Prospects of "Smart Maintenance" Utilizing ICT

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1 Introduction

The Technical Center started in April 1991 within the yard of the Oi Factory (Current Tokyo General Rolling Stock Center) in Shinagawa, Tokyo, as an organization to promote and support technical development on the front lines. It was later relocated to the Research & Development Center of the JR East Group (site of former Central Training Center) established in Saitama City, Saitama Prefecture, in December 2001 in an aim to further improve and speed up technical development at JR East. The Technical Center celebrated in April 2016 its 25th anniversary as a lab dedicated to maintenance.

Public concern about maintenance of infrastructure has risen since the December 2012 collapse of the Sasago Tunnel on the Chuo Expressway, which involved numerous fatalities. Japan is entering a period of population decline, and much of the country's social infrastructure built in the era of high economic growth is starting to see deterioration. A perspective of how we can effectively use existing aged assets and achieve a sustainable society is demanded today more than ever.

In order to meet those demands, the Technical Center has proposed the Smart Maintenance Initiative and is going forward with efforts to achieve that initiative.

2 Smart Maintenance Initiative

2.1 Overview of Smart Maintenance

The mission of maintenance worksites is to constantly provide safe and amenity-rich equipment and to reduce lifecycle costs as much as possible. In doing so, the most important thing is to perform appropriate inspections and diagnosis and perform effective maintenance (including equipment improvement) based on that.

Smart maintenance entails the utilization of information communications technology (ICT), which has advanced much in recent years, in that obvious endeavor to achieve high levels of maintenance. It is an effort to optimize the lifecycle cost of existing equipment. And it is based on the idea of utilizing data in order to enable existing equipment to be utilized as much as possible. If inspection and diagnosis data can be appropriately analyzed, weak points of equipment can be identified. Shoring up those weak points and improving equipment to make it resilient against breakdown also is an important part of smart maintenance.

The basic concept of smart maintenance—to use the power of data to bring out the most of the potential capacity of equipment—differs from the idea of maintenance-free measures (low maintenance track, streamlining of power equipment, and the like) and lengthening the time between inspections. Use of ICT has the potential to fundamentally change maintenance.

2.2 Features of Smart Maintenance

Smart maintenance is, as shown in Fig. 1, conducted by going through the cycle of performing inspections (accumulate and analyze data), judging places to repair from inspection results (make decision), conducting repairs (repair), and confirming effects (evaluate).

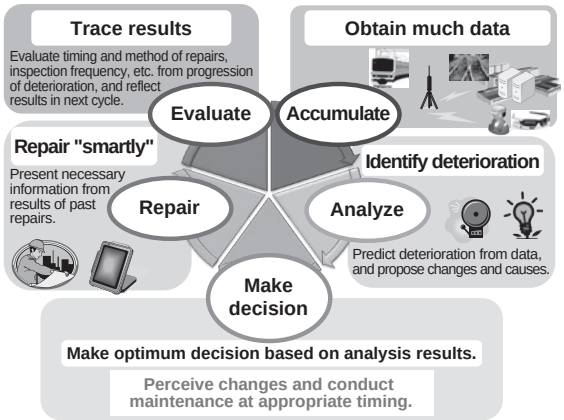

Fig. 1 PDCA Cycle

If it becomes possible through the advance of technology to greatly increase the frequency of inspections (accumulating data), the concepts of maintenance will undergo a transformation. This is reforming maintenance from time-based maintenance (TBM) to condition-based maintenance (CBM). And it will result in two major changes.

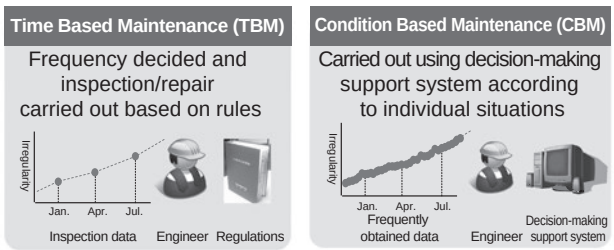

Fig. 2 TBM and CBM

(1) Identifying equipment condition in real time
In regular inspections (maintenance) up to now, only inspection data for every half year, for example, could be obtained. In this case, trains are run based on the inspection data of half a year ago when no problems were discovered. With CBM, safe and stable transport can be provided based on the current condition of equipment. With track, for example, it is based on data gathered though monitoring by trains in commercial operation.
(2) Accumulating large volumes of data day-to-day
Lifecycle management can be optimized by analyzing and judging large volumes of equipment data that has been accumulated (data mining). This is because the more data there is, the more accurate judgment can be.

