ANNUAL REPORT 2019-2020

For the year ended March 31, 2020

Railway Technical Research Institute

Foreword

Ikuo WATANABE
President of the Railway Technical Research Institute

I became president of RTRI on June 12, 2020. The year 2020 is marked as a major turning point for RTRI. This year, RTRI started to implement the new master plan "RESEARCH 2025" and our society and railways have been facing unprecedented difficulties caused by the increasingly serious Covid-19 pandemic.

Assuming the office of president in this time of difficulty, I have recognized the heavy responsibilities and renewed my determination to fulfill the tasks. Based upon the Vision of RTRI established by the former president, Dr. Norimichi Kumagai, I will set the direction in research activities and other businesses at RTRI to the best of my ability in order to create research results of higher quality.

Here we have published ***ANNUAL REPORT 2019-2020*** which covers all the activities at RTRI. In fiscal 2019, the final year of our previous master plan "RESEARCH 2020", 275 research and development projects were implemented in three categories, "R&D for the future of railways", "Development of practical technologies" "Basic researches for railways", and the master plan was completed.

We have also steadily pursued other business activities in order to achieve the goals under the master plan. We hosted the 12th congress of the World Congress on Railway Research (WCRR 2019) in Japan, 20 years after WCRR '99 which was also held in Tokyo. We promoted international activities including collaborative research with overseas academic institutions and railway operators and efforts of proposing and reviewing drafts of international railway standards. At the time of natural disasters such as East Japan Typhoon, RTRI actively supported the investigations and recovery work for damaged railway facilities.

The year 2019 was also marked with our 60th anniversary of the opening of Kunitachi headquarters in the current location. In commemoration of the anniversary, a new test building was completed and the construction of large-scale testing facilities were continued in order to enable more efficient testing and research for the future.

We also developed the new master plan "RESEARCH 2025" for the next 30 years of railway development to promote even more productive research activities. In the meantime, we had to cancel some of our planned research and business activities or carry them out in a smaller scale or in a different way. We have introduced a new working styles for employees including teleworking as well in order to adapt to the rapidly-advancing social changes caused by the pandemic.

As I wrote earlier, since railways are facing the rapidly changing social and economic environment, they have to pursue desirable work-and-life balance and to adapt new working styles. Under these circumstances, we will continue the research to further develop railways and to attain the sustainable society, making full use of our research potentials and enthusiasm as an institute which covers wide-ranging railway technical fields comprehensively. Through our efforts in the years ahead, continued support and advice from all the rail-related people would be greatly appreciated.

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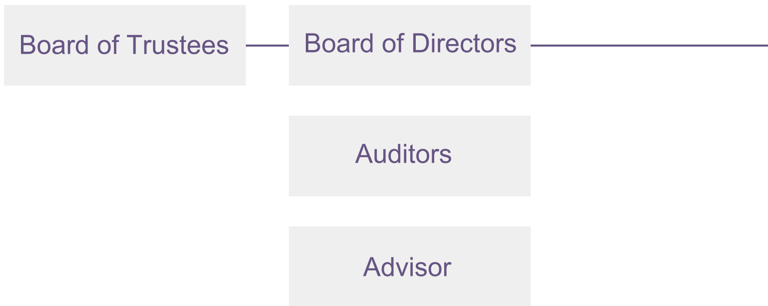
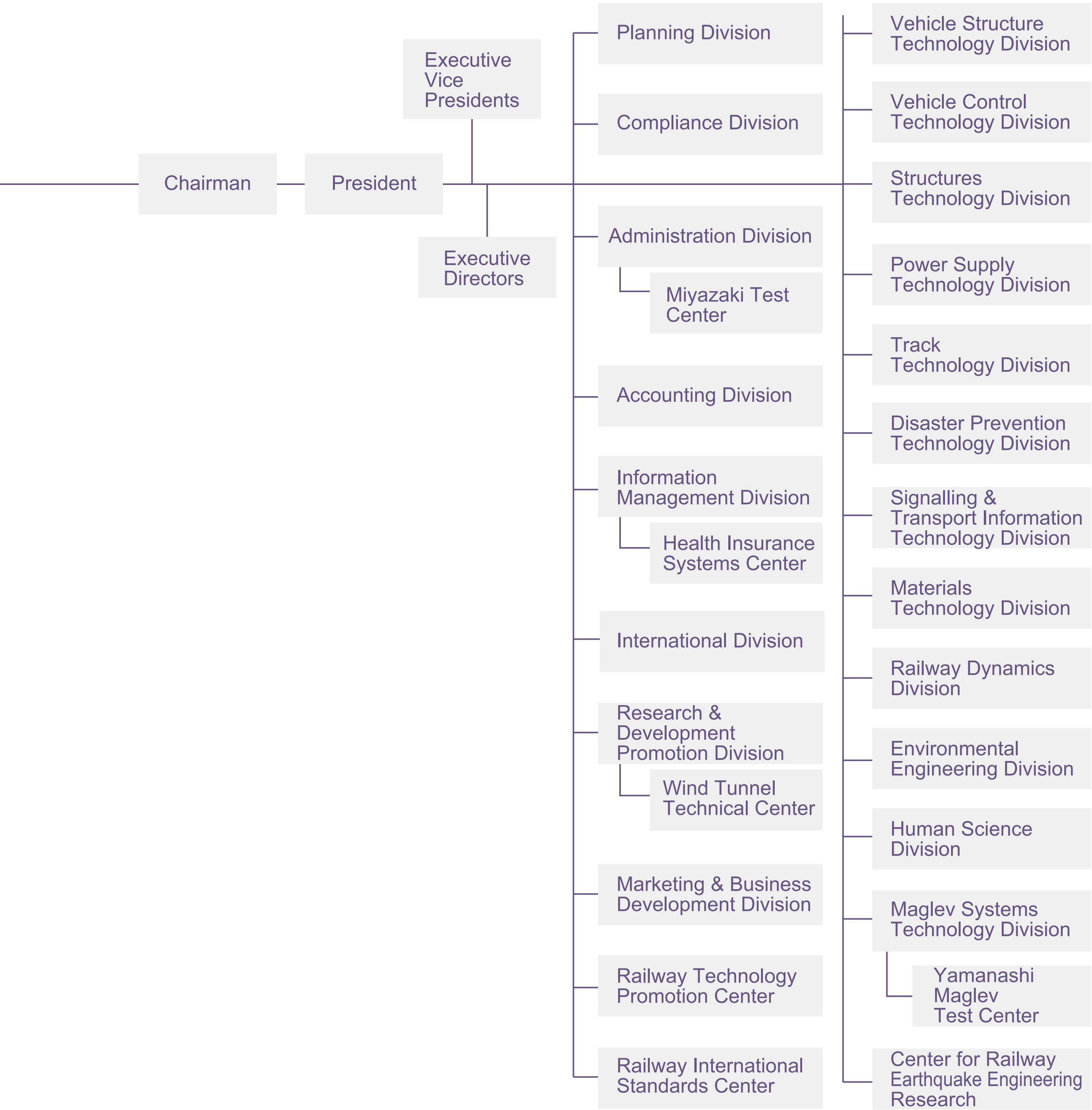
Organization





(As of April 1, 2020)

Major Results of Research and Development

IMPROVEMENT OF SAFETY

1. A blinking light detection method for obstruction warning signals by image processing

- We have developed a blinking light detection method for obstruction warning signals to support a driver.
- The method enables the blinking light of obstruction warning signals to detect at distances of up to 600 meters.
- The method uses a high-speed pattern matching algorithm to enable real-time detection

An obstruction warning signal notifies drivers of an abnormality along a railway track using a blinking light interlocked with the emergency button at a level crossing. Since drivers need to visually check the blinking light and operate the brake to stop the train on most railway routes, there exists the risk of overlooking an obstruction warning signal. Therefore, we have developed a method to detect a blinking-type obstruction warning signal's blinking light using an on-board camera to improve safety (Fig. 1).

In the developed method, an on-board camera fitted with an optical filter is used to capture images in front of the train and detect only the blinking light of obstruction warning signals by processing the captured images. To enable the rapid distinction of obstruction warning signals from other red blinking lights such as traffic signals, the obstruction warning signal's light-emitting pattern captured on the images is binarized to one of two values: 1 or 0. And the string of this repeated 1s or 0s is converted into a binary number. By matching the values with data in a database containing the pre-registered light-emitting patterns of obstruction warning signals converted into numerals, higher-speed detection is possible compared with the method based on frequency analysis of the blinked period (Fig. 2). A trial conducted on a test track at the Railway Technical Research Institute confirmed that we achieved a better than 85% accuracy in detection at a distance equivalent to 600 meters, and the detection time from the start of light emission was less than 1 second (Fig. 3).

We developed this method as a crucial element of front-monitoring technology using a camera. Since it uses a camera to detect the blinking light, storing the information as a video is possible. Furthermore, it is also applicable to other purposes.

Fig. 1: System notifying the driver

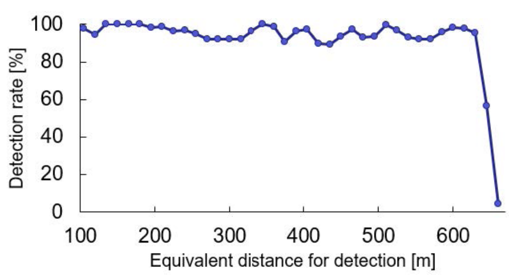


Fig. 3: Detection rate by distance

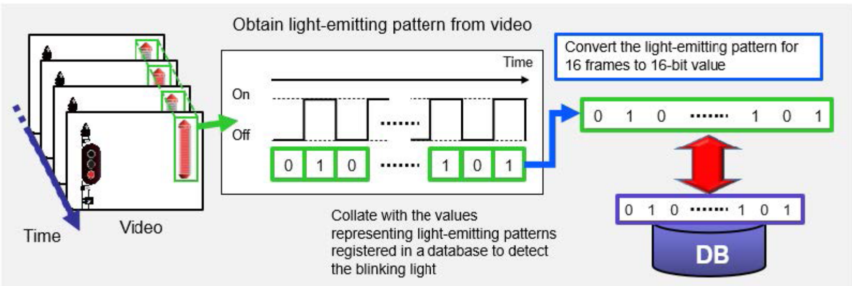


Fig. 2: Algorithm to detect a blinking light from the video

2. Crashworthiness evaluation index for carbody structure in railway accidents at level crossings

- An integrated deceleration value has been proposed as a crashworthiness evaluation index for carbody structures contributing to a reduction of injuries to passengers during accidents.
- It was confirmed that the correlation coefficient between the proposed index and the seriousness of injury was higher than that of American and European indices.

No index to evaluate crashworthiness is clearly indicated in the design standards for carbody structures in Japan. On the other hand, although evaluation indices are specified in Western countries, the accident proneness and the design specifications for carbody strength and interior facilities such as seat structures are different from Japan. Therefore, an evaluation index conforming to the actual situations in Japan and having a high correlation with the seriousness of passenger injury has been proposed, by collision analysis performed for accidents at level crossings under various conditions, based on the accident statistics and vehicle specifications in Japan.

How seriously seated passengers would be injured during a collision of a train with a large dump truck (vehicle weight: 11 tons, shipping weight: 0 to 13.75 tons) was estimated by analysis using a train model and a dump truck model (Fig. 1). The accuracy of analysis for these models was verified by collision tests. The analytical parameters set were: train speed, position and angle of collision, and total weight of dump truck; and the analysis objects were the passengers seated on rotary cross seats (cross-seat passengers). The correlation coefficient between the degree of injury estimated under each condition and the integrated value of impact deceleration occurring on the carbody (Fig. 2, referred to the integrated deceleration value) was 0.95 (Fig. 3), which indicated a higher correlation than the maximum value of impact deceleration comform to the American index (correlation coefficient 0.90) and the average value of impact deceleration conform to the European index (correlation coefficient 0.81) (Fig. 4). From the above, the integrated deceleration value was proposed as an evaluation index in Japan.

This will contribute to a reduction of injuries to passengers by applying the proposed evaluation index to the deceleration wave form on the carbody obtained by collision analysis during carbody design.

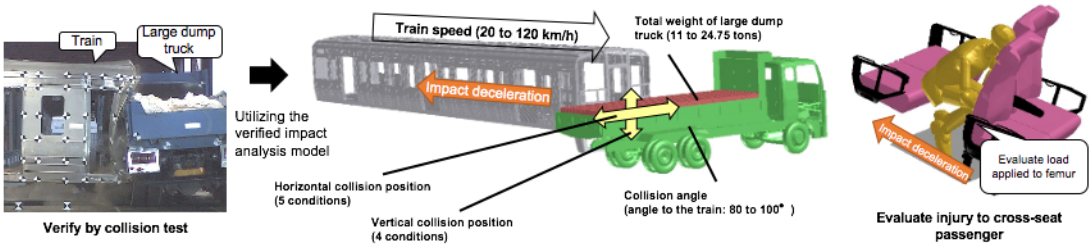


Fig. 1: Collision analysis under various collision conditions

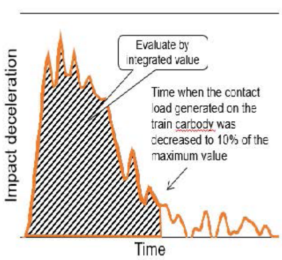


Fig. 2: Integrated value of impact deceleration (Shaded area, corresponding to the relative velocity of the passenger to the carbody)

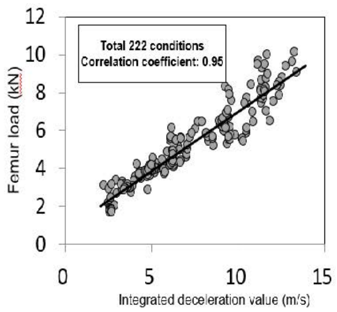


Fig. 3: Comparison of integrated deceleration value and degree of injury

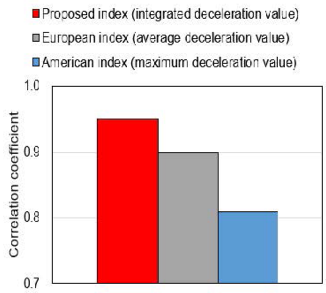


Fig. 4: Correlation coefficient between each index and the degree of injury

3. Prevention of pedestrian entry while a level crossing warning is sounding by means of a voice message and changing the timing of crossing gate closing

- A voice message and a method of controlling level crossing rods that has proved effective in preventing pedestrians from traversing a crossing immediately before a passing train have been proposed.
- Experiments were conducted to confirm that traversing the track by pedestrians immediately before a train passed through was reduced by 25% by adding a voice message to the warning sound and by 64% by starting to close the level crossing gates earlier.

A survey of 2,435 pedestrians using level crossings was conducted with the aim of reducing level crossing accidents and the result showed that 61% 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 “No entry.” Therefore, adding a voice message to promote a clear understanding of the intended meaning of the level crossing warning and starting to descend the crossing rods earlier without changing the time to complete their descending were proposed as measures to prevent pedestrians from entering the level crossing while the warning was sounding.

A voice message, which is expected to be effective in communicating the dangerous situation and instruct pedestrians not to enter the level crossing, was selected from several options with different message contents and speaking speeds in advance, and an experiment to simulate pedestrians traversing a level crossing was conducted to verify its effectiveness (Fig. 1). It was confirmed that the number of pedestrians who entered the crossing while the warning was sounding was reduced by 25% compared to the current rate (Fig. 2). It was also confirmed that by starting to close the level crossing rods earlier, which visually communicated “No entry,” the number of pedestrians who entered the level crossing during the warning was sounding was reduced by 64% compared to the current rate (Fig. 3).

Thus, it can be expected that the number of level crossing accidents can be reduced by reducing the number of pedestrians who enter the level crossing while the warning is sounding with these methods of presenting visual and auditory information.

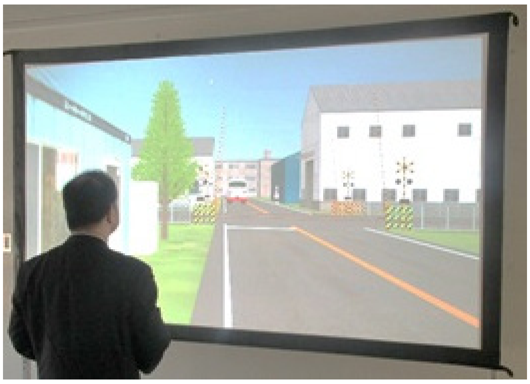


Fig. 1: Simulator experiment

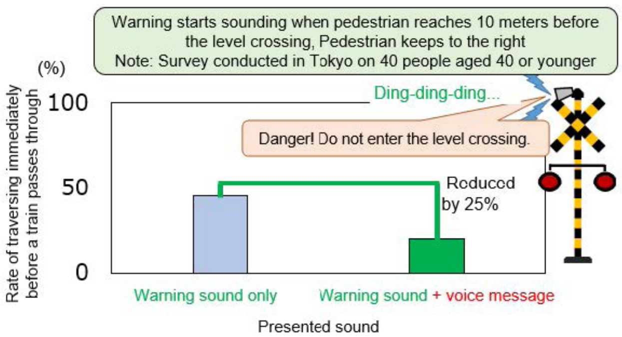
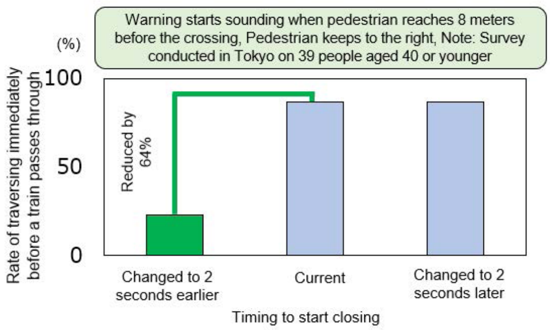


Fig. 2: Effect of auditory information



Note: Timing for "Current" is set to 4 seconds, as it is the standard for crossing two railway tracks

Fig. 3: Effect of changing the timing to start closing

4. Method of identifying resonant bridges by on-board measurement

- A method of using on-board measurement to identify resonant bridges in which significant vibration is generated when a train passes over them has been developed.
- As no in-situ measurement is required, resonant bridges can be identified quickly along the entire route.

Due to the increase in the speed of trains and a deterioration of bridges, the number of bridges that are affected by significant vibrations generated when a train passes over them (referred to as “resonant bridges”) is increasing and the impact on riding quality and utilities are matters of concern. As some sort of action is required if the vibration is especially intense, it is necessary to identify resonant bridges. However, to do so, previously a huge number of bridges had to be measured from the ground to check the deflection, which was very inefficient. Therefore, a method to identify resonant bridges by on-board measurement data without in-situ measurements has been developed.

The issue in making such identifications by on-board measurement was to separate the vibration of the bridge from other components such as track irregularities. The focus in developing the on-board method was placed on the fact that there is a vibrational component unique for resonant bridges, which becomes prominent only when the tail vehicle has passed over the bridge. In addition to filtering and enveloping processes to emphasize this vibrational component, a process to differentiate the lead and the tail vehicles was performed to extract only the vibrational component of the bridge, which made it possible to identify resonant bridges (Fig. 1). Not only data on the car-body vertical acceleration for management of riding comfort, but also the track irregularity data measured by inertial mid-chord offset track measurement devices can be used for this method. It was verified that resonant bridges could be identified on the track maintenance database system (LABOCS) using the proposed method by comparing the results of application on actual high-speed railway routes and in-situ measurements of deflection (Fig. 2).

This method is applicable for determining the existence of resonant bridges to permit speed improvements of Shinkansen, as well as for screening overhead contact line facilities that are easily damaged by large vibrations generated on resonant bridges.

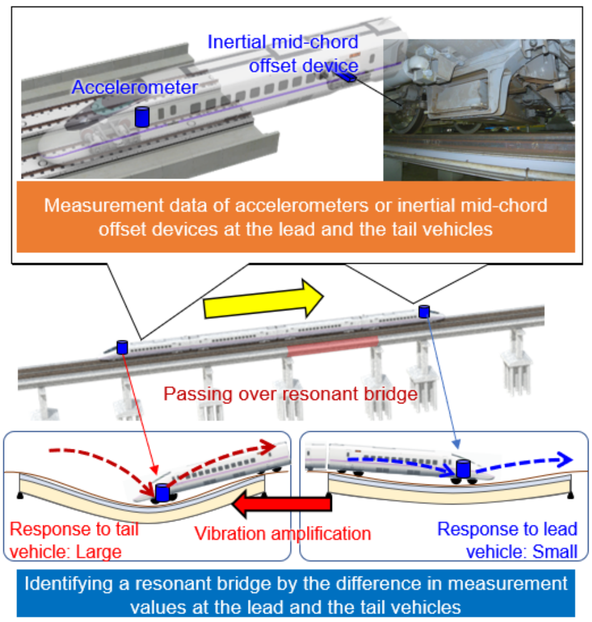


Fig. 1: Method to detect resonant bridges using the difference in measurement values at the lead and the tail vehicles

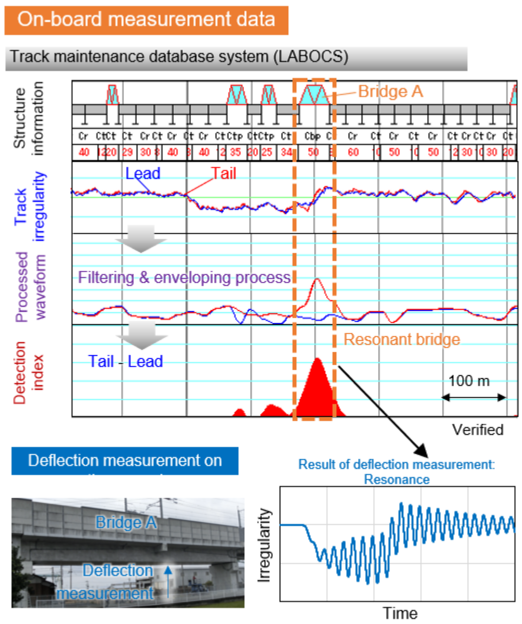


Fig. 2: Example of identifying resonant bridges by on-board measurement

5. Detection by displacement sensor of damage to bridge bearing parts after earthquake

- A method to determine whether to resume operation after an earthquake taking the amount of slip-out of rubber bearing and train speed has been proposed.
- To minimize a time for inspections after an earthquake, displacement sensor system to remotely detect slip-out amount has been developed.

When an earthquake occurs and the seismic intensity exceeds the regulation value specified by the railway operator, a visual inspection is required to check that there are no abnormalities in structures. However, a lot of labor and time is needed to inspect the bearings in high and narrow places at bridges, and furthermore, no clear criterion for the damage to bearings had been established for the resumption of operation. Therefore, an analysis was conducted to clarify the allowable slip-out amount of rubbers from rubber bearings after an earthquake relative to train speed, and a displacement sensor that made it possible to remotely detect the slip-out amount was developed.

In the development process, first the actual damage reported after an earthquake was investigated, targeting the rubber bearings installed on railway bridges and viaducts. It became clear that the slip-out of rubber bearings had an impact on running safety and the restorability of bearings and should be monitored by sensors. By using these slipped-out amounts and running speed as parameters for analysis, the allowable value of slip-out to satisfy the thresholds for running safety and restorability of bearings was calculated. Finally, a method to determine whether to resume operation according to the amount of slip-out displacement and train speed was proposed. For example, if the slip-out rate α is 30%, it is considered possible for trains to run at speeds of up to 80 km/h (Fig. 1).

In addition, displacement sensor system that makes it possible to remotely detect the slip-out amount quickly after an earthquake was also developed (Fig. 2). The amount of damage can be ascertained easily from a remote place without physically having to observe it close up, by measuring the slip-out amount and transferring the measurement data to a network server.

This system enables detection of damage to bearings and an early determination to be made as to whether to resume operation, serving to speed up inspections after an earthquake and support early resumption of operation.

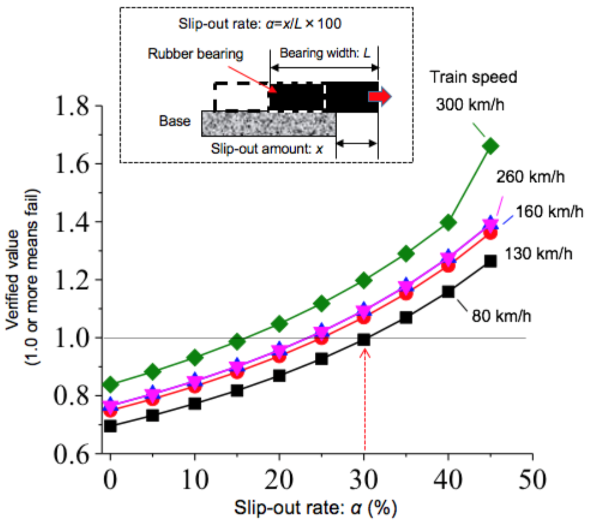


Fig. 1 Allowable slip-out rate relative to train speed

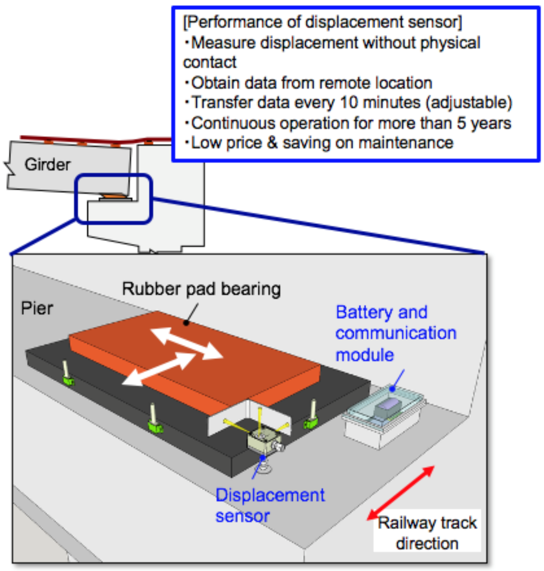


Fig. 2 Development of displacement sensor system enabling remote detection of damage to bearings

6. Seismic retrofitting method at bridge connections

- A seismic retrofitting method has been developed for the connection of bridges to support girders having different heights.
- It has been confirmed that proof strength is improved to 1.5 times better than that prior to reinforcement.

In an earthquake that occurred recently, there was a case reported in which the connecting parts of bridges used to support girders having different heights were damaged due to the buckling of reinforcing bars, requiring a long restoration period. (Fig. 1). When such connecting parts need to be reinforced, cross girders and bearings become obstacles and make it difficult to install anchors to girder joint gaps and steel plate lining, like on pillars. However, no effective reinforcing construction method has been established. Therefore, a seismic retrofitting method has been developed that uses prestressing bars, steel plates and post-construction anchors to eliminate the requirement of installing reinforcement materials at girder joint gaps (Fig. 2).

This method uses prestressing bars to improve the bending proof strength against the inertia force to the right, as shown in Fig. 2, and steel plates to improve the bending proof strength against the inertia force to the left, as shown in Fig. 2. Shear capacity can be improved by post-construction anchors.

By means of a loading test, it was confirmed that a part that was shear-fractured before reinforcement was not fractured after reinforcement, and the bending proof strength at the connection was improved 1.5 times compared to before reinforcement (Fig. 3).

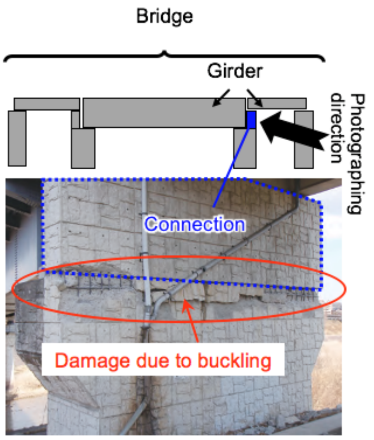


Fig.1 Damaged case

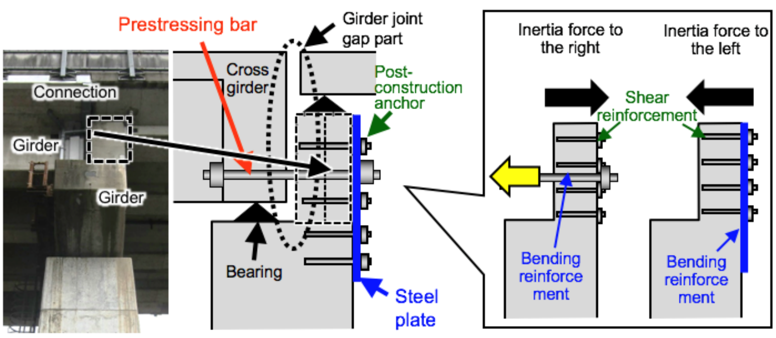


Fig. 2 Outline of seismic retrofitting method

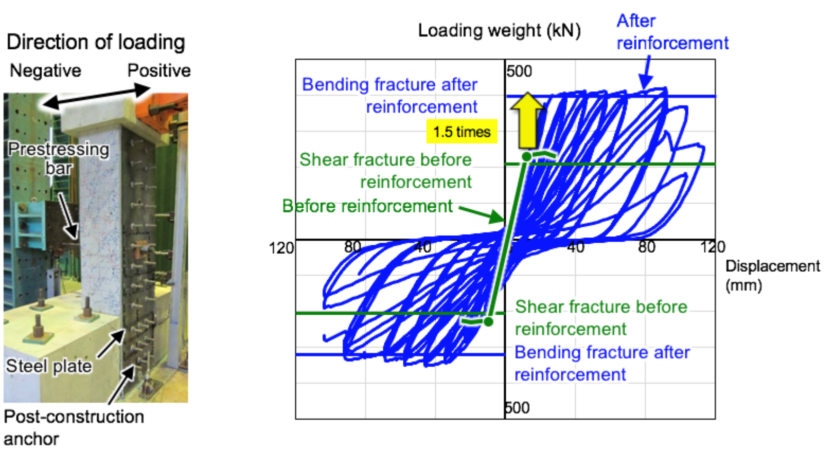


Fig. 3 Effect of reinforcement for proof strength improvement

7. Method to detect DC high-resistance ground fault accompanied by high current arc

- A method to detect a DC high-resistance ground fault with high current atmospheric arc discharge more than 1,000 amperes, within around 5 seconds, has been developed.
- The method uses only monitoring of feeding current at substation and does not require any additional trackside installations such as protective wires and discharging devices.

A method has been developed to determine the stability of slopes during snowmelt season using the amount of snowmelt as an index.

In the existing method, the maximum amount of snowmelt in the area is used as a threshold for determining that slope stability has declined. However, in past geo-disasters, there have been cases where it was not possible to determine whether slope stability had declined. Therefore, a method has been proposed to determine slope stability using two indicators: the snowmelt volume and snow depth.

The new method uses observation data from AMeDAS and public geographical data in the vicinity of the target point to estimate the amount of snowmelt and snow depth in order to determine slope stability. Using AMeDAS data, past snowmelt volumes for each snow depth are then calculated and then set as threshold values. By comparing the threshold values with actual snowmelt volumes and snow depth calculated on the basis of AMeDAS data updated on an hourly basis, it is possible to determine the slope stability (Fig. 1). Taking past geo-disasters as a reference, the ratios of successfully detected deteriorated slopes (disaster detection rate) using the existing and newly developed methods were compared. The results of the comparison confirmed that even though results in both systems were the same in terms of the time in which the amount of snowmelt exceeded the threshold value, the newly developed method's disaster detection rate was approximately 20% higher than the existing method (Fig. 2).

Given that the new method only uses publicly available data and information, it allows the stability of any slope to be examined, without the need to install a new network of observation equipment. In addition, the system is designed so that if the system is used in an environment with internet access, the user can obtain a visual display of the slope stability result in any location, as shown in Fig. 1.

