Impact of ICT Trends on Future Railway Maintenance

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The Technical Center at JR East aims for innovation of railway maintenance based on a vision of "smart maintenance". This vision consists of four concepts: condition-based maintenance (CBM), asset management, a maintenance work support system using artificial intelligence (AI), and construction of an integrated database. To realize this vision, we need to create a new system using the latest information and communication technology (ICT). It is important for the new system to properly manage all maintenance data in the company, including tacit knowledge of experts. For that purpose, we are developing an integration platform with big data analytics and technologies. This report covers the changing future of railway maintenance through latest ICT trends.

1 Introduction

The Technical Center at JR East aims for innovation of railway maintenance based on a vision of "smart maintenance". This vision consists of four concepts: condition-based maintenance (CBM), asset management, a maintenance work support system using artificial intelligence (AI), and construction of an integrated database. To realize this vision, we need to create a new system using the latest information and communication technology (ICT).

This report covers how railway maintenance will change, centering on the latest social and ICT trends through case examples of R&D.

2 Social Trends and the Direction of R&D

The population of Japan started to decline from about 2010, and has continued to decline since then. Japan's industry has experienced many successes in high-quality *monozukuri* (manufacturing) by mass production amidst the social circumstances of the post-war population increase and era of high economic growth. But changes to the economic structure with its decreasing population, diversification of values, and globalization mean conventional ways of thinking no longer apply, and traditional Japanese industry is thus in a decline. Across the world, the *monozukuri*-centered business model in place since the industrial revolution of the 18th century is crumbling, and companies offering new services using ICT under the concept of *kotozukuri* (value creation) are taking the lead in growth. For example, a manufacturer of photocopiers successfully switched from manufacturing and selling photocopiers (*monozukuri*) to leasing those and collecting usage fees (*kotozukuri*), gaining large profits (Fig. 1). This new business model proved to be a success because advances in ICT allow the company to identify the operational status of individual photocopiers at low cost, enabling maintenance to be performed before failures occur.[1]

Fig. 1 Change in Business Model by Photocopier Manufacturer

So, what direction should we go in R&D efforts when thinking from the perspective of railway maintenance duties? R&D up to now has centered on enhancing equipment and mechanizing inspection and repair work that had relied heavily on manual work. This was done in order to make a break from 3D work (dangerous, demanding, dirty) and reduce equipment maintenance costs. Equipment enhancement and mechanization are a kind of *monozukuri* idea that has fulfilled a role in reducing failures and human errors, but that has not resulted in a major change in how maintenance is done. However, with the coming population drop where an increase in revenues from railway transport cannot be expected, we have to deal with further degradation of equipment including in provincial areas. Moreover, passing down maintenance know-how is a pressing issue that cannot be ignored with veteran personnel who have played a core role in railway maintenance coming up on retirement. If we are to keep maintenance levels at a level equivalent to or greater than at present, we are probably at a point in time where it would be a good idea to think of new ways of performing maintenance duties overall (*kotozukuri*).

The following introduces the R&D we are conducting taking into account the latest ICT trends to put together a rough prototype of a new "system" necessary for *kotozukuri* that will transform maintenance duties in light of such internal and external conditions and verify the effectiveness of the system.

3 Future Trends in ICT

The following summarizes five topics that we are working on in ICT as we move toward 2020 and the trends seen in those.

3.1 Big Data

"Big data" is an idea that has received much attention around the world in recent years. In IT companies and amongst scholars, big data means more than just lots of data, being interpreted as "data that leads to knowledge helpful in corporate management and business and in people's lives". Big data includes diverse types of data as shown in Fig. 2, including text information typified by "tweets" and the like in social networking services (SNS), photos and videos, log information generated when accessing websites and the like, and information from various sensors. That data amounts to 2.8 zettabytes (2.8×10^{21} bytes) as of 2012, and it is expected to grow 14-fold to 40 zettabytes in 2020.[2)]

Technologies related to this continuously expanding big data are becoming easier to adopt in various industries with the advancement of ICT, and there are expectations for them to be adopted in the field of maintenance as well. The problem of deterioration of infrastructure built in Japan's era of high economic growth has come into focus in recent years, and the Ministry of Internal Affairs and Communications (MIC) estimates that economic effects of preventive maintenance on road bridges will be 270 billion yen. This amounts to 48% of bridge maintenance expenses for fiscal 2009.[3)] Thus, in the field of railways as well, we will likely need to use big data-related technologies to change maintenance duties.

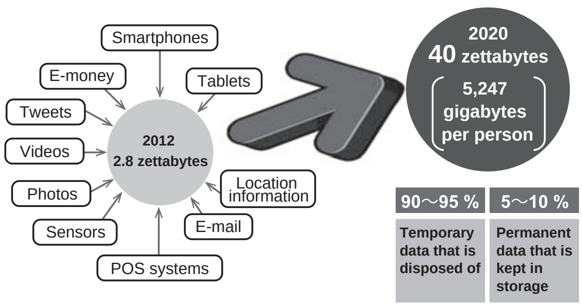


Fig. 2 Explanation of Big Data[2)]

3.2 Smart Devices

"Smart devices" have come to include in recent years wearable devices as shown in Fig. 3 as well as smartphones and tablets that are in common use.[4)] As shown in Fig. 4, the MIC expects the number of wearable devices sold to increase approx. six-fold from the 1.11 million devices in fiscal 2014 to 6.04 million devices in 2020.[5)] In that way, they will increasingly become part of our daily lives.

