

# Analysis of Rail Transit Interconnection Network Operation

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**Abstract:** Interconnected networked trains have become a viable measure to alleviate the current operating pressure. This paper analyzed the foreign mature operational experience and interpretation of the technical conditions for networked trains. At the operational level, the train operation plan is an important organizational content. It consists of three sub-processes: passenger flow, formulate transportation plan and prepare operation map. This paper proposes a train operation plan optimization method with separate optimization and overall integrated linkage optimization at each stage. According to the existing research, it provides suggestions and references for the future development of networked train operations.

## 1. Introduction

The development of urban rail transit in China has a history of more than 50 years. In the initial stage of operation, because the lines are not dense, the demand of passenger flow is not very large, and the lines are in independent operation. With the rapid development and expansion of the city, the urban track lines continue to expand, and the network form is increasingly obvious. At present, the train network operation only stays at the surface, although the lines are networked, but passengers still need to transfer at the transfer station to reach the destination. In order to alleviate the passenger flow pressure of the transfer station, meet the passengers' rapid and direct demand, promote the resource sharing among the various lines, and improve the utilization of the line capacity, the real interconnection and network operation is put on the agenda. Therefore, it is of great significance for the construction and operation of networked trains to study the conditions of networked trains and to find a reasonable method for operation and organization.

## 2. The Status of Interconnected Networked Trains

Urban rail transit interconnection means that trains can operate safely across different lines without requiring parking or changing driving modes in lines or networks containing equipment from different vendors. At present, China has not realized the network operation in the true sense, but many places have begun preparations before opening, and already have the opening conditions. For example, Chongqing has unified the models, limits, power supply and signals of some lines, and realized the crossing station and the same-station-transfer in the stage of new line construction, creating conditions for interconnection with other planned lines, making the 4th, 5th, 10th and ring lines have the conditions for the interconnection of interconnected networked trains. At present, the inter-line operation mode of interconnection has been successfully implemented on Line 6 and Guobo.

In Japan, Paris and other regions, it already has a well-developed wire network structure and mature networked operation organization technology. In 1960, the "direct-through" operation of the subway Asakusa line and the private railway Jingcheng was successfully implemented, and accumulated valuable experience. At present, the seven lines operated by the Tokyo Metro Company have been interconnected with private railways and national railways, and connected to fast and slow trains, provide a variety of train services, including fast, fast range, fast commute, and ordinary, to

meet the demand of different passengers. In addition, the only subway line in Japan's Saitama is also interconnected with the Tokyo Metro Namboku Line and the Tokyo Express Line.

The French RER line is a fast rail transit system in the Greater Paris region, covering Paris and surrounding area. The biggest feature is that each RER has a branch line in two directions. In the main area, it is usually connected a main line and branch lines at both ends. During the operation, the trains sent from the feeder line are merged into the main line before entering the urban area. After running into the suburbs, they travel to their respective feeder lines according to the different needs of the passenger flow, forming a collinear operation of different road trains. The mode of operation and over-the-counter mode provides passengers with a variety of travel options to reach their destination quickly and easily. RER's circuit map is shown below.