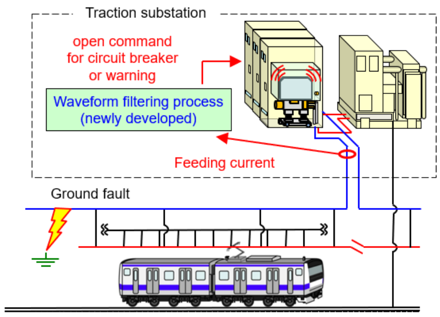


Fig. 1 Image showing application of fault detection system

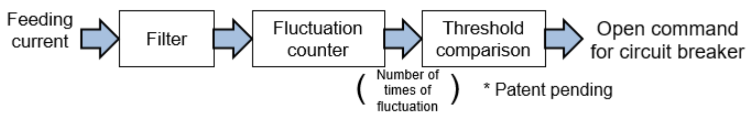


Fig. 2 Waveform processing algorithm

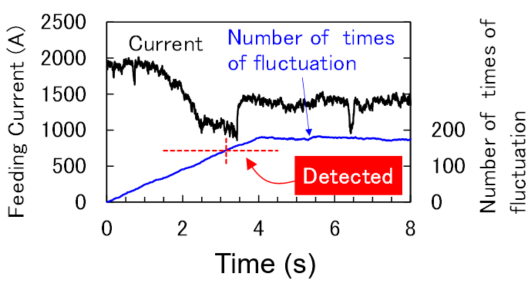


Fig. 3 Feeding circuit current during a failure and number of times of fluctuation by proposed method

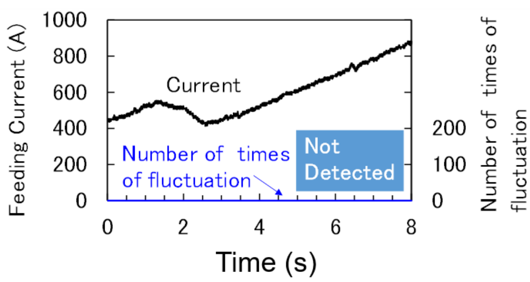


Fig. 4 Normal feeding circuit current and number of times of fluctuation by proposed method

8. Compound Catenary for preventing break of contact wires at insulated overlaps

- A compound catenary, with attached an additional wire by using clamp on a contact wire of simple catenary, was developed to prevent the break of the contact wire at insulated overlaps.
- Through field test, it was confirmed that excessive contact loss and excessive wear of contact wires were not occurred.

Trains must be stopped when an emergency stop button is pressed or another emergency warning is issued. If the train stops at insulated overlaps (Air Section (AS) in Japanese) where two overhead contact lines from different power supply systems are laid in parallel, an arc may be generated between the pantograph contact strip and the contact wire and causes a break of the contact wire. Several hardware measures had been proposed to prevent such problems, but all of them had issues such as high cost and difficulty in maintenance.

Therefore, a compound catenary for preventing break of the contact wire (named AS compound catenary) was developed for a simple catenary of conventional lines. With an AS compound catenary, even though the contact wire is extended due to the heat of the arc that is generated between the pantograph contact strip and the contact wire, the contact wire is lowered because of the transmission of the tension from the contact wire to the additional wire. As a result, the contact wire contacts with the pantograph contact strip to extinguish the arc (Fig. 1).

An AS compound catenary has a simple structure in which an additional wire is attached 50 mm above the contact wire by using clamp at intervals of 500 mm (Fig. 2). Since it is possible to measure the diameter of contact wire by an inspection car in the same way as a general catenary, low cost and labor saving for maintenance can be achieved.

It is necessary to evaluate the current collection performance of an AS compound catenary on account of increase of the mass of an AS compound catenary compared to a simple catenary. As a result of evaluation current collection performance of an AS compound catenary in a commercial line, it was confirmed that excessive contact loss and excessive wear of contact wires were not occurred (Fig. 3).

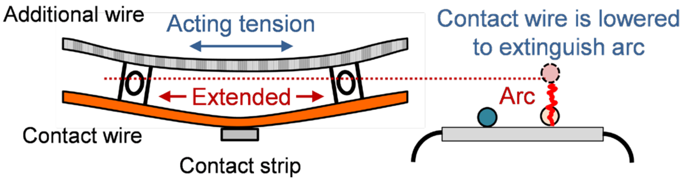


Fig. 1 Arc extinction with AS compound catenary

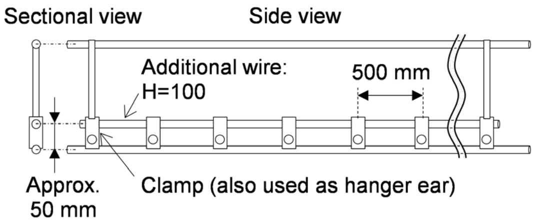


Fig. 2: Structure of AS compound catenary

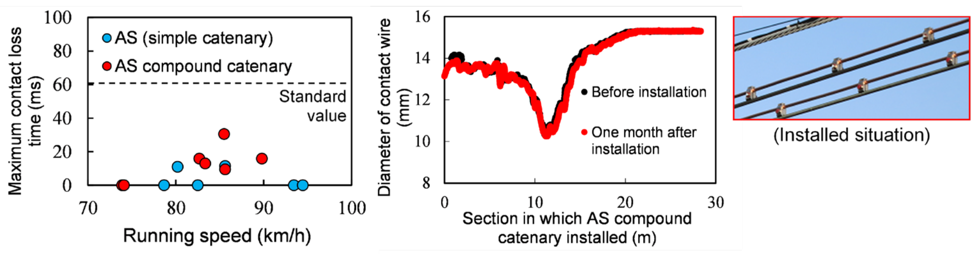


Fig. 3 Field test result in a commercial line

9. Low-cost and labor-saving lubricating oil analyzerfor driving equipments

- A lubricating oil analyzer has been developed to enable the measurement of the concentration of iron powder in oil for driving equipments in a short time, which reduces the cost of doing so to less than one-fifth that of conventional methods.
- As it is compact and easy to use, it is possible to diagnose the condition of equipment by analyzing the concentration of iron powder in oil in the immediate vicinity of the vehicle.

Optical emission spectrometers are currently used to analyze the concentration of iron powder mixed in with oil, as a measure to detect signs of abnormal wear and seizure occurring inside driving equipments such as engines and to prevent damage to equipment on commercial lines. However, current analyzers are large and expensive, and require skill acquisition to use them and for data analysis, so that places where such devices can be installed are limited to base factories and other large facilities. For that reason, in practice, collected oil samples need to be transported to a dedicated place for analysis, resulting in the problem of a longer time being required to obtain the analysis results.

Therefore, an oil analyzer that is easy to use and that can diagnose equipment conditions at vehicle maintenance sites has been developed (Fig. 1, Fig. 2). This analyzer is equipped with a sensor capable of electrically analyzing the iron powder concentration in oil by flowingg the oil through an internal coil. The accuracy of abnormality determination with this sensor is equal to or better than that of the conventional method using optical emission spectrometry. The structure of the analyzer has been designed to allow easy installation in the vicinity of vehicles, while the oil passage inside the analyzer has been shortened to downsize and shorten the analysis time, taking usage at inspection and repair sites into consideration.

With this analyzer, analysis of the iron powder concentration in oil can be completed in about 20 minutes in the vicinity of the vehicle without the need to place a sample of the oil in a container, leading to a significant reduction of analysis time compared to the conventional method (Fig. 3). In addition, the analyzer price is less than one-fifth of a conventional optical emission spectrometer. Moreover, as this sensor can be mounted on equipment for vehicles, it is expected to be used for monitoring the iron powder concentration in oil in real time in future.

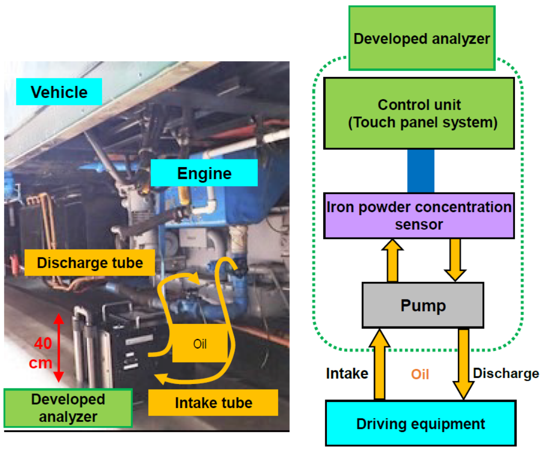


Fig. 1 Developed lubricant analysis device and its structure

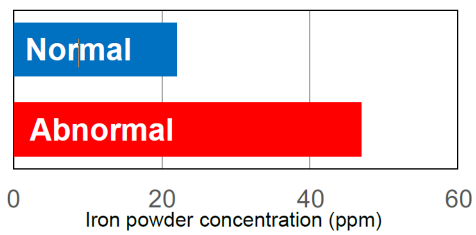


Fig. 2 Example of analysis using this analyzer

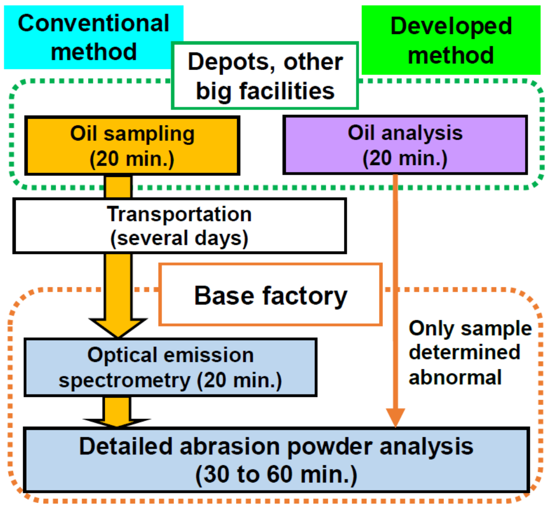


Fig.3 Comparison of analysis procedures with conventional method

10. Method to design and manage ballasted tracks equivalent to an increase in the spacing of sleepers

- A method to design and manage ballasted tracks has been proposed equivalent to an increase in the spacing of sleepers in regional railways.
- The spacing of sleepers can be determined according to the maintenance system in the section.

Some railway operators have started to look at increasing the spacing of sleepers for ballasted tracks as a measure to reduce the cost of railway track maintenance for regional railways. However, since there are concerns regarding the rapid rate of track settlement depending on the track bed and ballast layer conditions, as well as adverse effects on vehicle-running safety due to problems including local unsupported sleepers and rail fastener failures, the establishment of a design method is required. Therefore, a method to design and manage ballasted tracks has been proposed equivalent to an increase in the spacing of sleepers for regional railways.

The following is an outline of this method. (1) Calculate the lateral ballast resistance force corresponding to the increased spacing of sleepers as well as the track settlement amount under the condition of ballast mixed with fine-grained soil. (2) Calculate the effect of the rail fastening system design according to common usage conditions and examine the strength of the members. (3) Use the newly developed unsupported sleeper detection method (a method to detect unsupported sleepers by calculating the values from track irregularity data and track specifications) and determine the control index to secure running safety. The procedures above enable the calculation of the optimum spacing of sleepers possible to maintain running safety according to the maintenance system of each section including the level and frequency of track maintenance and patrol frequency.

Please note that the developed unsupported sleeper detection method is incorporated in the railway track maintenance management database system (LABOCS). The proposed design and management method will be reflected in the design standards.

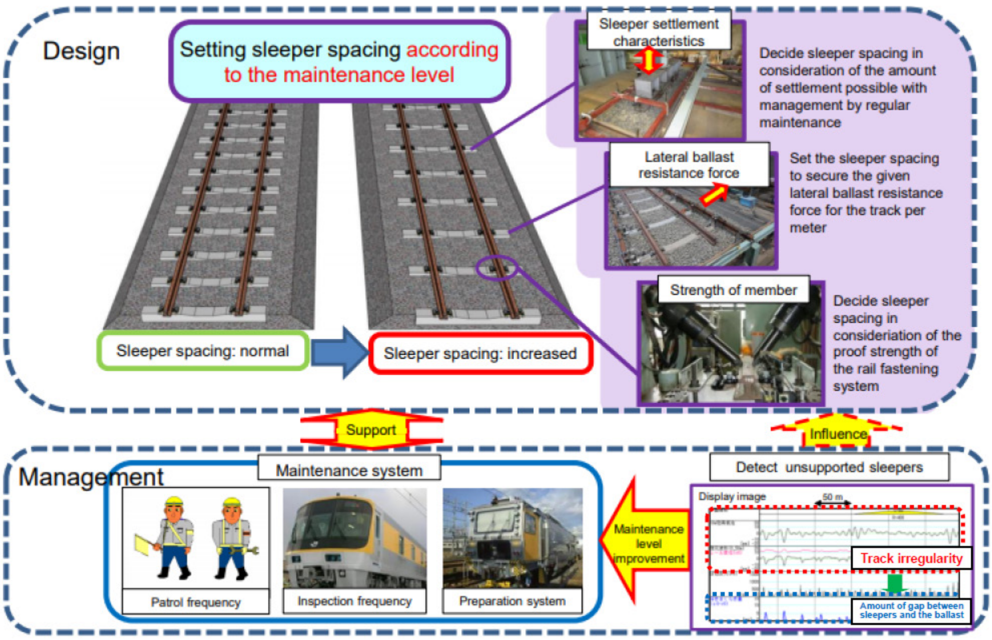


Fig. 1 Outline of method to increase the spacing of sleepers for ballasted tracks

11. Ballast soundness inspection method using sound characteristics

- The factors that cause crushing and refining of ballast have been clarified.
- A method has been developed to evaluate the state of deterioration using sound transmitted through the ballast.
- Inspection costs can be reduced by 70% compared to the conventional method.

Ballast is crushed and ground due to aging, but the factors that cause this have not been clarified fully so far. Therefore, cyclic loading tests assuming the train load, tamping tests using a tie tamper and multiple tie tampers, and impact loading tests assuming the impact load generated on rail joints were conducted to clarify the factors that cause crushing and refining. The results of the tests show that the deterioration of ballast was affected more by tamping than by train load, that manual tie tamper work could generate fine particles, and that grains of a larger particle size could be crushed into fine particles by multiple tie tampers (Fig. 1).

Periodical inspection to evaluate the state of deterioration of ballast is typically done by excavating the ballast to visually examine it; however, there are issues regarding the labor required for excavation as well as discrepancies in evaluations due to the subjective views of the inspectors. Therefore, an inspection method has been developed to evaluate the state of deterioration of ballast quickly and quantitatively by evaluating the loudness of sound transmitted inside the ballast (Fig. 2). Based on a laboratory test and a field test using this method, it was clarified that there was a strong correlation between the rate of fine particle content, which was a major factor in causing mud pumping, and the loudness of the sound transmitted inside the ballast (Fig. 3). The proposed method can reduce inspection cost by 70% compared to the conventional method, as the state of deterioration of ballast can be evaluated in a short time.

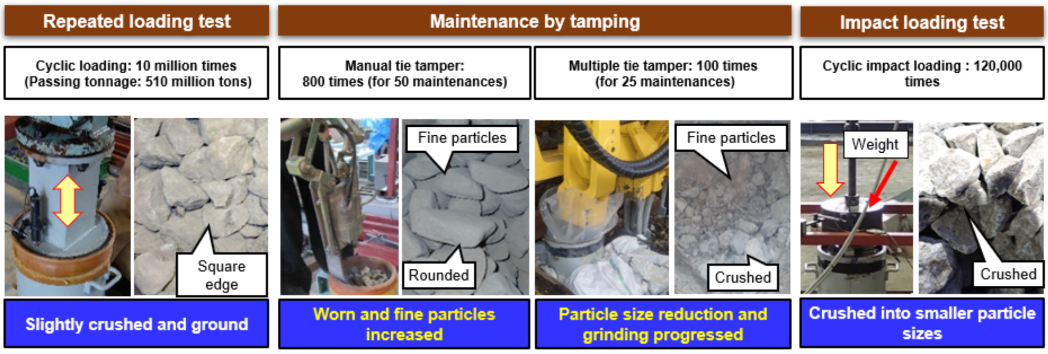


Fig. 1 Factors that cause crushing and refining of ballast

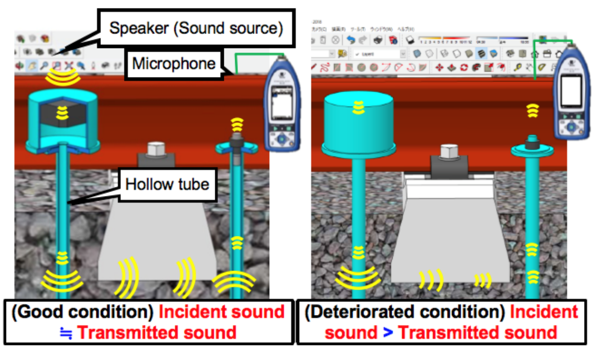


Fig. 2 Inspection of state of deterioration of ballast using transmitted sound

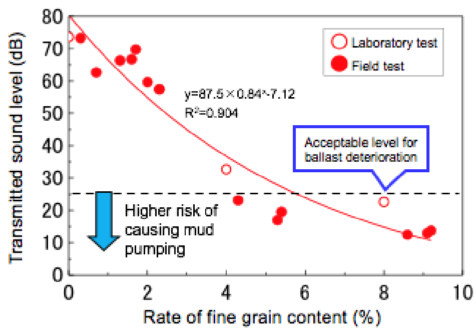


Fig. 3 Relation between rate of fine grain content and transmitted sound

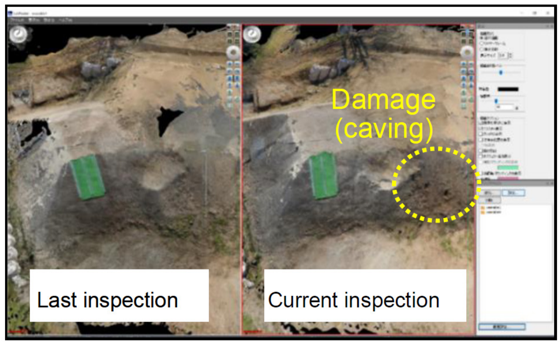
12. Visual inspection support system for structures utilizing 3D images

- A visual inspection support system has been developed to generate three-dimensional images of structures.
- The system can support to detect a damage and evaluate its progress by comparing images from different inspection timings.

During periodic inspection of structures as currently conducted, photographs and inspector's comments are recorded mainly for extracted damages. A system utilizing 3D images has been developed to support visual inspections of structures. By using this system, the condition of a structure and its surroundings can be checked intuitively with 3D images at any time. The 3D images are generated from the 2D images that were taken automatically during visual inspections, using SfM (Structure from Motion) technology (Fig. 1). Typically, images taken from all directions at even intervals are used to generate 3D images. However, in this system, the images are taken by multiple cameras whose positions are adjusted to cover a wide angle and then the needed images are selected automatically, so that 3D image generation can be achieved even when taking images with non-uniform movement during inspection.

This system can also support to detect damages and make a register. Not only does a direct comparison of 3D images taken at different inspection timings make it easy to detect damages (Fig. 2), but also a comparison of cross-sections enables any change in shape to be evaluated quantitatively. In addition, because this system can automatically extract the original images from any points designated in a 3D image and can prepare an inspection register from those images (Fig. 3), it is no longer necessary to spend time organizing and extracting images after an inspection, resulting in a reduced burden of office work.

Fig. 1 Photographing and 3D image generation screen



(RTRI Embankment testing ground)

Fig. 2 Function to compare 3D images from different timings

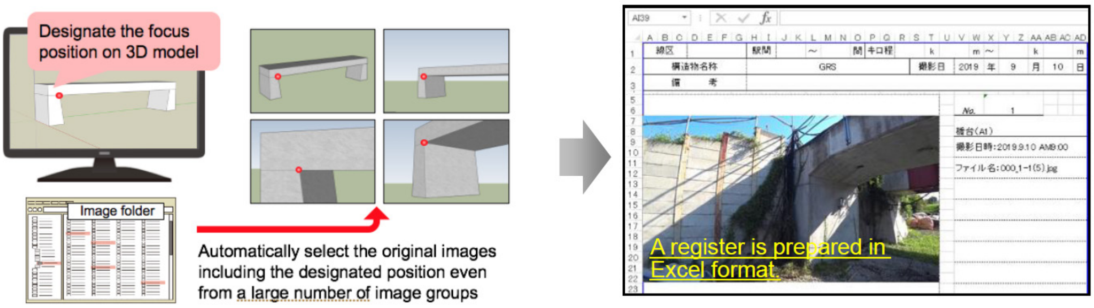


Fig. 3: Function to extract original images and compile an inspection register

13. Antiseismic reinforcement design method for existing embankments by slope protection work and soil reinforcement

- A design method for the antiseismic reinforcement of embankments has been proposed by evaluating the water shielding effect and the joining effect with soil reinforcement installed for slope protection work for existing embankments.
- The cost of reinforcement work can be reduced by 5 to 10% compared to that for an embankment designed using conventional design methods.

Slope protection work is often executed on an embankment as a measure against rainfall. However, the efficiency of slope protection work against earthquakes has not been ascertained yet, and therefore, was not considered at the time of antiseismic reinforcement design.

Accordingly, focusing on the water shielding effect of slope protection work to cover the embankment slope as well as the joining effect of the slope protection work with ground reinforcing bars, an investigation was conducted to ascertain the effects of both and establish an antiseismic reinforcement design method based on them. As the result of long-term field measurement and numerical analysis using an actual embankment, it was confirmed that slope protection work to cover an embankment had a water shielding effect in restraining the rise of the degree of saturation in the embankment (Fig. 1). In addition, it was also confirmed, by shaking table test, that the resistance of soil reinforcement was increased by the joining effect to integrate the slope protection work and soil reinforcement, and consequently the seismic resistance of the embankment was improved (Fig. 2). An antiseismic reinforcement design method incorporating these two effects has been proposed and the reproducibility has been confirmed through testings and on site.

By means of a trial design of antiseismic reinforcement for an embankment using the proposed method, it was found that the installation length of soil reinforcement could be shortened due to the effects of slope protection work (Fig. 3). This method can reduce the cost of antiseismic reinforcement work for embankments by 5 to 10%.

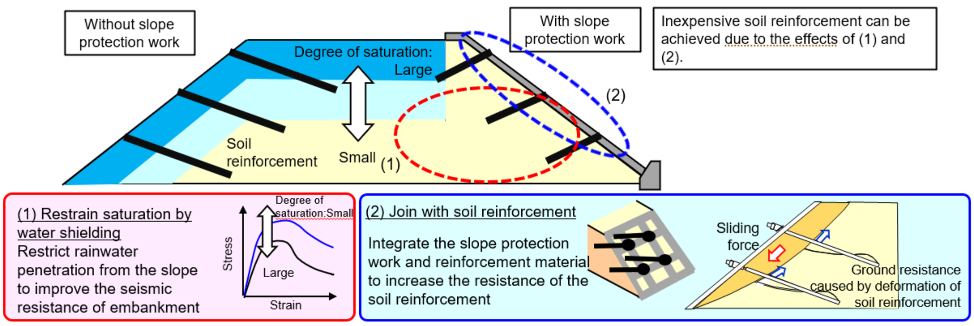


Fig .1 Seismic resistance improvement in existing embankment by slope protection work

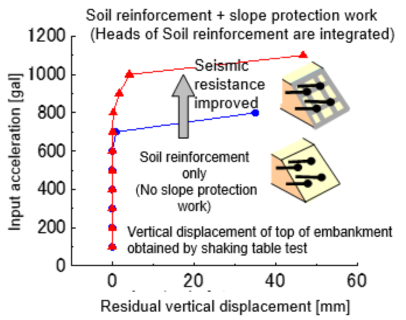


Fig. 2 Joining effect of slope protection work with reinforcing bars

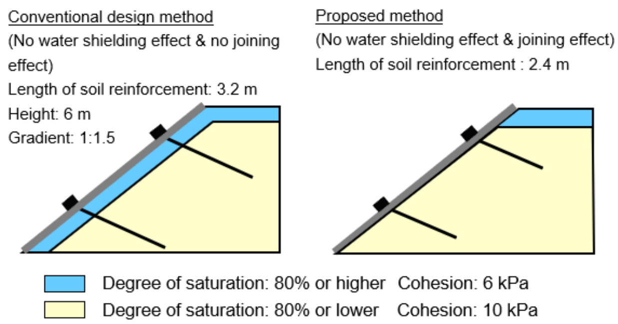


Fig. 3: Example of trial antiseismic reinforcement design of embankment

14. Overhead contact line measurement device using 3D measurement and image analysis

- A contactless 3D measurement device has been developed for overhead contact line facilities.
- Residual diameter can be determined with an accuracy of +/-0.1 mm by means of the developed contact wire wear measuring method using a light-section method.
- The data obtained by both methods can be utilized for high-precision measurement and the automatic diagnosis of an overhead contact line facility.

A contactless overhead contact line measurement device that is mounted on the roof of an electric inspection car and a commercial line vehicle to inspect the installation condition of wires for overhead contact lines (contact wire, messenger wire, and other wires) and fittings (droppers, connectors, and other fittings), as well as a contact wire wear measuring method using a light-section method to realize high-precision measurement with a compact device have been developed.

A contactless overhead contact line measurement device (Fig. 1) is used to measure the 3D position and the shape of each wire and fitting using a combination of image analysis and laser measurement. The results of a trial measurement using this device mounted on the roof of a conventional line vehicle traveling at speeds of up to 130 km/h, confirmed that the height and horizontal stagger of a contact wire could be obtained within a precision of +/-10 mm in repeated measurements; and that more than 90 % of droppers could be extracted automatically from the images (Fig. 2). As this device can record the condition of an overhead contact line facility in both numerical values and images, it is possible not only to inspect the difference in height of overhead crossing lines and the tension on a messenger wire, but also to diagnose abnormalities such as deformation of fittings.

A contact wire wear measuring method using the light-section method is used to measure the 3D shape of the lower half of a contact wire by image analysis using the shape of a laser slit light irradiated onto the contact wire (Fig. 3), and enables high-precision wear measurement regardless of the condition of the sliding surface. The results of a verification test conducted by mounting the experimental device on the roof of a Shinkansen vehicle (Fig. 4), confirmed that the residual diameter of a contact wire could be measured with an accuracy of better than +/-0.1 mm on average. Accordingly, this method can eliminate any deterioration in the accuracy of the measurement of the residual diameter of contact wires, caused by uneven wear and burrs on sliding surfaces.

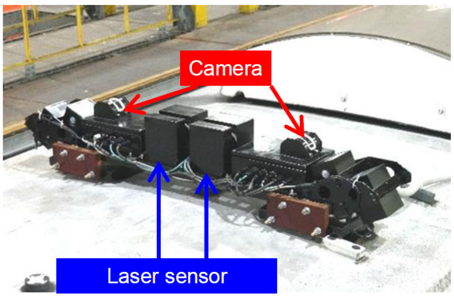


Fig.1 Contactless overhead contact line measurement device

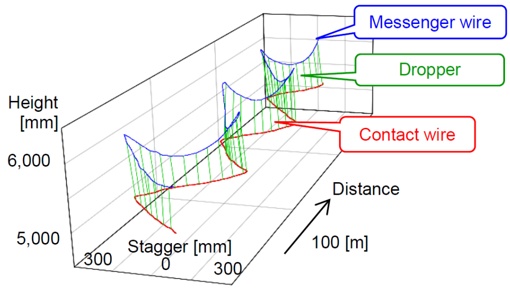


Fig. 2 3D static structure of overhead contact line (conventional line)

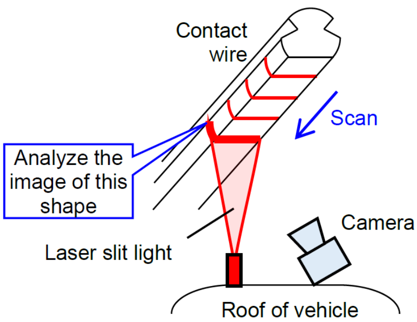


Fig. 3 Measurement principle of light-section method

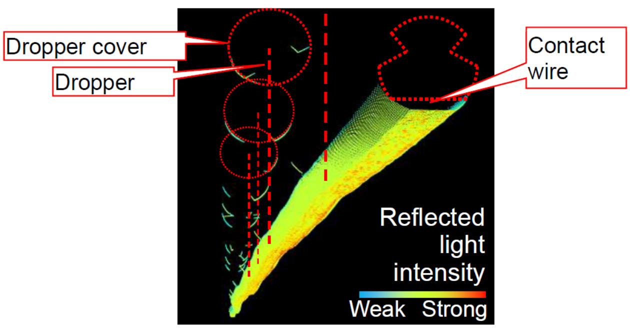


Fig. 4:3D shape of contact wire (Shinkansen)

15. Useful life evaluation method for electronic equipment of wayside signalling systems

- A new useful life evaluation method for electronic equipment of wayside signalling systems has been developed that takes into consideration the operational stress caused by energization as well as the environmental stress caused by temperature and humidity.
- With this method, equipment updates can be scheduled at a proper timing based on the usage environment.

Electronic equipment constituting the signalling systems used along a railway line is subject to operational stress due to energization as well as environmental factors including temperature and humidity, corrosive gases and vibration (Fig. 1). This has made it difficult to understand the main factor and the tendency of deterioration, leading to issues in determining the proper timing of updates.

Therefore, an investigation was conducted to better understand the environment in which wayside signalling systems are used and the actual conditions of failures. The results showed that the dominant deterioration factors impacting equipment useful life were operational stress due to energization and environmental stress caused by temperature and humidity changes. Based on the results of the investigation, a method to evaluate useful life has been developed focusing on cracks generated in solder joints of electronic parts themselves consisting of electronic equipment and their substrates (Fig. 2). With this method, not only can the useful life of an electronic part be calculated according to the usage environment by utilizing the results of a reliability test implemented by the part manufacturer, but also the useful life of solder joints can be calculated by accelerated tests to reproduce solder cracks caused by temperature change, so as to identify weak points based on each calculation result and estimate the service life of equipment. An evaluation was attempted by applying this method to train detectors for grade crossing in two types of equipment boxes under different usage conditions--with and without a shield to block direct sunlight. The results confirmed that weak points could be identified under each condition and the estimated useful life could be calculated (Fig. 3).

This method will help railway operators to quantitatively estimate the useful life of electronic equipment for signalling systems used along their railway lines and develop update schedules, if they use the evaluation tool implemented using this method in spreadsheet software along with the procedure manual. This method is also applicable for electronic equipment other than signalling systems.

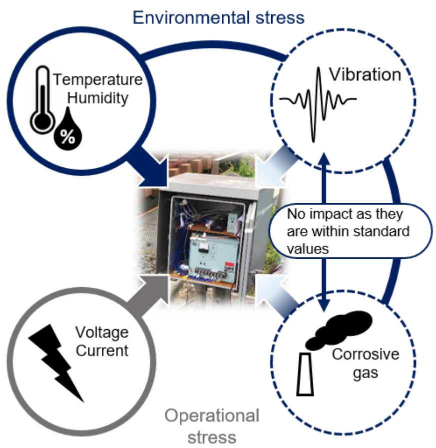


Fig.1 Stress factors for electronic equipment installed by the wayside

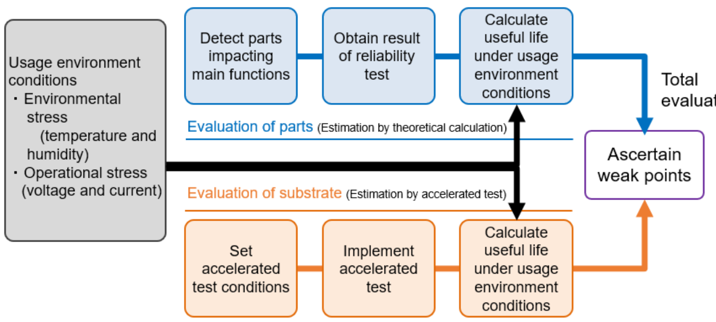


Fig. 2 Outline of useful life evaluation method for wayside electronic equipment

Type of equipment box (Existence of shield) Test track environment within RTRI site	With shield	Without shield
Part evaluation	29.5 years (semiconductor)	27.5 years
Substrate evaluation	41 years	17 years(solder)
Total evaluation	29.5 years	17 years

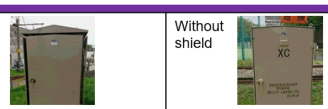


Fig. 3 Example of application to train detectors for grade crossing

16. Support system to determine the signal arrangement

- A support system has been developed to determine the signal arrangement, by means of which it is possible to calculate the signal aspect system and headway immediately.
- As both the signal aspect transition system and the headway can be evaluated using this system, efficiency in the review process for the signal arrangement can be improved significantly.

