Toward Railway Innovation

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The Initiatives of its Technology Divisions 3

Hisayo Doi
Managing Editor
General Manager (International Affairs),
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Message from Managing Editor

Continuing on from the previous issue of Ascent, this latest issue features the activities of RTRI's research divisions.

In this issue, we introduce three research divisions: the Railway Dynamics Division, the Environmental Engineering Division, and the Human Science Division. The Railway Dynamics Division focuses on interdisciplinary fundamental research, including research on boundary and interface issues. The Environmental Engineering Division specializes in aerodynamics and acoustics, and the Human Science Division conducts research on human factors, including research in the field of labor science. By introducing the activities of these research divisions, we hope to provide our readers with a better understanding of the diverse research and development at RTRI.

Furthermore, RTRI places significant importance on collaborative relationships with partners around the world. These partnerships are supporting RTRI's R&D efforts introduced in this issue, such as the development of international standards. We hope to continue strengthening our ties with our partners for the worldwide development of railway technologies.

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Railway Dynamics Division

The Railway Dynamics Division is performing fundamental research on dynamic problems in railway vehicles, catenaries, tracks, and structures, focusing on phenomena occurring at the boundary regions between vehicles and structures/tracks, rails and wheels, and pantographs and overhead contact lines. We are developing and utilizing unique techniques, including measurement evaluation, testing, and simulation techniques, to elucidate railway degradation and safety-related dynamic phenomena and propose specific solutions to identified issues. This report introduces our latest research and development (R&D) achievements and activities.

Dr. Fumiaki Uehan
Director,
Head of Railway Dynamics Division

Introduction

Railways comprise several components, such as vehicles, catenaries, tracks, and structures, all of which interact with each other in their boundary regions, resulting in complex and dynamic phenomena specific to railways. Understanding these railway-specific phenomena and proposing specific solutions to key issues are necessary to improve safety, mitigate railway accidents and disasters, and realize the efficient maintenance of deteriorating equipment and facilities. In the Railway Dynamics Division, five laboratories covering a wide range of fields (Vehicle Mechanics, Current Collection, Track Dynamics, Structural Mechanics, and Computational Mechanics) collaborate to develop measurement evaluation techniques for on-track testing, testing techniques using unique test facilities, and numerical simulation techniques. The division seeks to elucidate railway-specific phenomena and propose concrete solutions that could be game changers for the maintenance and development of railways via the sophisticated integration of measurement evaluation and testing techniques executed in real space with numerical simulation techniques executed in the computer space (*Integration of measurement evaluation, testing, and simulation techniques*).

We are developing several measurement evaluation techniques to measure the dynamic behaviors of vehicles and ground equipment, as well as status evaluation techniques based on measurement data. We are using numerical simulations to efficiently verify the validity of these techniques. Moreover, we intend to develop our measurement evaluation techniques as tools for collecting information to integrate actual railway tracks with virtual test tracks.

We are also developing unique test equipment that can reproduce railway-specific phenomena[1)] and improving testing procedures by integrating testing techniques with numerical simulations. Additionally, we are building a numerical laboratory, as a digital twin[*1] of the actual test equipment, in the computer space using simulation techniques.

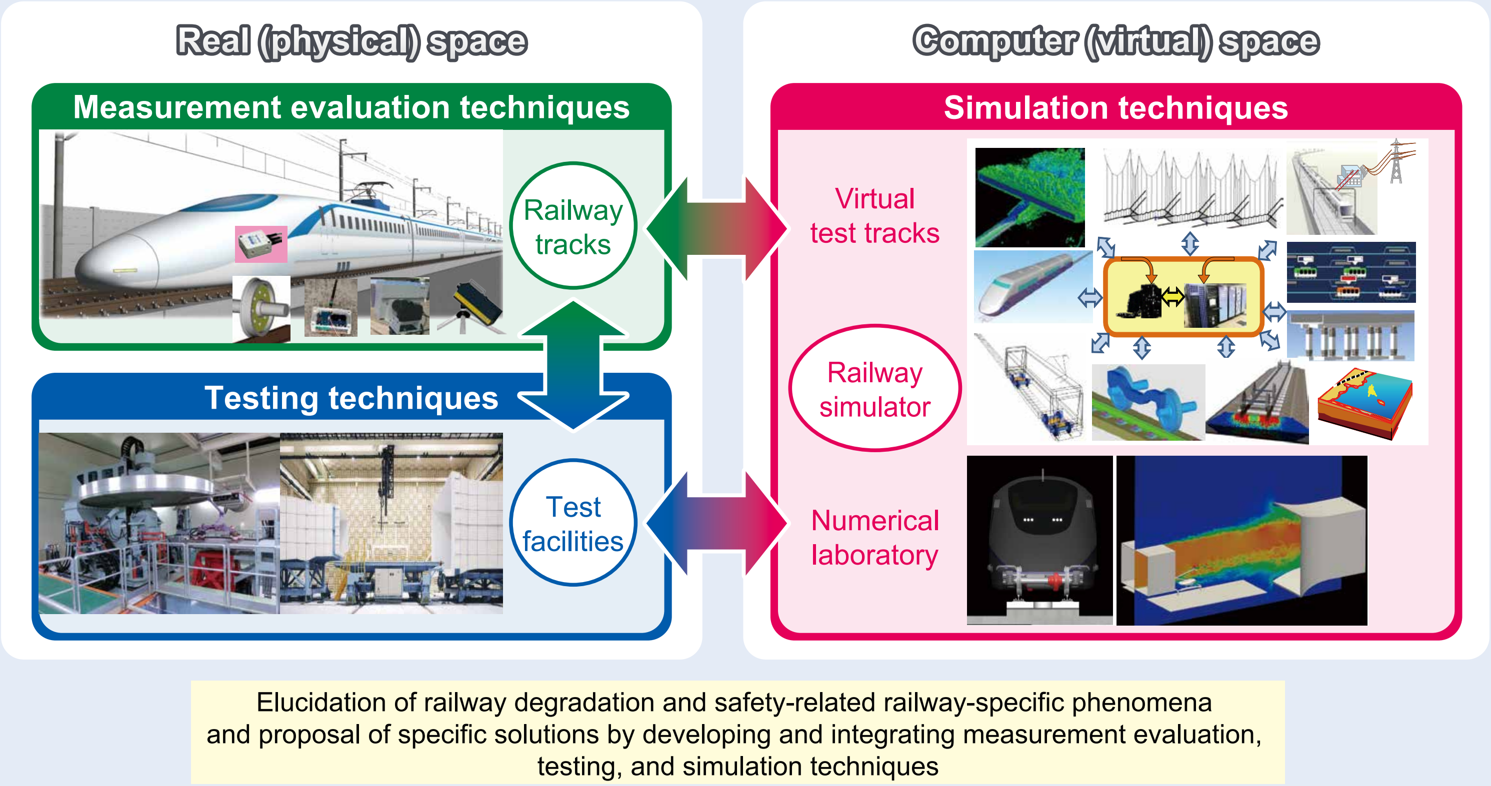
Finally, we are developing new analytical techniques, as well as a railway simulator, by integrating the simulation techniques previously developed by the Railway Technical Research Institute[2]. We are building virtual test tracks and digital twins of actual railway tracks in the computer space via the large-scale coupling of the physical phenomena occurring in various railway components.

Some of the most recent research activities and achievements of the Railway Dynamics Division in the areas of measurement evaluation, testing, and simulation techniques are presented below.

On-board evaluation of the structural soundness of railway bridges —Measurement evaluation techniques—

First, as an example of the development of techniques to measure and evaluate dynamic phenomena occurring in vehicles and ground equipment on actual railway tracks, we built a technique for evaluating the performance of railway bridges by means of on-board measurement. Numerical simulations play an important role in the development of measurement evaluation techniques by verifying the hypotheses of measurement evaluation theories and the appropriateness of measurement results, the details of which are omitted here.

The vibrations and girder deflections of a train passing over a railway bridge are

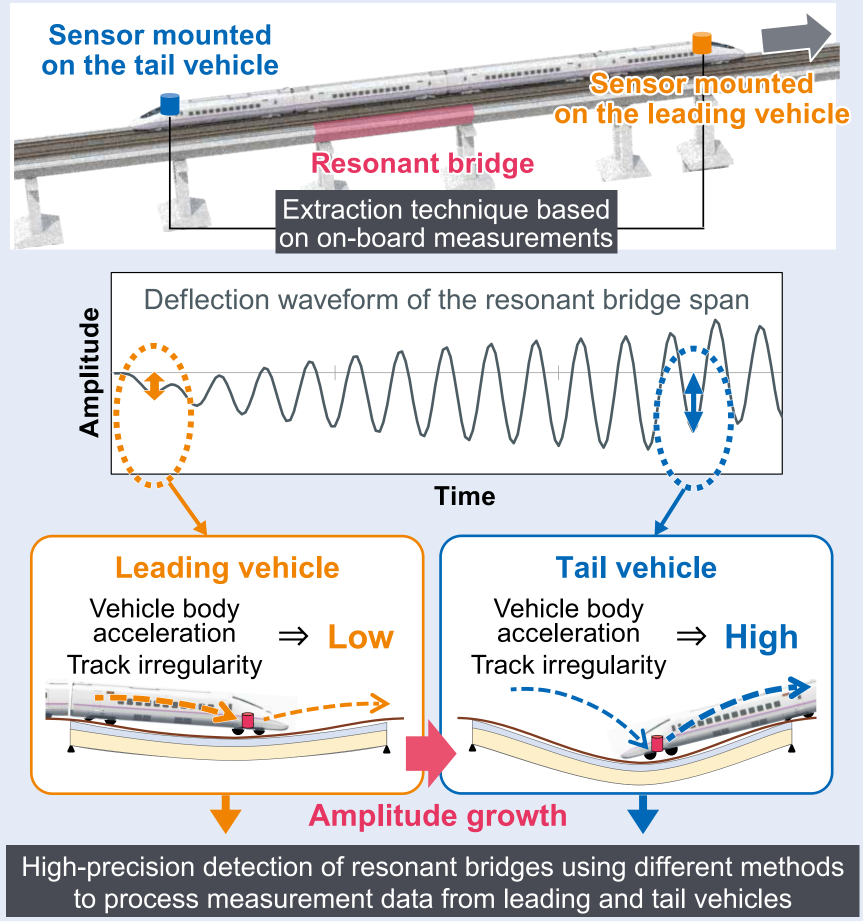


Integration of measurement evaluation, testing, and simulation techniques

typical evaluation indicators of train ride comfort and the structural soundness of railway bridges. The measurement of vibrations and girder deflections is performed at the ground level, one bridge at a time; therefore, this endeavor requires a great deal of labor and time. As an alternative to ground-based measurements, we are developing a technique for inspecting railway bridges using train vibrations and track irregularities measured by sensors mounted on trains passing over bridges.