Small changes in equipment and progression of track irregularity, which differ by location, can thus be predicted accurately, allowing the optimal repair timing and method to be determined.

2.3 Smart Maintenance Initiative in Rolling Stock

With the Series E235 commuter train EMUs introduced to the Yamanote Line in fiscal 2015, we were able to obtain tremendous volumes of data that recorded the condition of various equipment (big data). We are now aiming to introduce CMB (maintenance according to condition of rolling stock by data analysis) that utilizes that big data (Fig. 3).

We expect to be able to further improve safe and stable transport by utilizing that data obtained in real time. That involves tasks such as identifying signs of rolling stock failure and taking action on those in advance as well as accurately judging the situation when rolling stock failures occur and dealing with them.

We are currently studying a new image of smart maintenance for rolling stock in order to achieve more efficient maintenance. In that smart maintenance imagined, condition of individual rolling stock equipment is monitored and big data obtained is analyzed, with maintenance for rolling stock planned and implemented based on the results.

3 Advancement of ICT

Here we will briefly cover the advancement of ICT, which supports smart maintenance.

3.1 Big Data

The word "big data" is has come to be used frequently in recent years. This is the movement where knowledge most helpful to business is obtained from large volumes of data that is constantly generated.

Big data includes a diverse range of data including text data such as "tweets" on social network services (SNS), photos and videos, log information generated when accessing websites and the like, and various sensor data. That data totaled 2.8 ZB (zettabytes) worldwide in 2012, and it is forecast to reach 14 times that—40 ZB—in 2020.

Big data analysis is now starting to be utilized in the area of maintenance in addition to service in line with technical advances such as cloud computing covered below, Hadoop, and artificial intelligence (AI).

3.2 Cloud Computing

Cloud computing is a form of computer where IT resources held on users' computers are relocated to services connected to the Internet and just the necessary parts of necessary services are used. It has the benefits of allowing reduction of costs as well as construction of fast IT infrastructure. All sorts of computer elements—from simple web services to databases, application interfaces (API), and business logic—can be deployed on the cloud, and utilization of that is expected to grow.

At the Research & Development Center as well, we are employing cloud computing for big data analysis servers.

