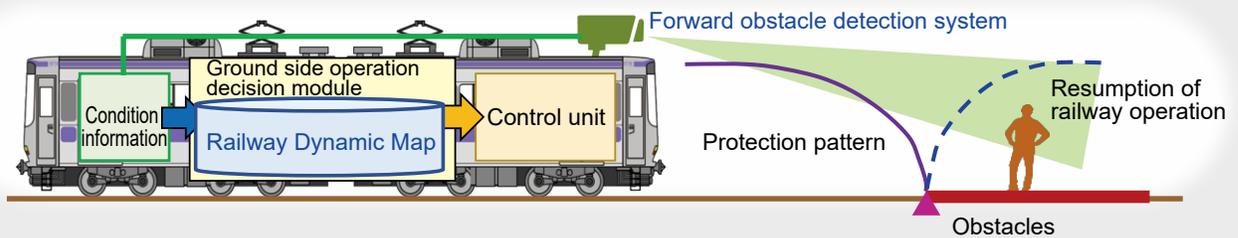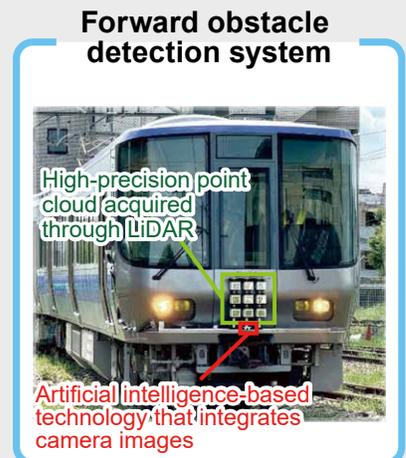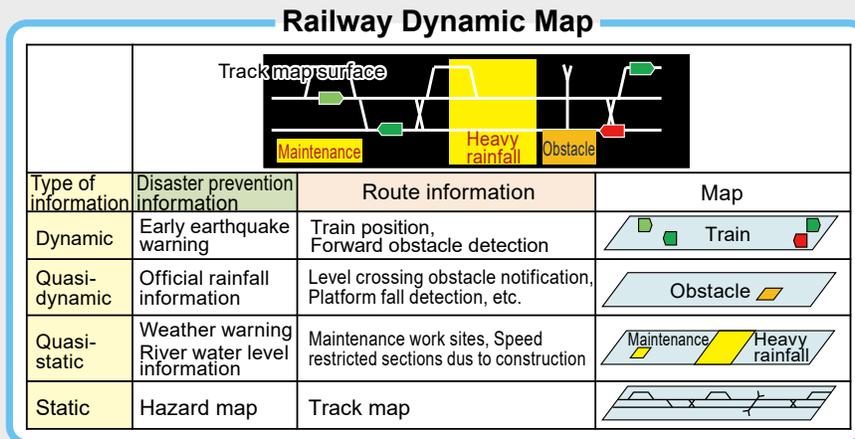
Railway Dynamic Map

Type of information	Disaster prevention information	Route information	Map
Dynamic	Early earthquake warning	Train position, Forward obstacle detection	Train
Quasi-dynamic	Official rainfall information	Level crossing obstacle notification, Platform fall detection, etc.	Obstacle
Quasi-static	Weather warning River water level information	Maintenance work sites, Speed restricted sections dus to construction	Maintenance Heavy rainfall
Static	Hazard map	Track map	

Forward obstacle detection system

High-precision point cloud acquired through LiDAR

Artificial intelligence-based technology that integrates camera images

Figure 3　Autonomous train operation

Integrated analytics platform

Set of analysis and evaluation modules

Set of core modules

Cross-system data in standardized format and kilometrage

Measurement and diagnosis　Facility ledger　Onboard measurement　Front image

Data from each system

Examples of sets of analysis and evaluation modules

Track patrol support using portable information terminals

Anomaly detection of overhead contact lines and pantographs

Figure 4　Labor saving through digital maintenance

Intensifying natural disasters
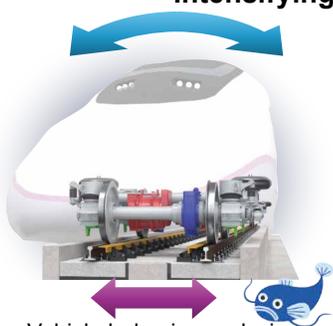
Vehicle behavior analysis during earthquakes
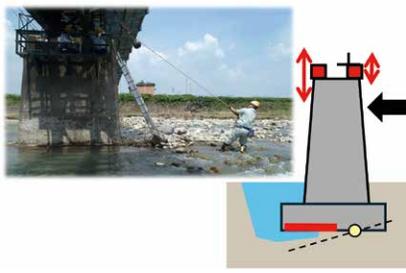
Emergency diagnosis techniques for bridges affected by scour

Innovation of railway systems through digital technology

- AI-based deterioration diagnosis
- Projection system

Support for the development of GOA 2.5 automated train operation system

Detailed inspection of tunnels

Realization of carbon neutrality by 2050

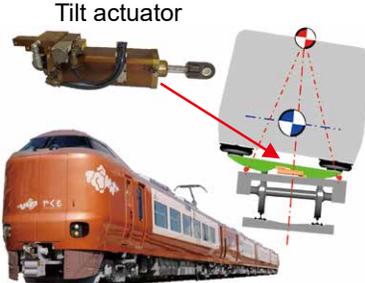- Simulation
- Risk assessment and proposal of risk reduction measures

H_2
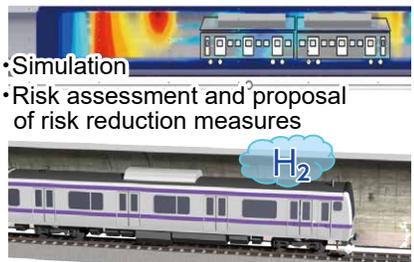
Measures to prevent hydrogen leakage in fuel cell rail vehicles

Performance evaluation of biodiesel-powered diesel engines

Urgent issues requiring prompt action

Tilt actuator

Next-generation tilt control system
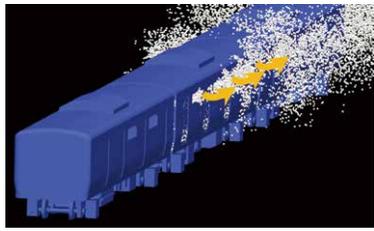
Effectiveness of opening windows for improved vehicle ventilation

Figure 5 Examples of priority R&D

a declining birthrate and an aging population, have become increasingly severe, visible, and complex. In the railway sector, labor shortages, aging infrastructure, and business continuity of regional railway companies are especially urgent concerns.

In response, RTRI will promote R&D to develop innovative technologies aimed at "Creating Sustainable Railway Systems," striving to make railways safer, smarter, more secure, more environmentally sustainable, and better suited to meet future demands.

Advancing R&D

RTRI has established the following four "R&D aims" : (1) Improvement of safety; (2) Improvement of productivity; (3) Harmony with the environment; and (4) Improvement of convenience. To achieve these aims efficiently, three "Pillars of R&D" have been set: (1) R&D for the future of railways; (2) Development of practical technologies; and (3) Basic research for railways (see *Figure 6*).

R&D projects are established in line with clearly defined goals and roadmaps. Each roadmap, with a clearly defined final goal, spans from basic research, which serves as a source of innovative technologies, through to applied development, with milestones appropriately set at each stage of the R&D process. During practical development, researchers with advanced expertise will independently and proactively contribute to the formulation of new laws, regulations, and technical standards essential for the social implementation of innovative technologies. To further promote international standardization, R&D projects have been designed to contribute to global standardization initiatives.

Regarding the pillar "R&D for the Future of Railways," which forms the core of the master plan, five mission-oriented R&D themes, 13 sub-themes, and 48 R&D projects have been launched. Specifically, RTRI will advance initiatives related to (1) Enhancement of railway system resilience against intensifying natural disasters; (2) Sophistication of automatic train operation; (3) Labor saving in maintenance; (4) Decarbonization of railway systems; and (5) Eluci-

dation of railway-specific phenomena through simulation (see *Figure 7*).

Conclusions

Despite the challenges posed by COVID-19, RESEARCH 2025 generally achieved its objectives, particularly in the six major research themes and priority projects focused on the future of railways. Building on these achievements, RESEARCH 2030 will drive R&D further with the objective of developing innovative technologies and creating sustainable railway systems.

RTRI will propose and pursue R&D aims and roadmaps to enable social implementation, fulfilling a leadership role in advancing technical innovation in close collaboration with railway companies and related organizations. In addition to cutting-edge digital technologies, RTRI will further enhance its core R&D technologies, such as physical and simulation technologies in which RTRI excels, that contribute to pursuing the essence of and finding solutions for fundamental railway issues. Through these efforts, RTRI aims to develop innovative technologies that generate shared benefits for the entire railway industry.

Your continued support and cooperation are greatly appreciated.

Figure 6 Advancing R&D
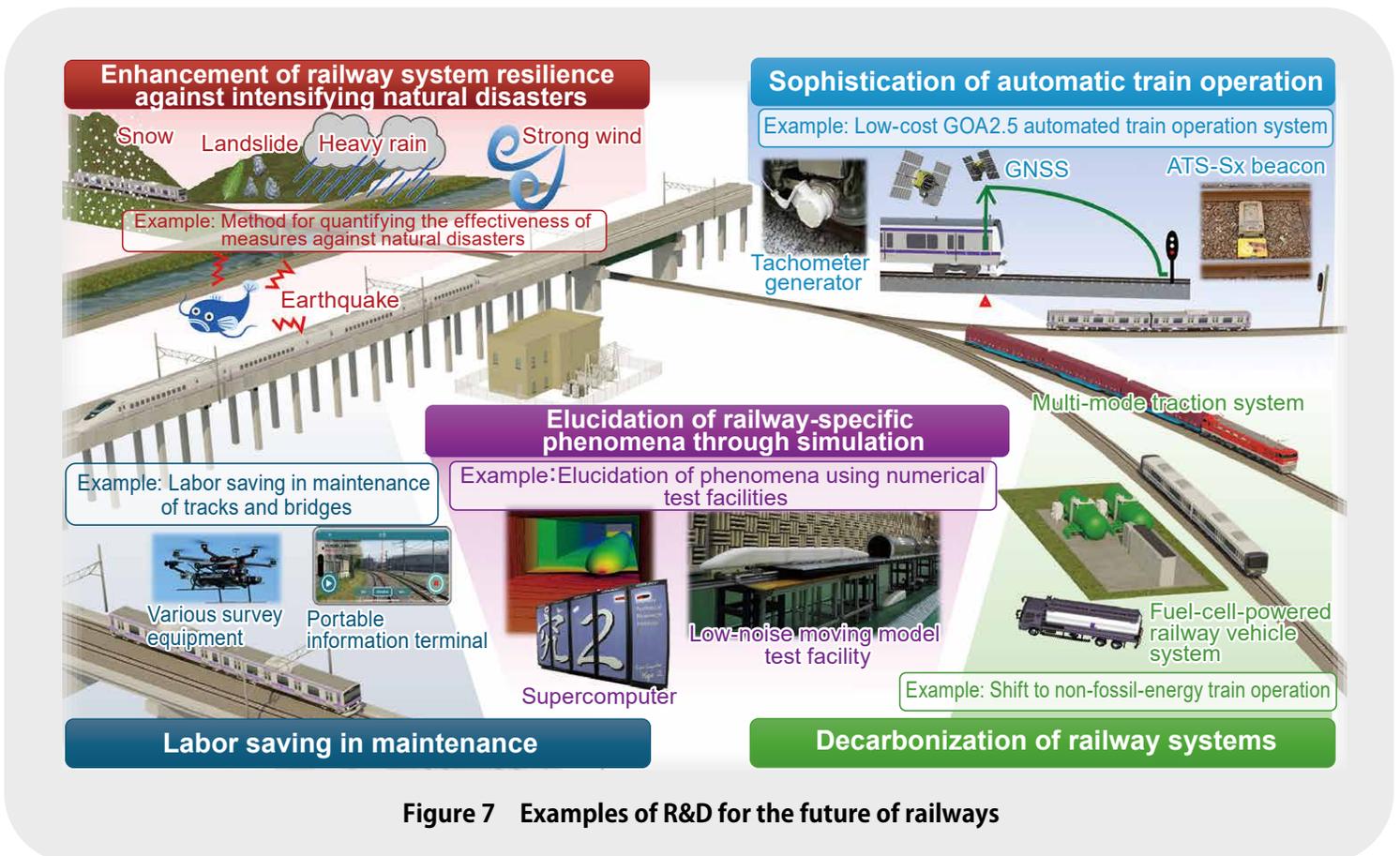
Figure 7 Examples of R&D for the future of railways

Enhancement of Railway System Resilience Against Intensifying Meteorological Disasters

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Introduction

In recent years, external meteorological forces, such as heavy rainfall and strong winds, have intensified, resulting in increasingly severe disasters. In response to this trend, our master plan, RESEARCH 2025, established the major research theme "Enhancement of Railway System Resilience Against Intensifying Meteorological Disasters," under which related research and development (R&D) activities have been conducted. This article provides an overview of the principal achievements of these efforts.

Background and Objectives

The Ministry of Education, Culture, Sports, Science, and Technology and the Japan Meteorological Agency (JMA) project that rainfall patterns will continue to become increasingly extreme and that typhoons affecting Japan will intensify[1]. Railway operators currently ensure tran safety during heavy rainfall and strong winds by implementing operation controls, such as canceling services or imposing speed restrictions. However, as these external forces become stronger and more frequent, both the
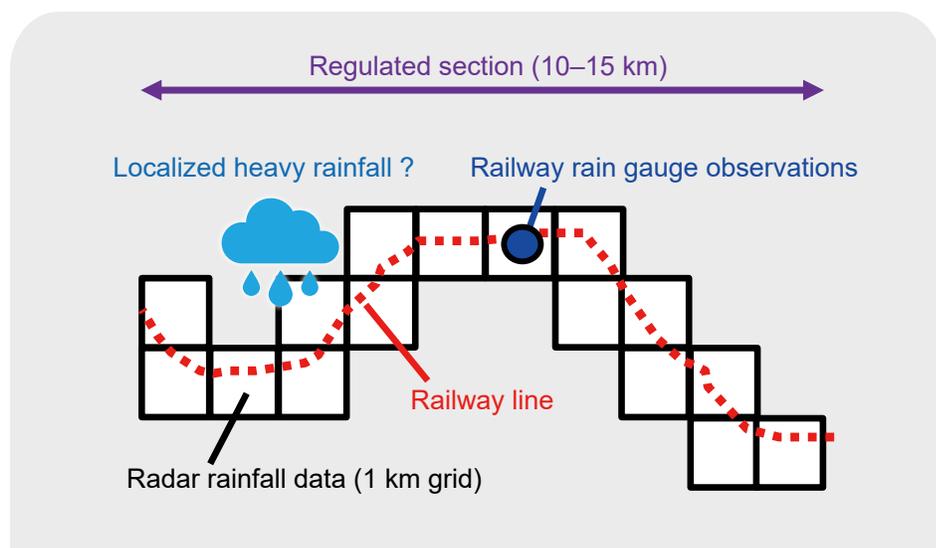

Figure 1　Conceptual relationship between railway rain gauge observations, radar rainfall data, and regulated sections

frequency and duration of such operation control measures are expected to increase. In addition, these changes raise concerns about a potential increase in slope-related disasters, including embankment collapse. In this context, two objectives were established for the major research theme: (1) to propose methods for enhancing operation control during heavy rainfall and strong winds to improve safety while maintaining punctuality, and (2) to propose methods for expediting responses to damaged embankments with the aim of reducing service downtime.

