Research on Passenger Dedicated Line Track Maintenance Information System

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***Abstract*—Track Maintenance is crucial for the safe and efficient of railway transportation. After analysis of foreign management techniques for high-speed railway track maintenance, combined with the characteristic of passenger dedicated line in China, this paper has explored new ideas of the information system of passenger dedicated line track maintenance and at the same time researched on the theory and method of system construction in depth. Combined with parts of after-operation data of Beijing-Tianjin intercity passenger dedicated line and based on the key technologies and system design in the paper, a prototype information system of track maintenance for Beijing-Tianjin intercity passenger dedicated line has been developed.**

***Index Terms*—Passenger dedicated line; Track maintenance; Information system; Data warehouse; GIS**

I. INTRODUCTION

A. The Importance of Track Maintenance Information System

Railway track is the infrastructure of the trains' high-speed and safe operation. However, with the influence of natural conditions and train high load, track will be deformed. Those deformations not only influence trains' high-speed and stable operation but also will threaten the traffic safety by decreasing and impairing the track structure strength when the deformation accumulates to a certain extent [1]. Track maintenance can keep the track equipment under excellent conditions and ensure trains to safely, stably and continuously operate at the set speed as well as extend the service life [2]. However, with the development trend of high speed and heavy load, the trains' operation speed and density become higher and higher, which accompanies the heavier burden of track maintenance work and less time for maintenance work. This problem increasingly becomes a severe challenge to railway engineering department.

Carrying out the research and development of track maintenance information systems, establishing the track equipment basic database can realize the mass data mining and the study on the change rules of equipments' condition. Based on accurately grasping the equipment conditions and through refining standards and finely inspection and repair, realize the integration and separation of the maintenance system, the optimization and configuration of maintenance resources, the positioning of potential equipment hazards and "preventive repair", and finally realize the double controls of maintenance costs and operation safety. Japan, France, Netherlands and other developed countries which have the high speed railways have carried out on a large amount of explorations and practice on high speed railway track maintenance and have developed some information systems to assist in the track maintenance work. Along with their efforts, sound results have been achieved [3-6].

B. Existing Problems In Our Country

Along with our country's large-scale construction and operation of passenger dedicated line and the progress in equipment and maintenance technology, the traditional track maintenance methods and concepts cannot adapt to the requirements of passenger dedicated line track maintenance. Although the domestic researchers have developed some information systems for railway condition analysis and maintenance management aided decision-making, these works are only about the simple statistics of data and the production of the daily reports and lacks the in-depth analysis in view of space and time. The track maintenance management, to a large extent, still stays at "failure-based maintenance" and is far from the requirements "condition-based maintenance" [7-9].

C. Our Contributions

Learning from the abroad experience of managing track maintenance work through informationalized means, this paper proposed the key technology of the informationalization construction of passenger dedicated line track maintenance information system specific to our country. First, construct an integrated data platform of passenger dedicated line track maintenance and integrate all kinds of data. Use statistical theories and analysis methods to find out the inner relationship and change

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rules between data. Then, with spatial position as a link, integrate the basic data of passenger dedicated line track maintenance and further explore from two dimensions of time and space by means of geographic information systems. In this way, the real-time monitoring of line conditions through computer technology comes true. Finally, with the above key technology as the core, this paper designed one passenger dedicated line track maintenance information system and carried out the prototype development.

II. KEY TECHNOLOGY

A. Basic Data Platform Constructing

Railway track maintenance pays great attention to the accumulation, analysis and exploration of basic data. In this way, the track condition can be monitored and grasped in real-time and the track maintenance work can be better implemented and guided.

Basic data of passenger dedicated line track maintenance are divided into two categories, attribute data and spatial data. Attribute data mainly include the equipment account data, inspection data, maintenance data, safety management data as well as equipment operation data (including train diagram, train list information after departure, train formation, train speed, etc.). Spatial data is the one that represents the position, shape, size and distribution characteristics of space entity and the information about other aspects. In addition, spatial data is unstructured variable length data, and has non-uniform distribution and spatial locality relationship characteristics [10]. The spatial data of passenger dedicated line is divided into basic spatial data, prospective design spatial data and thematic spatial data. The above two kinds of basic data have the following characteristics: they own a large quantity of data, possess polyphyly and heterogeneity and lack unified organization and management.

