Citation: CAI Runlin. Service-Oriented Development for Intercity Passenger Transportation Within Yangtze River Delta [J], Urban Transport of China, 2019 (01): 19–28, 35.

Service-Oriented Development for Intercity Passenger Transportation Within Yangtze River Delta

CAI Runlin

Shanghai Branch, China Academy of Urban Planning & Design, Shanghai 200335, China

Abstract: The integral development of Yangtze River Delta has become a national strategy, and the intercity transportation system is critical to the spatial structure of urban clusters. Based on the international experiences in intercity transportation development for clusters of cities, this paper analyses the demand characteristics of intercity travel at different spatial land use development levels, and makes adaptability analysis on different modes of intercity transportation to identify existing problems and challenges. The paper puts forward a service-oriented intercity passenger transportation development, and emphasizes the leading role of generalized rail transit along with its integral development, as well as the different requirements from different groups of travelers. The paper stresses that it is important from systematic perspective to pay close attention to the functional requirement modes in different spatial scales, especially the key points of constructing intercity transportation systems in large-scale cross regional areas, metropolitan circles, dense urban areas, and adjacent urban areas. From user perspective, the innovation on the intercity hub is required and two types of hub layouts are suggested to strengthen the junction of hubs and land use. **DOI:** 10.13813/j.cn11-5141/u.2019.0104-en

Keywords: intercity transportation; regional transportation hubs; metropolitan areas; Yangtze River Delta agglomeration

0 Introduction

Recently, the integrated development of the Yangtze River Delta has become a national strategy, and the path and measures to achieve higher-quality integrated development have become the regional focus. The total and frequency of intercity transportation demand in the Yangtze River Delta has grown rapidly [1] due to the increasing social and economic level of urban agglomerations, the closer industrial cooperation among cities and the continuous improvement of regional transportation infrastructure. At the same time, the intercity transportation system of the Yangtze River Delta is still facing many inconveniences and problems. The traditional organization mode of external transportation can hardly meet intercity commuters' requirements on regularity, high frequency and high timeliness. A high-quality intercity transportation system is not only an important support for constructing a world-level urban agglomeration in the Yangtze River Delta, but also an urgent need to better serve intercity commuters. It is thus necessary to break through the organizational scope of urban external transportation and take into consideration the whole trip chain and crucial links throughout the intercity travel process to meet commuters' real demands.

Previous studies on intercity passenger transportation in urban agglomerations can be classified into two types. The first type focuses on the spatial organization of cities (agglomerations) under the influence of intercity transportation. Based on the passenger flow data of high-speed rails and long-distance buses, Literature [2] analyzed the correlation intensity between Shanghai and its southern & northern wings in the Yangtze River Delta and pointed out the balanced evolution trend of the regional network. Literature [3] studied the site selection for high-speed rails and intercity hubs, and proposed that the layout of intercity transportation should pay more attention to the city's functional value and the reorganization of its functional structure. Literature [4] conducted a similar study on the characteristics and spatial pattern of intercity passengers in the Pearl River Delta. The second type of studies focuses on the optimization of the intercity passenger transportation system in urban agglomerations, especially the intercity rail transit system. Literature [5] analyzed the matching relationship between different spatial scales and multi-level rail transit networks in the Yangtze River Delta, and proposed ideas to optimize the multi-level rail transit system centered on Shanghai from various perspectives such as time constraint and facility guidance.

Received: 2018-12-23
Supported by: Science and Technology Innovation Fund Project of the Year 2017, China Academy of Urban Planning & Design (CAUPD)
First author: CAI Runlin (1980–), male, from Weihai, Shandong Province, PhD, professor-level senior engineer, director of the Shanghai transportation branch of CAUPD, is mainly engaged in the research on transportation development strategy, transportation system planning and rail transit planning. E-mail: cairunlin@foxmail.com

Literature [6] analyzed the spatial characteristics of trips in urban agglomerations and put forward the functional hierarchy, service functions, technical characteristics and connection requirements of the rail transit system in urban agglomerations. Literature [7] summarized the evolution trend of the characteristics of the intercity passenger flow between Guangzhou and Foshan, Guangzhou Province, China and proposed strategies to connect rail transit under the background of urban integration.

The limitation of existing studies lies in the deficiency of an overall description of the interaction between urban agglomeration space and transportation. In particular, studies are lacking on the differences in the transportation characteristics of different space hierarchies and typical regions. In addition, inadequate attention has been paid to the trend adaptability and key links (such as the layout mode of hubs) of intercity transportation, which leads to problems in the comprehensiveness of existing studies. This paper attempts to outline the interaction between the spatial hierarchy and transportation modes in the urban agglomeration of the Yangtze River Delta as comprehensive as possible, based on which an overall development mode is proposed for intercity transportation in the Yangtze River Delta.

