

Methodology of Preparing Train Running Diagram in High Speed Railway

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Abstract— The train running diagram (TRD) is the basic document for arranging the train operation and comprehensive planning for railway transportation, so the preparation quality is of great significance for improving the railway transport efficiency and application of railway technical equipment, ensuring the driving safety, increasing the efficiency of locomotives utilization, car turn-round and passenger and goods delivery and adapting to the transportation market needs. This paper analyzes and compares the similarities and differences of train running diagram between high speed railways (HSR) and existing railways premised on the operation organization modes of high and medium speed trains in the initial operational stage of Beijing-Shanghai High Speed Railway, and describes the main idea for preparing the train running diagram of Beijing-Shanghai High Speed Railway (HSR) based on railway network, diagram structure and preparation and optimization theories of running diagram for high and medium speed trains.

Index Terms— High speed railway (HSR); train running diagram; railway network

I. INTRODUCTION

The high and medium speed trains ran in a mixed mode and the medium speed trains ran in HSR line in the initial operational stage of Beijing-Shanghai High Speed Railway. Such operation mode determines that the preparation of diagram can neither mimic the method of the existing diagram in China, nor that in Japan, France and Germany. After years of research and discussion, lots of achievements have been obtained for the mode^[1] adopted by high speed train running diagram as well as preparation sequence and method^[2] for the diagram. However, the previous researches are not enough for the actual transport organization requirements of HSR, represented by simply researching the HSR and separating the condition of medium speed train accessing and departing from Beijing-Shanghai High Speed Railway and connection between the high speed line and existing main transportation channels. Literatures^[3,4] proposed a new preparation method for train running diagram for railway network based on the preparation experience of diagram in China and after years of research, which have been successfully used in actual production and research of science and technology projects of

HSR. The author states the basic theory for preparation of train running diagram in HSR on railway network by analyzing the characteristics of HSRs and existing railways.

II. COMPARISON OF TRAIN RUNNING DIAGRAM BETWEEN HSRs AND EXISTING RAILWAYS

2.1 Similarities

- (1) The line carrying capacity shall be fully used for reasonably arranging operation orders for trains of different classes and calculating the initial time of each train path of the diagram and the dwell time at each station.
- (2) The trains of lower classes shall shunt to allow trains of higher classes to pass, while short-distance trains shall shunt to allow long distance trains to pass.
- (3) Running speed of trains shall be maximized and stops and dwell time shall be minimized provided the train operation and running safety are ensured.
- (4) Quantity of train mobile devices (locomotives, passenger stocks or high speed EMUs) shall be minimized provided transportation demand and train running safety are ensured.
- (5) Under tracking operation organization mode, there is limitation on minimum interval time for stations and sections between trains.
- (6) The diagram drawing shall be based on the consideration that the continuous working hours of train crew shall not exceed the standard labor time.
- (7) The stopping and turning back time of the mobile devices at the outer district as well as the turnaround time shall be minimized provided the minimum turning back time of mobile devices is ensured.
- (8) The drawing of diagram shall be carried out simultaneously with the setting, calculation, check and adjustment.

2.2 Differences

- (1) Drawing objectives. The drawing of train running diagram in Beijing-Shanghai High Speed Railway shall be able to create a new situation for the diagram in China based on preparation experience of other nations in advanced transport organization and diagram in high speed railway. The diagram shall be prepared to offer conveniences for passenger travel and improve passenger service quality and high-quality train operation order. On this basis, the running time of medium speed trains accessing the high speed line, stops and dwell time for non-passenger boarding and landing operation, quantity of high-speed EMUs and locomotives for medium speed trains shall be minimized and the departure time and arrival time shall be reasonable. For the existing railway, as the carrying capacity does not match the traffic volume, the preparation of its train running diagram focus on tapping potentials, improving efficiency, making fully use of the carrying capacity of existing railway to shorten running

Manuscript received October 04, 2016

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interval time, improve running pairs and minimize the running time, connecting time for freight trains and quantity of locomotives.

(2) Attributes and types of running trains. Beijing-Shanghai High Speed Railway is a passenger dedicated line (PDL) for high speed trains and cross-line medium speed trains, while the existing railway is passenger and freight mixed line for passenger trains and freight trains. Passenger trains and freight trains fall into certain types according to train class. The existing railways can be divided into medium speed passenger trains accessing or not accessing the high speed line based on the research on the train running diagram in Beijing-Shanghai High Speed Railway.