As a subject-oriented, integrated, ever-changing with time and stable data set, data warehouse can effectively manage mass data, realize the data integration and organize and manage the subject oriented data according to the characteristics of passenger dedicated line track maintenance based data [11]. Making use of data warehouse technology to construct the passenger dedicated line track maintenance basic data platform can provide a single, centralized and rich data, improve the system response time and enhance the integrity and safety of data. At the same time, the data in the data warehouse is organized based on analysis-orientation, which can better satisfy the analysis requirements of passenger dedicated line track maintenance business than the traditional database organization based on analysis-orientation.

Fig. 1 described the passenger dedicated line track maintenance information integration solution based on data warehouse, which can be divided into three parts, data source, back end processing, and the user service.

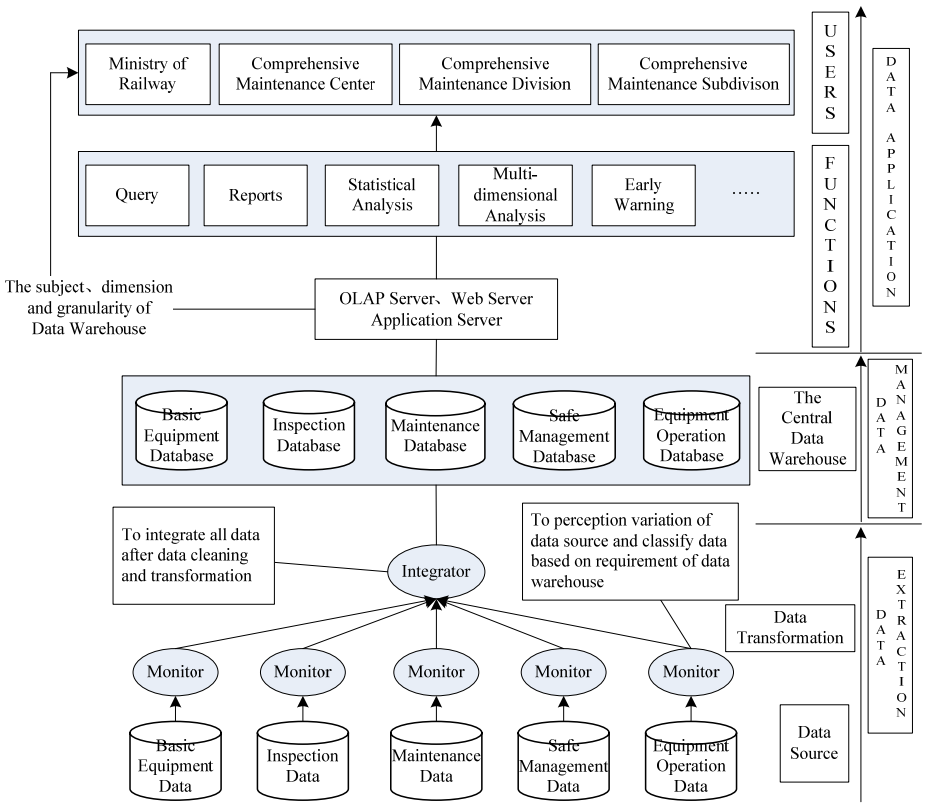

Figure. 1 Information integration solution base on data warehouse

The core of constructing the passenger dedicated line basic data platform based on data warehouse technology lies in the design of the data warehouse, which need to take the passenger dedicated line track maintenance

business as the principal line and follow the steps below (as shown in Fig. 2).

- First, find out the business object through the analysis on the passenger dedicated line track maintenance information system business requirements, so the subject of the data warehouse design can be determined.
- Around different subjects, analyze the dimension and granularity of data storage and the segmentation strategy of data, namely, the design of logic model.
- Specific to the logic models of different subjects, design dimension tables, index table and other concrete list structures and storage to assign optimization schemes, namely, the design of physical model.