Enhancement of Operation Control During Heavy Rainfall

  This section introduces a method for setting operation control thresholds during heavy rainfall using radar rainfall data. In recent years, national agencies and other organizations have improved the accuracy of real-time and forecast areal rainfall information (radar rainfall data[*1]), and some railway operators have introduced operation control based on radar rainfall data[2)-5)] to detect localized intense downpours[*2]. As the use of radar rainfall data becomes more widespread, it is anticipated that rainfall observations currently obtained from railway rain gauges will eventually be replaced by radar rainfall data.

  Currently, operational control during rainfall is implemented using point rainfall values observed by railway rain gauges, and restrictions are applied to a defined line segment, referred to as a regulated section. If operation control were implemented using radar rainfall data instead of railway rain gauge data, all radar rainfall data distributed in 1 km × 1 km grids within the regulated section would be used (*Figure 1*). In this case, if the operation control thresholds remained unchanged after the introduction of radar rainfall data, the increased number of observation points would, in turn, increase both the frequency and du-
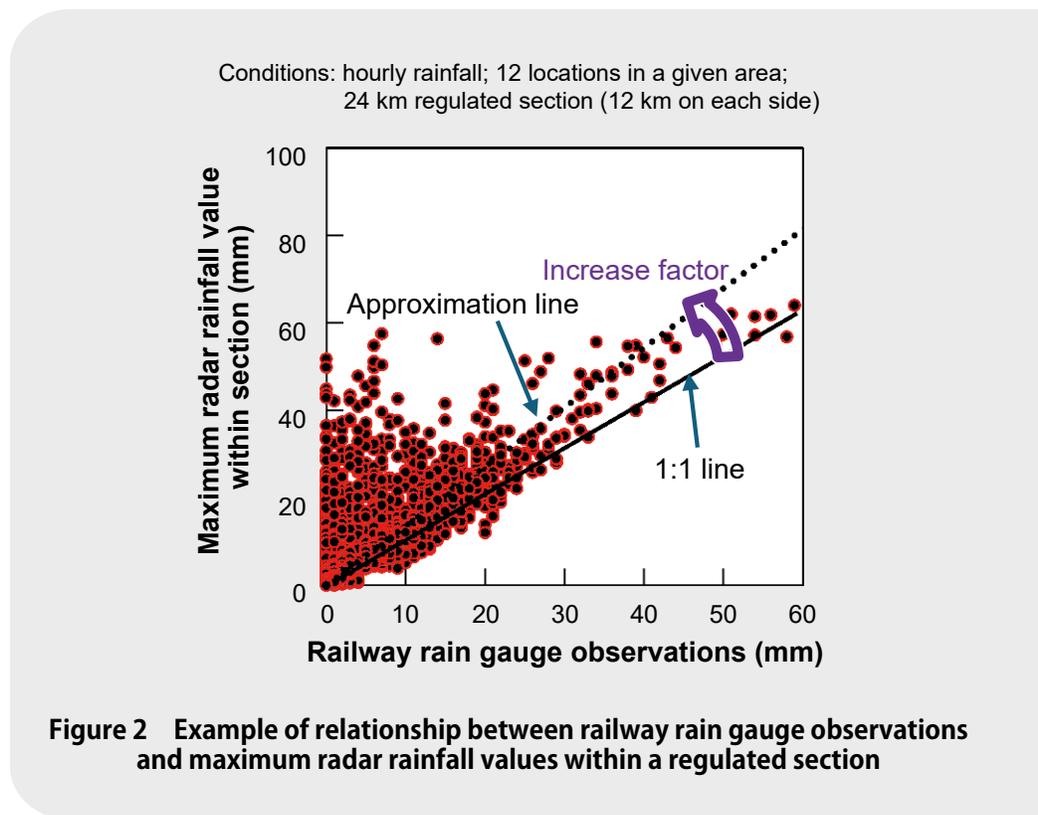
ration of restrictions. To address this issue, a method for setting radar rainfall control values was proposed.

  An example analysis of the relationship between railway rain gauge observations and the maximum radar rainfall value within a regulated section for hourly rainfall (*Figure 2*) shows that the data are primarily distributed in a range where the maximum radar rainfall exceeds the railway rain gauge observations. Based on this relationship, an increase factor was derived using a linear approximation, and a method was pro-

posed in which radar rainfall control values were calculated by multiplying the existing control values by this increase factor.

  Using the above method to set radar rainfall control values, we estimated, for both conventional operation control using railway rain gauge data and operation control using radar rainfall data, the number of disaster events captured and not captured, as well as the restriction issuance time (*Figure 3*). In this estimation, the proposed method was applied not only to hourly rainfall, which is a short-term rainfall index,

Figure 2   Example of relationship between railway rain gauge observations and maximum radar rainfall values within a regulated section

Control method	Railway rain gauge data	Radar rainfall data
A	[Existing control values]	Not captured
B	Not captured	[With correction]
C	Not captured	[Existing control values]
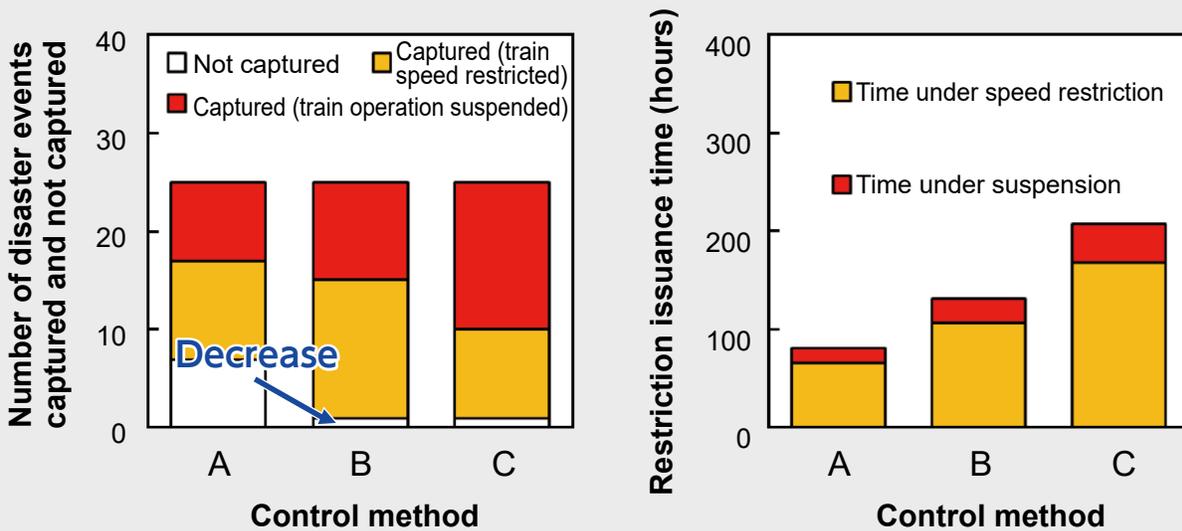
(Conditions: multiple regulated sections; 3–5 year period)

Figure 3   Number of disaster events captured and not captured and restriction issuance time for each control method

but also to long-term rainfall indices; cases in which the radar rainfall control values remained the same as the existing control values were also compared. As shown in *Figure 3* (left), radar rainfall data can capture disasters that conventional operation control fails to detect, thereby enhancing safety. As shown in *Figure 3* (right), restriction issuance time increases when radar rainfall data are used compared with conventional operation control; however, the proposed method suppresses this increase more effectively than simply maintaining the existing control values. In future stud-

ies, such estimations will be applied to a range of regions and line sections to identify remaining issues and establish a practical method for setting radar rainfall control values.

Enhancement of Operation Control During Strong Winds

This section introduces methods for creating real-time and estimated wind speed maps. As in the case of rainfall, wind speed has traditionally been monitored using anemometers installed along rail-

way lines, and operation control has been implemented when observed wind speeds exceed specified thresholds. However, anemometers are not installed along the entire length of a line; in many cases, they are located only at sites where strong winds are expected to occur, based on past experience (*Figure 4*). As noted earlier, because typhoons are expected to become stronger in the future, the likelihood of strong winds occurring at any location along the line will increase. Therefore, areal wind speed monitoring is increasingly necessary.

On the other hand, areal wind speed

Enhancement of operation control during strong winds

Strong-wind section | Weak-wind section | Strong-wind section

Station C

Station B

Anemometer

Station D

Station A

Regulated section | Regulated section | Non-regulated section
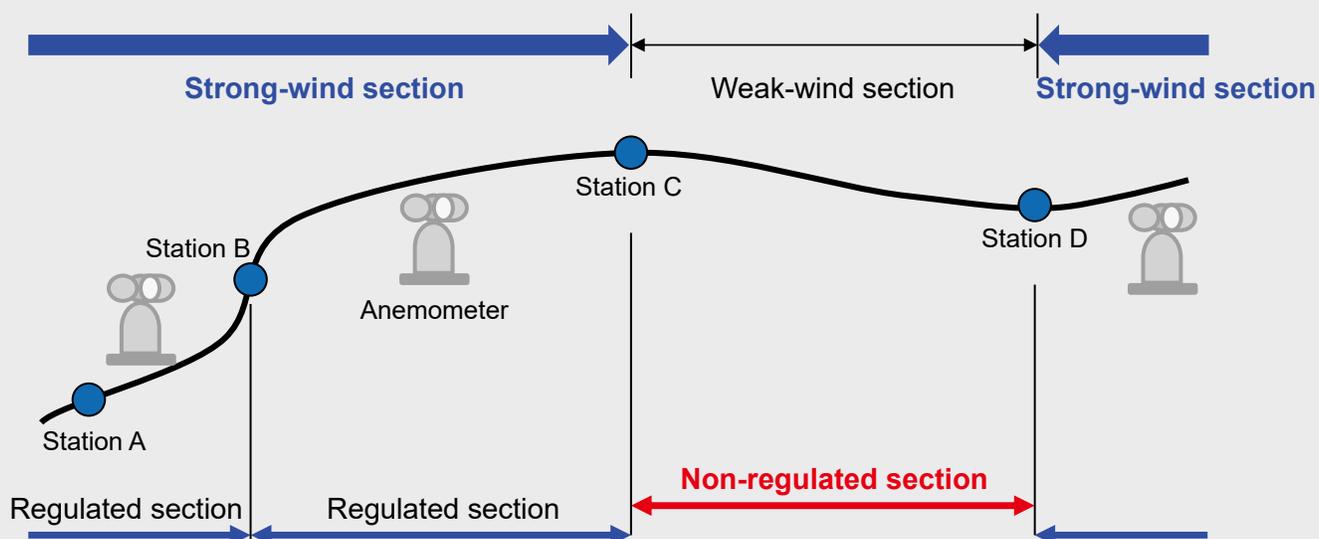
Figure 4　Conceptual relationship between anemometer locations and regulated sections

data distributed by national agencies and other organizations differ from rainfall data in that they currently lack the accuracy required for operation control and are provided as average wind speed[*3] rather than the instantaneous wind speed[*4] used for operation control. To address these issues, two approaches are proposed: (1) real-time wind speed maps aimed at improving safety by identifying wind speeds at low cost in areas without existing wind speed monitoring, and (2) estimated wind speed maps aimed at improving efficiency by supporting advance preparations for issu-

ing and lifting operation control.

For real-time wind speed map creation (*Figure 5*), average wind speed and average wind direction observed at point locations, such as Automated Meteorological Data Acquisition System (AMeDAS) sites, are used as input, and wind speeds equivalent to instantaneous wind speed are output as areal data. To ensure that the real-time wind speed map updates in step with the update interval of the observed wind speed, airflow analysis[*5] is conducted in advance, and a table is prepared for

[*3] Average wind speed
The value obtained by averaging wind speed over the 10-minute period preceding the observation time; when "wind speed" is mentioned, this value is typically meant.

[*4] Instantaneous wind speed
The wind speed at a given observed moment can reach 1.5 to 3 times the average wind speed.