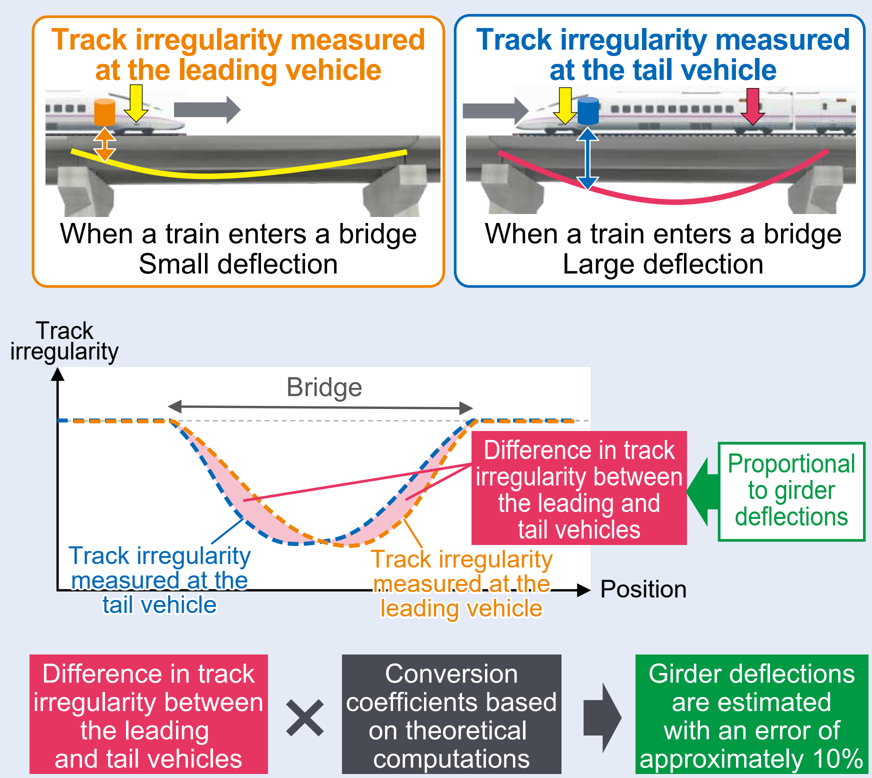
On-board detection of resonant bridges —Measurement evaluation techniques—

We have designed on-board measurement evaluation techniques for resonant bridges. The resonance phenomenon of railway bridges[*2] is known to cause large vibrations when a train passes over a bridge[3]. The developed techniques utilize sensors mounted on the leading and tail vehicles, and can detect increases in bridge vibrations when the tail vehicle passes over a railway bridge compared with that observed when the leading vehicle passes



On-board detection technique for resonant bridges

On-board measurement technique for bridge deflections

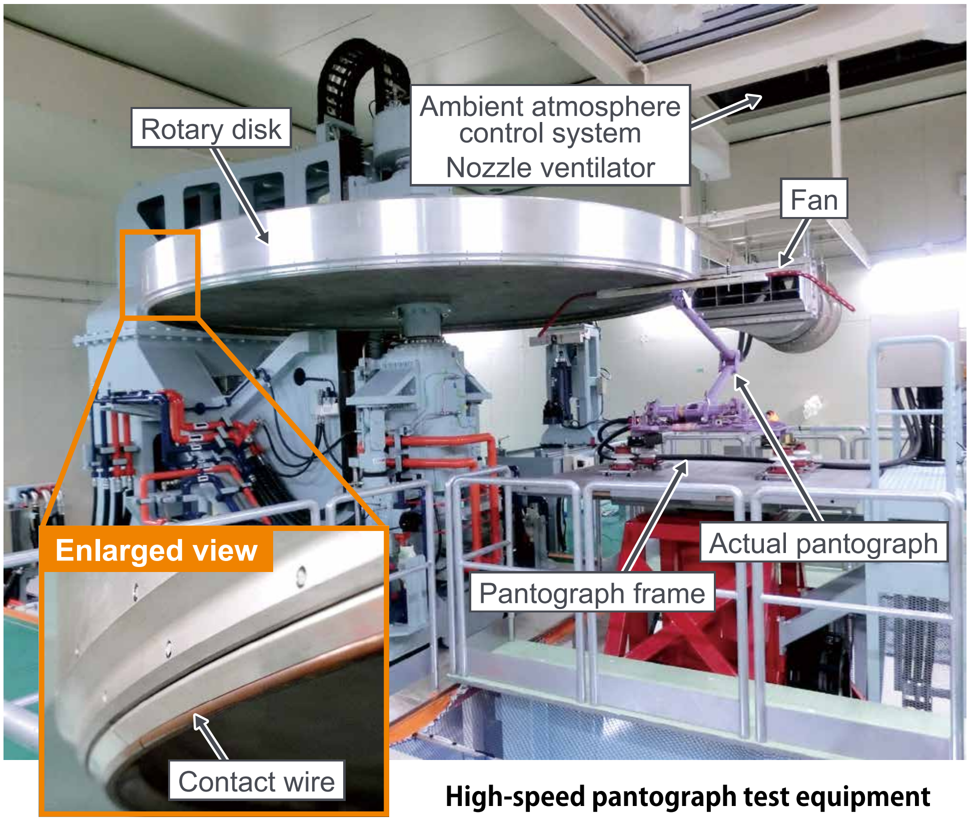


*1 Digital twin

A model that uses digital techniques to accurately reproduce a virtual space that exists in real space.

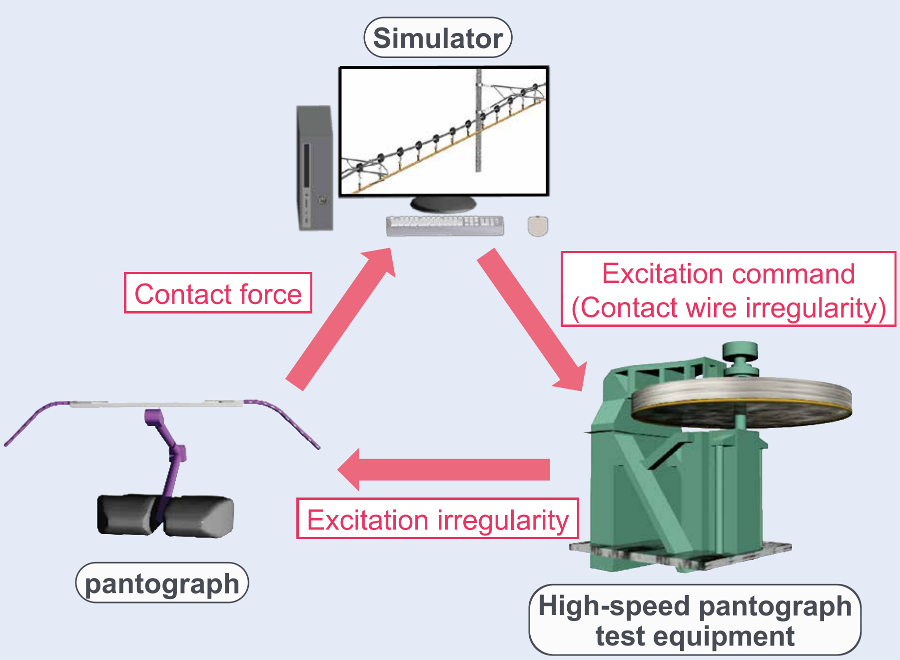
*2 Resonance phenomenon of railway bridges

When a train passes over a railway bridge, a vibration with a specific frequency is generated owing to the regular axle arrangement of vehicles; when this frequency approaches the natural bridge frequency, resonance occurs and causes excessive vibrations on the railway bridge.



High-speed pantograph test equipment

Components of the overhead contact line/pantograph HILS system



over the bridge (*On-board detection technique for resonant bridges*).

On-board measurement technique for bridge deflections —Measurement evaluation techniques—

We have developed techniques for estimating the girder deflections that occur when a train passes over a bridge based on the track irregularities measured on board. We theoretically elucidated that the difference between the track irregularity (high and low) measured at the leading vehicle and that measured at the tail vehicle of the train set contributes to the girder deflections that occur when a train passes over a bridge. Additionally, we estimated the girder deflections by multiplying the maximum difference in track irregularity with a conversion factor based on the span of the railway bridge (*On-board measurement technique for bridge deflections*). Using validation tests on an actual track, we showed that these techniques can be used to estimate girder deflections with an error of approximately 10%[4]. We are currently developing techniques for estimating girder deflections not only by measuring track irregularities at the leading and tail vehicles but also by using the difference in height measurements obtained by two-car inspection, which is often used in conventional lines.

These measurement evaluation techniques are being technically verified by field tests using dynamic interaction simulations[5] between vehicles and structures developed by the Railway Dynamics Division and noncontact vibration measurements[1].

High-speed pantograph test equipment and hybrid simulations —Testing techniques—

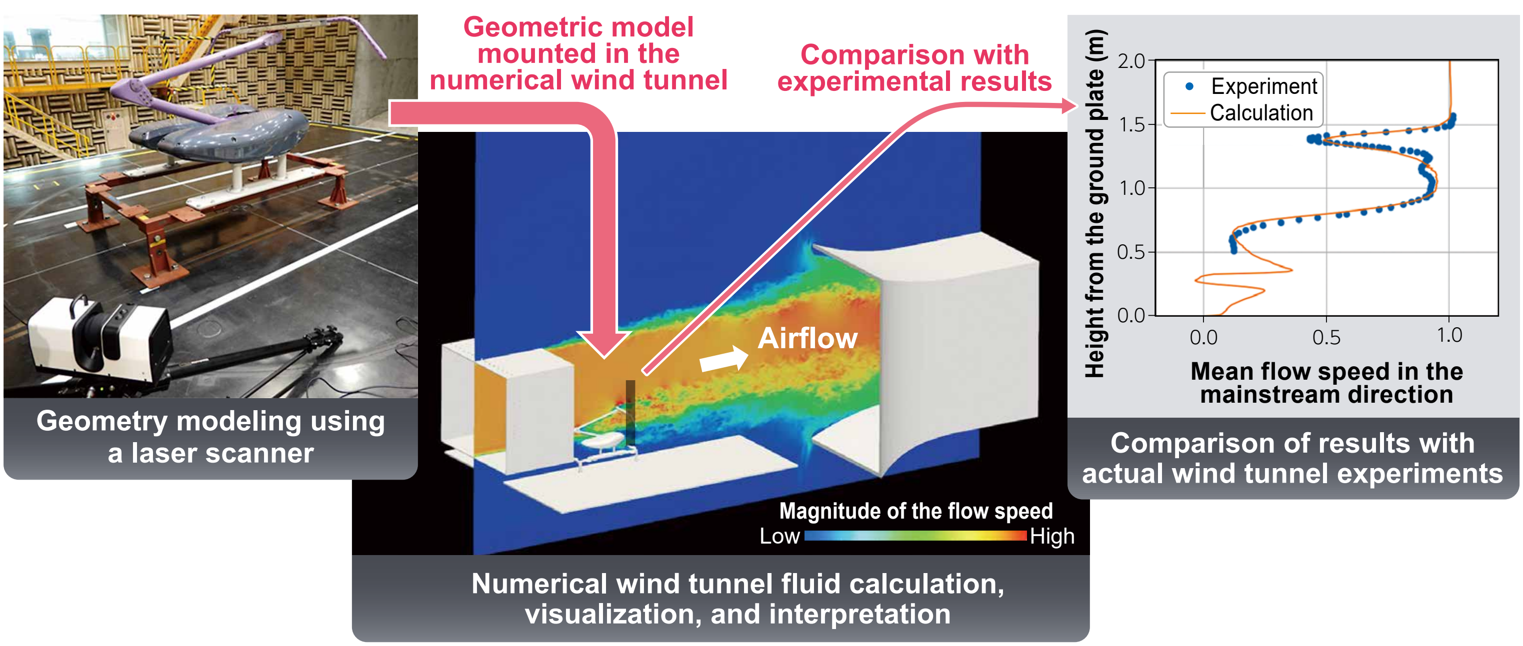
This section present examples of R&D work being conducted to realize more advanced testing through the development of testing techniques and test equipment unique to the Railway Technical Research Institute, and the integration of testing equipment and numerical simulations.

To evaluate the performance of pantographs by means other than on-track testing, we are conducting computer simulations of motion and various tests in our facilities. The Railway Dynamics Division has developed techniques to simulate the motions of overhead contact lines and pantographs, as well as tests and investigations using high-speed pantograph test equipment (*High-speed pantograph test equipment*) [6]. Our high-speed pantograph test equipment can conduct various tests on stationary pantographs by operating (rotating vertically and laterally displacing) a disk corresponding to an overhead contact line in a temperature- and humidity-controlled test chamber, simulating running conditions of up to 500 km/h.

Although the movement of the disk is generally preconfigured, more advanced hardware-in-the-loop simulation (HILS) tests[7] can be performed by integration with the aforementioned simulation techniques. HILS is a technique that integrates actual equipment and computer simulations in real time. The overhead contact line/pantograph HILS system was developed by linking real-time simulations to the vertical motions of the disk in contact with the pantograph of the actual equipment (*Components of the overhead contact line/pantograph HILS system*). This integration enables the mutual coupling of overhead contact lines and pantographs in high-speed pantograph test equipment, allowing tests to be performed under conditions that are closer to those that produce the observed phenomena. We intend to advance these techniques further to lower development costs and facilitate the more efficient maintenance of pantographs.

Numerical wind tunnel for large-scale low-noise wind tunnels —Simulation techniques—

Finally, a case example of the development of a numerical laboratory in which the test equipment is reproduced in a virtual space using numerical simulations is presented. A numerical laboratory was constructed to reduce the number of test ac-



Numerical wind tunnel
(left: model, center: visualization of the calculation results, right: comparison of the numerical wind tunnel and experimental results)

tivities by coupling numerical simulations with actual test equipment, investigating the influence of the size and specification limitations of the actual test equipment on the test results, and conducting numerical experiments that exceed the capabilities of the test equipment.