1 Case studies of international urban agglomerations

1.1 Three development patterns

Based on the cases of developed urban agglomerations in foreign countries, the organization patterns of intercity passenger transportation can be classified into three categories according to the dominate transportation mode.

The first category is dominated by railways and rail transit, represented by the Tokyo metropolitan area in Japan (see Figure 1) and the Paris metropolitan area in France. This pattern is generally applicable to metropolitan areas with single centers and radial networks. It presents clear spatial circles in its spatial structure, and a multi-level rail transportation system is matched to different spatial circles. The second category is dominated by highways, represented by the urban agglomerations in the northeastern U.S. A multi-level road system is formed within the urban agglomerations, which consists of interstate freeways, national highways, state highways and county highways, and serves different spatial circles. The urban agglomeration space expands along trunk roads. The third category is dominated by mixed railways and highways, represented by the urban agglomeration in the Great London Area. The circle-shaped metropolitan area consists of the inner London and the outer London, and has a powerful urban center. Its population and employment density decrease outwardly from the core area. Regarding the mode shares of intercity passenger transportation, private cars and public transit play an equal role.

1.2 Experiences

The formation of the intercity transportation pattern in an urban agglomeration is closely related to the spatial form of the metropolitan area, transportation facilities and policy guidance. The U.S. investment on the construction of highway facilities after the 1950s and the process of urban suburbanization made the sprawl of urban space and the travel mode of cars promote each other. Along with their development processes, Tokyo and London constructed railways and a multi-level rail transportation system, and regulated private cars in the central urban area. These efforts meet the commuting and daily travel needs at different spatial layers. On the other hand, it should be realized that even in urban agglomerations with a high level of individual motorization, such as the northeastern United States, there are regions that are highly dependent on commuting railways and urban rail transit, such as the Great New York Metropolitan Area.

Compared with the international urban agglomerations, the urban agglomerations in the Yangtze River Delta cover a wider territory and have a higher population and employment density. There are sub-regions with differentiated development, such as metropolitan circles, dense urban areas and areas adjacent to large cities, which require the support of a more efficient and diversified transportation system.

2 Intercity travel characteristics in the Yangtze River Delta

The intercity passenger transportation in the Yangtze River Delta shows significant differences at spatial levels (see Figure 2). A cross-provincial metropolitan circle has been formed with Shanghai as the center, which has close intercity connections with Suzhou, Wuxi, Nantong and Jiaxing. Provincial capital metropolitan areas have been formed by three capital cities, i.e., Nanjing, Hangzhou and Hefei, and surrounding regions, which have shown clear characteristics of circular layers. In addition, two dense urban areas are formed in the Suzhou–Wuxi–Changzhou region and the Shanghai–Jiaxing–Hangzhou region based on regional transportation corridors, with frequent contact among secondary cities and towns. Similarly, the Jinhua–Yiwu Integrated Development Zone and the Ningbo–Zhoushan Integrated Development Zone have increasingly enhanced internal industrial and social connections as a result of regional industrial cooperation and division of labor. Regarding the spatial scale, the major central cities in the Yangtze River Delta are about 150 km–300 km apart; neighboring prefecture-level cities are about 40–100 km apart; and adjacent county-level cities are about 20 km–50 km apart. According to the spatial hierarchy and scale, the intercity travel in the Yangtz River Delta can be classified into four types: large-scale trans-regional intercity travel, intercity travel in metropolitan circles, intercity travel in dense urban areas and intercity travel in adjacent urban

areas. In this section, the demand characteristics of these four travel types are analyzed respectively.

