Functional Analysis on Intelligent Traffic Control Auxiliary Decision-making System for HSR

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Abstract: Intelligent traffic control auxiliary decision-making is one of the core functions of HSR intelligent traffic control, which is of important significance for the intelligent HSR in China. The paper analyzes the functional characteristics of the train operation simulation system and dispatching command system of the foreign railways and the development of the railway dispatching command system in China and discusses the functional demands of the HSR intelligent traffic control auxiliary decision-making system of the high speed railway in China. It illustrates the specific meanings of key functions of intelligent traffic control such as data management, train operation simulation, train delay prediction, conflict analysis, auxiliary decision-making, quality evaluation of the traffic control decision-making and integrated visualization, providing theoretical and technical supports for the development of the HSR intelligent traffic control and command system in China.

Keywords: HSR; intelligent traffic control; auxiliary decision-making system; functional analysis

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1 Introduction

Large-scale construction and operation of the high-speed railway has led to the achievement of remarkable results in raising the scale and quality of the railway network, alleviating the tension of transport capacity and improving the service quality of transportation, thus playing an important supporting role in the continuous and rapid development of the national economy. China's HSR has entered into the era of large-scale network operation, topping the world's HSR for high speed, heavy density, large traffic volume and complex traffic organization.

Currently, big data and "Internet+" have been integrated into different areas of the society and "intelligence" has become the main theme of the times. By the end of 2019, the Beijing-Zhangjiakou High-speed Railway, the first intelligent HSR in the world with the speed of 350 km/h, was put into official operation, marking the intelligent upgrading of China's HSR in the aspects of train operation, service, and operation and maintenance. On January 4, 2020, the major consulting and research project "Research on Strategy for Intelligent HSR (2035)" undertaken by Chinese Academy of Engineering (CAE) came to a smooth conclusion. The research points out that "intelligence has become the important orientation of the global railway development and the intelligent HSR will be the hot spot and difficult point of the new-round competition in the area of the world's HSR". The advanced technologies such as cloud computing, Internet of Things (IoT), big data, BeiDou positioning, next-generation mobile communication and artificial intelligence (AI) will be adopted by intelligent HSR to achieve the goals of intelligent building, equipment and operation pursued by railway workers and researchers through integration, full mental perception through sensory organs, ubiquitous interconnection, integration disposal, active learning and scientific decision-making.

The HSR traffic control and command system undertakes the important tasks of organizing and commanding train operation and day-to-day production activities, which is the modern control and management system to guarantee safe, punctual and effective HSR operation. Intelligent traffic control is the foundation guarantee of HSR intelligent operation and the building of the high-level intelligent traffic control auxiliary decision-making system will provide better decision-making assistance to the HSR traffic controllers to reduce the working load and improve the traffic control decision-making quality. It represents the core problems that must be tackled and solved in the research and practice of intelligent HSR.

2 Simulation for Overseas Train Traffic Control Command and Auxiliary Decision-making and Practical System

In the background of intelligent railway, railways from countries such as Germany, Switzerland, Netherlands and Japan have put forward in succession the strategic plans for digital and intelligent development and worked out the implementation road maps and priority tasks, among which wide-spread importance have been attached to intelligent operation. A series of traffic control command system or auxiliary decision-making systems have been developed by railway operators or railway service institutions from different countries to realize intelligent operation, with which certain successes have been achieved in the aspects of reducing railway network train delay and improving transport capacity.

Based on values of simulation technology in the aspect of auxiliary traffic control decision-making, some foreign railway companies or scientific research institutions have severally or jointly developed the experimental systems for intelligent train operation or traffic control command simulation such as OpenTrack, ROMA and RailSys. Comprehensive management system of Shinkansen (COSMOS) for HSR in Japan was the earliest HSR traffic control command system, having achieved comprehensive integration of HSR traffic control command. The European railway transportation management system (ERTMS) is the comprehensive management system of railway operation which is jointly developed by the European railway operation departments and generally applicable, on the basis of which the railway operation departments of the major countries from the European Union make continuous upgrading of their systems according to their respective operational features. Constant exploration and development of the railway traffic control command and auxiliary decision-making systems have been carried out by different countries of the world. In the past nearly 5 years in particular, many countries have made efforts to start the research and exploration for the new-generation intelligent railway traffic control command system and achieve great progress in research and development projects such as Crossrail and Intelligent Traffic Management System. It can be foreseen that more intelligent railway traffic control command systems will be brought forth by different countries soon.

