

Application of Intelligent Maintenance Management System for Urban Rail Transit Communication and Signaling

Ying Feng*

Beijing Subway Operation Co., Ltd.Communication Signal Branch,Beijing,100035,China

*Correspondence to: Ying Feng, Beijing Subway Operation Co., Ltd.Communication Signal Branch,Beijing 100035,China,E-mail:fenyxiya@163.com

Abstract: The intelligent maintenance management system plays a significant role in the operation and maintenance of urban rail transit. Implemented through real-time monitoring, warning analysis, and intelligent maintenance management, this system application significantly enhances maintenance efficiency, reduces fault response time, and enhances the stability and reliability of station facilities and communication signaling systems. Additionally, the intelligent maintenance management system provides strong support for the long-term maintenance of facilities through data analysis and prediction. Its application not only improves the service quality of urban rail transit systems and passengers' travel experience but also drives urban rail transit towards a more efficient, intelligent, and reliable direction.

Keywords: urban rail transit; signaling; intelligent maintenance management system; system operation and maintenance

Urban rail transit, as an important part of urban transportation, plays a crucial role in alleviating traffic congestion and improving travel efficiency. With the continuous increase in operational mileage and passenger volume, the maintenance and management of communication signals have become particularly important. Traditional maintenance methods are no longer able to meet the development needs of modern urban rail transit. Therefore, the development and application of intelligent maintenance management systems are imperative.

1. Concept of Urban Rail Transit Communication Signal Intelligent Maintenance Management System

The concept of the urban rail transit communication signal intelligent maintenance management system encompasses an integrated platform incorporating advanced information technology, Internet of Things (IoT) technology, and artificial intelligence (AI). This system is dedicated to achieving efficient monitoring, precise diagnostics, intelligent maintenance, and scientific management of key equipment in urban rail transit systems, thereby ensuring the safety, stability,



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

and efficiency of rail transit operations. The intelligent maintenance management system deploys various sensors and monitoring devices to achieve real-time data collection and status monitoring of station facilities, communication signal systems, power supply systems, and track lines. Utilizing big data analysis and AI algorithms, the system can deeply explore and intelligently analyze the collected data, identifying potential safety hazards and performance issues, and providing targeted fault diagnosis and maintenance suggestions. Furthermore, the system possesses intelligent scheduling and optimization functions, enabling the formulation of reasonable maintenance plans and resource allocation schemes based on the actual conditions of facilities and maintenance needs, thereby enhancing the efficiency and quality of maintenance work. The system also facilitates information sharing and collaborative work with other related systems, thereby improving the overall intelligence level and operational efficiency of the rail transit system. Through the application of the urban rail transit communication signal intelligent maintenance management system, comprehensive monitoring and precise management can be achieved, thereby enhancing the intelligence and refinement of maintenance work, reducing manual intervention and errors, lowering operation and maintenance costs, and mitigating safety risks. This provides robust support for the sustainable development of urban rail transit.

2. The Importance of Communication Signal Maintenance System in Urban Rail Transit Systems

Urban rail transit, as an essential part of urban public transportation, plays a crucial role in meeting the travel demands of a large number of passengers and facilitating urban traffic flow and economic development. The maintenance of communication signals, as the cornerstone supporting the normal operation of rail transit systems, is of paramount importance.

Firstly, maintenance of communication signal equipment is crucial for ensuring the safe operation of rail transit systems. Key facilities such as station equipment, signal systems, and communication systems in rail transit systems are critical. Any faults or hidden dangers in these facilities could directly

threaten passenger safety and the stability of the entire rail transit system. Therefore, regular maintenance and timely repairs can help identify and address these issues, ensuring that the communication signal system remains in optimal operating condition and reducing the occurrence of rail transit safety accidents.

Secondly, maintenance of communication signal equipment ensures the efficient operation of urban rail transit systems. Precise maintenance of communication signal equipment through system monitoring and early warning can promptly identify and repair devices with performance degradation or damage, ensuring the normal operation of the entire system and reducing operational delays and passenger congestion caused by equipment failures. Maintenance and repair work conducted through the maintenance management system can also monitor and optimize the operating parameters of equipment in real-time, improving equipment efficiency and enhancing the overall service quality and efficiency of the rail transit system.

Thirdly, maintenance of communication signal equipment through the maintenance management system can extend the lifespan of equipment, reducing the cost of replacement and procurement of new equipment. By formulating scientifically reasonable maintenance strategies, equipment wear and aging can be effectively reduced, prolonging the service life of equipment and minimizing unnecessary cost wastage and expenditures.

