Special edition paper

Construction of a Decision-making Support System for Proposing Track Maintenance Plans



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Current maintenance plans are based on time-based maintenance (TBM). TBM is based on instruction for track maintenance and repair limits. On the other hand, in condition-based maintenance (CBM) the track maintenance plan is determined in consideration of cost-effectiveness and the maintenance level at which reasonable maintenance is possible. The decision-making support system introduced in this paper can propose track maintenance plans using details of track irregularity by analyzing frequently obtained data. Through the construction of the system, realization of high-quality track maintenance and improvement of technical capabilities can be expected. We report on the development and content of the decision-making support system in this paper.

●Keywords: Decision-making support system, Condition-based maintenance, Track condition prediction, Maintenance plan

1 Introduction

With the introduction of condition-based maintenance (CBM), front-line engineers have come to subjectively make decisions based on condition prediction results and simulation results based on the huge amount of diverse data at the worksite instead of based on rules and regulations as was done in the past. This is a great paradigm shift that can be seen as a complete turnaround in the process of maintenance.

In light of that shift, it is important to build a decision-making support system that helps front-line engineers in coming up with the best reasonable answers.

In this paper, we will discuss current efforts in development of a decision-making support system.

2 Overview of the Decision-making Support System

Currently, decisions in maintenance on whether or not repair is necessary are basically based on thresholds such as maintenance intervention levels. Front-line engineers are required to manage maintenance with the time parameters of cycle or limit, asking questions such as “is the inspection cycle appropriate?” or “are repairs completed by the time limit?” Equipment control systems also focus on backup functions to prevent missing the appropriate timing—a type of so-called alert system. Therefore, front-line engineers simply need to proceed with the maintenance plan as scheduled by the system. This is a very rational system when seen from the perspective of following rules; however, it is a system where front-line engineers can have fewer chances to utilize their own experiences and knowledge.

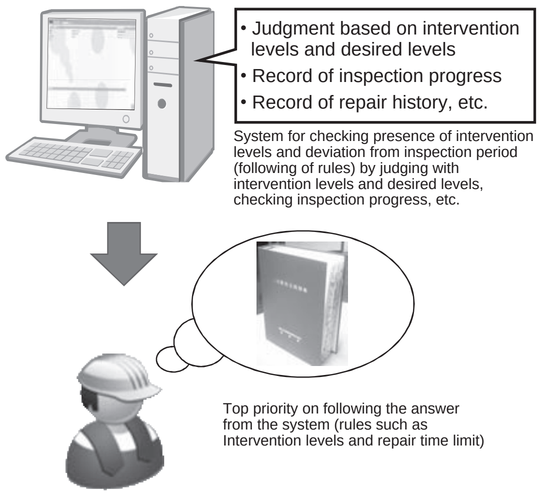

Fig. 1 Current Decision-making Process

On the other hand, the decision-making support system now under development is a support tool for engineers to find the best answers, assuming CBM is in place. With CBM, engineers will not simply search for answers from the system. Instead, they will make simulations based on suggestions from the system to decide on more rational maintenance plans and the like.

In this context, as more data is accumulated, the logic and algorithm will become more sophisticated and consequently suggestions from the system will become more intelligent. In other words, the effects will be seen gradually, but they will increase and be sustained even more as the volume of data increases.

The appropriateness of decision-making by engineers will be evaluated objectively based on the data. That should make the job of the engineers positive and creative, giving them motivation and sense of accomplishment.

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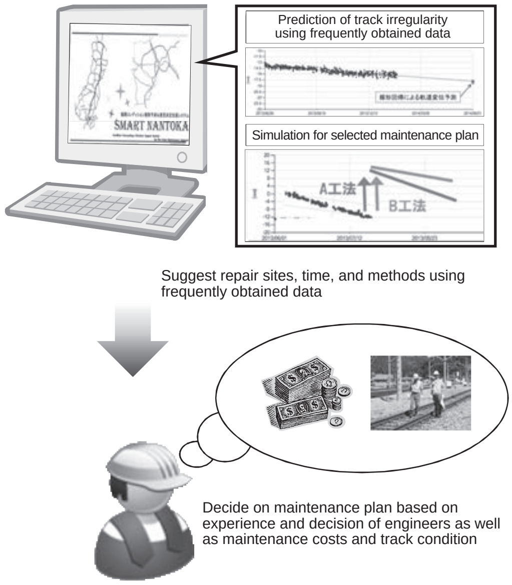