3 Functional Analysis for China's HSR Intelligent Traffic Control Auxiliary Decision-making System

The application of information technology systems for railway traffic control command in China started from the railway transportation management information system in 1990s. The traffic control command management information system was established for the project in 1996, achieving the automatic collection of operation data, storage of technical data as well as the remote connection and information interaction of the railway administrations' traffic control centers through the interconnection with TMIS. TMIS and DMIS were integrated into the train control command system (TDCS) in

2005, possessing such major functions as traffic control supervision, real-time macroscopic monitoring, train operation plan formulation and adjustment, automatic issuance of traffic control order, and traffic control information management and statistics. Meanwhile, research and development for the control system of centralized traffic control (CTC) started in 2002 based on DMIS/TDCS and CTC has achieved automatic triggering of station control, automatic routing arrangement and station signal equipment (computer interlocking equipment) on the basis of DMIS/TDCS data. Applications of TDCS and CTC in the railway network have, to a great extent, reduced the working load of traffic controllers and avoided errors due to human factors, but with very limited functions in intelligent traffic control decision-making. Currently, with the development of technologies such as big data, simulation, machine learning and visualization, the traffic control auxiliary system based on the principles of "data+arithmetic force+algorithm+visualization" will raise greatly the cognitive level of traffic controllers with respect to train delay. It has become a pressing demand to develop HSR intelligent traffic control auxiliary decision-making system so as to provide support to the traffic controllers in traffic control decision-making and improve the decision-making efficiency. Machine/deep learning methods have shown their superiority in the area of railway transportation and the artificial intelligence methods and technologies such as inference and recommendation system, machine learning, computer visual sense, knowledge expression and mode identification have achieved initial applications in the areas of railway transportation safety, passenger tickets and passenger services, but still require in-depth research for the intelligent traffic control command system

As the intergrowth system of the current HSR traffic control command CTC system, the HSR intelligent traffic control auxiliary decision-making system needs to achieve a perfect linkage of the train working diagram compiling system with the CTC system to provide assistance to the HSR traffic control command decision making. With the idea of intelligent traffic control, functions such as data management, operation simulation, train delay prediction, intelligent traffic control auxiliary decision making, visualized indication and analyses will be realized and perfected to improve the traffic control decision-making level.

The system will possess a static function and a dynamic function, in which the static function mainly realizes analyses of performance operation data, and data visualization to facilitate the man-machine interactive traffic control of traffic controllers; and the dynamic function mainly makes real-time auxiliary train dispatching, with which the traffic controllers can choose the performance operation data, EMU data and infrastructure data in the database and make use of the artificial intelligence modules such as machine/in-depth learning to teach the train delay and conflict prediction models as well as the traffic control decision-making models. The train delay and conflict prediction models are used to achieve predictions for train running time in the section, train-stop time at stations, train delay dissemination and influences, conflict possibility and conflict evolution. The traffic control decision-making models are used to realize the automatic adjustment proposals of traffic control solutions for the train operation adjustment and conflict elimination tactics under different traffic control goals.

The functional architecture of China's HSR intelligent traffic control auxiliary decision-making system is shown in Fig. 1. It should possess the following functions:

(1) Data management: The traffic control auxiliary decision-making system supports derivation of train working diagram data, train performance data (including all relevant data covering meteorology, train operation records, and EMU routing track operation), infrastructure data, and vehicle feature data from CTC/TDCS systems and also supports sending out simulation and prediction data in multiple patterns. As the data records might have errors or wrong data, it is permitted to make revisions and adjustments for the data by way of man-machine interaction to meet the requirements of basic functions for data operation.