To improve track layout, including building new stations, a process called “an examination of the signal arrangement “ is required to review the current signal arrangement. In this process, the following tasks need to be repeated until the headway target is satisfied: (1) prepare a signal aspect transition system to show transitions in signal aspect based on the proposed signal arrangement; (2) calculate the headway to show the interval of train operation based on this; and (3) check if the headway satisfies the target value (Fig. 1). The proposed signal arrangement needs to be adjusted in order to create a signal aspect transition system, requiring a lot of time for review to determine the signal arrangement. In addition, this process needs knowledge on creating a train performance curve having the requisite conditions to achieve the longest deceleration distance from the perspective of signalling safety.

Therefore, a support system that can calculate both the signal aspect transition system and headway immediately has been developed by devising a train performance curve preparation function taking signal aspect transition system conditions into consideration and a calculation method for deceleration distance between each signal, and implementing the algorithm owned by RTRI to calculate the train performance curve at high speed (Fig. 2). Through a verification test, it was confirmed that this system could evaluate in a few seconds the required the signal arrangement for a route about 15 km long and having 20 signals.

Since this system can automatically perform the calculations to evaluate both the signal aspect transition system and the headway, it is expected to shorten the time required for the review process of the signal arrangement.

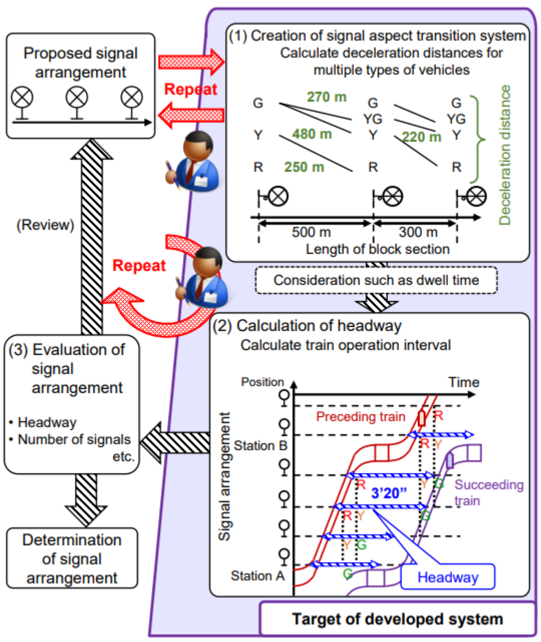


Fig.1 Process to review an examination of the signal arrangement and target of the developed system

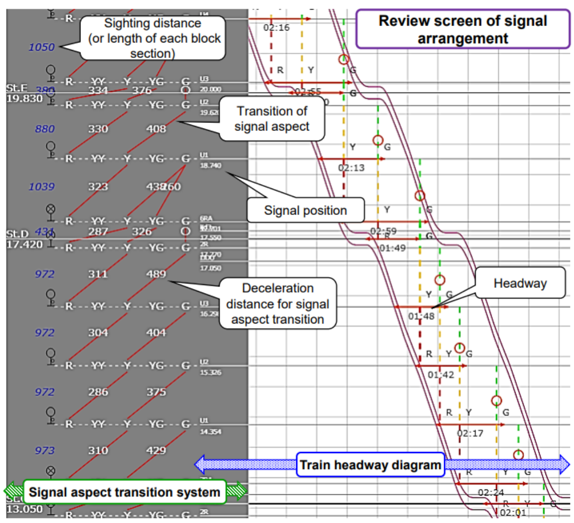


Fig. 2 Support system to determine the signal arrangement

17. High Performance Fuel Cell Hybrid Railway Vehicle

- A fuel cell hybrid railway vehicle with an acceleration performance equivalent to electric motive units has been developed by increasing power capacity of fuel cells and storage batteries.
- Passengers' space was secured by mounting the fuel cells and the power converter under the vehicle floor.

A fuel cell hybrid railway vehicle which is close to a practical use has been developed (Fig. 1). The vehicle secures passengers' space and has an acceleration performance equivalent to electric motive units (starting acceleration: 2.5 km/h/s), which will contribute to reduce ground electric facilities in electrified sections in the future. To achieve such a high performance, the total power capacity of fuel cells and storage batteries was increased to 690 kW. That was improved by 50% compared to the previous one and was the power required for operation on a flat section. Also, the main circuit equipment had to be downsized to be able to mount under the vehicle floor. To achieve this purpose, the power capacity ratio of the storage batteries compared to the fuel cells was increased in order to make the configuration superior to downsizing whole main circuit equipment. Furthermore, as for the fuel cells, by introducing fuel cell stacks with high current density and downsizing cooling equipment, the volume of the equipment per output could be reduced by 20% compared to the previous one. As for the power converters, by integrating the multiple power conversion components and using low-loss semiconductors (SiC), the volume of the equipment could be reduced by 45% compared to the previous one.

By these efforts, passengers' space was secured (Fig. 2). Also, in test runs on our test track, it was demonstrated that the vehicle ran with an acceleration performance equivalent to electric motive units by using the hybrid power of fuel cells and storage batteries (Fig. 3). This study result contributes to a CO2 reduction of railway vehicles and a reduction of ground electric facilities in electrified sections, which leads to a saving on maintenance work.

Part of this study was implemented with a subsidy from the Ministry of Land, Infrastructure, Transport and Tourism for railway technical development.Fig. 3 Example of diagnosis of track stiffness using the portable RFWD

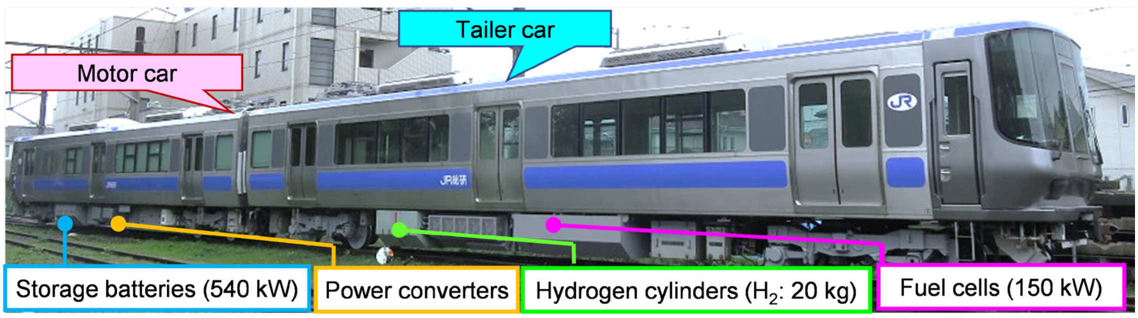


Fig. 1 Fuel cell hybrid railway vehicle

Fig. 2 Passengers' space

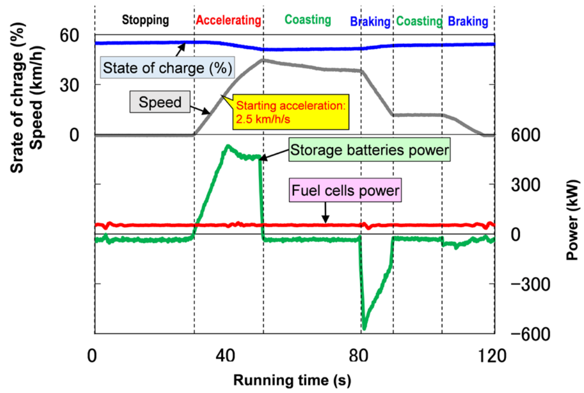


Fig. 3 Result of basic running performance test

18. Method to improve efficiency of electromagnetic compatibility tests for railway vehicle

- The electromagnetic compatibility (EMC) test essential for commercial use of newly produced and remodeled vehicles has been improved.
- Measuring instrument capable of measuring four frequencies at once has been developed.
- The time required for an EMC test can be halved thanks to the revised running conditions and the new measuring instrument.

Current electric railway vehicles achieve energy saving by using highly efficient power converters; however, the electromagnetic emission radiated from the power converter can have an adverse effect on railway signal devices. Because of this, an EMC test is performed to check the electromagnetic emission of newly produced and remodeled vehicles. However, the need for testing and the testing timings are increasing due to the increase of diesel electric cars and the introduction of new signaling system equipment to improve safety, leading to the need for efficient implementation of EMC tests. For example, in the case of a signal device commonly used by JR companies, the number of measurement times required in one testing is 40 times and it takes more than three hours to complete the test. Therefore, in addition to a revision of running conditions that is necessitated by the need for testing, a new measuring instrument has been developed to enable measurements to be repeated several times for each frequency to be completed at one time and a method to reduce measurement work has been proposed (Fig. 1).

First, with respect to the improvement of running conditions, electromagnetic emission is considered to be unchanged by acceleration or regenerative braking, as it has no relation to the magnitude and direction of current necessary for acceleration and deceleration. After taking actual measurements to verify this, testing with regenerative braking was decided to be optional, out of the current running conditions (five kinds). Next, because a general-purpose measuring instrument is used for the conventional measurements, only one frequency can be measured at one measurement and if the center frequency is different--even for the same signal device--the running tests need to be performed separately. Therefore, by making a measuring circuit that concentrates only on the necessary functions for EMC tests for four units out of all the functions of general-purpose measuring instruments, a measuring instrument that can measure four frequencies at one time has been developed.

Thanks to the revised running conditions and the newly developed measuring instrument, the measuring work necessary for EMC tests to be implemented by railway operator or vehicle manufacturer can be reduced from 40 times to 20 times (Fig. 1), and thus the testing time can be halved.

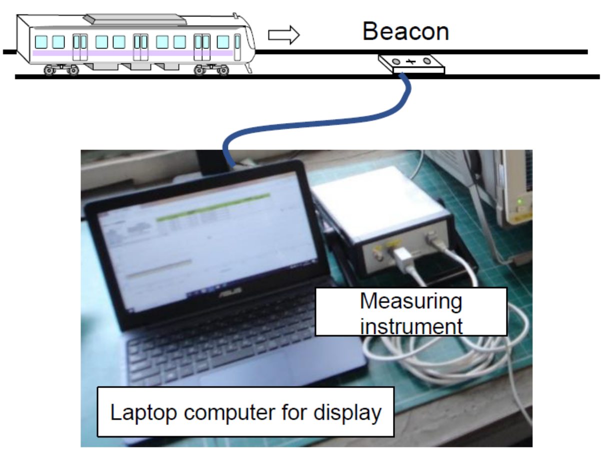


Fig. 1 Measuring equipment

Table 1: Effect on reducing number of measuring times

Type of device	Currently used	After improvement
Electronic train detector	5	4
ATS (1)	5	4
ATS (2)	10	8
ATS-P	20	4
Total number	40 ⇨	20

Number of measuring times reduced by half for signal devices commonly used by JR

19. Three-stage train nose shape for micro-pressure wave reduction

- The effectiveness of a multistage train nose shape for micro-pressure wave reduction has been made clear by acoustic theory.
- A multistage train nose shape of an axis-symmetrical configuration was designed by computational fluid dynamics (CFD), it was confirmed that the micro-pressure wave was reduced by about 5% by a multistage train nose shape compared to a train nose design based on the previous theory in model experiments.

Due to recent increases in the speed of the Shinkansen, the development of an effective train nose shape has been an important issue for suppressing micro-pressure waves generated at tunnel entrances. Therefore, a different approach than before was taken to develop a train nose shape that could suppress the micro-pressure wave more effectively than the conventional nose shape based on previous theory.

In the previous theory of designing train nose shapes, taking a shape derived from model experiments and CFD analysis, smooth configurations in which the change rate of the cross-sectional area is bigger at the tip of the train nose and constant in the middle to rear part have been recommended. However, further studies using linear acoustic theory has revealed that micro-pressure waves can be reduced by using a multistage nose shape in which the cross-sectional area changes in stages--each stage corresponding to the radius of the cross section of the tunnel. For example, in the case of a train nose with a length of about 12 m, the micro-pressure wave is more likely to be reduced by a three-stage shape (Fig. 1, Fig. 2).

Based on the theoretical knowledge explained above, the position and the size of each stage have been determined by CFD analysis in order to develop a three-stage train nose shape that can suppress micro-pressure waves without significant flow separation for axis-symmetrical tunnels without an entrance hood (Fig. 2). As the result of model experiments to confirm the effect of a three-stage train nose, it was found that the peak value of micro-pressure waves could be reduced by an additional 5 % or so compared to the conventional train nose based on the previous theory (Fig. 3). Furthermore, it is possible to shorten the length of a train nose by 1 m, while maintaining a performance equivalent to that of a 12 m long conventional nose shape.

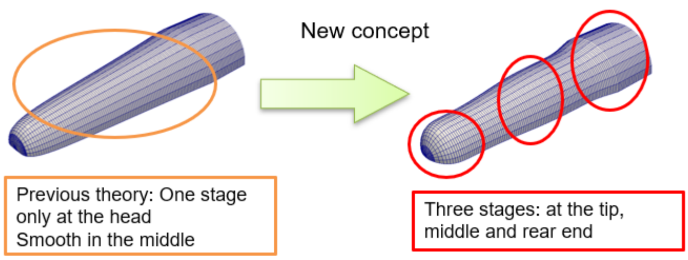


Fig. 1 New concept for train nose shape

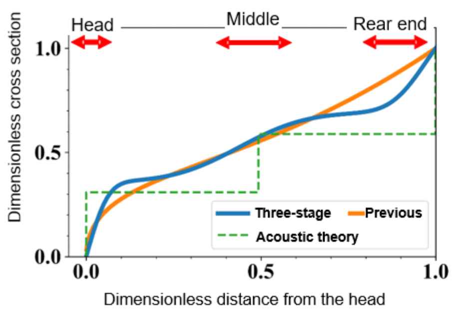


Fig. 2 New train nose shape and distribution of its cross-sectional areas

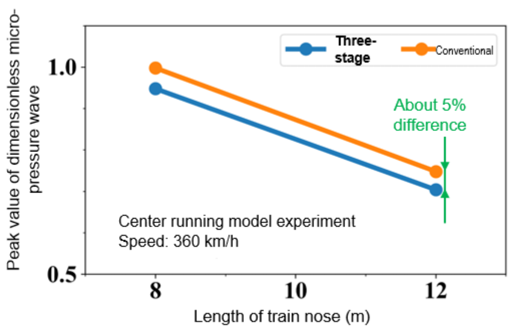


Fig. 3 Comparison of micro-pressure wave peak values between new train nose and conventional train nose

20. Aerodynamic noise-reduction measure and average lift force compensation mechanism for a Shinkansen pantograph

- A multi-segment smooth-shaped pantograph head and a low-noise head support have been developed and confirmed to have an aerodynamic noise reduction effect of 2.7 dB.
- An average lift force compensation mechanism has been developed to suppress the variations in average lift force to about one-fourth that of conventional mechanisms.

Due to the increase in the speed of the Shinkansen, measures to reduce the aerodynamic noise caused by pantographs are required. Therefore, focusing on the pantograph head and head support, which are the main sources of the noise, the pantograph head and head support detailed below have been developed: (1) a multi-segment smooth-shaped pantograph head capable of both aerodynamic noise reduction and compliance performance, and (2) a low-noise head support combining head support cover applying metal porous material and an improved head support to set the pantograph head position to the upstream side (Fig. 1). It was confirmed by a wind tunnel test that these developments could reduce the aerodynamic noise by 2.7 dB (Fig. 2). Please note that an aerodynamic noise reduction effect can be obtained to an extent by applying just one of these developments individually (Fig. 2).

The average lift force compensation mechanism is used to suppress lift force variation, which tends to become larger for a pantograph head having a smooth-shaped cross section with emphasis on low-noise performance. The lift force variation is compensated by estimating the average lift force of the pantograph from the pressures at five points on the pantograph head surface and by use of a signal to indicate the height of the pantograph head, controlling a pneumatic cylinder mounted on the pantograph and adjusting the static uplift force (Fig. 3). With this mechanism, it was confirmed in wind tunnel tests that the range in variation of the average lift force could be reduced to about one-fourth that of the conventional mechanism when the wear on the contact strip, working height, and attack angle were changed (Fig. 4). The average lift force compensation mechanism will help in the development of a low-noise pantograph with high current-collection performance.

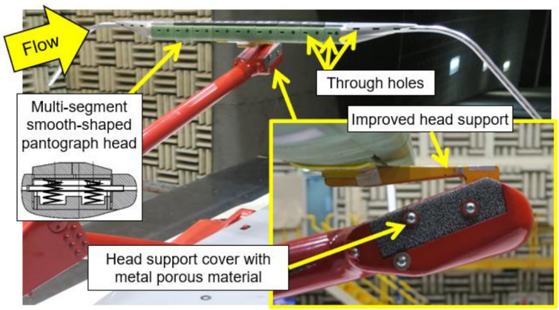


Fig. 1 Measure to reduce aerodynamic sound of pantograph

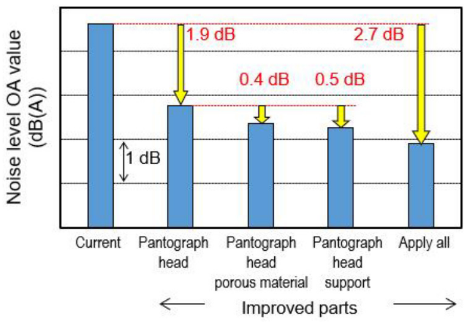


Fig. 2 Aerodynamic sound reduction effect (360 km/h)

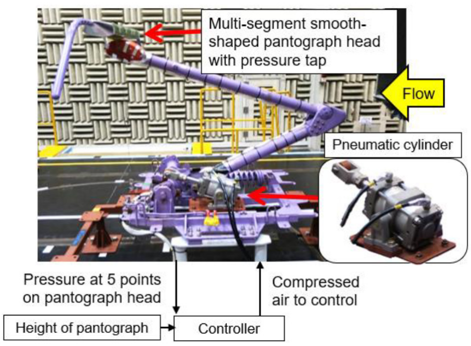


Fig. 3 Adverage lift force compensation mechanism

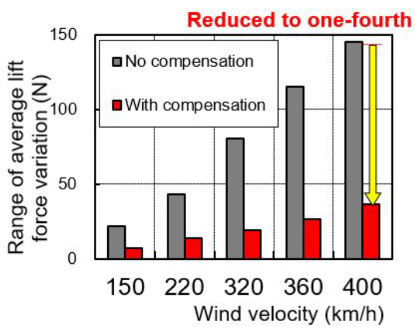


Fig. 4: Result of average lift force compensation

21. Demonstration of a superconducting feeder system function for commercial lines

- A running test using a test car was conducted by connecting a superconducting feeder system to the feeder of a commercial line in parallel.
- The test demonstrated that voltage drop was reduced and the superconducting feeder system could be disconnected smoothly without interfering with a running train.

In DC electric railways, there are several issues such as regenerative brake cancellation and transmission loss affected by the electric resistance of a feeder to the supply power from a substation to a vehicle, and feeding voltage drop between substations. Given that a feeder cable using a high-temperature superconductor can transmit power with no electric resistance when cooled with liquid nitrogen, by applying it for feeders, a number of effects can be expected such as reducing feeding voltage drop and leveling the loads of substations, in addition to saving energy by reducing regenerative brake cancellations and transmission loss.

Therefore, specifications--including the withstand voltage of a superconducting feeder system required for connection to a commercial line for the cable part and the cooling equipment part---have been organized and a superconducting feeder system has been produced based on them. First, tests for conductivity and other factors were conducted to check that this system had the desired performance to satisfy the specifications.

Next, running tests using test cars were conducted by connecting the superconducting feeder system to the feeder of a commercial line in parallel (Fig. 1) to confirm that the voltage drop could be reduced along a 408-meter section to connect the superconducting feeder system for feeding one train set. In addition, a test to disconnect the system and the existing feeder was conducted assuming a disaster or an accident to stop the superconducting feeder system, and it was demonstrated that the system could be disconnected smoothly without interfering with a running train (Fig. 2).

As a future task, development will be continued to accumulate technical knowledge such as that on temperatures and voltage drops for cooling performance as well as conducting performance to enable the desired support required by service conditions that vary by each section, with the aim of realizing a more practical system.

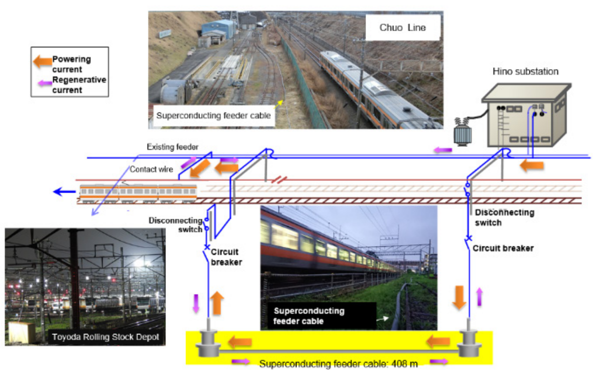


Fig. 1 Running test for superconducting feeder system on a commercial line

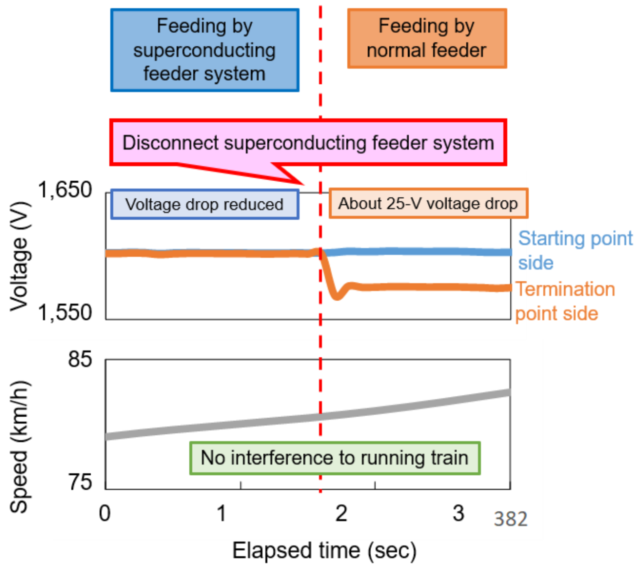


Fig. 2 Running test for superconducting feeder system on a commercial line

22. Rubber bush to suppress vibration transmission between bogie and carbody

- A rubber bush for single links and yaw dampers has been developed to reduce vibration transmission from bogies.
- A reduction in carbody vibration by more than 3 dB was achieved in running tests and bench tests.
- The cost is almost the same as current parts and it is replaceable with the existing rubber bush.

Vibration of the carbody during travel needs to be reduced as it has adverse effects on riding quality. Therefore, a rubber bush for single links and yaw dampers has been developed to suppress vibration transmission from the bogies to a carbody to reduce the elastic vibration of the carbody and improve riding quality (Fig. 1).With this rubber bush, the inner fixture (pin) and the rubber that are usually bonded and integrated are left unbonded, leaving a micro gap between them.to isolate the high-frequency vibration of the bogie. On the other hands, the pin makes contact with the rubber when the relative displacement between the bogie and the carbody becomes bigger so that the rubber exhibits the same performance as a regular buffer rubber. Thus, the rubber bushes achieve both the suppression of high-frequency vibration transmission and the running stability. The cost is almost the same as current parts, and it is replaceable with the existing rubber bush.

Running tests on a commercial line using this rubber bushes on the yaw dampers of a limited express car confirmed that the vertical vibration of the carbody was reduced by more than 3 dB and the ride quality level (LT) was improved, indicating the effect improved the ride quality (Fig. 2).

We have conducted high-speed rotation tests on the rolling stock test plant to confirm the running stability of a Sinkansen type test vehicle equipped with the developed rubber bushes in the single links and/or the yaw dampers. It was then verified by the excitation tests that the vibration acceleration power of the vehicle carbody was reduced by 60% under the condition where the longitudinal exciting forces became prominent (Fig. 3).

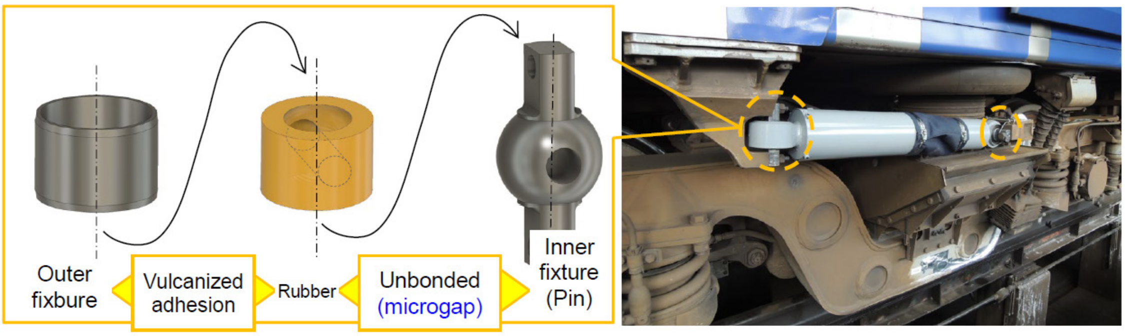


Fig. 1:Developed rubber bush and its installation on vehicle (Yaw damper of limited express train)

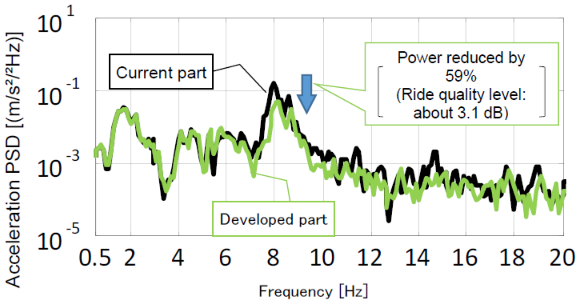


Fig. 2 Result of running test on limited express vehicle (Vertical acceleration PSD applied to center of carbody)

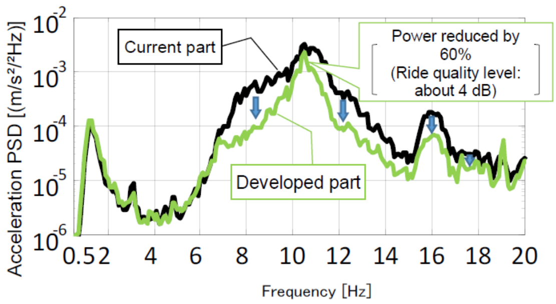


Fig.3 Result of excitation test on Shinkansen vehicle (Vertical acceleration PSD applied to center of carbody)

23. Re-adhesion control by detection system indicating current difference and acceleration for 1-inverter/4-motor vehicle

- A re-adhesion control method combining current difference detection and acceleration detection has been designed for 1-inverter/4-motor system electric railcars, of which there are a large number of vehicles.
- Due to the decrease in torque reduction after detection of wheel slip, the average acceleration was improved by about 5%.

For electric railcars, propulsion systems to drive multiple traction motors collectively by one inverter (for example, 1C2M to drive two traction motors by one inverter, and 1C4M to drive four traction motors) are used widely. Since four traction motors are collectively controlled by one inverter on an 1C4M railcar, if wheel slip occurs even on just one axis, the torques of all four axes are reduced due to re-adhesion, leading to a significant degradation of acceleration performance. Therefore, in order to utilize the adhesive force more effectively, torque control taking wheel slip into consideration is required. Two previously developed techniques that had proven records for tractive effort improvement: “acceleration detection” for a 1C1M locomotive and “current difference detection” for a 1C2M electric railcar were combined (Fig. 1) to make them applicable for a 1C4M electric railcar.

This combination of technologies enables a decrease in torque reduction, thus controlling wheel slip (Fig. 2), and resulting in improved acceleration performance. There are six possible combination methods for current comparison among the four traction motors of an 1C4M electric railcar, however, by focusing on the fact that the current of the traction motor on the axle experiencing wheel slip drops against the command value, and by replacing the drop in current for traction motors of all axles by current difference, a low-cost system capable of detecting sign of wheel slips using only one current difference detector set could be configurated.

To confirm the effectiveness of this control method, verification tests were conducted using a suburban train (3M3T) (Fig. 3). The results showed the average torque could be controlled to a high level, and the average acceleration of the train was improved by approximately 5%. The resulting the ride quality level (Lt value) was reduced by approximately 3dB and the maximum value of longitudinal vibration of the carbody was reduced by approximately 30%.

By using this controlling method in combination with the already exisiting re-adhesion control method for 1C1M and 1C2M, an improvement in the performance of re-adhesion control is made available for more than 90% of vehicles used on conventional lines. Furthermore, as most Shinkansen railcars use the 1C4M system, an improvement in acceleration performance in high-speed areas can be expected by applying this control method.

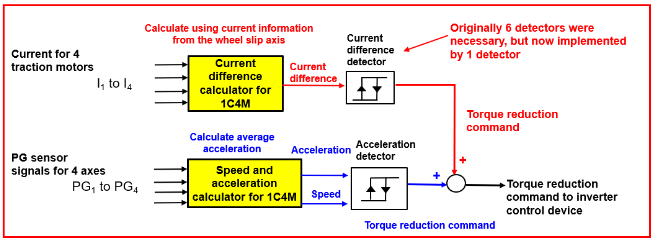


Fig .1 Torque control method for 1C4M electric railcar

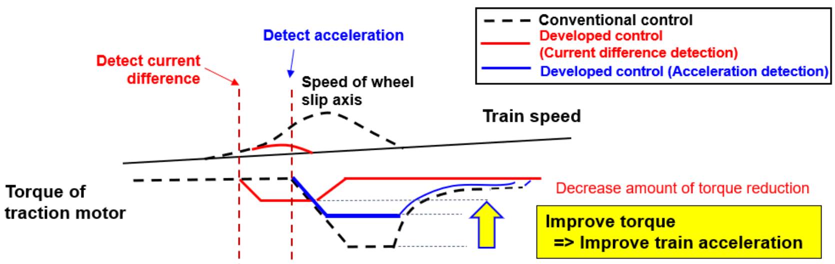


Fig. 2 Behavior of torque during re-adhesion control

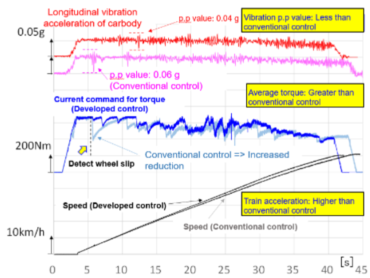


Fig. 3:Result of running test

This study used parts of the achievements obtained by “Basic Research Promotion System in the Transportation Field” of the former Corporation for Advanced Transport and Technology.

24. Method to extract points susceptible to ground vibration increase due to train speed increase

- A method to extract the combination of ground conditions and structure characteristics that may increase ground vibration larger than other conditions has been proposed.
- By adding a new vibration characteristics model of a structure to a conventional model of vibration amplification characteristics of the ground, the points susceptible to ground vibration increase can be assessed without detailed numerical analysis.

Ground vibration caused by running trains generally increases linearly in proportion to the logarithm of the train speed. To date, RTRI has proposed a method to assess the inclination of this line in advance based on the thickness of the ground surface layer and average N value of the surface layer (index of hardness) obtained through ground investigation for construction. However, even though the thickness of the ground surface layer and the N value were almost the same level, the amount of increase could differ from other points due to local variations.

Therefore, a detailed examination was performed based on numerical simulations and past measurements, to clarify that the vibration characteristics of a structure (for example, the natural frequencies of a girder) had an impact on the local variation. Based on this knowledge, a method has been developed to assess the increase in ground vibration when increasing train speed without performing detailed numerical analysis. With this method, vibration characteristics including ground vibration amplification characteristics and natural frequencies of a structure (Fig. 1) are combined to make a vibration transmission model for the target point of assessment (Fig. 2), and the ability to assess the increase in ground vibration involving local variations indicated on the actual measurement data has been confirmed (Fig. 3)

The process of this method is, first to roughly evaluate the amount of increase in ground vibration when increasing train speed according to the ground conditions, and then to narrow down the structure characteristics likely to influence the ground vibration under the ground conditions considered to have a large impact. This method is expected to be applied for prior assessment of a combination of ground conditions and structure characteristics that can increase the variation in ground vibration.