The large-scale low-noise wind tunnel in Maibara, wherein various wind tunnel experiments are conducted for over 200 days annually, is an important tool for aerodynamic R&D at the Railway Technical Research Institute. To obtain more efficient and advanced wind tunnel experiments, we have developed a numerical wind tunnel that reproduces the results of actual wind tunnel experiments using numerical simulations.

During the construction of the numerical wind tunnel, which was developed as a digital twin of the Maibara wind tunnel, we identified and numerically reproduced its airflow characteristics. To numerically and efficiently reproduce the complex geometry of the airflow, we used an airflow simulator developed by the Railway Technical Research Institute. We introduced a technique for modeling the geometry of a specimen using a three-dimensional laser scanner and built a system that can perform the entire process from defining the model geometry to performing the subsequent calculations (*Numerical wind tunnel*). We compared the results of the numerical wind tunnel calculations with the experimental results and found that they were in good agreement.

The constructed numerical wind tunnel can be used as a complementary tool to wind tunnel experiments, for example, by focusing on specific experimental conditions and reducing the number of measurement points. Integrating the numerical wind tunnel with actual wind tunnel experiments will help shorten experiment and, in turn, R&D times. In addition, this integration will present a new approach for railway operators and other interested parties to quickly address sudden challenges without relying on wind tunnel experiments.

Conclusions

This report covers the R&D policy of the Railway Dynamics Division, which is the basis of our work on elucidating railway-specific phenomena and proposing specific solutions by developing and integrating measurement evaluation, testing, and simulation techniques. As examples of our latest achievements and activities, this report introduces techniques to evaluate railway bridges using on-board measurements, testing techniques for pantographs, and a numerical wind tunnel for simulating large-scale low-noise wind tunnels. More information on other R&D projects can be obtained from the official website of the Railway Dynamics Division of the Railway Technical Research Institute (https://www.rtri.or.jp/rd/division/rd50/). The Railway Dynamics Division will continue to develop and integrate unique measurement evaluation, testing, and simulation techniques to produce research results that can contribute to improving railway safety and realizing efficient railway maintenance and management, ultimately meeting the needs of society and the railway industry, which are changing along with innovations in digital technology.

References

1) Fumiaki UEHAN: Technology for Experiment/Measurement to Clarify Phenomena Specific to Railway System, Quarterly Report of RTRI, Vol.63, No.2, pp.84-87, 2022.
2) Fumiaki UEHAN: Research and Development on Railway Simulators, Quarterly Report of RTRI, Vol.62, No.2, pp.88-91, 2021.
3) Kodai MATSUOKA, Kyohei KAWASAKI, Hirofumi TANAKA, and Mizuki TSUNEMOTO,and Development and Validation of Drive-by Detection Method for Resonant Bridges, Quarterly Report of RTRI, Vol.63, No.2, pp.133-138, 2022.
4) Kodai MATSUOKA, and Hirofumi TANAKA: Drive-by Deflection Estimation Method for Simple Support Bridges Based on Track Irregularities Measured on a Traveling Train, Mechanical Systems and Signal Processing, Vol.182, No.109549, 2023.
5) Masamichi SOGABE, Nobuyuki MATSUMOTO, Yozo FUJINO, Hajime WAKUI, Makoto KANAMORI, and Masaaki MIYAMOTO: Dynamic Response and Design of Continuous Concrete Railway Bridges in Resonance Area, Journal of JSCE, No. 724, pp.83-102, 2003 (in Japanese).
6) Tatsuya KOYAMA: Development of High-speed Test Facility for Pantograph/OCL Systems, Quarterly Report of RTRI, Vol.63, No.2, pp.128-132, 2022.
7) Shigeyuki KOBAYASHI, Tatsuya KOYAMA, Satoshi HARADA, and David P STOTEN: New Methods for Dynamically Substructured System Testing of a Railway Car Pantograph, Proceedings of the Institution of Mechanical Engineers, Part F, Vol.237, No.2, pp.146-156, 2022.

Dr. Sanetoshi Saito
Director,
Head of Environmental Engineering Division

The Environmental Engineering Division has focused on research on railway noise and aerodynamics. These include environmental issues, such as wayside noise, micro-pressure waves radiating from tunnels, and air resistance reduction; safety issues, such as vehicle overturning under crosswinds and winds induced by train passage, pressure changes in tunnels, and aerodynamic brakes; and comfort-related issues, such as the thermal environment in tunnels and airtightness of vehicles. We present the recent research conducted by the Environmental Engineering Division.

Environmental Engineering Division

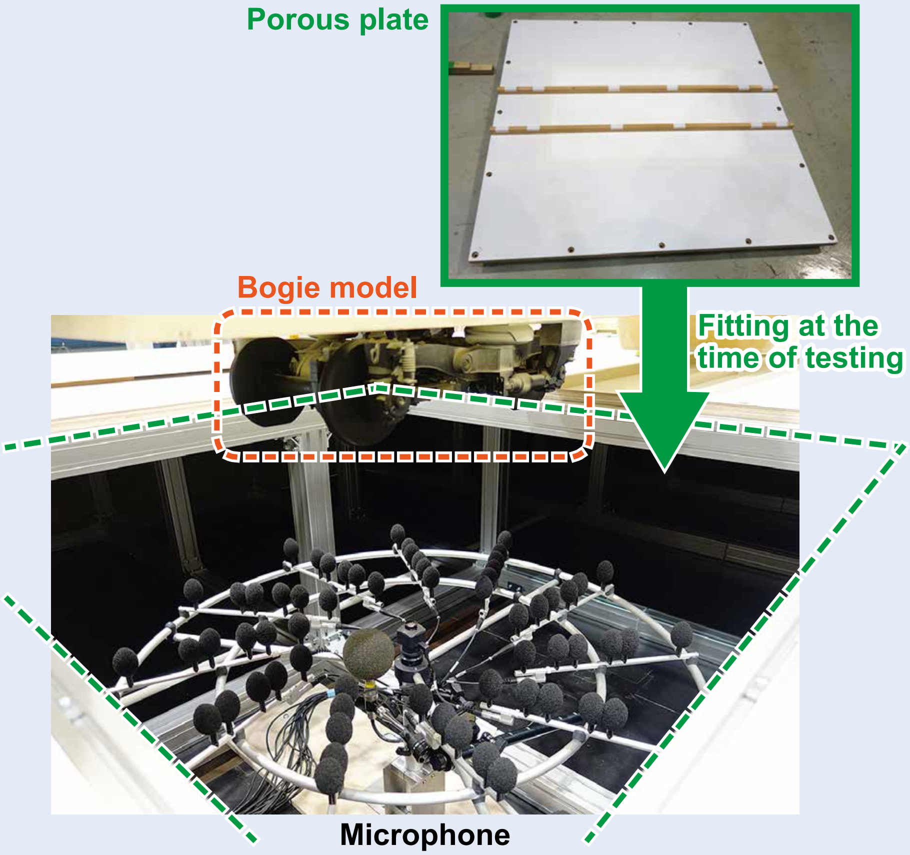
Introduction

Among the most investigated aerodynamic research subjects in the field of railways is aerodynamic drag, which is represented by the shape of the nose of the Shinkansen train. Aerodynamic drag reduction is particularly important in high-speed trains. However, there exist many aerodynamic issues in railways. Such issues include the overturning of a vehicle owing to strong winds, the aerodynamic sway of a high-speed railway, and winds generated on the platform when a train passes through a station. At times, people may feel an increase in temperature on a subway platform. This is also attributable to the heat generated by the running train and wind generated in tunnels, which is an issue related to heat and airflow. Further, noise is an important environmental issue in railways. There are various types of noises, including noise from wheels and rails, noise generated by structures such as railway bridges and viaducts, and aeroacoustic noise generated by high-speed vehicles such as Shinkansen trains.

As described above, railway noise and aerodynamic issues are remarkably diverse, and all are considered critical issues that affect the wayside environment, safety, and passenger comfort. The Environmental Engineering Division has focused its research and development efforts on elucidating and reducing railway-specific phenomena to propose concrete solutions to these issues. This report covers typical examples of our efforts to improve wayside environments, safety, and passenger comfort.

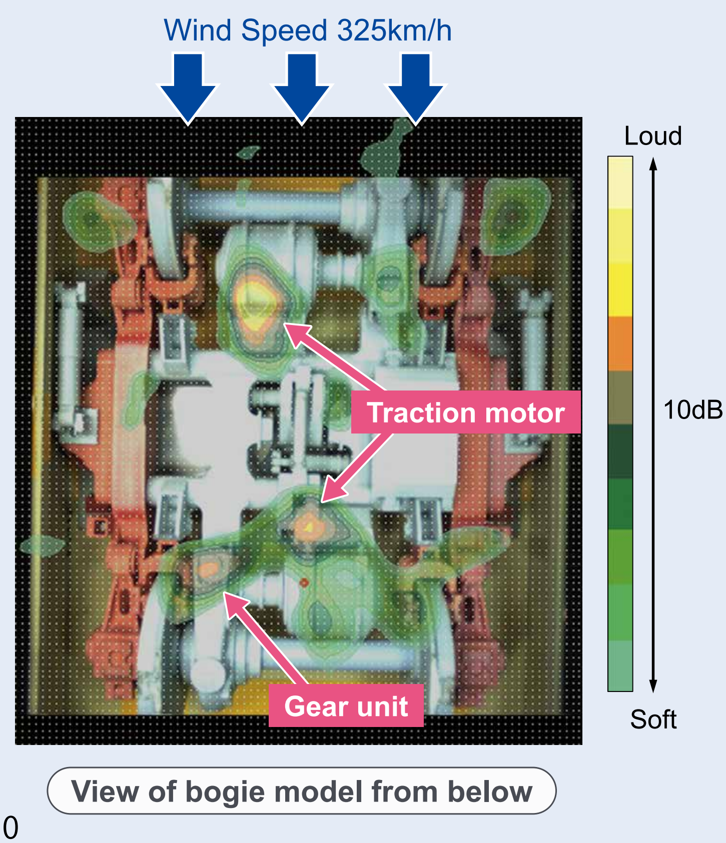
Wayside Environmental Issues —Wayside Noise—

The noise generated during the running of a Shinkansen train can be divided into noise generated by the vibrations of the wheels and rails (rolling noise) and that by the airflow around the vehicle (aero-



Wind tunnel test using porous plate

Detailed aerodynamic noise source in bogie sections

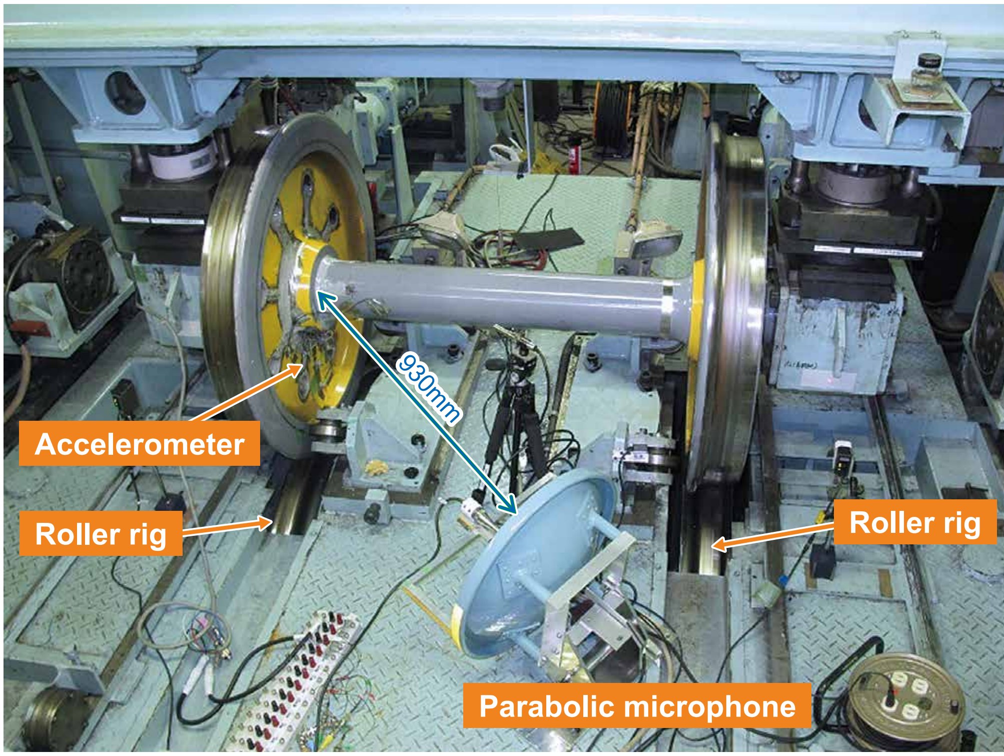


dynamic noise). For Shinkansen trains running at speeds of 300 km/h or higher, aerodynamic noise accounts for a larger proportion than rolling noise. Among the aerodynamic noises emitted by Shinkansen trains, the loudest noise is generated from the lower parts of vehicles, such as bogie sections, followed by the noise from pantographs. To solve this problem, we are currently developing measures to reduce the aerodynamic noise generated from the bogie sections to suppress wayside noise along the Shinkansen line. The large low-noise wind tunnel owned by the Railway Technical Research Institute is effective for conducting aerodynamic noise investigations. We replaced the ground plate directly under the bogie model with a porous plate (a plate that allowed only sound to pass through without disturbing the flow) and installed a microphone beneath it to identify the detailed locations at which aerodynamic noise was generated from the bogie sections (*Wind tunnel test using porous plate*)[1)]. We found that the primary sources of aerodynamic noise were near the traction motor (motor) and gear units (*Detailed aerodynamic noise source in bogie sections*). Based on these findings, we are currently conducting research and development on countermeasures to reduce the aerodynamic noise from bogie sections[2)].

