The Research about Line 3 and Line 4 run Independently Transformed of Shanghai Urban Rail Transit

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Abstract

As Shanghai rail network has been basically completed and its growth in passenger traffic, the situation about Line 3 and Line 4 collinear run has become a bottlenecks that constraint to improve overall network transport. This paper will be based on the analysis of the basic situation of Shanghai Rail Transit Network and Line 3 and Line 4 collinear running status, pointing out the drawbacks of Collinear run, which proposed the necessity and importance of the transformation to change the situation that Line 3 and Line 4 operate independently. And it will give the corresponding suggestions and measures.

Key Words: Shanghai rail transit; Line 3; Line 4; run independently

1. The Status Quo of Development of Shanghai Rail Transit Network and Collinear Operation of Line3 and Line 4

1.1 Development of Shanghai Rail Transit Network

With the rapid expansion of Shanghai urban rail transit network, the benefit of rail network passenger flow is increasingly prominent. The proportion of network passenger continues to rise, and enter the period of growing leaps and bounds with geometric growth. Based on fast, secure, high-capacity and other characteristics of rail traffic, it has changed the original way to travel for people.

When Shanghai rail transit operators just opened in 1993, the number of average daily passenger flow is only 0.4 million passengers, while daily traffic of Shanghai entire subway network has reached 6.21 million passengers in 2012. The number of days that a number of passengers of road network over 7 million in single-day is as high as 46 times. Meanwhile, the average number of daily passenger flow growth rate is accelerating. It takes 10-year period (1993-2003) that the average number of daily passenger flow of Shanghai rail transport network had reached 1 million people, but it takes only one year from 5 million to 6 million (2011 -2012).

After entering 2013, the number of average daily passenger flow is constantly growing with increasing network operation efficiency .In the March 8, the single-day passenger flow of the whole road network reached 8.48 million passengers as a historic record.

The significance of the completion of Shanghai rail transit network is not only a skill of engineering, but in its impact on the way of people travel. It makes the people in Shanghai form a new civilized way to travel, and a metro travel culture. We complete the task with two decades while it takes one hundred years in developed countries. It can not to imagine how crowded the traffic of Shanghai would be without this large capacity travel tools. Therefore, accelerating the development of rail transport, and further form a network of rail transportation network, will be our goal.

1.2 The Status Quo of Collinear Operation of Line3 and Line 4

Line 4 is the only link line of Shanghai Metro; it has 26 stations in total. 17 stations in Line 4 formed transfer stations with other rail lines, so that make the whole Shanghai rail transit network to be an organic whole. It shares the route from Baoshan Road to Hongqiao Road with the current Line 3 and there are 9 stations (ground high shelf) in the route. The length of the share line is 11.8 km, using collinear operators transport organization scheme. Line 3 extended to north and south in the integration Station (Baoshan Road Station and Hongqiao Road Station) respectively, connecting the north and south of Metro rail transit backbone lines, playing the role of the diameter line from north to south.

Meanwhile, with the Shanghai rail network has been basically completed, its passenger traffic continues to rise, the daily average passenger trips reached 6.36 million and the highest daily average passenger flow reached 848 million or more. In the more, the proportion of transfer passenger traffic rose from 30% to 40%, which the passenger flow of the loop link increased more obvious, such as Zhongshan Park Station, Shanghai Railway Station, Zhenping Road Station, Yishan Road Station, and Honkou Football Stadium Station .They are the transfer station in Line 4 and become the concentrated points in the entire transfer network.

The merger operation of Line 3 and Line 4 saved a lot of investment. But it is at the expense of sacrifice transport capacity between each other, enhancing the complexity of the automatic control. And it is difficult to shorten the interval of train operation for the both two lines. It cannot meet passenger demand, but also bring a certain extent to of expansion and operational safety of the two lines.

2. The Situation of Building of the Loop Link around the World and the Role of the Loop Link

2.1 The Situation of Building of the Loop Link around the World

Currently, more than 120 cities have built urban rail transit system, and there are about 30 loop lines. Some cities including London, Madrid, Sydney and Tokyo and other cities have two loop lines, while Singapore has 3 loop lines. The average length of loop is 20 km, the shortest was 3km (Miami, Chicago), and the longest is 50 km (Seoul).

Although all rail transport loop lines have a ring on the line in physical form, but they form different ways of operation because of different wiring outside the loop lines. Typical loop can be divided into Separate operations, Dippers loop operation, Collinear loop operation and Combination loop Operations.
A typical city to use Collinear loop operating mode is Berlin and it can be shown in Figure 2-1.

