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Research on Rail Transit Network System and its Connection Model in the Metropolitan Area

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Abstract

In order to plan rail transit network in metropolitan area, this paper firstly analyzes metropolitan space structure and features of land layout. It then proposes an effective rail transit network system in Chinese metropolitan area and provides technical suggestions based on the available experience with rail transit network systems and corresponding connection models in foreign metropolitan areas. This study considers the land layout, passenger flow distribution and the corridor characteristics. It also employs Yangzhou as an example. The article suggests that the suburban transit with ribbon land layout in the metropolitan area is not suitable to directly enter the city centre and station is needed in the periphery of the city centre to connect urban rail transit network system.

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1. Introduction

A metropolis is a high-integration city region with non-agricultural industries, concentrated population, economic and social activity. It's developed from the large-scale and highly functional urbanization, and gradually formed in the periphery of city. In addition to the scale, space facilities, landscape quality, cultural characteristics and a high degree of urbanization is consistent with its main city.

A metropolitan area is an urban populous region with its surrounding territory that is linked to the urban core by socio-economical activity. A metropolitan area is also known as a commuter belt or a labor market area. Thus, metropolitanization is an inevitable and regular phenomenon with the development of urbanization and has arisen throughout all the developed countries. In 1910, the American put forward the concept of metropolitan area for the first time. Before that, the British had called London as the Metropolis of UK, which was given the meaning

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of ‘modern metropolitan’ firstly. In 1949, the regional unit of city which had statistical standards and was established to survey the national conditions was named as Standard Metropolitan Area (SMA). And it was renamed as Metropolitan Statistical Area (MSA) in 1980.

Generally speaking, central city, fringe region and countryside constitute a mature metropolitan, in which the population distribution takes on the circle layered pattern. The continuous distribute of dense population is within the radius of 20km where have the highest urbanization and the most centralized urban functions, while the population density out of the 20km circle decreases rapidly. However, according to the high commuter rate, the area with the high social and economic integration will extend to the 50km circle. Take Tokyo, London and Paris for instance, the metropolitan area covers the area of 10000 square kilometers with the distance of 50-60km from the central area. Their central area covers 600-1000 square kilometers and the radius is about 15-20km.

The formation of city community space in the metropolitan area needs the support of perfect regional or urban transport system, especially the comprehensive transport system characterized by high-capacity rapid rail transit system. Nowadays, the problems about energy and environment are becoming more and more serious. Under these circumstances, rail transit, an intensive public transport, has far more superiorities. Different rail transit has different technical characters and serves transport demands of different areas. As we know, traditional urban rail transit including subway, light rail train mainly serves the central area of metropolitan with large transport, short distance and slow speed between two stations; while high-speed railway, inter-city railway and suburban transit have been used in a wide range of the metropolitan area.

The building of a mature metropolitan area is on the basis of high integration of rail transit. In this process, different rail transit deployment is applied and different railway terminals are wirelessly linked according to the relationship among central area, suburb and countryside. In recent ten years, high-speed railway, inter-city railway and urban railway in China have grown rapidly. However, a lack of mature metropolitan area and the understanding to rail transit in metropolitan area, the planning, construction and management of regional and urban rail are short of effective conjunction and coordination, so the rail transit system cannot be displayed it's all functions. In view of the circle-layered and different features of transport needs in the metropolitan area, the author firstly analyzes the applicable scope on types of rail transit, transport capacity, vehicle type, line feature, designed vehicle speed, running space, environment impact, economic indicator and technology compatibility, then puts forward a proposal that the transport network system and connection model in the Chinese metropolitan area, which has important significant to fully play the transport capacity of rail transit and improve the sustainable development of transport system in the metropolitan area.

2. Rail Transit Network System in the Metropolitan Area

2.1. Development experience of world cities

Developed metropolises in foreign countries have rich rail transit system with clear function division. The traditional urban rail transit mainly serves the central area such as subway and light railway. Apart from this central area, the rest area of metropolitan is served by such corresponding suburban rail transit system as RER and suburban transit in France, state-operated railway JR and private railway in Japan, Regional Express and S-BAHN in German, commuter rail service in America and so on. The long distance journey in metropolitan area needs the support of regional rail network through the homeland.

