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Improving Labor Efficiency by Digital Maintenance

Introduction

The maintenance of railway equipment is essential for ensuring safe and stable train operations. However, the declining birth-rate, aging population, and shrinking workforce have significantly increased the difficulty in securing sufficient maintenance personnel. Meanwhile, advances in sensor and communication network technologies have made it possible to collect and store vast amounts of data that were previously unobtainable. Furthermore, advanced ana-

lytical techniques and artificial intelligence (AI) have greatly expanded the ways in which the accumulated data can be utilized. Under the major research theme “Improving labor efficiency by digital maintenance,” the Railway Technical Research Institute (RTRI) has been conducting research and development aimed at improving the efficiency of maintenance work and reducing manpower requirements by applying digital technologies to suitable areas such as condition monitoring of railway equipment and automation of inspections.

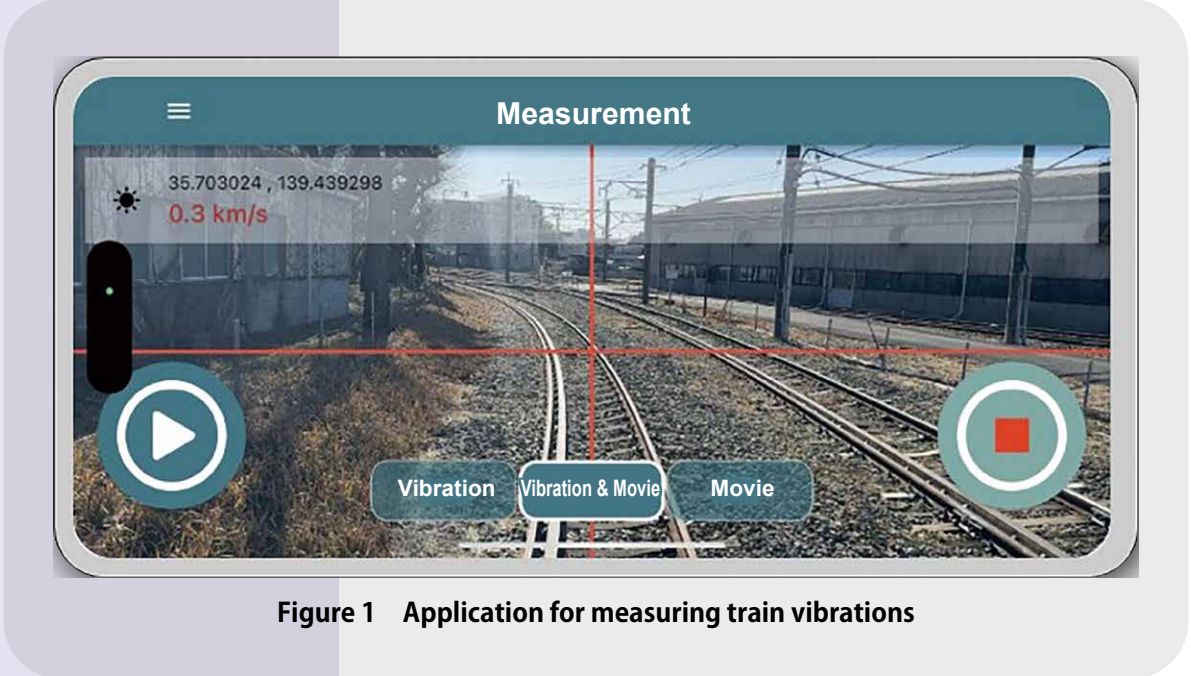


Figure 1 Application for measuring train vibrations



Figure 2 Installation on the front windscreen

Improvement of Labor Efficiency Through Condition Monitoring

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

Condition monitoring of tracks

In track maintenance, control values that incorporate safety margins are defined for each parameter related to

track irregularity^{*1}, and any section where these values are exceeded are repaired within a specified period. Major railway operators regularly measure the track irregularity using dedicated track-recording vehicles; however, because such vehicles are expensive, their use is generally limited to relatively large operators. In addition, some of the measurements obtained by track-recording vehicles are known to be strongly correlated with train vibrations.

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

*1 Track irregularity

The deviation of the track from its correct position is called track irregularity (the terminology may vary across railway operators). A substantial level of track irregularity interferes with the smooth running of vehicles, deteriorating the ride comfort and reducing the running stability. Therefore, track conditions are regularly inspected, and where necessary, track re-alignment (track maintenance) is performed..