[*5] Airflow analysis
A technique for analyzing airflow and related phenomena using computer-based methods grounded in theoretical principles, such as fluid dynamics.
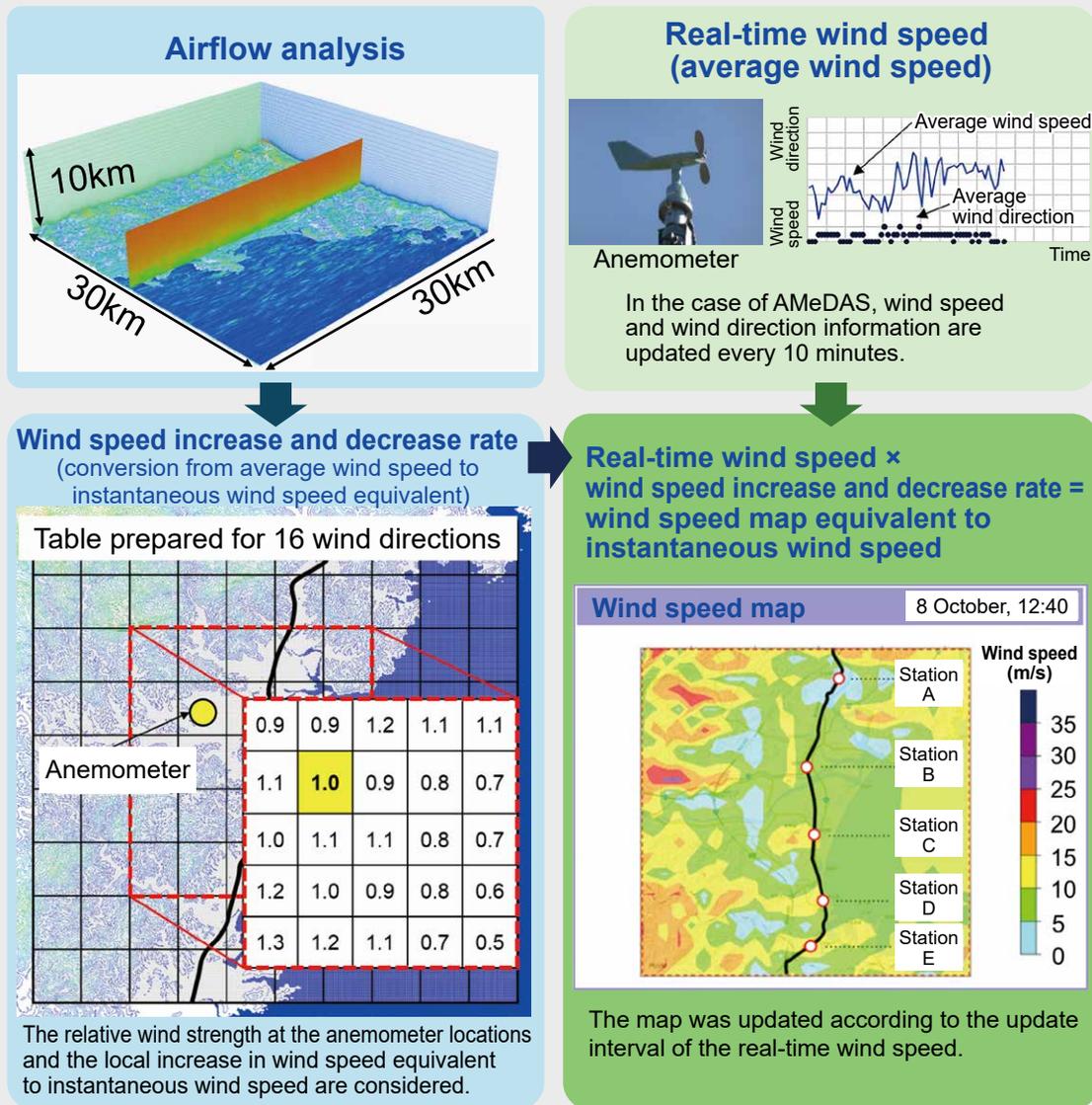
Airflow analysis

10km

30km

30km

**Real-time wind speed
(average wind speed)**

Wind direction

Wind speed

Average wind speed

Average wind direction

Time

Anemometer

In the case of AMeDAS, wind speed and wind direction information are updated every 10 minutes.

Wind speed increase and decrease rate
(conversion from average wind speed to instantaneous wind speed equivalent)

Table prepared for 16 wind directions

Anemometer

0.9	0.9	1.2	1.1	1.1
1.1	**1.0**	0.9	0.8	0.7
1.0	1.1	1.1	0.8	0.7
1.2	1.0	0.9	0.8	0.6
1.3	1.2	1.1	0.7	0.5

The relative wind strength at the anemometer locations and the local increase in wind speed equivalent to instantaneous wind speed are considered.

Real-time wind speed × wind speed increase and decrease rate = wind speed map equivalent to instantaneous wind speed

Wind speed map   8 October, 12:40

Station A

Station B

Station C

Station D

Station E

Wind speed (m/s)

35
30
25
20
15
10
5
0

The map was updated according to the update interval of the real-time wind speed.

Figure 5   Overview of the method for creating real-time wind speed maps

each of the 16 wind directions. These rates serve as multipliers for converting the average wind speed at the observation point, normalized to 1, into an instantaneous wind speed. This approach makes it possible to instantaneously convert point-based information into areal information.

To create the estimated wind speed map (*Figure 6*), areal forecast average wind speed data distributed by the JMA and other agencies are used as inputs. Airflow analysis is also performed in advance; however, in this case, a table of wind speed increase rates for converting average wind speed to an instantaneous wind speed equivalent is prepared. Using this table, forecast maps equivalent to instantaneous wind speed can be generated in accordance with the
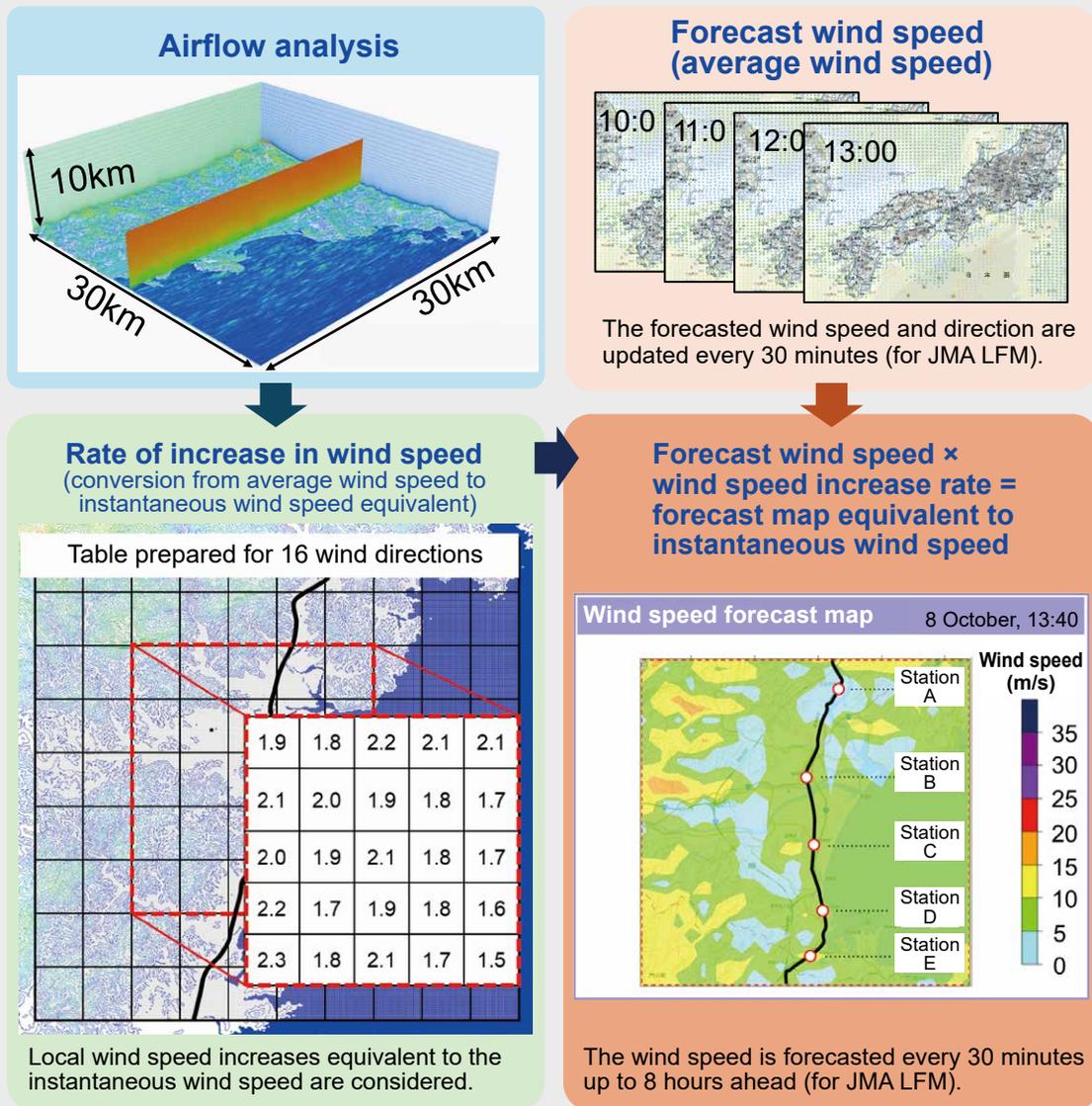
Figure 6   Overview of the method for creating estimated wind speed maps

distribution interval and forecast lead time of the forecasted average wind speed data.

The accuracy of both types of maps was verified using field measurements, and the resulting prediction error was found to be less than 5 m/s. Future work will focus on further improvements in accuracy.

Expediting Response to Damaged Embankments

This section introduces a method for per-

manently restoring damaged railway embankments in a timely and cost-effective manner to a performance level equivalent to that prior to the damage. Emergency repairs using large sandbags, which offer excellent workability, are commonly imple-

Figure 7   Example of emergency embankment repairs using large sandbags

mented to enable the rapid resumption of train operations when a railway embankment is damaged (*Figure 7*). However, because large sandbags have limited long-term durability, permanent repairs are required after train operations have resumed in order to restore the embankment to its pre-damage performance level.

In conventional permanent repair methods (*Figure 8*), (1) temporary earth retaining walls are installed to protect trains, (2) large sandbags are removed, and (3) the embankment is reconstructed. However, this approach presents challenges in terms of both construction time and cost. To address these challenges, a permanent repair method is proposed in which the sandbags

used for emergency repairs are left in place.

In the proposed permanent repair method (*Figure 9*), (1) only the upper sandbags are removed, and (2) the embankment is constructed on the removed area and in front of the remaining large sandbags. Estimates have shown that, compared with conventional permanent repair methods, this approach can reduce construction time by approximately 60% and costs by approximately 80%. Experiments and analyses confirmed that embankments restored using this method exhibit performance equivalent to that prior to the damage. We plan to promote wider adoption of this method by including it in maintenance and management documentation and

other related materials.

Conclusions

This article presents an overview of the main achievements of the major research theme, "Enhancement of railway system resilience against intensifying meteorological disasters," under RESEARCH 2025. Although the intensification of natural disasters is projected to continue, some types of natural hazards are not addressed within this theme. Accordingly, beginning with RESEARCH 2030 in the current fiscal year, a new major research theme, "Enhancement of railway system resilience against intensifying natural disasters," has been

Emergency repairs:
provisional resumption of train operation
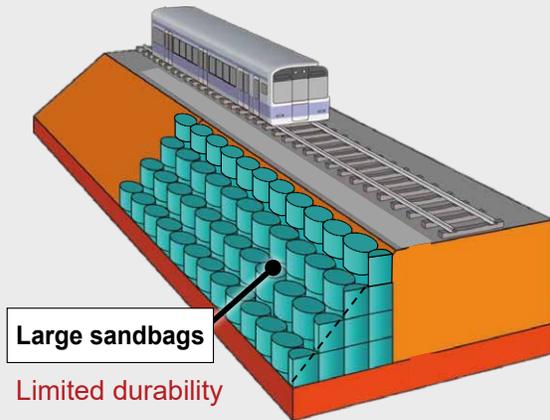
Permanent repairs:
full restoration to original profile

(2) Removal of large sandbags

Large sandbags

Limited durability

(3) Embankment construction
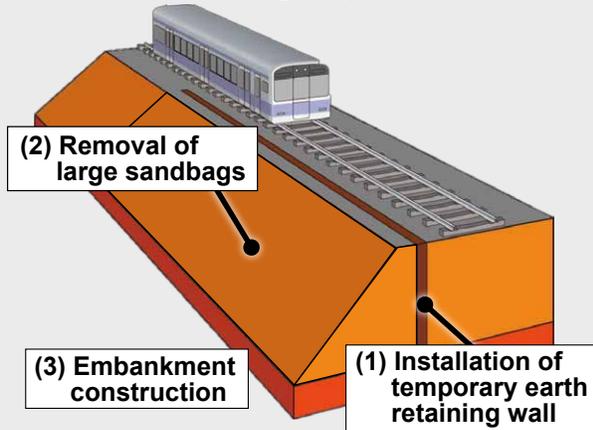
(1) Installation of temporary earth retaining wall

Figure 8   Conventional method and sequence for emergency repairs using large sandbags and subsequent permanent embankment restoration (Schematic)
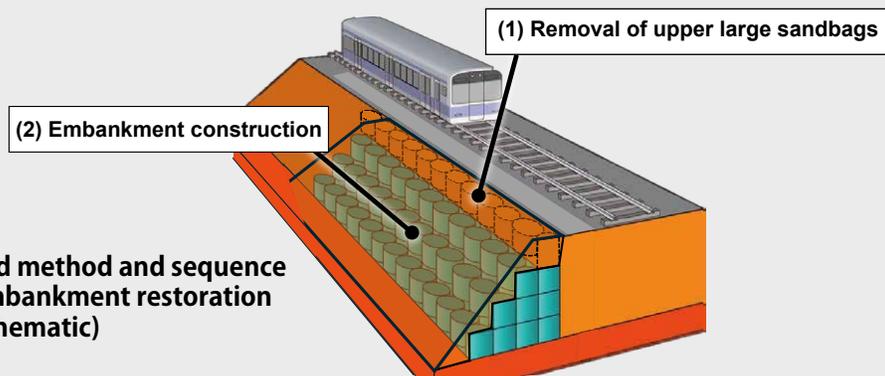
(1) Removal of upper large sandbags

(2) Embankment construction

Figure 9   Proposed method and sequence for permanent embankment restoration (Schematic)

established, under which R&D will be pursued to strengthen railway system resilience against a wide range of natural disasters, including earthquakes, rainfall, snow, and falling rocks.

Note: Some of the achievements introduced in this article were obtained through joint research with Toshiba Energy Systems & Solutions Corporation.

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Autonomous Train Operation

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Introduction

The shrinking working-age population in Japan is having an increasingly serious effect across many industrial sectors. The railway industry is no exception, as securing sufficient number of train drivers and other railway personnel has become a pressing issue. Consequently, there is a growing need for labor-saving train operations.

Currently in Japan, driverless automatic train operation without personnel at the front of the train is already in service on several automated urban guided transport (AUGT) systems. If such driverless operation can be extended to standard railway lines with level crossing systems, an even greater expansion of labor-saving railway operations can be expected.

The Railway Technical Research Institute (RTRI) has been pursuing a major research theme, "Autonomous Train Operation," aiming to achieve greater labor savings not only in driving tasks but also in the overall train operation, including train operation

management. This article introduces verification tests for autonomous train operation, conducted on the test track of RTRI using elemental technologies essential for autonomous train operation and a prototype autonomous train operation system that integrates these elemental technologies.

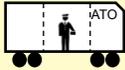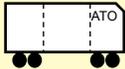## Overview of Autonomous Train Operation

The Grades of Automation (GOAs) for railway operation are defined by the International Electrotechnical Commission (IEC) Standard IEC 62267:2009, "Automated Urban Guided Transport (AUGT)—Safety Requirements" (corresponding to JIS E 3802:2012), except for GOA 2.5[*1], and are classified according to the operation modes of onboard drivers and attendants[1] (*Table 1*).