(3) Preparation sequence. Trains running in high speed line are all passenger trains, but the class of high speed trains is higher than the medium speed train accessing the high speed line. Thus, considering the train class and travel distance, diagram for high speed trains shall be drawn prior to the medium speed train as a whole, followed by cross-line medium speed trains (express and speed-raise passenger train in existing railways) in existing railways based on the departure and arrival time of medium speed trains at docking station, and then departure and arrival time of the trains are checked for the reasonability. The class of passenger trains running in existing railways is obviously higher than that of the freight trains, so passenger trains shall be drawn before the freight trains. Based on through schemes for passenger trains in the entire railway, the specific drawing sequence is inter-railway administration through passenger trains (the drawing sequence for such train is determined according to the number of inter-railway administrations), local passenger trains, inter-railway administration freight trains and local freight trains.

(4) Drawing strategies. As the diagram in HSR is drawn to offer convenience for passenger travel and improve passenger service quality and high-quality train operation order, Beijing-Shanghai High Speed Railway shall pursue the similar drawing strategies for regular diagram in HSR of Japan, i.e. running quantity, operation sequence, running speed, overtaking or refuge station are basically the same, with regular trains, seasonal trains and temporary trains drawn in basic diagram in different train paths, fully considering the passengers' requirements in different time and for different trip purposes. While the diagram in existing railway is drawn to ensure the uniform distribution of train paths of freight trains of different types and reasonable operational loads at marshaling stations and district stations by meeting the running quantity of passenger trains and travel time range to some extent.

(5) Adjustment & optimization strategies. Trains running in HSR are all passenger trains. Although the class of the high speed trains is higher than the medium speed trains, cross-line medium speed trains are basically express and high quality speed-raise trains of high class in existing railways, with high demand requirements on departure and arrival time range, running speed and on-schedule rate. Thus, the adjusting priorities for the high and medium speed trains are of same importance. Besides, the adjustment of medium speed trains shall also consider the conformance of departure and arrival time at main passenger stations to seats allotment^[5]. As the passenger and freight trains run in existing railway in a mixed mode and the adjustment and drawing of passenger trains precedes the freight trains, the train paths of passenger trains

can be adjusted preferentially and freight trains will shunt to allow the passenger trains to pass, given that the uniform distribution of train paths is ensured and automatic crossing untwining guarantees are provided.

(6) Time period for drawing train paths. The setting of maintenance interval (maintenance of engineering facilities and catenary) for high speed electrified railway greatly reduces the time slot (24h in a day less about 6h maintenance intervals time and invalid time) of diagram in HSR used for drawing the high and medium speed trains, compared to that of existing railway. The maintenance intervals time also splits the reusable, continuous time of diagram, shortening the departure time of long distance medium-speed trains accessing high speed line. While the maintenance (construction) intervals of existing railway are set flexibly, the rectangular intervals and V-shaped intervals can be used in a staggered mode according to actual requirements on transportation organization, with short intervals time.

(7) Reasonable departure and arrival time range of passenger trains. Determination of reasonable departure and arrival time range of passenger trains is one of the most important measures to improve passenger train service quality and attract passenger flow and also the key consideration for the drawing of the diagram of passenger trains. It is simple to determine the departure and arrival time range of passenger trains in existing railway, with consideration of combined railway and urban transportation and travel habit of passenger trains. By considering the travel distance of passenger trains, the departure time is generally not earlier than 7:00AM and arrival time not later than 24:00PM. The calculation of reasonable departure and arrival time for the medium speed trains accessing and departing from Beijing-Shanghai High Speed Railway is more complicated, due to multi-constraints on departure time range (providing medium speed trains access the high speed line) of trains in existing railways, drawing range of train paths affected by intervals in high speed line and arrival time range (providing medium speed trains depart from the high speed line) of trains in existing railways.

III. PREPARATION THEORIES OF HIGH SPEED TRAIN RUNNING DIAGRAM

3.1 Types of high speed passenger trains

According to the mixed operation mode of high and medium speed trains, train classes and travel distances in the initial operational stage of Beijing-Shanghai High Speed Railway (HSR), the trains running in Beijing-Shanghai HSR fall into the following types.

(1) Single-line high speed trains and cross-line medium speed trains (by train class).

(2) Long distance, medium distance and short distance trains (by travel distance of all train types). Beijing-Shanghai HSR covers 7 hubs and 5 dispatching districts, with average distance of each dispatching district being approximately 300 km. Long distance trains refer to the high and medium speed trains with the travel distance over 800 km on the Beijing-Shanghai HSR; medium distance trains refer to the high and medium speed trains with the travel distance between 300 km and 800 km; short distance trains are these with the travel distance less than 300 km. Therefore, the high speed trains can be classified into three types by travel

distance: long distance, medium distance and short distance trains. Medium speed trains are also similar.