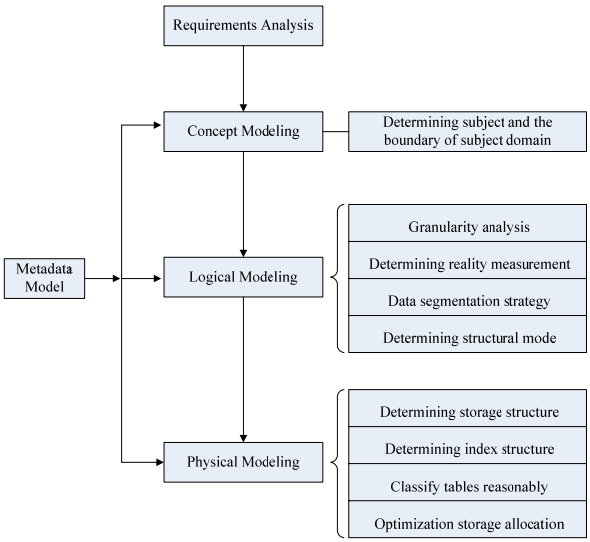

Figure. 2 The design procedure of data warehouse

B. GIS of Passenger Dedicated Line Track Maintenance

The passenger dedicated railway maintenance basic data has two kinds of relationship in terms of spatial position, coordinate corresponding relation and mileage corresponding relation. The data with coordinate corresponding relation is mainly about the spatial data. Attribute data generally contain mileage position information and has very strong spatial characteristics. Therefore, according to the mileage information, the spatial data and attribute data can be related together.

As shown in Fig. 3, with spatial position as the link and according to the unified spatial coordinates, unified coding standard and classification standard, we can realize the integration of passenger dedicated line track maintenance attribute data and spatial data. The reasons were as follows.

- Railway track is an object of continuous distribution, with spatial continuity and duration.
- The track condition changes were related to many factors, such as the located geographical position and climate environment, etc. Therefore, with spatial position as the link of the passenger dedicated line track maintenance integrated data platform, we can comprehensively analyze the track condition in view of space and grasp the influencing factors of track condition changes.

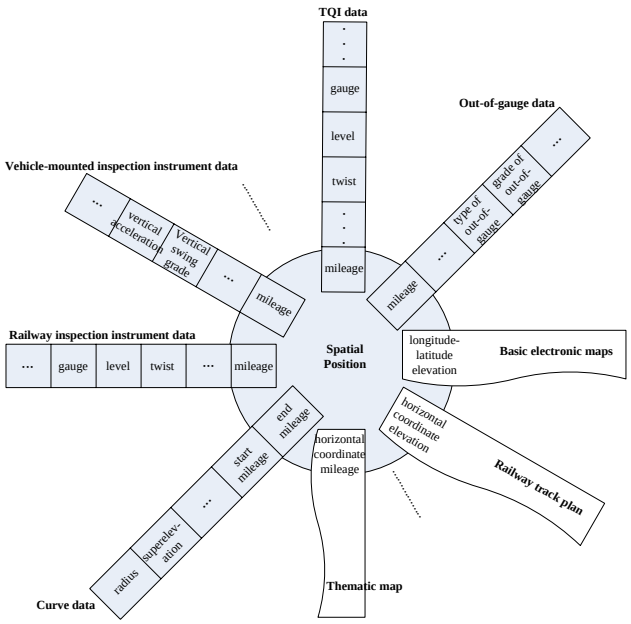

Figure. 3 Data integration base on spatial position

In addition, attention also should be paid to the accumulation of historical data, especially the changes at certain point or the overall changes during a certain period. Analyze the change rules and development trend of track condition in view of time.

To sum up, the effective way to grasp the change rules and the development trend of track condition relies in the realization of data integration with spatial position as the link and the in-depth exploration of the inspection data in view of time and space and different use aspects. All these can be realized through the Geographic Information System (GIS) [12]. GIS, taking the map spatial databases as a foundation, uses the geography model analysis method and supplies many kinds of spatial and the dynamic geography information at the runtime[13]. It can efficiently integrate the spatial data and attribute data of passenger dedicated line track maintenance on the basis of spatial position. Making full use of the characteristics of the GIS, this system is combined with data warehouse technology as system technology support. Through connecting the inspection data, maintenance data and basic equipment account data with railway boundary information and railway facility synthetic map in form of histogram, broken line graph and other thematic maps to realize the passenger dedicated line track maintenance visualization.

III. SYSTEM DESIGN

A. Data Warehouse Design

Data warehouse design covers the design of conceptual model, logic model and physical model. Among them, the conceptual model design stage needs to determine the subject fields and the relationship between those subjects according to the system's requirements,

which can be expressed by E-R diagram. Based on passenger dedicated line track maintenance business, this paper determined the following subjects of the system.

