Research on Intelligent Rail Transit Operation and Maintenance Management

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Abstract. At present, urban rail transit is faced with multiple problems such as aging infrastructure, backward technology and high management cost. The research topic of this paper is intelligent rail transit operation and maintenance. Through intelligent means, a large amount of equipment data can be obtained, new applications of equipment can be deeply explored, operations can be optimized, and traffic efficiency can be improved. The system introduces advanced technology and data analysis, enabling real-time monitoring of train operations, passenger services and equipment maintenance. The result is a highly intelligent transportation ecosystem that improves overall efficiency and safety. In addition, actively exploring the application of intelligent operation and maintenance of rail transit can promote technological innovation. The conclusion shows that intelligent operation and maintenance can provide a new idea for urban traffic and has a broad application prospect. This study has far-reaching significance for the sustainable development of urban transportation, and provides theoretical support and practical reference for building a more intelligent and efficient transportation system.

Keywords. Intelligent rail transit, operation and maintenance, rail traffic.

1. Introduction

With the continuous development of global urbanization, a series of challenges facing urban rail transit operation and maintenance management have become increasingly prominent. These problems include aging infrastructure, late technology update, inefficiency of data management and analysis, impact of natural disasters, scarcity of professionals and urban expansion. In this context, intelligentization can provide new ideas for track operation and maintenance management. Intelligent rail transit operation and maintenance management research is a process to make full use of intelligent, informatization and big data, obtain a large number of equipment operating status data, and guide the use and maintenance of equipment, optimize operation management methods and management costs, improve urban traffic efficiency, reduce traffic congestion and reduce energy consumption through data calculation and deep mining.

Through the introduction of advanced technology and data analysis means, the intelligent rail transit system is likely to achieve real-time monitoring and accurate management of train operation, passenger service and equipment maintenance. From trains to tracks, to stations and communication systems, all components of the intelligent rail transit system work closely together, forming a highly intelligent transportation ecosystem. This not only enhances the overall efficiency of the transportation system, but also improves its reliability and safety. The scope of intelligent rail transit operation and maintenance management research involves many aspects, including data acquisition and transmission equipment, data analysis platform and operation and production tools, and is integrated into a set of intelligent equipment. The goal of intelligent operation and maintenance system is to improve equipment reliability, reduce labor intensity, optimize equipment maintenance mode and driving organization mode, improve operation service level and scientific production activities of urban rail transit enterprises.

The international intelligent rail transit operation and maintenance has been developing for a long time. Among them, CRRC Zhuzhou vehicle fault health management system can realize vehicle operation condition monitoring and health evaluation, and Alstom health intelligent management system can realize intelligent infrastructure management and real-time health assessment of key components. Thales can carry out state health assessment on key equipment such as communications, fiber optic networks and servers. Japan's COSMOS Shinkansen Integrated transport management system, Germany's COBRA train equipment diagnostic system and France's TIGRE EMU maintenance monitoring system are relatively mature in application [1]. The intelligent operation and maintenance of urban rail transit in China is still in the stage of discussion and research. Beijing and Shanghai started the research of intelligent operation and maintenance earlier, and are building operation and maintenance platforms with intelligent vehicle operation and maintenance as the core, but have not yet formed a unified technology [2]. In terms of standards, the O&M system has a huge structure, many interfaces and high construction cost, but the development prospect is broad and promising.

This paper will focus on the research of intelligent rail transit operation and maintenance management, and discuss the design objectives, characteristics, system architecture and key technologies of intelligent management. The purpose of this paper is to explore a more intelligent and efficient urban transportation system.

2. Intelligent Rail Transit Management and Operation

2.1. Design Objectives and Characteristics

(1) Improving transportation efficiency

Through real-time monitoring, optimize train operation, signal system, passenger service and other aspects, so as to improve the transportation efficiency of the entire rail transit system. With the rapid expansion of the network scale, the number of urban rail transit equipment is increasing rapidly, and the intelligent operation and maintenance of rail transit is also an inevitable choice. For example, there are more than 400,000 units (sets) of facilities and equipment in the whole network of Guangzhou Metro, distributed in the extended area of the network [3]. Due to the wide variety and large quantity of equipment, unexpected failures caused by long-term operation have a great impact on operation services. Maintenance of such a large amount of equipment and facilities cannot be carried out only by traditional manual maintenance mode.