3. Maintenance and Prevention Strategies for Intelligent Maintenance Management System of Communication Signals

3.1 Intelligent Operation and Maintenance Management of Station Communication Signal Equipment

In urban rail transit systems, station communication signal equipment is the core component that ensures the smooth operation and passenger service of stations. With the rapid development of information technology, the maintenance of these devices has become increasingly complex, involving multiple sub-fields such as CCTV, office automation, transmission, clock, telephone, turnout, axle counting, interlocking, etc. Consequently, the requirements for maintenance have also increased accordingly. Traditional maintenance of station equipment typically relies on manual periodic

inspections, meter readings, daily fault diagnosis, and repairs, which are not only inefficient but also unable to cope with sudden equipment failures. The introduction of the urban rail transit intelligent maintenance management system has brought revolutionary changes to the maintenance of station communication signal equipment. Intelligent maintenance management relies on advanced Internet of Things (IoT) technology and big data analytics to achieve real-time monitoring and intelligent diagnosis of station communication signal equipment. By installing sensors on the equipment, the system can collect real-time operational data and analyze it through cloud computing platforms to promptly detect abnormalities or potential failures. Based on this, the intelligent maintenance management system can automatically generate maintenance and repair job suggestions, guide maintenance personnel to quickly locate problems, and carry out repairs. At the same time, the system can predict the operating status of the equipment, foreseeing in advance whether the equipment is healthy, planning maintenance operations accordingly, and avoiding interruptions in station operations due to equipment failures. Intelligent maintenance management can also enhance the safety protection capabilities of other station equipment. By monitoring real-time data traffic, identifying abnormal behaviors, and employing other means, the system can effectively prevent and eliminate security risks such as network attacks and maintenance data leaks, ensuring the stable operation of the station communication signal system and the security of passenger information.

3.2 Maintenance and Monitoring of Communication Signal Equipment

In the digitalized urban rail transit system, the importance of communication signal equipment is self-evident. These devices bear the responsibility of ensuring the normal operation of stations and trains, as well as safeguarding the security of passenger data, operational information, and traffic control systems. Therefore, maintenance and monitoring of communication signal equipment are indispensable components of station facility maintenance. The urban rail transit intelligent maintenance management system integrates network security technology to provide comprehensive and efficient maintenance and monitoring solutions for station communication signal equipment. The intelligent maintenance system

first conducts a comprehensive health check of the communication signal equipment, collecting real-time operation logs, traffic data, and security event information. Through backend data aggregation and in-depth analysis, it can promptly detect and diagnose abnormal behaviors, potential threats, and imminent high-risk events during equipment operation. It provides precise security alerts and event response suggestions and plans to maintenance personnel in advance. Furthermore, the intelligent maintenance system can automatically update and optimize the configuration of network security equipment, enhancing their defense capabilities and ability to respond to new types of equipment maintenance. In terms of maintenance, the intelligent maintenance system can predict maintenance needs and fault risks of equipment based on its operational status and performance indicators. It generates maintenance plans and suggestions in advance to ensure that the equipment is always in optimal operating condition. Through automated monitoring and maintenance, the intelligent maintenance system not only significantly reduces the workload and response time of maintenance personnel but also enhances the security and reliability of station communication signal equipment.

3.3 Fault Handling and Prevention Strategies

3.3.1 Fault Handling Strategy

When station facilities malfunction, the intelligent maintenance management system promptly activates the fault diagnosis mechanism. Firstly, the system collects real-time data and backs up logs using sensors and monitoring devices deployed on station facilities. Secondly, it conducts in-depth analysis of the collected data using built-in big data analysis algorithms and fault diagnosis models to accurately pinpoint the cause of the fault. Once the cause of the fault is determined, the system automatically generates troubleshooting guidance and solutions, dispatches maintenance personnel to the scene for repairs through the intelligent scheduling system. Additionally, the system records fault information, diagnostic results, and repair processes in the cloud platform database for future fault handling and analysis reference.

3.3.2 Prevention Strategy

To reduce the probability of station facility failures, the intelligent maintenance management system

implements a series of preventive measures. Firstly, the intelligent maintenance system conducts regular inspections of station facilities. By collecting operational data and status information of the facilities, it predicts potential fault risks. Once potential safety hazards or performance degradation trends are detected, the system immediately sends warning notifications to maintenance personnel and generates maintenance plans, work orders, and repair suggestions in advance. The system adjusts equipment execution parameters and maintenance cycles based on the classification and usage of communication signal equipment, operating environment, and other conditions to extend the safety assurance time and service life of the equipment, thereby reducing the likelihood of faults.