(3) Sunset-departure and sunrise-arrival trains and non-sunset-departure and sunrise-arrival trains (for cross-line medium speed trains, by departure and arrival time based on practicality). According to the structure and traveling characteristics of Chinese passengers, by analyzing the experience of drawing the train running diagram since the speeding-up railway transport of passenger in 1998, we found that the sunset-departure and sunrise-arrival trains are favored by the passengers[6]. The medium speed trains of sunset-departure and sunrise-arrival refer to the trains with the travel time over 6 h, departing between 19:00 and 24:00, and arriving between 6:00 and 9:00.

(4) Through high speed trains, non-through high speed trains, through medium speed trains and non-through medium speed trains (by dwell frequency).

3.2 Major Idea for Preparation of High Speed Train Running Diagram

(1) The high speed train running diagram based on networked structure: As per the integrated planning of road network in

China, by 2010 (2015), Qinhuangdao-Shenyang Passenger Dedicated Line (PDL), Tianjin-Qinhuangdao PDL, Shenyang-Harbin PDL and Shanghai-Hangzhou PDL will be completed while Beijing-Shanghai HSR (more than 1300 km) is constructed. The highest speed of the above four PDLs can reach 200 km/h and above, and the specific data is shown in Table 1. Based on the above analysis, a network for rapid passenger transport with radius of about 3000km will be formed in China with Beijing-Shanghai HSR as the main transport line and the above PDLs as the radial lines by 2010(2015).

The initial operation mode in Beijing-Shanghai HSR decides from the view of transportation organization that the train running diagram of the line cannot be prepared separately by ignoring the existing road network. The cross-line medium speed trains mainly are the inter-railway administration express and high speed quality trains of high classes in the existing railways, and shall be drawn preferentially in the preparation of the existing train running diagram.

Table 1 Passenger Dedicated Lines Related to Beijing-Shanghai HSR

Name	Departure Station	Arrival Station	Line Length /High km	Speed Docking Station
Qinhuangdao-Shenyang PDL	Qinhuangdao	Shenyang	420	-
Tianjin-Qinhuangdao PDL	Tianjin	Qinhuangdao	280	Tianjin
Shenyang-Harbin PDL	Shenyang	Harbin	540	-
Shanghai-Hangzhou PDL	Shanghai	Hangzhou	190	Shanghai

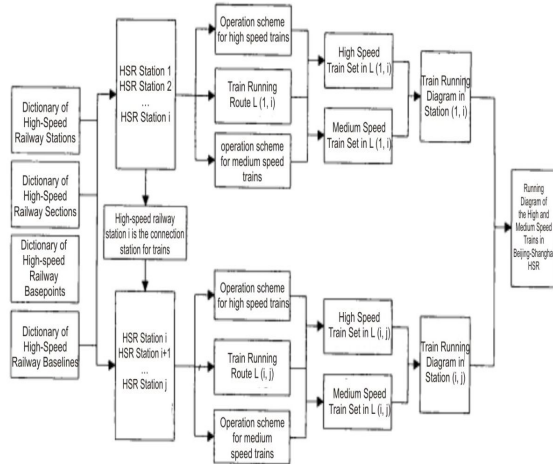
Therefore, the range of departure and arrival time of trains, train travel speed, train punctuality and the time when the trains pass through the existing main passenger stations are also highly required. The preparation of train running diagram shall be taken overall consideration with high speed train. By absorbing the experience of preparing the train running diagram of the existing railway network line^[4], the idea for preparation of high speed train running diagram is confirmed, i.e., the railway network is established based on Beijing-Shanghai HSR and the existing main transport lines, taking the graph theory and geographic information system as the theories. The preparation of high and medium speed train running diagram in high speed railway are taken as the focus, the connection problem of train running diagram between high speed railway and the networked structure of existing line will be solved reasonably, to ensure the reasonable range of the departure and arrival time of the medium speed trains in the existing lines, and to satisfy the requirements of the passenger flow assignment (seats allotment) on the departure and arrival time of trains when the trains pass the main passenger station.