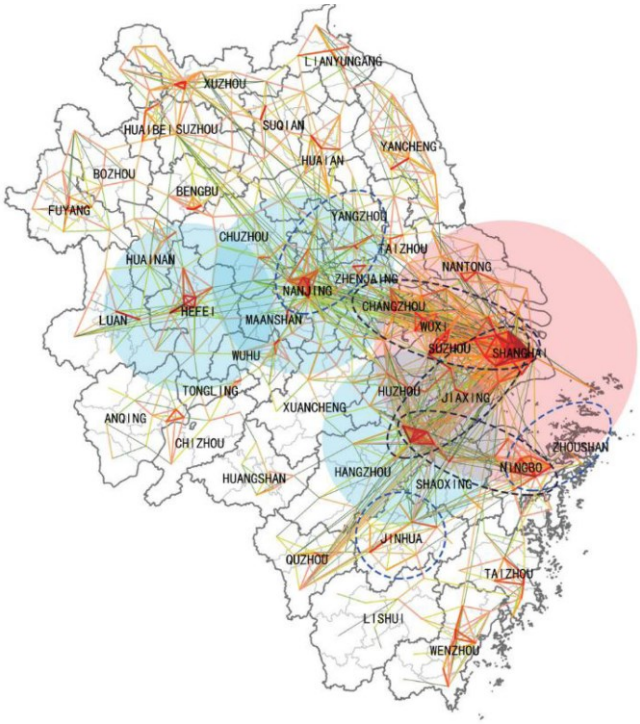


Figure 1 Intercity connections in Yangtze River Delta

2.1 Large-scale trans-regional intercity travel

The connection channels between the major central cities in the Yangtze River Delta are more than 150 km long and they overlap with the primary external corridors in the region. The prominent characteristics of such large-scale trans-regional intercity travel are "large volume, high demand and fast growth". As each central city has formed a metropolitan circle or a dense urban area around it, the scale of the total population is over ten million. For example, the total population in Shanghai's urban area exceeds 20 million; the population of the Hangzhou metropolitan circle exceeds 25 million; the population of the Nanjing metropolitan circle exceeds 30 million; and the population of the Suzhou, Wuxi and Changzhou areas also exceeds 20 million. As a result, the demand in the cross-regional intercity passenger corridors grows rapidly. However, the primary regional transportation corridors are concentrated and limited, leading to prominent contradictions between the supply and demand of corridor transportation. According to relevant research statistics, the total passenger flow of intercity railways along Shanghai and Ningbo grew by over 50% between 2011 and 2013 [8]; and the total railway passenger flow from Jinhua to the major central cities in the Yangtze River Delta grew by 21% in 2016. In this context, the traditional Shanghai–Ningbo Corridor and Shanghai–Hangzhou Corridor have reached saturation point; in addition, the emerging Ningbo–Hangzhou Corridor and Tongzhou–Suzhou–Jiaxing Corridor also see prominent supply-demand contradictions due to the rapid demand growth.

More importantly, the enterprise relevance degrees between metropolitan circles, especially between central cities, are constantly enhanced, which places increasingly higher requirements on the timeliness of trans-regional travel. It is reflected by the increasingly flourishing demand for intercity business travel and the growing reliance on railways (see Figure 2). The high-speed railway shows its advantage. With Shanghai as an example, its external railway passenger flow has increased by 12.5% since 2012, and the share of railways among external passenger travel reached 52.9% in 2017 [8].

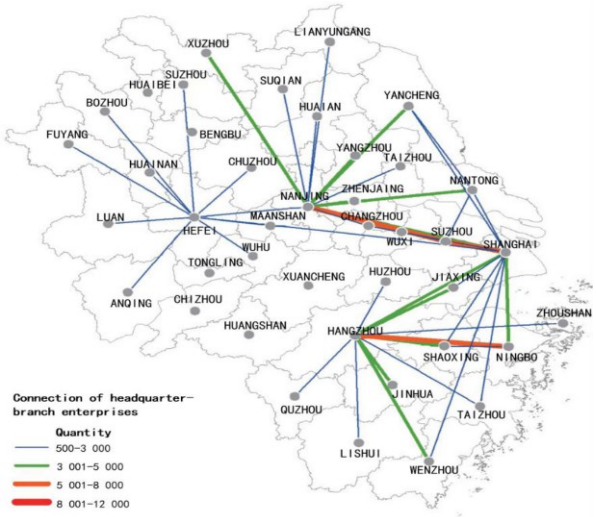
2.2 Intercity travel in metropolitan circles

Several metropolitan circles have been formed with central cities as the core, including Shanghai, Hangzhou, Nanjing and Hefei. The intercity travel in these circles shows obvious circular characteristics and closely connected boundary effects (see Figure 3). The radius of the close circle of the Hangzhou metropolitan circle is 60 km, which covers Hangzhou and surrounding cities such as Haining, Shaoxing, Tongxiang, Deqing, Anji and Zhuji. The radius of the close circle of the Nanjing metropolitan circle is 40 km–70 km, which covers Nanjing and surrounding cities such as Yangzhou's urban district, Jurong, Chuzhou's urban district, Ma'anshan urban district, Lai'an, Tianchang, Bowang and Hexian. The radius of the close circle of the Hefei metropolitan circle is 50 km–80 km, which covers Hefei and surrounding cities such as Shucheng, Jin'an, Shouxian, Hanshan, Wuwei and Dingyuan.

