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STUDY ON THE PERMANENT WAY SAFETY MANAGEMENT INFORMATION SYSTEM FOR HIGH-SPEED RAILWAY OF CHINA

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Abstract

With the development of the high-speed railway in China, the safe operation has become the most important topic of transportation by railroad. As equipment safety management system, whether it can achieve information management, information utilization and information transmission scientifically or not is the key to the working order of permanent way equipment. However, study on permanent way management information system (PWMIS) in railway system of China is just beginning and the MIS of the safety of permanent way for the high-speed railway has not been established yet. There are still many defects in current PWMIS, such as the use of manual books of account of equipment, the slowness of information transmission, little visualization, a lack of information sharing and so on. Current PWMIS can't forecast sudden safety accidents or hidden troubles and provide appropriate treatment in time. Moreover, the leaders can't make scientific and timely decisions by the help of the system. Although having information of accidents and historical data, current PWMIS is unable to make systematic analysis after the accident happened. Furthermore it can't provide valuable data for the prevention of accidents and make optimum decisions by historical data automatically. In this paper, aiming at the shortage hereinbefore, the framework and the structure of the permanent way safety management information system (PWSMIS) for high-speed railway of China are discussed. And the main subsystems of PWSMIS such as basic database, prediction, decision-making by use of artificial neural network (ANN) and expert system (ES) are studied. PWSMIS will lay the foundation for the modernization of the digital information system of the permanent way management for Chinese high- speed railway.

Key words: Permanent way management, MIS, high-speed railway, prediction, decision-making, ANN, ES

Introduction

Along with the overall increase of speed in trunk lines of railway net and the development of the high-speed railway in China, safe operation has become the key problem to transportation. The increasing speed of trains speeds up the worsening process of the permanent way equipment, and also results in the increase of hidden troubles of transportation. The workload of permanent way department becomes heavier. At the same time, the time for safety examination and maintenance task is decreasing continually because of the increase of the density of traffic (passenger transport or freight) and the decrease of intervals of traffic. Thereby, hidden trouble of transportation increases more and more and the conflict between the safe operation and the maintenance task sharpens increasingly. Some of the permanent way equipment in trunk lines have been replaced or enhanced for high-speed trains. But the enhancement of structures of trunk lines is limited because of the increase of the interaction between the track and the wheel caused by running trains and the increasing need for the smoothness of the track. The behindhand traditional technique of examination and maintaining and the lack of the maintain ability put the permanent way department under great stress and the safety problem becomes more and more crucial. That is to say, the permanent way department must adopt the scientific mode of permanent way safety information management system for the development of the high-speed railway.

How to obtain the best economic efficiency on the premise of safe running of vehicles is the key problem on which both domestic and abroad permanent way researchers have focused all their attention for a long time. How to arrange the labor, implement and equipment more reasonably in order to make use of the limited fund more efficiently and how to plan major overhaul, medium repair and daily maintenance more scientifically are studied.

Railroads all over the world started to make use of computer technique for railway permanent way safety management information systems since the beginning of 70's and some of them have succeeded. These railway permanent way safety management information systems fulfilled the dynamic superintendence of the permanent way work information and had functions of forecast, analysis and decision, which provided powerful supports to maintenance plans. As a result, the permanent way equipment can keep good status and safety operation is guaranteed availably. For example, the Relational & Integrated Databases system for Shinkansen track in Japan, the Surface Management System of the United States, the permanent way information system of Canada Pacific railroad, the decision-making support system GEV of Switzerland, the ECOTRACK (the economy track maintenance) of ERRI (European railroad research bureau), have succeeded. In addition, the permanent way sections of Germany, Holland, Poland etc. have done plentiful researches on the permanent way safety management information system too.

In a long time, the daily record management is the main model of the permanent way safety management in China. Paper is used to transmit information and to give a report or assign a task. The maintenance and repairing task are carried out mostly according to the maintenance statute combined with the personal experience of workers. So it is hard to make scientific prediction and decision, especially to make quick reactions to sudden safety accidents.