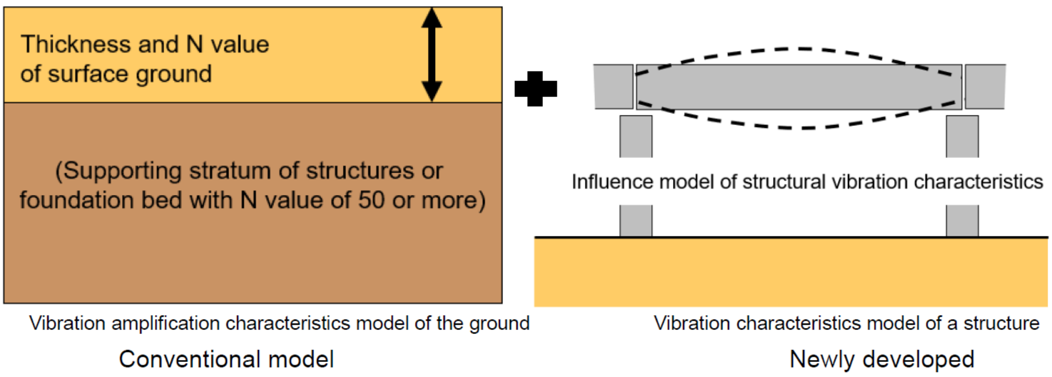


Fig. 1 Proposed model

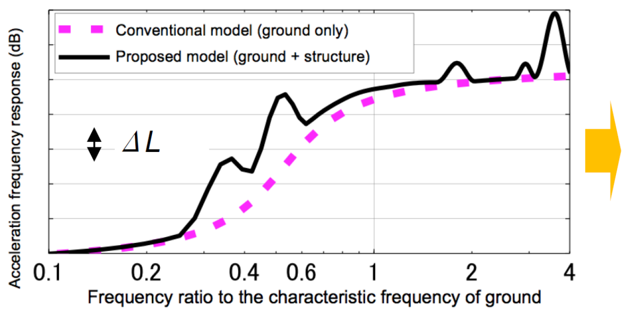


Fig. 2 Example of vibration transmission characteristics incorporating the impact by a structure

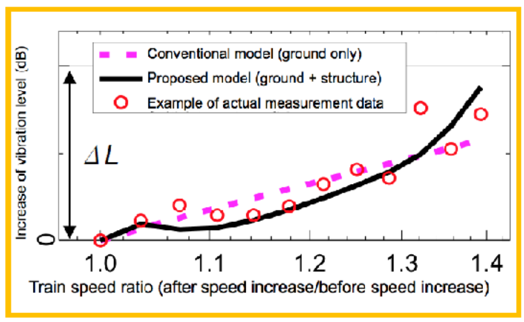


Fig. 3: Example of vibration level assessment result

25. Impact-enegy absorption structure to suppress deformation of an aluminum alloy carbody structure in a collision

- A new design for a replaceable impact-energy absorption structure to be attached to the head car made of aluminum alloy has been proposed.
- This structure suppresses the deformation of a carbody structure in the event of a grade crossing accident, and shortens the time for restoration of the carbody.

When a carbody is damaged significantly in a grade crossing accident, the train cannot be used for an extended period of time due to the restoration of it. Aiming to achieve early restoration of a carbody following such an accident, a basic examination was performed regarding a replaceable impact-energy absorption structure for a carbody made of aluminum alloy for use on conventional lines with restoration issues.

An arrangement has been proposed, as shown in Fig. 1, to install replaceable impact-energy absorption structures in front of the underframe (floor framing) having relatively high strength and rigidity. As they can be attached to an existing carbody structure, no large-scale design change is necessary, making them practical use at a low cost. To verify the effectiveness of this structure, a collision analysis with a large truck (vehicle weight: 9.2 tons, without cargo) was implemented (Fig. 2). In the case of a full-wrap collision condition with a collision speed of 54 km/h, significant deformation was observed on the underframe, which is the main structure, for the conventional structure; whereas maximum deformation was reduced by about 77% when the impact-energy absorption structure was used (Fig. 3). Figure 4 shows the maximum deformation amount of the main structure (underframe) and reduction rate of it under each collision condition. For example, if a maximum deformation amount of 10 mm is allowable, early restoration of a carbody can be deemed possible when the collision speeds are up to about 55 km/h for a full-wrap collision, about 60 km/h for a half-wrap collision, and about 80 km/h for a quarter-wrap collision, and thus, the period when the train cannot be available can be reduced to a minimum

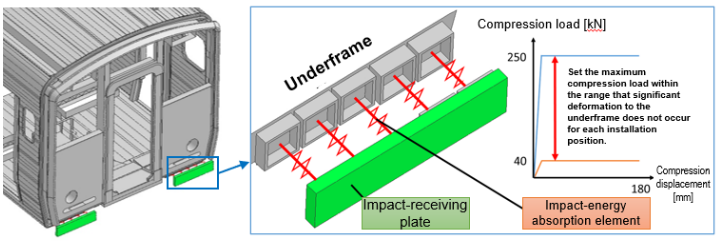


Fig. 1 Proposed specification of low-cost replaceable impact-energy absorption structure

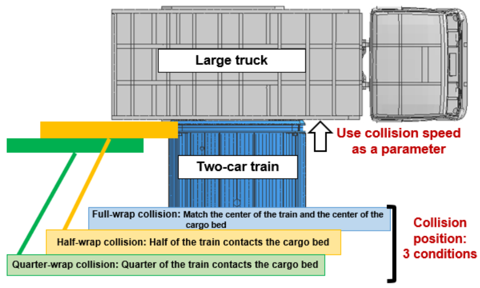
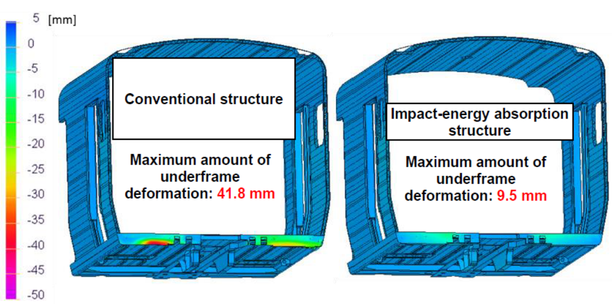


Fig. 2 Analysis conditions of grade crossing collision



Comparison of analysis results for a full-wrap collision involving a large truck with a speed of 54 km/h (contour diagram shows the amount of rail-direction deformation on main structure)

Fig. 3 Example of effect by using replaceable impact-energy absorption structure

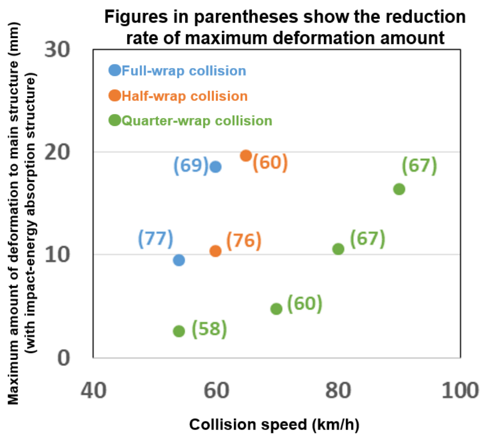


Fig. 4: Maximum amount of deformation on main structure

26. Wheel-rail rolling contact simulation to clarify deterioration by braking

- A method to analyze rolling contact between a wheel and a rail has been developed to evaluate the thermal stress and plastic deformation, which is necessary to clarify causes of deterioration such as hollow wear and wheel flats.
- By comparative verification with braking test results, it was confirmed that the rise in wheel temperature could be reproduced within an error of 10%.

Damages caused by the contact of a wheel with a rail include those considered to be related to heat generation such as hollow wear on a wheel tread due to braking; and wheel flats generated by the slip and sliding of the wheel. As a tool to clarify these phenomena, by extending the functions of a conventional wheel-rail rolling contact simulation method (Fig. 1), an analysis method has been developed to enable elasto-plasticity calculation by coupling(thermal and structural coupling) with thermal conductivity analysis and structural analysis.

Characteristic changes in materials caused by temperature rise such as a lowering of the yield stress of a wheel are incorporated in this analysis method, so that temperature rise and consequent thermal stress and elasto-plastic deformation at the site of wheel-rail contact, as well as the change in shape due to wear, can be calculated simultaneously and in detail (Fig. 2, Fig. 3). Comparison with the test results obtained by a braking test device (Fig. 4) confirmed that the internal temperature immediately under the wheel tread could be reproduced within an error of 10% (Fig. 5).

A wheel-rail rolling contact simulation method can indicate contact conditions in detail, including the stress acting on the wheel and the rail, position of contact, magnitude and direction of the force, which are difficult to measure in experiments and running tests, while also moving and rolling the wheel in the simulation. By adding these thermal and structural coupling functions, the method can be utilized to clarify the phenomenon and propose measures to counter damages generated on wheels and rails, such as hollow wear and thermal cracks on wheels.

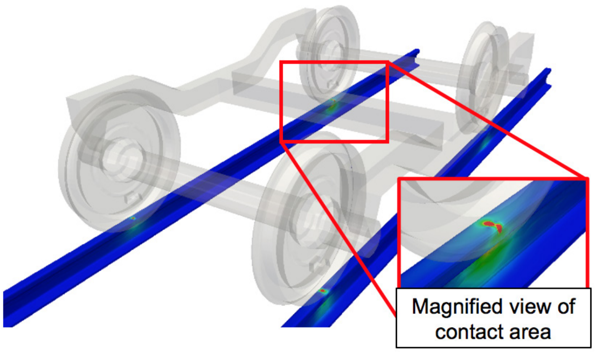


Fig. 1 Example of running on a curve using a 1-bogie model (indicating equivalent stress)

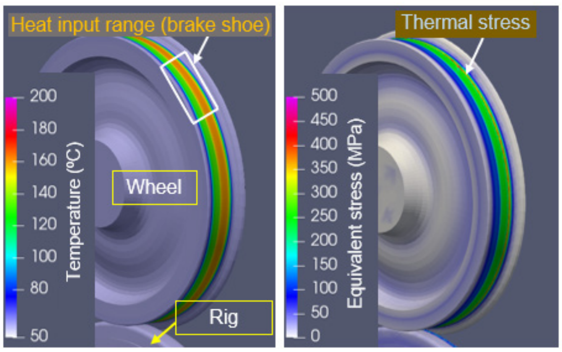


Fig. 2 Example of calculation of temperature and equivalent stress

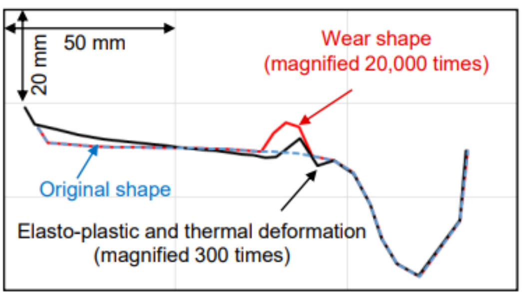


Fig. 3 Calculation example of wheel cross section by elasto-plastic, thermal stress and wear

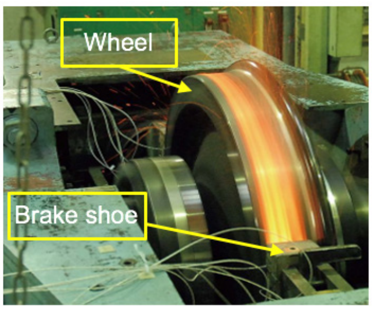


Fig. 4: Braking test device

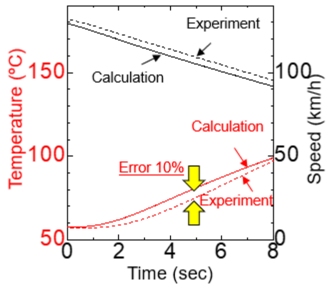


Fig. 5: Example of temperature verification

27. Clarification of growth mechanism and evolution process of rail corrugation

- It has been clarified that there are four anti-resonance phenomena governing the growth factor of rail corrugation.
- It also has been clarified that the evolution process of rail corrugation includes formation period, growth period and saturation period.

Rail corrugation is a phenomenon in which roughness is formed on the top surface of rail with a regular wavelength due to the passage of vehicles, causing noise and vibrations (Fig. 1). As a remedy, rail grinding is implemented periodically to remove surface roughness. However, since the growth mechanism and the evolution process remain unexplained, fundamental control measures have yet to be established.

To ascertain the growth mechanism of this roughness, a theoretical analysis has been performed taking the dynamic interaction of track and vehicle into consideration, leading to the discovery that there were four kinds of growth factors subject to the vibration characteristics of track and vehicle, and the wheelbase (Fig. 2). By comparing the occurrence of rail corrugation measured on commercial lines and the result of theoretical analysis, each wavelength was confirmed to almost agree with the theoretical value, and the growth factor was identified (Fig. 3). The measurement of surface roughness was continued on commercial lines to show that there existed a formation period, growth period and saturation period in the evolution process of rail corrugation (Fig. 4). This evolution process was confirmed to be reproducible by dynamic interaction analysis of track and vehicle.

Fig. 1: Example of rail corrugation generated on a curve

In the future, control measures based on the growth mechanism of rail corrugation and proper rail grinding method based on the evolution process will be proposed.

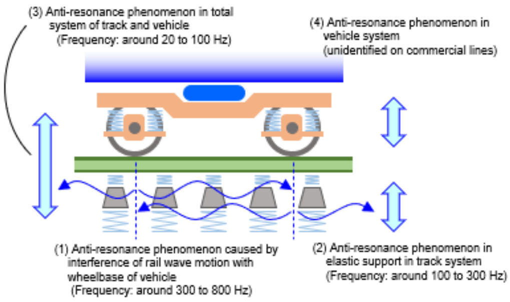


Fig. 2 Four growth factors and their characteristics for rail corrugation

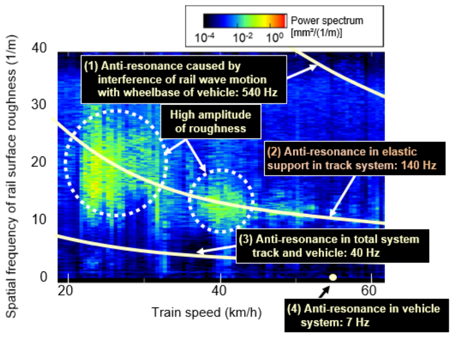


Fig. 3: Example of verification of growth factor for rail corrugation

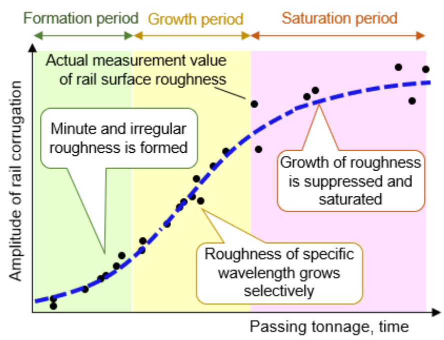


Fig. 4: Evolution process of rail corrugation

28. Damage process of an embankment during an earthquake

- It has been clarified that the damage state of an embankment up until its collapse due to earthquake.
- By comparing the shear strain generated around the toe of an embankment and the deformation characteristics of the embankment material, the damage to the embankment can be evaluated.

For the seismic performance assessment of an embankment, the sliding displacement is calculated assuming that a circular sliding failure occurs. However, this method cannot often explain the actual damage to an embankment subject to an earthquake. Therefore, shaking table tests were performed using centrifuge model test apparatus to understand damage process during an earthquake in detail. The results showed that displacement accumulated gradually due to vibration and increased rapidly from a given displacement level as shown in Fig. 1. After that, a sliding line was generated to end up with a brittle fracture (Fig. 2). The shear strain distributions inside the embankment were observed by using PIV image analysis (Fig. 2), and it was also found that the strain accumulated from the vicinity of the toe of the slope and gradually expanded to inside the embankment. The maximum value of shear strain inside the embankment when the displacement increased rapidly was 9.6% around the toe of slope (Fig. 2 (3)). this value agreed with the value immediately before reaching Damage Level 3 of embankment material at which point the strain in the embankment material increased rapidly (Fig. 3 (3)), when the damage level of the embankment was defined using the deformation characteristics of embankment material (as shown in Fig. 3),. From the above, it was found that when the shear strain in the vicinity of the toe of the slope, which was the origin of the sliding line, reached Damage Level 3 for the embankment material, the displacement started to increase rapidly, and when it reached Damage Level 4--which corresponded to the peak strength for embankment material--a sliding line was generated to occasion a brittle fracture. In this manner, the damage process of an embankment makes it possible to explain the actual damage sustained under an earthquake. This finding can be utilized for detailed seismic performance evaluations for embankments, and investigations to determine the cause after an earthquake.

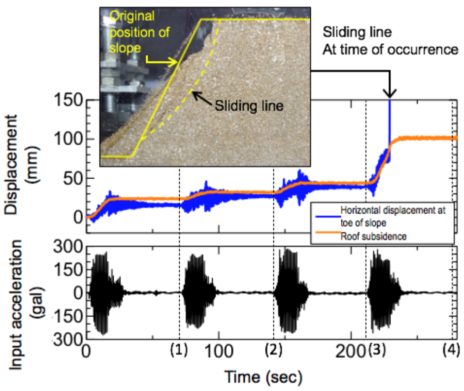


Fig. 1 Accumulation of displacement and occurrence of sliding line

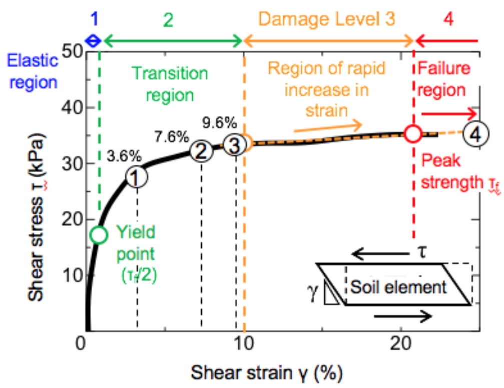


Fig.3 Deformation characteristic and damage level of embankment material
((1) through (4) correspond to Fig. 2).

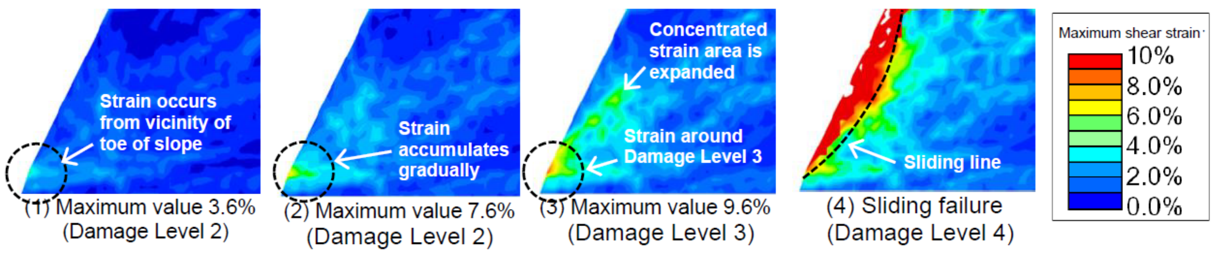


Fig. 2 Damaged condition inside embankment (distribution of shear strain) ((1) through (4) corresponds to Fig. 1)

29. Three-dimensional simulation method of overhead contact lines and pantograph dynamic interaction

- Three-dimensional simulation method of overhead contact lines and pantograph dynamic interaction has been developed.
- The behavior of overhead contact lines and a pantograph in a curved section of track and a crossing section, which were impossible to estimate previously, can now be estimated.
- The influence of cross wind and temperature change on the current collection performance can also be evaluated.

Three-dimensional simulation method of overhead contact lines (OCL) and pantograph dynamic interaction has been developed, to help the development and design of OCL and pantographs as well as to investigate the cause of accidents related to OCL and pantographs. Although the actual OCL was modeled in 2D space previously, the new method can model the OCL in 3D space as actual one and evaluate current collection performance.

With this method, it is possible to predict the dynamic motion and the deformation of the OCL and pantograph by construction 3D OCL and pantograph model. It is possible to perform simulations to reproduce the 3D behavior of a pantograph which has some small contact strips (Fig. 1), analyze the position of the contact wire in a curved section of track and crossing section (Fig. 2), and consider static structure change of the OCL caused by temperature change (Fig. 3), which were difficult to do with the conventional method. Figure 3 shows that the contact force decreases at Part A where the height of contact wire is up-gradients, while it increases at Part B where the height of contact wire is down-gradients, because the contact wire is pulled up at the center of its span by temperature change. In addition, it is possible to perform two coupled simulations, one is coupled simulation with numerical calculation of air flow in tunnel, another is with vehicle dynamics simulation. The former can analyze the change of contact force of a pantograph when train enters a tunnel. The latter can evaluate the relative position of the contact wire and pantograph considering the inclination of the entire pantograph caused by vibration of vehicle.

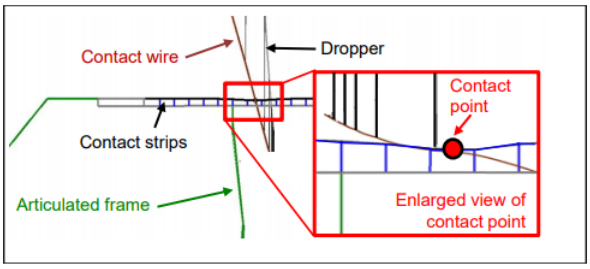


Fig. 1 Example of simulation of a pantograph with some small contact strips

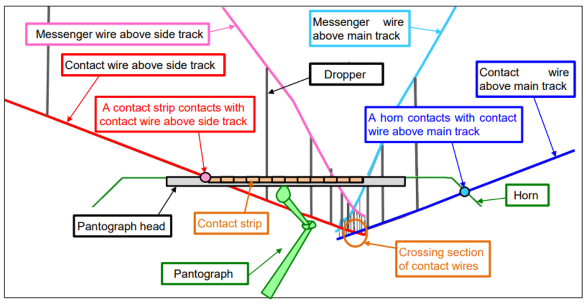
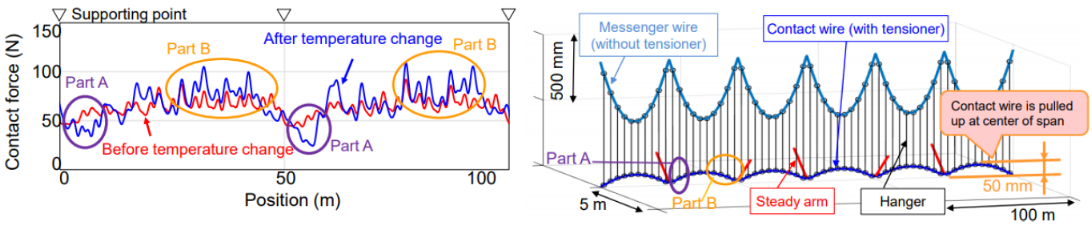


Fig. 2 Simulation result when a pantograph enters crossing section to a main track from a side track (The height of contact wire above side track is 60 mm higher than the one above main track)



(a) Static structure of OCL after temperature change

(b) Contact force before and after temperature change

Fig. 3 Example of simulation before/after temperature change (when the temperature decreases from 15°C to -10°C)

News Release

1. The 12th World Congress on Railway Research, WCRR 2019 held in October in Tokyo

The Railway Technical Research Institute will host The 12th World Congress on Railway Research, WCRR 2019, from October 28 to November 1 this year at the Tokyo International Forum under the theme "Railway Research to Enhance the Customer Experience".

【12th World Congress on Railway Research, WCRR 2019】

WCRR was established for the purpose of providing an overview of the world's development of railway technologies and discussing future directions to be taken by the railway sector. This is the world's largest international congress on railway research, proudly unprecedented in the sense that railway researchers and engineers gather together with managers and executives of railway operators in one congress.

This is the second WCRR congress held in Japan following the WCRR'99 which was 20 years ago. 500 participants from 30 countries and 500 from Japan are expected to join WCRR2019.

【Theme: Railway Research to Enhance the Customer Experience】

Although economic and social circumstances under which railways are doing business differ greatly from region to region or from country to country, it is common for all railways that their important role is to further deepen ties among people by realizing safe and comfortable mobility of people as well as secure and efficient transportation of goods. Providing railway customers with quality experience by fulfilling this role is what railway businesses should aim to achieve and will lead to the raison d'être of railways. In order to enhance the value of railways at the global level, the railways need to keep providing high-quality and reasonably-priced customer services, while maintaining high standards of safety and excellent environmental performance. Innovation which will be brought about by technological breakthroughs will be indispensable, and the role of research and development for this purpose is exactly the main agenda of the entire congress.

【Features of WCRR2019】

WCRR congresses have covered and focused on a broader range of research fields such as human factors, railway business management and transport economy as well as specific railway technologies regarding vehicles, track, overhead lines, signaling and communications, structures, train operation and environmental measures. The features of WCRR2019 based on the policy of WCRR are shown below.

(1) For the purpose of providing railway company executive persons and different fields of researchers and engineers the opportunity to share information, WCRR 2019 provides Plenary Sessions, Organized Sessions, an Exhibition and a variety of Social Events as well as Oral and Interactive Poster Sessions for ordinary paper presentations.

(2) The Plenary Sessions will take the form of panel discussion (Table 1). Having an eye on the optimum form of future railway systems, each participant will discuss the direction that railway research and development is to take, technical fields to be focused on and desirable way of international cooperation from each point of view. Through these discussions, WCRR aims to highlight the roles of railway research and development to explore the theme of this congress, enhancing the customer experience.

(3) Organized Sessions will be prepared for specific topics attracting a high level of interest in many countries. At the Organized Sessions, in-depth discussions will be made under the leadership of chairpersons who are leading experts of each field. Interdisciplinary topics such as "horizon scanning" and "global certification" have been chosen as well as the state-of-the-art

hot-topic technologies including "autonomous driving" and "preventive maintenance with digital technologies".

(4) Interactive Poster Sessions combining short presentations and poster presentations will be provided as opportunities for effective publishing and active information sharing by paper authors.

(5) Due to the surging interest in the application of digital technologies to railway maintenance, 51 papers dealing with condition-based maintenance (CBM) have been accepted for WCRR 2019. To accommodate these presentations, one Organized Session and 6 Oral Sessions have been prepared for the topic of CBM.

(6) WCRR 2019 will be providing 11 Technical Visit courses covering a wide variety of fields including vehicles, facilities, operation and human development. Thanks to the cooperation by JR companies, Japan Railway Construction, Transport and Technology Agency, Tokyo Metro and other railway-related companies, these courses will provide participants good opportunities to see the technologies that support the high level of safety, efficiency, convenience and environmental performance of Japanese railways.

【Outline of the congress】

1. Host: Railway Technical Research Institute
2. Special supporting organizations
   Ministry of Land, Infrastructure, Transport and Tourism
   Tokyo Metropolitan Government
3. Supporting organizations:
   Embassy of Italy in Japan, British Embassy Tokyo, German Embassy Tokyo, Embassy of France in Japan, Austrian Embassy Tokyo, Embassy of the People's Republic of China in Japan
   Institute of Electrical Engineers of Japan (IEEJ), Japan Society of Mechanical Engineers (JSME), Japan Society of Civil Engineers (JSCE), Japan Railway Technical Services (JARTS), Société Franco-Japonaise des Techniques Industrielles (SFJTI), Japan Railway Engineers Association (JREA), Japan Overseas Railway System Association (JORSA), Japan Association of Rolling Stock Industries (JARi), Japan Subway Association, Japan Private Railway Association
4. Congress period: October 28 - November 1, 2019
5. Sessions and events:
   •Plenary Session
   3 Plenary Sessions of panel-discussion style will be provided as described in Table 1.
   •Paper presentations
   Total 361 paper presentations
   10 Organized Sessions (Table 2, 43 presentations)
   40 Oral Sessions (170 presentations)
   20 Interactive Poster Sessions (148 presentations)
   •Technical Visits: 11 courses
   •Exhibition: technical exhibition by sponsoring companies
6. Venue: Tokyo International Forum (Marunouchi, Chiyoda-ku, Tokyo)

Table 1: Plenary Sessions

No.	Title	Moderator and panelist
1	The Role of Railway Operators in Enhancing the Customer Experience	**Moderator** Prof. Anson Jack：Professor, University of Birmingham **Panelists** Mr. Masaki Ogata, Vice Chairman JR East Mr. Shun-ichi Kosuge, Executive Vice President, JR Central Mr. Pierre Izard, Deputy CEO - CTO, SNCF Mr. Rolf Härdi, CTO, DB AG Mr. Marco Caposciutti, CTO, Trenitalia AAR (panelist TBD)
2	Contribution of Railway Suppliers to Elevating the Value of Railways	**Moderator** Mr. Nick Kingsley, Managing Editor, Railway Gazette International **Panelist** Mr. Jay Monaco, Vice President Global Engineering, Amsted Rail Mr. Jürgen Schlaht, Head of Innovation Management, Siemens Mobility Mr. Takao Nishiyama, Executive Vice President, J-TREC CRRC (panelist TBD)
3	Research and Development for Future Railways	**Moderator** Prof. Roderick Smith：Emeritus Professor, Imperial Collage London **Panelist** Dr. Norimichi Kumagai, President, RTRI Mr. François Davenne, Director General, UIC Ms. Luisa Moisio, Director of Research and Development, RSSB Ms. Carole Desnost, CIO, SNCF Mr. Carlo Borghini, Executive Director, Shift2Rail, China Academy of Railway Sciences (panelist TBD)

Table 2: Organized Sessions

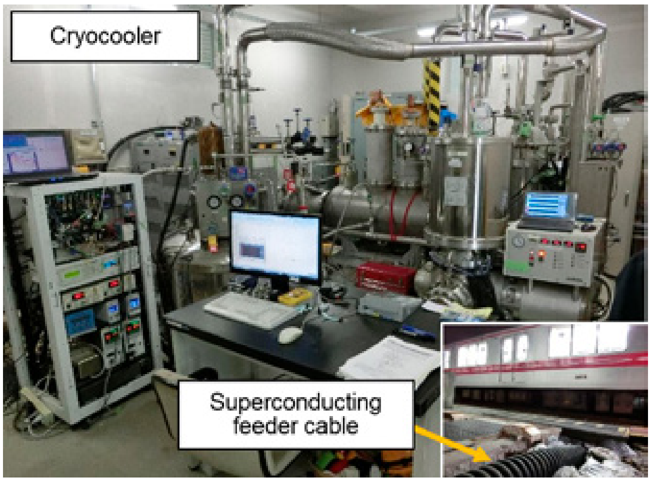
No.	Session title	Chairperson
1	Horizon Scanning for the Railways: An International Collaboration Perspective	Mr. Olivier Marteaux, RSSB
2	Decision-Aid for Real-Time Railway Operation Control	Dr. David De Almeida, SNCF
3	Autonomous Trains on Main Lines	Mr. Rolf Härdi, DB AG Mr. Ralf Marxen, DB AG
4	Global Certification for Innovative Product Development	Ms. Lisa Stabler, TTCI
5	On-Board Monitoring for Vehicle/Infrastructure Diagnostics and CBM	Prof. Giorgio Diana, Polytechnic of Milan
6	Integration of On-Board and Wayside Measurements with Virtual Methods towards Safer, More Cost-Effective, Risk-Conscious and Innovation-Spurring Assessment Methods for Running-Dynamics	Prof. Gabriele Malavasi, Sapienza University of Rome
7	Digital Technologies for Predictive Maintenance	Mr. Valéry Versailles, SNCF
8	Maglev and Other Fixed Guideway Transport, Part I & Part II	Dr. Ken Nagashima, RTRI
9	Global Vision for Railway Development	Prof. Boris Lapidus, UIC IRRB Mr. Jerzy Wisniewski, UIC IRRB Mr. Dennis Schut, UIC IRRB
10	From Research to Benefits: How to Accelerate the Innovation Process	Ms. Luisa Moisio, RSSB Dr. Corinne Talotte, SNCF

WCRR 2019 Official Website
http://wcrr2019.org/
Contact: wcrr2019@issjp.com

2. Superconducting Feeder Cable System Tested on 600V-DC-Powered Commercial Service Tracks

The Railway Technical Research Institute has been developing the superconducting feeder cable system. Most recently, RTRI conducted a shut-off test and power feeding test on 600V-DC-powered commercial lines for the first time in the world. These tests were implemented in cooperation with the Bureau of Transportation of the Tokyo Metropolitan Government and Tokyo Metro Co., Ltd., in order to check whether this system can be applied to commercial service operation.

