RAILWAY TRACK MAINTENANCE OF JR EAST

Atsushi Yokoyama[1]

ABSTRACT : Maintenance work of railway facilities is an important issue to sustain the safety and the reliability for High Speed and the conventional line.
JR east is responsible for the maintenance of Shinkansen , the maximum speed 320km/h, and Tokyo metropolitan area railway lines, the most heavily dense railway in the world.
One of the key technologies is the diagnostic of the infrastructure.
We introduced special inspection vehicle, "East i" for the diagnostics of the track and other facilities like catenary and signaling and the cutting-edge diagnostic device equipped with the commercial train for inspecting the track conditions.
Also, the analysis of the collected data is very important for the proper decision making in the aspect of the maintenance cycle.
We always try to improve the PDCA cycle in accordance with the advance of the technology.
In this paper, I would like to introduce the latest technology and the future strategy for railway maintenance activity of JR east by using ICT.

KEYWORDS: railway, smart maintenance, monitoring equipment, CBM, ICT, asset management, expert system

1. INTRODUCTION

In recent years, the issues related to the aging infrastructure such as bridges and tunnels and other facilities including the railway structures attract the attention of the society.
As the maintenance engineer of railway industry, we understand that we are at the historical point for changing the maintenance concept and the methods drastically by using ICT.

2. CHARACTERISTICS OF THE FACILITIES OF RAILWAY

We have to deal with the wide variety of the railway facilities such as track, catenary, bridges, tunnels, signaling and other electric facilities in order to operate trains steadily.
We adopt the fail-safe policy to keep the train operation secured, that means we must pay much attention to the maintenance of these facilities.
As the railway operator, we have almost all operational data (**Figure 1**). This situation gives us a big advantage for R & D activity for the modernization of the maintenance of railway.

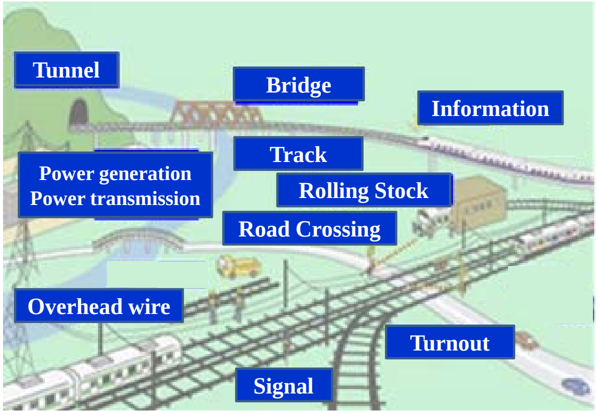


Figure 1. Railway facilities

[1] Director, Technical Center, Research and Development Center of JR East Group, East Japan Railway company, Japan,

3. THE BACKGROUND OF SMART MAINTENANCE

Figure 2 shows the demographics of Japan from 20th century to 21st century.

As for the railway facilities, after the word war Ⅱ, railway industry had constructed the railway lines all over Japan as the increase of the population and in 1964 the first high speed line, Tokaido Shinkansen between Tokyo and Osaka was completed. These railway networks had contributed to the development of the Japanese society in 20th century.

In 1987, the former Japan National Railway was privatized and divided into 6 passenger companies and JR east is one of them.

Since the privatization, we had tried to keep the facilities stabilized and have succeeded to it.

Now, in 2013, we are at the point of the beginning of decrease for the number of population, which means that for the railway company, we should prepare for the drastic decrease of revenue from the passengers.

Moreover, the infrastructure is going to be older and become more difficult to be properly maintained.

That is the main reason why we should change the maintenance policy from the conventional way to smarter one.