For the sake of improvement, railway permanent way department in China began to make use of the computer technique with other advanced techniques to manage the equipment, resource, monitoring data of the permanent way system since 1980's and some valuable software packages are developed, such as the permanent way equipment daily record database, superintendence software, track-checked vehicle, the database of line scene, E-maps which reflect the national railway information all over the country, and so on. The PWMIS developed by Information Technology Center of the Ministry of Railways of China does better in static management. However there is no efficient dynamic permanent way management information system in China, especially no one for high-speed railway.

Compared with other countries, the total mileage of railway in China is long and the lines are over a large area. The administrative management levels are numerous and complex. The standards of maintenance and repairing are different from other countries. So the foreign successful systems mentioned above are unlikely to run well in China. Aiming at the characteristics of Chinese railway, a design of PWSMIS is presented on the basis of our long-term research. At first, it is essential to fulfill the functions of static management. Then on the basis of modern test methods for railway, a permanent way safety management information system with the functions of analysis, prediction, decision-making by means of advanced computer technique must be developed according to the characteristics of high-speed railway safety management. This system will have the important theoretical and realistic meaning for the modernization management of the high-speed railway in China.

Main Frameworks of PWSMIS for High-Speed Railway

On the basis of research work on the actuality of management for the high-speed railway and synthetic analysis of requirements of permanent way sections of all levels, the framework of PWSMIS that is true of the situation of China is presented as shown in Figure 1. Generally speaking, the safe information management should include the treatment of sudden accidents and daily safety maintenance of equipment such as the emergency repair, daily maintenance of the equipment and major overhaul or medium repair. Therefore, the PWSMIS for high-speed railway will have the functions of prediction and decision-making, which could be achieved on the basis of dynamic and static management for the permanent way equipment by means of the experience of specialist and intelligent analysis.

To fulfill the functions put forward in the above framework of PWSMIS, an appropriate structure of it is presented as shown in Figure 2. The workflow of PWSMIS is also reflected in Figure 2.

To build the PWSMIS with the presented framework and structure, many research works must be done. Differing from other conventional MIS, PWSMIS has some specialties requiring an in-depth study, such as dynamic data management, prediction, decision-making and so on.