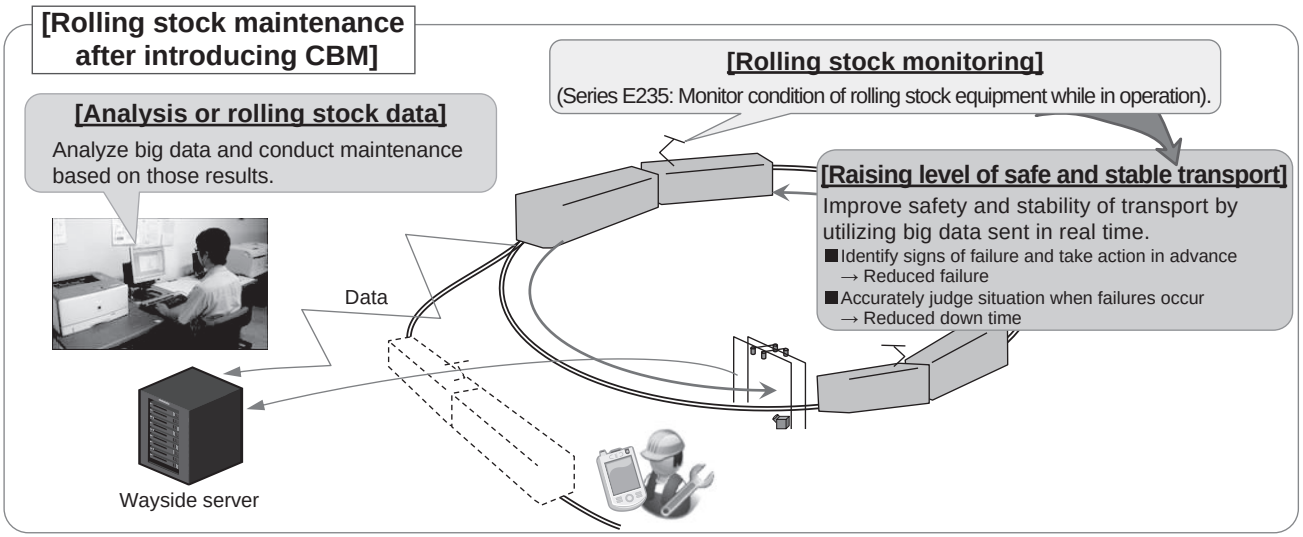

Fig. 3 Image of Smart Maintenance for Rolling Stock

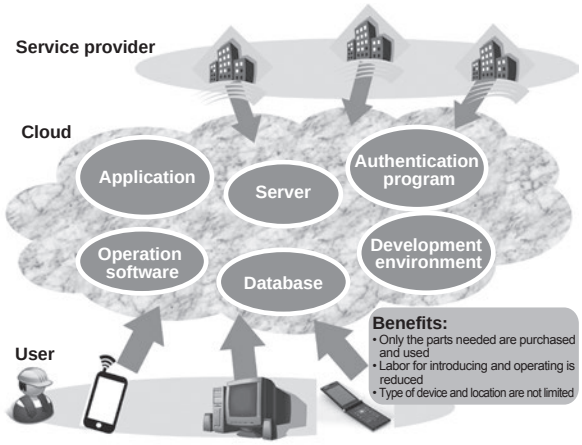

Fig. 4 Image of Cloud Computing

3.3 Artificial Intelligence (AI)

The greatest feature of AI is that it has "ability to learn things and mature" (machine learning). Cutting-edge AI is able to evolve autonomously by learning the massive volumes of data in cyberspace and the real world (big data) through deep learning without being taught by humans. There are expectations for this technology to be applied to language processing, image recognition, and voice recognition, which conventional computers are not good at.

In railway maintenance, past data such as periodic inspection results and accident reports is spread across many systems. If that data can be utilized effectively, AI with abilities that rival veteran engineers could be created. At the Technical Center, we are putting together a database of tactic information and vast experiences of veteran engineers and conducting fundamental studies of a system to infer by AI the causes of accidents.

3.4 IoT and Sensor Technology

Just as humans exchange information via the Internet, "things" too share information via the Internet, produce useful information, and work without human intervention. Internet of Things (IoT) has come to be scrutinized in recent years due to the advance of a ubiquitous communications environment, as seen by smartphones, and sensor technology.

IoT technology is already being utilized in areas such as monitoring the condition of aircraft and automobiles. In railways, embedding sensors in rolling stock and wayside equipment should allow operational condition and equipment condition of rolling stock to identified, thereby enabling smart maintenance.

4 Current Status of Smart Maintenance

4.1 Monitoring by Trains in Commercial Operation

For Yamanote Line Series E235 pre-mass production EMUs, we installed various monitoring equipment to obtain data from wayside equipment, and we are currently working on development of methods to utilize that for identifying deterioration and failure of onboard and wayside equipment. Fig. 5 shows some of the monitoring devices installed on those EMUs.

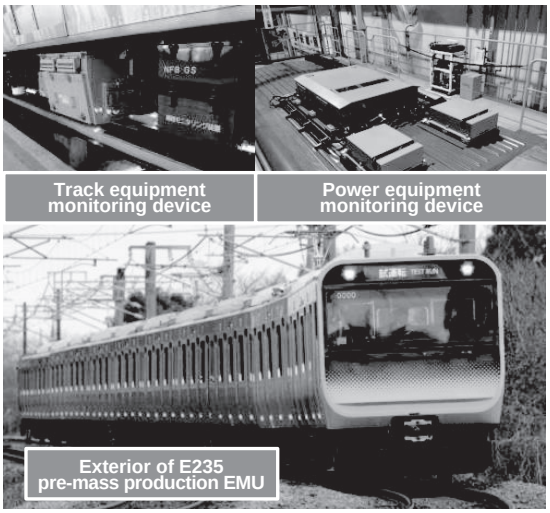

Fig. 5 Yamanote Line Series E235 Pre-mass Production EMU

Track equipment monitoring devices measure things such as track irregularity and condition of rail fasteners. Those are used on lines such as the Yamanote Line and Keihin Tohoku Line, and they are scheduled to be introduced to more lines starting at the end of fiscal 2016. Data on track irregularity measured is sent to maintenance worksites wirelessly in real time. Track irregularity is captured consecutively, and that data is used to predict future irregularity.

4.2 Targets of Smart Maintenance

In smart maintenance (or CBM), track equipment monitoring started first, but it can be applied to all equipment related to railway operation. R&D is proceeding where items where development is completed and that are technically feasible are introduced and gradually expanded.