Traditionally, automatic train operation has not been implemented on conventional railway lines with level crossing systems, classified as non-automated

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[*1] GOA 2.5

GOA 1 and GOA 2 train drivers hold a driving license for operating motive power cars and are on duty in the driver's cab in the leading car, from where they operate the train (in the case of GOA 2, driving operation between stations is, in principle, not required). GOA 2.5 included automation, in which an "attendant for automatic operation" who does not hold a driving license for operating motive power cars, is on duty in the driver's cab in the leading car and performs actions such as an emergency stop operation. GOA 2.5 is not defined in IEC 62267 (JIS E 3802) but is defined in the report compiling the findings of "The Automatic Operation Technology Study Group on Railways" of the Ministry of Land, Infrastructure, Transport and Tourism, Japan, published on September 13, 2022.

Table 1   Grades of automation (GOAs) of railway operation

Grades of Automation (defined by IEC (JIS))	Visualized Operation Modes		Current Status of Implementation (Japan)
GOA 0 On-sight train operation	Driver (and Conductor)		Tram / Streetcar
GOA 1 Non-automated train operation			Conventional lines with level crossing systems
GOA 2 Semi-automated train operation	Driver [Train start, emergency stop operation, evacuation guidance, etc.]		Some metro lines
GOA 2.5 *Not defined in IEC or JIS* Semi-automated train operation (with attendant for emergency stop, etc.)	Attendant on the leading car [responsible for emergency stop operation, evacuation guidance, etc.]		JR Kyushu Kashii Line
GOA 3 Driverless train operation	Attendant on board [responsible for evacuation guidance, etc.]		Some monorail lines
GOA 4 Unattended train operation	Unattended (No staff onboard)		Some AUGT lines
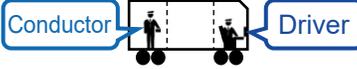
Created based on the Ministry of Land, Infrastructure, Transport and Tourism's "The Automatic Operation Technology Study Group on Railways," version dated September 13, 2022
https://www.mlit.go.jp/tetudo/content/001512320.pdf

operation (GOA 1). On some lines, such as certain metros, semi-automated operation with a driver in the leading cab, classified as GOA 2, has been introduced. GOA 3 and GOA 4 correspond to driverless automatic train operation. In Japan, these two grades have been introduced only in AUGT lines without level crossing systems and equipped with structures that prevent easy access by pedestrians. Internationally as well, automatic operation of passenger trains, excluding freight trains, has thus far been introduced only in AUGT lines and metros without level crossing systems.

In automatic train operation under GOA 2 and above, the control of acceleration and deceleration from station departure to halting at the next station is automated, and the train runs between stations in accordance with an onboard operational speed profile.

This enables labor saving in the current driving operation of trains. In contrast, the concept of autonomous train operation proposed by RTRI is not limited to achieving enhanced labor saving in driving tasks that constitute the foundation of train operation through the realization of driverless automatic train operation on conventional railway lines with level crossing systems. Rather, it also aims to realize comprehensive smart train operation, including train operation management, without human intervention. This objective is based on the concept that human resources should be focused not on routine train operation tasks but on customer service tasks that only humans can perform[2]. Specifically, in autonomous train operation, a driverless automatic train autonomously consolidates the information relevant to train operation onboard, such

as obstacles on and along railway tracks, operational restrictions caused by maintenance work or disasters, passenger flow, and power consumption, and independently evaluates the safety of its route (onboard operational decision-making) based on the consolidated information. During this process, the train operates safely and flexibly by controlling the signalling equipment on the ground (e.g., point machines and level crossing systems) via radio communication from the onboard. In this article, systems that enable such autonomous operation are referred to as autonomous train operation systems.

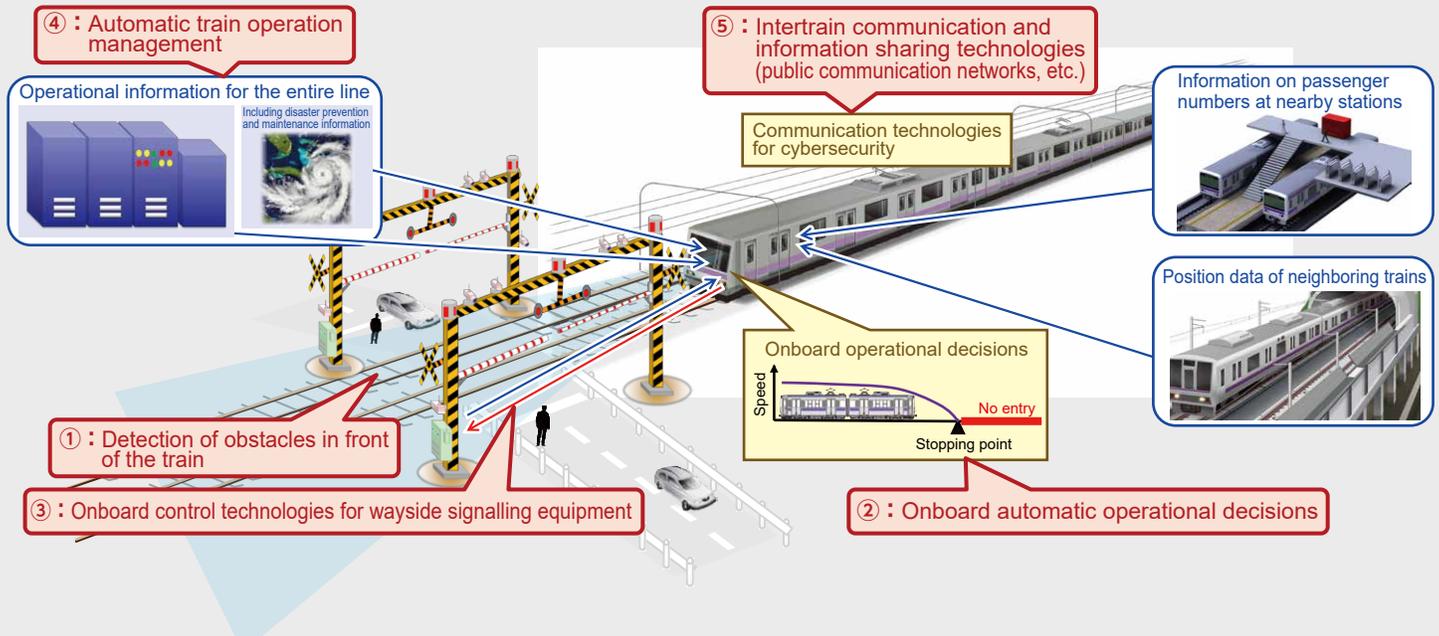**Elemental Technologies Constituting Autonomous Train Operation System**

Figure 1   Five elemental technologies constituting the autonomous train operation system

The establishment of an autonomous train operation system requires five elemental technologies. RTRI has been conducting research and development to establish these elemental technologies[3),4)] (*Figure 1*).

Technology (1): Detection of obstacles in front of the train and on and along the railway tracks by using cameras and LiDAR (Light Detection and Ranging) sensors

Technology (2): Railway Dynamic Map, an information platform that consolidates the conditions on and along the railway tracks and the train condition, and onboard automatic operational decisions based on the information obtained from the Railway Dynamic Map

Technology (3): Onboard control technologies for wayside signalling equipment (point machines and level crossing systems) utilizing radio communication

Technology (4): Automatic train operation management, including train traffic rescheduling techniques, across wide areas to prevent the cascading of delays, enable early recovery from train delays after disruptions, and ensure energy-efficient operation.

Technology (5): Intertrain communication and information sharing technologies utilizing public communication networks with appropriate cybersecurity measures

This article introduces Technologies (1) and (2) described above.

Obstacle Detection Technology

RTRI has developed an obstacle detection algorithm combined with integrated camera–LiDAR sensing to detect obstacles on and along the railway tracks[5)] (*Figure 2*).

A conventional visible-light camera captures light reflected from an object and focuses it onto its image sensor, making it possible to not only detect the presence of an object but also identify the
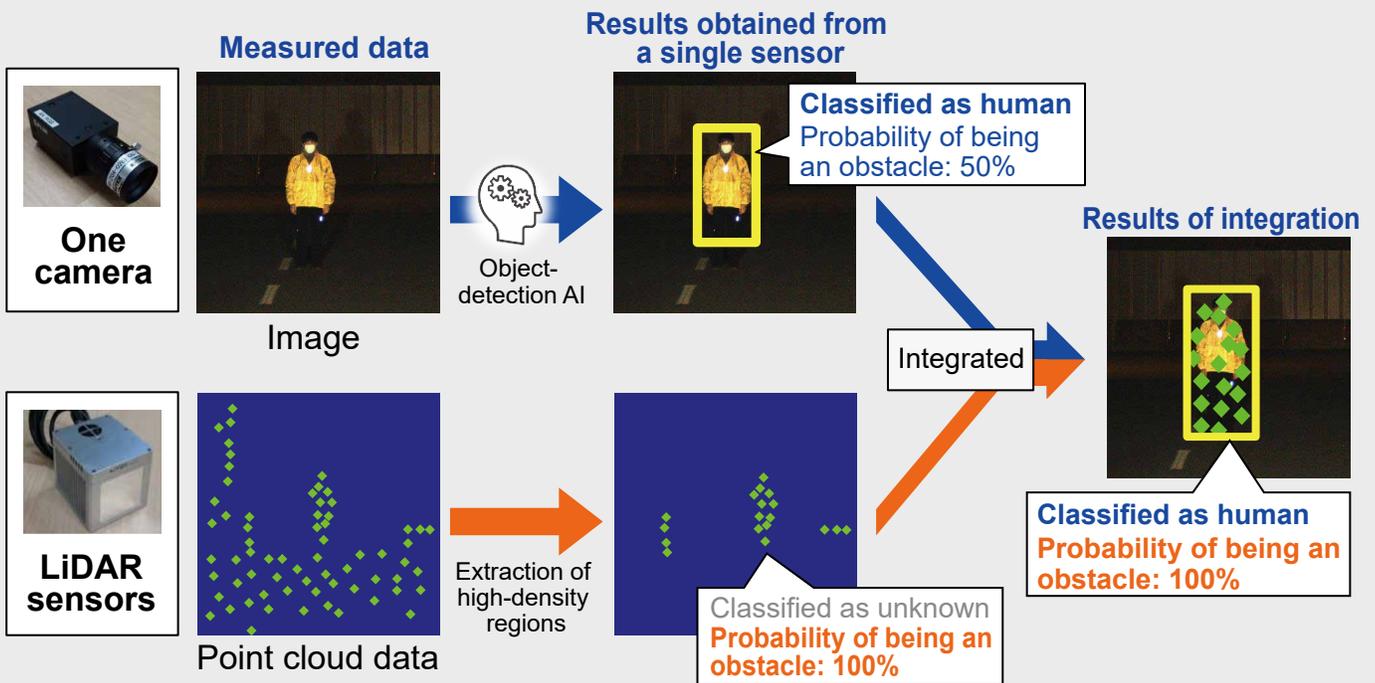
Figure 2   Visualized detection of obstacles using integrated camera–LiDAR sensing

type of object by processing the camera images. However, while the detection performance of the camera is not affected in the daytime, its detection performance is degraded at night owing to the low-light conditions. Meanwhile, the LiDAR sensor irradiates target objects with near-infrared (IR) laser light with a wavelength of approximately 900–1,500 nm and measures the distance by capturing the reflected waves from the objects. As a result, objects can be recognized during both daytime and nighttime as point-cloud data consisting of laser reflection points. Thus, it is possible to prevent the degradation in the detection performance at night by integrating the image processing results obtained from a camera with the point-cloud data acquired from the LiDAR sensors.

An evaluation test was conducted to as-sess the human-detection performance at night by integrating the data from the camera and LiDAR sensors. In this test, instead of mounting the equipment on a train, we installed one camera, nine LiDAR sensors, and two LED headlights on a truck bed at a height of approximately 1.5 m above the ground to simulate the installation conditions on an actual train, and obtained images and point-cloud data at 50 m intervals from a stationary target object. Under clear nighttime conditions, we confirmed that humans 400 m away could be detected with a probability of 90% or higher by the combined use of one camera and nine LiDAR sensors (*Figure 3*). In addition, we estimated that the detection rate increases with increasing laser point-cloud density[*2] from the LiDAR sensors (the results for 12 LiDAR sensors shown in *Figure 3* are desk

calculations of the detection rate based on the point-cloud density).

Onboard Automatic Operational Decisions Based on Railway Dynamic Map

In the current railway operations, dis-patchers at operation control centers de-termine whether train operations can be resumed in a wide-area operation involving numerous trains, whereas train crews are

*2 **Laser point-cloud density**
Laser point-cloud density is a value that indicates the number of laser points that hit a given target object and is expressed as the number of points per m²
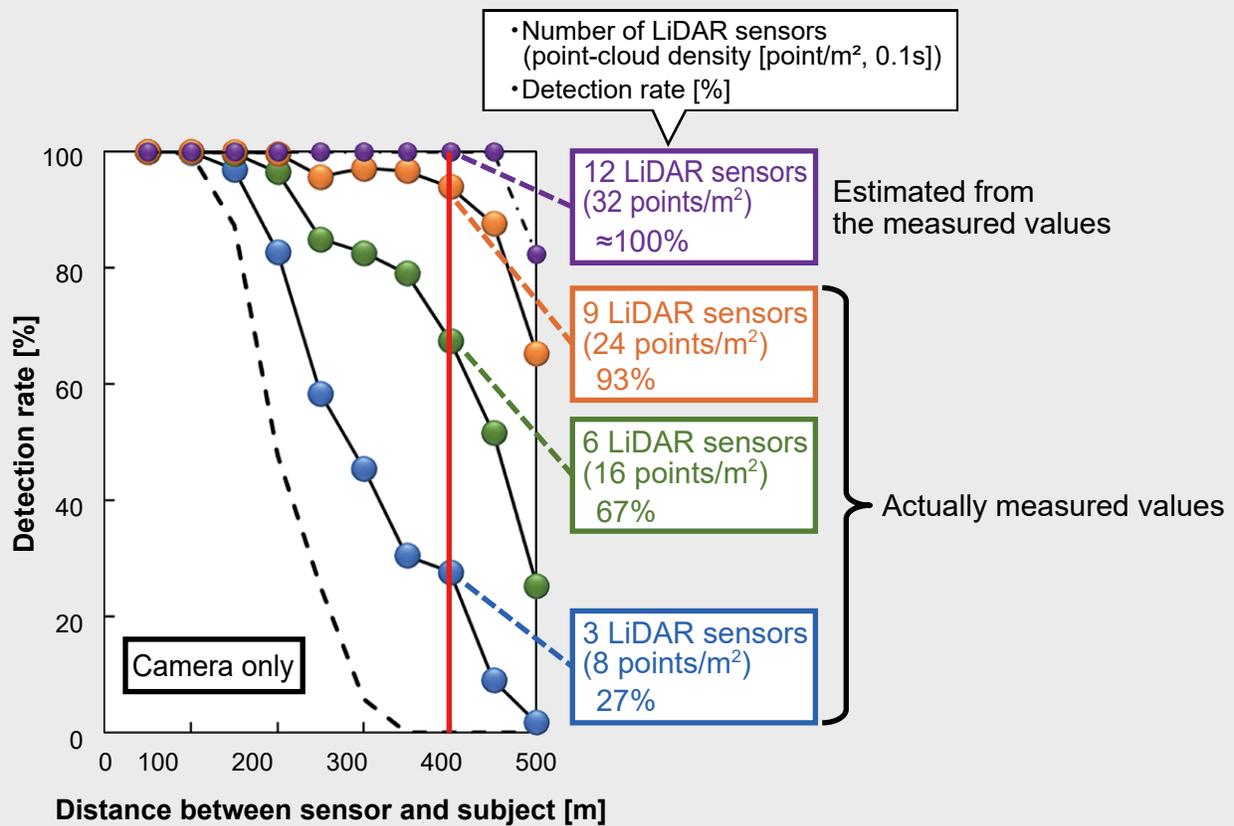
Figure 3 Human-detection performance of integrated camera–LiDAR sensing at night

responsible for onsite operational decision-making. In contrast, in autonomous train operation, each train consolidates various types of condition information required for operational decision-making and automatically performs onboard control according to the consolidated condition information (e.g., stopping within a certain point, running at a reduced speed in a specific section, and avoiding no-stop areas) and decision-making for resuming the railway operation. We have developed the Railway Dynamic Map as an information platform that consolidates the condition information and performs onboard automatic op-

erational decision-making[6] (*Figure 4*).