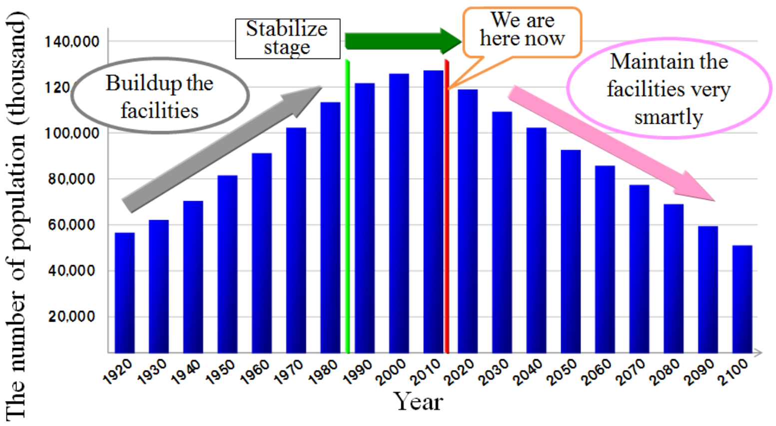


Figure 2. Demographics of Japan

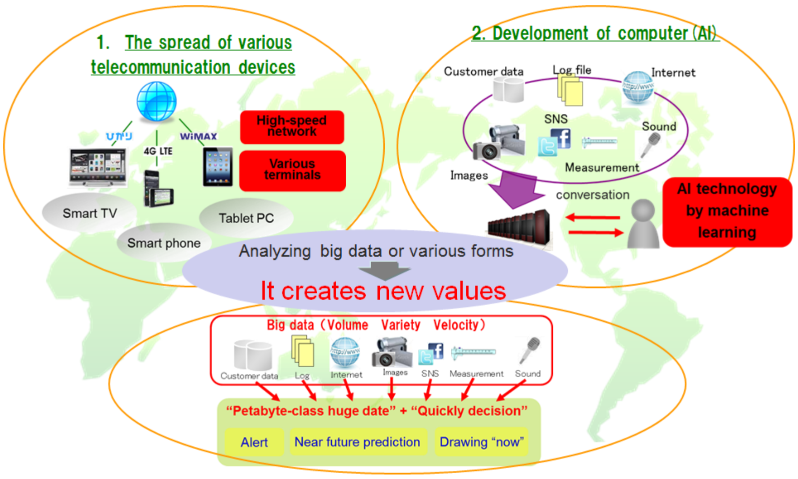


Figure 3. Rapid development of ICT

And another background is the rapid development of ICT as shown in **Figure 3**.

4. THE CONCEPT OF SMART MAINTENANCE

I will introduce the Smart Maintenance concept that consists of 3 aspects.

(1) Shift from TBM to CBM
(2) Applying the Asset Management
(3) Develop the Expert system by AI technology

I will refer to these 3 aspects. [2]

(1) Shift from TBM to CBM

JR east has adopted TBM(Time Based Maintenance)method as the maintenance so far.

TBM is the way that we collect the data of the facilities to check the condition at the interval determined by the regulation or the low.

As for the conventional track, we inspect the track geometry every 3 months regularly by the special inspection car called “East i”. For Shinkansen, we collect the track geometry data every 10 days at the same speed as the commercial train.

The **Table 1** shows the specs and the main characteristics of the “East i”.

Table 2 is the outline of other inspection devices.

Table 1. Overview of Electric & Track General Inspection Car "East i"

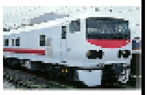
Car Series	Shinkansen	Conventional line	
	Series E926 (TEC) 	Series E491 (EC) 	Series E193 (DC) 
Max speed	275 km/h	130 km/h	110 km/h
Sets	6 cars	3 cars	
Inspection Equipment	(Track): Track irregularity measuring equipment (Longitudinal level, Alignment etc…), Train acceleration, Track center distance (Electric facilities): Overhead contact line measuring equipment (Wear, Isolation etc…) (Signal): Signal & Information condition measuring equipment		
Body weight	About 46 tons	About 45 tons	About 45 tons
Body length	About 20 m	About 20 m	About 20 m
Body width	2,945 mm	2,900 mm	2,900 mm
Body height	4,280 mm	4,051 mm	4,051 mm

Table 2. Overview of Other Inspection Equipment

Name	Inspection	Inspection Items	
Tunnel Lining Inspection Car(for Shinkansen)	General Inspection (Tunnel)	Grasping inside of tunnel lining (self-propelled type)	
Track Lower Cavity Proving Car	Inspection for Earthwork Equipment	Proving condition of track lower cavity by using radar (self-propelled type)	
Rail Flaw Inspection Car	Close Inspection of Rail, etc…	Grasping inside rail flow by using ultra sonic wave for preventing rail flow accident. (self-propelled type)	
Turnout Inspection Equipment	Turnout Functional Inspection, Turnout Track Condition	Grasping wear & flow of turnout materials for preventing rail flow accident. (hand-push type)	
Automatic Expansion Gap Measuring Equipment	Expansion Gap Inspection	Measuring gap between rails for preventing track buckling in summer (self-propelled type)	