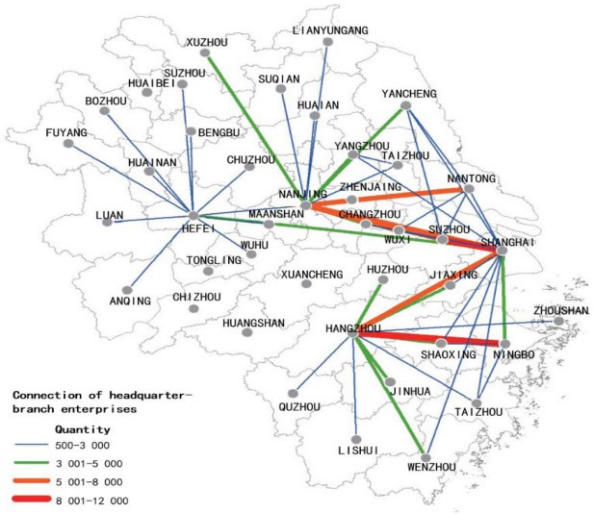
Regarding the characteristics of transportation demand, business commuting trips account for a high proportion of passenger trips and present the characteristics of high frequency and regularity. For example, business, public affairs and commuting trips account for 40% of railway trips between Shanghai and Suzhou, and 40% of travelers make a round trip for more than four times a month [9]. On the other hand, such trips show an obvious radial characteristic. Most destinations are located in the central business districts or primary functional districts of central cities, so these trips highly depend on radial public transportation (particularly rail transit). According to a study on Hangzhou, the radial transportation demand in the Hangzhou metropolitan circle will be close to the transportation volume within the internal groups of the city by 2030. Restricted by the transportation bottlenecks of the main city, more than 70% of passenger flow between the peripheral of the metropolitan circle and the main city should be taken by public transportation.

2.3 Intercity travel in dense urban areas

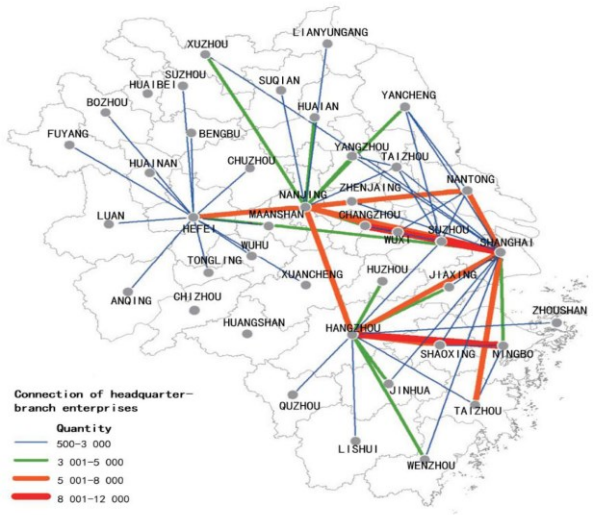
The dense urban area is a typical area in the Yangtze River Delta. It has a high level of social and economic development. In particular, the economy is strong at the county level with close industrial, economic and social connections, which are not obstructed by administrative boundaries. In such areas, urban space shows an obvious clustering layout



a Year 2005



b Year 2010

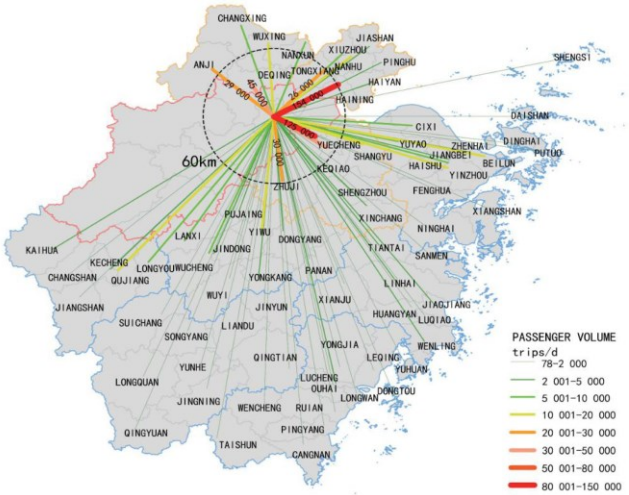


c Year 2015

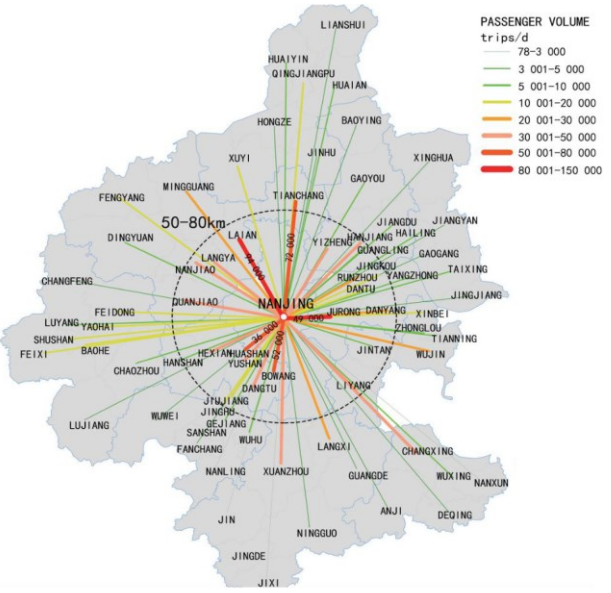
Figure 2 Trend of enterprises relevance degree in Yangtze River Delta (2005–2015)

pattern with weak urban centers, and industries and space distribute continuously along transportation corridors. Hence, the demand of intercity travel within dense urban areas is featured with being network-based, integrated and diversified.