(2) Train operation simulation: Input planned operation diagram will be chosen through data management modules to simulate train operation and check the quality of train working diagram compilation on the time domain. The operation interference scenarios can be provided to make self-defined interference degree, time of occurrence, and area of influence and check the robustness of train working diagram so as to find out the weak links. Simulation of train performance operation data will be made to inquire about the potential hidden troubles with respect to safety in the course of train operation.

(3) Train delay prediction: Machine/deep learning methods will be used and prediction models trained with performance data will be utilized to facilitate accurate predictions of the train delay dissemination process, estimating train operation time and possible influences and realizing measurement of train delays.

(4) Conflict analysis: Models and methods of automatic detection, grading and evolution for HSR train operation conflict will be established based on historic data, operation data science and artificial intelligence theory to achieve perception and analysis of the train operation conflict situations.

(5) Intelligent adjustment auxiliary decision-making: Intelligence models of HSR traffic control command and decision-making as well as train operation adjustment will be established to create solutions for conflict elimination tactics and train operation adjustments in combination with the required tactics. This can provide train dispatching suggestions to the traffic controllers who will check and confirm before making issuance and achieve rapid and intelligent adjustments of the

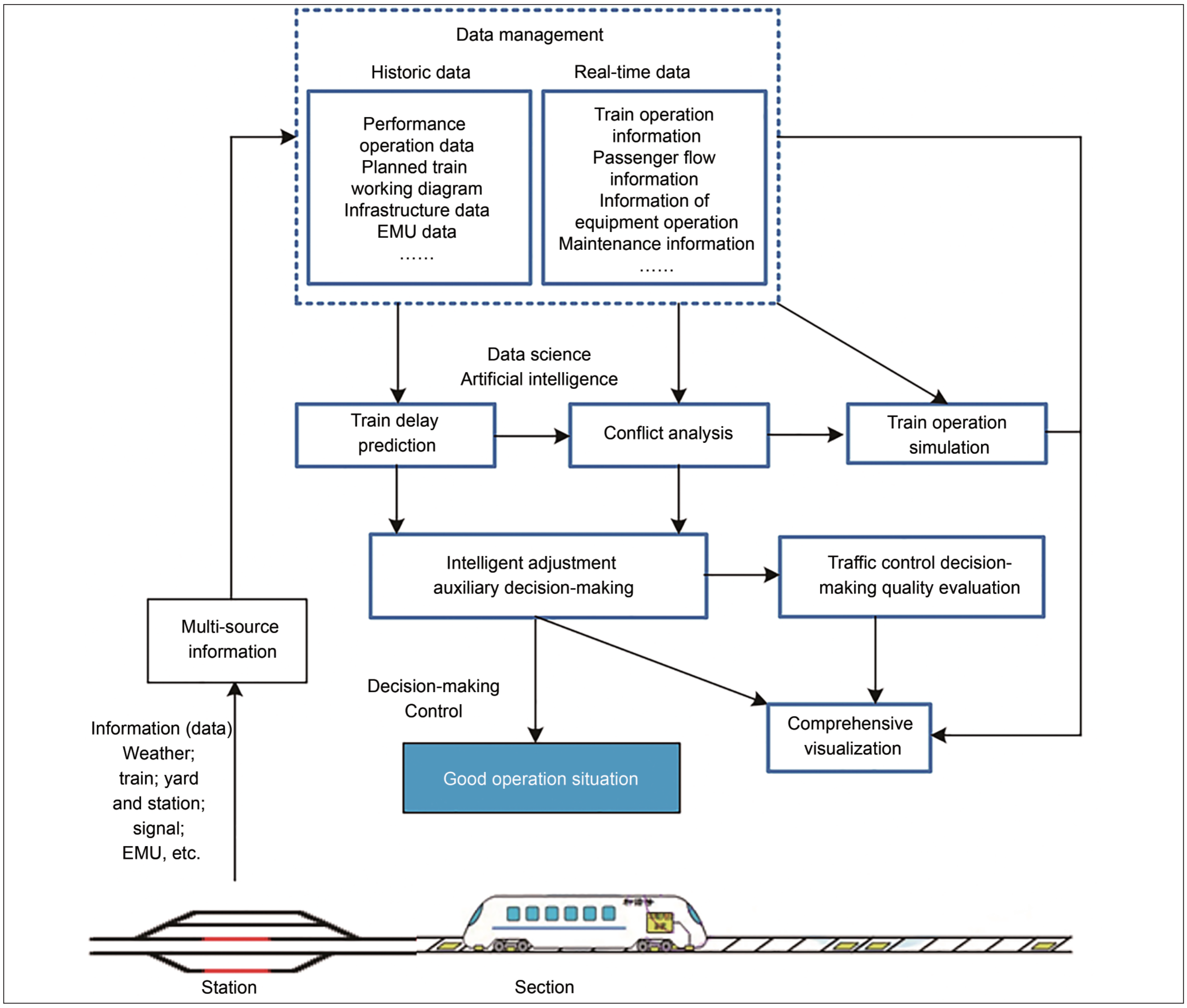

Fig. 1 Functional architecture of China's HSR intelligent traffic control auxiliary decision-making system

train operation plan.

(6) Evaluation of quality for traffic control decision-making: Evaluation of the implementation quality for traffic control adjustment tactics will be carried out by using indices such as train delay restoration, conflict elimination, and related influences due to train delay to achieve the evaluation of quality for traffic control decision-making.

(7) Comprehensive visualization: The method of visualization will be used for simulation result output so as to indicate the situations of train delay in general, train delay at stations, train delay for the track line and the sections of capacity tension by way of visualization.

To sum up, China's HSR intelligent traffic control auxiliary decision-making system is a set of traffic control auxiliary decision-making system independent of the train working diagram compilation system and the centralized traffic control system. The system takes historic data and real-time data of the HSR operation as the foundation, uses data science and artificial intelligence methods and establishes train delay and conflict prediction models, and intelligent models for HSR train operation adjustment to achieve prediction and evaluation of trains' future transportation situations, put forward suggestions for traffic control decision-making and realize the serial functions of data management—train operation management—traffic control decision-making—visualization.