After collecting the data, we make a decision whether or not we should take action for the repair work based on the some criteria.
The **Table 3** is the example of these criteria for the track irregularities.
Based on this traditional way of maintenance (TBM), we are to take action just after the data exceed these criteria.
In TBM it is difficult for us to take preventive action based on the future situation of the facilities.
Instead of TBM, we now consider to take new way of maintenance called CBM(Condition Based Maintenance).
We consider that there are 5 aspects in CBM as shown in **Figure 3**.

Table 3. Criteria of track irregularity in JRE

				(order: mm)
Maximum Speed	Faster 120 km/h	Faster 95 km/h	Faster 85 km/h	Faster 45 km/h
Gauge	Straight line and curve with radius exceeding 600m			… +20
	Curve with radius from 200m to 600m, inclusive			… +25
	Curve with radius less than 200m			… +20
Cross level	Maintenance is done on the basis of twist			
Longitudinal	23	25	27	30
Alignment	23	25	27	30
Twist	+23 (includes the diminishing amount of cant)			

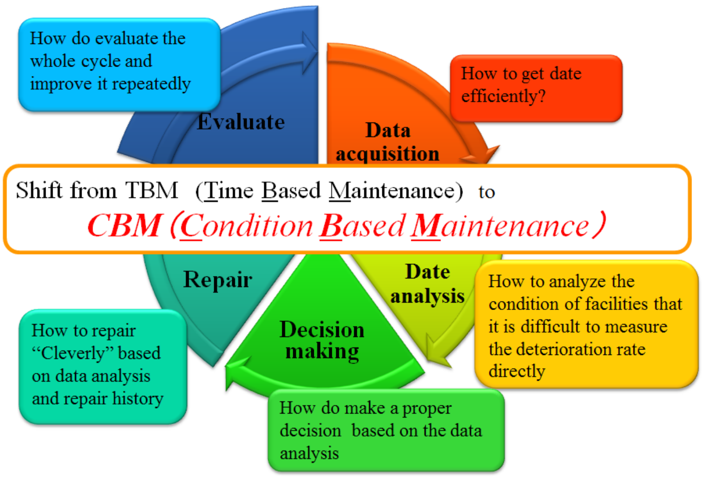


Figure 3. 5 aspects in CBM

i) <u>Data acquisition</u>

Figure 4 shows the difference of concept between TBM and CBM regarding the track irregularity.

To realize CBM, First of all, we should gather the data as many as possible to catch the degradation of the facilities.

We started the test run to monitor track irregularities and the track images by using the commercial train from this May (**Figure 5**) [3]

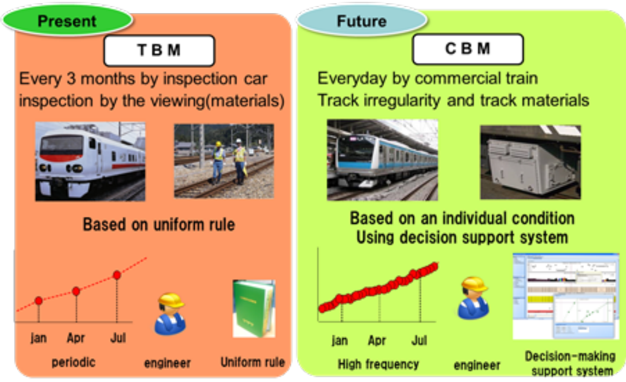


Figure 4. TBM & CBM

Figure 5. Track monitoring equipment

With the equipment, we can monitor the condition of track continuously and predict the track condition of near future to take the preventive maintenance.

Other than the track irregularity, we are now operating the test train to monitor the condition of electric power equipment as shown in **Figure 6**.