With the most typical Jiangsu–Wuxi–Changzhou region as an example, its spatial distribution of intercity travel is characterized by a decentralized and balanced network layout (see Figure 4). The radial connection intensities of the urban areas of Suzhou, Wuxi and Changzhou and the peripheral areas are very different, and the transportation connections between neighboring counties are strong. For instance, the transportation demand among Changzhou, Jiangyin and Zhangjiagang is high. Hence, the overall intercity transportation layout in such regions is not in a center–peripheral form, but rather in a network form woven by several corridors.

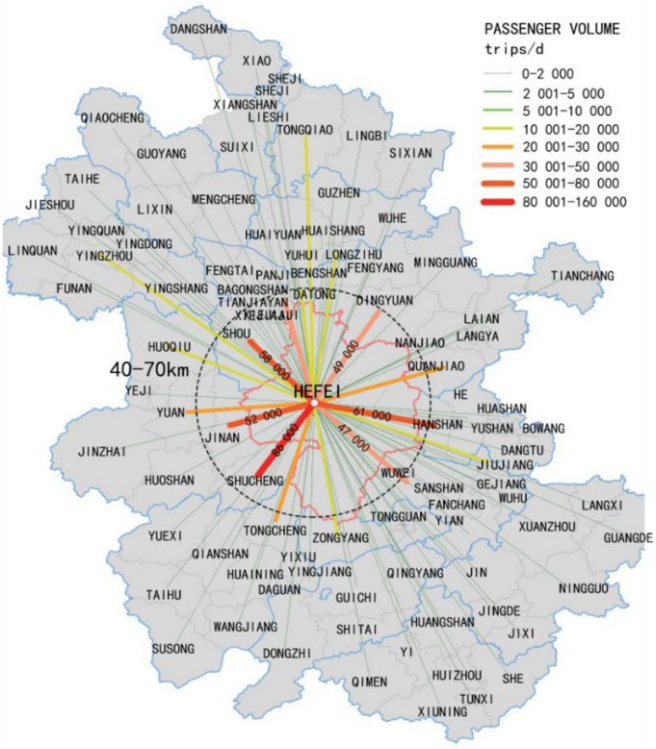


a Hangzhou metropolitan circle



b Nanjing metropolitan circle

Figure 3 Intercity transportation intensity in provincial capital metropolis circles



c Hefei metropolitan circle

Figure 3 continued

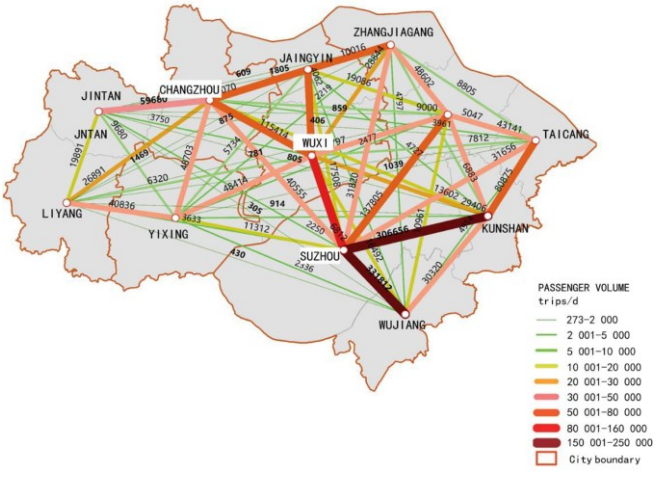


Figure 4 Intercity travel distribution in urban areas of Suzhou, Wuxi, and Changzhou

Note: The passenger volume is the interval OD data obtained by big data of mobile communication.

2.4 Intercity travel in adjacent urban areas

Adjacent urban areas refer to the areas adjacent to two central cities in which newly developed cities and towns are developed continuously. Regarding the spatial structure, newly developed cities and towns are located on the regional development belt, and the development belts of adjacent urban areas are connected (see Figure 5). In terms of land layout, the expansion directions of newly developed cities and towns in the adjacent urban areas are opposite; in terms of land use, it shows a clear characteristic of division of labor. Those divisions complement and cooperate with each other, which are highly mixed and present an obvious trend of urban integration. Typical examples include Jiading New Town in Shanghai and Kunshan and Taicang in Suzhou.