(2) The operation of cross-line sunset-departure and sunrise-arrival trains: According to the preparation experience of the passenger train speeding-up and the current running diagram in recent years, the quality trains with the running time less than 6h may choose sunrise-departure and sunset-arrival; the quality trains with the running time between 6h and 15h may choose sunset-departure and sunrise-arrival. The successful operation of the sunset-departure and sunrise-arrival trains in the existing lines also exerts a profound influence on the train transportation organization of Beijing-Shanghai HSR. As mentioned above, as per the railway development plan of China, building PDL and speeding up the passenger trains will become a

development tendency for railways in China. Especially, when those PDLs are completed in the future, Tianjin-Qinhuangdao PDL will connect with Qinhuangdao-Shenyang PDL by Tianjin and Beijing-Shanghai HSR, and the existing lines of Beijing and Shanghai, providing a lot of medium and long distance passenger flow for Beijing-Shanghai railway transportation lines. The trains departing from Harbin, Changchun, Shenyang and Dalian run in the high speed lines passing through PDL, and sunset-departure and sunrise-arrival basically can be realized. Hence, certain pairs of sunset-departure and sunrise-arrival trains running in Beijing-Shanghai HSR are necessary. The sunset-departure and sunrise-arrival trains running in the high speed lines certainly would be impacted by the construction interval of high speed lines (from 0:00 to 6:00 at night). The possible running mode would be alternately blocking the high speed line in one direction and organizing two-way traffic in the other direction. By adopting single line and semi-automatic block system (this mode shall take the comprehensive control of the improper organization mode of construction and catenaries in high speed lines full consideration), the passing capacity and train speed would be greatly influenced, which also shall be studied intensively. Another possible mode is to ensure the operation of certain number of sunrise-departure and sunset-arrival trains, the capacity of the existing Beijing-Shanghai lines and high speed lines, and the trains' travel time are fully considered. Under the premise of speeding up the existing Beijing-Shanghai lines, these sunrise-departure and sunset-arrival trains are remained running in the existing Beijing-Shanghai lines.

3.3 Basic Structure for Preparation of High Speed Train Running Diagram

The structure of train running diagram refers to the predefined number of blocks displayed in each running diagram, and the relations between the departure and arrival stations of each block and the train routes, based on the train dispatching district, or the attributes of railway hubs, trunk lines and branches; the train sets in each block are calculated. The calculation of the structure of train running diagram is the basis for preparing the running diagram of the trains in Beijing-Shanghai High-Speed Railway network. The structure of the running diagram of the high and medium speed trains in Beijing-Shanghai High-Speed Railway is shown in Figure 1.



The structure of the running diagram of the high and medium speed trains in Beijing-Shanghai High-Speed Railway

3.4 Basic Methods for Preparation and Optimization of High Speed Train Running Diagram

(1) As mentioned above, Beijing-Shanghai HSR network is a railway network consisting of Beijing-Shanghai HSR and the existing main transport lines engaging in train connection with high speed lines. Thus, for the high speed train running diagram, macroscopic and microcosmic railway network of HSR shall be built first. The macroscopic network (upper level) is used for describing the connection relations between the structure and lines of Beijing-Shanghai HSR network, fixing the positions of point (station) and side (section), and calculating the running routes of the high and medium (ordinary) speed trains. The microcosmic (low level) station layout shall be built based on track circuit, turnout, curve, scissors crossover, and the central number of main track or station tracks, used for calculating and describing the receiving, departure, receiving routes, parallel routes, crossing routes and infeasible routes of trains.

(2) The mathematical model of the running diagram of the high and medium speed trains in Beijing-Shanghai HSR is built and the running diagram of the high and medium speed trains in HSR is prepared based on the passenger service quality of Beijing-Shanghai HSR, the preparation proportionality of high speed train running diagram, the quantity of high speed trains used and locomotives used by medium speed trains as the preparation target, restrained by the running time of high and medium speed trains in the section, interval time of high and medium speed trains in the station and section, minimum reverse time of high speed trains and medium speed trains, continuous working time of

train crew, minimum conversion time of medium speed locomotives in the docking station, and the travel speed of medium speed trains in the high speed lines.

(3) The running diagram for the medium speed trains in the existing railway lines are drawn, the departure and arrival time of cross-line medium speed trains are checked for feasibility based on the running time, additional time for start and stop and station dwell time of the medium speed trains in the existing section calculated.

(4) The running lines for the high and medium speed trains are adjusted and optimized by using the optimization method of reducing stops and station dwell time of the medium speed trains not used for passengers, balancing the usage of the station tracks (main track and arrival-departure track) for the high and medium speed trains, and preparing the turnaround diagram for the high speed trains and medium speed locomotives.

CONCLUSIONS

After years of research and actual application, the method for preparation of the train running diagram based on railway network becomes mature. The computer simulation experiment shows that, compared with the preparation of running diagram by merely relying on high speed lines, building a high speed railway network on the basis of Beijing-Shanghai HSR and the existing main transport lines, and preparing the high speed train running diagram by mainly depending on the preparation of the running diagram of the high and medium speed trains in high speed railway can produce more optimized and practical results with more complete and accurate index statistics.

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