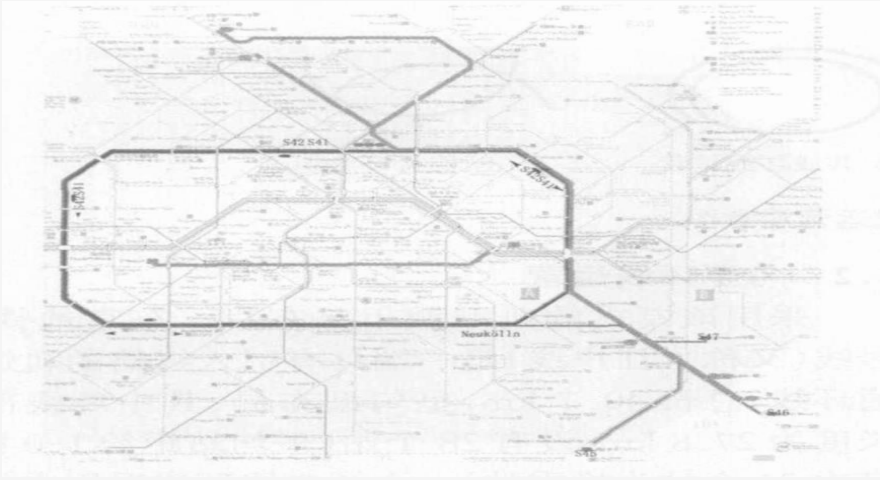

Figure 2-1 The **Diagram of Berlin Subway Loop Link**

If the traffic density is small and the line capacity is sufficient, you can operate in such a way. London Underground Circle Line and Regional Line, Hammersmith & City and Metropolitan line are also operating in such a way.

2.2 The Role of the Loop Line

The loop line has two main functions .The first one is the function of the circumferential contact, to assume the passengers' distribution in city and urban. The second is the capability of interception .It provides more passenger transfer path between suburban and inner city, reducing the transfer pressure in the central area. Loop line not only provides many passengers path choices in the inner and outside region, but also improves the transportation convenience of the circumferential edge of the central area. In addition, the loop line also creates favorable conditions for the transfer among different transport systems.

At present, the Line 4 is the only loop link in Shanghai Rail Transit System, so it can be called a ring rail line. Line 4 form the Shanghai Rail Transit System as a "申" word with Line 1, Line 2 together, to build the basic framework of Shanghai Metro.

According to the construction and operation experience of foreign rail transit, a loop line with length of 30 to 40 km has a greatest performance of the play in the whole rail transport system in rats. Therefore, the 33.7 km length of Shanghai Metro Line 4 can maximize the benefits of loop link. Loop Link diagram of Shanghai Metro Line 4 can be seen in Figure 2-2.