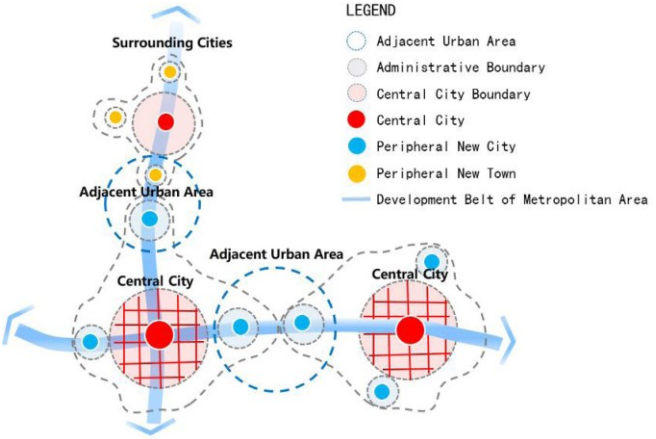


Figure 5 Intercity links in urban adjacent areas

According to the characteristics of intercity transportation connections, the external transportation connections of adjacent urban areas close to big cities have broken the administrative borders and reflected the main direction of economic development. For instance, the main external connection of Kunshan and Taicang, two cities in the adjacent urban area between Shanghai and Suzhou, is Shanghai, rather than their administrative center, Suzhou. The daily passenger traffic between Kunshan and Shanghai is 47 000 person-trips·d^{-1}, which is higher than 31 000 person-trips·d^{-1} between Kunshan and Suzhou; the daily passenger traffic between Taicang and Shanghai is 7 617 person-trips·d^{-1}, which is higher than 6 623 person-trips·d^{-1} between Taicang and Suzhou's urban district. This characteristic is also reflected in Nanjing and its adjacent city, Jurong. According to the mobile phone signaling data, the daily passenger traffic between Jurong and Nanjing is about 98 000 person-trips·d^{-1}, which is 2.2 times that of the passenger traffic between Jurong and Zhenjiang.

On the other hand, the travel demand between a big city and its adjacent areas is dominated by the commuting passenger flow caused by the separation of jobs and housing. There are two types of separations: living in adjacent urban areas but working in central cities, and living in central cities but working in adjacent urban areas as the jobs have been moved there. With Shanghai and Kunshan examples, a big data analysis shows 56% of the Suzhou residents who work in Shanghai actually live in Kunshan; and 47% of the Shanghai residents who work in Suzhou actually work in Kunshan [10]. Since commuting trips account for most of the trips, facility connection has become the primary demand for adjacent urban areas at the current stage. For instance, the number of connection roads between Shanghai and Kunshan

is planned to increase from seven to eleven to meet the demand for close commuting connections.

3 Adaptability analysis of different modes of transportation

The current intercity passenger transportation system in the Yangtze River Delta consists of long-distance buses, railways, urban rails, intercity buses and private cars. The role and adaptability of each mode in intercity transportation are analyzed respectively based on status quo and future trends.

3.1 Long-distance buses

The highway network in the Yangtze River Delta is close to fully developed. Freeways, as well as primary and secondary highways, have been supporting the spatial layout and industrial development of cities and towns in this region for a long time. As the urban space expands and the requirement on travel timeliness becomes higher, the freeways in regions with dense towns and cities gradually begin to carry long-distance motorized trips. The Beijing–Shanghai freeway, Shanghai–Changzhou freeway and Suzhou–Jiaxing–Hangzhou freeway in Suzhou's urban area carry a large number of urban trips, and the function of freeway is gradually shifted to accommodate local trips. On the other hand, urban expressways are expanding from urban areas to adjacent urban areas. The construction of urban trunk roads is approaching the standards for urban expressways, and their development shows a fusion trend in terms of construction standards and demand characteristics. The trend of functional fusion of freeways, urban expressways and urban trunk roads reflects the growing requirements of intercity transportation on travel timeliness and quality.

As a whole, long-distance passenger transportation on highways presents the trends of shrinking scale and weakening functions. Frist, the distance of highway passenger transportation has been declining and stabilized. Second, the scale of long-distance bus passenger transportation keeps shrinking. For example, the average trip distance of Suzhou's highway passenger transportation decreased from 50 km to 35 km after the Shanghai–Ningbo and Beijing–Shanghai high-speed rails were opened successively. The share of external highway passenger transportation in Shanghai decreased from 27.0% in 2010 to 17.3% in 2017.

On the other hand, new business models that are in response to the call for quality services appear in the highway passenger transportation industry. The long-distance bus companies in Suzhou, Wuxi, Nantong and Changzhou jointly established "Bus Manager", and adopted the model of "Internet + Transportation" to provide door-to-door intercity passenger transportation services, which achieved favorable business development and won a good market reputation.