The system possesses different jurisdictions and open functions for the different levels of China State Railway Group Co. Ltd., China Railway Regional Group Co. Ltd., and stations and depots. At the traffic control offices of the level of China State Railway Group Co. Ltd. and that of the level of China Railway Regional Group Co. Ltd., the system should possess all the functions including comprehensive management of the region for HSR train operation situations, train operation analyses and prediction, situation deduction, traffic control adjustment decision-making, and comprehensive visualization for the entire railway sector and the Railway Regional Group Co. Ltd. At the level of railway stations and depots, the system should possess the basic functions including comprehensive management of data, real-time dynamic indication of train operation situations, and comprehensive visualization.

4 Conclusion

It is clearly pointed out in the project of "Research on Strategy for Intelligent HSR (2035)" that intelligent traffic control of train operation is one of the key goals to be achieved. Improvement of efficiency for railway transportation organization, raising of transportation service quality and guarantee of railway transportation safety through railway intelligence have become the only ways for railway development of different countries in the world. The achievement of HSR traffic control intelligence based on the historic and real-time data of railway and by using the data driven method is an urgent requirement for the intelligent railway development in the world. The era of "speaking with data, making decision with data, conducting management with data and innovating with data" has quietly arrived.

To cope with the strategic demands of "making China powerful with its transportation and letting the railway sector go ahead of the rest" and making the HSR "go global", the paper elaborates the development of domestic and foreign railway traffic control command simulation experimental and practical systems, analyzes the functions that China's HSR intelligent traffic control auxiliary decision-making system should possess, explains the meaning of data management, train operation simulation, train delay prediction, conflict analysis, intelligent adjustment auxiliary decision-making, traffic control quality evaluation and comprehensive visualization so as to provide theoretical support to the development of China's HSR intelligent traffic control auxiliary decision-making system.

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