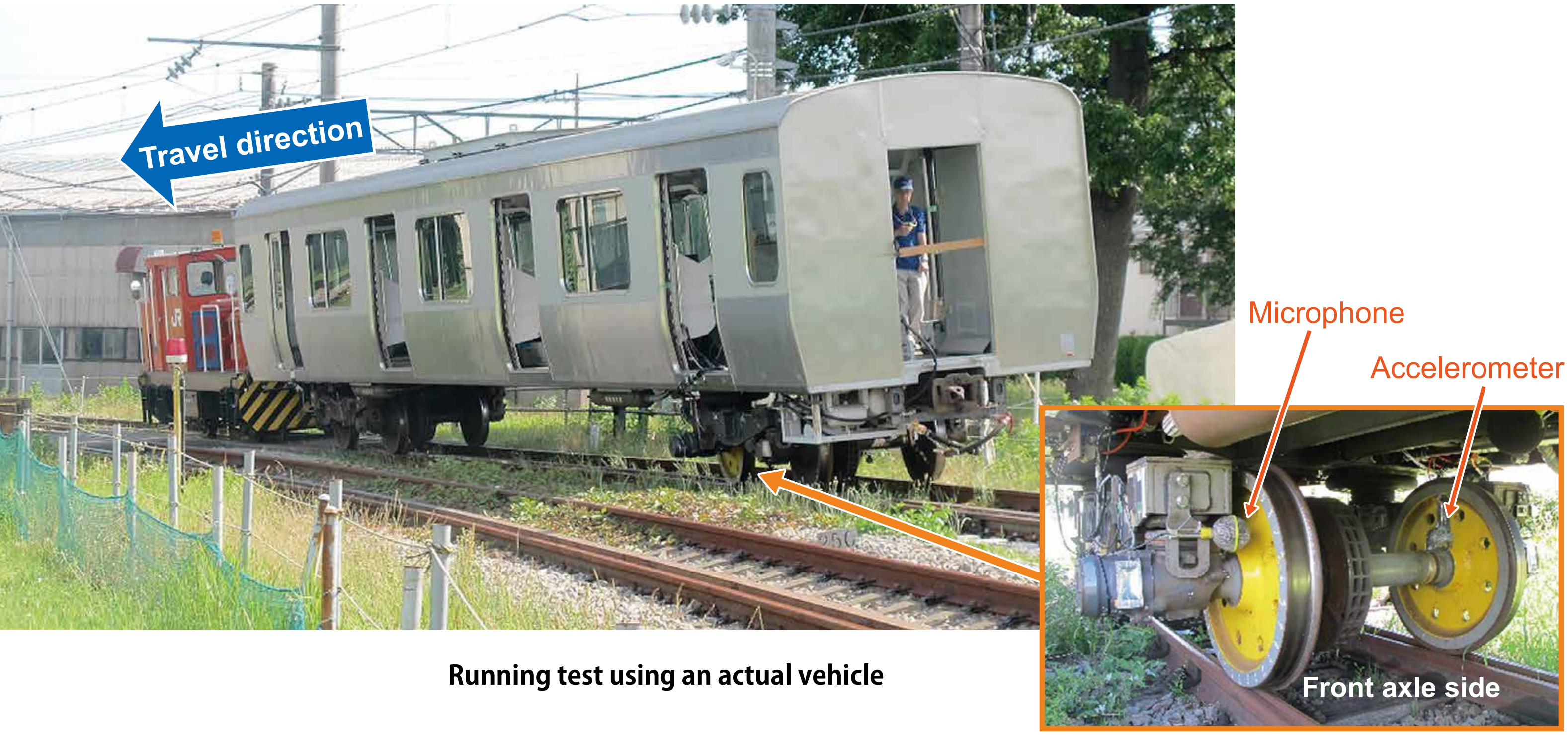
Because the noise generated between the wheels and rails, which is also a problem in conventional lines, is an extraordinarily complex phenomenon, the mechanism of noise generation, particularly on curves, remains unclear. Therefore, we are proceeding with our efforts to understand the underlying mechanism of the noise phenomena generated between wheels and rails, primarily through experimental methods. Through an experiment using an actual wheelset and experimental equipment that simulate the running conditions by rotating rigs (*Full-Scale Experiment with* *experimental equipment*), and a test using an actual vehicle (*Running test using an actual vehicle*)[3][4], we are currently examining the relationship between rail/wheel vibrations and the noise they generate to ascertain the characteristics of the relationship. Consequently, we constructed physical models to identify the cause of the noise.

Safety Issues — Crosswind Aerodynamic Characteristics of Railway Vehicles —

To ensure safe vehicle operation under strong wind conditions, the crosswind aerodynamic forces acting on vehicles must be determined accurately. Therefore, we are proceeding with our research and development, which will contribute to elucidating the aerodynamic characteristics of vehicles through wind tunnel tests and



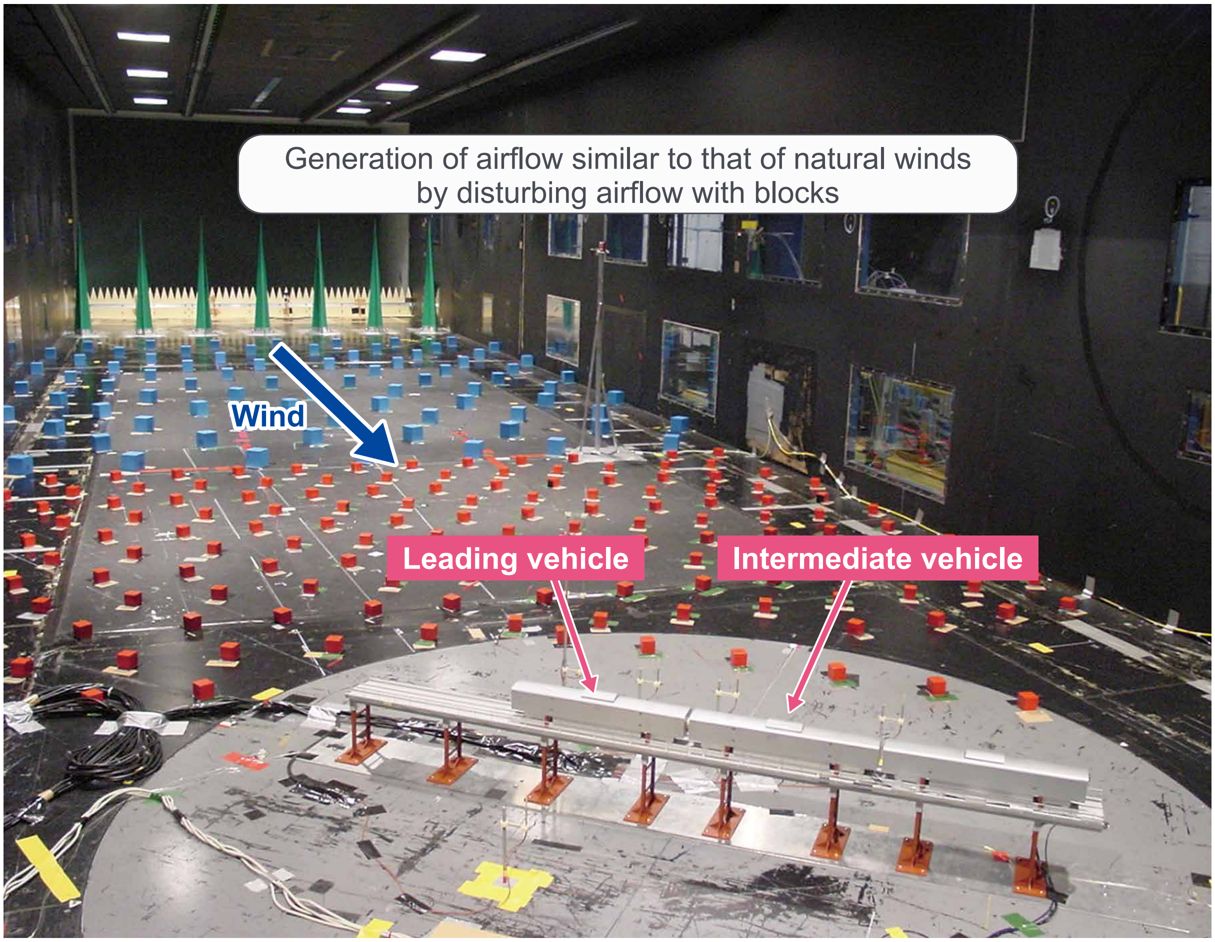
Full-Scale Experiment with experimental equipment



Running test using an actual vehicle

numerical simulations. The crosswind aerodynamic characteristics acting on railway vehicles are dependent on the shapes of the vehicles as well as the crosswind speed distribution and wayside structures, such as bridges, viaducts, and embankments. To resolve this issue, we performed wind tunnel tests at level ground conditions as well as under conditions simulating wayside structures such as bridges and embankments. Further, we simulated the mean wind speed and turbulence intensity distribution of natural winds to apply airflow to the model under conditions as close as possible to the actual conditions (*Wind tunnel test for aerodynamic characteristics of a vehicle against crosswinds*). We are currently working on wind tunnel tests using vehicle models with systematically varied cross-sectional shapes to investigate the relationship between the cross-sectional shapes and aerodynamic forces of the vehicle models and to evaluate and study the effects of windbreak fences[5)6)].