- Equipment account data subject
- Track irregularity subject
- Rail defects and failure subject
- Safety subject
- Maintenance subject

Various subjects are connected with each other rather than completely isolated (as shown in Fig. 4). When carrying out analysis specific to different subjects, various kinds of dynamic and static inspection data, gross passing tonnage data, equipment information data, maintenance data, etc. all need to be integrated.

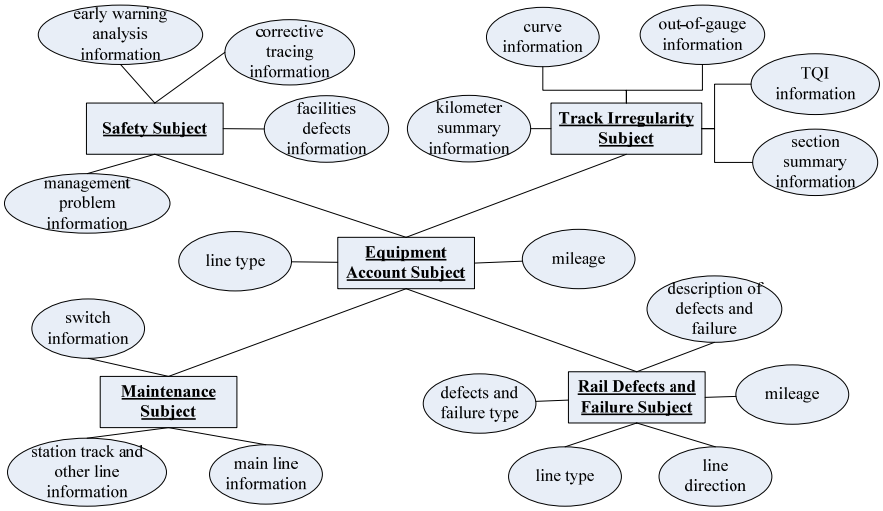

Figure. 4 Data warehouse conceptual model diagram

The logical model design of the data warehouse usually adopts multidimensional data model, such as the star model. According to the selected subject, this system made use of the star model to construct models for single subject. Take rail defects and failure subject as an example, its star model was as shown as Fig. 5.

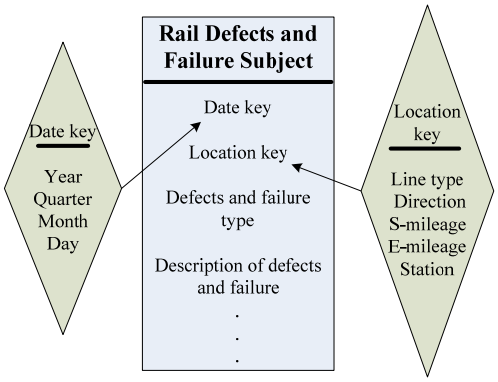

Figure. 5 The topic of rail defects logic model

The physical model design was used to solve the detailed problems in the implementation of relation model, such as physical storage means, data storage location, index structure, storage allocation optimization, etc. Taking the access speed, storage efficiency, system reliability, system maintainability, system cost, and other aspects of the railway work inspection data management and analysis system into consideration, the system chose RAID5 as data storage structure. According to the storage characteristics of the system data, this paper mainly adopted B - Tree index and Bitmap index, and combined the index technology with table partitioning technology in order to improve the efficiency of data retrieval.

Moreover, one of the most important decisions in designing a data warehouse is the selection of materialized views to be maintained at the warehouse[14,15]. As the system often dealt with the time-consuming operation such as table joins and statistics, materialized views have been built to improve the query speed.

B. Architecture Design

The system adopted B/S structure. The client computer users can conveniently browse, inquire and analyze all kinds of information through the browser. The server mainly included database server, program application server, OLAP analysis tools and application middleware and other components. This part was responsible for data storage, processing, analysis and user response and other tasks. In addition, the system also included the basic input/output office equipment, such as printer, etc. Its software system structure was as shown as Fig. 6.