Fig. 2 Decision-making Process Using the Support System

3 Functions of the Decision-making Support System

3.1 Provision of Predictions Based on Different Indexes and Accuracy of the Predictions

The P-value has been long used as one of the indexes that indicate track condition. The P-value is the ratio of the part of the track with track irregularity larger than ±3 mm compared to the total track section to be checked. With track in better condition, the P-value is smaller, and with track in poorer condition, it becomes larger. As the P-value can be obtained simply by totaling the length of the track with track irregularity larger than ±3 mm, it can be easily calculated manually, but not very accurate as an index of track condition. A new index (σ-value) that indicates track condition by the standard deviation of track irregularity was later introduced after computers came into common use, making statistical processing much easier. Another example of an index is the maximum irregularity value in the section.

As seen here, there are different indexes that indicate track condition, and those have different advantages and disadvantages. How suitable they are differs depending on the track condition. We thus thought it would be helpful in decision-making support for engineers to suggest prediction results using different indexes instead of using a single index. That would allow any future breakthrough indexes also to be handled.

Prediction essentially requires accuracy, and accuracy of prediction is often the criteria by which users evaluate the system as being good or bad. Accuracy becomes lower in prediction of situations further into the future, but if we are afraid of that and suggest predictions just for the shorter term or only specific items for which accuracy can be assured, front-line engineers will naturally not use such predictions. On the other hand, if we suggest predictions while hiding their low accuracy, the engineers will not use such predictions either because of low reliability. Taking such into account such tendencies by users in evaluation, we believe it best to suggest predictions results as-is, including prediction accuracy.

The decision-making support system thus indicates prediction accuracy (probability) and prediction error too. Fig. 3 shows a part of the screen.

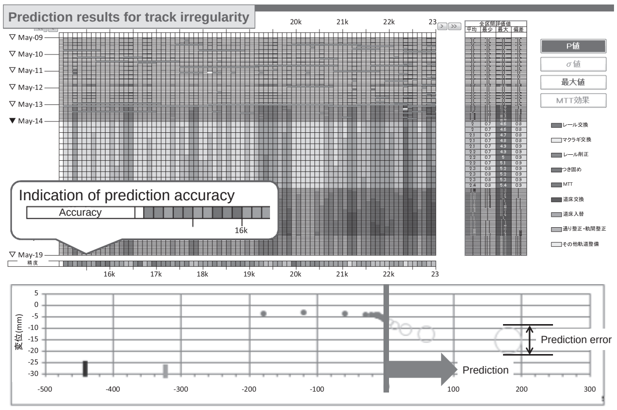

Fig. 3 Example of Prediction Results Screen

3.2 Display of Related Data Needed by Engineers

Track irregularity occurs from different causes, so maintenance planning involves investigation of many factors that might affect irregularity to identify the root cause and making a plan for maintenance of both of track irregularity and the causes of irregularity.

We thus provided a function to display with the system many types of information in parallel. The items and order of display can be flexibly changed as engineers desire. Fig. 4 shows an example of a screen.