Tokyo Sakura Tram



Nakano Maintenance Depot

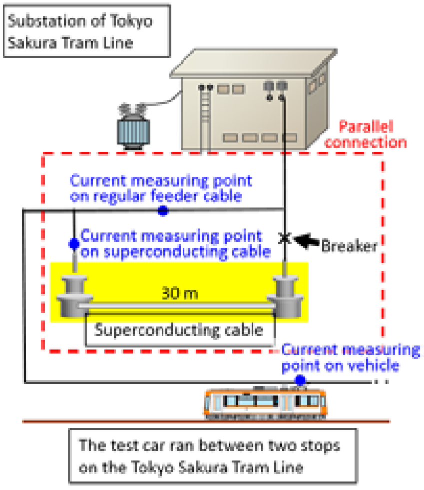
Figure 1: Superconducting feeder cable system used for the tests

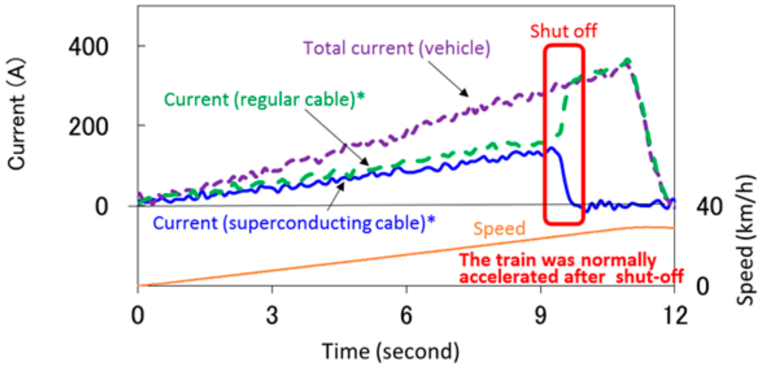
【Results of shut-off tests】

In the shut-off test, the superconducting feeder cable system is parallely connected to the regular power feeding circuit of a tram line powered with 600V DC and is shut off while a test train is running. With this test, it is confirmed that the train keeps running, being powered by the regular feeding circuit, even after the superconducting system is shut off.

A 30-meter-long superconducting cable was placed next to a substation of the Tokyo Sakura Tram, a light rail line operated by the Bureau of Transportation of the Tokyo Metropolitan Government. It was cooled to cryogenic and superconducting condition with liquid nitrogen and parallelly connected to the 600V DC regular power feeding circuit of the tram line (Figure 1, left).

A single tramvehicle ran and accelerated on the section between two stops on the Sakura Tram line and, during the accelerated running, the superconducting feeder cable system was shut off from the regular circuit by a breaker. At the instant of shut-off, the current flowing through the superconducting cable flowed through the regular circuit (Figure 2) and the test train was able to continue acceleration, powered by the regular circuit, even after the shut-off. This result has confirmed that, when a trouble occurs to the superconducting cable system, trains can keep running by switching the feeding system from superconducting to regular one.





* Since the superconducting cable used in this test is just 30 meters long, the electric resistance at the connecting part has a comparatively larger impact on the current. Therefore, the superconducting and regular system showed the same level of electric resistance and almost the same level of current flowed through both cables.

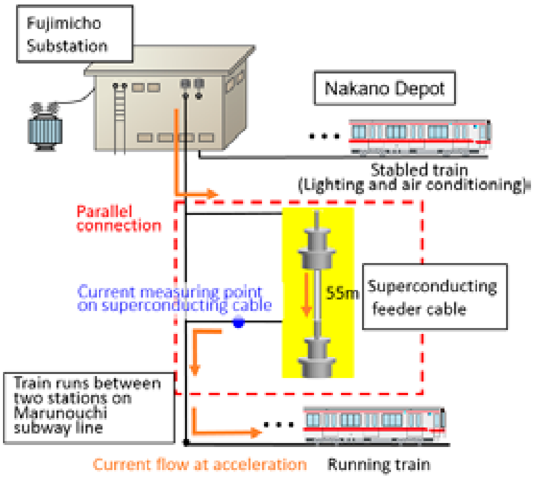
Figure 2: System layout of shut-off test and the results

【Results of power feeding tests】

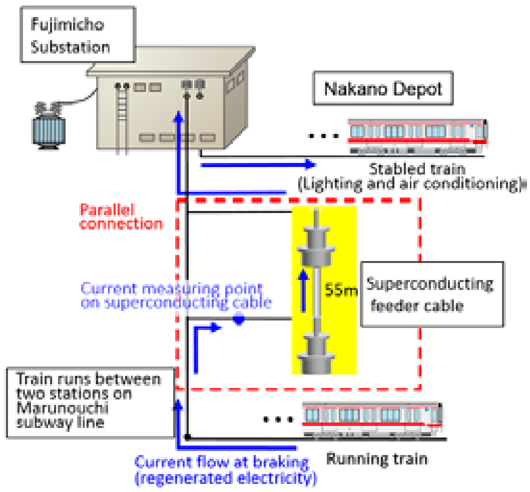
This test is conducted to confirm that the superconducting feeder cable system can transmit the power to accelerate trains on a 600V DC-powered railway line and transmit regenerated current created in braking.

In this test, the 55-meter superconducting feeder cable was set at the Nakano Maintenance Depot of Tokyo Metro Marunouchi Line, cooled to cryogenic and superconducting condition with liquid nitrogen, and then parallelly connected to the 600V DC regular feeding circuit of the tram line (Figure 1, right, Figure 3). The cable was placed just below the rail, a space that suffers a lot of shaking by running trains.

Then, a 6-vehicle test trainset of Marunouchi Line ran between Honancho and Nakano-Sakaue stations and it was confirmed that, during the acceleration, maximum 1881A current flowed through this system and when brake was applied, regenerated power was transmitted through the superconducting cable to a train standing in the Nakano Depot. (Figure 3 and 4) The maximum 1800A current is the largest one that flowed through this cable while an actual vehicle is running. The vibration caused by train running did not damage the superconducting state of this system.



(a) Current flow in acceleration



(b) Current flow in braking

Figure 3: System layout of power feeding test and flow of current

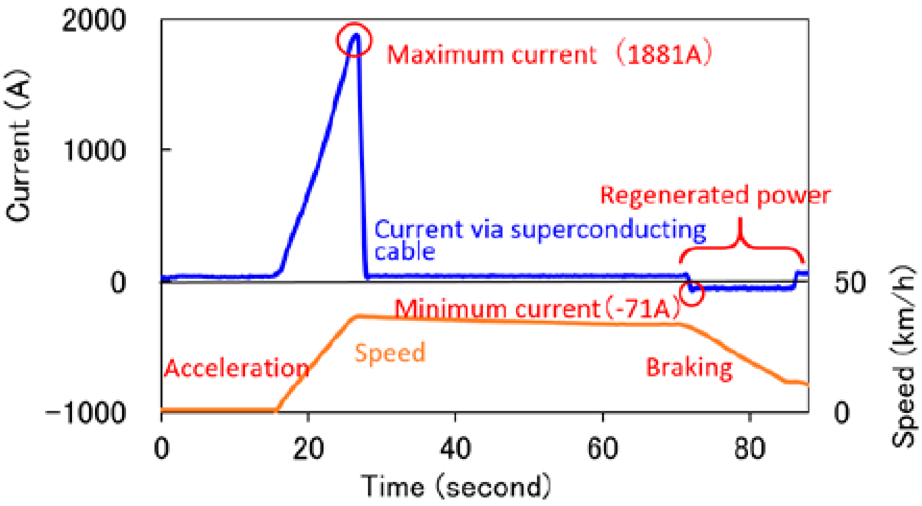


Figure 4: Results of power feeding test

RTRI will continue to address the issues to be cleared to use this system in commercial services by further implementing feeding tests to verify whether it is able to transmit electricity over the distance between actual substations (several kilometers).

◇ Part of this project has been implemented as “the Program to Promote Strategic Innovation” by the Japan Science and Technology Agency (JST). The development of superconducting feeder cable has been supported by the subsidy of the Ministry of Land, Infrastructure, Transport and Tourism and carried out as a project of the New Energy and Industrial Technology Development Organization and of “the Program to Create Future Society “ by JST.

3. RTRI Develops a Seismic Retrofitting Method for the Suspended Ceilings with Shorter Hanging-Distance

The Railway Technical Research Institute has developed a seismic retrofitting method for suspended ceilings with shorter hanging-disrtance. This method has been adopted by JR West to retrofit its station buildings.

【Main characteristics】

RTRI has developed a seismic retrofitting method that can be applied to the suspended ceilings with a smaller ceiling cavity that allows only a short hanging distance. That type of ceilings are frequently seen in the station facilities constructed beneath viaduct with rather lower heights. The key point of this retrofitting method is to pass the hanging bolt through a steel pipe (square pipe) of standard product and to press the pipe up against the viaduct with a nut at the ceiling side end (Fig. 1). This method has the following advantages.

- Antiseismic performance can be improved while sufficient space for passing plumbing and other pipes etc. is secured.
- As this method makes the construction work easier and uses pipes of standard product, the cost is less than half that of the existing retrofitting method for short-hanging-distance ceilings.

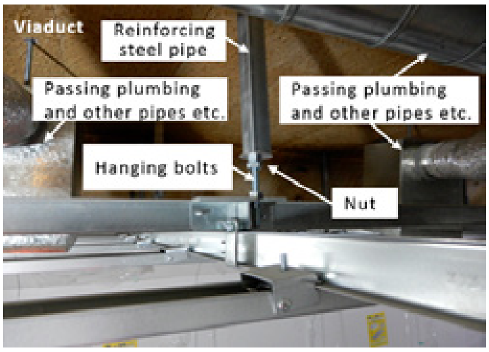


Figure 1: Ceiling retrofitted with steel pipe

【Process of development】

Since train station buildings are accessed by a large number of people, seismic safety must be secured so that the suspended ceilings will not collapse when an earthquake occurs. In the case of seismic retrofitting for ordinary suspended ceilings with 500 to 1500 mm hanging distance, seismic braces can be mounted to bear horizontal load acting on the ceilings at the time of an earthquake (Fig. 2).

However, the brace can only be mounted when its angle shown in figures 2 and 3 falls within the range between 30 to 60 degrees. If the hanging distance is not long enough as is the case for station facilities beneath lower viaduct, the angle will be smaller than 30 degrees and the braces cannot be mounted. In such cases, another seismic measures will be required also because braces occupy the ceiling cavity necessary for passing plumbing and other pipes etc.. Meanwhile, another alternative is to fix the ceiling to the viaduct using channel steel (Fig. 3). However, the construction work of this method is hard and expensive. That is why we have developed this method that enables less expensive retrofitting while leaving sufficient under-roof space (Fig. 4).

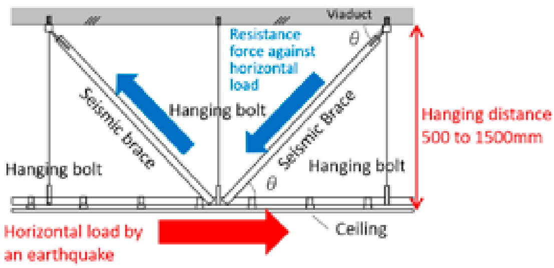


Figure 2: Seismic reinforcement with brace

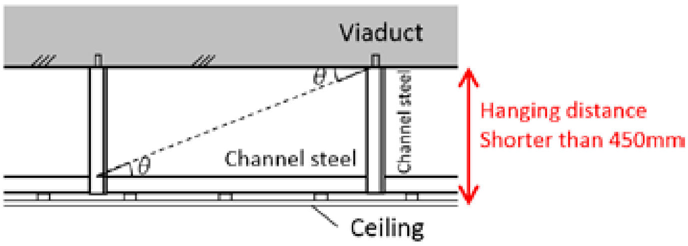


Figure 3: Seismic reinforcement with channel steel
(Existing construction method for short-hanging-distance ceilings)

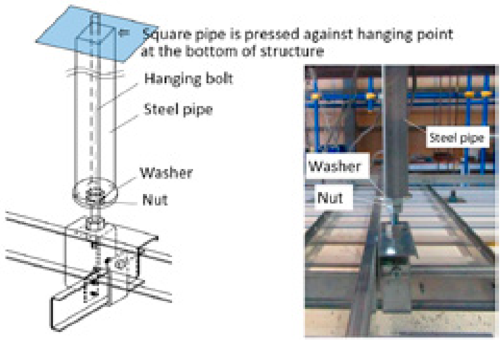


Figure 4: Retrofitting with steel pipe

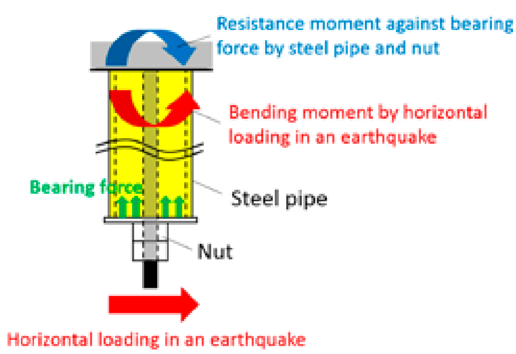


Figure 5: Resisting force against seismic force

【Outline of the method】

In this retrofitting work (Fig. 1 and 4), the horizontal load acting on the ceiling in an earthquake is borne by the force pressing the steel pipe up against the structure (Fig. 5).

We implemented structural testing according to “the Technical Standards Concerning Measures to Prevent the Collapse of Ceilings in Buildings” using a real-size test specimen. The steel square pipes of test specimen are 25 mm-wide and 1.6 mm-thick in consideration of the natural period of the suspended ceiling. In this testing, it was confirmed that the retro-fitted ceiling attained necessary seismic performance and its horizontal load did not diminish under the repeated loading that exceeds the maximum design load (Fig. 6). From this result, we have concluded that this method can be applied to retrofitting work for suspended ceilings with short hanging distance (distance: shorter than 450 mm, angle: smaller than 30 degrees).

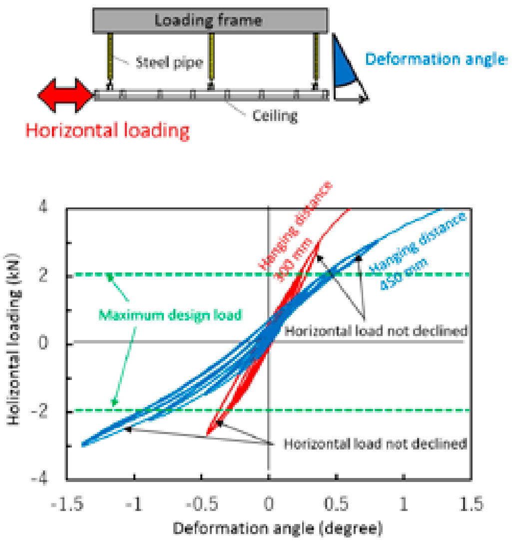


Figure 6: Result of structural testing

【The station retrofitted with this method】

The suspended ceiling of bathrooms in Osaka station building was retrofitted with this method and it contributed to cost reduction (Fig. 1)

【Patent filing】

RTRI has applied for a patent regarding part of this method jointly with Kirii Construction Materials Co., Ltd.

4. Superconducting Feeder Cable System
- Running Test Conducted on 1500 V DC Chuo Line -

The Railway Technical Research Institute has been developing the superconducting feeder cable system. Most recently, RTRI conducted a power feeding and shut-off test in cooperation with the East Japan Railway Company in order to apply the system to commercial service operation. The system was connected to the regular catenary system of the Chuo Line (1500V DC) and the tests were implemented while a test train was running on the track.

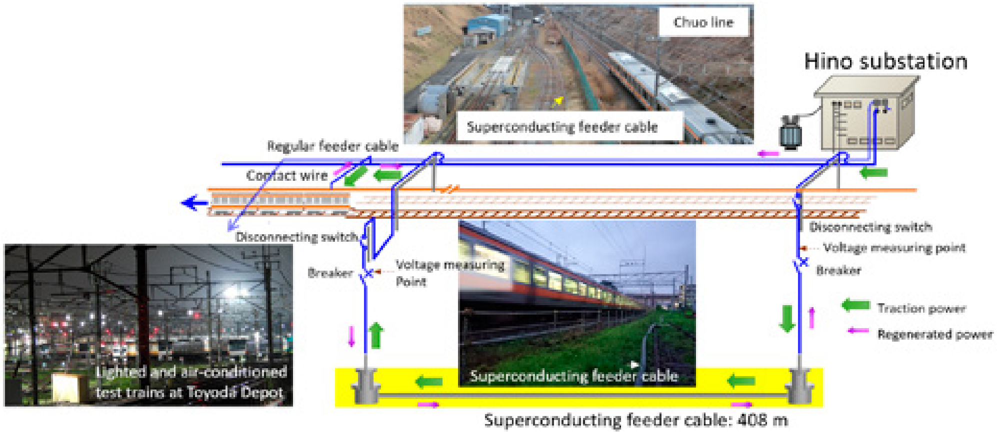


Figure 1: Superconducting feeder cable system at Hino Civil Engineering Testing Station

【Result of power feeding tests】

The purpose of this test is to confirm that the superconducting feeder cable system can transmit both the power to accelerate trains and the regenerated power created in braking (reverse-direction current) on a 1500V DC-powered railway line.

The superconducting feeder cable system (408m cable) placed in the Hino Civil Engineering Testing Station was cooled to cryogenic and superconducting condition with liquid nitrogen, and parallelly connected to the regular feeding circuit of Chuo line (Figure 1). Then, a test train (Series E233, 10-vehicle) ran on the line powered by the system, and at the Toyoda train depot, 10 test trainsets (Series E233, 10-vehicle) were powered by the regenerated current for lighting and air-conditioning.

Through this test, it was confirmed that up to 2200A or larger current flowed from the substation to the test train through this system while the train was being accelerated. Meanwhile, when brake was applied, regenerated power was transmitted in the reverse direction through the system to the trains standing in the Toyoda depot (Figure 2). The maximum amount of the current, 2258A, is the largest that flowed through this cable while an actual vehicle is running. Furthermore, it was confirmed that the test train was able to pass the section without any troubles.

【Result of shut-off tests】

In the shut-off test, the superconducting feeder cable system is parallely connected to the regular power feeding circuit of a 1500V-DC-powered railway track and is shut off while a test train is running. The test confirms that, even after the superconducting system is shut off, the train is able to keep running, being powered by the regular feeding circuit.

As in the power-feeding test, the system under superconducting state was parallelly connected to the regular catenary system of the Chuo line (Figure 1) and the test train (Series-E233, 10-vehicle) ran on the track.

After the superconducting system was shut off from the regular circuit by a breaker during the acceleration, all the current flowing through the system was turned into the regular circuit (Figure 3, top) and the test train was able to continue acceleration, powered by the regular circuit (Figure 3, bottom).

This result has confirmed that, even if a trouble occurs to the superconducting cable system, trains can keep running by switching from superconducting to regular system. In addition, the voltage dropped 25V after the shut-off, while it was almost zero before shut-off. That result has confirmed the effect of the system to reduce the electrical resistance to zero (Figure 3, middle).

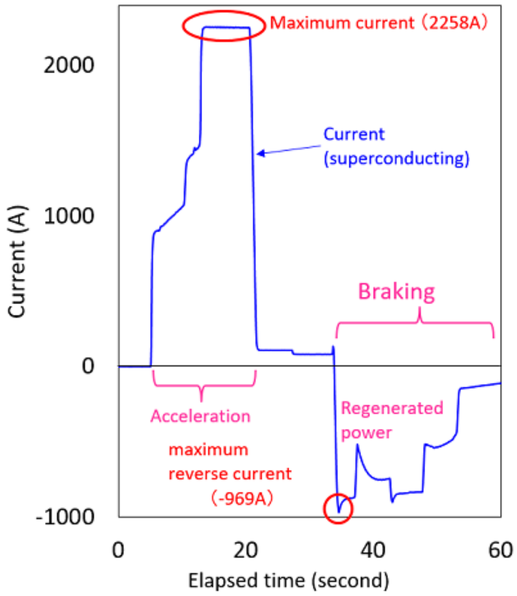


Figure 2: Result of power feeding test

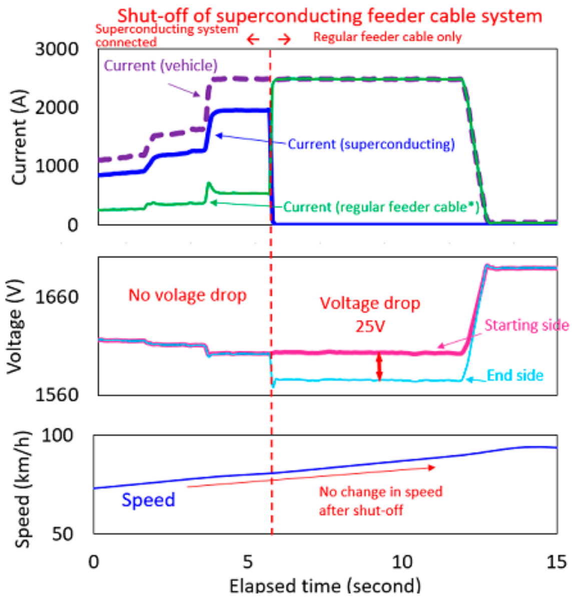


Figure 3: Result of shut-off test

* Since the cable connecting superconducting and regular feeder cable has electrical resistance, part of the current flowed through regular feeder cable.

RTRI will develop a system that accommodate the distances between actual substations (several kilometers or longer) and continue to address the issues to be cleared before introducing the superconducting cable to commercial services.

◇ The development of the superconducting feeder cables has been implemented as “the Program to Promote Strategic Innovation” and “the Program to Create Future Society “ by the Japan Science and Technology Agency (JST) and supported by the New Energy and Industrial Technology Development Organization (NEDO) and the Ministry of Land, Infrastructure, Transport and Tourism.

5. A New Fuel Cell Hybrid Test Vehicle Completed - Compact and High-Performance -

RTRI has been developing a next-generation train, fuel cell hybrid train which uses hydrogen energy in order to save fossil energy and reduce the environmental footprint, and has completed a test vehicle that is close to practical use. Considering the deployment to many commercial-service lines, this vehicle has allowed a larger cabin space by reducing the size of the on-board apparatus and improving its performance and has boosted its traction power output and startup acceleration.

【Major characteristics】

- •50% increase in the power output of the fuel cell and 20% decrease in the volume per output by raising power density and dispersedly locating the cooling apparatus.
- •The volume of the power converter for fuel cell has been reduced 45% by adopting silicon carbide element and compact circuit breaker.

With these advantages, this test vehicle will speed up future introduction of fuel cell vehicles by railway operators.

【Previous test vehicle】

Since the Paris Agreement took effect, further reduction of greenhouse gas has been required. RTRI has been developing a fuel cell railway vehicle that will be able to reduce greenhouse gas emission by replacing diesel engine vehicles powered by fossil fuel. Since 2008, we have conducted running tests on our test track using a fuel-cell-battery hybrid test vehicle and confirmed its basic performance. However, the vehicle in that stage had larger onboard devices and some of them were laid in the cabin, and its acceleration performance remained at the same level as diesel cars.

【Outline of the new test vehicle】

Figure 1 and 3 show the test vehicle and its cabin. The layout of devices and vehicle performance are shown in Figure 2 and Table 1 respectively.

【Development for the next phase】

By continuing the running tests on RTRI's test track, we will improve the controlling method for the hybrid system in order to raise the energy efficiency and develop a method to reduce the load to fuel cell.

◇ Part of this development has been implemented with the subsidy for railway technical development by the Ministry of Land, Infrastructure, Transport and Tourism.

Figure 1 New test train

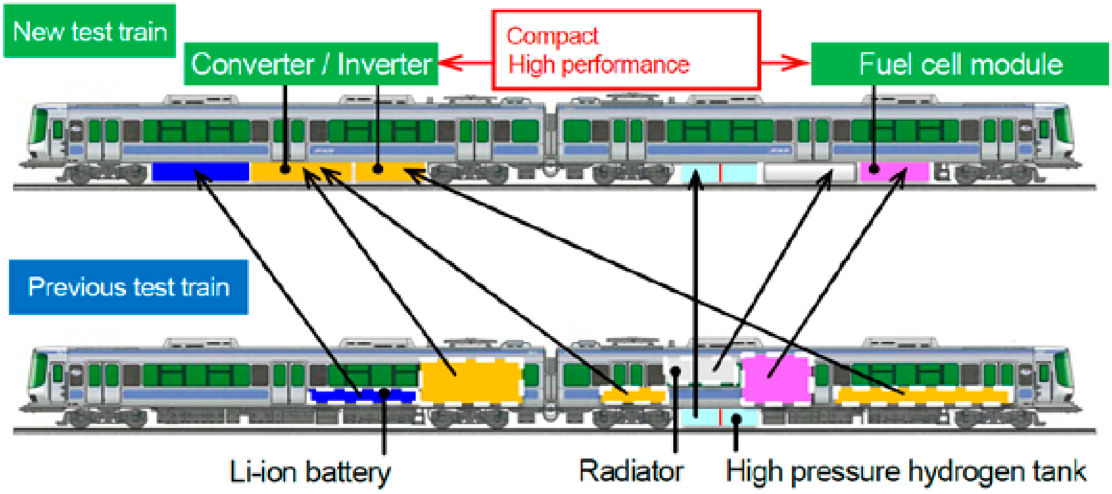


Figure 2 Layout of devices

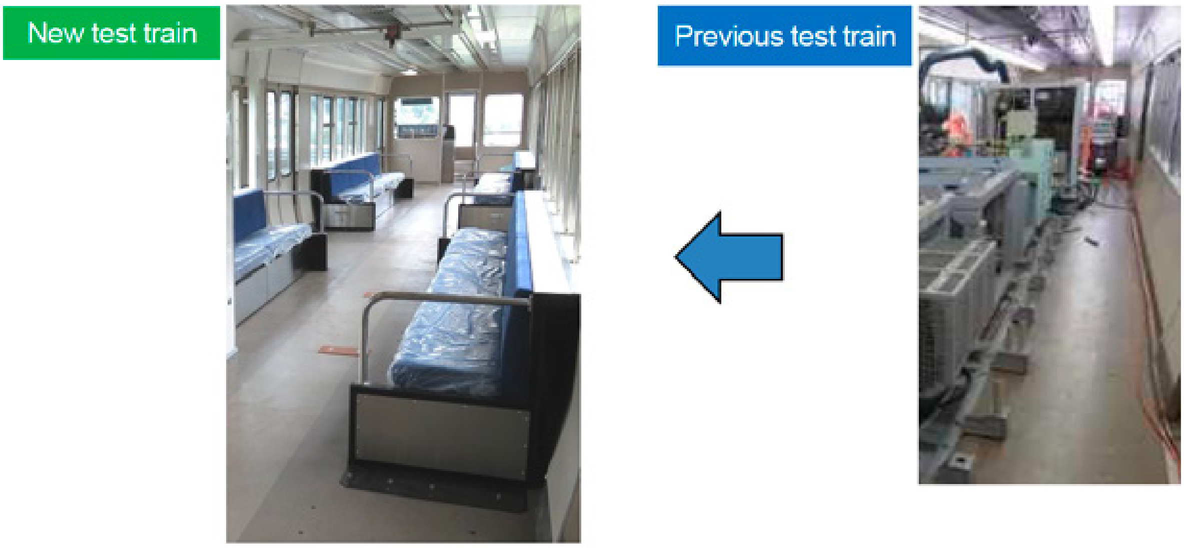


Figure 3 New cabin without devices

Table 1 Test train performance

Item	Performance	Previous performance
Startup acceleration	2.5 km/h/s	1.5 km/h/s
Number of drive shafts per trainset	2 bogies 4 axles	1 bogy 2 axles
Trainset power output (fuel cell output (net))	690kW (150kW)	460kW (100kW)

6. Tree-Planting Ceremony Celebrating the 60th Anniversary of Moving RTRI Head Office and Main Facilities to Kunitachi

Celebrating the 60th Anniversary of moving to Kunitachi, the board members of RTRI and its affiliated companies planted a cherry tree on October 16, 2019.

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In 1959, 60 years ago, Railway Technical Research Institute, the then in-house research wing of the Japanese National Railways, moved from Hamamatsucho to Kunitachi. President Shinji Sogo and Vice President Engineering Hideo Shima of JNR and about 200 concerned people celebrated the opening of the main building of RTRI at Kunitachi on October 16, 1959. 60 years later, on October 16 this year, RTRI's Chairman Eisuke Masada and President Norimichi Kumagai planted a commemorative cherry tree in the front yard of RTRI at Kunitachi. The commemorative photo exhibition was held as well until November 1 this year at the entrance hall of RTRI's main building.

Chairman Masada and President Kumagai planting a cherry tree

Inscription

Participants of the ceremony

【Greetings by President Kumagai】

It has been 60 years since RTRI moved to Kunitachi. At the time of moving, the opening ceremony was held with around 200 persons including President Sogo, Vice President Engineering Shima, Director Oishi and the people who were involved in the construction work. After 60 years since the ceremony, we would like to renew our perception of what was expected of RTRI in those days and what RTRI has accomplished. This is just a small ceremony, but we would like to recharge and revitalize ourselves on this occasion.

When RTRI moved to Kunitachi, the then President Sogo stressed the value of an in-house research institute and said that railways were standing at a crossroad of contributing to economy, or fading into history, and that the most important thing for a research institute is human resource and the cooperation among employees.

After 60 years, we have to ask ourselves whether we still have maintained the DNA, the tradition. I can say yes, but what we have now has been achieved and accumulated by our predecessors. Since RTRI made a restart as an independent institute 32 years ago, we have generated significant research outcomes in broad-ranging fields including the development of superconducting Maglev train systems, speed increase and seismic measures. We will keep our motivation to continue the research and to achieve sustainable development for the next 60 years.

Over these years, we have discussed what railways should be in the future. We should pursue even higher level of safety and achieve this goal with digitalization technologies. Now we have original, large-scale test facilities and advanced computer simulation techniques that did not exist 60 years ago and have accumulated a vast amount of test data. Hoping to make use of these resources and capabilities of RTRI in the technical innovation of railways, I am planting this commemorative cherry tree.

7. The Basic Running Performance Demonstration of the Fuel Cell Hybrid Powered Test Railway Vehicle

RTRI has been developing the fuel cell hybrid powered test railway vehicle uses hydrogen energy in order to save fossil energy and reduce the environmental footprint as a next-generation railway vehicle. We carried out the basic running tests with the test vehicle that was introduced in RTRI's news release dated August 28, 2019 (*) and demonstrated its basic running performance.

(*) News Release dated August 28 (https://www.rtri.or.jp/eng/press/is5f1i000000c68o-att/201905.pdf)

【Specification of the test railway vehicle】

RTRI has been developing a fuel cell hybrid powered test railway vehicle. The vehicle contributes to reduce the greenhouse gas emission by replacing fossil-fuel-powered diesel multiple unit.

The fuel cell hybrid powered test railway vehicle that was completed in August this year (Fig. 1) has attained the running performance comparable with electric multiple unit (EMU) and allowed larger cabin space by improving the performance and reducing the size of the fuel cell and power converters. The major specifications of the test vehicle are shown in Table 1:

Table 1: The major specification of the test railway vehicle

Maximum power output	fuel cell (PEFC): 150kW(net) Battery (Li-ion): 540kW
Power source	① Catenary wire ② Catenary wire & battery ③ Fuel cell & battery ④ Battery
Main motor	95kW×4
High-pressure hydrogen tank	20kg-H_2 (35MPa×180L×4)
Vehicle weight excluding apparatus	Mc: 37 (t) Tc: 31 (t)
Vehicle dimensions	Length: 19,670 (mm) Width: 2,950 (mm) Height: 3,702 (mm)
Startup acceleration	2.5 (km/h/s)
Maximum deceleration	3.1 (km/h/s)

【Outline and results of the basic running performance test】

RTRI carried out the basic running tests on the test track at RTRI with the maximum speed of 45km/h and demonstrated the basic running performance of the test vehicle with fuel cell and battery hybrid system as follows.