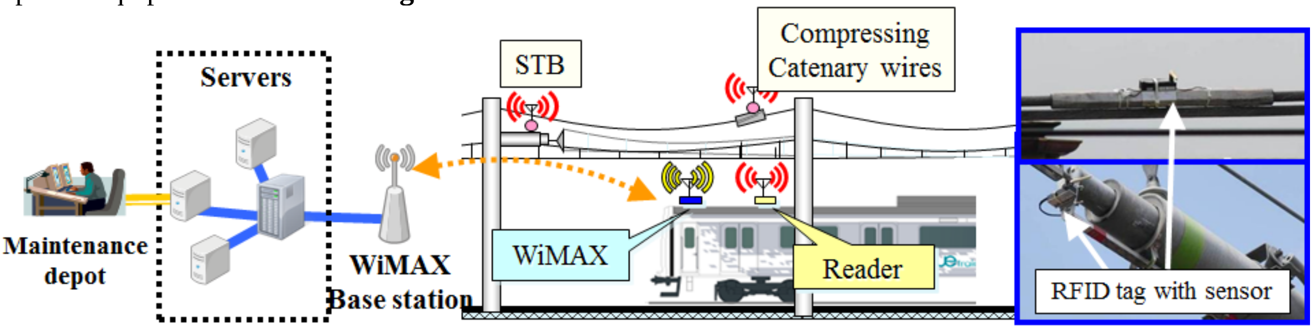


Figure 6. Overview of electric power equipment monitoring

Anyway, effective data acquisition is the key to carry out CBM.

So we are going to try to get data more effectively by means of commercial train, various sensors, graphical images and robotic technology.

ii) Data analysis

After gathering large amount of data, we have to analyze those data to catch the degradation of facilities.

In this stage, there are 2 types of methods for data analysis.

First one is the analysis of the facilities that the degradation is measured or observed directly from the data.

For example, track irregularities, wear of rail or wire are measured by the figure and it is not difficult to assess the degradation and predict the future condition of those facilities.

On the contrary to the examples, it is more difficult to evaluate the degradation of facilities such as electric devices or machines.

But with the advancement of “Big data analysis technology”, we are now able to know the degradation and the symptom of the failure of this type of facilities.

In our R & D center, we are now trying to analyze the data in terms of the door troubles of train sets as shown in **Figure 7**.

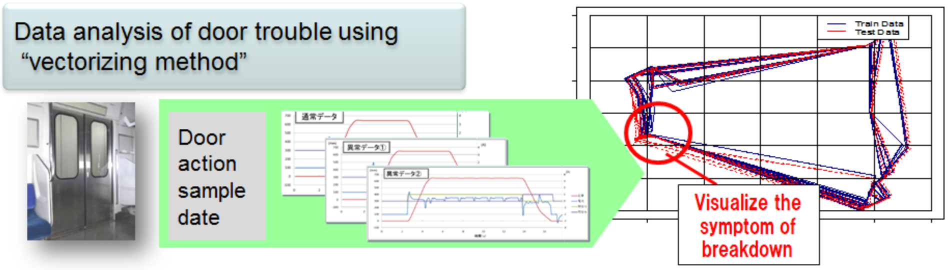


Figure 7. Concept of date analysis (Door troubles)

In this figure, we can visualize the symptom of breakdown of train door by the analysis of various data regarding door system like electric current, position of doors, friction of doors and so on.

This type of big data analysis is now at the testing stage, but in the near future we will do very effective condition based maintenance for the machines or electric devices that we currently inspect and change these facilities at regular intervals and also we can take proper countermeasure to prevent the failure occurrence.

And also **Figure 8** is the data analysis example of switching machine.

As for this machine, we are trying to find the signs of failure by using the “Bayes estimation” and “Wavelet analysis” that are both latest “Big data analysis” methods.

