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

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

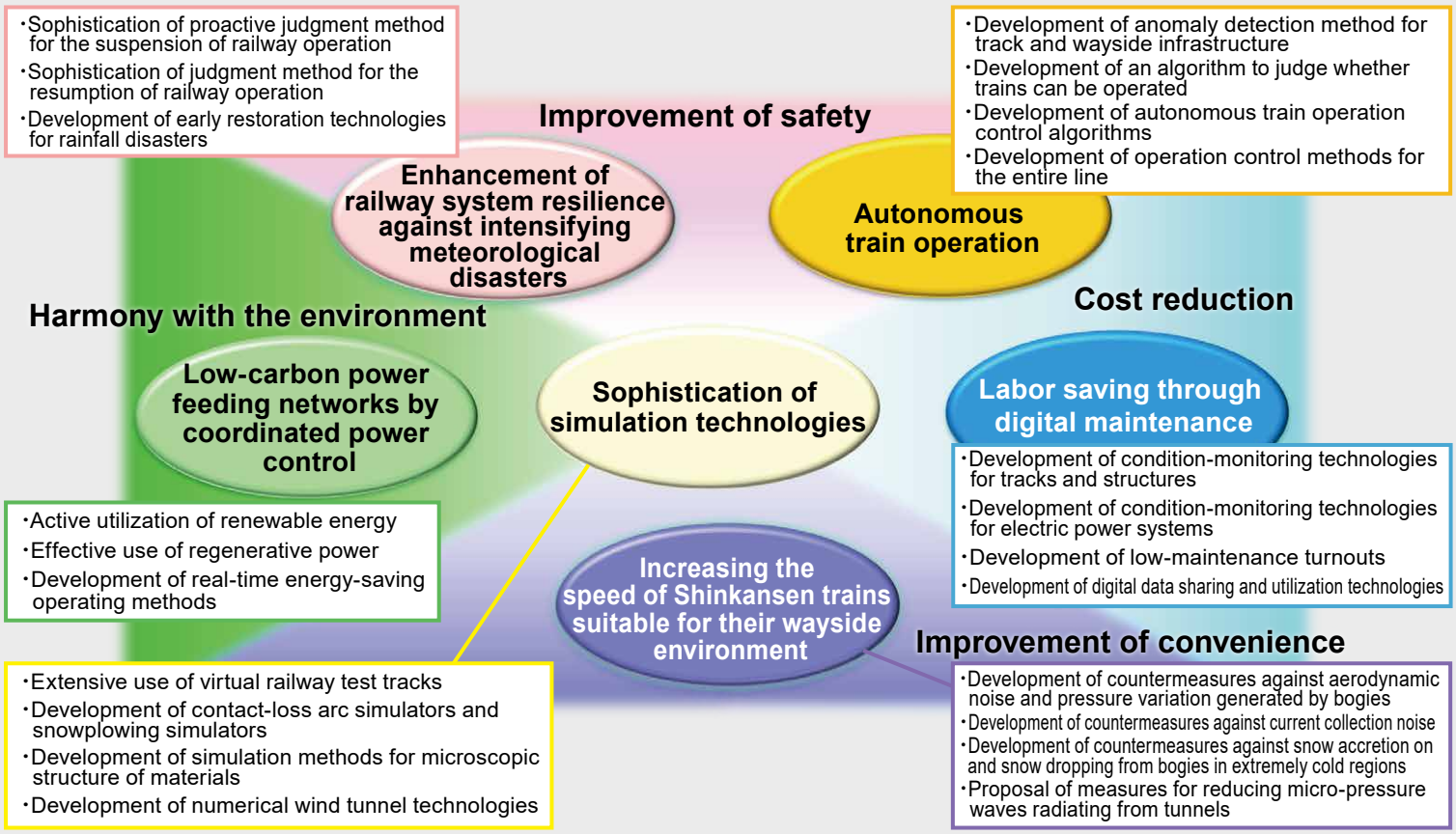

Figure 1 Six major research themes and 22 sub-themes for R&D aimed at the future of railways