4. Case Study: Application of Intelligent Maintenance Management System in Communication Signal Equipment Facility Maintenance

4.1 Practical Case Analysis: Maintenance Management Based on Station Facilities and Communication Signal Systems

In this urban rail transit system, a comprehensive upgrade and transformation of station facilities and communication signal systems were carried out through the introduction of an intelligent maintenance management system. Firstly, sensors and monitoring devices were deployed at key locations of various communication signal devices to collect real-time data on equipment operation status, signal transmission quality, power supply status, and other key parameters. These data are analyzed and processed in real-time through a cloud computing platform to promptly detect potential issues and perform predictive maintenance. Once anomalies or potential faults are identified, the system immediately sends warning notifications to maintenance personnel and generates detailed repair suggestions. This enables maintenance personnel to swiftly locate and rectify problems, preventing further deterioration and impact of faults. Regarding the communication signal system, the intelligent maintenance management system integrates advanced fault diagnosis algorithms and big data analysis technologies to achieve intelligent diagnosis and maintenance of signal equipment. The system can monitor the operational status of signal equipment in real-time, comprehensively evaluate

signal transmission quality, equipment performance, and other indicators. Moreover, based on historical data and operational patterns, the system can predict maintenance needs and fault risks of equipment, generating maintenance plans and suggestions in advance.

4.2 Case Studies of Efficiency Improvement and Successful Fault Handling

The introduction of the intelligent maintenance management system has significantly improved the maintenance efficiency and fault handling of the communication signal system in this urban rail transit system, leading to notable successes. Taking a communication signal fault as an example, such a system malfunction could result in serious consequences such as train control errors and signal transmission interruptions, posing threats to passenger safety and operational efficiency. Under the traditional maintenance mode, communication signal system faults are often difficult to be promptly detected, and the diagnostic and repair processes are complex, requiring professionals to conduct lengthy troubleshooting. This not only affects passengers' travel experience but also increases maintenance costs and operational risks. Through the application of the intelligent maintenance management system, the urban rail transit system can promptly detect and respond to communication signal system faults. The system monitors the operational status and key indicators of communication signal equipment in real-time, and automatically performs data analysis to successfully predict and identify potential faults. Before the fault occurs, the system issues timely warning notifications and generates repair work orders and suggestions. Maintenance personnel swiftly arrive at the scene and perform repairs based on the precise positioning and fault analysis provided by the system. Compared to the traditional mode, the intelligent maintenance management system not only significantly shortens the time for fault detection and repair but also improves the accuracy and efficiency of maintenance. The timely handling of this fault ensures the safety and stable operation of the urban rail transit system, earning recognition and praise from passengers. The intelligent maintenance management system also provides strong support for the long-term maintenance of the communication signal system through data analysis and prediction.

4.3 Data Analysis and Effect Evaluation of Application Cases

Through comparative analysis of maintenance data and fault records before and after the introduction of the intelligent maintenance management system, it was found that the application of the system significantly improved maintenance efficiency and fault handling speed. Under the traditional maintenance mode, the average fault response time often required several hours or even longer. However, after the introduction of the intelligent maintenance management system, the average fault response time was shortened to within a few tens of minutes. The application of the system also reduced the frequency and severity of faults, and enhanced the stability and reliability of station facilities and communication signal systems. In terms of data analysis, the urban rail transit system also evaluated the performance and potential of the system by collecting and analyzing operational data and usage patterns. The data showed that the monitoring function and data analysis capability of the intelligent maintenance management system were fully utilized, providing strong support and assistance to maintenance personnel. Additionally, the system has significant room for expansion and upgrades, allowing for the integration of more functional modules and algorithm models to enhance the intelligence level and overall effectiveness of maintenance management.

Conclusion

In conclusion, the application of intelligent maintenance management systems in the maintenance of urban rail transit infrastructure has provided strong support for improving maintenance efficiency and

ensuring stable operation of facilities. Through real-time monitoring, warning analysis, and intelligent maintenance management, the system not only optimizes maintenance processes and reduces fault handling time but also enhances the service quality of urban rail transit systems and passenger travel experience.

Looking ahead, with continuous technological innovation and the expansion of application scope, intelligent maintenance management systems will play an even more important role in the field of urban rail transit, promoting the development of urban rail transit systems towards higher efficiency, intelligence, and reliability.

References

- [1] Tao, K., Yang, F., Zhao, G., et al. (2016). Intelligent Management System for Urban Rail Transit Infrastructure Maintenance. *Railway Technology Innovation*, (6), 62-67. DOI:10.3969/j.issn.1672-061X.2016.06.015.
- [2] Zhang, W., Liu, J. (2022). Research on Intelligent Maintenance Management System for Urban Rail Transit Based on Internet of Things Technology. *Automation and Instrumentation*, 37(2), 67-71.
- [3] Wang, Z., Li, J. (2023). Practice and Reflection on Intelligent Maintenance Management System for Urban Rail Transit Infrastructure. *Railway Transport and Economy*, 35(1), 89-93.
- [4] Xu, H., Wang, Z. (2022). Application Research of Intelligent Maintenance Management System in Urban Rail Transit Infrastructure Maintenance. *Urban Mass Transit*, 35(4), 127-132.