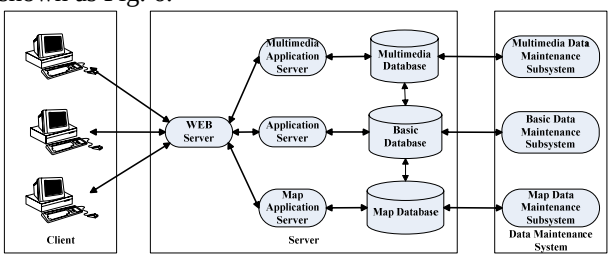

Figure. 6 System Software Architecture

C. Function Design

According to the requirements of passenger dedicated line track maintenance business and functions, the

system divided functions into five modules, comprehensive monitoring, safety management, equipment management, production management and system maintenance management. Each module existed as a subsystem and each subsystem corresponded to different functions to meet the needs of the business, as shown in Fig. 7.

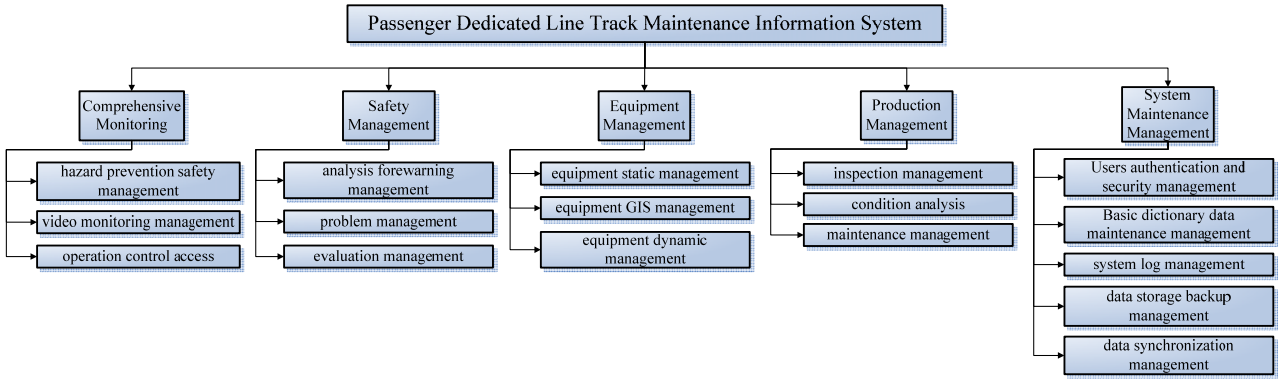

Figure. 7 System function modules diagram

Comprehensive monitoring subsystem integrated the hazard prevention safety monitoring, video monitoring and operation control access as a whole, focusing on the comprehensive monitoring of the capital equipment and information equipment of the passenger dedicated line track maintenance.

Safety management subsystem included three functions, the analysis forewarning management, problem management and evaluation management. According to the information in the passenger dedicated line track maintenance management problems library and referring relevant regulations and standards, this subsystem carried out comprehensive analysis on the existed accident cases to achieve safety forewarning and the appraisal management of various departments' safety performance.

Equipment management subsystem was about the management of static attribute information, equipment geographic information (basic geographic information, equipment photographs, video equipment, etc.), equipment dynamic information (information of equipment inspection and repair, etc.) of relevant dedicated passenger line track equipment and the utilization of GIS platform to realize the equipment visualized management of users at all levels.

Production management included inspection management, condition analysis management, and maintenance management three sub-modules. Inspection management reflected the implementation progress of the equipment inspection and monitoring by all levels of management department. Condition analysis management aimed at scientifically and reasonably making track maintenance plan and providing recommendations on the basis of the analysis and prediction of track condition changes according to inspection data. Maintenance management mainly was to make annual, monthly and daily maintenance plan for track maintenance and track and manage the maintenance condition to grasp the maintenance implementation progress.

System maintenance management mainly could realize the follow functions, user authentication and security management, basic dictionary data maintenance management, system log management, data storage backup management and data synchronization management.

Taking the equipment management as the core, the production management as the principal line, the safety management as the goal, the comprehensive monitoring management as the means, system design realized the digitalization and integration of passenger dedicated railway maintenance management. The system modules were not isolated subsystems. They transmitted information with each other. The information flow of the entire system was shown as Fig. 8.