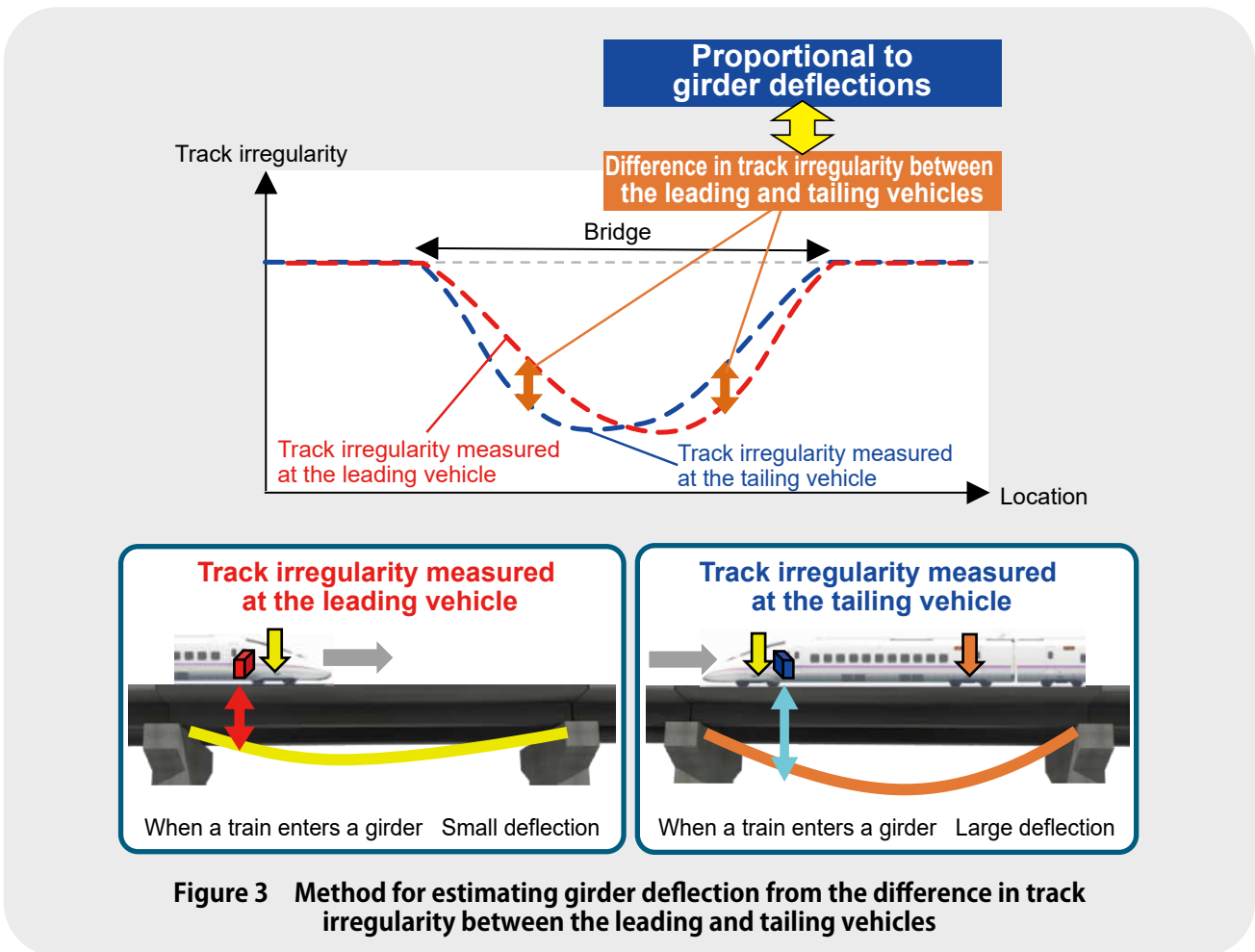


Figure 3 Method for estimating girder deflection from the difference in track irregularity between the leading and trailing vehicles

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

Condition monitoring of bridges

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

timate girder deflections and detect loose bearings.

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

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

sections with consecutive simple girders.

Condition monitoring of OCLs and pantographs

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



Figure 4 Monitoring of component detachments using object-detection AI

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

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

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

Development of Labor- and Manpower-Saving Equipment

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

resource-saving maintenance.