•The test vehicle can attain the startup acceleration of 2.5km/h/s. This is comparable to EMU and has been attained by improving the power output of the fuel cell, etc.

•The test vehicle is driven by the fuel cell and battery hybrid power supply, and:

(a) In acceleration, the motor is driven by the hybrid power of fuel cell and battery.

(b) In deceleration, the battery is charged by regenerative power and fuel cell power.

(c) While coasting and standing, the battery is charged by the fuel cell power.(Fig. 2)

Using these power modes, the state of charge of the battery (SOC) can be maintained at the same SOC before and after the running. (Fig. 3)

•The two fuel cells charge the battery and the fuel cell output was up to 139kW so far. (Fig. 4)

【Further improvement and development】

Through the running tests on RTRI's test track, we will enhance the energy efficiency by improving the method of controlling the hybrid system and develop a controlling method to reduce the fuel cell output fluctuations.

◇ Part of this development has been implemented with the subsidy for railway technical development by the Ministry of Land, Infrastructure, Transport and Tourism.

Fig.1: Fuel cell hybrid powered test railway vehicle

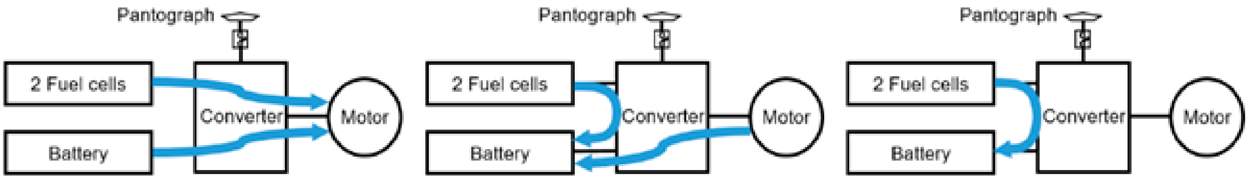


Fig.2: Power flow of the fuel cell-battery hybrid system

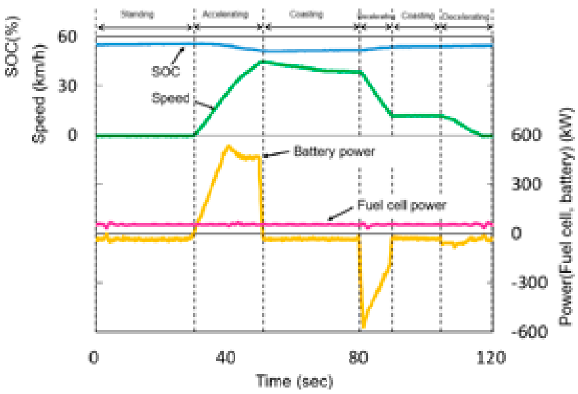


Fig.3: Results of basic running performance test

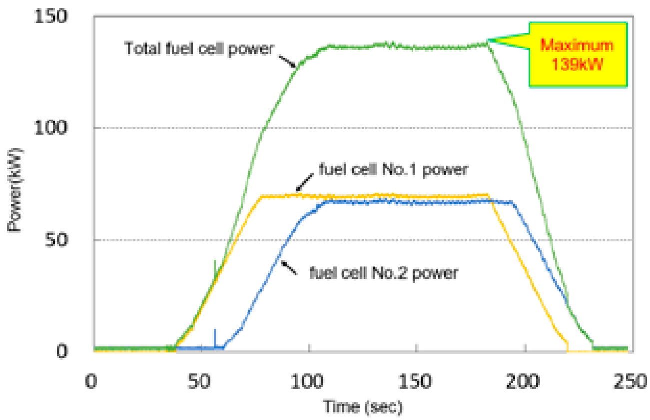


Fig.4: Results of dual fuel cells operation test (in charging battery)

8. RTRI Hosts WCRR 2019

The Railway Technical Research Institute held the 12th World Congress on Railway Research, WCRR 2019 from October 28 to November 1 this year at the Tokyo International Forum under the theme “Railway Research to Enhance the Customer Experience”.

WCRR is an international congress organized by the WCRR Organizing Committee composed of Union International des Chemins de fer (UIC), Société Nationale des Chemins de fer Français (SNCF), Deutsche Bahn AG (DB AG), Trenitalia, Rail Safety and Standards Board (RSSB), Transportation Technology Center, Inc. (TTCI) and RTRI.

WCRR 2019, the 12th congress of WCRR, was held for the second time in Japan, 20 years since 1999. Total 993 people, 424 from 37 countries and 569 from Japan, participated in the congress. Under the congress theme “Railway Research to Enhance the Customer Experience”, three plenary sessions, 10 organized sessions, and 60 oral and interactive poster sessions covering eight research fields were provided. In particular, the organized sessions were included in the congress program for the first time. They are intended to encourage in-depth discussions on the world’s hottest topics and characterized by the unity among presentation topics and flexible styles of presentations. 44 presentations (10 from Japan) were made at the organized sessions under the leadership of the chairpersons who are outstanding experts in each field. At the oral and interactive poster sessions, 167 oral presentations (44 from Japan) and 142 (59 from Japan) interactive poster presentations were made. Each session theme is as follows:

① Plenary sessions
1. The Role of Railway Operators in Enhancing the Customer Experience
2. Contribution of Railway Suppliers to Elevating the Value of Railways
3. Research and Development for Future Railways

② Organized sessions
- Horizon Scanning for the Railways: An International Collaboration Perspective
- Decision-Aid for Real-Time Railway Operation Control
- Autonomous Trains on Main Lines
- Global Certification for Innovative Product Development
- On-Board Monitoring for Vehicle/Infrastructure Diagnostics and CBM
- Integration of On-Board and Wayside Measurements with Virtual Methods Towards Safer, More Cost-Effective, Risk-Conscious and Innovation-Spurring Assessment Methods for Running-Dynamics
- Digital Technologies for Predictive Maintenance
- Maglev Systems
- Global Vision for Railway Development
- From Research to Benefits: How to Accelerate the Innovation Process

③ Oral and interactive poster sessions
- Improvement of Service Quality, Speed, Time to Destination, and Functionality
- Economics, Policy and Planning
- Sustainability
- Safety and Natural Hazard Management
- Rolling Stock
- Infrastructure
- Railway System Interface
- Maglev and New Transport Systems

An exhibition on railway technologies was also held.

126 companies and organizations supported WCRR 2019 as sponsors.

【Congress schedule and outline】

October 28

WCRR 2019 was started with the welcome reception

October 29

Opening remarks

Dr. Ikuo Watanabe, Chair of WCRR OGC

Welcome by RTRI

Dr. Norimichi Kumagai, Pesident of RTRI

Greetings

Mr. Nobuhide Minorikawa, State Minister of Land, Infrastructure, Transport and Tourism

Mr. Takashi Nakajima, Director, Bureau of Urban Development, Tokyo Metropolitan

Prof. Gianluigi Castelli, Chairman of UIC, Chairman of FS Group

Plenary session 1:
The Role of Railway Operators in Enhancing the Customer Experience
(Moderator: Professor Anson Jack, University of Birmingham)

From Japan, Mr. Masaki Ogata, Vice Chairman of JR East and Mr. Shun-ichi Kosuge, Executive Vice President of JR Central joined the discussion.

Mr. Ogata talked about “MaaS” (Mobility as a Service) system that JR East is building and pointed out open innovation, collaboration among operators and the first and last mile solution as the three key factors to realize “MaaS”. Mr. Ogata also encouraged the researchers attending to have a vision for the future when starting a development project.

Mr. Kosuge introduced the technical achievement by the mass high-speed transportation system, Shinkansen, and explained the progress in the construction of the superconducting Maglev line. He also stressed the necessity of more advanced and efficient operation and maintenance systems for the future.

October 30
Plenary session 2:
Contribution of Railway Suppliers to Elevating the Value of Railways
(Moderator: Mr. Nick Kingsley, Managing Editor of Railway Gazette International)

From Japan, Mr. Takao Nishiyama, President of the Japan Transport Engineering Company (J-TREC) joined the discussion.

Mr. Nishiyama said that, at J-TREC, the life-cycle cost has been reduced by thoroughly sharing platforms and the technologies and know-how of their parent company, JR East, have been integrated into their production systems. He referred as well to the importance of keeping good relationships with affiliated companies.

Gala dinner

About 800 people attended the gala dinner in the evening, where Mr. Kazuyosi Akaba, Minister of the Land, Infrastructure, Transport and Tourism, Dr. Eisuke Masada, Chairman of RTRI and other guests gave welcome greetings.

October 31
Plenary session 3:
Research and Development for Future Railways
(Moderator: Emeritus Professor Roderick Smith, Imperial College London)

From Japan, President Kumagai of RTRI joined the discussion and stated the following views:

•Digital technologies contributing to corporate profits are important.

•It is necessary to ensure sufficient research and development budget and produce quality outcomes.

•The development of condition-based maintenance technologies is a high-priority task for utilizing aging railway asset.

•We need to contribute to the society, having awareness that railways are a key player in the entire mobility.

Closing ceremony

The best paper awards and the young researcher award were given to an outstanding paper in each field. From among Japanese researchers, Mr. Hiroyuki Nakajima of JR East and Mr. Hirotake Noguchi of Tokyo Metro won the awards in the fields “Rolling Stock, Maglev and New Transport Systems” and “Infrastructure” respectively.

November 1
Technical visits

Eleven courses of technical visits to railway related facilities and construction sites were provided and the participants joined a tour of their preference. The technical visits included two courses to see the facilities of RTRI, one to visit RTRI and Railway Information Systems Co., Ltd. in Kunitachi and the other to RTRI’s Wind Tunnel Technical Center in Maibara and the Kyoto Railway Museum. 53 and 26 people joined the tours respectively.

【Next WCRR】

The next WCRR will be held in Birmingham, UK, in June 2022. At the closing ceremony, WCRR 2019 Organizing Committee Chairperson, Executive Vice President Watanabe of RTRI handed over the WCRR plaque to the next chairperson Ms. Luisa Moisio of RSSB, UK, and Professor Anson Jack of University of Birmingham.

Minister of the Land, Infrastructure, Transport and Tourism, Mr Kazuyoshi Akaba at the gala dinner

State Minister of Land, Infrastructure, Transport and Tourism, Mr. Nobuhide Minorikawa at the opening ceremony

UIC Chairman Prof. Gianluigi Castelli at the opening ceremony

Professor Anson Jack of University of Birmingham moderating the Plenary Session 1

Vice Chairman of JR East Mr. Masaki Ogata at Plenary Session 1

Executive Vice President of JR Central Mr. Shun-ichi Kosuge at Plenary Session 1

Managing Editor of Railway Gazette International Mr. Nick Kingsley moderating the Plenary Session 2

J-TREC President Mr. Takao Nishiyama at the Plenary Session 2

Emeritus Prof. Roderick Smith of Imperial College London moderating the Plenary Session 3

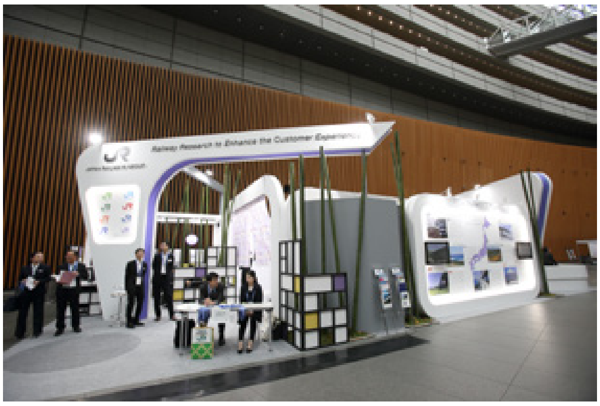
RTRI President Mr. Norimichi Kumagai
at Plenary Session 3

Organized Session

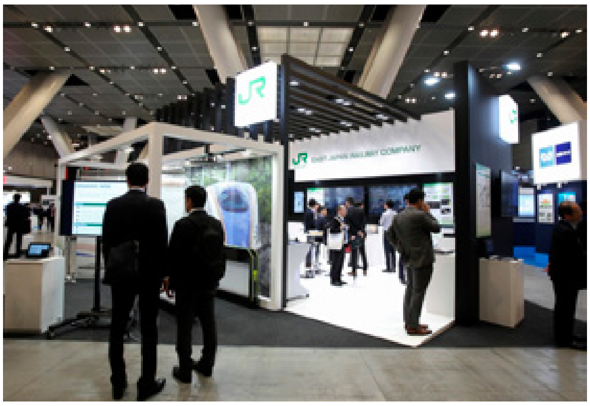
Oral Session

Interactive Poster Session

Exhibition with 126 domestic and overseas exhibitors



Exhibition booth by 8 JR group companies



Exhibition booth by JR East

Exhibition booth by 8 JR group companies

Exhibition booth by JR East

Technical visits

Participants on board the fuel cell hybrid powered test vehicle at RTRI

Participants listening to the explanation of the railway seat reservation system “MARS” at JR Systems

Closing Ceremony

Dr. Matthias Landgraf of Graz University of Technology (left) wins the best paper award

WCRR 2019 Organizing Committee Chair Watanabe delivers closing remarks

WCRR2019 Organizing and Executive Committee members

WCRR 2019 Organizing Committee Chair Watanabe
hands over the WCRR plaque to the representatives of UK, the host country of WCRR2022

9. The New Master Plan “RESEARCH 2025” Developed

The Railway Technical Research Institute developed a new master plan “RESEARCH 2025” for the five years starting 2020 as a concrete plan to fulfill RTRI’s vision “We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society”.

Master Plan - Research and Development Creating the Future of Railways - RESEARCH 2025

1. Introduction

We are facing increasingly complicated social issues including the global environmental problems, social impact of the aging population, and regional disparity of economy. Under such circumstances, “Sustainable Development Goals” (SDGs) were adopted by the United Nations in 2015. The Japanese government also proposed “Society 5.0” and the government has been addressing the goal of realizing a sustainable society where issues will be solved with state-of-the-art technologies and all the people can enjoy the benefit. Internet of Things (IoT), big data analysis and artificial intelligence (AI) have been enabled by the rapid advancement of computing technologies and high-speed, large-capacity communications technologies and they have been pushing forward the global-scale innovation toward digitalized society.

Since the Japanese economy is gradually recovering, the traffic volume of Japanese railways has been steadily increasing with an increasing number of inbound tourists. However, there is a concern that the number of railway users will decline in a longer term, due to declining total and productive-age population resulting from the decreasing number of children and aging population and diversified working patterns. Furthermore, railways are facing an urgent need to provide more effective solutions to the issues of extreme weather events, aging railway infrastructure and labor shortages. In addition, railways are expected to play an increasingly important role in creating the services that connect different transport modes seamlessly.

Railway researchers and engineers have been seeking to change railway systems drastically in order to address a number of issues by using digital technologies. It is also important that several organizations cooperate and share information to solve increasingly complicated technical issues.

Against such a background, RTRI developed a new master plan “RESEARCH 2025” for the five years starting 2020 as a concrete plan to fulfill RTRI’s vision. We need to look into the railway technologies in the decades ahead. At the same time, we are expected to provide the society with timely R&D outcomes that will be befitting the changing business environment and developing technologies. Therefore, the term of this master plan has been set to be 5 years until the fiscal year 2024.

2. Basic policies

Under the changing social and technological conditions, we will emphasize improving further safety of railways and enhancing resilience to extreme and frequent natural disasters. We will introduce digital technologies into all fields of research and development and innovate railway systems. We will produce high-quality research outcomes by pursuing excellence across all fields of activities and enhancing the global presence of Japanese railway technologies to promote further overseas development. The following are basic policies of RTRI’s activities.

(1) Enhancing safety with an emphasis on improving resilience to natural disasters

Research and development to further improve safety and stability of railway transport is essential. In particular, RTRI will be focusing on the research and development to enhance resilience to increasingly serious and frequent natural disasters such as heavy rainfall, strong wind and major earthquakes. We will also intensify the research and development to prevent failures of ground facilities and vehicles and to address aging of these facilities. We will conduct disasters and accidents investigations and propose restoration and prevention measures as an impartial third-party organization.

(2) Developing innovative railway systems based on digital technologies

RTRI will emphasize the research and development to introduce to railways digital technologies including IoT technology, big data analysis and AI combining advanced information processing and high-speed telecommunications network such as 5G. With the digitalization, we will develop labor-saving technologies such as autonomous train operation and digitalized maintenance in order to solve the labor shortage in railway operation. We will also promote research and development for the speed-increase on Shinkansen that will not damage the trackside environment and energy-saving railway operation. In addition, RTRI will start an endeavor to create new customer services such as MaaS (mobility as a service) and contribute to the innovation of railway systems.

(3) Creating high-quality research outcomes by pursuing excellence across all fields of activities

RTRI will continue the research and development for railways in the future, practical technologies to be quickly introduced to railway operation and basic research to analyze the phenomena specific to railways. We will further improve our simulation technologies and construct test and research facilities with originality. At the same time, we will continue to gather the know-how on railway technologies, develop human resources, address the issues on railways with cross-sectional teams and build trust through creating and providing high-quality research outcomes at home and abroad.

(4) Enhancing international presence of the Japanese railway technologies

We will seek to enhance international presence of the Japanese railway technologies through cooperation with overseas railway operators and research organizations and intensified information sharing. We will play a leading role in the strategic activities of international standardization to support overseas advancement of Japanese railways.

(5) Creating a work environment to help the employees develop their full potential and undertake challenging tasks

Respecting each of our personnel, we will develop researchers who are able to address the needs of railway operators and produce creative research outcomes from a global perspective. We will continue to improve safety and hygiene at workplace, pay attention to the mental health and work-life-balance of employees and provide a comfortable and open work environment where employees can be relaxed and proud of their work.

3. Activities of RTRI

RTRI will implement the following eight fields of activities for public-interest purposes:

- Research and development
- Investigation
- Technical Standard Services
- Information services
- Publishing and Training
- Diagnosis and Consulting
- International Standardization
- Qualifications

RTRI will also strategically and systematically promote the activities of the Railway Technology Promotion Center and Railway International Standards Center in coordination with rail-related engineers in other organizations and contribute to enhancing international presence of Japanese railway technologies. In addition, we will implement profit-making activities to promote the wide use of R&D results by railway companies.

【Research and development】

(1) Principles for research and development

① Enhancing safety with an emphasis on improving resilience to natural disasters

RTRI will focus on R&D to enhance safety. In particular, we will develop a system to evaluate the risks of natural disasters in real time and to support quick train operation control to ensure safety and early recovery by utilizing the weather and earthquake data measured by the advanced, high-density observation network of a public institution and our simulation technologies.

② Developing innovative railway systems based on digital technologies

RTRI will gather basic knowledge and knowhow on advanced information processing technologies and high-speed telecommunications network and send researchers to research organizations dedicated to each field on a long- and short-term basis. Through these efforts, we will develop research capability to fully utilize the most advanced digital technologies. We will outsource the research work that requires use of AI technologies.

③ Creating high-quality research outcomes by pursuing excellence across all fields of activities

RTRI will address basic research and development that will solve railway-specific issues and will be the source of innovative technologies and, at the same time, intensify the development of practical technologies having strong impact on actual railway operation. In particular, RTRI will increase the resource to be appropriated for the development of much-needed practical technologies.

RTRI will further strengthen collaborative relationships with universities, research institutes and companies at home and abroad and address railway technical issues with multidisciplinary approaches. RTRI will keep effectively providing quality research outcomes by using newly-constructed large-scale test facilities and further construct facilities with originality directly contributing to research and development.

(2) Goals and pillars of research and development

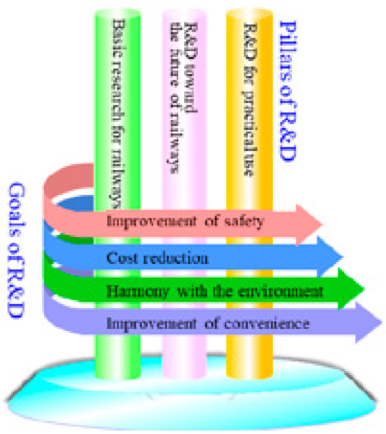
RTRI has set the following four goals of research and development:

"Improvement of safety" such as enhancing the resilience to natural disasters

"Cost reduction" such as labor saving in maintenance

"Harmony with the environment" such as low-carbon power feeding networks

"Improvement of convenience" such as further speed increase



Three pillars of research and development, "Research and development toward the future of railways", "Research and development of technology for practical use" and "Basic research for railways" have also been set in order to promote research and development effectively with efficient use of the resource.

(3) Research and development toward the future of railways

Aiming at introduction to commercial services within a few decades, RTRI will address the research topics needed by the society and railway operators. In particular, RTRI will put emphasis on the issues in the fields where RTRI has outstanding research capabilities and unique test facilities and the topics that require multidisciplinary approaches.

Research and development toward the future of railways

The following six research targets have been set:

- Enhancing resilience to extreme weather disasters
- Autonomous train operation
- Labor saving by digital maintenance
- Low-carbon power feeding networks by coordinated power control
- Speed increase on Shinkansen considering trackside environment
- Improving simulation technologies

(4) Research and development of technology for practical use

RTRI will develop technologies quickly effective for actual railway operation in order to provide railway companies with practical and timely solutions.

(5) Basic research for railways

RTRI will intensify basic research and development that will solve railway-specific issues and will be the source of innovative technologies. The topics for the basic research will be prediction of weather disasters, running stability of vehicles and improvement of trackside environment in the area of "Analysis and prediction of phenomena", the mechanism and inspection methods for deterioration and damage and human factors in "Building analysis, tests and assessment methods", and wear and service life extension and AI in "Introduction of new technologies, materials and research methods".

[International standards activities]

RTRI will strategically promote international standardization for railways in order to maintain and improve Japanese railway technologies and to support their advancement into overseas markets.

As a Japanese mirror committee of ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission), RTRI will propose draft railway standards from Japan and take the lead in reflecting Japanese design policy and technologies in the standards proposed by other countries. At the same time, RTRI will conduct research into the standardization activities by internationally influential railway-related organizations and take necessary actions. Together with related organizations, RTRI will also address the other issues regarding standardization which the Japanese railway sector is currently facing, including codifying Japanese technologies and knowhow and examining the certification scheme.

[International activities]

In order to enhance its technical capabilities and global presence, RTRI will expand joint research activities with overseas universities and research bodies, increase the number of researchers who will be sent abroad and improve the quality and quantity of the information that RTRI will globally share. RTRI will also boost the speed and quality of its research activities through intensifying investigations of the latest overseas research trends and accepting a larger number of visiting researchers from overseas. RTRI will continue its contribution to developing Japanese railway technologies to overseas markets. For this purpose, RTRI will support railway operators and related companies to advance into overseas markets, help their human development and promote overseas development of RTRI's technologies.

4. Management of RTRI

Observing Japanese laws and regulations and its articles of incorporation as a public-interest corporation, RTRI will seek sound and fair management.

[Compliance with laws, rules and ethical codes and concepts]

RTRI will provide educational programs and on-the-job training regularly in order to raise the employees' awareness of work ethics and to ensure their compliance with laws, rules and ethical codes and concepts.

[Information control]

RTRI will strictly control the research and development information and others and implement more strict security measures for information management and sharing.

[Personnel management]

(1) Recruitment

RTRI needs to recruit researchers and engineers necessary for the research and development in the fields of particular significance in a medium- and long-term perspective. For this goal, RTRI will enhance the awareness and deepen the understanding of RTRI's research activities by researchers and students through the efforts of strengthening the collaborative relationships with universities and other research bodies and promoting internship programs. RTRI will continue recruiting researchers regularly in order to maintain technical continuity.

RTRI will diversify the way of recruitment and recruit mid-career experts so that it can employ outstanding experts in the state-of-the-art technologies such as digital technologies and advanced simulation.

(2) Human resources development

RTRI will develop researchers capable of inheriting the technologies that have been accumulated over years at RTRI, responding the needs of railway operators and promoting original and creative research and development. For this purpose, RTRI will improve on-the-job training and educational programs designed for each job level from newly-recruited employees to management people. The personnel exchange programs with JR group and other companies will be further expanded to management-level employees as well as younger employees.

Researchers will also be sent to research organizations dedicated to the most advanced technical fields such as digitalization in a short- and long-term basis. RTRI will further promote joint studies and personnel exchange with overseas universities and research bodies in order to develop the personnel who will be able to contribute to enhancing the international presence of Japanese railway technologies from a global perspective.

Researchers will be strongly recommended to obtain doctoral degrees and the certification of the professional engineer and to actively join the activities of academic associations in order to develop their own research abilities, gain expertise and enhance the presence of RTRI.

(3) Work environment that provides employees a sense of achievement

RTRI will make the workplace safer and more hygienic, care about the mental health of employees, and support the reform of working practices and nurturing the next generation people. Furthermore, RTRI will create the work environment where they can choose work styles flexibly and pursue their tasks without worry, enjoying mental and physical health.

RTRI will provide a work environment where the researchers of wide-ranging technical fields will be able to have candid discussions beyond the difference between generations and job positions, and all the employees will be highly motivated and satisfied with their work.

5. Concluding remark

We will have to address immediately the issues of unprecedented weather disasters and the serious labor shortage due to declining working-age population. However, it is difficult to solve these problems within the current framework.

In order to solve them, technological innovation is indispensable. RTRI will take a leading role in railway technical innovation and pursue the research and development to solve the challenging issues that railways are facing, build a sustainable society and create the future of railways in cooperation with railway operators, research bodies and related companies.

RTRI will accumulate know-how on railway technologies, conduct accident and disaster investigations and propose restoration and prevention measures as an impartial third-party organization.

RTRI will strictly observe laws, regulations and articles of incorporation and further enhance the credibility of RTRI. Since RTRI does not own railway tracks and facilities for commercial services, it will promote personnel exchange with railway operators more actively in order to develop researchers who have a good understanding of actual train operation and its issues and to steadily pass on the technologies to younger generations.

RTRI will implement “Master Plan - Research and Development Creating the Future of Railways -RESEARCH 2025” based on its vision “We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society”.

For more details on RESEARCH 2025, please refer to the Appendix to this report.

10. Safety Education Program for Maintenance Work within Track Area Using VR Training Material (STAT-VR)

The Railway Technical Research Institute developed a safety education program using a virtual reality training material STAT-VR (Safety Training Aid for Trackman) that provides virtual experience of the processes leading to accidents that occur during maintenance work within track.

【Overview of the program】

This program provides two tasks to participants, training with virtual-reality material STAT-VR (Fig.1) and “case transer exercise” that enable participants reflect on how the processes leading to an accident could apply on their own workplace. (Fig. 2)

STAT-VR

Using STAT-VR, participants are able to experience how an accident occurs and raise safety awareness through implementing maintenance work as a team leader in the virtual space. (Fig. 1) With this virtual-reality material, the participant can learn the limit of human attentiveness (when focusing on the maintenance work, attention to approaching trains is distracted) and the importance of early evacuation (If not evacuate earlier, it may lead to an accident).

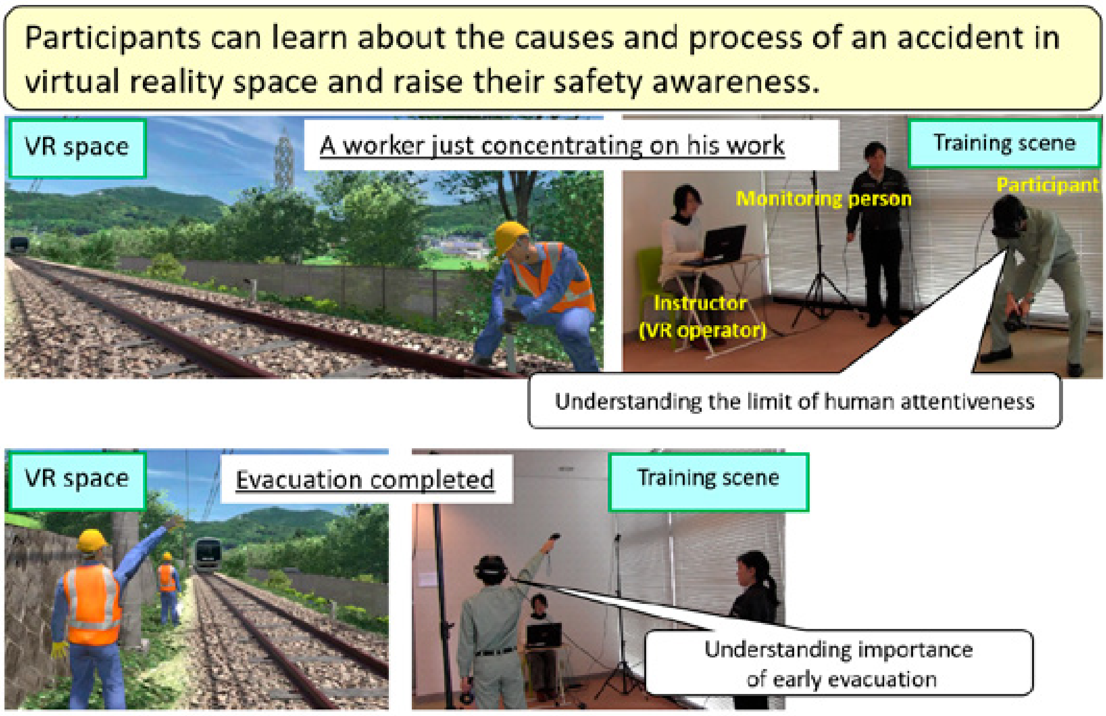


Figure 1: Training with STAT-VR

【Case Transfer Exercise】

In case transer exercise, the participants fill in a work-sheet and have group discussions on specific measures to behave safely, applying the example of an accident caused by delayed evacuation in other workplace to their own work scene. Through the discussions, participants can deepen their understandings of the process of the accident and necessary measures.

After taking this training program, it was found that an increasing number of maintenance workers behave more safely. In particular, the participants are highly satisfied with the training with virtual-reality material and 96% of them rated "There is reality".

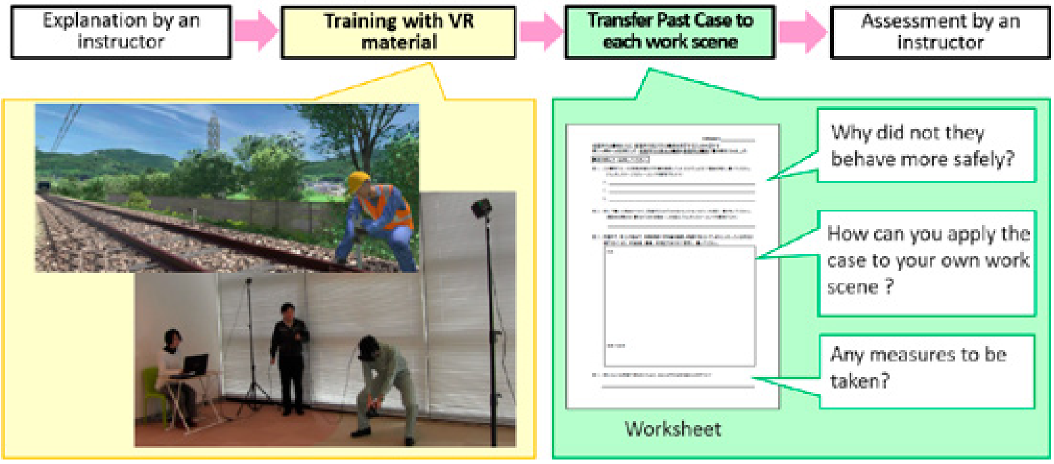


Figure 2: Steps of the safety education program

【Background of development】

RTRI has analyzed accidents that occurred during the maintenance work for track and electrical installations and conducted an opinion survey of maintenance staff. According to the results of them, we have found that it is necessary to provide the staff with the opportunities to learn about causes and processes of accidents triggered by unsafe behaviors as well as about scary results and impacts by accidents in order to further encourage them to make best efforts to ensure their safety during the work within track. (Fig.3)

This is the reason why RTRI has developed a new safety education program to learn about the process of accidents. (Fig.2)

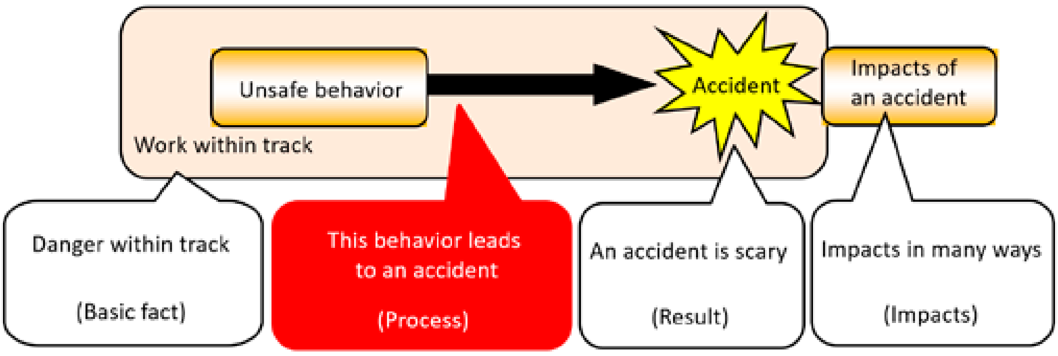


Figure 3: The progress of a situation when an accident occurs

11. Integrated Tread Surface Conditioning Block to Reduce Wheel-Flange Wear Developed

The Railway Technical Research Institute developed dual-function integrated tread surface conditioning block to keep proper wheel surface conditions by enhancing rail-wheel adhesion* while reducing reduce flange wear.