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-

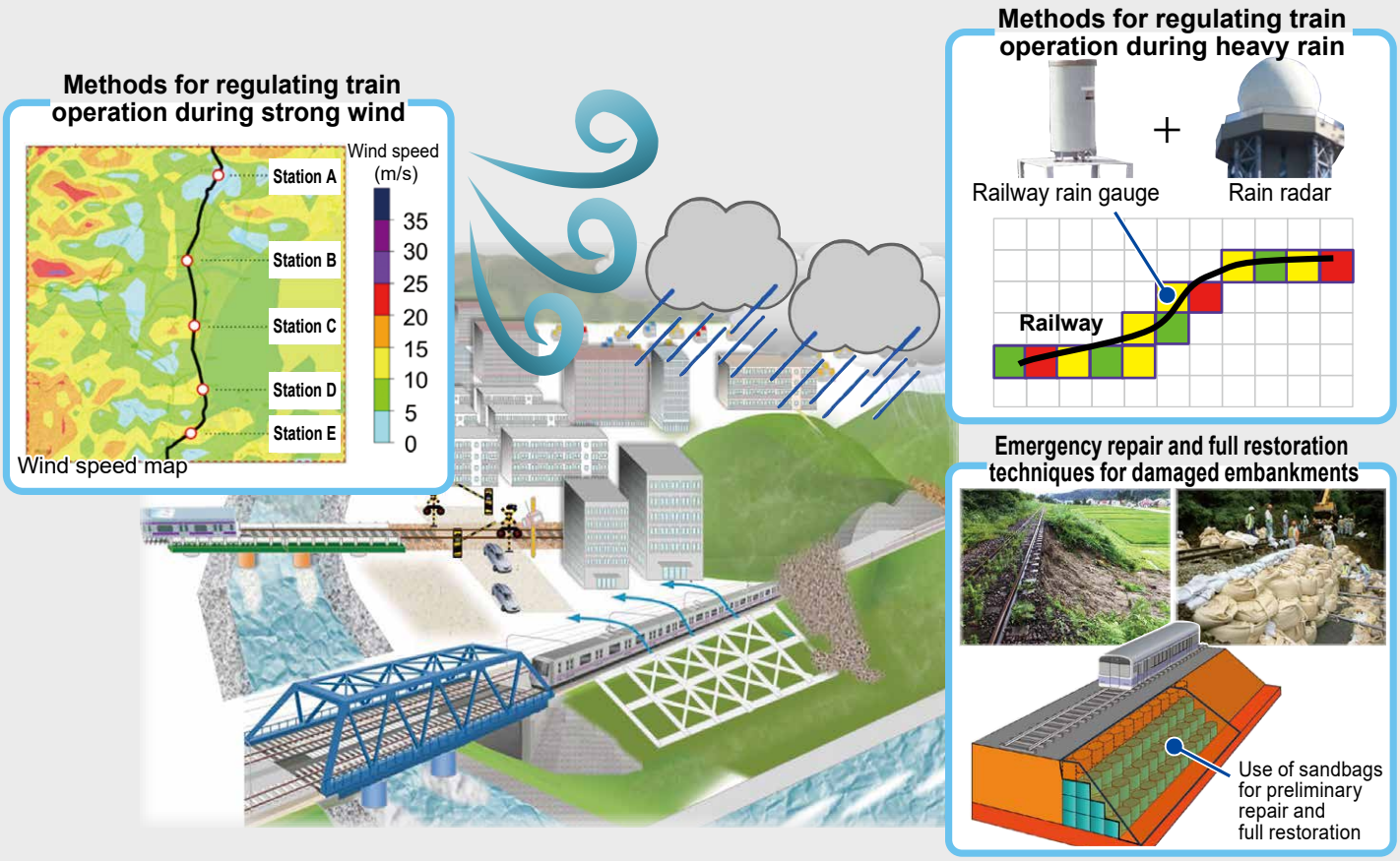

Figure 2 Enhancement of railway system resilience against intensifying meteorological disasters

