Research on Creating an Integrated Analysis Platform for Effective Use of Railway Maintenance Data

This paper describes research on creating an integrated analysis platform for effective use of railway maintenance data. Current systems in JR East are independent and have different data structures. First of all, we made a work support system by using the data of certain systems to evaluate the user interface and extract potential problems with an integrated database. As a result, it was found that “coordinates” and “time” are important in linking data of various systems. However, our wayside facilities and trains in service do not have information on coordinates. Therefore, we are studying to efficiently obtain the coordinates of railway facilities and trains with the Mobile Mapping System and Global Positioning System. We believe that a database of railway facilities based on Geographic Information System helps the integrated analysis platform.

Keywords: Smart maintenance, Data integration, Facilities management system, GIS, GPS, MMS

1 Introduction

The Technical Center is working to achieve the “Smart Maintenance Initiative” with an aim of innovating future railway maintenance. One objective in that is integrating databases. To achieve that objective, we aim for uniform management of inspection data accumulated in daily maintenance of railway facilities and rolling stock to make that data easier to handle. In this way it is expected that maintenance engineers will be able to analyze various inspection data themselves and find new insights that can lead to work improvement and cost reduction.

JR East performs maintenance of diverse items including civil engineering structures such as tracks, bridges, and tunnels, electric facilities such as substations and signal/communication equipment, and rolling stock such as Shinkansen and commuter train cars. We have many systems that have been built in the maintenance and management of those wayside facilities and rolling stock, and a huge volume of data has been accumulated. The formats of that data include not only structuralized ones such as numerical data, but also non-structuralized ones such as texts and diagrams. Many issues need to be overcome in order to uniformly manage and allow that data to be used in a manner as needed at individual workplaces.

In this paper, we introduce the advantage of cross-divisional use of the data accumulated over a long time as well as report on the issues found in such uses and the research and development we are working on to solve those issues.

2 Smart Maintenance and Data Integration

2.1 Smart Maintenance Initiative

The Smart Maintenance Initiative is composed of the four concepts shown in Fig. 1. Those include “achievement of condition based maintenance (CBM)”, “introduction of asset management”, “work support by artificial intelligence (AI)”, and “integration of databases”, and integration of maintenance data is one of those pillars of this initiative. Achieving the other three concepts above requires various data obtained in maintenance. Specifically, to achieve CBM and introduce asset management, data on facility and equipment condition and accumulation of such data are required, and for work support by AI, technical information and data recording the experience (know-how and failures) of engineers is important. In this context, integration of databases is an important concept that will be the basis of effective and efficient use of the data obtained in maintenance work.

2.2 Necessity of Integration of Maintenance Data

2.2.1 Current Situation of Maintenance-related Systems

Currently we have many systems to maintain and manage wayside facilities and rolling stock. For example, even with wayside facilities alone, we have facilities management systems...
for individual maintenance divisions (track, civil engineering, signals and communications, electric power, and machinery), and those systems do not have common unified specifications and data structure. Even within a division, there are independent systems for individual work, so transfer of data between systems is often done manually.

Much work is now performed in system-centered flows. For that reason, inputting data to the systems itself often becomes a main purpose of work, and the input data is often not effectively utilized. For example, in order to make analysis when it is not according to the workflow, personnel have to first search for the required data and modify it. Such labor might lead to reluctance to conduct analysis to improve work. In order to remove such a disadvantage and effectively use the maintenance data accumulated in JR East, we believe that building a system where data can be easily used is important.

### 2.2.2 Examples of Integration of Maintenance Data Outside Japan

There are many projects outside Japan to uniformly manage wayside facilities, not being bound by the boundaries of maintenance. For example, Dutch railway infrastructure management company ProRail is building a system called SIGMA to uniformly manage wayside facilities. Swiss railway operator SBB started a project to uniformly manage wayside facilities in 1989 and has been compiling and updating facilities asset data daily. Now, data of track facilities, power facilities, cumulative number of passing trains and the like are uniformly managed on a geographic information system (GIS), and geographic relation between facilities and specification data can be confirmed at a glance. Furthermore, German railway infrastructure manager DB Netz is working on the development of a platform called DIANA on which wayside facilities can be analyzed and diagnosed in an integrated manner. As seen in those examples, uniform management of wayside facilities is a global trend of the times. We believe that JR East, too, needs to promote integration of maintenance data while looking at evolution of ICT and global trends.

### 2.2.3 New Work Support Created by Data Integration

The Technical Center is carrying out various studies on new changes in maintenance work brought about by data integration. The following introduces some of the studies.

1. Providing applications to support work done in collaboration by different divisions

We examined what work support could be done for field divisions by integrating maintenance data already held. Much work requires coordination between different divisions and confirmation by the worksite, and we chose three types of that work and made prototype work support systems: “work support in planning repair using multiple tie tampers (MTT”), “work support in clearance gauge management,” and “work support in platform height and distance management.”