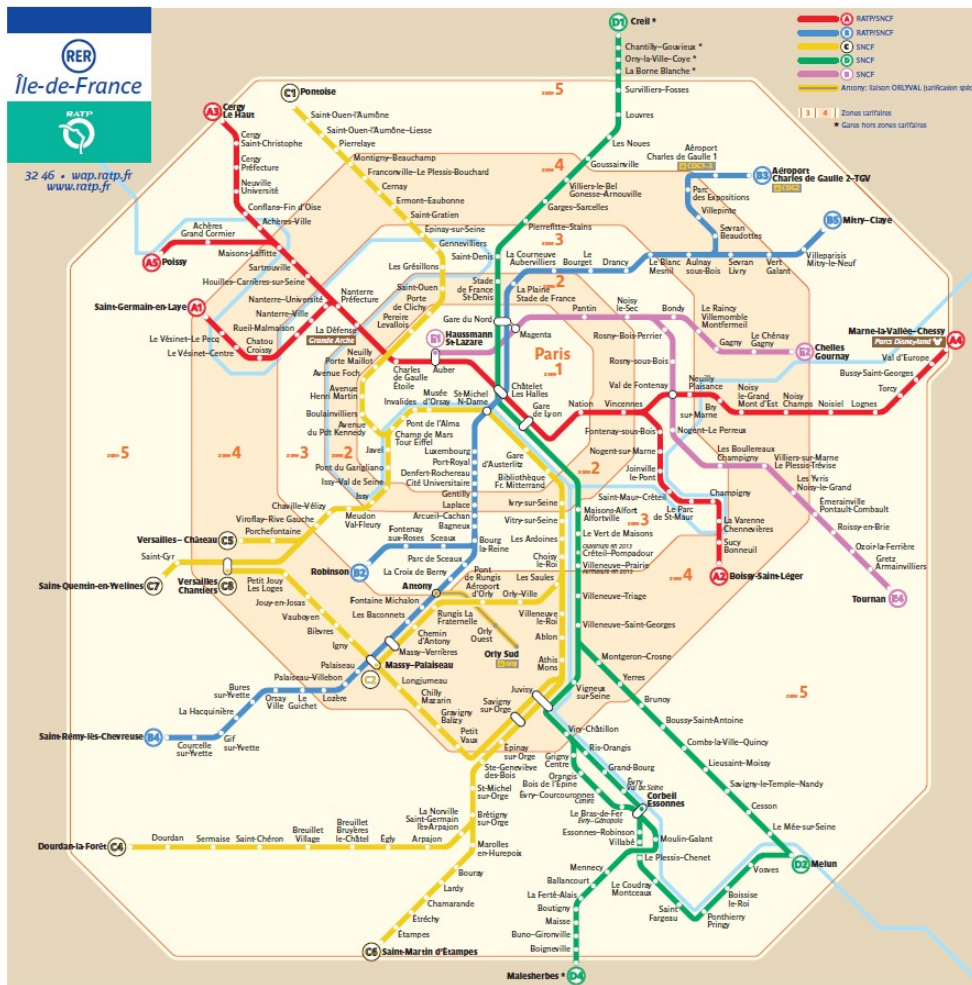


Fig. 1 Circuit map of RER

Many scholars have made recommendations on the networked operation of China by analyzing the characteristics of the network of foreign metropolitan areas and diversified transportation organization models, as described in the literature [1-3]. In terms of specific operational organization, most of them adopt a combination operation mode, which is mainly based on alternate stop and bus speeds and flexible roads, and considers the different passenger flow requirements to realize the continuous operation of the city railway and the city rail transit, embodied in literature [4-6].

### 3. Technical Conditions for Networked Trains

In order to open network-connected trains and achieve resource sharing, the facilities and equipment of each line must have uniform standards and be compatible with each other, mainly

including the following prerequisites: a unified vehicle, signal and dispatch system, taking full account of the train's cross-line operation and the line configuration of the return station.

(1) Vehicles. At present, the outline size of the rail transit lines and the equipment used in many cities are different. In order to achieve cross-line operation, it is necessary to ensure that the vehicle boundaries, equipment boundaries, and building boundaries standards for entering the line are unified;

(2) Power receiving mode. The power receiving mode of rail transit trains is mainly divided into contact nets and contact rails. If the lines adopt different power receiving modes, the structure of the two-flow type trains is very complicated, the price and maintenance cost have increased, which will bring inconvenience to the operation;

(3) Signal system. The signal system is the nervous system of rail transit. It must be able to control the trains of each line in order to achieve interconnection and interoperability.

The existing research have achieved certain results for the test method of CTCS train control vehicle equipment and the interface design of ATS system. The 4th, 5th, 10th and ring lines of Chongqing Rail Transit have realized the conditions for the interconnection of technical equipment, and it is the country's first interconnected demonstration project.

#### **4. Networked Train Operation and Organization**

The biggest advantage of networked trains compared to ordinary single-line trains is that they can meet the different passenger flow requirements of different time periods, different sections and the passengers' demand for travel speed and destinations. Therefore, the operational organization mode of networked trains is mainly divided into cross-line operation, fast and slow vehicle operation, large-small train routing and flexible grouping. The train planning is the basis for realizing the networked train operation organization. Its premise is the passenger flow. According to the characteristic nature of the passenger flow, a reasonable transportation planning from passenger flow to traffic flow is compiled. At present, there are few studies on the development of the model for this model in China. The traditional single-line train scheme does not reflect its characteristics. The preparation for train planning of the urban rail is mainly divided into three aspects.