The Paris subway system mainly serves its central area, part lines of which extend to the outside its central area. The central area of Paris covers about 105 square kilometers and it has 14 railway lines with a total length of 210 kilometers and its average length of 15 kilometers. The subway system serves the space within the radius of 10 kilometers. RER system and suburban transit extends the commuter scope to the radius of 60 kilometers in the Paris metropolitan area. The metropolitan area of Paris is formed by the city of Paris, three surrounding provinces and four provinces in the outer suburbs of Paris, among which the city of Paris and its three

surrounding provinces make up of the central area, covering an area of 762 square kilometers. Besides, 23% of the central city journey comes from the four provinces in the outer suburbs of Paris. RER system mainly serves Paris' agglomeration within the radius of 30 kilometers.

Compared to developed countries, the urbanization and rail transit construction in China starts later. However, the metropolitan area around several metropolises is growing fast. And the development of modern metropolitan area is emphasized in the new city planning. The planning scope of rail transit network is extended correspondingly. Learning from the successful experiences of international metropolitan area planning, the relatively complete rail transit network system has formed. For example, Beijing's rail transit is similar to London and Moscow, its rail network is made up of suburban transit which is connected with the railway stations at the edge of central area, subway of central area and light railway; While Shanghai, Guangzhou, Wuhan, Nanjing's rail transit is similar to Paris and Tokyo, and their rail transit is formed by suburban transit, inter-city rapid rail transit, subway of central area and light railway, among which inter-city rapid rail transit goes through the central area of the city and connects the city and the suburbs.

The features of rail transit network system and its services in the international developed metropolitan area can be summed up as follow:

- Urban rail transit system including subway, light railway, monorail and so on often serves the central area with high urbanization. Its service covers within the radius of 15-20 kilometers in light of city space layout and land features.
- Suburban transit often serves the new district outside the city and the commuter between the new district and central area, within the scope of 50 kilometers.
- Regional railway often serves the national or inter-city transport. According to city land layout, some regional railway between cities also serves the long distance journey among the inter groups of metropolitan area.

2.2. Rail transit network system in Chinese metropolitan area

At present, the basic district unit of Chinese city statistics and research contains the central area and a wider range of the city. The rail transit in the city has two systems, the regional railway system serving the city commuting to the outside with national railway, inter-city railway and urban transit system serving the inhabitants' commuting.

Through contrasting the corresponding relation of city rail transit network between China and other countries, daily commuting is limited into the central area for the real mature metropolitan area has not formed in China. Therefore, the passenger requirement of suburban transit transport has not formed, which is also a vacancy in the railway network system. According to the above international experience, metropolitan area usually has developed suburban transit or commuter rail to connect the central area and its countryside, in which the distance among stations and the speed is about the distance between the urban railway and inter-city railway, having certain passenger flow. Furthermore, with the development of metropolitanization, the commuting percentage which the inhabitants living outside the central area go to the central area will gradually increase and the need of suburban transit construction is becoming more and more intensive. Nowadays, Beijing, Shanghai, Nanjing have formulated corresponding strategies in their planning, for example, Beijing has drawn up 6 railway lines with a total length of 430 kilometers, which are operated by Beijing Railway Bureau; Nanjing has drawn up 6 rapid suburban transit lines to serve the commuting and business journey between the central area and its nearby regions.

To sum up, the railway transport network system of metropolitan area can be divided into regional railway and urban railway, in which regional railway serves the passenger going to the outside the city, urban railway serves the inhabitants commuting within metropolitan area. In addition, according to service area, regional railway system can be divided into national railway system and inter-city railway system; urban railway can be divided

into suburban transit system and city transit system. Here is a chart about railway transport network system and service is:

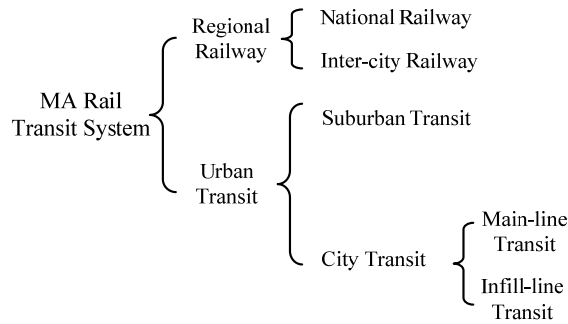


Fig.1. Railway transport network system of metropolitan area

It is not necessary to explain about the functions and features of regional railway system, for it maintains the same technical standard as the railway system in China. The suburban transit system in the urban transit system serves the long distance journey mainly the commuting between the suburb and the central area. It is characterized by the long distance between stations, high speed which is over 45 km/h and wide service. The city transit system serves the journey in the high urbanization area within the radius of 20km. It is characterized by the large transport, short distance between stations and slow speed and can be classified into the main-line transit in districts and infill-line transit. The specific functions of each transit line can be seen as table 1.