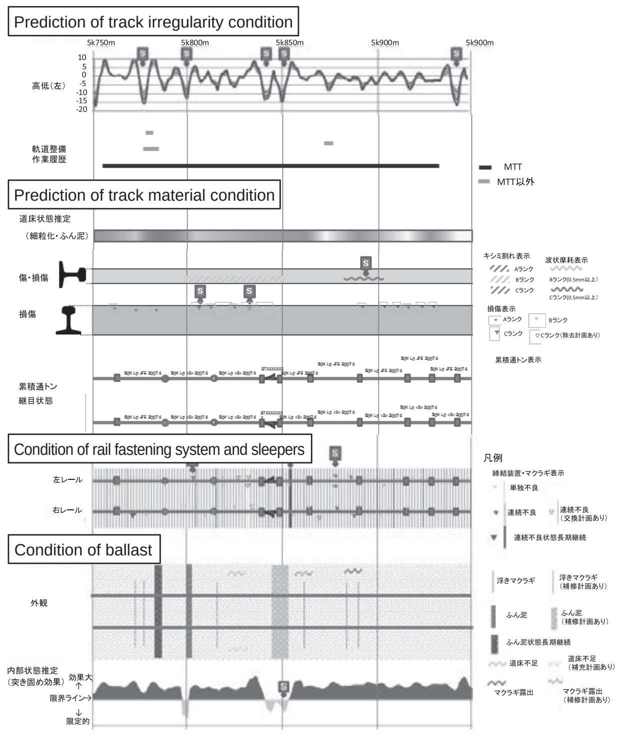

Fig. 4 Example of Related Item Screen

3.3 Function for Making Multiple Suggestions and Simulations

The most important feature of the decision-making support system is the function for making multiple suggestions and simulations. That is a function where effects and costs are suggested for different maintenance methods and where a prediction of change in track condition is displayed by inputting a maintenance plan. Fig. 5 shows an example of a screen. As shown, the screen displays a prediction of track irregularity, prediction of track material condition, and suggestion of maintenance methods for the predicted track material condition. The system suggests more than one maintenance method, and it ranks the methods based on maintenance effects and costs. That supports front-line engineers in making decisions based on track condition, maintenance effects and costs, and the like.

The effects of individual maintenance methods could not be simulated with measurement data from the currently used electric and track inspection car (East-i) at a practical level of accuracy. But, analyzing data frequently obtained by track monitoring using trains in operation enabled precise simulation per individual repair site.

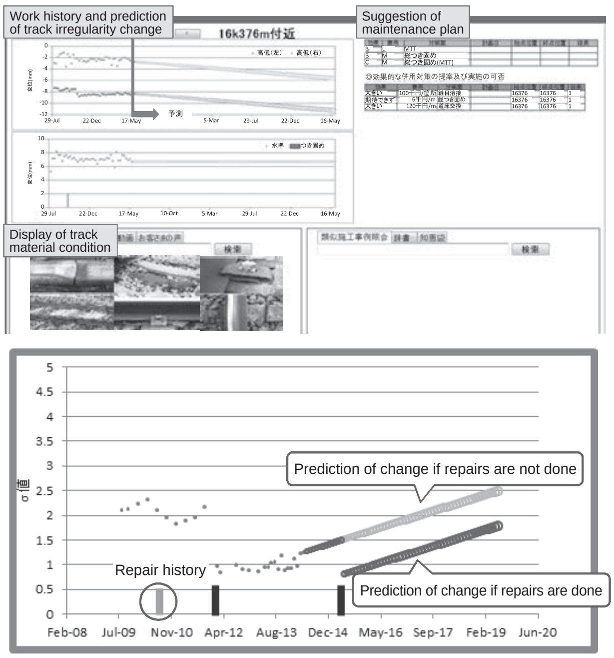

Fig. 5 Example of Multiple Suggestion and Simulation Screen

3.4 Constantly Upgraded System

The decision-making support system is not a conventional system that is updated or replaced due to obsolescence or lifetime of the machine. It is rather being developed as a system that is upgraded or customized as needed by the worksite at the request of front-line engineers or when a new index or theory that will support decision-making is discovered. This means the system can be introduced before completion of development; the parts completed can be introduced and then gradually upgraded. As the system is constantly upgraded, it does not fall under a concept of being a "complete" system, rather being a "constantly evolving" system.

4 Effects of Introducing the Decision-making Support System

The aim of the system is not to replace work or to reduce work time, so we cannot expect with the system direct reduction of labor cost or other costs where specific figures can be presented. Rather, it may actually involve factors resulting in cost increases initially.

However, rational decision-making using the system and penetration of CBM will generate huge cost reduction effects. Furthermore, upgrading the system will lead to more rational decision-making, further improving cost effects. Those cost effects will be sustainable, rather than temporary, meaning they will increase further into the future.

5 Future Efforts

As a track monitoring system using trains in operation was introduced in the second half of fiscal 2014, we introduced a prototype decision-making support system and started test operation by front-line engineers. We plan to make future improvements to the system taking into account the comments and requests of engineers.

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