- (1) Forecast passenger flow and analysis characteristics;
- (2) Form train planning based on passenger flow characteristics
- (3) Preparation of train operation diagram

The advantages and disadvantages of the train planning directly affect the actual operational effects. According to the three aspects mentioned above, the optimization method can be divided into several situations.

(1) Static optimization. It refers to the generation of train planning optimization scheme under the condition of known OD passenger flow, which belongs to static optimization and is also the main research content at present. According to different modes of operation, some scholars consider the train running across the line.

(2) Comprehensive optimization. The train planning and the operation diagram are comprehensively optimized. The operation diagram is a concrete manifestation of the train operation planning. It involves the connection operation after the train arrives at the train and the connection process of different modes of trains. Synchronous linkage optimization can achieve better results. At present, only a few scholars have conducted in-depth research in this area, as described in the literature [7].

The basis of the operation planning is passenger flow, and the passenger flow prediction process involves the running characteristics of the train. Therefore, the combination of the two is also studied, but only the completeness of the route or the setting parameters are different, and there is not a real integrated optimization.

Considering the three phases as a whole to comprehensively optimize the networked train planning is the most ideal optimization solution, but such research has not been seen yet.

In the process of preparing the operation plan, the content is obtained from the above three aspects, and each process interacts with each other. The work done in each link is shown in Table 1. It can be seen that the parameters required in the completion of the three processes and the final optimization results are mutually infiltrated, each having an influence, forming a linkage relationship. The linkage optimization relationship between the various parts is shown in Figure 2.

Table 1. Sub-process of Networked train Planning Formation

Process	Parameter	Optimization Content	Optimization Results
Passenger Flow Forecast	Service attributes, Socioeconomic conditions, line parameters, etc.	Passenger flow forecasting, line distribution	OD passenger flow, passenger flow intensity, etc.
Transportation Planning	Train attribute parameters, line capacity, OD passenger flow, capacity utilization parameters, etc.	Train planning	Driving frequency, start-end point, stopping plan, grouping plan
Train Diagram	Train related parameters	Vehicle operation, train diagram	Time to arrival and leave, running time, travel speed, number of vehicle turnovers and connection, etc.