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

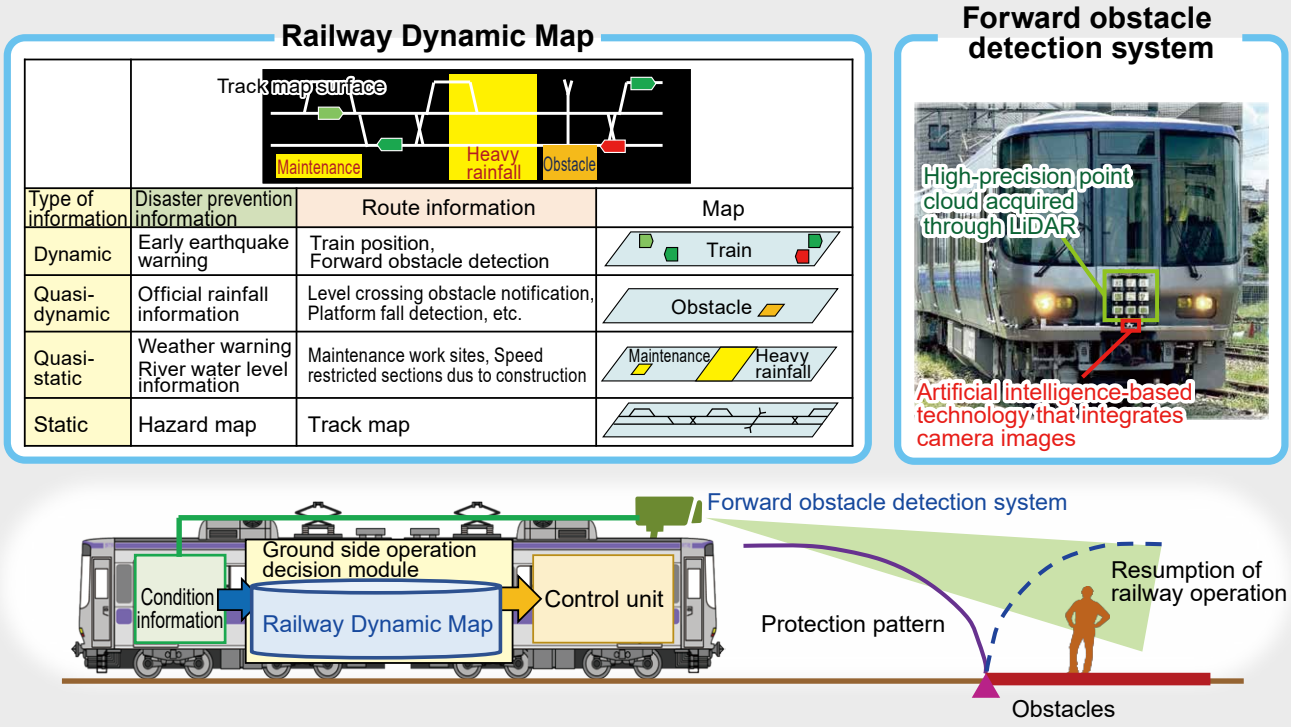

Figure 3 Autonomous train operation

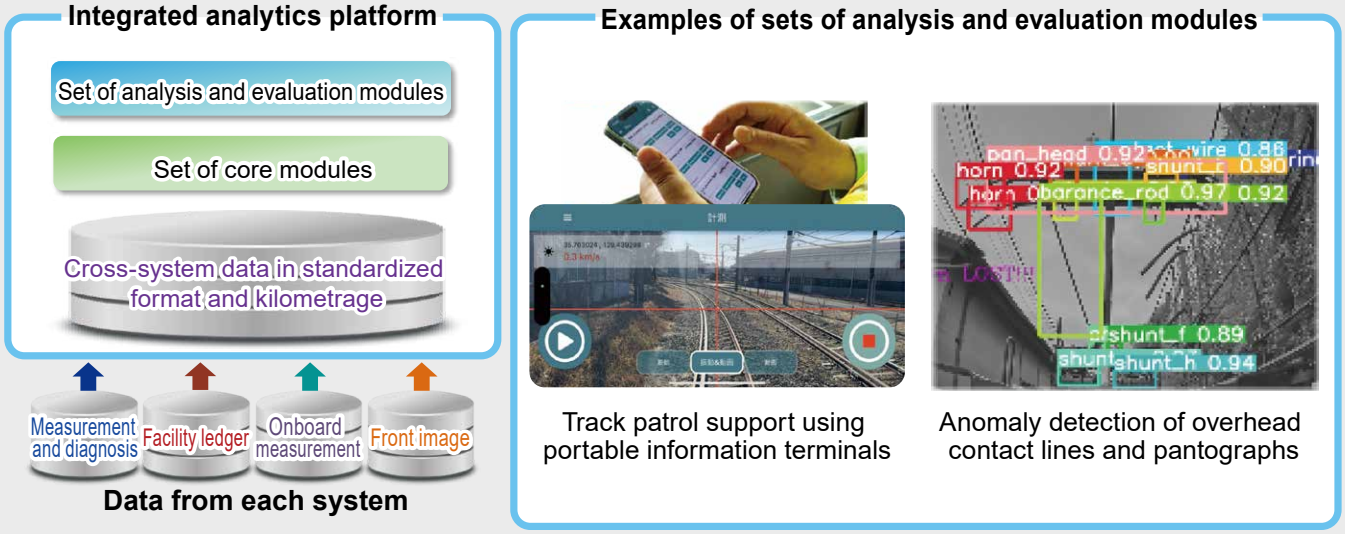

Figure 4 Labor saving through digital maintenance

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.