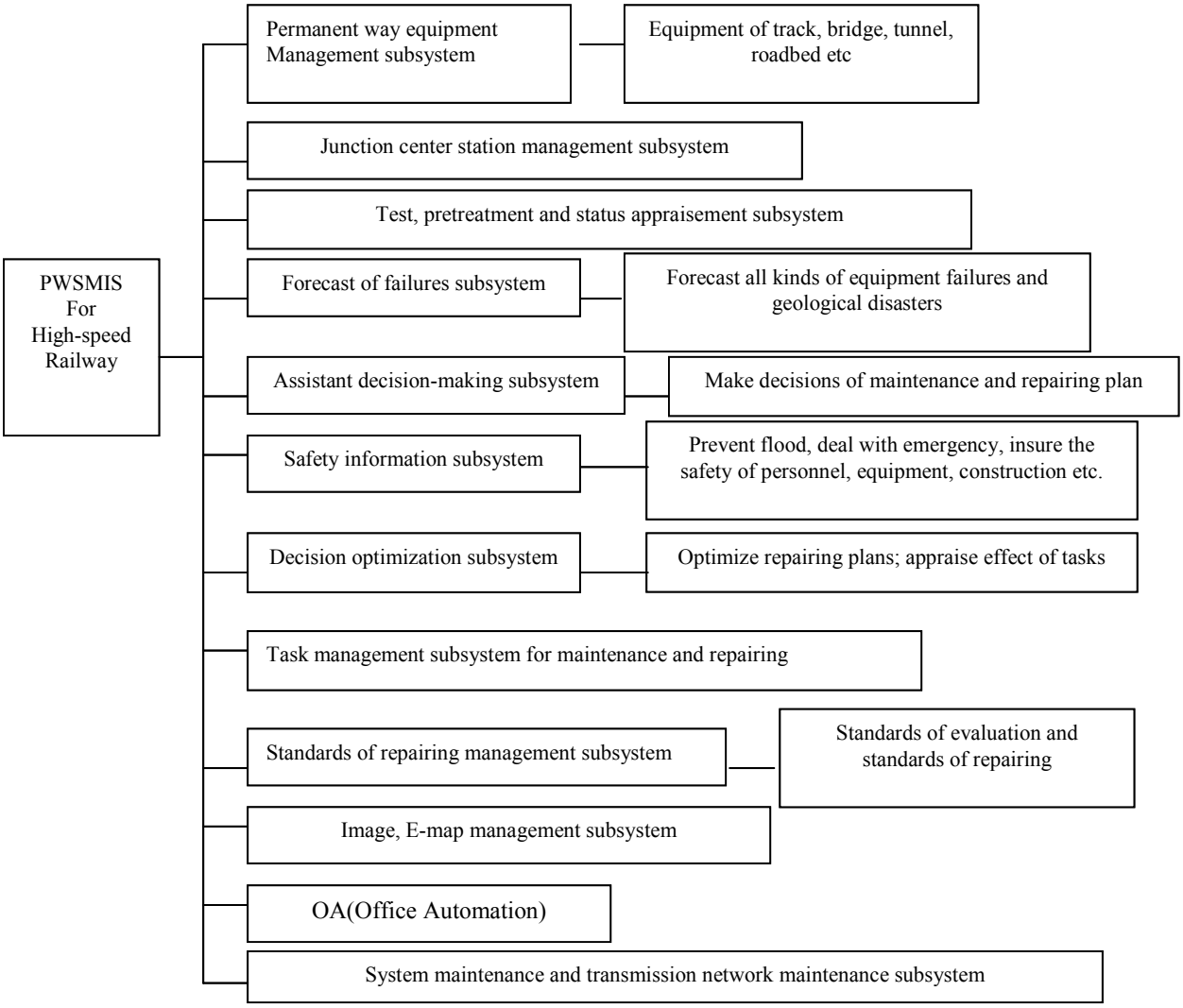

Figure 1. The Framework of PWSMIS

Main Study of PWSMIS

In this section, main problems of PWSMIS will be discussed. Some valuable conclusions drawn from our study are also presented.

Study on Basic Database

As basis of the whole system, data source is one of the keys to prediction and decision-making. Static and dynamic information database is the basis of the permanent way safety management. The information database consists of the equipment database, which is relatively steady, the status database of equipments, which must be adjusted dynamically at any moment, the standards and the test data. All these databases must be supplemented and perfected according to classification and source on the basis of the present PWMIS. The dynamic database is one of the features of PWSMIS that is different from the former MIS for permanent way equipment. The timely test data of track inspection vehicle, inspection vehicle for steel failure, and inspection vehicle for elasticity and manual examination data will be collected through wired or wireless network. This is the good foundation of prediction and decision-making.