The Railway Dynamic Map consists of a base map and track map and a hierarchical structure that is divided according to the update frequency of various types of condition information. For example, information on the detection of obstacles in front of the train, where sudden changes in condition may occur, has a high update frequency of the condition information, whereas information on large-scale planned construction work lasting for a long period has a low update frequency of the condition information. The Railway Dynamic Map, can be converted between positions on a

base map and track map, integrate railway-specific kilometrage-based condition information and official condition information (e.g., weather information) based on the position on the map, and chronologically manage the integrated information.

When abnormalities occur in the condition information affecting the train operation (e.g., conditions on and along the railway tracks) or in the weather-related condition information (e.g., rainfall amount and wind speed), the detected information is mapped on the Railway Dynamic Map. Each train can search for and identify abnormalities on its running route on the
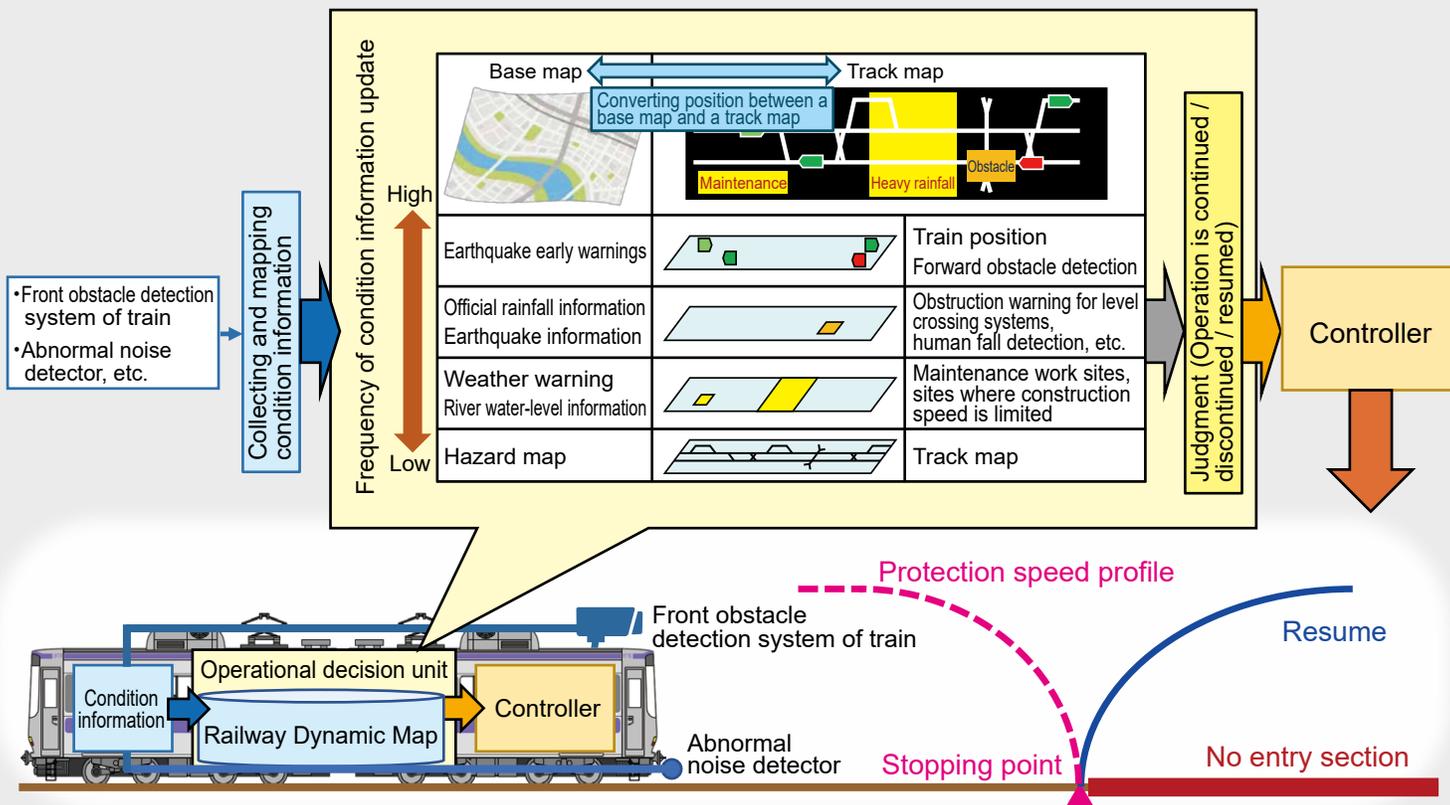
Figure 4　Railway dynamic map

map based on its current position and automatically stop or resume its operation.

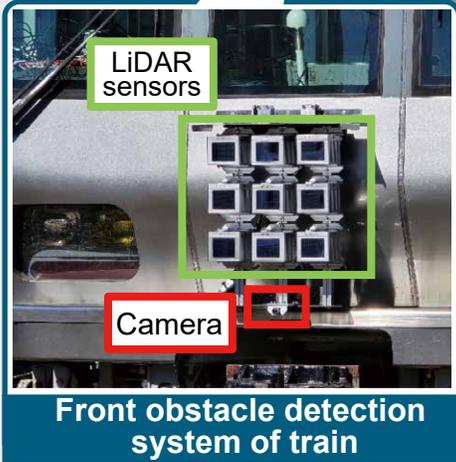### Verification of Autonomous Train Operation

The autonomous train operation was verified on the test track of RTRI using a prototype autonomous train operation system, which implements the five elemental technologies, including the detection of obstacles in front of the train and onboard automatic operational decisions.

Through the verification, the following functions of the system were confirmed:

- The test vehicle can be automatically operated according to the operational speed profiles while controlling wayside signalling equipment (e.g., point machines and level crossing systems) via radio communication from the onboard system.
- Information about obstacles on the track, detected by the front obstacle detection system (*Figure 5*, top) of the train, is mapped onto the onboard Railway Dynamic Map (*Figure 5*, middle).
- Based on the information mapped on the Railway Dynamic Map, the

onboard system determines whether the train needs to stop, and if necessary, the train can be stopped before reaching the obstacle. After the removal of obstacles from the track, the onboard system automatically decides whether it is possible to resume the train operation, and if so, automatic train operation can be restarted (*Figure 5*, bottom).
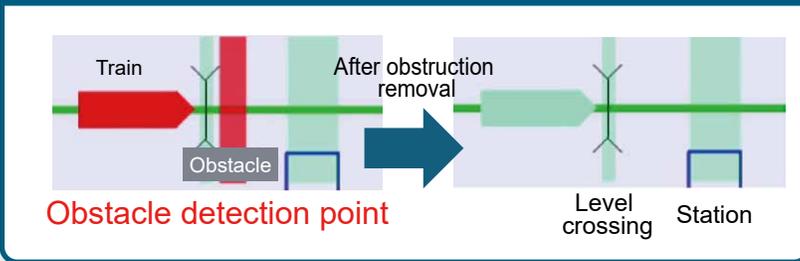
The results of the aforementioned function verification under both normal and abnormal conditions confirmed the feasibility of autonomous train operation.
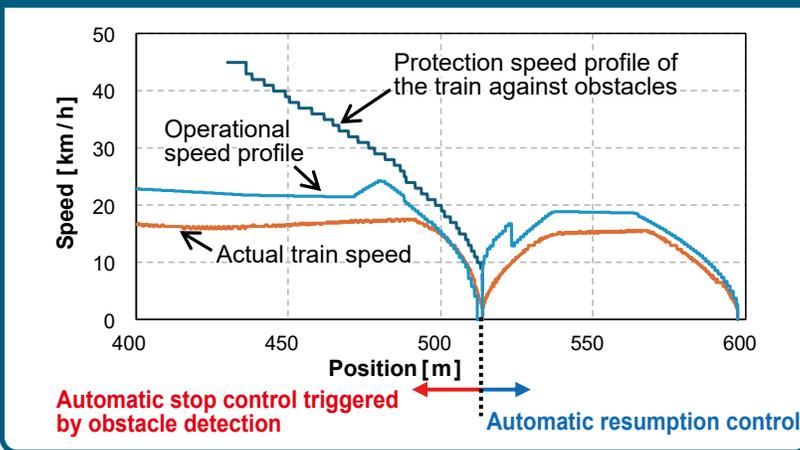
Front obstacle detection system of train

LiDAR sensors

Camera

Obstacle (Test dummy)

Mapping of obstacle information on the Railway Dynamic Map

Train

After obstruction removal

Obstacle

Obstacle detection point

Level crossing

Station

Control of automatic stopping before reaching the obstacle and automatic resumption of operation after obstacle removal

Protection speed profile of the train against obstacles

Operational speed profile

Actual train speed

Speed [km/h]

Position [m]

Automatic stop control triggered by obstacle detection

Automatic resumption control

Figure 5   Example of verification tests of autonomous train operation on the test track of RTRI

Effects Achieved by Applying Autonomous Train Operation System

The autonomous train operation system allows for onboard automatic operational decision-making and automatic operation management. Consequently, it becomes possible to reduce the personnel required not only for driving operation but also for operation management tasks such as issuing dispatch instructions. The flexible operation provided by the autonomous train operation system makes it possible to improve customer service, secure sufficient maintenance work intervals, and perform energy-saving driving operation by considering the running conditions of multiple trains. In addition, by directly controlling the point machines via radio communication from the onboard system[7], it is possible to reduce the number of signal houses, especially on regional railways with fewer trains and small-scale station premises (*Figure 6*).

Furthermore, the forward obstacle detection technology, which is one of the elemental technologies, can be utilized not only for autonomous operation but also for advancing driverless automatic train operation on conventional lines with level crossing systems. In addition, information sharing technologies and automation technologies for operational decision-making using the Railway Dynamic Map, as well as automation technologies for operation management, can be applied to reduce the burden on current train operation management tasks.

Conclusions

This article introduced the autonomous train operation system. However, challenges, such as improving the environmental robustness in forward obstacle detection (including the evaluation of detection performance under rainy and snowy conditions) and enhancing the scenarios for onboard automatic operational decisions us-

ing the Railway Dynamic Map, persist. RTRI will steadily resolve these issues and realize labor-saving train operation through the autonomous train operation system, which is a highly advanced form of automatic operation, thereby contributing to the sustainable development of railways.

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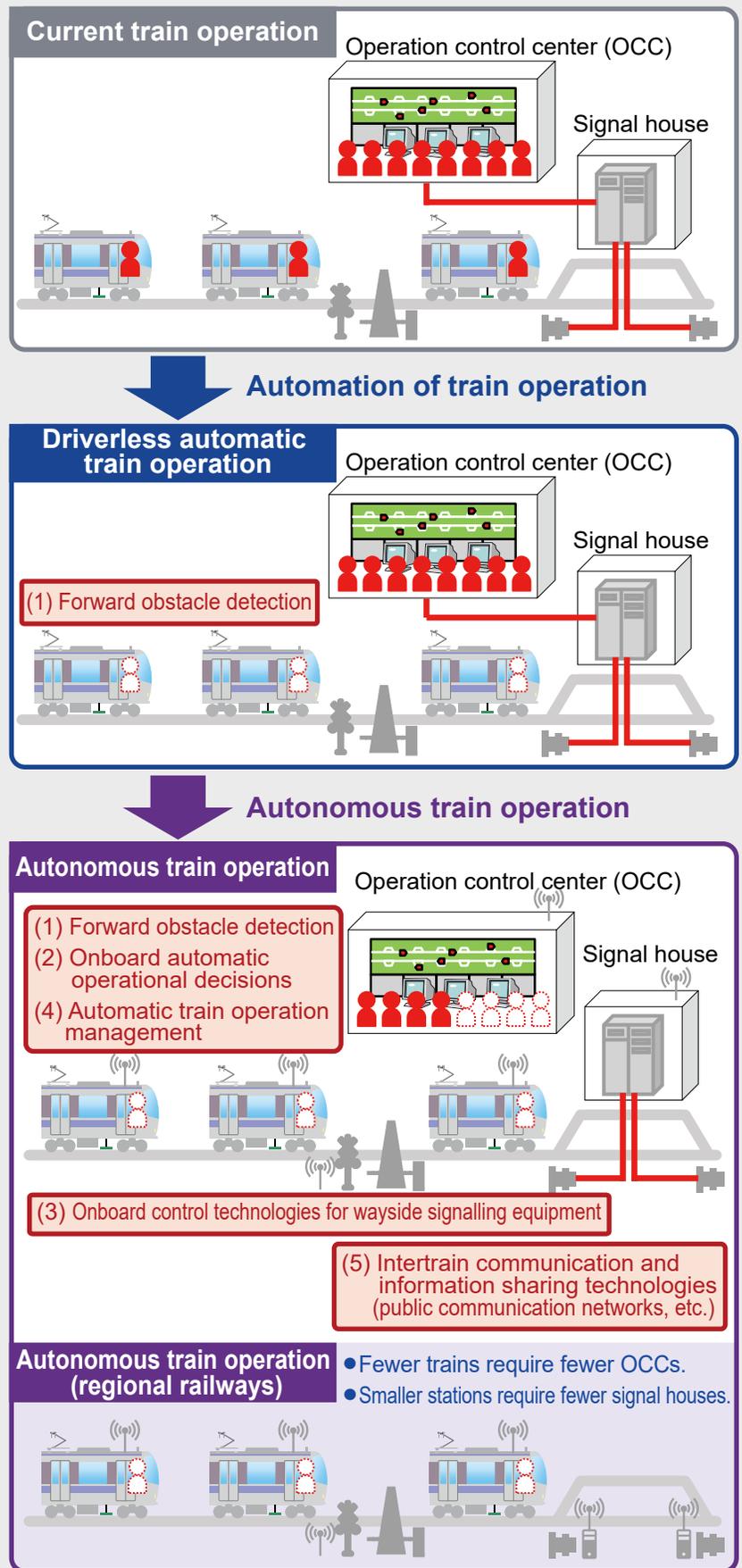
Figure 6   Labor saving through autonomous train operation (comparison between current train operation and driverless automatic train operation)