(2) Reducing operation and maintenance costs

Labor cost and facility and equipment maintenance cost are the main parts of the cost expenditure of urban rail transit enterprises. The former accounts for 50% ~ 60% of the cost expenditure of urban rail transit enterprises, while the latter accounts for 10% ~ 15% [4]. Intelligent operation and maintenance system through predictive maintenance, automatic processing and other technical means, can reduce the failure rate of equipment, reduce emergency maintenance and outage time, so as to reduce operation and maintenance costs. Reasonable equipment maintenance strategy can extend the service life of equipment and reduce the frequency of replacement and maintenance. The comprehensive inspection of rail vehicles of Shanghai Metro Line 17 has reduced the ratio of train maintenance personnel to vehicle from 0.6 to 0.33, and achieved the reduction of personnel and efficiency [5].

(3) Adapting to urban development

With the growth of urban population and the increase of transportation demand, traditional methods of operation and maintenance may not be able to meet the rapidly changing urban transportation demand. Intelligent operation and maintenance systems can adapt more flexibly to urban development and provide sustainable transportation solutions. At present, some lines in Beijing, Shanghai, Tianjin, Chongqing, Wuhan, Nanjing and other cities have been in operation for more than 15 years. With the increase of service time, manual maintenance of some facilities and equipment not only has low maintenance efficiency and high work intensity, but also cannot guarantee maintenance accuracy [6].

2.2. Intelligent System Architecture

The key of intelligent rail transit operation and maintenance management is to change the existing rail transit mode in a more intelligent way through modern information technology, and bring more efficient, safe and comfortable intelligent transportation system to human social activities. The gradually rising intelligent information processing process from data intelligence collection - data intelligence fusion and data analysis - intelligent decision-making can eventually achieve the deeper intelligent purpose of intelligent rail transit.

(1) Intelligent data collection

Sensors, cameras and other equipment are used to monitor the status of various elements of the rail transit system in real time, collecting different aspects of data, including train operation, equipment status, station status, people flow and so on. Through big data analysis, anomalies can be detected in time, and fault warning and processing capabilities can be improved. At the same time, technology such as video surveillance and intelligent identification will be used to conduct all-round safety supervision of the rail transit system. Thus, security risks can be identified in real time, and security countermeasures can be taken in time to improve system security.

(2) Data intelligent fusion and data analysis

Intelligent algorithm and data analysis technology are used to realize dynamic adjustment and optimization of train operation plan. By analyzing device running data, device health status can be predicted and monitored, potential faults can be detected in advance, preventive maintenance measures can be taken in time, maintenance costs can be reduced, and device reliability can be improved. The integration of different data analyses can respond to emergencies, optimize train speed, improve overall transportation efficiency, and ensure efficient and collaborative operation of the system.

(3) Intelligent decision-making

Various data of the rail transit system can be collected, analyzed and processed to provide decision support for the management. Through data visualization and analysis reports, managers can make reasonable decisions and optimize business strategies. In the aspect of ticket management, intelligent technology can also be used to improve management efficiency and provide more convenient ticket purchasing methods and services. Fig. 1 shows the design of intelligent decision software function system. In Fig. 1, the main business of Man-machine interface Decision-making Support System (DSS) acquires dynamic and static data of various layered services, and ensures data sharing and transmission under the monitoring system. This is of great help to the personalized design of the communication mode and data format of urban rail transit.