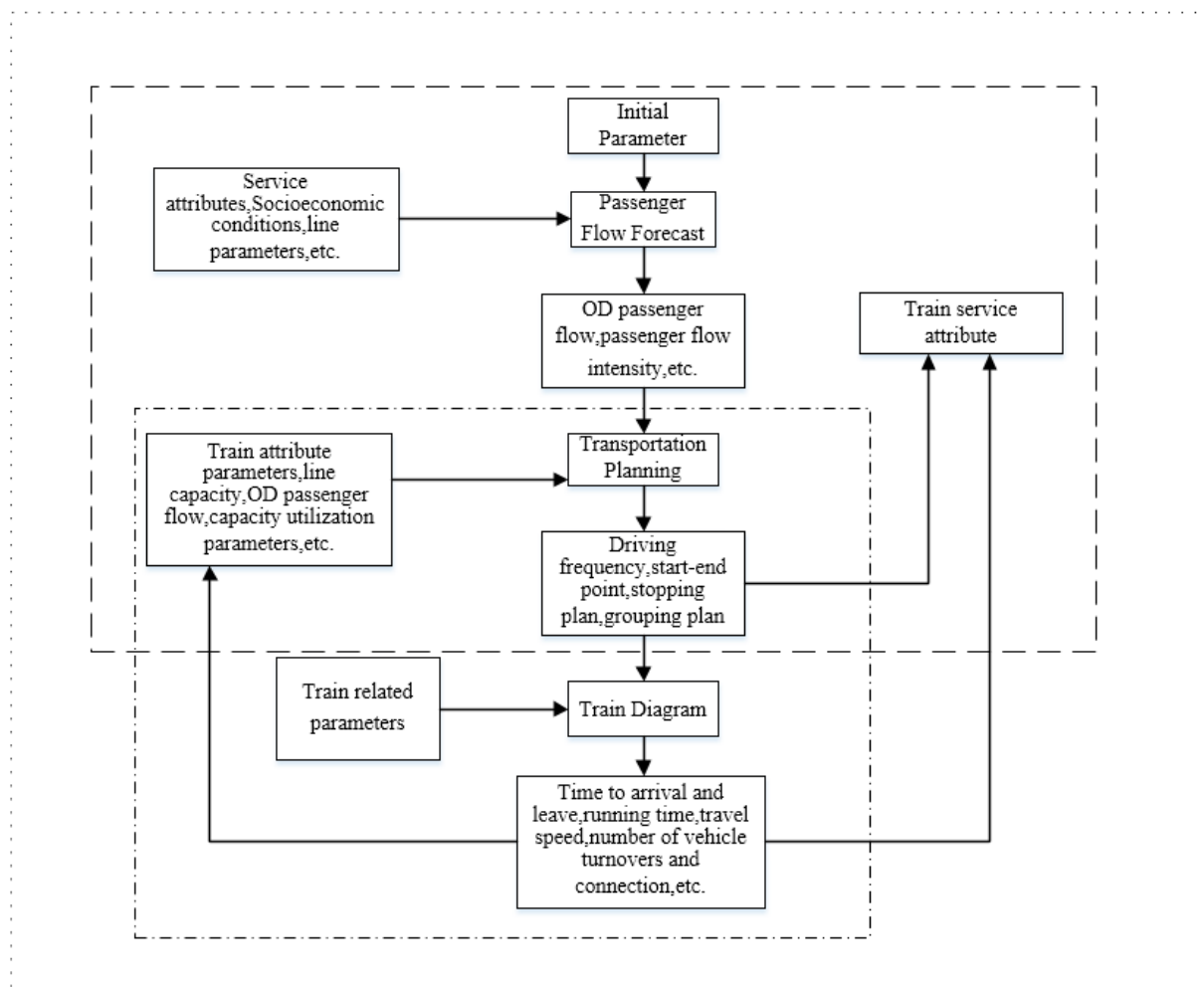


Fig. 2 Relationship of Networked train planning linkage optimization

The current optimization research is mainly in the sub-process of formulating networked train transportation planning, and is in its infancy. The existing literature analyzes the necessary conditions and feasibility of the networked trains in terms of engineering construction, passenger

flow conditions, line capacity, station configuration, etc. Whether the transmission capacity, passing capacity, and section passenger flow strength of the line can meet the cross-line conditions, the operational capacity of the cross-line station, the re-entry station, the lines configuration and the layout of the platform have become the main research directions of the networked train planning, and this is used as the optimization target or constraint condition, mostly under the premised train grouping and station stop, solving the two parts of train route and driving frequency. The main work is reflected in the literature [8-11]. There are few studies on the frequency of stopping, routing and driving frequency.

The advantage of networked trains is to combine different modes to meet the diversified needs of passengers, and rationally allocate resources and passenger flow to achieve a win-win situation. Compared with single-mode operation, the combined mode is more complex in organization, but it can achieve better results in flexibility and diversity. Existing researches have combined networked trains with fast and slow trains, multiple routes, and flexible groupings to meet the demand of long-distance passenger flow for time, and also to meet the needs of convenience, effectively alleviating the transfer pressure of large number of passenger staying in the station, attracts more suburban passengers to choose urban rail transit, while saving operational costs, as described in the literature [12-13].

However, it can be seen that the train planning is implemented in the dynamic process of separate optimization and comprehensive optimization in different stages, and the linkage optimization involves optimization of sub-processes, parameter adjustment of each stage and iterative cycle. From a holistic point of view, the use of an unified comprehensive optimization model and algorithm can achieve the purpose of comprehensive linkage optimization, but the complexity will be greatly improved. The ability to converge during loop iterations or implementation is also a major factor limiting the continued deepening of such research. So far, relevant literature discussion on the comprehensive optimization of networked train operation planning has not been seen.

## 5. Conclusion

Looking at the current status of interconnected networked trains, there is still a lack of research on the operational level, which can be studied in depth from the following aspects.

(1) Coordinating the train planning and the operational diagram, while combining the dynamic passenger flow to realize comprehensive optimization;

(2) At present, most of the network-based trains are designed for the actual optimization of the two lines of local line network, it can be extended to the network level for overall consideration in the future;

(3) In order to achieve the effect of networked trains, in the future, multi-routing, fast-slow train, multi-grouping and other modes can be combined to develop a more flexible and convenient operation planning to meet the needs of different time periods and different types of passenger flow, at the same time, reduce the operational costs.

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