Improving Labor Efficiency by Digital Maintenance

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Introduction

The maintenance of railway equipment is essential for ensuring safe and stable train operations. However, the declining birthrate, aging population, and shrinking workforce have significantly increased the difficulty in securing sufficient maintenance personnel. Meanwhile, advances in sensor and communication network technologies have made it possible to collect and store vast amounts of data that were previously unobtainable. Furthermore, advanced analytical techniques and artificial intelligence (AI) have greatly expanded the ways in which the accumulated data can be utilized. Under the major research theme "Improving labor efficiency by digital maintenance," the Railway Technical Research Institute (RTRI) has been conducting research and development aimed at improving the efficiency of maintenance work and reducing manpower requirements by applying digital technologies to suitable areas such as condition monitoring of railway equipment and automation of inspections.
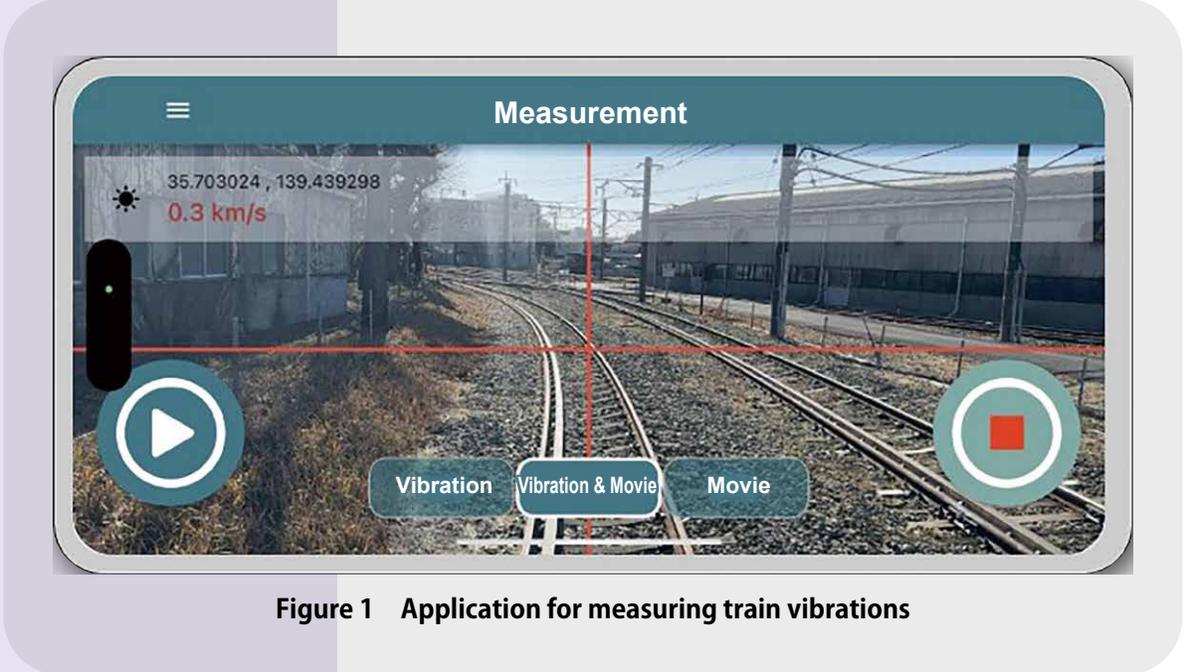

Figure 1   Application for measuring train vibrations

Figure 2   Installation on the front windscreen

Improvement of Labor Efficiency Through Condition Monitoring

In maintenance work, there are cases where workers must visit the site to inspect equipment. Automating such inspections would promote labor saving and manpower reduction by curtailing the requirement for onsite personnel. Several systems have already been introduced for remote monitoring of equipment. In this context, installing condition monitoring devices on train vehicles makes it possible to inspect equipment installed over a wide area while the trains are in operation.

Condition monitoring of tracks

In track maintenance, control values that incorporate safety margins are defined for each parameter related to track irregularity[1], and any section where these values are exceeded are repaired within a specified period. Major railway operators regularly measure the track irregularity using dedicated track-recording vehicles; however, because such vehicles are expensive, their use is generally limited to relatively large operators. In addition, some of the measurements obtained by track-recording vehicles are known to be strongly correlated with train vibrations.

Therefore, RTRI developed an application that measures train vibrations using a smartphone (*Figure 1*). The measured vibration data can be used to determine the sites requiring maintenance. Measurements can be performed simply by fixing a smartphone to the front windscreen of the train while it is running (*Figure 2*) and starting the application. Thus, even frequent measurements impose little burden. In addition, view-ahead images from the train

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[1] **Track irregularity**
 The deviation of the track from its correct position is called track irregularity (the terminology may vary across railway operators). A substantial level of track irregularity interferes with the smooth running of vehicles, deteriorating the ride comfort and reducing the running stability. Therefore, track conditions are regularly inspected, and where necessary, track re-alignment (track maintenance) is performed..
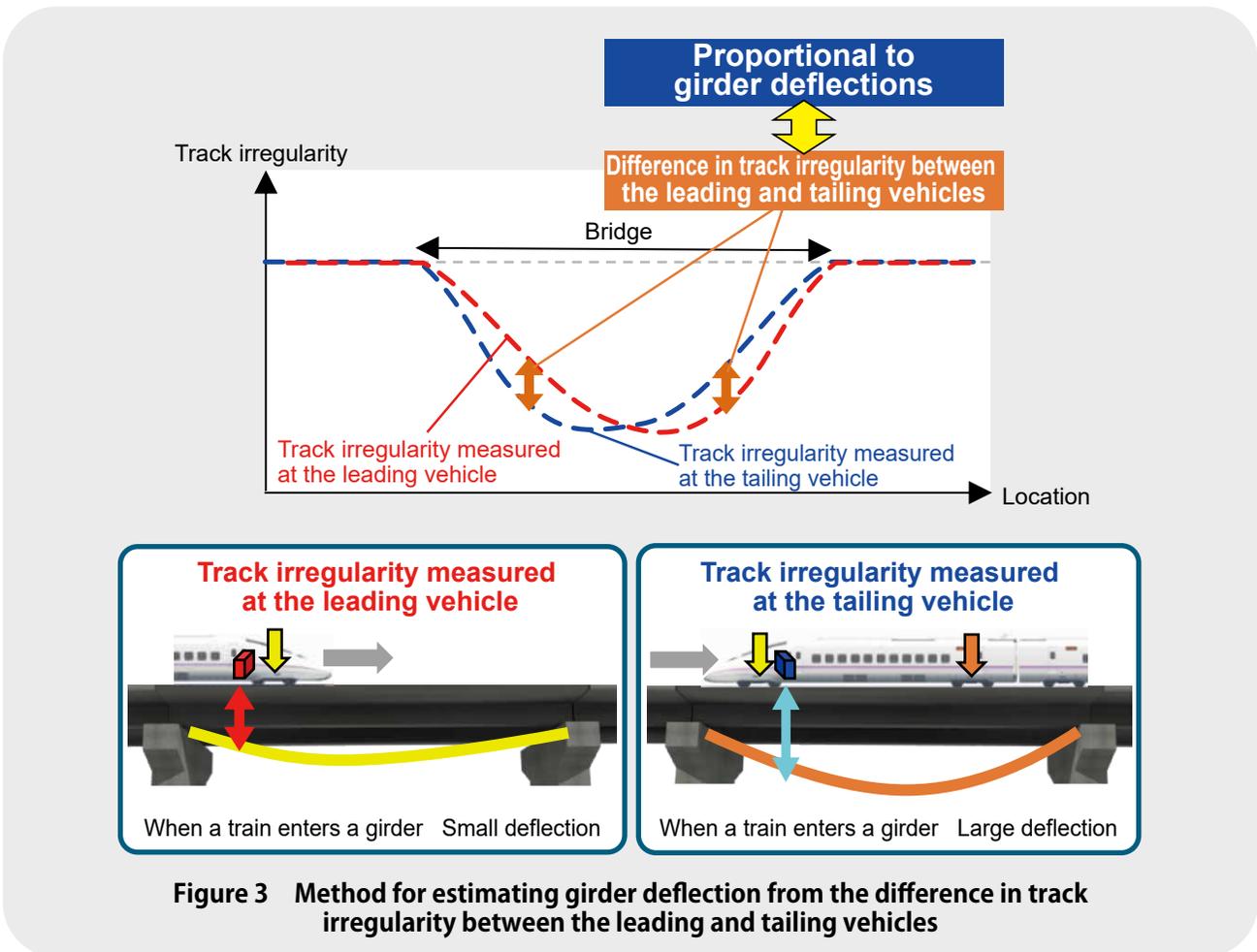
Figure 3   Method for estimating girder deflection from the difference in track irregularity between the leading and tailing vehicles

can be acquired simultaneously with vibration measurements, allowing the system to be used not only for checking the track conditions but also for monitoring the equipment in other sections.

Condition monitoring of bridges

Bridge maintenance includes inspections of girder deflections and loose bearings. For railway operators with long route networks, considerable labor is required to inspect multiple bridges along the railway lines, necessitating streamlined inspections. Therefore, RTRI developed methods that use the data measured by the aforementioned track-recording vehicles to es-

timate girder deflections and detect loose bearings.

An investigation of the relationship between track irregularity and girder deflection showed that the difference in track irregularity between a leading vehicle entering the girder and tailing vehicle leaving the girder is proportional to the girder deflections (*Figure 3*). Based on this finding, RTRI developed a method for estimating the girder deflections.

In addition, RTRI analytically clarified the effects of loose bearings on the track irregularity and developed a detection method for loose bearings using the information on the track irregularity, which is applicable to

sections with consecutive simple girders.

Condition monitoring of OCLs and pantographs

Abnormalities in pantographs or overhead contact lines (OCLs) may cause extensive damage to the OCLs and even result in the sequential destruction of all pantographs in a trainset, leading to a major disruption in the railway services. Therefore, RTRI developed a method in which the conditions of pantographs and OCLs are monitored and, when an abnormality is detected, the pantograph is automatically lowered to prevent the cascading of damage. If damage to the OCL is limited or

Figure 4   Monitoring of component detachments using object-detection AI

some pantographs in the trainset remain intact, service recovery can be conducted relatively quickly, which in turn contributes to labor saving and manpower reduction in restoration work.

For monitoring the condition of pantographs, RTRI developed a method that uses object-detection AI to determine the presence or absence of each pantograph component (*Figure 4*). This method enables component detachments to be detected in approximately one second. For monitoring the condition of OCLs, RTRI developed a method that detects unspecified flying objects around the OCL from the front of the train. Furthermore, RTRI developed a

prototype automatic pantograph-lowering system and confirmed that it could detect pantograph component detachments and flying objects near the OCL within one second and automatically lower the pantograph.

Development of Labor- and Manpower-Saving Equipment

When condition monitoring alone is insufficient to achieve the desired effect, the equipment can also be upgraded to achieve labor saving and manpower reduction. Therefore, RTRI developed a turnout system that enables labor-saving and

resource-saving maintenance.

Conventional turnouts have several issues: for example, rods installed between sleepers for point operation create areas where ballast tamping cannot be performed, and the adjustment of point machines and related equipment is difficult and time-consuming. In addition, a point can have a major impact effect on the train operation. However, it is difficult to detect signs of such a failure in advance.

The turnout developed by RTRI is shown in *Figure 5*. Because the equipment is entirely installed on the sleepers, ballast tamping can be conducted, eliminating weak points in the track. In this turnout
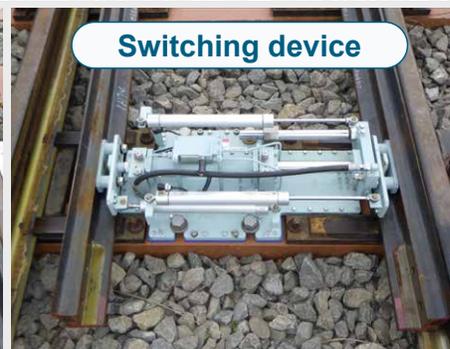
Figure 5   Installation of the test turnout

system, a switching device first moves the switch rails, after which an adjustment device automatically adjusts their position. This eliminates the need for complex adjustment work. Furthermore, by monitoring the load during point operation, conditions such as lack of lubrication can be identified and point failures can be detected in advance.d point failures can be detected in advance.

Digital Data Sharing and Analysis

Integrated analysis platform

In the railway sector, maintenance and certain other types of data are stored separately in individual sections, and each section has its own approach for data analysis and utilization. In addition, the railway is a complex system in which vehicles, track, and electrical sections interact with one another. Hence, data sharing across multiple sections and analyzing and utilizing the data in a cross-sectional manner might enable the detection of phenomena that could not be identified previously. To

enable such integrated use of data, RTRI developed an "integrated analysis platform," which centrally manages the data from multiple sections and supports cross-sectional analyses and other methods of utilizing the data (*Figure 6*).