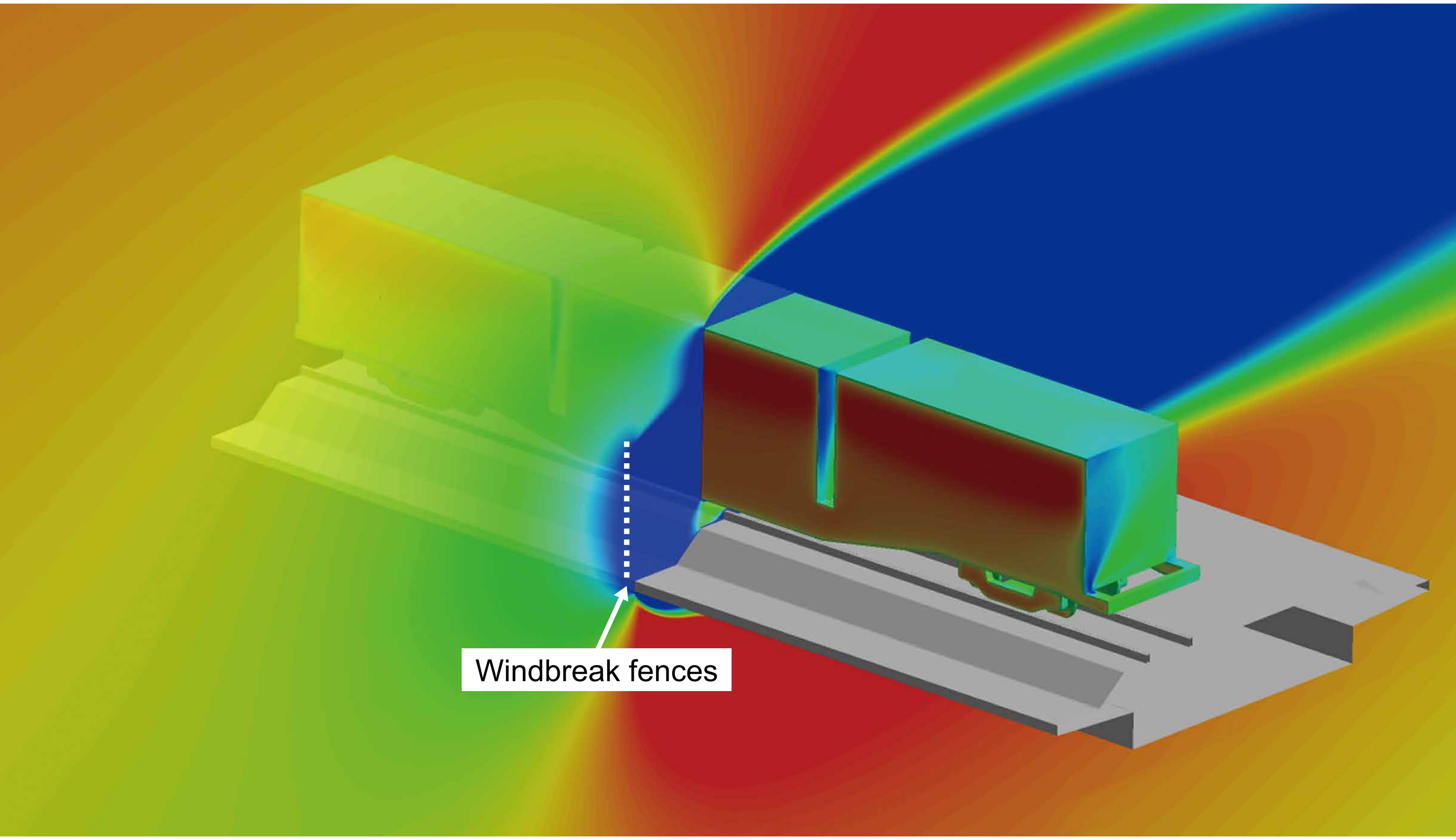
Whereas wind tunnel tests are highly effective tools for evaluating aerodynamic forces, numerical simulations that provide detailed insight into the flow field are effective for identifying the factors that affect aerodynamic forces. We systematically investigated the manner wherein wayside structures and wind direction angles affected the flow field around vehicles subjected to crosswinds (*Numerical simulation reproducing wind tunnel test with windbreak fences*)[6)]. We intended to conduct further studies on effective windbreak equipment while benefiting from the results of the wind tunnel tests and calculations.



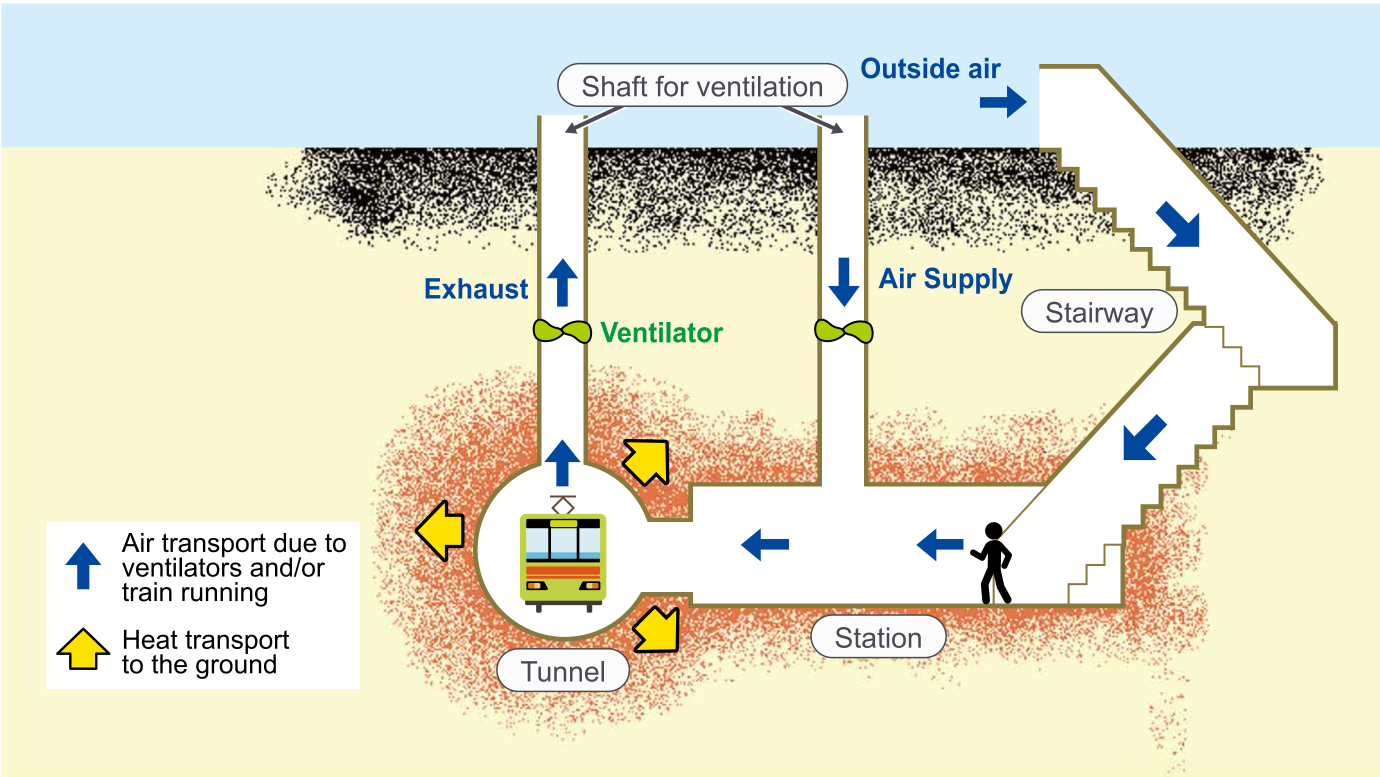
Wind tunnel test for aerodynamic characteristics of a vehicle against crosswinds

Comfort-Related Issues — Thermal Environment in Tunnels —

In urban tunnels, including subway tunnels, the heat generated by trains traveling in tunnels increases the temperature in the tunnels and underground stations. Unless any measures are taken, an increased temperature can compromise comfort on the platform and adversely affect the equipment in the tunnel. To avoid this, urban tunnels are often equipped with ventilation systems for the cooling stations. However, to accurately estimate the ventilation and cooling capacities, the temperature inside the tunnel must be predicted. The Railway Technical Research Institute has been developing simulations to predict the thermal environment in tunnels for ordinary trains running in urban areas as well as tunnels for high-speed railways with ventilation equipment, such as the Seikan Tunnel (*Heat and air transport model for urban tunnels*). The accuracy of the numerical simulations was verified using theoretical analyses and model experiments[7]. In recent years, temperature prediction in the long mountain tunnels of Shinkansen trains has become an increasing challenge, in addition to that in urban tunnels. This is because, on Shinkansen trains running in areas with heavy snowfall such as Hokkaido and Hokuriku, snow clumps that adhere to the train may melt and fall during travel in tunnels with high temperature. The temperature inside the tunnels must be predicted to estimate the location of snowdrops. In contrast to urban tunnels, mountain tunnels do not have ventilation



Numerical simulation reproducing wind tunnel test with windbreak fences



Heat and air transport model for urban tunnels

equipment. Therefore, they are more likely to be affected by natural winds. We are in the process of improving our calculation models by comparing the measurement results obtained from actual tunnels with those obtained through simulations developed for urban tunnels such that such simulations can be applied to mountain tunnels as well.

Conclusions

In this report, we covered the recent activities of the Environmental Engineering Division, including representative research subjects in the areas of railway wayside environments, safety, and comfort. We will continue to research and develop various issues related to noise and aerodynamics to contribute to the operations of railway operators.

References

1) Toki Uda, Mariko Akutsu, and Toshiki Kitagawa,"Sound sources and measures of aerodynamic noise generated from bogies of Shinkansen train," INTER-NOISE and NOISE-CON Congress and Conference Proceeding, InterNoise20, pp.5009-5017, 2020.
2) Kiyoshi Nagakura,"Recent Studies on Wayside Environmental Problems," RTRI Report, Vol.35, No.6, pp.1-4,2021 (in Japanese).
3) Takeshi Sueki, Tsugutoshi Kawaguchi, Yasuhiro Simizu, Toshiki Kitagawa, Hiroyuki Kanemoto, and Masahito Kuzuta,"Evaluation of Railway Curve Squeal Noise Using Roller Rig and Running Tests," RTRI Report, Vol.36, No.9, pp.25-31,2022 (in Japanese).
4) Takeshi Sueki, Toshiki Kitagawa, and Toru Yamazaki,"Evaluation Method of Rolling Noise Using Scale-model Tests," RTRI Report, Vol.34, No.3, pp.35-40, 2020 (in Japanese).
5) Yuhei Noguchi, Minoru Suzuki, and Tatsushi Otobe,"Results of Wind Tunnel Tests on Effect of Reducing Aerodynamic Forces by Fences," RTRI Report, Vol.36, No.9, pp.55-60, 2022 (in Japanese).
6) Yuhei Noguchi, and Minoru Suzuki,"Computational Fluid Dynamics Analysis on the Mitigation of Aerodynamic Force by Wind Fence," Proceeding of World Congress on Railway Research 2022, WCRR2022.
7) Hiroyuki Saito, Hiroshi Kajiyama, and Sanetoshi Saito,"Verification of prediction Method for Thermal Environment in Tunnel by Model Experiment and Analytical Solution," RTRI Report, Vol.34, No.3, pp.17-20, 2020 (in Japanese).

Mr. Naoki Mizukami
Director,
Head of Human Science Division

The Human Science Division is currently conducting research and development (R&D) on human factors. We aim to enrich and support the education and training of railway workers to enhance their safety, as well as station and on-train environments to enhance passenger safety, convenience, and comfort. We are capitalizing on digital techniques to perform various tasks more effectively and efficiently and are advancing our R&D efforts by cooperating with other research hubs. In this document, we report the results of our recent R&D activities.