Fig. 2 shows a screen of the system for work support in planning repair using MTT as an example. Repairs involving a work of lifting up and leveling track partially settled due to train load, and in this work, checking whether or not overhead contact lines or cables in the ballast are interfered with is needed. The system simultaneously displays a chart indicating the height of overhead contact lines (power), a chart indicating track condition (track maintenance), and a diagram indicating signal and communication equipment near the track (signal/communications) on a screen, thus enabling confirmation and design in the office in advance.

![Fig. 2 Screen of Job Support System in MTT Repair Plan](https://www.example.com/fig2.png)

(2) Support decision-making of novice personnel by visualizing knowledge and experience of veteran engineers

We investigated a method in which knowledge and experience of veteran engineers can be visualized using past data that has been accumulated. Here we focus on the example of track maintenance work. Level of deterioration of track greatly varies according to location because it is affected greatly by environment and track components. An experienced engineer selects the track area to be repaired and repair method in a comprehensive manner taking into account the environment and maintenance cycle. As a substitute for such know-how, we developed a heat map using accumulated data (here, data of past track condition, Fig. 3). This chart shows the change in the condition of a 2.4 km section of a line over 48 months. In the actual chart, track condition per area is classified by colors: good (smaller values) in green and poor (larger values) in red, with darker shades indicating better or poorer condition. Changes in track condition can be clearly recognized on that chart, and difference in deterioration level can be easily identified as well. That enables visual understanding of deterioration trends as a whole, so the order of priority of repair can be decided without relying on experience.

![Fig. 3 Heat Map of Change of Track Condition](https://www.example.com/fig3.png)
As described above, we found that one important type of data in data integration is "location information". In order to efficiently obtain and manage location information, it would be best to apply GIS and global positioning system (GPS), which have been widely utilized among European railways. For example, with an asset management system for wayside facilities based on GIS as shown in Fig. 5, we can easily indicate relative location between facilities and position of running trains. We are now working on the research needed to efficiently deploy that system.

### 3 Solutions in Integrating Data

#### 3.1 Development of a Location Information Conversion System

In order to link information of different divisions in terms of kilometerage, locations of individual facilities have to be shown as absolute position (in longitude and latitude) in order to know their relative relation. As past research revealed that absolute positions of some facilities that are registered as being located at the same single kilometerage position are actually different, we need a system that allows kilometerage information of different divisions to be converted. Fig. 6 is a partly modified screen of an iPad app that has the system. By starting up the app, kilometerage information of a location close to the user's current position is shown. On the example screen, the app indicates that the position at 2k360m in track maintenance kilometerage (A) is 2k359m in electric power kilometerage (B). By converting the
data via this system, we can link the data of different divisions without changing kilometerage data that individual divisions have developed and managed.

3.2 Research on Efficiently Providing Location Information to Wayside Facilities
In order to link data of wayside facilities, we need to assign absolute positioning information to facilities that do not have kilometerage data. However, case examples in other countries have shown that this involves much labor. In light of that, we have recently started studying application to railways of the mobile mapping system (MMS), which enables information of roadside facilities to be obtained efficiently. Fig. 7 shows a result of measurement of a line using MMS. The figure looks like a photograph, but it actually is a diagram that shows a group of points that are given geographic coordinate data in longitude and latitude. We believe that it may be possible to efficiently obtain absolute location information of facilities by analyzing that data.

3.3 Efficiently Obtaining Onboard Location Information
In linking locational relation of wayside facilities and trains, we are studying application of GPS, which has been already been adopted by automobile navigation systems. Since GPS allows longitude and latitude information as well as time to be easily obtained, it also makes linking trains with wayside facilities easy. Currently some issues remain, such as positioning accuracy with errors of up to 10 m and data processing for tunnels and the like where satellite signals cannot be received; however, we believe those can be solved in future.

Concerning accuracy of outdoor positioning, a system using quasi-zenith satellites will be completed in 2018, and it is said that the system will greatly improve accuracy of GPS positioning. In past running tests using an actual train, we gained results that accuracy of GPS positioning could be within an error range of a few centimeters with that system. We will further work on research on a method of linking wayside and onboard data.

4 Conclusion
In this paper, we introduced issues in building a data integration and analysis platform to fully use railway maintenance data and efforts in achieving solutions to those issues. There are many issues in linking data accumulated in individual maintenance systems, and provision of location information in particular was found to be important. We believe that building map infrastructure based on geographic data in longitude and latitude is essential for wayside facilities and positioning using GPS is essential for rolling stock. We will further proceed with research with an aim of building a system where maintenance engineers can easily obtain and use necessary data across divisional boundaries.

*1 MTT: A multiple tie tamper is a large maintenance vehicle that can repair ballasted track.
*2 kilometerage: Kilometerage is locational data from the start point to the end point of a railway line (for example: a point at 5k300m).

Reference:
1) "ProRail and CGI develop the SIGMA system", YouTube video, Posted by CGI on Mar 25, 2014, https://www.youtube.com/watch?v=xPjMElI-IIE