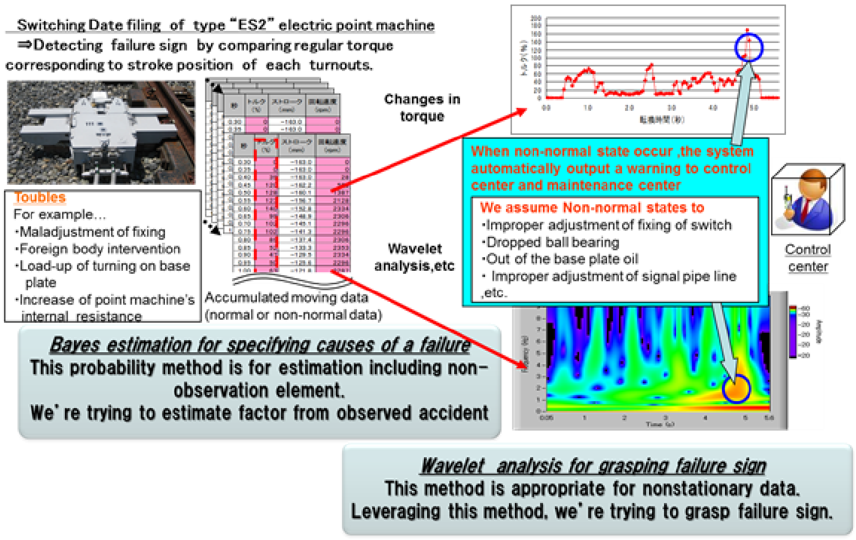


Figure 8. Concept of date analysis (Point machine)

iii) Decision making system

In the maintenance field, it is vital to introduce the sophisticated decision making support system for the engineers who are responsible for the maintenance work at the sites of railway maintenance.

This system makes us to simulate the repair plan considering the various conditions like budged, operation plan of maintenance machines with very user-friendly manner.

Figure 9 is the image of decision making support system for the track maintenance work with the function of calculating the deterioration rate as for track irregularity and predicting the timing of repair work necessary before it reaches the threshold.

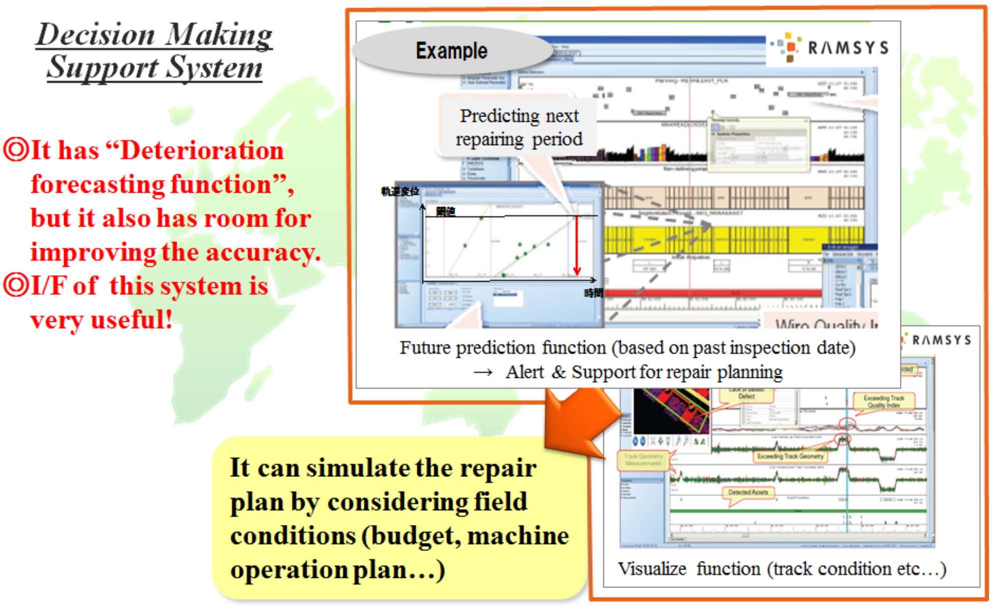


Figure 9. Image of decision making support system

iv) Repair work

Doing the repair work cleverly based on the data of past repair work and the characteristics of each section as well as the result of data analysis is the important issue for maintenance cycle.

Figure 10 shows the typical repair work called tamping that is vital to keep the good condition of railway track.

In this tamping, it is important to adjust the squeezing time or tool depth in accordance with the condition of track currently determined by the "veteran's tacit judgment".

So from now on, we have a plan to make a sophisticated computer system that suggests the best way for tamping based on the various data including the results and the way of past repair work.