Human Science Division

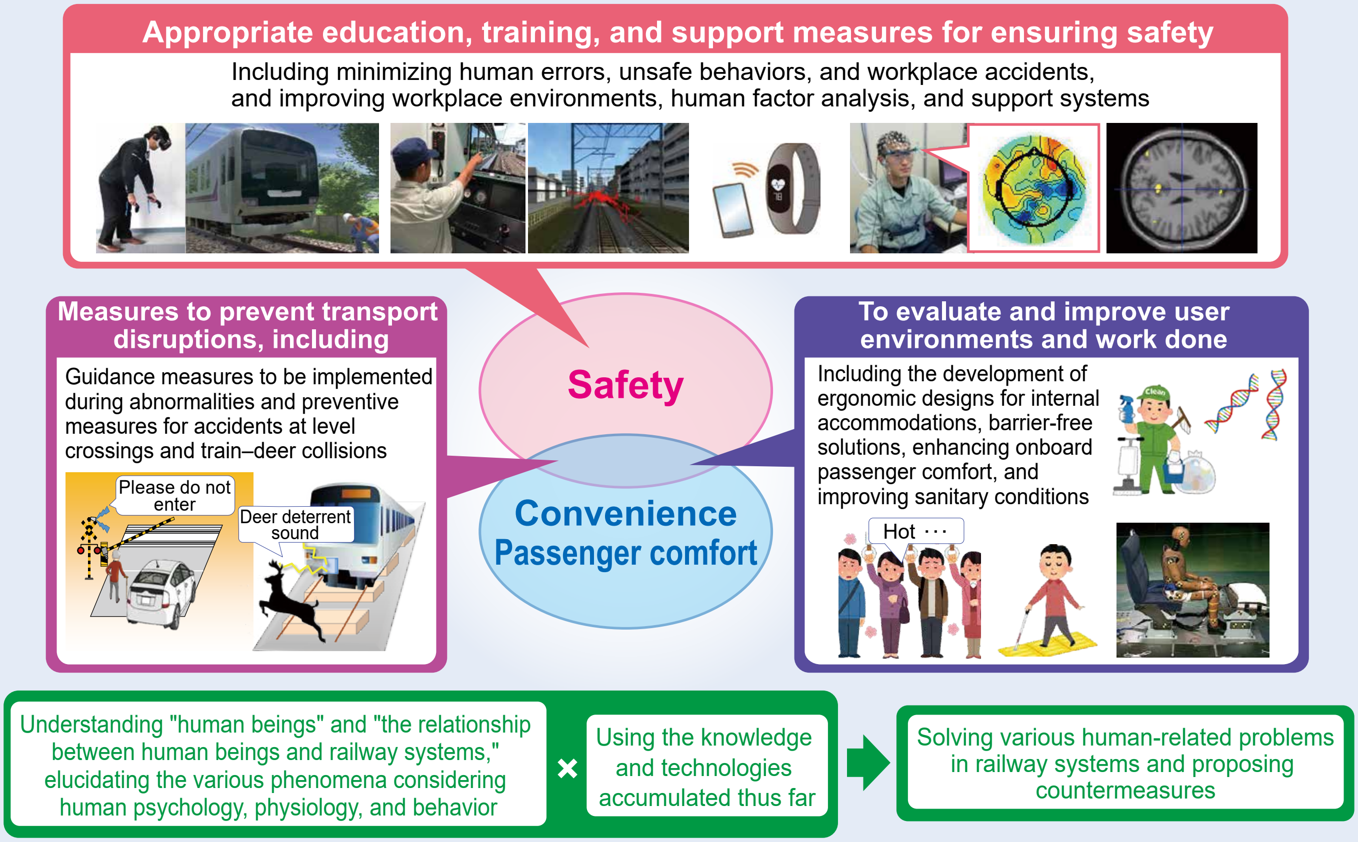
Introduction

The Human Science Division aims to solve various human-related problems in railway systems and devise countermeasures to ensure passenger safety, convenience, and comfort. Consequently, it is essential to understand "people" and "the relationship between people and railroad systems" to elucidate their psychological, physiological, and behavioral phenomena and employ the knowledge and technologies accumulated thus far.

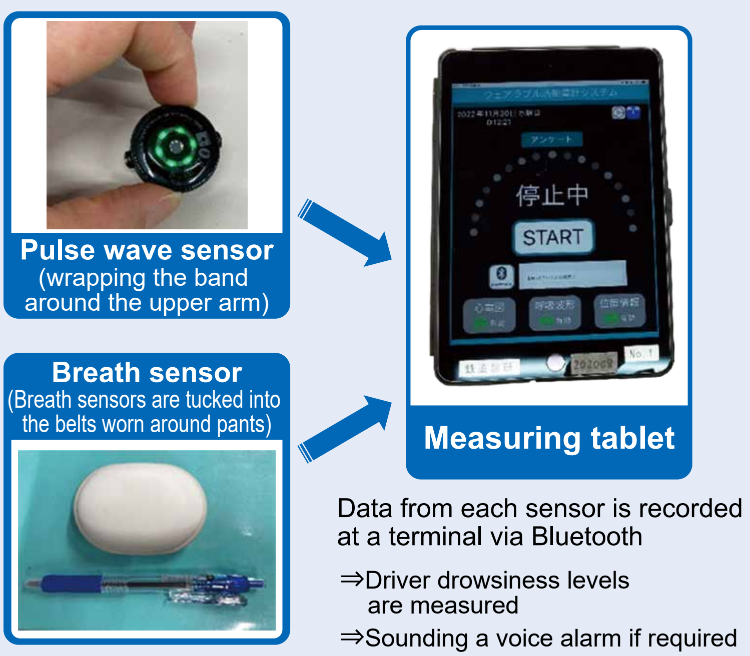
Our division initially comprised four research laboratories (Safety Psychology, Ergonomics, Safety Analysis, and Biotechnology). However, in April 2022, it was restructured and now comprises three laboratories (Safety Psychology, Ergonomics, and Comfort Science and Engineering) to enhance the efficiency of R&D, with the aim of improving the environment surrounding railways and satisfying the requirements related to passenger safety, security, and comfort.

Major R&D efforts of the Human Science Division shows our major R&D efforts thus far. To provide appropriate education, training, and support to drivers for ensuring safety, we are focusing our R&D efforts to minimize human errors, unsafe behaviors, and workplace accidents; improve workplace environments; and implement driver-support systems. To prevent transport disorders, we are developing guidance measures to be implemented during abnormalities and preventive measures for accidents at level crossings and train–deer collisions. To evaluate and improve user environments and the work done thus far, our R&D efforts are focused on developing ergonomic designs for internal accommodations, barrier-free solutions, enhancing onboard passenger comfort, and evaluating and improving sanitary conditions. We are working in conjunction with other research divisions, including the Information and Communication Technology Division, and considering cost reductions to solve the issues identified thus far and employ digital technologies to address them.

Here, we introduce the latest examples of our R&D efforts based on digital technologies for developing advisory techniques for drivers that monitor changes in their physical and mental states, enhancing pedestrian safety at level crossings, and developing low-cost and efficient weeding techniques.



Major R&D efforts of the Human Science Division

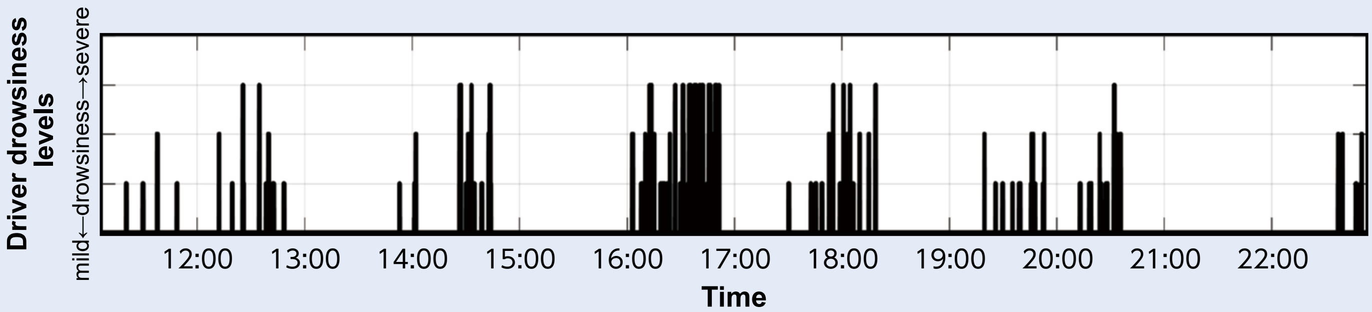


Examples of systems for monitoring changes in the physical and mental states of drivers

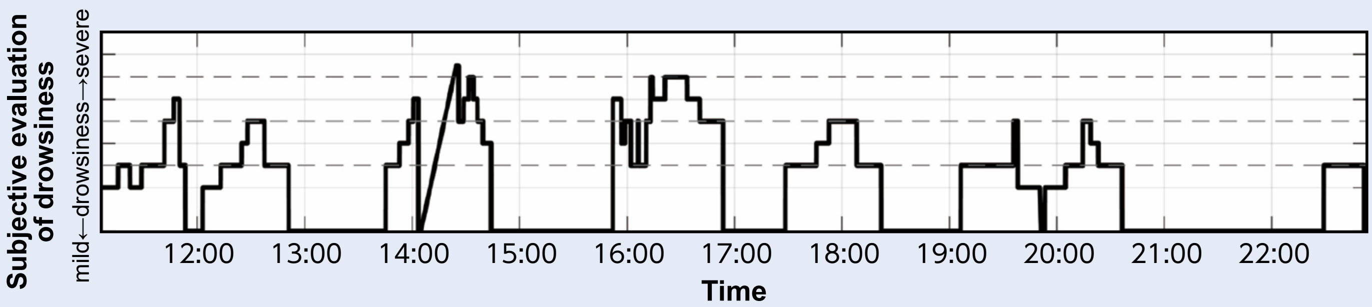
Driver-support System by Monitoring their Physical and Mental States

We are developing a system that monitors the physical and mental states of drivers and sounds an alarm in case drowsiness is detected to prevent errors and accidents owing to lowered attention, i.e., drowsiness. There are two major approaches for detecting drowsiness: photographing the driver's face and employing image-analysis technology to detect drowsiness, and physiologically measuring drowsiness using wearable sensors. The Railway

Driver drowsiness levels detected by the proposed system



Drivers' self-evaluation of their drowsiness



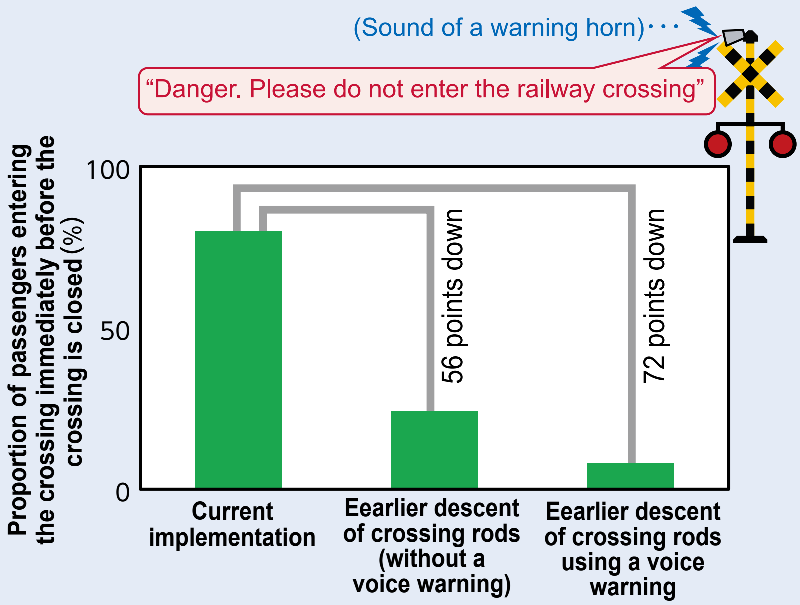
Examples of driver drowsiness levels detected by the proposed system (above) and those obtained by the drivers' self-evaluations (below)

Technical Research Institute (RTRI) is parallelly researching and developing both approaches to satisfy the various requirements of railway operators. The following paragraphs elucidate the approaches for conducting physiological measurements of drowsiness.

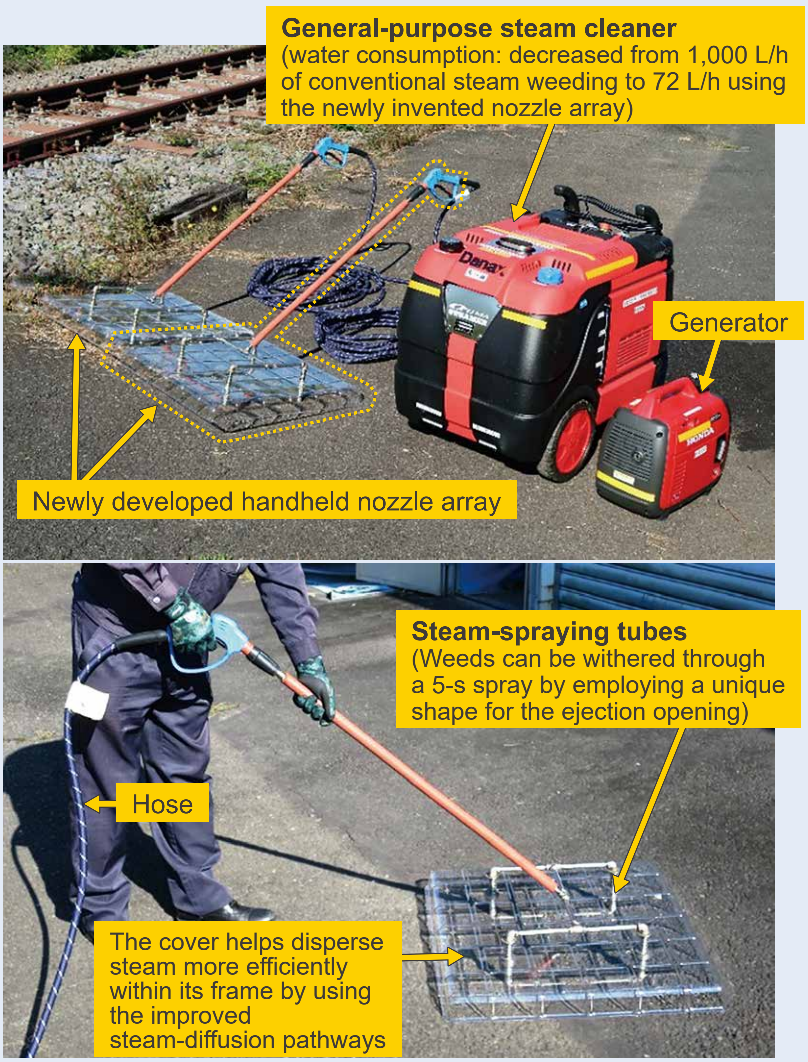
We are studying heartbeat-based (i.e., pulse wave-based) and respiration-based techniques from a practical standpoint, given the simplicity of their measurements for monitoring a wide range of physical and mental states, from low to high arousal[1]. The actual deployment of these systems involves accurate and real-time measurements using wearable sensors that do not cause discomfort to drivers.