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

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



Adjustment device



Switching device

Figure 5 Installation of the test turnout

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

Digital Data Sharing and Analysis

Integrated analysis platform

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

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

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

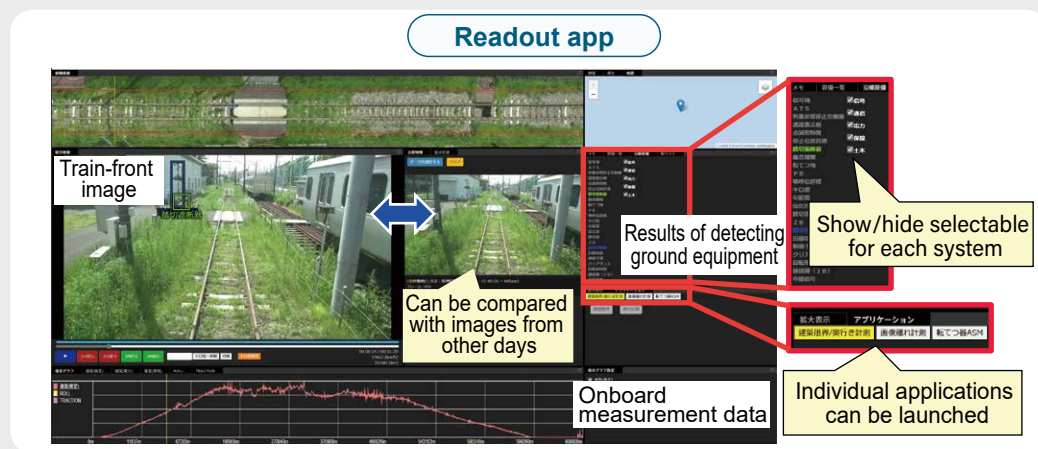
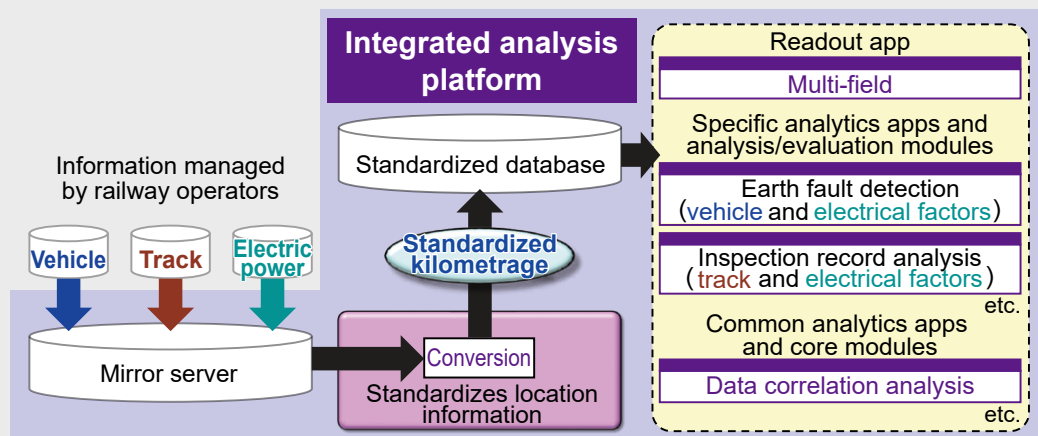


Figure 6 Integrated analysis platform

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

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

Early anomaly detection by monitoring the electric power network

Substations are equipped with various

monitoring functions to protect equipment by detecting overcurrent and other abnormal conditions. However, in DC-electrified sections, high-resistance ground faults are difficult to detect because the fault current is comparable to or even smaller than the train current. These faults can be detected by obtaining and calculating the difference between the collected current (onboard current) of the train and current supplied by the substation (groundside current). Although this idea was proposed long ago⁹⁾, recent advances in communication

and other information and communication technologies have made its implementation increasingly feasible. The onboard current and train location data (vehicle-section data) and ground current data (power-supply-section data) are collected by the integrated analysis platform. High resistance ground faults are identified by continuously calculating the difference between these currents and comparing it with a threshold value (Figure 7). On the in-house test track of RTRI, conditions involving multiple substations and multiple