3.2 Railways

In general, railway passenger transportation has developed rapidly, and the dependence level of intercity travel on railways has been rising. Affected by the higher requirements of intercity business trips on timeliness and the policies to restrict motorized vehicles in Shanghai and Hangzhou, high-speed railways have become more and more attractive to intercity passenger travel. The share of railways among external trips in Shanghai increased from 45.3% in 2010 to 54.2% in 2017. This share would be even much higher for the Yangtze River Delta. In addition, the traditional railway organization model of primary corridor + main hub in the Yangtze River Delta shows poor adaptability in the trend of rapid growth of railway passenger transportation. The passenger transfer issue is increasingly notable in primary hubs, such as Shanghai's Hongqiao Station (Shanghai–Ningbo Corridor and Shanghai–Hangzhou Corridor) and Hangzhou East Station (Ningbo–Hangzhou Corridor and Shanghai–Kunming Corridor).

The development of railways in the Yangtze River Delta faces another challenge: the long-distance high-speed rails and short-distance intercity rails are competing each other for passengers (see Figure 6). With Beijing–Shanghai high-speed rail and Shanghai–Ningbo intercity rail as an example, their target speeds are both 350 $km \cdot h^{-1}$. Due to the strong demand for intercity travels between Shanghai and Nanjing, this section on the high-speed rail is short of supply and has been operating at its full capacity. As a reflection of this issue, it is difficult to buy a ticket for the high-speed rail between Beijing and Shanghai (the travel time is about 4 h and 30 minutes); and the tickets for the morning and evening peak hours are often hard to buy for the section between Shanghai and Ningbo (especially for the section between Shanghai and Suzhou). According to data, the passenger volume between Shanghai and various cities in the Yangtze River Delta grew by 189% on average between 2012 and 2016 on the Beijing–Shanghai high-speed rail; but it decreased by 14% on average on the Shanghai–Ningbo intercity rail. There are primarily three reasons: (1) the market-oriented operation of the Beijing–Shanghai high-speed rail makes it a necessity to pursue short-distance passengers. The external drive for passenger tickets' revenues has a priority over the internal improvement of system efficiency. 2) The Shanghai–Ningbo section of high-speed rail has an insufficient capacity. However, this section undertakes the operation of the high-speed rail network for a wider range, which makes it difficult to fully meet the regular intercity travel demand in the Yangtze River Delta. 3) The Matthew Effect of the strong getting stronger damaged the interests of some trains in the Yangtze River Delta, with the biggest damage on the intercity rails between normal cities.

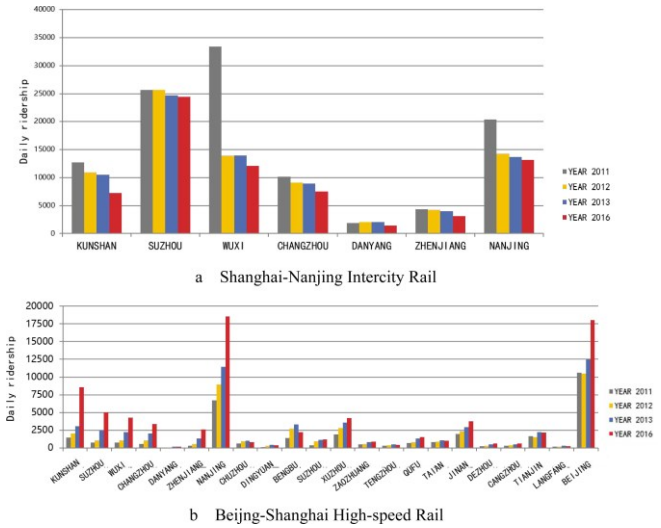


Figure 6 Passenger volume changes of Shanghai–Nanjing intercity rail and Beijing–Shanghai high speed rail

3.3 Urban rails

With the accelerated construction of urban rails in various cities in the Yangtze River Delta, the demand for connecting and extending urban rails in dense urban areas and adjacent urban areas is getting stronger. The most typical example is the No. 11 line of Shanghai urban rail, which crosses the boundary and extends to the town of Huaqiao in Kunshan and achieves the first cross-city urban rail extension in the Yangtze River Delta. According to the rail construction plan that is recently approved, Suzhou's S1 line will be connected with Shanghai's No. 11 line at Huaqiao Station for passengers to transfer. In addition, Taicang and Wujiang are also actively seeking to connect urban rails with neighboring cities.