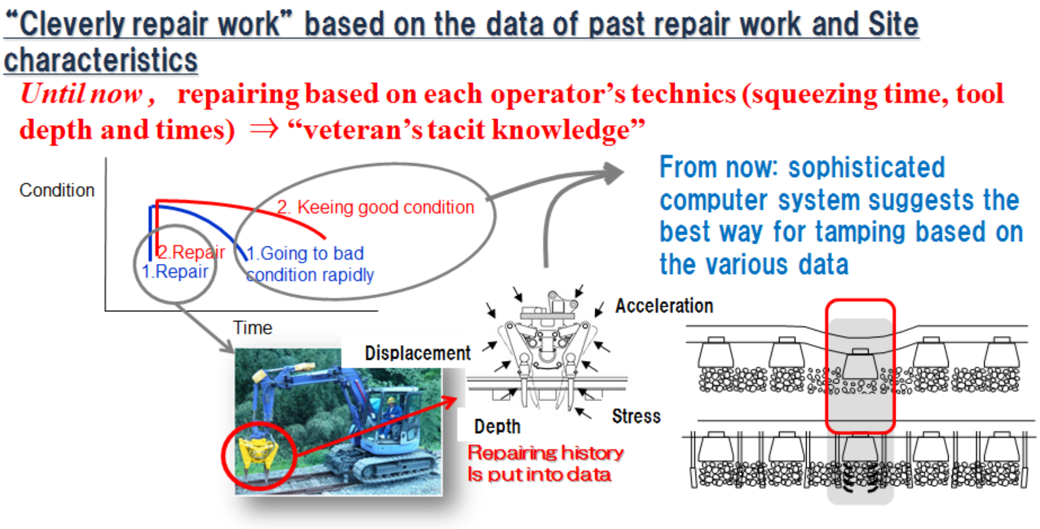


Figure 10. Image of "Cleverly repair work" support system

v) <u>Optimization of whole PDCA cycle</u>

The most important issue to realize the Smart Maintenance concept is to optimize the PDCA cycle as shown in **Figure 11**.

Even if the cost for the data collecting increases, we can do efficient maintenance by making the decision making stage more effectively. Consequently we could always make the cycle progress by evaluating the result of the repair work and optimize whole cycle.

In accordance with the advance of ICT, we can improve this method more and more efficiently and we would like to build the most sophisticated and cost effective maintenance system in the world.

We now consider making the whole computer system that covers the all aspects of CBM with continuous flow of data from data acquisition to evaluation of the results of repair work.

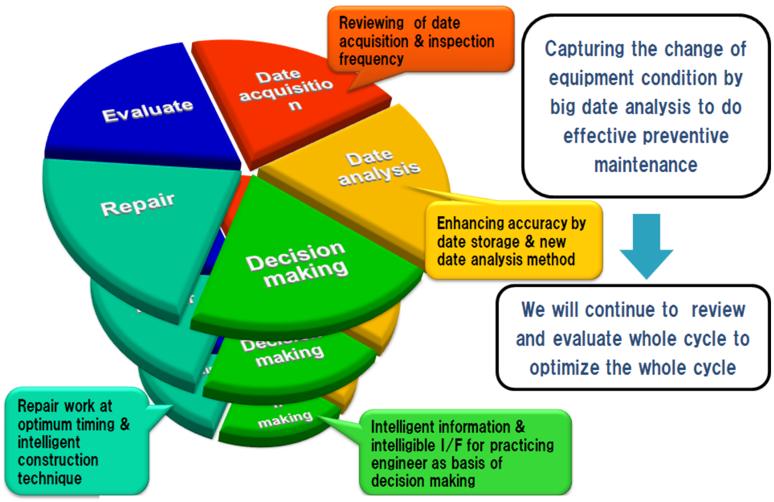


Figure 11. Optimizing the PDCA cycle

(2) Asset Management

Another aspect of Smart Maintenance is Asset Management.

Asset Management is the well-known concept to make a strategic whole plan for managing the Life Cycle Costs and the investment for replacing the facilities.

In order to apply this Asset management concept to the railway facilities, we have to get the data in terms of the deterioration and express them as a statistic way like Markov chain.

And also by using the date regarding the repair work to restore the ability of the facility, we can calculate the balance between risk cost and maintenance cost and find the minimum point of total cost (**Figure 12** & **Figure 13**).