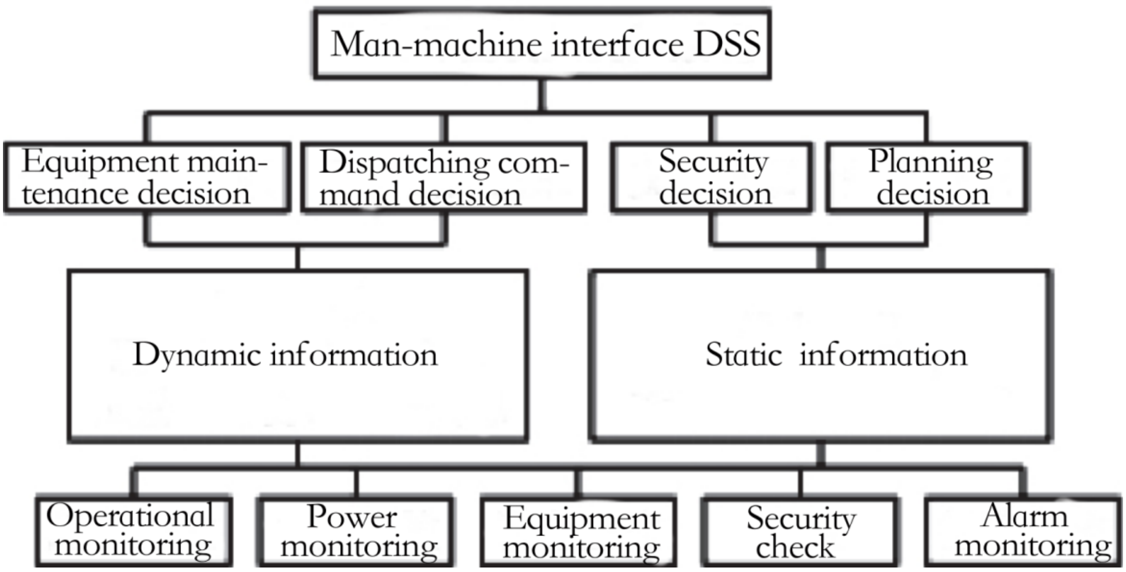

Fig. 1 Software function system design [7]

2.3. Key Technologies

2.3.1 Ubiquitous Internet of Things (IoT) sensing technology of equipment

In order to solve the problem of missing equipment monitoring status information, for key equipment such as escalators and screen doors, the direct-connected acquisition method based on ubiquitous IoT perception is adopted, and the sensing means such as RFID, sensors, acquisition cards and chips are used to build the IoT sensing layer and self-organizing network to realize the collection, transmission and processing of key equipment information in stations [8]. By integrating various sensors on the equipment, the ubiquitous IoT sensing technology can comprehensively perceive the status, performance and various parameters of the surrounding environment of the equipment. This includes many aspects of information such as temperature, humidity, pressure, illumination, and operating status. Real-time monitoring through the real-time collection, transmission and processing of perceptual data enables rapid action to be taken, improving the safety and reliability of the equipment.

2.3.2 Data intelligent fusion technology

The widely accepted levels of data fusion are three levels: raw data level, attribute parameter level and decision level. The data fusion algorithms are rich, and the corresponding general methods and specialized technologies can be summarized for different data fusion levels. Commonly used algorithms are: classical statistical and inference methods, such as Bayesian decision method, Dempster-Shafer (D. S) evidence theory; Kalman filtering, fuzzy logic, cluster analysis, expert system, decision model, automatic target identification and classification, situation assessment and estimation based on neural network, etc. [9]. Since the data from various sensors or systems have different characteristics, the design of data fusion model needs to consider the requirements generated by different data characteristics. For example, the Geographic Information System (GIS) data related to railway works has no time dimension, and the latitude and longitude positioning adopted by it is different from the current railway line kilometer positioning; The data from some traditional physical quantity sensors (such as pressure and temperature) have no time dimension, and the spatial dimension of the data from the train acceleration sensor is expressed as the line kilometer mark [10]. Therefore, the design of the data fusion model of rail transit should not only explore the requirements of different data fusion levels, but also aim at the characteristics of heterogeneous data from multiple sources. It is necessary to establish a multi-level data fusion model, cover the characteristics of different sources of data layer by layer, and establish a multi-level data fusion system.

2.3.3 Integrated equipment monitoring based on digital twin technology

In the urban rail operation simulation scenario based on digital twin technology, the virtual simulation model of equipment and its operation process is established to realize the visual display of equipment status by integrating state data and three-dimensional space model, integrating equipment status perception, dynamic monitoring of operation, anomaly identification, automatic alarm and dynamic tracking of fault handling. It is convenient for the equipment operation and maintenance personnel to quickly grasp the equipment status at any time. This technology complements data fusion technology to enhance professional data sharing and enhance capacity building.

2.4. Operation and Maintenance of Advanced Technology-5G

There are more service facilities that should be maintained in the rail transit transformer, with a wide range of points and more maintenance workload. Make full use of the IoT technology to transmit various electromechanical subsystem status data and public works subsystem status data, which are accessed through 5G network platform and transmitted back to professional maintenance staff. The operation should be changed from passive maintenance to intelligent supervision to improve the efficiency of maintenance and management. Fig. 2 shows the composition of the monitoring system.