* Adhesion: Friction between wheel and rail. Trains can be accelerated or decelerated by this adhesive force.

【Background of development】

Train wheels have two areas, tread to keep rolling with rail head constantly {(A) in Fig. 1} and flange to prevent derailment on curves. {(B) in Fig. 1} Wheel tread needs to have proper roughness to prevent skidding and sliding (adhesion). Meanwhile the flange is required to have lower frictional coefficient in order to reduce rail and wheel wear (lubricity), as it contacts with rail while the train is running on curves.

Currently, two separate devices, tread abrasive (① in Fig. 2) and flange lubricators are used to improve two different properties of wheels, adhesion of tread and lubricity of the flange. (② in Fig.2). Instead of using two devices, RTRI's team led by the Frictional Materials Laboratory has developed the integrated tread surface conditioning block capable of improving both properties as a single device (Fig.1)

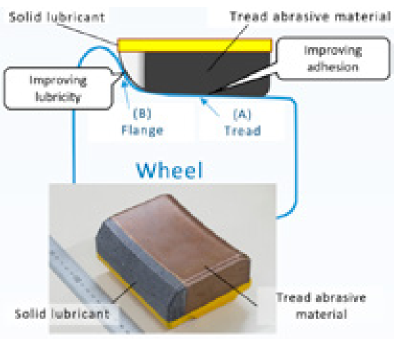


Figure 1: Integrated tread surface conditioning block

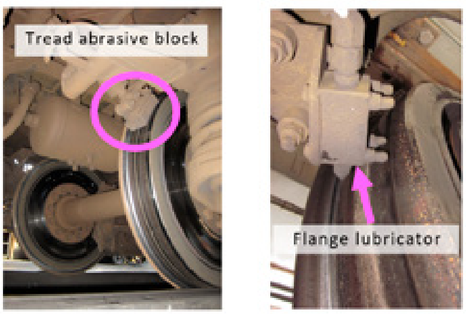


Figure 2: Current tread abrasive and flange lubricators

【Characteristics of the integrated tread surface conditioning block】

RTRI has developed the solid lubricant with the same base material, thermosetting resin, as current abrasive block in order to integrate solid lubricant and abrasive block into one device. The lubricity of the integrated conditioning block is mainly attributed to MoS2. The properties of the developed block are as follows:

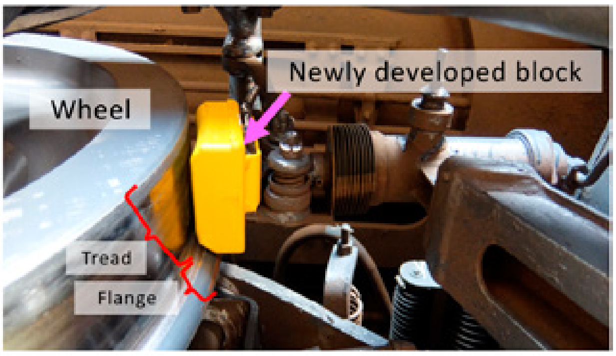


Figure 3: Newly developed block mounted on a truck

- The block can increase both lubricity of the flange and adhesion of the wheel tread at one time.
- Since the fittings of the developed block has the same dimension and structure as that of the current abrasive block, they are interchangeable.
- Since the block has almost the same durability for wear as does the current abrasive block, the replacement period will remain unchanged. In addition, the current flange lubricator will not be necessary any more.
- The joint surface between the solid lubricant and abrasive material could be a weak spot in terms of durability. But it meets the standard value of impact strength for tread abrasive block (2.0kJ/m2).

【Advantages of the integrated tread surface conditioning block】

The developed block was mounted to an express tilting train whose wheel flange tends to wear rather rapidly and running tests were conducted in order to confirm its lubricity and effect on adhesion. The current abrasive block and the newly-developed block were mounted to the same type of trains and the flange wear rates (amount of flange wear per 10,000 km of running distance) were compared. The wear rate of the vehicle with the newly-developed block is 45% lower than that of the vehicle with current abrasive block (without flange lubricator) and the lubricating performance of the block was confirmed. (Fig.4) If train wheels skid during running due to lowered wheel/rail adhesion, wheel damage called "flat" is likely to occur. Since the wheel flat was not found on the wheels of the block-mounted test vehicle after the test running, it is also confirmed that the developed block has the same level of performance to keep adhesion as that of the current device.

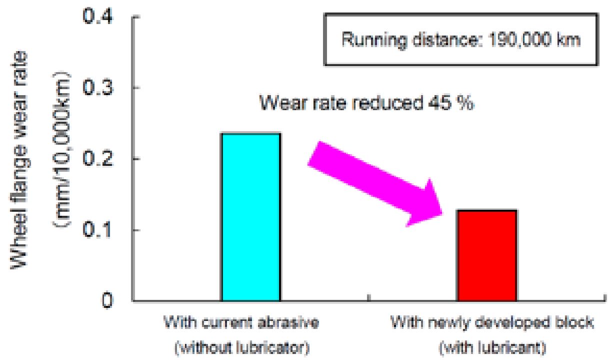


Figure 4: Reduced flange wear rate by the developed block

It is expected that vehicle and rail maintenance work will be reduced by mounting this block to vehicles. This product has already been mounted to some of commercial-service vehicles (Series 883 and 885 of the Kyushu Railway Company) for the test purpose.

【Patent filing】

RTRI has filed patent applications on part of the technologies used for the block jointly with Ueda Brake K.K.

Appendix

Master Plan

- Research and Development for Creating the Future of Railways -

RESEARCH 2025

(2020–2024)

December 2019

Railway Technical Research Institute

Master Plan

Contents

1. Introduction

In light of global environmental issues, increasing societal burdens due to the aging population, and the increasing complexity of social issues that need to be resolved such as regional economic inequality, the United Nations adopted a series of targets entitled the "Sustainable Development Goals" (SDGs). The Japanese government is advocating the construction of a "Society 5.0", which outlines a vision of society in the future that Japan should aspire to. As such, initiatives and programs have been launched or are planned, aimed at building a sustainable society, which is capable of overcoming the various challenges that lie ahead by using cutting-edge technology, enabling everyone to enjoy the benefits of prosperity. In the field of technology, rapid advances in computing and high-speed, high-capacity communications are driving innovation toward a digital society on a global scale, through the adoption of digital technologies such as the Internet of Things (IoT), big data analytics, and artificial intelligence (AI).

In terms of Japan's railways, while transport volumes are steadily increasing due to factors such as the gradual recovery of the Japanese economy and a growth in inbound demand, there are concerns that the number of railway users will decrease in the long term because of the country's decreasing overall population and working-age population, which are the result of an aging society with a low birth rate and also the consequence of new working practices that have emerged through workstyle reforms. Moreover, there is an urgent need to address a growing number of issues: increasingly frequent and severe natural disasters such as heavy rain, strong winds, and earthquakes, an aging railway infrastructure, and labor shortages in the railway sector. The response to these issues must go beyond the framework of conventional approaches. Railways are also playing an increasingly important role in the creation of new services to build a seamless intermodal transportation network.

Digital technology is being increasingly used in the railways, to change systems and as a solution to various problems. As such, it is essential to form partnerships with relevant organizations and share information to solve increasingly complex technical problems.

RTRI has therefore developed a master plan for the fiscal year 2020 and beyond, as a roadmap guiding the Railway Technical Research Institute (RTRI) towards the realization of its vision: "We will develop innovative technologies to enhance the rail mode so that railway can contribute to the creation of a happier society." In addition to anticipating the development of railway technologies over the next 10 to 15 years, this master plan also aims to anticipate changes in the business environment and fundamental technological developments in the railway business in order to avoid squandering the opportunity of sharing the results of its research and development (R&D) with society. The master plan therefore covers a 5-year period up to 2024.

2. Basic Policies

In light of the changes in society and technology and advances in R&D, along with efforts to further improve the safety of railways with a particular emphasis on improving the resilience of the railways against frequent and increasingly severe natural disasters, RTRI is actively encouraging the adoption of digital technologies in all fields of R&D, with a view to stimulating innovation with regard to railway systems. In addition to obtaining high-quality R&D results that demonstrate the competence and expertise of our Institute, we are increasing the visibility of Japanese railway technologies on the international stage, in order to drive the development of railways on a global scale.

In order to realize these objectives, future undertakings will be based on the following fundamental guidelines:

(1) Enhancing safety with an emphasis on improving resilience to natural disasters

R&D that contributes to safer and more reliable railway transportation is essential, and we are placing particular emphasis on R&D that contributes to increasing the resilience of railways to frequent and increasingly severe natural disasters such as heavy rain, strong winds, and large earthquakes. In addition, we are also actively conducting R&D for preventing the failure and aging of ground and vehicular equipment.

We will also actively conduct impartial activities as a third-party organization such as conducting surveys of the damage and causes of disasters and accidents and proposing methods for recovery and measures to prevent recurrence.

(2) Developing innovative railway systems based on digital technologies

While advocating the adoption for railways of digital technologies such as IoT, big data analytics, and AI, which combine high-speed information processing with high-speed, high-capacity networks such as 5G, we will also place emphasis on R&D for labor-saving technologies, such as the autonomous train operation and digital maintenance, in order to respond to labor-shortages in the railway sector. In addition, we will promote R&D that contributes to increasing the speed of high-speed trains while protecting the trackside environment and finding ways to help the railways save more energy. In addition, we will promote initiatives that contribute to the creation of new customer services such as mobility as a service (MaaS) and innovation in railway systems.

(3) Creating high-quality results by taking advantage of our collective strength

We will promote research and development for the future of the railways, the development of practical technologies that can yield immediate benefits for railway businesses, and basic research for understanding railway-specific phenomena. In addition, we will promote the advancement of simulation technology and the development of original testing and research facilities. We also aim to further increase trust in RTRI by continuing to acquire know-how relating to railway technologies and the development of human resources, using interdisciplinary and cross-cutting approaches for resolving various issues in the railways, and realizing high-quality results and disseminating them both in Japan and internationally.

(4) Enhancing international presence of the Japanese railway technologies

Through partnerships with foreign railway operators and research institutions and strengthening information sharing, we aim to increase the international presence of Japanese railway technologies. In addition, as a base for international standardization activities to support overseas development, we will perform strategic and planned activities that demonstrate leadership.

(5) Creating a motivating workplace where staff can demonstrate their abilities

Based on the recognition that each individual staff member is a valuable human resource, we will train researchers that are able to respond to the needs of railway operators, hold a global perspective, and can creatively drive R&D. In addition to initiatives for workplace health and safety, mental health, and ensuring a proper work-life-balance, we will work to foster an open workplace environment where free and energetic discussions can be held, to create a positive and fulfilling workplace atmosphere.

3. Business activities

RTRI's business activities which serve the public interest fall into eight areas: R&D, surveys, technical standards, information services, publishing and seminars, diagnostic advisory, international standards, and qualification. In addition, we will strategically and systematically promote the activities of the Railway Technology Promotion Center and Railway International Standards Center operated in partnership with other parties involved in railway technology, as well as activities to increase the international presence of Japanese railway technology. At the same time, we will actively advance the commercialization of the results of R&D and promote for-profit projects, necessary for their widespread adoption.

3.1 Public interest activities

3.1.1 Research and development

(1) Advancing R&D

1. Enhancing safety with an emphasis on improving resilience to natural disasters

With an emphasis on R&D that contributes to improving safety, particularly as a response to intensifying natural disasters, we are actively using high-accuracy meteorological and seismic information obtained from state-of-the-art observation networks belonging to public institutions along with simulation technology to evaluate disaster risk in real time, thereby re-enforcing the contribution of R&D to safe and prompt train operation control and early recovery.

2. Developing innovative railway systems based on digital technologies

In addition to accumulating fundamental knowledge and know-how relating to advanced information processing and high-speed communication networks, RTRI seconds staff to specialized research institutions either on a short or long-term basis, to fully realize potential synergies in cutting-edge digital technologies for promoting R&D. We also actively employ external expertise in the field of AI.

3. Creating high-quality results by taking advantage of our collective strength

In addition to actively addressing basic research linked to solving various problems that are specific to the railways and as a source of innovative technology, we will drive high-impact, challenging R&D, implementing original ideas which could have potentially high impact on railway operations, as well as promote the bolstering of resources required for practical technological developments that are in high demand in the railways. In addition to strengthening initiatives such as joint research among universities in Japan and overseas, research institutes, and relevant companies, we aim to find new solutions to different railway technology issues through more cross-cutting projects. In addition, new large-scale testing facilities will be used effectively to produce high-quality results. Furthermore, a creative new test facility that is directly linked to R&D will be established.

(2) R&D Objectives and pillars

RTRI has set four R&D Objectives, namely, “safety improvements” including resilience against severe natural disasters, “cost reduction” including labor-saving measures for maintenance, “harmony with the environment”, including carbon reduction in power supply networks, and “improved convenience’ including higher running speeds.

RTRI has also defined a series of “Pillars of R&D” which are fundamental to ensure efficient use of resources and to drive R&D, and are referred to as "R&D for the future of railways", "development of practical technologies", and "basic research for railway" (Figure 3-1).

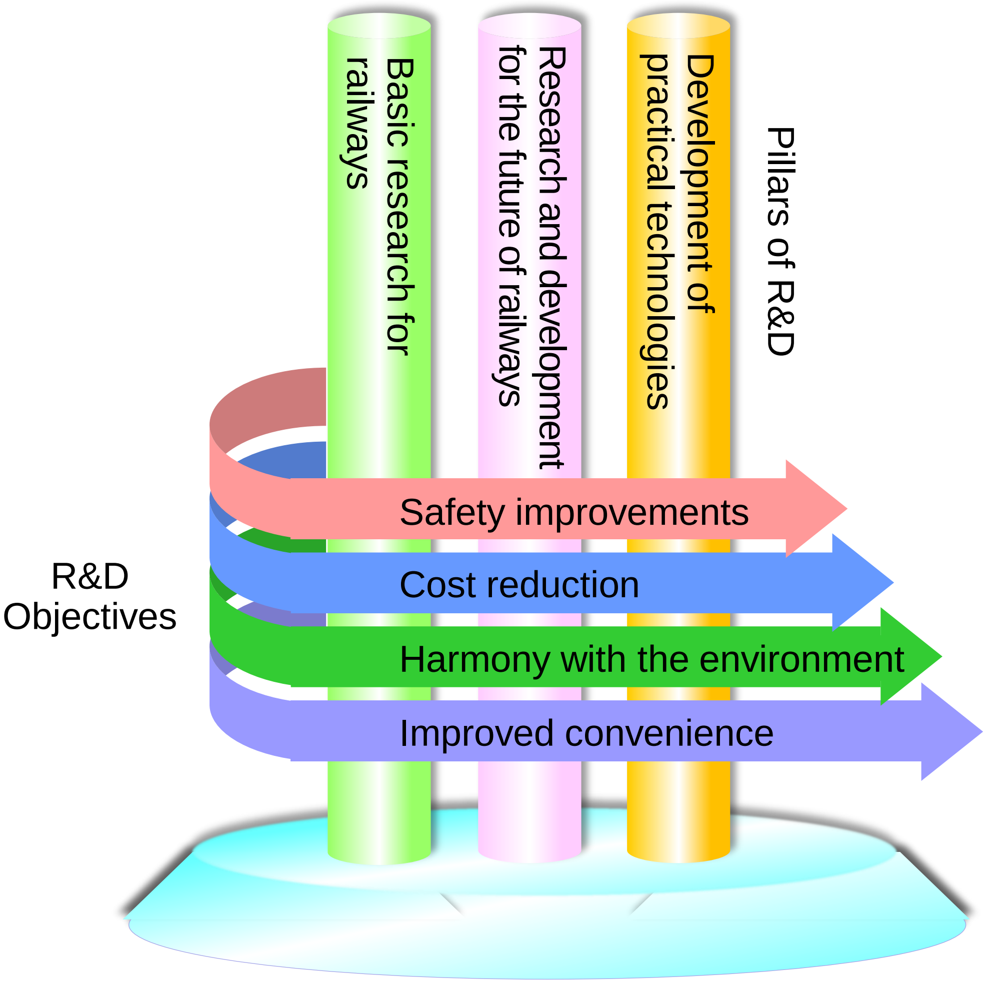


Figure 3-1. R&D objectives and pillars

(3) Research and development for the future of railways

Working with a lead time before practical application of 10 to 15 years, RTRI is already focusing on issues that address the changing needs of railway operators and emerging social trends, making use of the fields in which RTRI has high R&D capability and specialist facilities, as well as demonstrating the collective strength of RTRI.

The following six major research themes have been specifically defined (Figure 3-2):

○ Enhancing the resiliency of railway systems against severe meteorological disaster
○ Autonomous train operation and control
○ Improving labor efficiency using digital technology
○ Low-carbonization of electric railway systems through cooperative control of the power network
○ Increasing Shinkansen train running speeds in harmony with the trackside environment
○ Sophistication of simulation technology

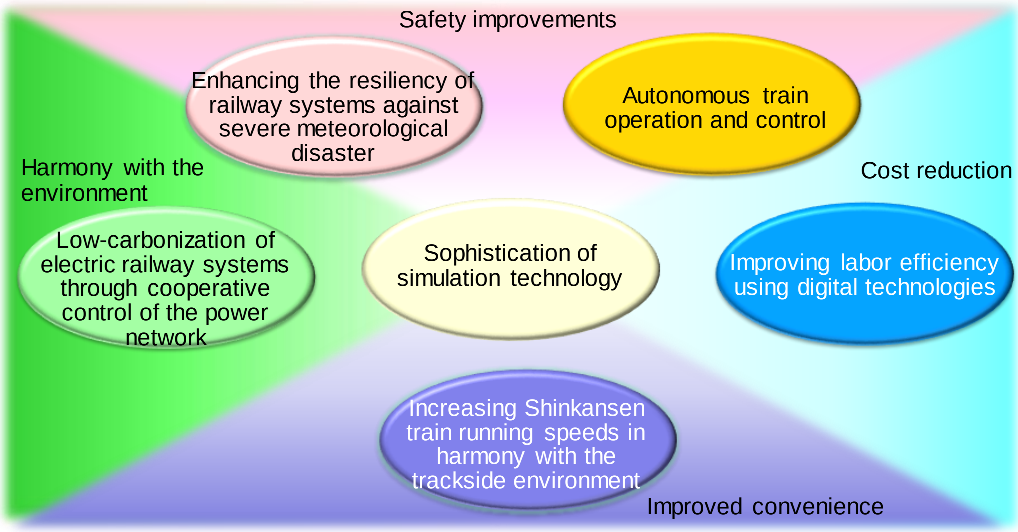
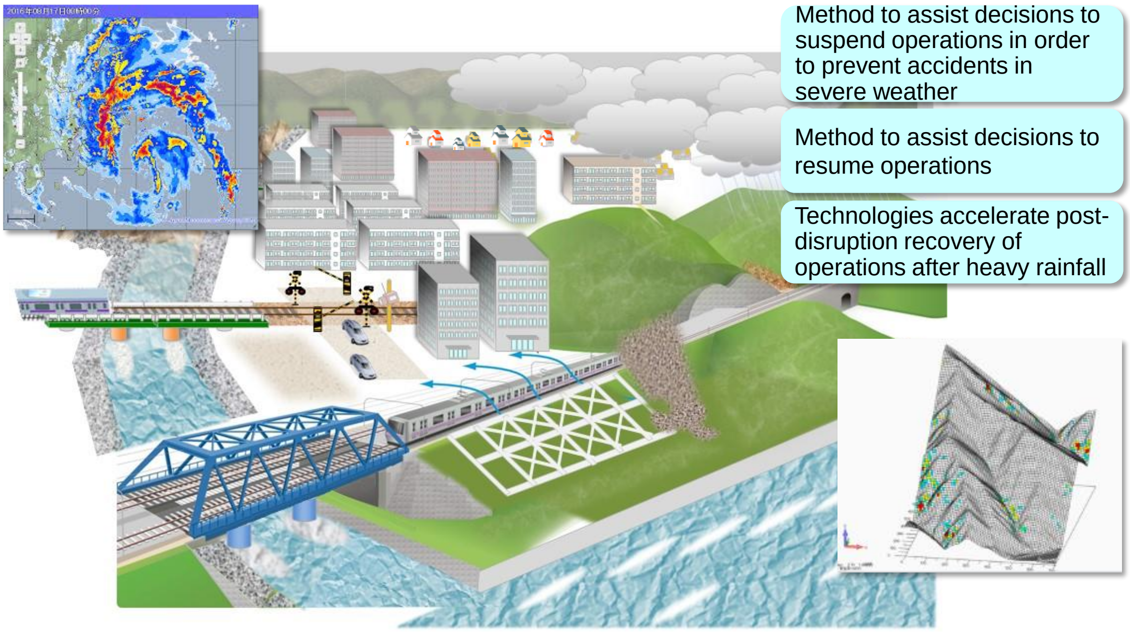


Figure 3-2 Research and development for the future of railways

○ Enhancing the resilience of railway systems against severe meteorological disasters

RTRI will aim to design measures to reduce the downtime in railway systems in the case of heavy rain and strong wind, by optimizing decisions to suspend and resume operations, based on results of meteorological disaster risk assessments using high-density and real time meteorological data. We will also establish methods to ensure rapid and targeted repairs considering the residual strength of slopes and embankments which suffer damage from heavy rain (Figure 3-3).

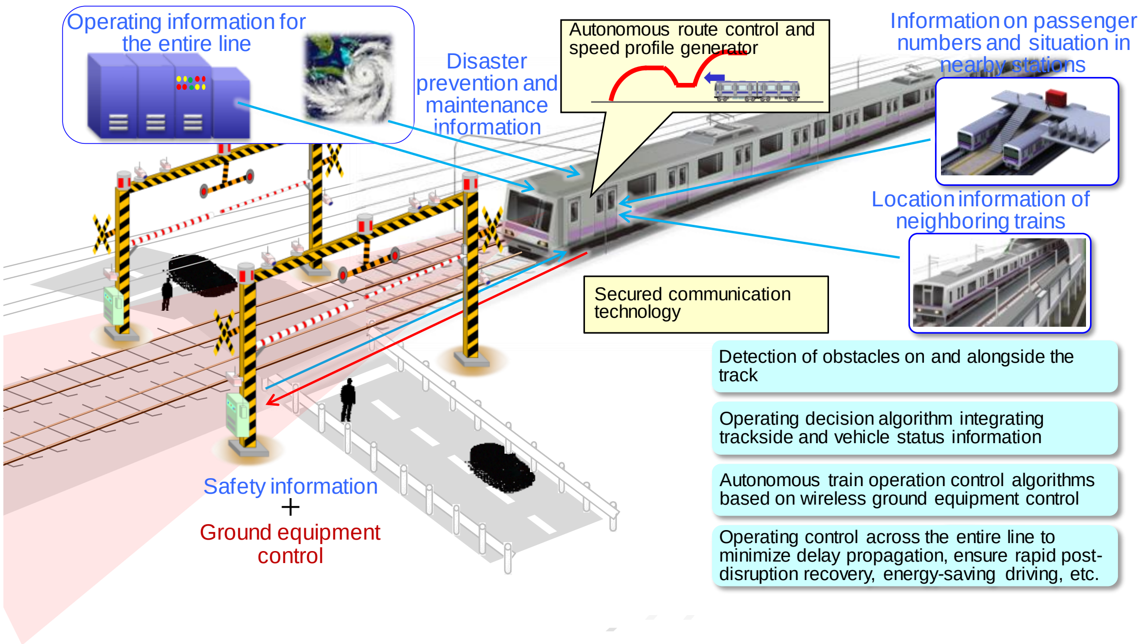


Topic	2020	2021	2022	2023	2024	Expected result
Enhancement of methods to assist decisions to suspend operation in order to prevent the accident in severe weather	Method for selecting representative sites for stability assessments in case of heavy rain Real-time strong wind hazard map			Method for assisting decisions to suspend operations in case of heavy rain and strong winds		Real-time hazard map in case of heavy rain or strong winds Method to assist decisions to suspend operations
Enhancement of methods to assist decisions to resume operations	Method for assessing slope-stability recovery progress after heavy rain Method for deciding when to resume operations after strong winds			Method for deciding when to resume operations following heavy rain and high winds		Method to assist decisions to resume operations
Development of technology to allow prompt restoration work following damage caused by heavy rain	Methods for assessing facility restoration			Temporary safeguarding measures according to scale of embankment or slope collapse		Method for assessing damaged embankments for restoration Manual of proactive and reactive measures

Figure 3-3. Overview of "Enhancing the resilience of railway systems against severe meteorological disasters"

○ Autonomous train operation and control

Autonomous train operation depends on a number of control systems including speed control, monitoring of track status and the surrounding area and ground equipment control, such as level crossings. RTRI is therefore developing methods to assist operational decisions, based on trackside information and data obtained from ground equipment controls, and from rolling stock using wireless vehicle-mounted positioning sensors, as well as satellite positioning devices and sensors to detect obstacles on the tracks or in the surrounding area. In addition, operation control methods are also being developed to prevent delays, ensure rapid post-disruption recovery, and save energy in urban areas (Figure 3-4).

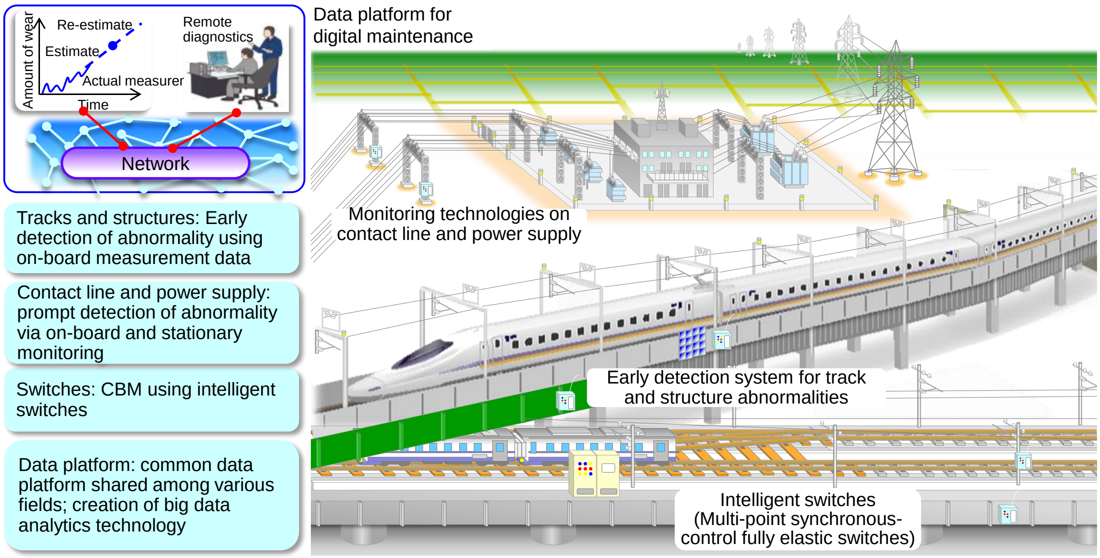


Topic	2020	2021	2022	2023	2024	Expected result
Development of track and trackside obstacle detection methods	Technology for the detection of obstacles on and alongside the track			On-track anomaly detection system		Method to detect obstacles on the track ahead
Creation of operating decision algorithms	Operating risk assessment methods	Operating decision algorithms		Autonomous train operation control system		Operating decision methods
Development of autonomous operation decision algorithms	Autonomous ground installation control methods; Real-time inter-train communication technology		Autonomous operation control algorithms			Autonomous operating control methods
Development of operating control methods for the entire line section	Methods for multidimensional evaluation of train operation	Operation management algorithms for autonomous train operation				Methods for controlling operations along entire line sections

Figure 3-4. An overview of "Autonomous train operation and control"

○ Improving labor efficiency using digital technologies

A platform will be built to integrate the analysis of data collected from various sources which can be input to a digital maintenance system that detects abnormalities and predicts changes in the condition of tracks and structures based on the data obtained from sensors. The system will be able to determine when and what appropriate repair or maintenance work is required. The integrated data analysis platform will also be used to develop automatic diagnostic technologies for track and structures, using on-board sensing devices including on-board sensors for the overhead contact line system. In addition, technologies will be developed for the timely detection of abnormalities, such as high-resistance ground faults, by monitoring power supply networks (Figure 3-5).

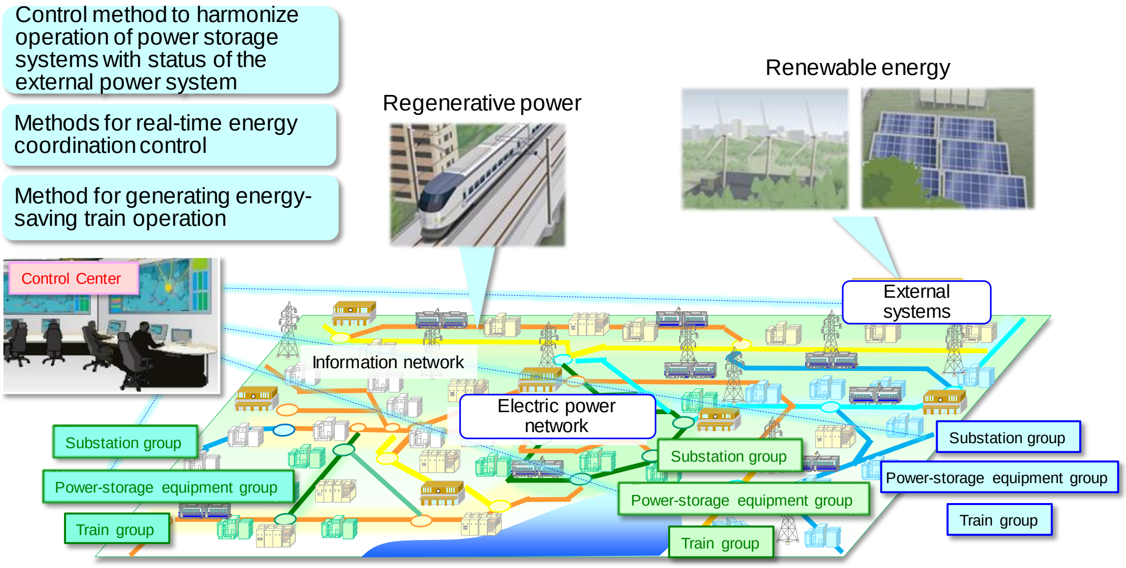


Topic	2020	2021	2022	2023	2024	Expected result
Development of track and structure condition-monitoring technology	Method for the early detection of track and structure abnormalities		Early detection system for track and structure abnormalities			Early track and structures abnormality-detection system
Fabrication of technology for monitor power-equipment status	Technology for monitoring train line equipment and condition of power equipment		Technology to detect and mitigate a damage in power collection system Method for early detection of abnormalities using power network monitoring		Digital data platforms	Technology for monitoring power-equipment condition
Development of low-maintenance switches	Basic specifications for intelligent switches			Basic configuration of intelligent switches		Multi-point synchronous-control fully elastic switches
Developing technology for the sharing and use of digital data	Basic technology for data analysis and evaluation Construction of data servers and data collection					Data platform for digital maintenance

Figure 3-5. An overview of "Improving labor efficiency using digital technologies"

○ Low-carbonization of electric railway systems through cooperative control of the power network

To achieve low-carbonization of railway systems through active use of renewable energy connected to the external power system, we will develop new control methods to harmonize operation of energy storage systems with status of the external power system. Furthermore, in order to achieve further energy-saving of railway systems through more effective use of regenerative power, we will develop real-time cooperative control methods for energy-saving devices, such as energy storage systems and controlled rectifiers, as well as developing a method for energy-saving driving operation depending on train operating status (Figure 3-6).