We have an intention to apply this management method to the civil engineering assets like bridges and then to track facilities.

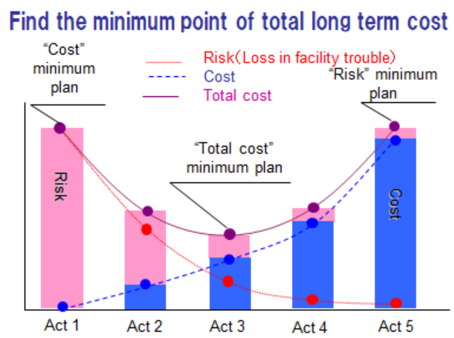


Figure 12. Concept of asset management

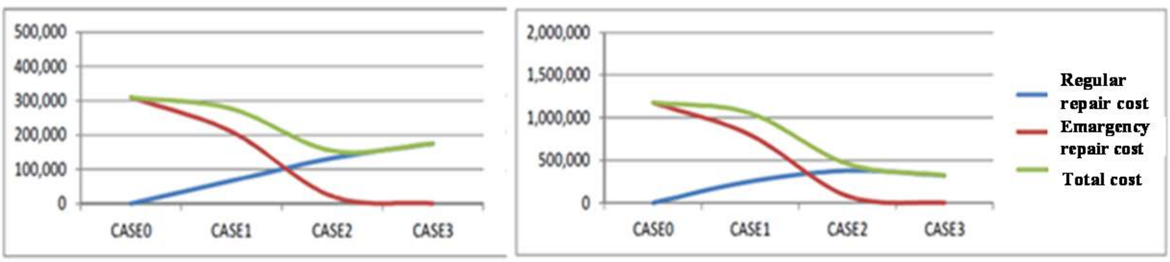


Figure 13. Simulation example of asset management (civil engineering structure)

(3) Develop the Expert system by AI technology

The third aspect of Smart Maintenance is the Expert System by using AI (Artificial Intelligence) technology.

In the maintenance field, the engineers of the sites need to respond or take action properly to the various matters that occur almost every day such as accidents, weather change (raining, thunder storm, snowing) and so on.

We now rely on the veteran's know-how or experience for these proper actions to various matters.

But we are currently at the stage of generation change of maintenance engineers. It means most of engineers with lots of experience for responding the happenings are going to retire and replace them with the engineers with less experience.

So we have a plan to build up the" Expert System" that will deal with the troubles as same manner as veteran engineer by teaching the way of thinking or skill for proper troubleshooting. (**Figure 14**)

Figure 15 is the concept of "Expert System" for responding the troubles and finding the possible cause of the trouble by reading the all related documents (by Text mining) and seeking the similar documents (by Machine leaning).

We know that it could be very hard task to build the system practical enough, but it is worth challenging for the future generation.