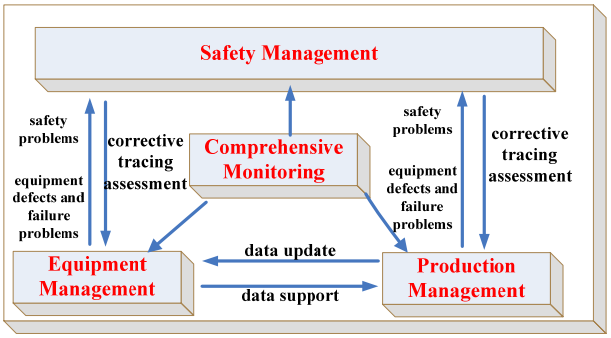

Figure. 8 The information flow chart of system

IV. Prototype System Development

Combined with parts of after-operation data of Beijing-Tianjin intercity passenger dedicated line and based on the above-mentioned key technologies and system design, this study carryout out prototype development of Beijing-Tianjin intercity passenger dedicated line track maintenance information system. The following was the display of partial system function.

A. Data Maintenance

Data maintenance realized the interface between system and external data, so it was the realization foundation of the system functions. For all kinds of

manual form data, after a summary they could be typed in by field staffs and then sent to the data warehouse through the network. Take the maintenance interface of route inspection data as an example, which was shown as Fig. 9.

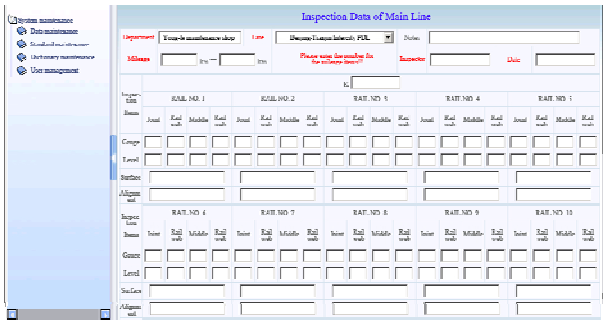

Figure. 9 Route inspection data input page

In terms of the data with specific formats, such as the inspection data of track geometry vehicle and track inspection instrument, it could be stored only after the data analysis through the data processing program. Users needn't care about the data processing process. What they need to do was to upload the data file by the simple interface provided by the system. Please see Fig. 10.

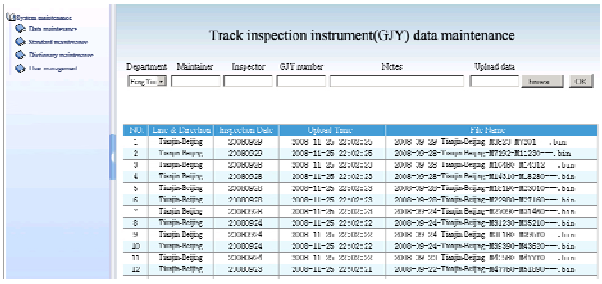

Figure. 10 Track inspection instrument data maintenance page

B. Inspection Statistic Report

Based on all kinds of inspection data of the maintenance entering warehouse, at present, the system is able to generate all kinds of statistical reports of Beijing-Tianjin intercity passenger dedicated line, which included out of gauge report, line deduction, TQI (Track Quality Index) calculation and the statistical reports of other forms. The page shown in Fig. 11 prompted at the current login time whether there were out-of-gauge data of track geometry vehicle inspection. Through the monthly analysis or annual analysis, the out-of-gauge statistical data at any month or year could all be inquired and shown to users in form of images.

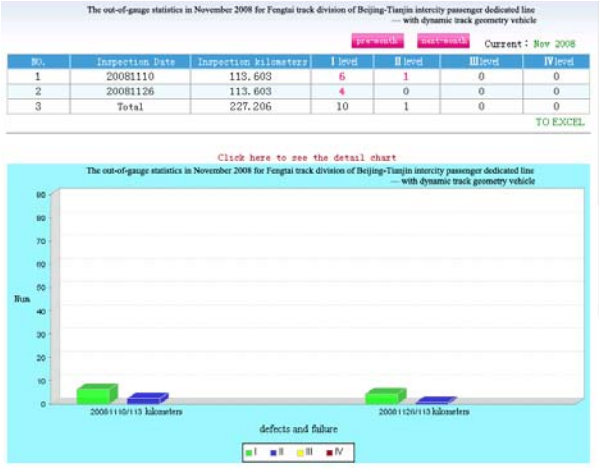

Figure. 11 Track geometry vehicle out-of-gauge month analysis page

C. Track Condition Analysis

The core of track maintenance lied in the track condition analysis, which analyzed modules based on the track condition analysis of the inspection data and provided all-round and multi-angle data analysis specific to line quality condition by combining with Beijing-Tianjin intercity passenger dedicated line management requirements. The page in Fig. 12 showed line TQI statistical analysis and the page in Fig. 13 showed the comparative analysis of the dynamic TQI and static TQI.