Table 1 shows the major targets. Necessary maintenance data is accumulated for equipment set up continuously along lines (track and contact line equipment) by monitoring with trains in commercial operation, and by sensors and communications technology for equipment set up in "points" along the track (bridges, tunnels, substations, switches, etc.).

Table 1 Major Targets of Smart Maintenance

Area	Obtaining data from trains in commercial operation	Obtaining data at wayside (including maintenance vehicles)
Track maintenance	• Track irregularity • Track materials • Patrol by train	
Civil engineering	• Bridges (utilize track irregularity data)	• Bridges (install sensors) • Tunnel lining
Rolling stock	• Onboard devices (function inspection, deterioration identification, failure information)	
Electric power	• Contact line wear • Feeder compression joint part • Automatic tensioner	• Substation devices
Signaling		• Static state monitoring system

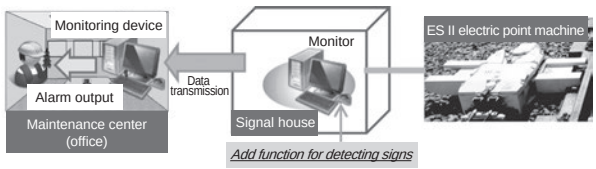

Fig. 6 Image of Point Machine Monitoring

4.3 Future Development

Maintenance work in railways involves securing safe and stable transport by continuously going through the PDCA cycle shown in Fig. 1. The Smart Maintenance Initiative can only be said to have been fulfilled when the entire cycle is "smarter". The monitoring by trains in commercial operation and sensor development covered herein is no more than the "accumulate and analyze data" part in Fig. 1. Currently, the data accumulation part alone is going ahead of others. Into the future, we will need to go forward, having a sense of urgency, with technical development related to tools for analyzing and judging big data accumulated and with that for repairs.

For track irregularity, we are developing a system to support decision-making by worksites using monitoring data. The system will predict future track irregularity, propose repair plans interactively taking into consideration restrictions such as budget and repair machinery utilization, and evaluate the effects of repairs after they are done.

Monitoring data is accumulated daily in various areas, starting with track irregularity. In order to effectively utilize this "treasure mountain" and create new value, we will need to analyze the relationship with data of other areas, such as equipment data (age of equipment, materials used, past failure history, etc.) and train operation data (frequency, speed, etc.). And in order to efficiently carry out such analysis, we need to put in place a cross-disciplinary database that includes monitoring data.

The following is an example of making repairs "smart". The Technical Center investigated, as a method of repairing track, how to use multiple tie tampers (MTT) and the progression of track irregularity. We developed an "MTT monitor" and record the amount of rail raising, number of time ties are tamped, deepness, and the like. By analyzing that data, we are working to establish methods of repairing, optimized for repair locations, that help prevent track irregularity.

With the decline in the working population, we are also researching and developing methods of mechanized construction in order to allow construction with the minimum number of people. In conjunction with full-scale conversion of Shinkansen track to continuous welded rail (CWR) from fiscal 2017, we are proceeding with mechanization of core work. Fig. 7 is an example of that, a multi-head type bolt power wrench that allows for rail fastener tightening and loosening with reduced labor.

Fig. 7 Multi-head Type Bolt Power Wrench for Shinkansen Track (Prototype)

4.4 Considerations

Cost and urgency in particular need to be considered in development. In order to satisfy both of those, we utilize general-purpose items as much as possible, avoiding development of dedicated items whenever possible. It is thus necessary for us to pay attention to technical trends around the world and know of the latest technologies. We must constantly be aware of open innovation and cooperation with outside entities.

According to a study on the success rate of projects at US companies, "technical success rate" was 80%, while "commercial success rate" was 20%. The hurdle of commercialization is much higher than the initial technical hurdle. The process of making products catch on also, not simply developing them, is an important role of the Research and Development Center.

5 Conclusion

The environment surrounding railway business is changing at blinding speed with the rapid advancement of ICT, falling population, progression of globalization, and other factors. Maintenance is becoming more important than ever in order to deal with those factors flexibly and further advance railways, an important infrastructure supporting Japan. We will thus seek, through open innovation, advanced technologies from around the world and make further efforts in R&D with an aim of innovating railways systems.

As covered in this article, there are still many things we need to do to achieve smart maintenance. And we ask for the support and cooperation of readers in this endeavor.

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