In railways, the unit used to describe a location (such as kilometrage) differs among sections, which has been a challenge when utilizing data across multiple sections. In the integrated analysis platform, data are managed using a "unified kilometrage" that uniquely specifies the positions along
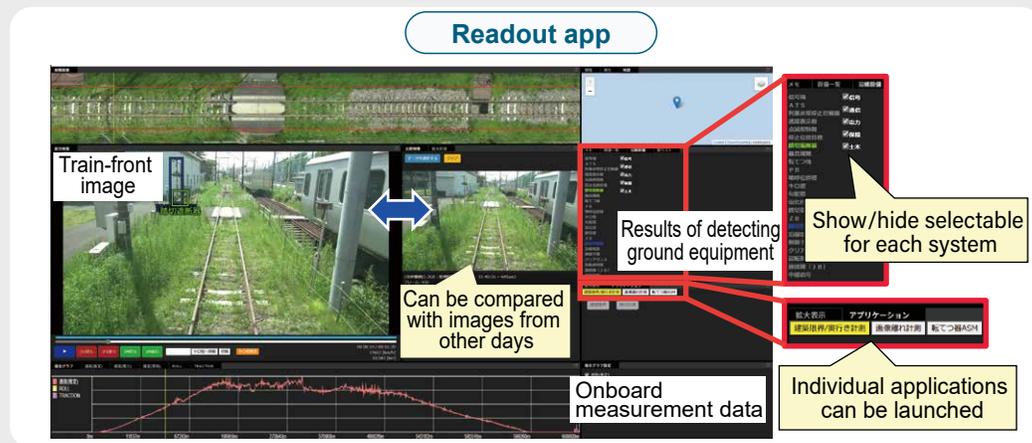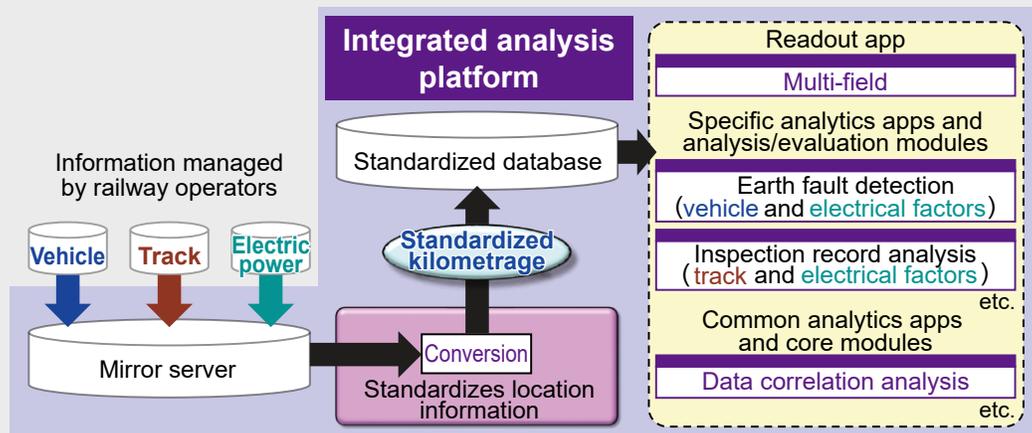
Figure 6 Integrated analysis platform

the track. Because the unit used for the location in a section can be converted to and from the unified kilometrage, location-specific data of a particular section can now be analyzed in terms of those used in the other sections via the unified kilometrage.

Next, we present examples of solutions that can be more easily developed by using the integrated analysis platform.

Early anomaly detection by monitoring the electric power network

Substations are equipped with various monitoring functions to protect equipment by detecting overcurrent and other abnormal conditions. However, in DC-electrified sections, high-resistance ground faults are difficult to detect because the fault current is comparable to or even smaller than the train current. These faults can be detected by obtaining and calculating the difference between the collected current (onboard current) of the train and current supplied by the substation (groundside current). Although this idea was proposed long ago[8], recent advances in communication and other information and communication technologies have made its implementation increasingly feasible. The onboard current and train location data (vehicle-section data) and ground current data (power-supply-section data) are collected by the integrated analysis platform. High resistance ground faults are identified by continuously calculating the difference between these currents and comparing it with a threshold value (*Figure 7*). On the in-house test track of RTRI, conditions involving multiple substations and multiple
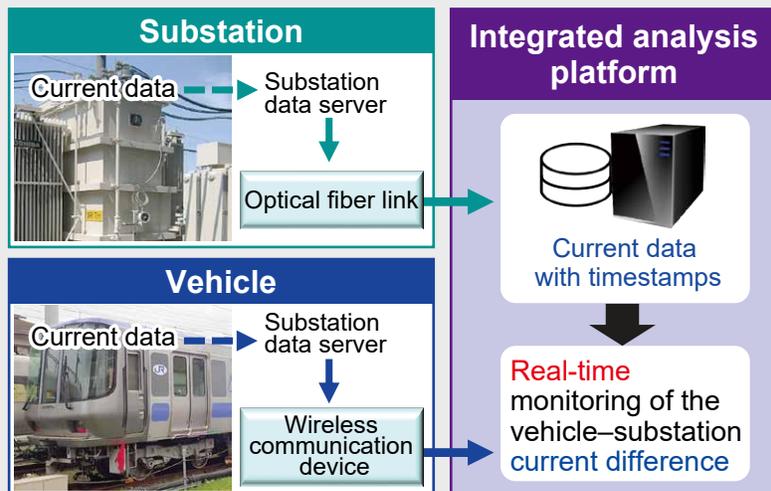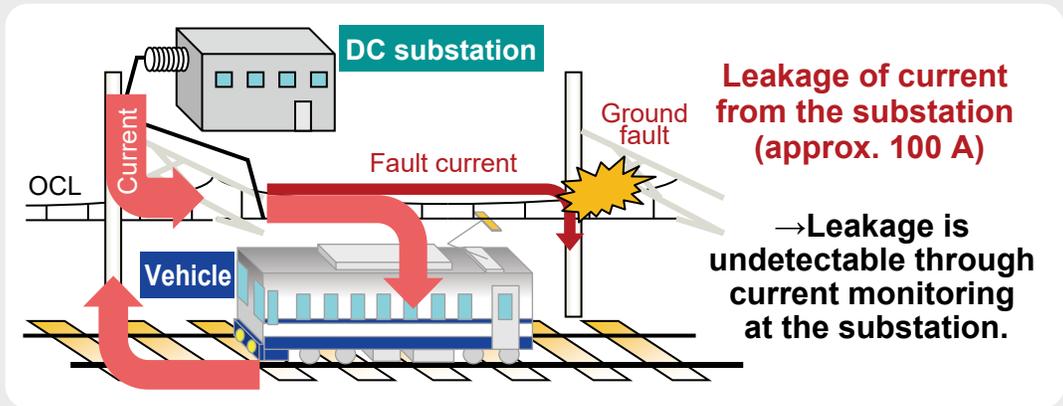
Figure 7   Conceptual view of electric power network monitoring

trains were simulated, and it was confirmed that high-resistance ground faults could be detected within one minute after their occurrence.

Asset management based on equipment inspection records

In day-to-day maintenance work, extensive visual inspection data, recorded by engineers during their periodic equipment inspections, are accumulated in addition to the measurement data from sensors. Although the inspection data comprise only simple ratings such as " ○ (good)," " △ (adjustment required)," or " × (abnormal)," their long-term accumulation has resulted in a large-scale dataset. These data have not been effectively utilized. The statistical characteristics of failure occurrences underlying these data can be extracted through statistical modeling and applied to the review of existing inspection intervals. Accordingly, by using the data accumulated in the integrated analysis platform, RTRI developed a model to predict equipment failure. An analysis based on a model constructed for 280 electric point machines installed on actual railway lines revealed that, except for a few machines, the inspection intervals could be extended by approximately 1.3 times without exceeding the historically accepted failure rates.

Conclusions

This article introduced research and development outcomes across various technical fields and presented an integrated analysis platform for cross-sectional data

sharing and analysis, aimed at achieving labor saving and manpower reduction in railway equipment maintenance through digital technologies. RTRI plans to put these individual outcomes into practical use and promote further initiatives to enhance the effective utilization of the platform.

This research was partly conducted in collaboration with the University of Tokyo, Politecnico di Milano, the University of Tsukuba, Shikoku Railway Company, and the University of Osaka.
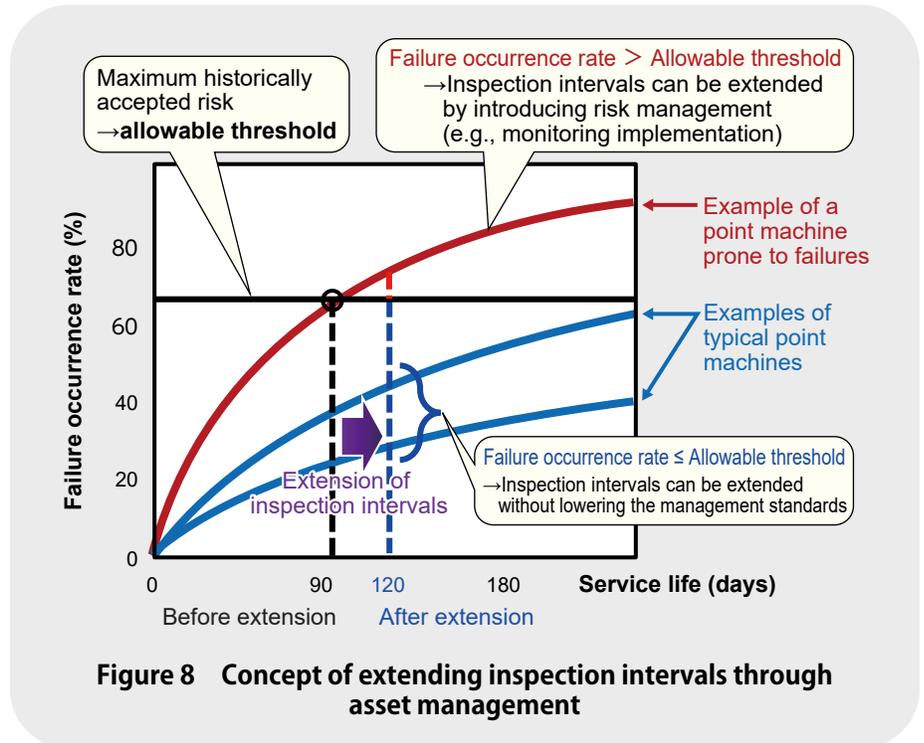

Figure 8 Concept of extending inspection intervals through asset management

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RTRI Successfully Supplies Power to Commercial Trains Using Superconducting Feeding System

– Over one year of operational verification on the Sunzu Line and demonstration test results in the metropolitan areas on the Chuo Line –

 The Railway Technical Research Institute (RTRI), in cooperation with the IZUHAKONE Railway Co., Ltd. Sunzu Line and the East Japan Railway Company (JR East), has installed a superconducting feeding system on commercial railway lines* and has conducted demonstration tests under actual operating conditions. The results confirmed that power transmission can be achieved while maintaining a stable superconducting state.

Railway Technical Research Institute (RTRI)
IZUHAKONE Railway Co., Ltd.
East Japan Railway Company (JR East)

* "RTRI Starts Verification of World's First Power Transmission for Commercial Line Operation Through Superconducting Feeding System," March 13, 2024
(https://www.rtri.or.jp/eng/press/d2sij10000000kpt-att/d2sij10000000ksa.pdf)

"RTRI Conducts Demonstration Test on Chuo Line, Supplying Power to Commercial Trains Using Superconducting Feeding System," February 25, 2025 (in Japanese)
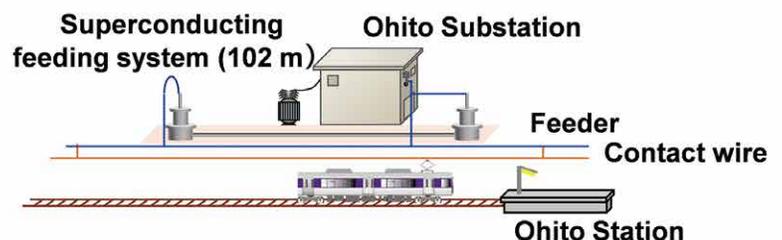(https://www.rtri.or.jp/press/g51jdh0000000t2a-att/20250225_001.pdf)

Operational Verification on the IZUHAKONE Railway Sunzu Line

Overview

 A superconducting feeding system was installed at the Ohito Station on the Sunzu Line (*Fig. 1*) and began operation on March 13, 2024. The system continues to supply power to commercial trains on the line.

Fig. 1   Train running through a power supply section consisting of the superconducting feeding system (long-term operation on the Sunzu Line)
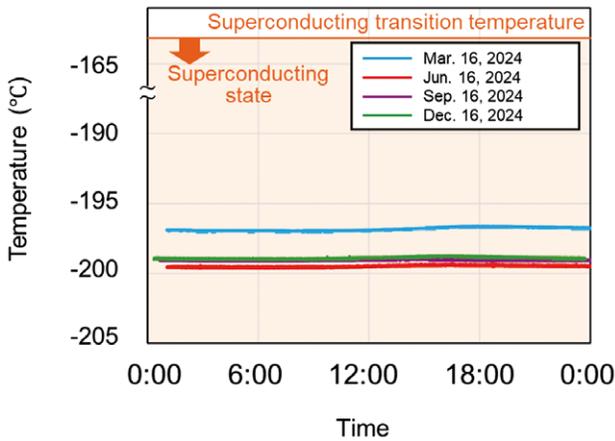
Fig. 2 Daily variation of the cable temperature during operation of the superconducting feeding system
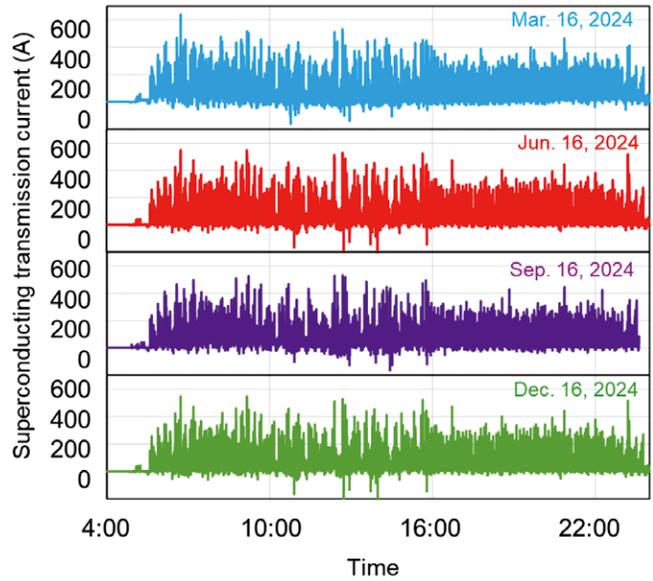

Fig. 3 Daily variation of the current transmitted using the superconducting feeding system
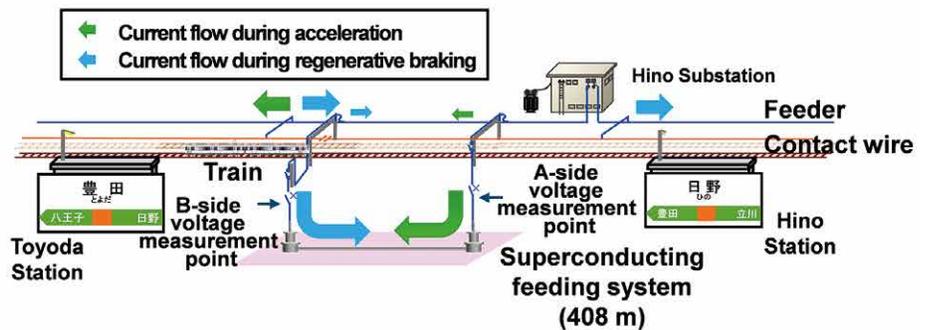

Fig. 4 Train running through a power supply section consisting of the superconducting feeding system (high-current power supply on the JR East Chuo Line)

Status of the Operational Verification

Stable operation was maintained for over one year, supplying power to approximately 40,000 commercial trains to date. The system was observed to maintain a stable superconducting performance through the continuous cooling of the internal section of the cable throughout the day (*Fig. 2*). The current profile remained nearly identical each day (*Fig. 3*), confirming constant power transmission corresponding to the train load from the first to the last service. Thus, the durability of the system over one year of operation was confirmed.