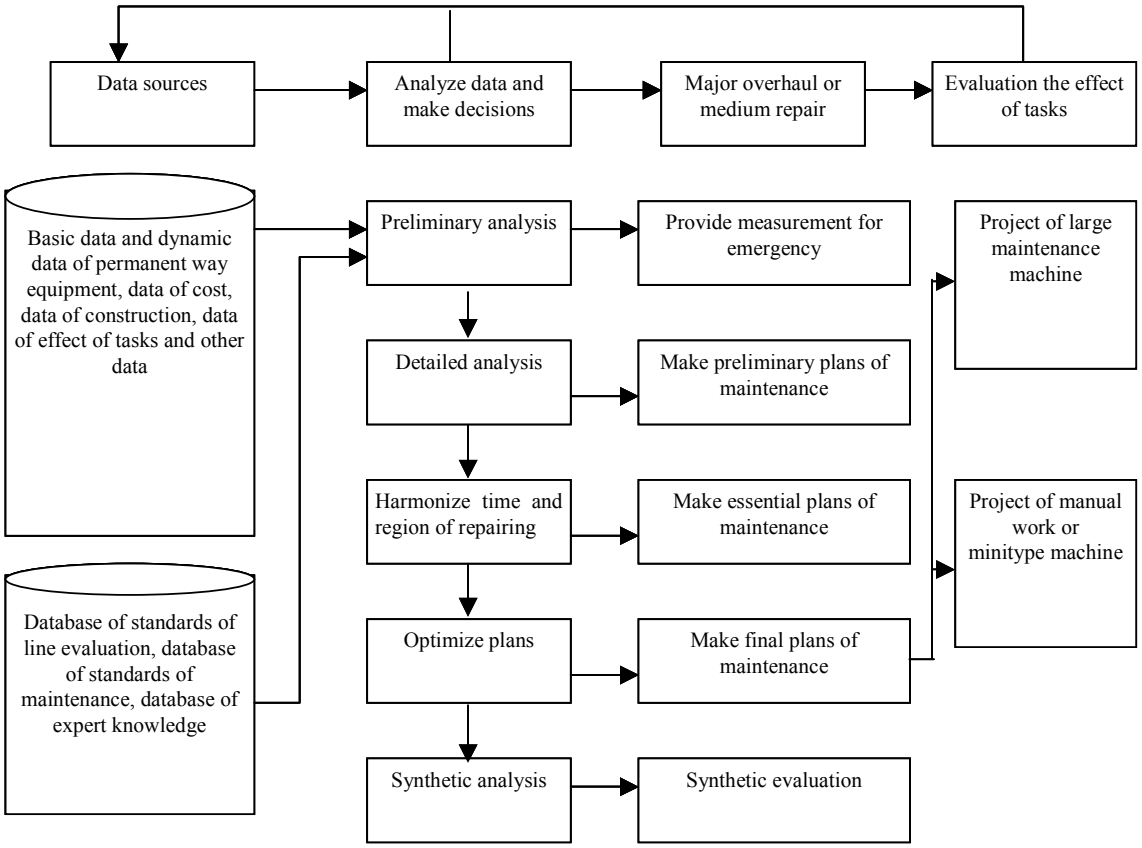

Figure 2. The Structure of PWSMIS

When many events come about at the same time, not only one database needs to be modified. In order to reduce the workload of modification and enhance the timeliness of the data, the modification for many databases must be associated. Further more, new database must be compatible with the present PWMIS in order to use the data of it in consideration of money. Some historical records should be reserved for the redundancy of the data and the request of prediction and decision-making,. Generally speaking, the reservation time should be studied according to characteristics of equipment and relevant tasks. Some conclusions could be drawn from our study, such as the accomplishment record and inspection record of track task should be reserved for 6 years; the task record of ballast replacement, which has a long replacing cycle, should be reserved for 10 years; the task record of steel replacement should be reserved for 20 years.

Study on the Prediction Subsystem

As pointed out by Zhang (2000), accurate prediction is the premise of precise decisions. Successful prediction will bring about more economic and social benefit. So it is of great significance to study the prediction subsystem for the realization of the intelligent decision-making of PWSMIS.

Target of This Subsystem

An effective prediction subsystem of PWSMIS should have the functions as follows:

(1) Realize the functions of analysis, classification and taking statistics to the historical data and current data;
(2) Analyze the influence factors and mechanism of changes for all kinds of troubles in order to make decisions of repair aiming at main factors.

(3) The scientific prediction of the evolution of the permanent way equipment, especially to the evolution and result of all kinds of troubles. Based on these predictions, the maintenance and repair plan will be mapped out by the decision-making system.
(4) Forecast the life of the permanent way equipment and the cycle of the major overhaul or medium repair;
(5) Forecast and appraise effect of tasks according to the method and the time of tasks that are mapped out by decision-making system. For making scientific decisions and optimizing the plans, all kinds of task combinations should be evaluated synthetically with the use of data collected by periodical inspection equipment such as track inspection vehicle, steel inspection vehicle etc.
(6) Forecast the workload of maintenance and make cost estimation.
(7) Forecast all kinds of natural disasters.