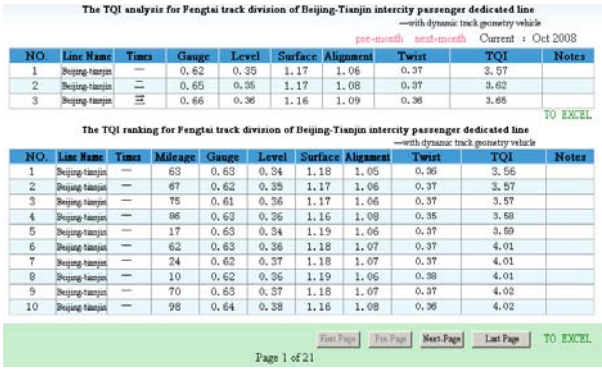

Figure. 12 Track geometry vehicle TQI analysis page

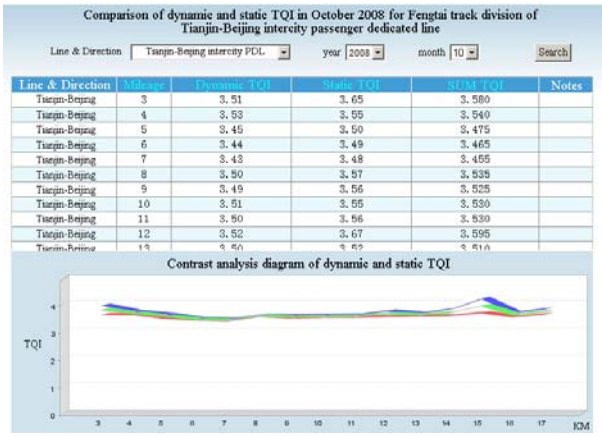

Figure. 13 Dynamic and static TQI comparison analysis page

V. CONCLUSIONS AND FUTURE WORK

Learning from the foreign experience of managing high speed railway track maintenance by information system, this paper summarized the key problems of constructing the domestics passenger dedicated line track maintenance information system, carried out the systematic design of passenger dedicated line track maintenance information system and developed a prototype system. The major achievements included:

- Establishing the passenger dedicated line track maintenance basic data platform based on data warehouse. This paper studied the data integration based on data warehouse, which can realize the effective management of the mass information and provide data support for the condition analysis on passenger dedicated line track quality as well as the aid decision-making of track maintenance.
- Establishing the passenger dedicated line track maintenance visualization platform based on geographic information system. According to the spatial distribution characteristics of the passenger dedicated line track maintenance basic data, this paper realized the integration of attribute data and spatial data and used GIS powerful spatial data analysis ability to further analyze the data in view of time and space, providing richer and more intuitive information for decision-making managers.
- Designing the implementation scheme of the passenger dedicated line track maintenance information system supported by data warehouse technology and geographic technology. The scheme design, with the guiding ideology of "condition-based maintenance" closed-loop management, divided the function modules of the system. Each module was correlative and covered all aspects of the passenger dedicated line track maintenance management business.

At present, the passenger dedicated line track maintenance information system is still in prototype development stage and some future research will be undertaken on this subject matter:

- To save and manage spatial data effectively. Spatial database is the basis of building passenger dedicated line track maintenance geographic information system. The object-relational database to support the integrated storage of attribute data and spatial data is the mainstream of the current study, and the spatial module of oracle database has defined the storage format of space vector data. This module provides a set of queries and indexing mechanism, while the Intermedia module provides a mechanism for the storage and manipulation of images, video and other multimedia data. Thus, the unstructured railway spatial data can be stored in two-dimensional form, and managed with the relational database systems.
- To build analysis and prediction models for track condition in our system. Track condition has a significant impact on traffic safety. It can ensure high smooth of the track from predicting the deterioration of track quality accurately, and then fundamentally eliminate hidden dangers. Based on the huge amounts of inspection data for track condition, this system will provide comprehensive analysis and forecast results to schedule track maintenance activities for managers in the future.

We will carry out further study on the basis of the study achievements in this paper and perfect each function module. In this way, this information system can be truly applied in the passenger dedicated line track maintenance management work.

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