Demonstration Tests on the JR East Chuo Line

Overview

A superconducting feeding system was installed at the RTRI Hino Civil Engineering Testing Station, adjacent to the Chuo Line (*Fig. 4*). From March to April 2025, the system was connected to the outbound track of the Chuo Line, supplying power to commercial trains from the first to the last service each day.
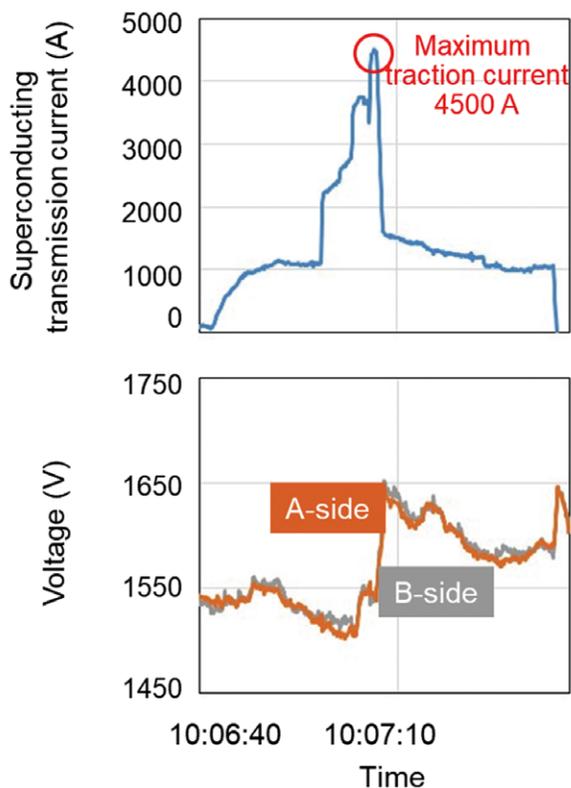
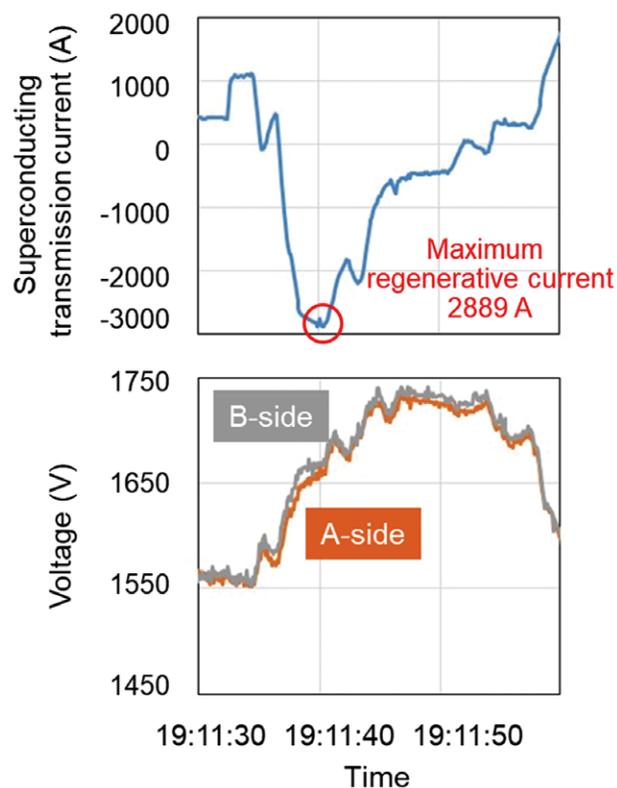**Fig. 5   Examples of current and voltage resulting due to the superconducting traction power supply**

Fig. 6   Examples of current and voltage resulting due to the superconducting regenerative power supply using superconductors

Demonstration Test Results

In the demonstration tests on the Chuo Line, simulating the simultaneous traction operation typical of metropolitan railways, the system successfully supplied a maximum current of 4,500 A (*Fig. 5*). During regenerative braking, a return current as high as 2,889 A flowed back from the train toward the feeding line (*Fig. 6*). Even under such high-power-supply conditions on a densely operated line, where the current magnitude and direction frequently fluctuate, almost no voltage difference occurred between both ends of the superconducting cable. The system operated stably and provided the required power as confirmed by the data obtained. These results demonstrate that the superconducting feeding system is capable of providing stable power supply in dense metropolitan railway networks.

Future Challenges

To realize the benefits of this system, such as the consolidation of the substations for simplified facility management and reduced maintenance requirements, it is necessary to achieve longer power transmission distances. The RTRI will continue to develop technologies for connecting longer cable sections, improving the superconducting materials and their cooling performance, establishing post-installation management and maintenance methods, and enhancing cost efficiency. These efforts aim to advance the research and development toward commercial implementation of the superconducting feeding system.

WCRR 2025 Held in Colorado Springs

Panel discussion
(Executive Director Sogabe of RTRI, center)

Photo 1
Photographs from the third panel discussion
(November 19, 2025)

The 14th World Congress on Railway Research (WCRR 2025), hosted by MxV Rail, was held from November 17 to 21, 2025, at The Broadmoor, Colorado Springs, USA.

Group photo
(Executive Director Sogabe of RTRI, second from the right)

Table 1　Panel discussions

No.	Panel topics
1	The Innovation Pipeline: From Discovery to Deployment
2	Tech on Track: Advancing Railway Safety Through Innovation
3	Driving Excellence: Harnessing the Power of Research to Advance Railways
4	Turning Ideas into Impact: How Supplier Leadership is Shaping the Rail Industry's Future

**Photo 2
Best Paper Award – Taku Nakamura,
Senior Researcher, Power Supply
Technology Division, RTRI**

○ Background and objectives:

The World Congress on Railway Research (WCRR) began with an international conference titled the "RTRI International Conference—Current Situation and Future of the Railways of the World," which was held in October 1992 in Shinjuku, Tokyo, to commemorate the fifth anniversary of the establishment of the Railway Technical Research Institute (RTRI). Spurred by discussions among participants from countries such as France, the UK, and the USA, it was decided to hold an international congress on railway research on a rotating basis among different countries. Thus, ever since the first conference held in France in November 1994, WCRR has been held every few years. A committee comprising the Union Internationale des Chemins de fer

(UIC), MxV Rail in the USA, the Rail Safety and Standards Board (RSSB) in the UK, Société Nationale des Chemins de fer Français (SNCF) in France, Deutsche Bahn (DB) in Germany, Ferrovie dello Stato Italiane (FS) in Italy, and RTRI have been operating the congress with the aim of enhancing the value of railway-related research, sharing technical information, and promoting international cooperation. The following is an overview of the 14th Congress.

○ Congress theme:

"Inspiring Innovative and Resilient Railways".

○ Participants:

WCRR 2025 was attended by 384 participants from more than 25 countries, including 62 participants from Japan, with 24 from RTRI. WCRR 2025 was held concurrently with the 2025 International Heavy Haul Association conference (IHHA 2025), and was attended by a total of 1,114 participants from over 29 countries.

○ Plenary sessions:

Four plenary sessions were held featuring keynote speeches and panel discussions by WCRR committee members and representatives from railway operators, research organizations, industry suppliers, and other organizations (*Table 1*). In the third panel discussion on, "Driving Excellence: Harnessing the Power of Research to Advance Railways," Executive Director Sogabe of RTRI took the stage on the panel and spoke on topics such as building a collaborative research framework to accelerate innovation and evidence-based countermeasures against natural hazards (*Photo 1*).

○ Awards:

Out of the 244 research presentations, seven were selected for the Best Paper Award. From RTRI, the paper, "Applicability of Contact Wire Splices for Shinkansen Overhead Contact Lines," by Taku Nakamura, Senior Researcher, Power Supply Technology Division, was selected for the Best Paper Award (*Photo 2*).

○ Exhibition:

An exhibition was held in parallel with the conference, with participation from more than 40 companies and organizations. RTRI exhibited a JR Group booth and presented the digitalization initiatives of each JR company as well as the R&D activities of RTRI (*Photo 3*).

The next WCRR will be held in Poland in 2028 and will be hosted by the Polish State Railways.

Photo 3　JR Group exhibition booth run by RTRI

Dr. Masao Mukaidono
RTRI

Photo 1   Greeting

Mrs. Carole Desnost
SNCF

Dr. Norimichi Kumagai
RTRI

Dr. Kimitoshi Ashiya
RTRI

Photo 2   Commemorative lectures

30ᵗʰ Anniversary Seminar of SNCF-RTRI Collaborative Research Held

The Railway Technical Research Institute (RTRI) held the "30ᵗʰ Anniversary Seminar of SNCF-RTRI Collaborative Research" in Tokyo on November 28, 2025.

The Railway Technical Research Institute (RTRI) concluded an agreement concerning collaborative research with Société Nationale des Chemins de fer Français (SNCF) in 1995. Since then, the two organizations have conducted collaborative research and information exchange in various technical fields, as well as personnel exchanges. As a milestone marking 30 years of this partnership, a seminar was held, as described below, to look back on the accumulated achievements of the exchange and cooperation and to reaffirm the shared commitment of both organizations to further deepen their collaborative research and personnel exchanges going forward, and continue to contribute to mutual development.

Outline of the Seminar

1. Date and time: November 28, 2025, 14:30–17:00
2. Venue: TAKANAWA GATEWAY Convention Center
3. Number of participants: Approximately 50
Guests of honor:
  ○ Mr. Jun Yokoyama, Auditor and Chairperson of the Railway Transportation Committee,
     La Société Franco-Japonaise des Techniques Industrielles (SFJTI)
  ○ Mr. Jean-Baptiste Bordes, Science and Technology Attaché, Embassy of France in Japan
     (attended on behalf of the Science and Technology Advisor)
SNCF: Mrs. Carole Desnost, Chief Technical Officer (CTO), and six

other representatives
RTRI: Dr. Masao Mukaidono, Chairman, and approximately 40 other representatives

4. Contents
The seminar opened with greetings by Dr. Masao Mukaidono and Mrs. Carole Desnost, followed by three commemorative lectures as listed below:

- **"30 Years and a View to the Future"**
  – Dr. Norimichi Kumagai, Fellow (former President), RTRI
  While looking back at 30 years of collaborative research between RTRI and SNCF, Dr. Kumagai introduced four core principles—"Wa, Kei, Sei, Jaku" (harmony, respect, tranquility, and serenity), the spiritual foundation of the Japanese tea ceremony—and explained that these principles share the same spirit of inquiry and willingness to take on challenges required in collaborative research. He expressed his hope of seeing an even more fruitful partnership between the two organizations over the next 30 years while cherishing these principles.

- **"Railway of the Future in Europe"**
  – Mrs. Carole Desnost, CTO, SNCF
  Mrs. Desnost outlined the greenhouse gas reduction goals of Europe and its plans to increase the use of high-speed rail and rail freight transport to help achieve them. She also described challenges such as the different operating rules and systems in each country and the high costs involved, and explained that digitalization, standardization, and automation, combined with public–private partnerships in research and

development (R&D), can help address these issues.

- "Building a Sustainable Future"
  – Dr. Kimitoshi Ashiya, Executive Vice President, RTRI
  Dr. Ashiya outlined the changing environment surrounding Japanese railways and the R&D initiatives of RTRI for the future. He reaffirmed the determination of RTRI to further strengthen its collaboration with SNCF, enhance collaborative research between the two organizations, and work together to lead the world through technological innovation and open up new avenues in the future for railways.

Additional Information
Background and achievements of the SNCF–RTRI Collaboration

1. History of the collaboration
In 1994, SNCF proposed collaborative research with RTRI in the field of human science. The two organizations signed an agreement for the same in November 1995.

2. Achievements of the SNCF–RTRI collaborative research
The collaboration began with four initial projects, and over the past 30 years, a total of 87 projects have been conducted. R&D topics of these projects cover a wide range of railway technologies, including the maintenance and environmental fields. Collaborative research seminars have been held alternately in Japan and France, totaling 12 sessions by 2024.

3. Personnel exchanges
Two staff members have been temporarily assigned from SNCF to RTRI and two from RTRI to SNCF. The knowledge and research outcomes obtained on-site, including the utilization of a pantograph simulator, have been steadily reflected in the subsequent R&D activities of both organizations.

4. Major outcomes to date
The SNCF–RTRI collaborative research has implemented projects in a broad spectrum of fields, including maintenance, environmental engineering, and service-related fields, with continuous efforts particularly in current collection systems and aerodynamics. In recent years, the two organizations have also actively collaborated

on disaster prevention technologies such as measures against heavy rainfall associated with global warming.

(1) Projects on pantograph and current collection
Since 2003, continuous collaborative research has been conducted in the fields of power supply and current collection. This work initially focused on information exchange regarding the dynamic interaction between overhead contact lines and pantographs, through which RTRI obtained knowledge on highly efficient pantograph simulation techniques that had yet to be developed in Japan then, thus contributing to the subsequent development of simulators in Japan. The scope of the collaboration has since expanded to include the maintenance of power supply systems and decarbonization.

(2) Projects on aerodynamics
Both SNCF and RTRI share the view that suppressing the aerodynamic noise generated around the bogie area is crucial for reducing the exterior noise from railway vehicles running at high speeds. Collaborative research on this aspect, combining fluid dynamics analysis using numerical simulations with wind-tunnel tests in a large-scale low-noise wind tunnel, has led to the clarification of the mechanisms generating aerodynamic noise and the development of noise reduction measures.

(3) Projects on disaster prevention
In the field of disaster prevention, SNCF and RTRI have worked together to enhance maintenance and management methods for railway bridges subjected to scouring damage. The two organizations have exchanged existing technical information on methods for identifying locations susceptible to scouring in both countries and, more recently, have collected data on railway bridge structures, rivers, and other factors related to scouring damage in order to develop new machine-learning-based methods for identifying such locations. Each organization has independently built machine-learning models using the collected data to identify potentially vulnerable sites.

5. Future seminars
The next collaborative seminar is scheduled to be hosted by SNCF in 2026.

Photo 3 Group photo of the participants