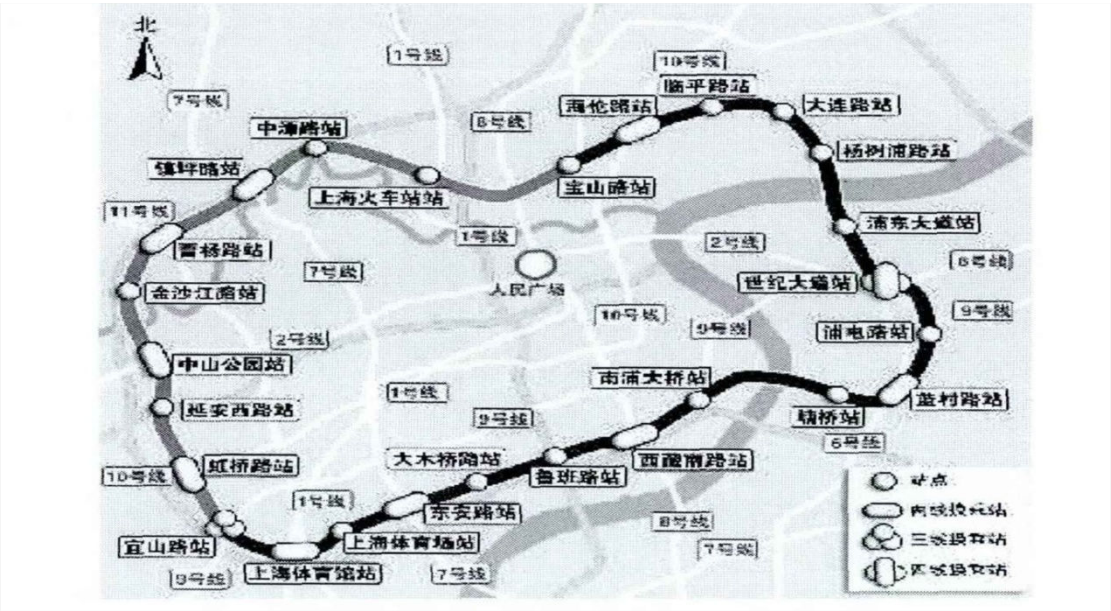

Figure 2-2 Loop Link Diagram of Shanghai Metro Line 4

3 The Necessity and Importance of the Transformation for Line3 and Line 4 Run Independently

Although operating on the collinear way is not uncommon in abroad organization of urban rail transit operators, but the collinear line is usually shorter, and the station have much wiring. Moreover, the typical loop line operations abroad program has a remarkable similarity that collinear segments have less traffic. There is no precedent to operate in collinear line with so much collinear stations, simple wiring and little headway as Line 3 and Line 4 of Shanghai Metro. Combined passenger traffic showed a rapid growth trend, the mode of existing collinear operation of Line 3 and Line 4 cannot meet the existing situation. So some necessary transformation must be made to change the situation.

3.1 Passenger Transport Capacity Cannot Meet Demand

With the new round of new lines have been built in network traffic, the network transfer passenger traffic will continue to rise, which makes the current mode of collinear operation of Line 3 and Line 4 is difficult to meet the existing operating conditions. The current mode of collinear operation must be transformed so that the Line 4 can be a separate ring.

As the present case of collinear operators of Line 3 and Line 4, Line 4 is subject to Line 3. Besides the headway of collinear line can reach about 2.5 minutes, the headway of the remaining sections can only be five minutes or so. Moreover, from the transfer traffic in cross section peak hour of Line 4 of view, the peak hour traffic between Helen Road Station and Baoshan Road Station has reached 21,000 people, and the load factor reach nearly 96 percent. (Seen in Table 3-1 and Table 3-2)

Table 3-1 The Average Daily Passenger Traffic (Shanghai South Railway Station – Yi Shan Road)

Average daily passenger flow in weekends	Inbound passenger traffic	Outbound passenger traffic
Shanghai South Railway Station	**41807**	**40521**
Shi Long Road	**12881**	**11233**
Long Cao Road	**19927**	**21176**
Cao Xi Road	**9925**	**9944**
Yi Shan Road	**12157**	**13516**

Table 3-2 The Situation Maximum Cross Traffic (Shanghai South Railway Station – Yi Shan Road)

maximum cross	Morning peak			Evening peak		
	Period	Intervals	cross traffic	Period	Intervals	cross traffic
Upstream	8:00~9:00	Cao Xi ~ Yi Shan	15715	18:00~19:00	Cao Xi ~ Yi Shan	7518
Downstream	8:00~9:00	Yi Shan ~ Cao Xi	7379	18:00~19:00	Yi Shan ~ Cao Xi	10015

3.2 Inevitable Requirement of Geographical Patterns in Shanghai

In terms of geographical patterns of the entire city of Shanghai, it presents a ring-shaped distribution pattern including outer ring, the ring, inner ring. There is a separate rail networks which constitutes the transfer points with other lines. It would greatly enhance convenience of the entire rail network operator, but also closely matching with the geographical layout of Shanghai.

4. Suggestions and Measures

4.1 Problems Caused By Transformation of Line 3 and Line 4

We recommend that the Line 3 should be divided into two sections. The northern section extends to Shanghai Railway Station, and the southern section extends from Yi Shan Road Station to Shanghai South Railway Station. So that Line 4 can be independently operated. Since operating independently, the Line 4 can play a greater performance capability of the transfer loop to enhance Link transport capacity (e g: If the running intervals reach 2.5 minutes, the transport capacity can reach 44,000 people in the peak hours), this can fundamentally solve the issues that improve transfer convenient in the entire network, but it also brings some problems that should be solved.

4.1.1 Problems for Parking

Currently, the greatest potential parking capacity can only stop 30 trains at the Pu Tong parking of Line 4.And it is impossible to re-building a new parking around the Line 4. If the trains of Line 4 stop to Baoshan parking which is at the northern section of Line 3, facility capacity would be greatly affected. And transport capacity would be greatly wasted; energy consumption would be increased considerably.