Accurate decision should be made out to prevent the hidden trouble from damage with the help of predictions. Thereby the safety operation will be guaranteed in deed. For the sake of reducing errors of prediction and improving the precision as pointed out by Chen (1998), the original data must be processed through mathematics method because of the variance or abnormity of data. Methods of prediction and decision-making will be amended according to the actual testing data and evaluation. Models will continue self-study training for more accurate predictions and more effective decisions in the future by the help of the neural network technique as pointed out by Zhu (1998).

The Way of Studying

By using the knowledge of railway engineering and computer technology, the way of studying the prediction subsystem is presented as follows:

(1) Analyze and appraise the evolution merit of prediction items and the related influence of the exterior condition.
(2) Present the evolution trend of prediction items in the form of graph.
(3) Make comparison and modification of all kinds of forecast models and choose one suitable for practical considerations in China or study the evolution function by means of statistics and regression directly.
(4) Establish the validation standard of model and validate the chosen model.
(5) Make prediction using the chosen model or trend extrapolation.
(6) Make qualitative conclusion to the prediction and study the relationship between the unevenness evolution of track and the workload of maintenance by the help of the current maintenance and repair standard.
(7) Make dynamic modification to the method and the model according to the effect of prediction, new change trend and new difference for the best adaptability and precision making use of the neural network technique.

Study on the Intelligent Assistant Decision-Making System

The main target of the subsystem is to make all kinds of plans of maintenance and repairing on the principle of optimization. Further more, the economic appraisal to all kinds of plans and the evaluation of the effect of tasks should be made. The research methods include:

(1) Design the analysis system for original data, causation and mechanism of troubles to identify the main factor.
(2) Assure the accuracy of decisions by the help of expert system and artificial neural network technique.
(3) On the basis of expert system and historical repairing record, decisions should be made concretely including repair plans, repair methods, priority of tasks, locations of tasks considering both the evaluation of line status and standards of evaluation, maintenance and repairing of line.
(4) Evaluate the activity and the accomplishment of tasks synthetically.
(5) Make the economic appraisal and complete the auto study of the system.

Prediction and decision-making are two important functions of PWSMIS. Although some systems in other countries as mentioned hereinbefore have the functions of prediction and decision-making using the theory of ES and decision making tree, it is hard to get satisfying effects by imitating them directly in China. Because of the long mileage and the large area, there are different style of lines and different geogenerations. As a result, it is difficult to build a static expert database and unified rules for prediction and decision-making. Further more, the management levels in different sections are various so that predictions must be more precise and decisions must be made more directly and more concretely. Owing to the abundant historical data, it is possible for us to use ANN in PWSMIS. We had success with using ANN to estimate the status of the line. All kinds of testing data of the line with the corresponding judgment achieved by experiential operators according to the standards and the practical situation

compose the training examples. ANN is trained by these examples. Then, the trained ANN can be used for the estimation of a certain line by inputting new test data. The result of experiment is satisfying because ANN is characteristic of nonlinear mapping, strong fault tolerance and self-learning. We are in process of using ANN for more modules. In deed, it seems that better results will be achieved by combining the theory of ES and ANN.

Conclusions

In this paper, the framework and main content of PWSMIS for high-speed railway of China are presented on the basis of studying a large number of current domestic and international PWMIS. Study shows that it is desirable for PWSMIS with the functions of dynamic management, analysis, prediction, intelligent decision-making, accident treatment, dynamic information sharing, reasonable arrangement of personnel and equipment, cost management and etc. The success of using new computer techniques such as ANN improves the efficiency of this system. The accomplishment of PWSMIS will be of great significance for the modern permanent way management for high-speed railway in China.

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