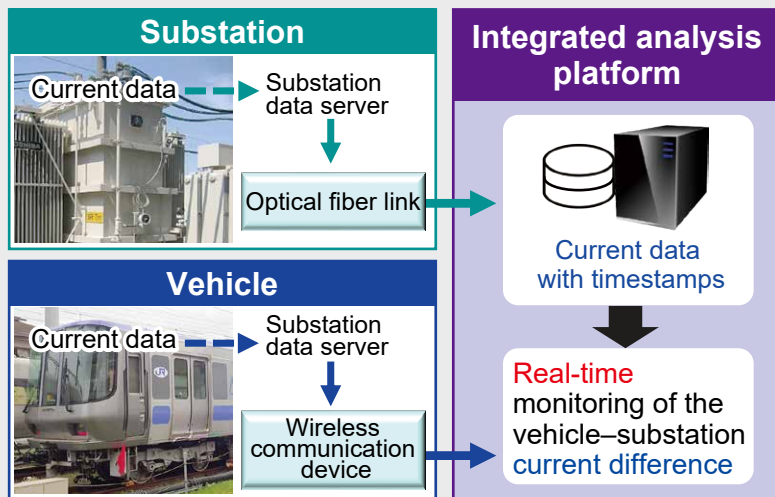
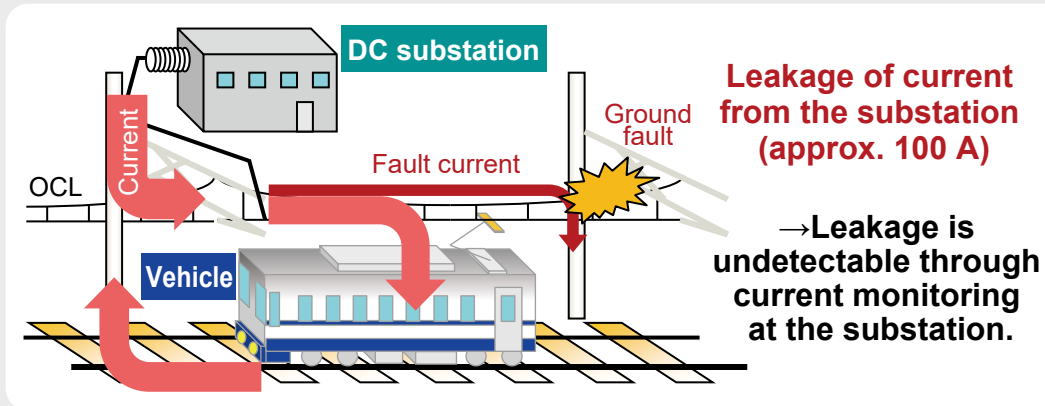


Figure 7 Conceptual view of electric power network monitoring

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

Asset management based on equipment inspection records

In day-to-day maintenance work, extensive visual inspection data, recorded by engineers during their periodic equipment inspections, are accumulated in addition to the measurement data from sensors. Although the inspection data comprise

only simple ratings such as “○ (good),” “△ (adjustment required),” or “× (abnormal),” their long-term accumulation has resulted in a large-scale dataset. These data have not been effectively utilized. The statistical characteristics of failure occurrences underlying these data can be extracted through statistical modeling and applied to the review of existing inspection intervals. Accordingly, by using the data accumulated in the integrated analysis platform, RTRI developed a model to predict equipment failure. An analysis based on a model

constructed for 280 electric point machines installed on actual railway lines revealed that, except for a few machines, the inspection intervals could be extended by approximately 1.3 times without exceeding the historically accepted failure rates.

Conclusions

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

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

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

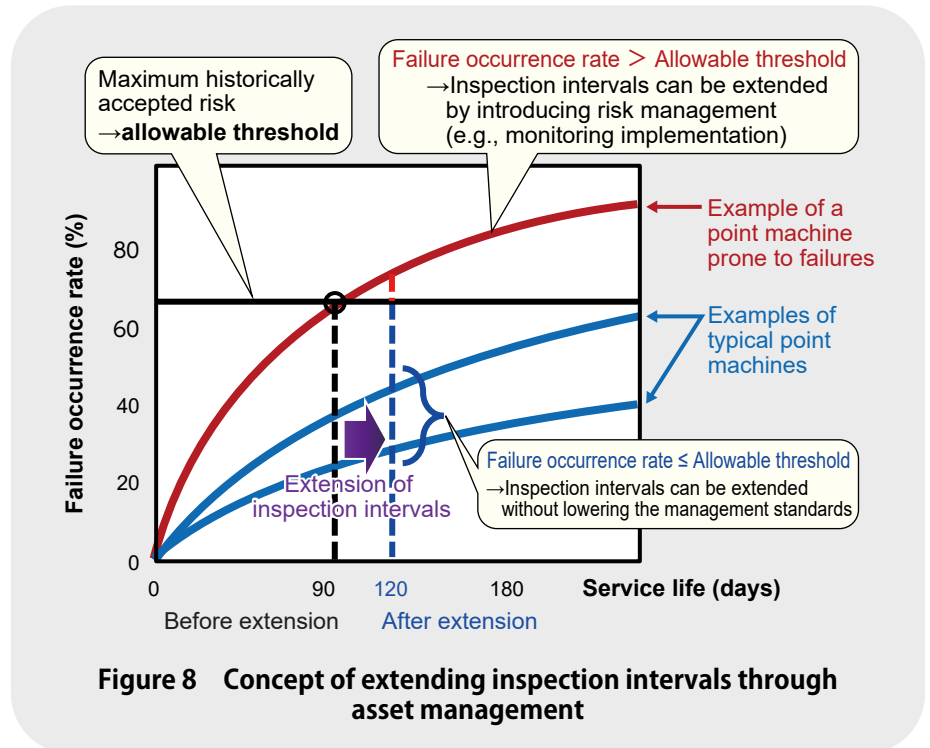


Figure 8 Concept of extending inspection intervals through asset management

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