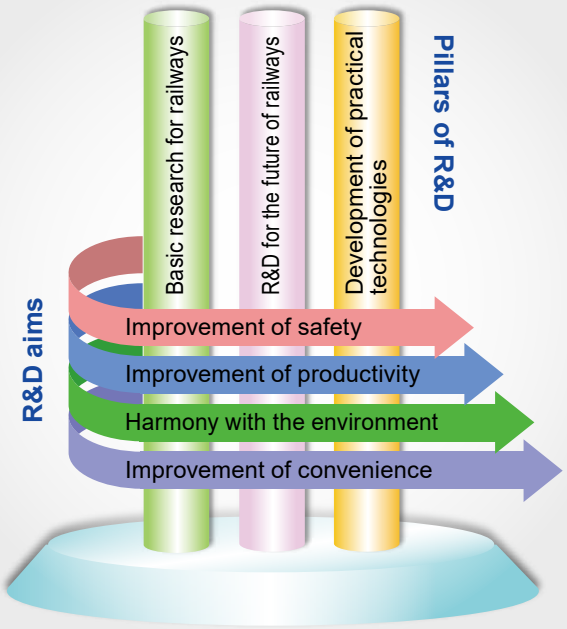

Figure 6 Advancing R&D

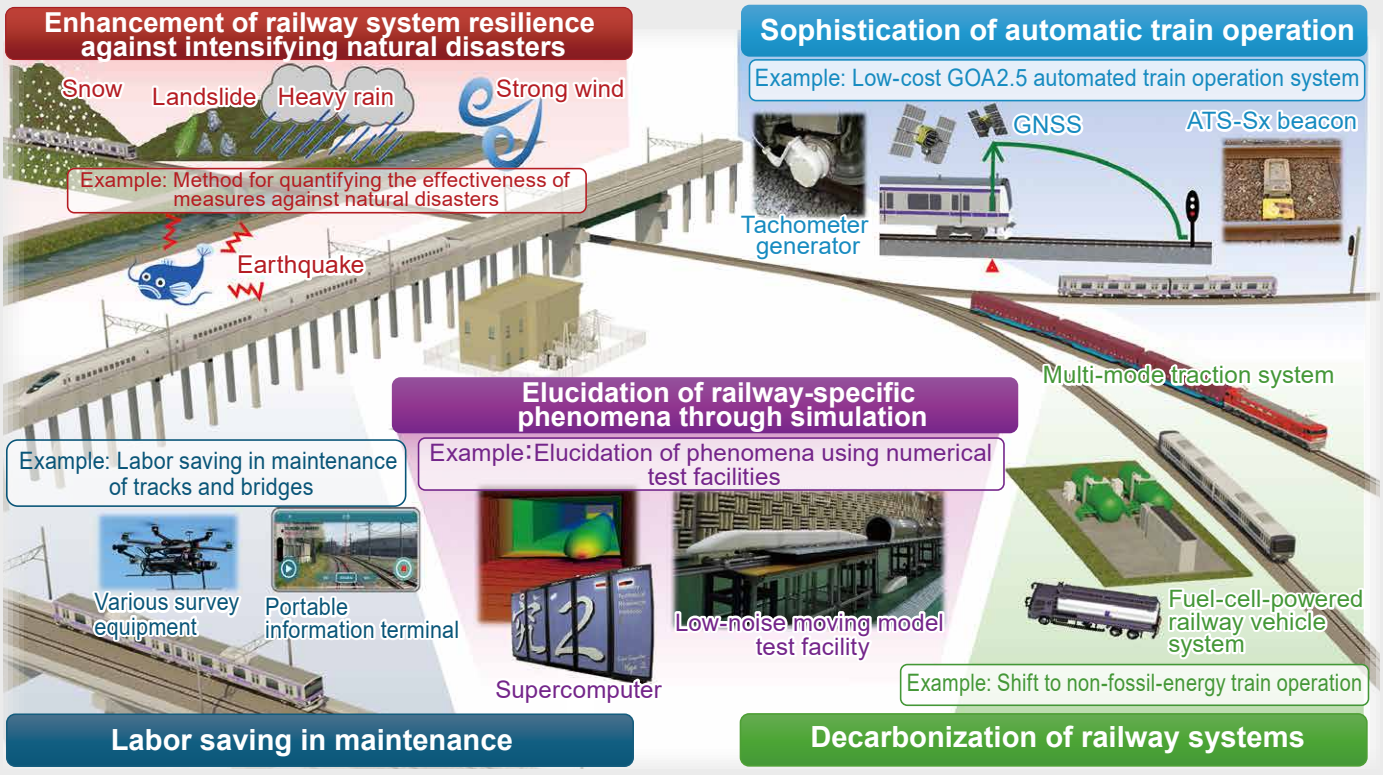

Figure 7 Examples of R&D for the future of railways