Table 1. Suggested railway transport system and its functioned features in Chinese metropolitan area

| Layers | Region Railway | | Urban Transit | | |
|-----------------------------------|---|---|--|--|---|
| | National Railway | Inter-city Railway | Suburban Transit System | City Transit System | |
| | | | | Main-line Transit | Infill-line Transit |
| Service area | Long-distance Communication Of Nation Level | 50-300Km Close Contact Radius or longer | Contact between countryside around central city and central area | High Strength and Density passenger corridor of central city | Partial inferior passenger corridor of central city |
| Service radius | >200km | 50-300km | 20-100km | About 20km | Below 20km |
| Average distance between stations | 50km | 10-20km | 2-5km | 0.8-2km | 0.8-1.5km |
| Maximum speed | 350km/h | 250km/h | 120-160km/h | 80-100km/h | 70-80km/h |
| Journey Speed | 80-350km/h | 160-250km/h | 45-60km | 35-40km | 25-35km |

3. Rail Transit Network System and its Connection Model in Metropolitan Area

3.1. Connection between region railway system and urban transit system

Apart from the network, whether different rail transit network system can be fully used depends on the railway lines and network connection model. The connection between regional railway and urban railway can be achieved through comprehensive city passenger terminals, which are the transposition and transformation in different passenger transport networks and the core to realize 'no transfer' and integrated transport. The comprehensive passenger terminals can be classified and graded in accordance with location conditions, service area and passenger capacity. For example, Shanghai classifies its comprehensive passenger terminals into type A, type B, type C and type D according to their sizes and transport functions. Type A relying on a number of large communication facilities, serves middle and long distance journey among cities and regions and it is also key to transfer the connection of passenger flow by regional railways and city railways.

3.2. Connection between suburban transits and city transit

The connection models of suburban transit system and city transit are different from each other because they have experienced different development of urbanization. In general, three kinds can be summed up: building the terminal at the edge of central area, building the terminal at the central area and building the railway line throughout the central area.

Like London, Tokyo and Osaka in their early forms, there are several railway terminals at the edge of the central area, which are also the starting points of suburban transit system, extend to the periphery of metropolitan area and improve the communication between suburbanites and the city centre. Each railway station is connected by the convenient city transit lines for the transport transfer. For example, the city transit lines of London have connected more than six railway stations. In the cities like New York and Moscow with a big city centre more than 1000 km, the subway and suburban transit provide the service to the nearby suburbs of the city and the outer suburbs depending on the suburban transit system which is linked to the city centre. The Grand Central Terminal in New York and the Union Station in Chicago and Washington are both located in the heartland of the city and serve the passenger flow of commuting out of the city centre. In European cities, like Paris, Berlin and Munich, and Asian cities, like Tokyo and Osaka, rapid region rail transit system including RER in Paris, S-Bahn in German, private railway in Japan, JR and straight-through subway runs through the city centre and provides the service to the metropolitan area.

Different connection models between suburban transit and city transit have different effects on the city development and its transport service. Suburban transit, which establishes terminals in the city centre or runs through the city centre, belongs to the extension model. This kind of model helps to improve the function assemblage of the central area and reduce the transfer. The suburban transit constructs terminals outside the central area where the land can be greatly developed. This method can improve the function of the outside area and relieve the transport congestion of the central area on the basis of the anti-magnetic force formed by comprehensive transport terminals.

In recent years, with the development of metropolitan integration and the improvement of rail transit operation, it is necessary for suburban transit to extend to the city centre. However, a reasonable connection model between suburban transit and city transit referring to the urban morphology urban spatial structure and land arrangement has to be designed. Different city, like the shape of group, strap, star and so on, the function of region railway and the balance between the length of urban railway that could extend to the outside and the operation benefit have great influence on the connection model.

4. Case analysis

Lying just on the north of the Yangtze River, situated in the middle part of the eastern coastal economic belt, Yangzhou is one of the most important cities on the Grand Canal and is a delightful place to visit, retaining to some extent the feeling of its rich cultural and historical traditions. According to the overall planning, the strap and group shaped metropolitan area will be divided by Yangzhou government, of which the construction land using covers an area of 995 km with about 3.5 million to 4 million people.