We built a prototype measurement system using commercially available wearable sensors (*Examples of systems for monitoring changes in the physical and mental states of drivers*) that is currently being tested on drivers during operation. *Examples of driver drowsiness levels detected by the proposed system (above) and those obtained by the drivers' self-evaluations (below)* shows an example of the drowsiness levels of drivers detected by this system and the results of the drivers' self evaluations[2]. The onset and duration of drowsiness detected by this system, as shown in *Examples of driver drowsiness levels detected by the proposed system (above)*, substantially matches those felt by the drivers, as shown in *Those obtained by the drivers' self-evaluations (below)*.

Through close cooperation with the Data Analytics Laboratory, a subdivision of the Information and Communication Technology Division, we plan to not only acquire more data and provide more accurate monitoring but also develop systems that are easy to use by the drivers and their supervisors.



Preventing pedestrians from entering the railway crossing immediately before it is closed by earlier descent of crossing rods and sounding a voice warning



Steam-weeding technique

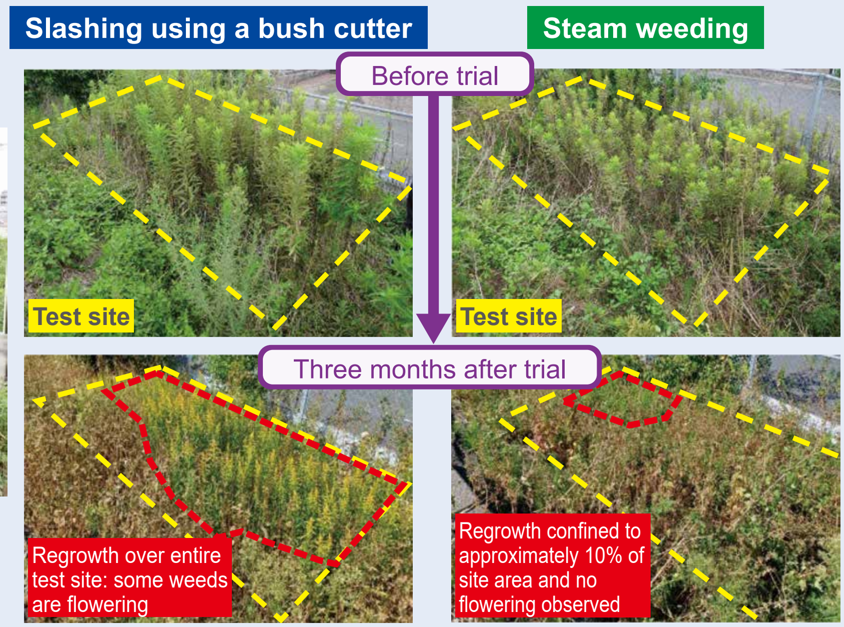
Enhancement of Level-crossing Safety[3)]

The number of level-crossing accidents involving automobiles has recently declined, whereas those involving pedestrians remain unchanged[4)]. According to one study, approximately three-quarters of level-crossing accidents involving pedestrians are caused by pedestrians entering the crossing while the warning is sounding (immediately before the crossing is closed)[5)]. We are currently working on preventing such occurrences.

A survey of pedestrians using level crossings showed that approximately 60% of those who experienced fallen barrier traps by entering the crossing while the warning was sounding had misunderstood the meaning of the warning to be "Caution" instead of its intended meaning of "No entry[6)]." To prevent this, we propose sounding a voice message stating "No entry" during an active warning, as well as blocking entry to the railway crossing earlier (hereinafter referred to as earlier descent of crossing rods). We employed multiple types of messages, including "Danger. Please do not enter the railway crossing." The crossing rods on the entry side descend quickly when the descent starts before slowing down, ensuring that the barrier descent completes within the same time as that in the current setup.

We also conducted an experiment by simulating a level crossing to verify the effect of blocking access to the railway crossings earlier. The participants were showed an image of an alarm sounding when approaching the railway crossing and selected whether to stop or enter the railway crossing. The results, presented in *Preventing pedestrians from entering the railway crossing immediately before it is closed by earlier*

Solidago altissima
Removing large weeds commonly found along railway lines



Comparison between steam weeding and slashing using a bush cutter

descent of crossing rods and sounding a voice warning, show that adding a voice warning, earlier descent of crossing rods, or a combination of both resulted significantly reduced the proportion of passengers entering the crossing when the warning was sounding compared to the current implementation. Based on these results, we conducted verification experiments using actual systems.

Low-cost and Efficient Weeding in Railways[7)]

Weeding in along railway lines requires considerable workforce and time, demanding higher work efficiency. The Human Science Division has developed a steam-weeding technique with weed-controlling effects and usability based on our accumulated knowledge of weed control in conjunction with the Track Technology Division.

Herbicides can be used to efficiently control weeds growing outside the tracks within the railway-property boundaries. However, to avoid impacting the residential and agricultural areas along the line, it is necessary to limit the locations where they are used. For this, bush cutters, which can rapidly remove weeds, are widely employed. However, during the summer, weeds grow back quickly. Moreover, workers must use bush cutters for relatively short periods to avoid adverse health impacts such as injuries from rebounding rotary blades and vibration-induced upper-limb disorders. Furthermore, because signaling and communication cables are installed along the railway lines, employing extreme caution is crucial to avoid cutting these cables.

Therefore, we focused on a method used in agricultural fields: steam spraying to denature proteins and wither weeds. Conventional steam-weeding methods require large boilers and considerable quantities of water. Because obtaining large amounts of water in railway areas is challenging, we developed a handheld nozzle array composed of steam-spraying tubes and a cover, which uses less than one-tenth of water than conventional steam-weeding systems while providing sufficient heat to wither weeds. We confirmed that excellent steam diffusion can be obtained by improving the shape of the steam-diffusion pathways inside the cover and weeds caught within its frame can be withered through a 5-s spray by improving the shape of the ejection opening. In addition to this, a general-purpose steam cleaner and small generator are required for generating the steam (*Steam-weeding technique*).

Trials conducted at a test site covered with a thick growth of large weeds demonstrated that compared to slashing by the bush cutter, less than 10% of the weeds regrew after three months, and less than 70% regrew after one year using this method (*Comparison between steam weeding and slashing using a bush cutter*). Additionally, it is approximately 30% faster than slashing using bush cutters and reduces the required work force by 60%.

This system is already available on the market and we are also developing more effective weeding techniques to remove weeds growing on the tracks.

Conclusions

This report introduces the Human Science Division and the latest R&D efforts for addressing the challenges faced in railways, including driver-support systems, level-crossing safety enhancements, and efficient weeding methods. For more information on our other achievements and ongoing research, please refer to the RTRI website (https://www.rtri.or.jp/rd/division/rd52/).

The Human Science Division is committed to continuing R&D to develop innovative systems that focus on human behavior, specifically those of railway employees and users, by employing rapidly advancing digital technologies.

References

1) Chizuru NAKAGAWA, Ayako SUZUKI, Fumitoshi KIKUCHI, Takahiro WATANABE, Naohiro AKIU, and Takashi KOJIMA, “Estimation of Strong Tension State Using Multiple Physiological Indices Optimized for Each Individual,” The Japanese Journal of Ergonomics, Vol. 58, No. 2, pp. 84-95, 2022.

2) Chizuru NAKAGAWA, “Investigation of a Condition Monitoring System Using Wearable Devices for Detecting Changes in the Driver’s Arousal Level During Railroad Driving Operation,” The 64th Conference of Japan Human Factors and Ergonomics Society, 2023.

3) Toshiaki KABURAGI, Naohiro AKIU, and Yumeko MIYAJI, “Experimental Results of Deterring Effect for Level Crossing Entry by Combination of Crossing Rod Movement and Voice Message,” The 35th Autumn Symposium on Reliability, 2022, Reliability Engineering Association of Japan.

4) Information on Safety of Railway and Tramway Transportation (FY2007 to FY2020), Ministry of Land, Infrastructure, Transport and Tourism, Japan, http://www.mlit.go.jp/tetudo/tetudo_ tk8_000001.html (received on February 13, 2023).

5) Toshiaki KABURAGI, “Preventing Pedestrians from Entering Level Crossing during Warning Alarm Based on Voice Alarm and the Start Timing of Level Crossing Rod,” The 346th Railway Technical Research Institute Monthly Presentation, 2021.

6) Ayano SAITO, Naohiro AKIU, Daisuke SUZUKI, Hiroharu ENDO, and Naoki MIZUKAMI, “The influence of alarm interpretation on the intention of passing through the railroad crossing when the alarm sounds,” Collection of Papers of the 26th Jointed Railway Technology Symposium (J-RAIL), pp. 455-458, 2019.

7) Hikaru TANIGAWA, “Steam Weeding Technique with Excellent Weed-Controlling Effect and Usability,” The 360th Railway Technical Research Institute Monthly Presentation, 2019.

Mr. Hiroyuki Nozawa Awarded ISO Excellence Award

We are delighted to announce that Mr. Hiroyuki Nozawa of the Railway Technical Research Institute (RTRI) has been awarded the ISO Excellence Award by ISO (the International Organization for Standardization) for his contributions to the development of the international standard for railway quality management systems.

Description of Award Winner :
Mr. Hiroyuki Nozawa,
Deputy General Director,
Railway International Standards Center

Center, Mr. Hiroyuki Nozawa (Award Winner)
Right, Mr. Hiroshi Tanaka (Chairperson, ISO/TC 269)
Left, Ms. Elena Kamps (Committee Manager, ISO/TC 269)

ISO Excellence Award

The ISO Excellence Award was created to reward the achievements of technical experts for their outstanding contributions to the development of the international standards published by ISO.

Summary of Mr. Hiroyuki Nozawa's Major Contributions (as released by ISO)

Mr. Nozawa is a technical expert with a dedicated six-year career with ISO/TC 269-Railway applications and ISO/TC 269/WG 5-Railway quality management system. He made significant contributions to the development of ISO 22163-Railway quality management system*. Using his technical experiences and expertise, he managed the Japanese team participating in WG5 and established excellent working relationships with technical experts from other countries.

*The international standard ISO 22163-Railway quality management system (RQMS) was developed to obtain higher-quality railway products by adding existing railway-specific requirements to ISO 9001, the international standard for general quality management systems. It was published in July 2023.

RTRI and the National Science and Technology Development Agency of Thailand Co-Host Railway Technology Forum

The Railway Technical Research Institute (RTRI) and the National Science and Technology Development Agency of Thailand (NSTDA) co-hosted a Railway Technology Forum for strengthening mutual technical collaboration between the two parties on November 22, 2023, at Thailand Science Park in the suburbs of Bangkok. The forum was attended by five people from RTRI and approximately fifty people from Thailand, including Dr. Asira Fuongfuchat, Deputy Executive Director of NSTDA.

1. Date: November 22, 2023, from 9:00 to 14:00 (local time)

2. Venue: Thailand Science Park (located in the suburbs of Bangkok)

3. Background and Outcome of the Forum

Since RTRI and NSTDA concluded a technical cooperation agreement on July 1, 2021, under travel restrictions imposed by the pandemic, the two parties continued information exchange between experts online every four months.

In the long-awaited Railway Technology Forum that was finally held face-to-face, RTRI and NSTDA gave three presentations each (see Table below). Each presentation was followed by lively and informative discussions with many questions and answers.