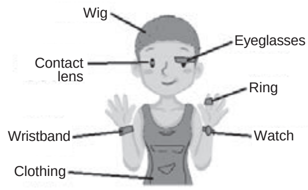


Fig. 3 Types of Wearable Devices

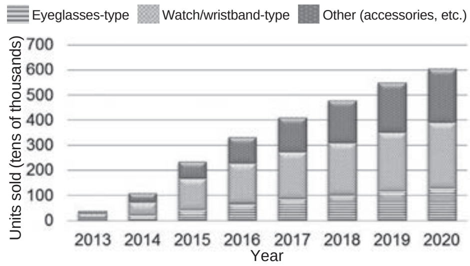


Fig. 4 Predicted Unit Sales of Wearable Devices[5)]

3.3 Smart Machines

"Smart machines"—also called artificial intelligence (AI)—are computers that are able to autonomously learn and deduce.[4)] Some famous examples are Deep Blue, which defeated a chess master in 1997; Watson, which beat the champion of a famous American TV quiz program in 2011; and Ponanza, which beat a professional *shogi* (Japanese chess) player in an official match in 2013.

Such AI with processing close to how humans think have come to receive much praise recently as a result of the introduction of machine learning. Research on AI started in the 1950s, and rule-based expert systems were in the spotlight in the 1980s. This was an attempt to express the complexity of the real world by rules alone, but it ended in failure. Reflecting lessons learned, current AI has become closer to thought patterns of humans by ignoring rules for data input and speculating just the result by statistical processing. In 2012, a joint research team by Stanford University and Google successfully used the technology of deep learning, which models the human nervous system, to obtain the concept of a "cat" from images on a network. This deep learning technology is used not only in image recognition, but also as voice recognition technology in smartphones and tablets.[6)]

3.4 Social Power

"Social power" is the condition where social media has influence on society by using smartphones and the like to loosely connect people by means such as SNS.[4)] On a certain portal site, Twitter information is displayed with some railway operational information to give real-time guidance on railways. A weather information company also provides information predicting short localized rainstorms using social power. Of the 2,800 short localized rainstorms in August and September 2012, 91% were caught in advance at an average of 56 minutes before their occurrence.[7)] This shows that social power complements catching of the occurrence of such rainstorms, which is difficult to do just by the AMeDAS observation network of the Japan Meteorological Agency.

3.5 Virtualization

The last keyword is "virtualization", which expresses separating from hardware resources that up to now had been tightly tied to hardware and making them abstract.[4] For example, virtualization technology is necessary to run software without having to be concerned about the OS of the computer running it. As shown in Fig. 5, virtualization is starting to be adopted by various ICT fields, and it can be said to be greatly changing the usage environment and the structure of the industry.

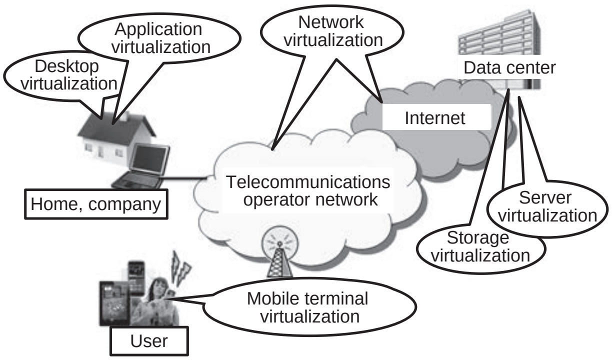


Fig. 5 Virtualization Technologies[4]

4 Efforts in R&D

JR East will explore by R&D how the ICT trends introduced here will change railway maintenance in the future.

4.1 Research Handling Big Data

Current inspection work was established since before the concept of big data came into being. For that reason, it is common practice for the volume of data generated in inspection work to be kept to the minimum necessary and for data to be used within that scope. The frequency of inspections is also the absolute minimum necessary and the threshold at which decision to conduct repairs is made is a value with a margin of safety kept taking into account the frequency of inspections. Furthermore, in inspections managed by numerical values, some items require precision in units of 1/10 mm and strict precision is demanded even for mechanization of measurement work, so much time and money is spent in development of that equipment. But in the future when large volumes of data can easily be handled, it will probably be possible to easily identify trends in deterioration of facilities and machinery without worrying about the volume of data.