4.1. Rail transit network system

In general, the metropolitan areas with different morphology and scale have similar rail transit network system, such as Hiroshima in Japan, its subway serves the central area with the radius of 15-20km; and the private railway servers the nearby suburbs; in addition, the Shinkansen and JR serve the communication between the central area and outside. Therefore, except for Hironshima, the city development experience of Tokyo, London, Hamburg, Osaka can have positive effect on constructing the rail transit network system of Yangzhou.

Considering the feature of the urban spatial structure and the scope of inhabitants commute, the rail transit network system of Yangzhou can be divided into two levels in conformity with the suggestion mentioned above, namely region railway system and urban transit system. The region railway system is composed of ‘two latitudes, two longitudes’, in which two latitudes mean the Nanjing-Qidong Railway and Shanghai-Taizhou-Nanjing Railway respectively; two longitudes mean Huan’an-Yangzhou-Zhenjiang Railway and Yangzhou-Maanshan Railway respectively.

The urban transit system is composed of suburban transit and city transit. Around the CBD on the east of river, the central area of Yangzhou, extending to the east and south along the Wenchang Road, has developed one superior plate and three inferior plates, which covers an area within the radius of 20km. The center is also the place with high urbanization and provides the transport service through the high density city transit network. The plates flanked on the central area are located in the 40-50km from the central area. Thus, the suburban transit can satisfy the rapid communication between the plates on the flanks and the central area.

As for the function and characteristics, city transit mainly serves the central area. And the transit system with high strength and density passageways closely connects the CBD, the center of each plate and each transport hub ensuring the commuting of high urbanization area. This kind of rail system is characterized by large transport, short distance with 0.8-1.5km between two stations, slow speed with 35km/h at the average speed and 35-40km/h at the operation speed and 80-100km/h at the maximum speed. The suburban transit serves the middle and long distance journey between the flanked plates and the central area which is characterized by long distance between two stations with 2-3km, fast speed with 45-60km/h at the operation speed and 100-120km/h at the maximum speed.

4.2. Connection model of transit network system

The connection of regional railway and urban transit in Yangzhou depends on one superior and three inferior transport hubs. Especially, the layout of city transit gives the strong support to Yangzhou east railway station. According to the features of the communication and corridor distribution, the connection model of strap shaped metropolis between suburban transit and city transit is different from group shaped metropolis. As for Yangzhou, a strap shaped metropolis, transport terminals outside the central area should be constructed to connect the city transit instead of building the suburban transit through the central area. There are several reasons.

- The communication between the flanked plates and the central area is seldom. Above all, without frequent communication, the distance between Yizheng plate and Jiangdu plate is more than 30km. Then, because

Yizheng plate adjoins Nanjing which is the capital of Jiangsu province, some inhabitants choose to take a journey to Nanjing. Moreover, as a county city, Yizheng is different from the other traditional new towns or districts for historical reasons. This plate has high self-balance and its inter-city commuting is higher than other new towns or districts.

- The regional railway shares responsibility for the long distance journey. Conformed to the strap shaped city planning, the Yizheng plate, central area and Jiangdu plate are connected by the Nanjing-Qidong Railway and Shanghai-Taizhou-Nanjing Railway. It is the strap shaped land arrangement that the overlay area of regional railway terminals is greatly expanded. The national railway and regional railway have the advantages of high efficiency and punctuality on serving the communication of different plates. Therefore, the two transit system will share responsibility for the frequent commuting between the flanked plates and the central area.
- The city with the shape of strap has limited resources on the longitudinal corridor. Compared with the radial group shaped cities, the resource of latitudinal corridor in the strip shaped city is limited as well. The model that the suburban transit goes through the central area directly will seize the limited corridor resource. Meanwhile, the collinear operation model will reduce the operation efficiency of rail transit network in the central area.

5. Conclusion

The gradual formation and development of metropolis plays a great role in the process of urbanization in China and is also in conforming to the urbanization development in the world. As one of the main functional factors in the spatial forms of new cities, the railway transport system is confronting the challenge in lots of respects, from pattern to operation. The article firstly studies the rail transit networks of other major metropolitan area. And then proposes rail transit network system and connection model in Chinese metropolitan by analyzing the space structure and layout of land. It puts forward the suggestion that the connection model between suburban transit and city transit in the strap shaped city like Yangzhou. The results of study have certain reference significance for the layout and planning of rail transit network system in Chinese metropolises.

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