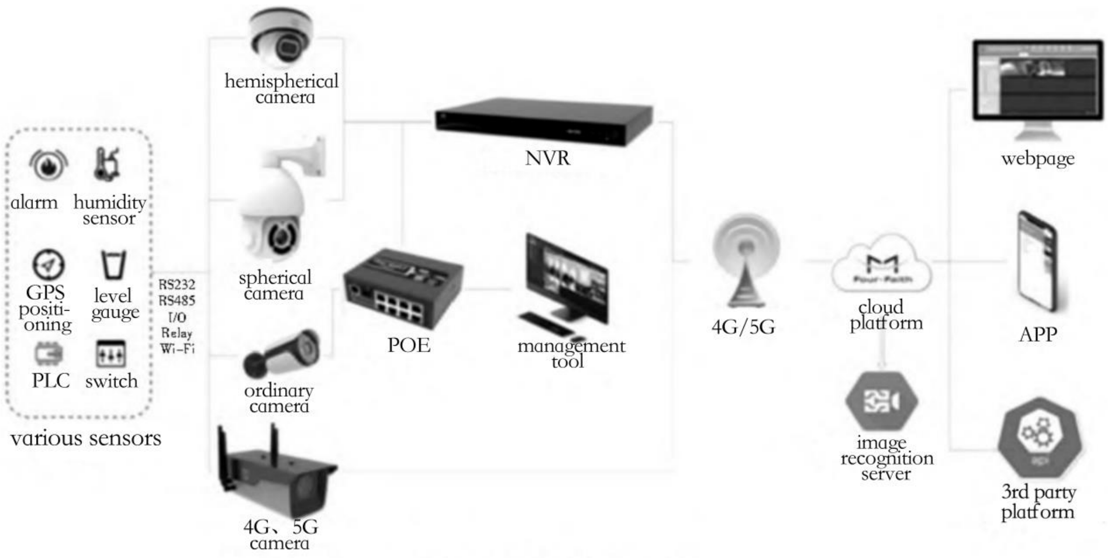

Fig. 2 Composition of monitoring system [10]

This technology can be tried out in cities with wide coverage and large equipment volume. Take Shanghai as an example. By the end of June 2021, there are 12,130 infinite terminals of various kinds, 48,000 telephone terminals of various kinds, 4,995 screens of various kinds, and more than 40,000 cameras of various kinds in Shanghai urban rail transit network [11]. The superior infrastructure lays the foundation for the intelligent operation and maintenance of rail transit. In addition, before 21 years ago, each communication system was equipped with network management for equipment management and status detection, weak data analysis ability, low automation program, imperfect operation and maintenance mode upgrade conditions, equipment management system is not strong and other problems are promoting the intelligent upgrade process of operation and maintenance system.

At present, the technical system, network architecture, function modules and business applications of the intelligent operation and maintenance platform of the train control system of Shanghai urban rail transit have been preliminarily constructed. In addition, the intelligent operation and maintenance line network center of Longyang Road has been established to complete the first stage of the improvement of the underlying data collection, and the access of the existing line train control system of Line 1, 2, 6, 7, 8, 9, 11, 12, 13, 16 and 17, to help the line network train control system maintain high reliability continuously, so as to ensure the safe travel of more than 10 million passengers per day in Shanghai [12].

3. Conclusion

This paper mainly studies the design objectives, system architecture and key technologies of intelligent rail transit operation and maintenance management, and draws the following conclusions:

(1) The goals of rail transit intellectualization include improving efficiency, reducing cost and adapting to urban development. In order to achieve these goals, the intelligent rail transit management system adopts the architecture of intelligent data collection, integration and analysis, and intelligent decision-making.

(2) Key technologies include equipment ubiquity IoT perception, data fusion, equipment monitoring based on digital twin technology. Device ubiquity IoT perception can realize comprehensive device monitoring through sensors. Data fusion uses different algorithms to improve system adaptability. Digital twin technology establishes virtual simulation model to improve equipment operation and maintenance efficiency. The advanced technology of operation and maintenance can use the IoT and 5G to transmit system status data, realize intelligent supervision, shift operation and maintenance from passive maintenance to intelligent supervision, and improve management efficiency.

(3) However, there is still a big problem of data island. Various majors have collected and monitored the data of equipment and facilities, but the data format between devices is not uniform and non-standard, and it is difficult to deeply integrate the data, which can only form data island. The construction of intelligent operation and maintenance system of urban rail transit has just started, and the integration of multi-professional systems, the extraction of data value, standardized and unified data interface, artificial intelligent analysis and cloud platform and other technologies need to be continuously accumulated and continuously improved in order to finally achieve intelligent operation and maintenance system.

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