The following introduces the benefits of being able to handle frequently obtained data, using track subsidence as an example. We have developed a device to inspect daily using trains in commercial operation tracks that were previously inspected using the East-i inspection train four times a year (Fig. 6). Fig. 7 shows the data obtained by this inspection device. From this data, track conditions can be obtained up to five times a day, allowing us to quickly find changes even in cases of changes to the environment that would cause track to rapidly subside. Moreover, it has become possible to very accurately estimate predictions of track subsidence because we know with certainty the day-to-day changes in the track. Such a major change in the concept of measurements will lead to major changes in the substance of future inspection devices. In other words, we should be able to perceive trends in deterioration by indirect measurement without directly making high precision measurements of the condition of equipment. Such research is ongoing at universities for road bridges and railway facilities.[8) 9)]

Fig. 6 Track Inspection by Train in Commercial Operation

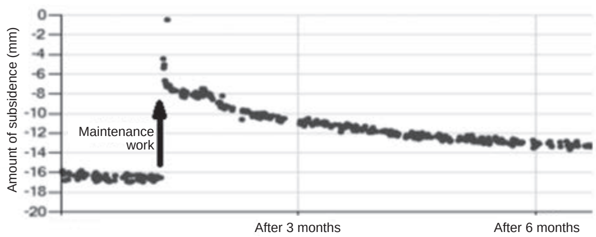
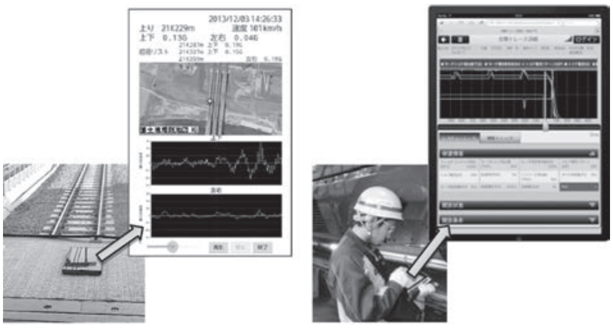


Fig. 7 Utilization of Frequently Obtained Data (Track Subsidence)

4.2 Utilization of Smart Devices

Up to now, development of inspection devices and the like was normally done from a viewpoint of "making specialized devices to deal with difficulties in work". But, looking at recent trends in ICT, we have reached a point where that way of thinking needs to change. For example, general-purpose terminals are utilized where smartphones control and store data of wristband-type wearable devices equipped with sensors. In light of such trends, many general-purpose terminals will be used for purposes such as inspection devices used by front line personnel.

The Technical Center is developing decision support tools that use general-purpose terminals. Fig. 8 (1) shows a device for checking train vibration. It uses the accelerometer and GPS functions built in to a terminal with the assumption that a smartphone or other general-purpose terminal will be used. Fig. 8 (2) shows a device for supporting rolling stock inspection work. With that, inspection confirmation for workers at different places on the train and decision support using cameras becomes possible. For the future, we are studying display of data obtained by monitoring the status of rolling stock. Functionality of general-purpose terminals is increasing greatly, and low cost inspection devices that can be handled intuitively will probably be introduced in conjunction with the advancement of virtualization technologies.



(1) Train vibration measuring device (2) Rolling stock inspection support device

Fig. 8 Research on Decision Support Using General-purpose Terminals

4.3 Smart Machines and Passing Down of Skills

The know-how of veteran engineers is very important information for conducting maintenance. However, many of the veteran personnel hired in the era of JR East predecessor Japanese National Railways are coming up on retirement and their know-how must be passed on to younger engineers in a short period of time. We in R&D have started studying the possibility of supporting the passing down of skills by using maintenance data amassed up to now along with social data such as meteorological information. We anticipate that AI technology used by smart machines could give the answer to this issue.

At the same time, a “system” where the large volume of data on maintenance can be handled freely will be necessary to effectively utilize AI technology. In other words, we have to make so the independent systems of individual fields can be freely referenced. For that reason, we believe it is important to built a platform where maintenance information can be shared. To start, we have built a prototype virtual environment and support tool where infrastructure and equipment and inspection information separated in individual systems can be displayed on a single screen, and we are evaluating and extracting issues for those (Fig. 9).

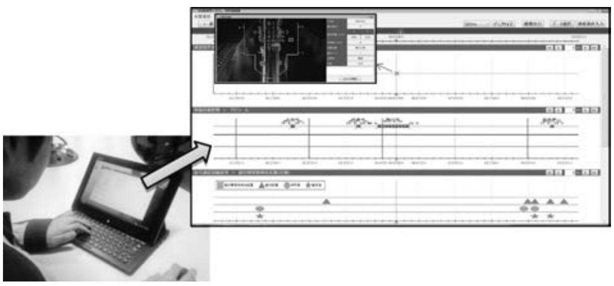


Fig. 9 Decision Support by List Display of Information from Different Fields

5 Conclusion

This article has shown the thinking from an R&D perspective on how to change railway maintenance work in the future while looking at trends in ICT towards 2020. We believe that status monitoring will be done for some rolling stock, tracks, and overhead contact lines in 2020. With such a “system” in place, *kotozukuri* for maintenance into the next generation will be possible.

The foundation of maintenance is to inspect and conduct repairs before infrastructure and the like fails. That principle remains unchanged, but one must wonder what maintenance would be like in a world where equipment operational status gained on a day-to-day basis could be tangibly perceived. One could imagine that maintenance that once relied on experience and intuition will become maintenance based on data. In order to realize such a world, the Technical Center is promoting R&D under the idea of open innovation, proposing new styles of maintenance work.

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