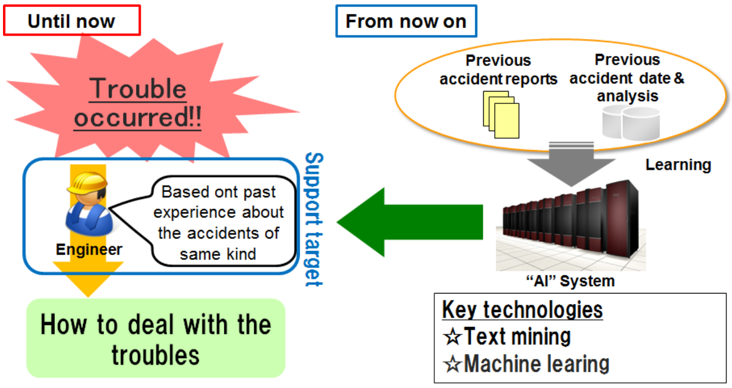


Figure 14. Support target of Expert system

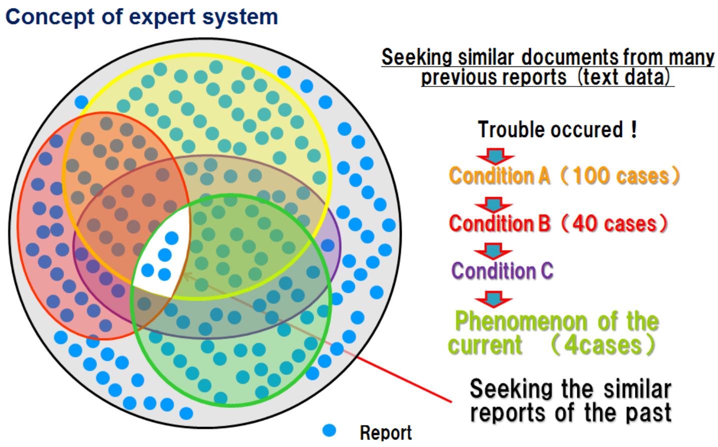


Figure 15. Concept of Expert system

5. WHOLE SCHEDULE FOR SMART MAINTENANCE

Figure 16 is a whole plan of Smart Maintenance. We are trying hard to realize it as soon as possible.

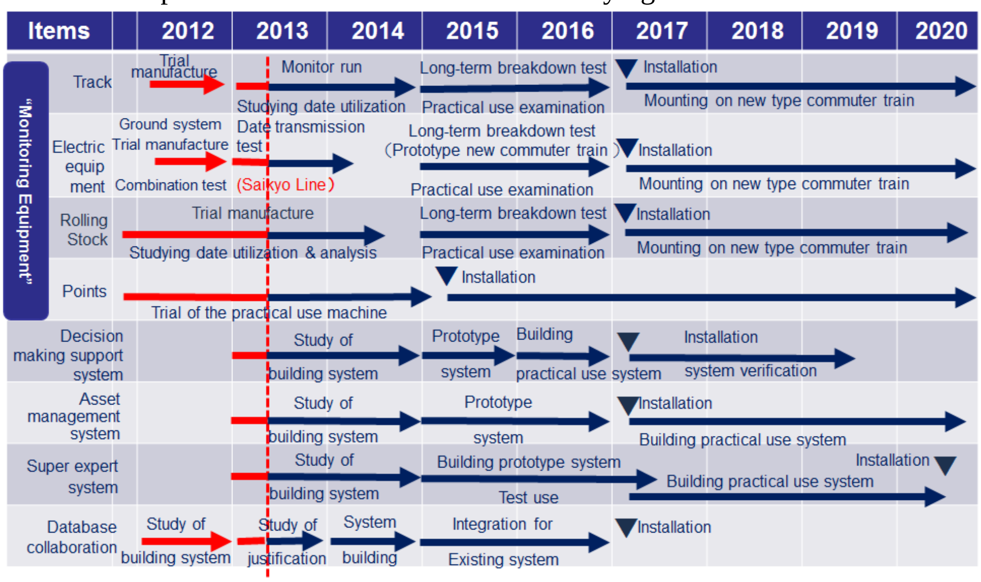


Figure 16. Whole plan of Smart Maintenance

The most important issue to realize the Smart Maintenance concept is to optimize the PDCA cycle as shown in Figure 8.
Even if the cost for the data collecting increases, we can do efficient maintenance by making the decision making stage more effective. Consequently we could always make the cycle progress by evaluating the result of the repair work and optimize whole cycle.
In accordance with the advance of ICT, we can progress this method more and more efficient and we would like to build the most sophisticated and cost effective maintenance system in the world.

6. CONCLUSION

It is no exaggeration to say that we are at the turning point with regards to maintenance methods considering the aging infrastructure in Japan.

We, JR-east, have a strong intention to lead the innovation in terms of the technology of maintenance with the latest ICT.

To realize it, it could be inevitable to corporate with the organizations or companies of various fields.

7. REFERENCES

[1] National Institute of Population and Social Security Research, “Future population estimates in Japan”, 2012, URL: http://www.ipss.go.jp/

[2] Atsushi Yokoyama, “Arrival of a Great Turning Point in Maintenance: Smart Maintenance Initiative”, *JR EAST Technical Review*, No.22, Spring 2012, pp. 4-5.

[3] Ryou Terashima, Hiroyuki Matsuda, Mitsunobu Takikawa, Masanobu Kozeki, “Development of Track Monitoring Systems: Development of Prototypes for Trains in Operation and Running Tests Using a Test Train”, *JR EAST Technical Review*, No.22, Spring 2012, pp. 11-14.