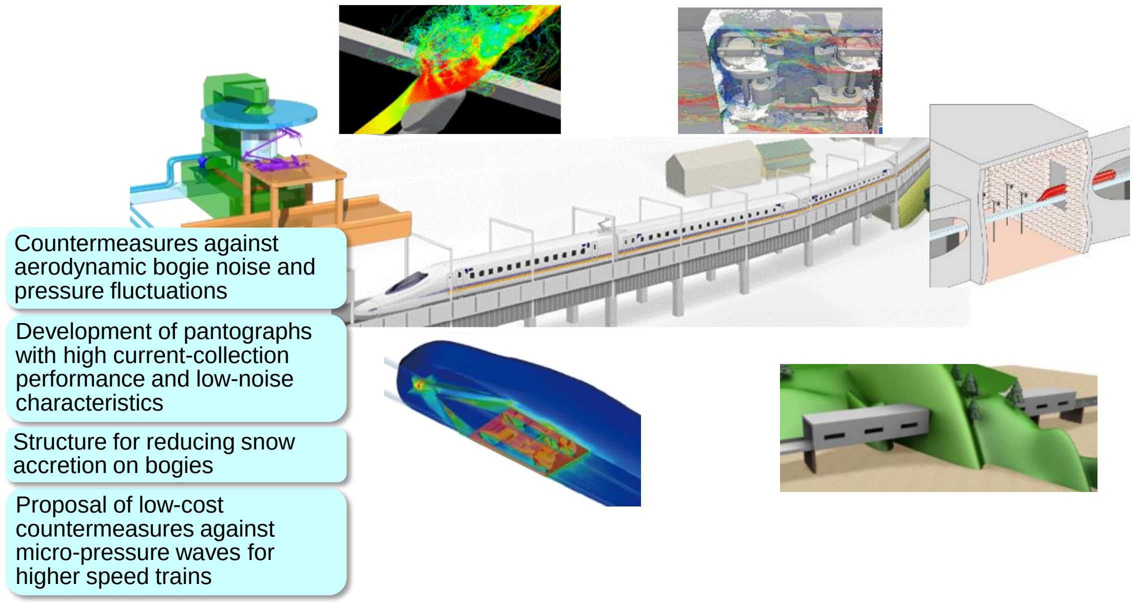


Topic	2020	2021	2022	2023	2024	Expected result
Effective use of renewable energy	Control method for energy storage systems			Control method to harmonize operation of power storage systems with status of the external power system		Control method to harmonize operation of power storage systems with status of the external power system
Efficient use of regenerative power			Real-time cooperative control method for energy-saving devices			Real-time cooperative control method for energy-saving devices
Development of dynamic energy-saving driving operation method		Derivation method of energy-saving train schedule considering usefulness for passengers				Method for generating energy-saving train operation
	Dynamic energy-saving driving operation method					

Figure 3-6. Overview of "Low-carbonization of electric railway systems through cooperative control of the power network"

○ Increasing Shinkansen train running speeds in harmony with the trackside environment

We will develop technologies for reducing aerodynamic bogie noise and tunnel micro-pressure waves by using a newly installed low-noise moving model facility. We will also develop a pantograph with high current collection performance and low-noise characteristics for high-speed trains by using RTRI’s new high-speed pantograph test facility. Furthermore, we will develop a technology for reducing snow accretion on bogies by controlling the airflow around bogies during high-speed train operation (Figure 3-7).

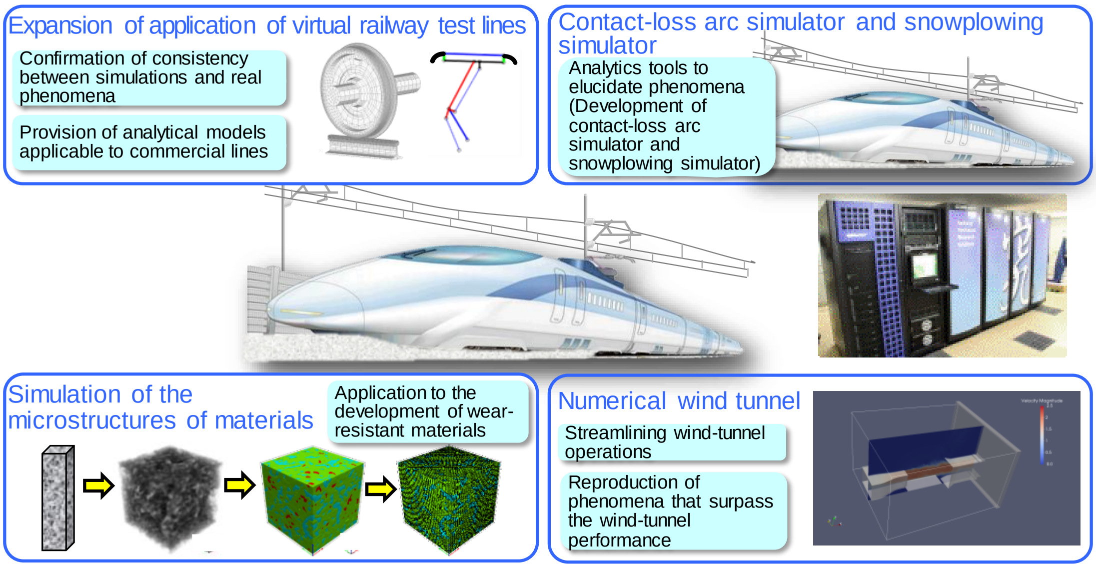


Topic	2020	2021	2022	2023	2024	Expected result
Development of countermeasures against aerodynamic bogie noise and pressure fluctuations	Estimation of contribution of noise sources to wayside noise (2020–2021) →		Prediction and evaluation of wayside noise generated by higher train speeds (2022–2024)			Measures for reducing aerodynamic bogie noise and pressure fluctuations
	Measures for reducing aerodynamic bogie noise and pressure fluctuations (2020–2022) →			Technology for reducing noise and pressure fluctuations (2023–2024)		
Development of measures for reducing pantograph noise	High current collection performance and low noise pantograph (2020–2022)					High current collection performance and low noise pantograph
Development of measures for reducing snow accretion on bogies in extremely cold regions		Measures for reducing snow accretion on bogies using air flow control (2021–2023)				Structures for reducing snow accretion on bogies
			Risk assessment of accreted snow dropping from Shinkansen bogies (2022–2024)			
Proposal of countermeasures against micro-pressure waves	Cost-reduction of countermeasures against micro-pressure waves (2020–2022) →			Extension of application range of countermeasures against micro-pressure waves (2023–2024)		Low-cost countermeasures against micro-pressure waves

Figure 3-7. Overview of "Increasing Shinkansen train running speeds in harmony with the trackside environment"

○ Sophistication of simulation technology

We will create an analysis model that is applicable to commercial railway lines and that comprises a virtual railway test line which simulates vehicle motion, overhead lines, pantographs, and rolling contact between wheels and rails. We will also develop a simulator that evaluates the state of wear of current-collecting materials when contact loss arcing occurs on pantograph and that evaluates the safety of vehicles operating at high speed while also self-snowplowing. Furthermore, we will develop a microstructural simulation of materials that can contribute to the development of wear-resistant materials and a numerical wind tunnel that simulates large-scale, low-noise wind tunnel experiments using numerical calculations (Figure 3-8).



Topic	2020	2021	2022	2023	2024	Expected result
Expansion of application of virtual railway test lines	Improved consistency between the simulator and real phenomena →			Practicality verification using an analytic model applicable to commercial lines		Analytics models applicable to commercial lines
Development of contact-loss arc simulator and snowplowing simulator	Method for coupled analysis of snowplowing and vehicle dynamics → ; Elucidation of contact-loss arc phenomena →	Contact-loss arc simulator →				Contact-loss arc simulator and snowplowing simulator
Development of methods for simulating the microscopic structure of materials		Microstructural simulations →		Application to the development of wear-resistant materials		Efficient development methods for wear-resistant materials
Creation of numerical wind-tunnel technologies	Development of constituent technologies →			Scale-up and expansion of functions		Numerical wind tunnel

Figure 3-8. Overview of "Sophistication of simulation technology"

(4) Development of practical technologies

In order to provide timely practical results, we are addressing topics with immediate relevance to the railway business (Table 3-1).

1. Technical developments requested by Japan Railway (JR) companies

Upon receiving a specific request, we will rapidly provide technological development results that contribute to the resolution of issues at various sites while taking into consideration specific local features such as cold regions. Particularly, we will focus on the allocation of resources to issues that are considered to produce a strong ripple-effect when commercialized and are greatly needed among railway operators and promote their commercialization.

2. Development of practical technologies implemented independently by RTRI

By fully understanding the needs of railway operators and using the facilities, analytic technology, and know-how, which are the strengths of RTRI, we will address topics that can be rapidly adapted to solving on-site issues.

3. Research and development commissioned by the government

As part of the practical application and dissemination of the results of R&D, we are conducting R&D that has been commissioned by the government.

Table 3-1. Example topics for "Development of practical technologies"

R&D Objectives	Topic
Safety improvements	○ Earthquake early warning system for nearfield earthquakes ○ Enhanced seat safety in the event of a collision ○ Methods of maintenance and repair that extend the lifespan of ground equipment
Cost reductions	○ Railway monitoring technologies comprising the use of sensors ○ Methods for confirming safety using vehicle-side cameras
Harmony with the environment	○ Application of superconductor technologies such as superconducting power cables to conventional railways ○ Practical application of fuel-cell hybrid trains
Improved convenience	○ Brake equipment that contributes to reduced braking distance ○ Vertical vibration control systems for high-speed trains

(5) Basic research for railways

We will actively engage in basic research to provide solutions to various issues that affect railways specifically and can serve as a source for innovative technologies. In the field of "Elucidation and prediction of phenomena," we will conduct basic research into forecasting meteorological disasters, vehicle running safety and stability, and improvements in the trackside environment. With regards to "Creating methods of analysis, experimentation and assessment," we will conduct research into damage and degradation mechanisms, inspection methods, and human factors. Finally, in terms of "Adoption of new technologies, materials, and research methods," we will conduct basic research into friction, wear, prolonging the serviceable life of parts, and Artificial intelligence (AI) (Table 3-2).

Table 3-2. Example topics of "Basic research for railways"

Item	Topic
Elucidation and prediction of phenomena	○ Forecasting meteorological disasters ・ Methods of estimating the properties of snow cover on the lines ・ Methods for predicting weather phenomena using big data analysis to publicly available information ○ Running safety and stability of rolling stock ・ Methods for analyzing conditions that cause hunting and methods for assessing stability ・ Assessing vehicle behavior at the moment a vehicle reaches the overturn limit due to crosswinds ○ Improvements to the wayside environment ・ Study on the generation mechanism of squealing and bridge noises and development of the mitigation measures ・ Methods for estimating and visualizing radio noise caused by running trains
Creating methods of analysis, experimentation, and assessment	○ Degradation mechanisms and inspection methods ・ Assessment of the fatigue crack growth rate and inspection intervals of railway axles ・ Elucidation of crack propagation mechanisms in bogie frames and development of inspection methods ・ Study on crack propagation mechanisms in rail heads and maintenance methods for cracks ○ Human factors ・ Clarifying physiological indices for assessing mental and physical condition ・ Total evaluation method of railway passenger comfort based on factor analysis
Adoption of new technologies, materials, and research methods	○ Friction, wear and increasing longevity of materials ・ Elucidating mechanisms underlying increased adhesive wear of contact wires and pantograph contact strips ・ Elucidation of the frictional deterioration factors of wheel treads and proposals for new materials for wheels and brakes ○ Artificial intelligence (AI) ・ A model for introducing human technical skills into AI ・ A method for tracing control and decisions by AI

R&D of superconducting maglev will be conducted as research activities while focusing mainly on the ongoing application of technologies such as superconductors and linear motors to conventional railways. At the same time, R&D for maintaining necessary technological capabilities will be conducted as fundamental research.

(6) Testing facilities

We will install two new large-scale testing facilities as proprietary testing facilities directly tied to R&D, and we will also install new and highly demanded testing facilities and renew existing aging facilities.

1. Establishing a new large-scale testing facility

Two large-scale testing facilities will be constructed to assess the safety of the ground and embankments against earthquakes and heavy rains and to assess the response and durability of tracks and structures during high-speed train operation.

○ Centrifuge test facility

In order to assess the state of the ground during earthquakes and heavy-rain, and to solve various related problems, such as performing a collapse analysis, we will install a facility to assess the behavior of the ground and structures that reproduce stress states equivalent to those observed in the actual ground within a scale model by applying a centrifugal force using high-speed rotation against a reduced-scale model ground.

○ High-speed movement loading test facility

In order to develop a vibration-controlled track for high-speed rail and a maintenance-free track for regional railways, we will install new facility to assess the response and durability of tracks and structures by reproducing the loads borne by tracks with high-speed trains (maximum speed 360 km/h) while using multiple actuators installed at sleeper intervals on the real track structure.

2. New installation and renewal of test equipment

We are installing new test facilities that are required for conducting high-quality R&D. In addition, we are updating the test equipment that has exceeded its useful life and has deteriorated significantly, with priority given to what is needed most and most urgently for R&D.

3.1.2 Survey

In addition to understanding changes in society, the economy, and technology, we will collect and analyze information concerning mid- to long-term trends in Japan and overseas, in the fields of safety, the environment, and the transportation economy, as they relate to railways and trends in cutting-edge technologies such as digital technology. The results of these surveys will be used for R&D, and we will actively disseminate these findings. In addition, we will conduct survey activities to predict the future of rail and to identify technical items for R&D.

3.1.3 Technical standards

With the increasing importance of the maintenance and management of social infrastructure and with consideration for the shrinking labor force, we are strategically promoting the development of design standards, maintenance and management standards, and examples of design calculations such that the design can be conducted while reflecting construction and maintenance management efficiency perspectives.

3.1.4 Information services

We will collect, compile, and actively disseminate Japanese and foreign technical railway information. In addition, using various media such as mass media and the Internet, in addition to providing society with timely and accurate technical rail information, including high-quality R&D results and activities, we will act as a base for information transmission and disseminate information that contributes to rapid recovery following earthquakes.

3.1.5 Publication and seminar

We will further improve the content of periodical reports such as RTRI reports, Railway Research Review (RRR), Quarterly Report of RTRI (QR,) and Ascent, as well as educational activities such as lectures and technical forums, while striving to disseminate the results of R&D in society. In addition, we will provide systematic training courses on topics such as railway technology for all levels of knowledge, from beginner to expert.

3.1.6 Diagnostics advisory

We will meticulously respond to the needs of all railway operators and continue to actively support them. With regards to consultations on disasters, accidents, and equipment failures, we will promptly survey the damage and causes and propose methods for recovery and the prevention of recurrence. We will respond to severe natural disasters by forming cross-cutting teams.

3.1.7 International standards

We will develop strategic international standardization activities to maintain and further improve Japanese railway technology and expand it overseas.

With regards to the development of ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) standards, in addition to continuing to promote proposals from Japan as a secretariat for the National Mirror Committee, we will actively incorporate Japanese design ideas and technologies in our response to standards proposed by other countries.

In addition, we will also investigate trends in standardization activities being promoted by rail-related organizations that may be able to exert international influence and engage with them as necessary.

Furthermore, with regards to various issues relating to standardization in the Japanese railway industry, such as the stipulation and systematization of Japanese technologies and know-how and examination of the state of the domestic certification system, we will work with related parties to develop standards.

3.1.8 Qualification

In addition to creating an environment that makes it easy for railway engineers to apply for professional railway design engineer examinations through the verification of entire processes under examination, we will contribute to the development of human resources for the entire railway industry with the aim of maintaining and improving the technical knowledge level of railway engineers.

3.1.9 Railway Technology Promotion Center

With a focus mainly on the systematization of technologies, problem solving, and the maintenance and improvement of technological know-how and technical information service activities, in addition to partnering with the Japanese government and relevant institutions to undertake activities that contribute to safe and reliable railway transport, we will contribute to improving the technical level of those involved in railways. In particular, we will focus on technical support to revitalize regional railways through measures such as providing advice based on site visits. In addition, through investigative research into topics of particular interest to railway operators, we will promote information sharing between railway operators.

3.1.10 Railway International Standards Center

With the aim of maintaining and further improving Japan's railway technologies and their overseas expansion, we will act as a central organization responsible for international standardization activities while closely cooperating with the Japanese government, Japanese standards organizations, railway operators, and railway-related companies.

In addition to strengthening the cooperation with organizations conducting standardization activities in Europe and Asia and promoting the use of standards developed and issued at Japan's initiative, including standards for railway project planning and promoting the understanding and adoption of Japanese railway technologies, we will increase awareness about international standards among Japanese stakeholders and promote human resource development.

3.1.11 International activities

In order to further enhance the technological prowess and global presence of RTRI, we will expand joint research with and staff secondment to overseas universities and research institutions as well as improve both the quality and quantity of information disseminated overseas. In addition, we will strengthen our capability to investigate the latest trends in research overseas and actively promote the intake of researchers from overseas with the aim of invigorating R&D. Furthermore, we will contribute to the uptake of Japanese rail technologies by providing active support for the overseas expansion of railway operators and railway-related companies, providing support for human resource development, and through the international expansion of technologies developed by RTRI.

3.2 For-profit projects

We will promote for-profit projects in order to commercialize R&D outcomes, and drive their widespread popularization. To this end, in addition to strengthening marketing and promotional activities and accurately understanding the needs of customers including the railway operators, we are actively implementing initiatives for promoting the commercialization of the results of research and providing results that are perceived by clients as being high-quality.

Securing revenue and promoting business efficiency to ensure stable and solid income, and management of expenditures will help to strengthen the management foundations of RTRI.

4. Management

4.1 Management concepts

As a public interest incorporated foundation, we comply with laws and regulations and our articles of incorporation, and we encourage sound management.

In addition to increasing staff numbers in technological fields, placing a priority on R&D, we shall make efficient use of the limited human resources to respond appropriately to solving various problems in railway technology.

In order to cultivate researchers that can perform the R&D sought by RTRI in response to the needs of railway operators in addition to enhancing level-specific training programs for staff, ranging from new recruits to executives, and to ensure the reliable transfer of technological skills and knowledge, we are also actively exchanging personnel with railway operators such as JR companies.

In order to complete the new installation, and update of RTRI's testing facilities, and renovation of research buildings based on a mid- to long-term plan, we aim to further increase efficiency across all aspects of operation based on sound financial planning.

4.2 Compliance

We will promote continuous development through training courses and on-the-job training (OJT) with the aim of raising the ethical awareness of staff and strengthening compliance with laws, regulations, and ethical codes.

4.3 Information management

In addition to the strict management of R&D information, we are strengthening security measures used for the management and use of information communications and data.

4.4 Human resources

4.4.1 Recruitment

In addition to promoting initiatives to further understanding of the activities of RTRI by strengthening collaboration with universities and research institutes and proactively offering internships and ensuring a supply of skilled employees to meet the demand in the technical fields highlighted in the mid- to long-term plan, we are hiring strategically in order to avoid skills gaps in the various fields of technology.

In order to ensure a sufficient supply of skilled experts in cutting-edge technical fields such as digital technologies and advanced simulation technologies, we intend to diversify recruitment to include mid-career recruitment of experts.

4.4.2 Developing human resources

In addition to ensuring the transfer of technological skills and knowledge accumulated over many years to the next generation, we will train researchers able to perform creative R&D to respond to the needs of railway operators. Therefore, we will enrich OJT and level-specific training programs offered at various career stages, from new recruits through to executives. We will also actively conduct personnel exchanges with railway operators including JR companies, not only among younger employees but also at managerial level.

We will conduct short- and long-term staff secondment to specialist research institutes involved in cutting-edge technical fields such as digital technology.

From a global perspective, we are actively engaging in joint research with foreign universities and research institutions and personnel exchanges in order to develop a pool of highly skilled employees that can raise the presence of Japanese rail technologies on the international stage.

To promote the self-development of researchers in order to accumulate specialist knowledge and raise the international presence of RTRI, we will encourage the acquisition of higher qualifications (PhDs and professional engineers) and promote participation in academic and professional association activities.

4.4.3 Creating a motivating workplace

We will strengthen efforts to improve workplace health and safety, mental health, and reform working practices, as well as support employees with childcare, and creating a workplace where employees can benefit from flexible working, and where they can work safely and healthily both in mind and body.

We will nurture a culture of openness that allows researchers in various technical fields to have free and vigorous discussions irrespective of differences in age and position, and we will create motivating workplaces where all employees, from junior staff to veterans, can have a high degree of motivation to work.

4.5 Personnel

Based on current recruitment performance, about 20 new employees should be recruited each fiscal year, to maintain staffing at its current level of 550 (Table 4-1).

In R&D activities, we will reinforce technical fields that have been prioritized, such as increasing resilience to natural disasters, promoting the adoption of digital technologies, improvement of energy-saving technologies, and advancement of simulation technologies.

We will increase the number of staff in international standardization activities in order to strengthen cooperation with international railway-related organizations and respond to certification needs.

We will continue to assign staff to appropriate positions with the aim of increasing the efficiency of their work including other activities not mentioned above.

Table 4-1 Number of personnel

(Units: Persons)

	FY2019	FY2020 – FY2024
Research and development	440	442
Survey	18	13
International standards	10	13
For-profit projects	40	40
Administration duties	42	42
Total	550	550

4.6 Revenue and expenditure

In estimating the contribution income from JR companies, we take into consideration changes in the rail transport revenue of JR companies in recent years and the anticipated economic situation of the society in the future. Although the repayment of loans from the Development Bank of Japan will be completed within the period covered by this master plan, strict income expenditure management will still be adopted with the intention of ensuring effective budget management. One reason for this is that R&D expenditure is increasing as priority issues need to be addressed and practical application of research results also need to be promoted. Another reason is that we should reserve funds for the creation of new large-scale testing facilities, the renovation of old facilities, and reconstruction of the head office building in *Kunitachi* (Table 4-2).

4.6.1 Revenue

(1) Contribution revenue

In regards to the contribution revenue, revenue for each year is expected to remain at 2019 levels, as the revenue growth of JR companies over the past few years has been consistently high.

(2) Business revenue

In regards to the business revenue, because the current scale of revenue is expected to continue into the future, the revenue for each year is expected to be the same as that in 2019.

(3) Subsidy revenue

We continue to request subsidies to cover interest on repayments of money borrowed from the Development Bank of Japan. Subsidies from the Japanese government in addition to competitive grants will be actively sought, to ensure that RTRI can continue to engage actively and creatively in R&D.

4.6.2 Expenditure

(1) Personnel expenditure

Personnel expenditure is based on the number of personnel.

(2) R&D expenditure

We will strengthen initiatives for priority issues such as data collection and validation testing for various meteorological conditions required to advance the R&D contributing to enhancing the resilience of the railways to natural disasters, promoting practical applications such as validation experiments for superconducting power transmission cables, and bolstering R&D expenditure for establishing test methods for new large-scale testing facilities.

(3) Fixed asset acquisition expenditure

In addition to installing and renewing testing facilities, we will update and expand general facilities to improve safety and address the issue of the aging of general equipment.

(4) Repayments to DBJ

Repayments are made under contract with the Development Bank of Japan and will conclude in 2022.

(5) Purchase of reserve assets for reconstruction of the *Kunitachi* head office building

After examining what functions the new office building will need to ensure an environment conducive to creative research, the building will be redesigned to a similar scale as the current building, but with higher earthquake resistance.

The " Reserve assets for reconstruction of the *Kunitachi* head office building " will be set aside as a fund for use in this reconstruction.

Table 4-2: Revenue and expenditure

(Units: billion JPY)

		FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	Total
Revenue	Contribution revenue	15.1	15.1	15.1	15.1	15.1	15.1	75.6
	Business revenue	3.0	3.0	3.0	3.0	3.0	3.0	15.2
	For-profit projects revenue	*2.9*	*2.9*	*2.9*	*2.9*	*2.9*	*2.9*	*14.5*
	Public-interest activities revenue	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.7*
	Subsidy revenue	0.1	0	0	0			0
	Membership revenue	0.2	0.2	0.2	0.2	0.2	0.2	*1.1*
	Other revenue	0.1	0.1	0.1	0.1	0.1	0.1	0.9
	Proceeds from secured assets for *Yamanashi Maglev Test Track* construction debt	1.1	0.9	0.5	0			1.5
	Balance carried forward from the previous period	2.4						
	Total revenue	**22.3**	**19.5**	**19.1**	**18.6**	**18.6**	**18.6**	94.5
Expenditure	Personnel expenditure	5.9	6.2	6.3	6.5	6.5	6.9	32.6
	Non-personnel overhead expenditure	2.7	2.7	2.7	2.7	2.7	2.7	13.8
	R&D expenditure	3.0	3.4	3.4	3.4	3.4	3.4	17.2
	Research and development for the future of railways	*0.8*	*0.9*	*0.9*	*0.9*	*1.2*	*1.0*	*4.9*
	Development of practical technologies	*1.3*	*1.4*	*1.4*	*1.4*	*1.1*	*1.3*	*6.8*
	Basic research for railway	*0.8*	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*	*5.5*
	(Within parentheses, Technical development requested by JR companies)	*(1.2)*	*(1.4)*	*(1.4)*	*(1.4)*	*(1.4)*	*(1.4)*	*(7.0)*
	Other public-interest activities expenditure	0.7	0.6	0.6	0.6	0.6	0.6	3.3
	For-profit project expenses	1.9	1.9	1.9	1.9	1.9	1.9	9.8
	Fixed asset acquisition expenditure	3.8	1.7	1.7	1.7	2.7	2.7	10.5
	(Of which, large-scale testing facilities)			*(0.3)*	*(0.6)*	*(2.0)*	*(1.9)*	*(4.9)*
	(Of which, testing facilities)	*(0.2)*	*(0.7)*	*(0.7)*	*(0.7)*	*(0.5)*	*(0.5)*	*(3.1)*
	(Of which, general facilities)	*(0.2)*	*(0.3)*	*(0.6)*	*(0.3)*	*(0.1)*	*(0.3)*	*(1.8)*
	Repayments to DBJ	1.1	0.9	0.5	0			1.5
	Purchase of reserve assets for reconstruction of the *Kunitachi* head office building	2.8	1.5	1.6	1.3	0.3		4.9
	Emergency funds	0.1	0.1	0.1	0.1	0.1	0.1	0.5
	Total expenditure	**22.3**	**19.5**	**19.1**	**18.6**	**18.6**	**18.6**	94.5

(Note) ・ FY 2019 figures represent amounts budgeted at the beginning of the fiscal year.
・Subsidy revenue is recorded only for subsidies against interest due to the Development Bank of Japan. (It should be noted, however, that FY2019 includes a national treasury subsidy for research and development (110 million JPY))
・FY2019 research and development expenditures include the national treasury subsidy (110 million JPY).
・The totals may not add up due to rounding up.

5. Conclusion

The labor shortage caused by a shrinking working-age population in Japan, and unprecedented meteorological disasters are pressing issues that cannot be addressed through conventional frameworks.

Radical technological innovation is essential to overcoming these challenges. RTRI plays acts as a leader in technological innovation for railways, partnering with railway operators, universities, and research institutes in Japan and overseas, as well as related companies to overcome difficult problems encountered by railways, and it pursues research and undertakes development to create the future of railways for the realization of a sustainable society.

In addition, we are accumulating know-how related to railway technology and proactively undertaking impartial activities as a third-party organization including the investigation of damage due to and causes of disasters and accidents and proposing measures for recovery, and to prevent their reoccurrence.

As a public interest incorporated foundation, we adhere to the law and to our articles of incorporation, and we are working to strengthen compliance and further deepen trust in RTRI. RTRI, which is not an operator itself actively engages in personnel exchanges with railway operators, and strives to build a pool of trained personnel that are able to grasp the status and issues that are specific to the railways, while encouraging the transfer of technological skills and knowledge to the next generation.

Based on the vision of "We will develop innovative technologies to enhance the rail mode so that railway can contribute to the creation of a happier society", we promise that RTRI pledges to invest its utmost efforts to realized its Master Plan RESEARCH 2025: R&D for creating the future of railways.

Reference

RTRI's Vision

RISING

Research **I**nitiative and **S**trategy—**I**nnovative, **N**eutral, and **G**lobal

Vision

"We will develop innovative technologies to enhance the rail mode so that railways can contribute to the creation of a happier society."

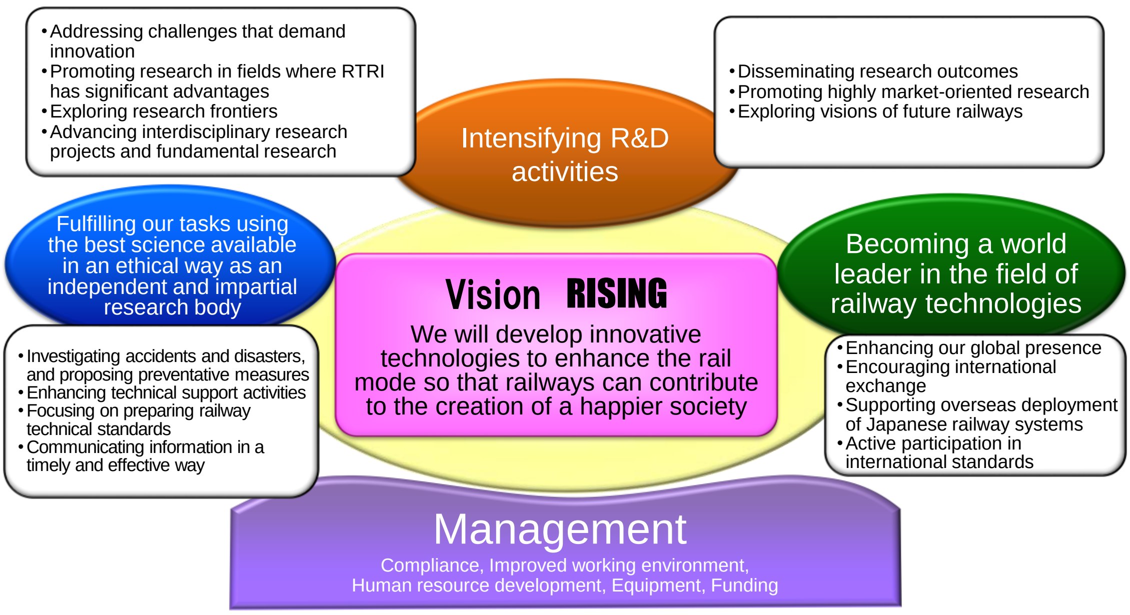
Mission

①To intensify research and development activities so as to improve railway safety, technology and operation, responding to customers' needs and social change

②To develop professional expertise in all aspects of railways and, as an independent and impartial research body, to fulfill our tasks using the best science available in an ethical way

③To pioneer cutting-edge technologies for Japanese railways and become a world leader

Strategy



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