In the final presentation, Dr. Miyauchi of RTRI reported what had been done so far in the course of our specific collaborative project (Technical Cooperation with NSTDA and RTRI).

Participants form NSTDA and RTRI

Program of the 2023 RTRI and NSTDA Railway Technology Forum

Time	Event
9:00-9:15	**Opening remarks** Asira Fuongfuchat, Deputy Executive Director, NSTDA Toru Miyauchi, Associate Director (International Affairs), Research and Development Promotion Division, RTRI
9:15-9:40	**Presentation 1:** Study on bogie strength design considering seismic motion Masakazu Takagaki, RTRI
9:40-10:05	**Presentation 2:** Modernizing load-bearing structure design of railway bogies through computational simulation Ekkarut Viyanit, NSTDA
10:05-10:20	Break
10:20-10:45	**Presentation 3:** Rail fastening systems and buckling of continuous welded rails Shingo Tamagawa, RTRI
10:45-11:10	**Presentation 4:** Rail track predictive maintenance Panadda Sheppard, NSTDA
11:10-11:35	**Presentation 5:** Computational simulation for understanding rail dynamics safety Asst. Prof. Panya Kansuwan, King Mongkut's Institute of Technology Ladkrabang (KMITL)
11:35-12:00	**Presentation 6:** Current activity of ISO/TC269/SC1 “Infrastructure” Ryuichi Yamamoto, RTRI
12:00-13:00	Lunch
13:00-14:00	**Presentation 7:** Technical cooperation with NSTDA and RTRI Toru Miyauchi, RTRI
14:30-16:30	NSTDA Lab Visit
18:00-20:00	Dinner

Railway Technology Forum

Dr. Asira Fuongfuchat of NSTDA (Left) and Dr. Toru Miyauchi of RTRI (Right) exchanging gifts

The Railway Technical Research Institute established the Railway International Standards Center (RISC) and has been promoting development of international standards for railway technologies together with member organizations of RISC.

The International Electrotechnical Commission (IEC) has issued the Japan-led international standard "IEC 62973-5 applied to lithium-ion batteries for auxiliary power supply systems used on rolling stock". RISC will continue to develop international standards for the technologies in which Japan has technical expertise.

Japan-Led International Standard on Lithium-Ion Batteries for Auxiliary Power Supply Systems Used on Rolling Stock Issued

Background

To run rolling stock on electric power, two circuit systems are required: the main circuit and the auxiliary circuit (auxiliary power supply system). The main circuit supplies electric power to the traction motors (motors), and the auxiliary power supply system operates the equipment that controls the main circuit, and lighting and door systems. For the auxiliary circuit, a battery is used to supply the power taken from the vehicle to the equipment, and nickel-cadmium and lead-acid batteries have been used so far.

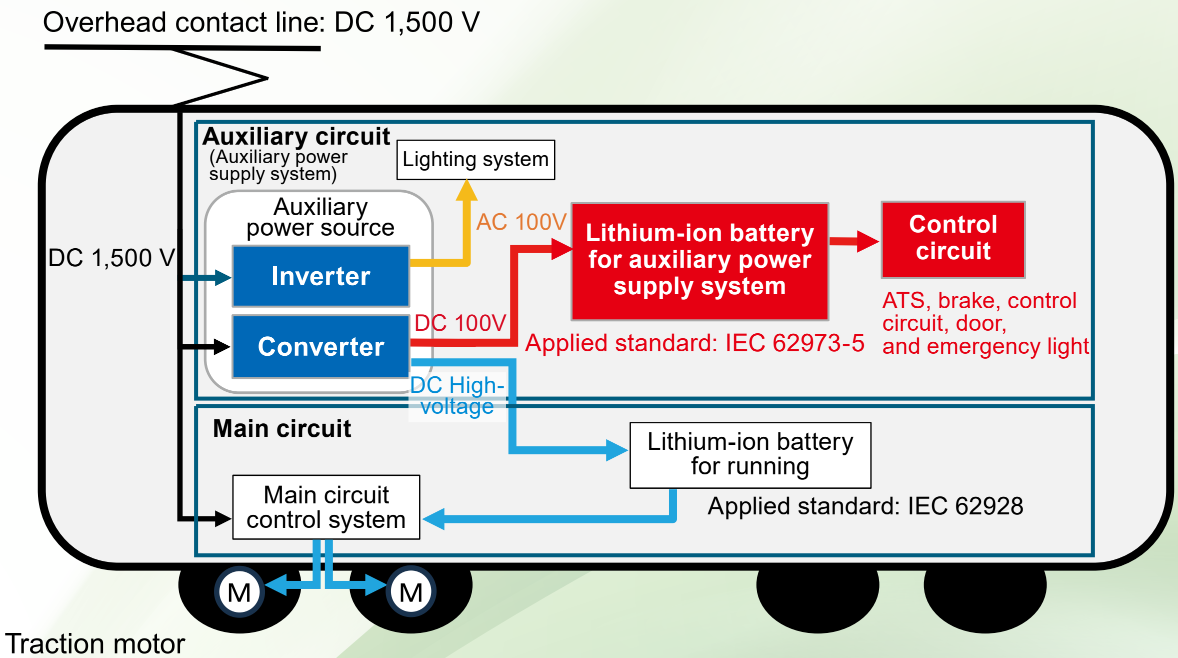
Meanwhile, in the main circuit, lithium-ion batteries with compact and high-capacity features are used as running batteries, instead of nickel-cadmium batteries. In hybrid vehicles that run on electricity incorporated into the vehicle and battery power, lithium-ion batteries have been introduced in recent years. As for a lithium-ion batteries used in the main circuit, the international standard "IEC 62928 applied to onboard lithium-ion batteries" was published in 2017, which was initiated by Japan and reflects Japanese technology.

The batteries used for the auxiliary power supply system were also expected to be lithium-ion. However, since no international standards existed for the batteries, it was hoped that an international standard would be issued that reflected Japanese technology.

History

(1) In October 2018, Germany proposed the international standardization of IEC 62973-5 in the 58th IEC TC 9 Plenary Meeting. Under the initiative of Japan as the project leader, the Ad Hoc Group 25 (AHG 25) was organized to discuss standardization themes.

(2) In October 2019, the 59th IEC TC 9 Plenary Meeting decided on starting votes for the New Work Item Proposal (NP).



Reference: Example of how lithium-ion batteries work in rolling stock (Example of a Direct Current (DC) hybrid vehicle).

(3) In March 2020, the result of the voting was approval of the NP, and PT 62973-5 was launched.

(4) On August 30, 2023, "IEC 62973-5: railway applications—rolling stock—batteries for auxiliary power supply systems—part 5: lithium-ion batteries" was issued .

Short description of international standard IEC 62973-5: "Railway applications—rolling stock— batteries for auxiliary power supply systems—part 5: lithium-ion batteries"

This standard defines the following provisions specific to lithium-ion batteries:

- **Terms and definitions**
  Among terms specific to lithium-ion batteries, "lithium-ion battery cell" and "rated battery capacity of lithium-ion batteries" are defined.
- **Management systems of battery chargers**
  Battery management systems for lithium-ion batteries, including overcharge and over-discharge protection and temperature management systems, are specified.
- **Handling regulations (for transport and storage)**
  Requirements for charging conditions during transport and storage of lithium-ion batteries are specified.
- **Testing methods**
  As lithium-ion batteries have a specific (flammable) electrolytic solution, in addition to common electrical performance testing, shock-and-vibration-resistance tests are also specified.

The establishment of this international standard will be helpful to create an environment where economic benefit due to compact, high-capacity lithium batteries is expected, and developed in Japan.

Group Photo

Land Transport Authority, MTR Corporation Ltd. and RTRI Co-Host Information Exchange

The Railway Technical Research Institute (RTRI), the Land Transport Authority (LTA), and the MTR Corporation Ltd. (MTR) held an information exchange forum online on December 7, 2023. The forum was attended by 18 people from the RTRI, including Dr. Atsushi Furukawa, Executive Director of the Railway Technical Research Institute, 47 people from the LTA, including Mr. Leong Kwok Weng, Chief Engineer (Systems), and 48 people from the MTR, including Ms. Sha Wong, Head of E&M Engineering.

1. Date: December 7, 2023, from 14:00 to 18:30 (JST)

2. Videoconferencing tool: Microsoft Teams

3. Organizer: MTR

4. Theme: Digitalization, Innovation and Sustainability

5. Background and Overview of the Forum

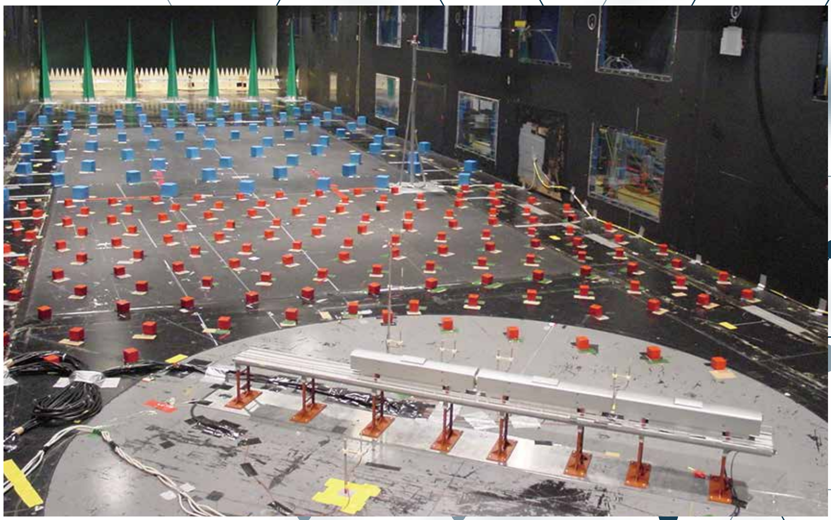
RTRI, LTA, and MTR had hosted face-to-face information exchange forums on a rotating basis by each of the three parties since 2017 to strengthen partnership with Asian countries and

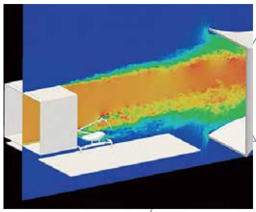
Presentation and Speaker

Time	Presentation	Speaker
14:00-14:15	Opening Remarks From Each Organization	Sha Wong (MTR), Leong Kwok Weng (LTA), Toru Miyauchi (RTRI)
14:15-14:40	Technical Study of Adopting Catenary Free Low-Floor LRV in MTR	Ken Fan (MTR)
14:40-15:05	Our Journey in Exploring Alternative Medium Capacity Transit Systems	Rico Chan (MTR)
15:05-15:30	Health Condition Monitoring and Maintenance Regime for Escalators	Edmond Yeung (MTR)
15:30-15:40	Break	
15:40-16:05	Singapore's Sustainability Journey in Rail E&M (Electrical and Mechanical)	Wang Wei Jun, John Yang, Jamie Lim, Eric Wong (LTA)
16:05-16:30	Sustainability Efforts in Planning, Design and Constructions -LTA's Experience	Lee Hoen May, Kelvin Goh, Samuel Teo (LTA)
16:30-16:55	Cutting-Edge Technologies for Railway Infrastructure Maintenance and Renewal	Chan Kim Hoong (LTA)
16:55-17:05	Break	
17:05-17:30	The Current Status of the Development of Decarbonization Technology for Railway Systems in Japan	Hitoshi Hasegawa (RTRI)
17:30-17:55	Development of International Standards for Ground-Borne Vibration and Ground-Borne Noise From Railway Systems	Kiwamu Tsuno (RTRI)
17:55-18:20	Track Geometry Monitoring and Management Systems in Japan	Daiki Saito (RTRI)
18:20-18:30	Closing Remarks	Sha Wong (MTR)

promote the transfer of Japanese railway technologies abroad. The most recent face-to-face opportunity was on October 31, 2019, when the 12th World Congress on Railway Research, WCRR 2019 was held in Tokyo. Thereafter, under travel restrictions imposed by the pandemic, we continued annual information exchange online.

Even with the pandemic subsiding over time, taking into account country-specific conditions, and just to be safe, we had an information exchange forum online in 2023 similarly to the previous year. RTRI, LTA, and MTR each gave three presentations (see Table below). Each presentation was followed by lively and informative discussions with many questions and answers.





Railway Technical Research Institute