4.1.2 The Transfer Problems for Passengers

After Line 4 operates independently, a small portion of passengers who need to transfer in Line 3 and Line 4 would need to increase the number of transfer.

The passengers who are at the stations that are at the south of Yi Shan Road Station in line3 want to go to other stations must transfer, especially to the station that is at the north of Bao Shan Road Station need to transfer twice. Meanwhile, the passengers who are at the stations that are at the north of Ban Shan Road Station in line3 want to go to other stations must transfer, especially to the station that is at the south of Yi Shan Road Station need to transfer twice. It is also true that a passenger who is at the loop line want to go to the north and south stations in the Line 3 must transfer. This will be inconvenience for passengers with increase the passengers' travel time.

4.1.3 The Southern Section of the Line is Too Short

The southern section of the Line 3 from Shanghai South Railway Station to Yi Shan Road is too short. There are only five stations across the board and the length is only about 5.5 km. If the Line 3 runs independently, it would be need to increase investment in trains and spare car, resulting in wasting of cost and energy.

4.2 Improvement Measures

4.2.1 In View of Parking Problems of the Line 4

While the Line 3 extending to the Wu Jing, we can establish a parking in the Wu Jing for the Line 3. So that it can lend Shi Long Road parking of Line 3 to Line 4 (Shi Long Road parking has 22 parking spaces. It can meet the basic needs).

4.2.2 In View of the Transfer Problems for Passengers

The organizers of construction and operation of Shanghai rail transit, should strengthen the operational organization, carefully designed transfer station, especially the two collinear integration stations --Baoshan and Hongqiao Road Station. The present and future of the whole network traffic and other aspects of the situation need to be fully took into account to design the layout and structure of the transfer station. Seriously consider the convenience and safety of passengers, designing and building the transfer station, to the maximum extent to reduce impact on passengers in loop transformation.

4.2.3 In View of the Situation That the Southern Section of the Line is Too Short

In view of the situation that the southern section of the line is too short,here we propose two reform proposals. The frist proposal is that the southern section of Line 3 extends from Shanghai Railway Station to the direction of extension of the Wu Jing, or change the direction of walking Wu Jing to substitute the southern section of line 15. The another proposal is that the southern section of Line 3 bifurcates from Shilong Road, extends directly to Wu Jing areas in order to solve the Wu Jing area residents travel problems, promotes regional economic development of Wu Jing. At the same time, Line 3 should establish a parking in Wu Jing. Shilong Road car park will lend to Line 4 for parking (Shi Long Road parking has 22 parking spaces. It can meet the basic needs). The original section from Shilong Road to Shanghai South Railway Station used Y operating mode with five minutes of the operation interval at morning and evening peak hours. After the transformation, it can be achieved for at least 2.5 minutes operating interval operations map, fully meet passenger needs.

5 Conclusions

With the rapid development in recent years, Shanghai Rail Transit has been largely achieved rail network operation, network efficiency has become increasingly evident. With increasing of network traffic, Shanghai Rail Transit as a key role in urban transport has become increasingly prominent. But the collinear running of Line 3 and Line 4 makes the trains are difficult to shorten the grid spacing, which bring a certain impact of expansion and operational safety of the two Lines. To this end, the transformation of 3,4 line has been very urgent. We need to improve the transformation of Line 3 and Line 4 grasping science, long-term, holistic thinking to ensure it play an active process and important role in rail transportation network of Shanghai.

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References

Cai Wei. The analysis of key technologies of Shanghai Rail Transit Line 3 reconstruction project [J]. China Municipal Engineering, 2011,06:58 -59 +63 +85.

Cai Wei. The research of Shanghai Rail Transit Line 3 reconstruction scheme[J]. Urban Mass Transit, 2012,01:97 -100.

Yu Xuan Ping, Zhu Weijie. The overview Shanghai Rail Transit Line restoration project [A]. Shanghai Society of Civil Engineering, Shanghai Tunnel Engineering Co., Ltd.. Underground construction and risk prevention technologies - 2007 Third Shanghai International Tunnel Engineering Symposium [C]. Shanghai Society of Civil Engineering, Shanghai tunnel Engineering Co., Ltd., 2007:10.

Xuze Cheng, Xia-Fei Ye, Bao-Nan Gu. Shanghai Metro Line 3 and Line 4 operating model [J]. Urban Mass Transit,2004,02:10-12.

He Jing, Zhu Haiyan, Song Min. The analysis of Line 3 and Line 4 collinear operationa of Shanghai Metro [J]. Urban Mass Transit,2008,04:48 -51 +55.