The "Huaqiao model" has met the travel demand in the connection area between Shanghai and Kunming to a certain extent, especially the commuting travel demand caused by the separation of jobs and housing. However, it is actually unable to adapt to and meet the appeal for quick intercity travel. The travel time between Huaqiao (in Kunshan) and People's Square in Shanghai exceeds 1.5 hours on urban rails. If Suzhou and Shanghai are connected through Line S1, the travel time would exceed at least 2.5 hours, whose timeliness is much lower than that of intercity rails or freeways.

3.4 Intercity buses

Intercity buses play an important role in providing commuting services and meeting daily transportation needs between adjacent regions. According to estimates, the daily transportation demand in adjacent regions is growing strongly: 40 000 and 38 000 commuters travel every day between Kunshan and Jiading and between Zhangjiagang and Jiangyin, respectively. Therefore, the active explorations into the cross-regional bus services between adjacent cities have achieved good results. One is to use long-distance buses (such as Jiading–Taicang Express Bus) to achieve one-stop connection with urban rails. Another is to use the regular bus operation mode (such as K588 between Hangzhou and Deqing in Huzhou) and the operation is coordinated by two regions.

3.5 Private cars

With the increased popularity of private cars, they have become an important choice for intercity travel due to their characteristics of being comfortable and flexible. In particular, the Yangtze River Delta is the home of numerous tourist attractions, and it is popular to travel by private cars on weekends or holidays. The proportion of tourists who drive private cars reached 27% in 2015 in the Suzhou scenic zone. The Taihu Resort in Huzhou, Zhoushan Mountain, Putuo Mountain and other scenic zones are subject to unbearable impact from private cars on the road network and parking facilities. From the perspective of travel timeliness and the distance range, private cars still face many limitations and the acceptable range is generally within 2 hours (or 150 km).

4 Development pattern of intercity passenger transportation in the Yangtze River Delta

4.1 Overall pattern

In the past, intercity transportation was organized based on a city's planning and construction of external transportation. As intercity transportation's scale, frequency and requirement on quality increase, its characteristics become more and more similar to transportation within internal groups of a city. It is necessary to accommodate both the overall benefits of the system and the travel needs of different people, and to reshape the service system of intercity transportation.

The change that must be realized is to change from the existing perspective of facility construction to a service-oriented perspective. In the existing mode that is oriented to a city's external transportation facilities, more emphasis is placed on the standards and scale of external transportation hubs and corridors, and more attention is paid to construction. In this process, planning, construction and operation pass in one direction, and service is only considered as a passive derivative with an obvious terminal effect. This mode can hardly meet the requirements on transportation quality and fails to achieve feedbacks and interactions among each link.

In the context of the new development trend, the integral development of the Yangtze River Delta has become a national strategy. As an important supportive element, intercity transportation must meet intercity commuters' growing demands for high-quality transportation services and focus on the construction of a service system for intercity transportation. The service level should be used as the basic orientation and guideline to determine the key links and systematic weakness of the intercity transportation system, to guide the planning, construction and operation of new facilities and

provide feedbacks to each link, and to strengthen the effective update of existing facilities to adapt to the changes in travel chains (see Figure 7).

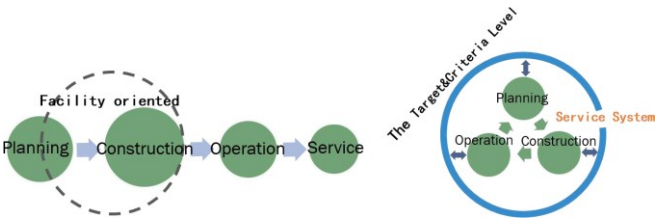


Figure 7 Intercity passenger transportation pattern of Yangtze River Delta

At the same time, differences of different groups should be reflected and diversified intercity transportation services should be provided. Commuters travel regularly and frequently, with a higher requirement on timeliness and accessibility, preferring the simplicity and convenience of the travel process. The starting and ending points of business trips are mostly located in be urban center or functional zones. Such trips have a high requirement on the timeliness and comfortableness, and prefer direct access or seamless connection. Tourists pay more attention to travel quality, have many chained trips between attractions and prefer good travel experience.

Population and cities are densely distributed in the Yangtze River Delta. As a result, the transportation corridor resources that can be utilized are extremely limited. The construction of future intercity transportation should place more emphasis on the high-quality development based on intensification and high efficiency. The general rail system consisting of high-speed rails, intercity rails, rails in urban areas and urban rails should become the dominant transportation mode and development focus for intercity transportation.

4.2 System perspective: the dominant mode and its functions

As a system, intercity transportation should comprehensively coordinate the connections and restrictions between each component, meet the requirements of system optimization, give full consideration to the intercity transportation demands at different spatial levels and select differentiated transportation modes. In addition, intercity transportation should enhance the functional requirements on dominate mode through comprehensive organization and management to meet different people's requirements on service standards.

4.2.1 Large-scale trans-regional intercity travel

High-speed rails (design speed of 350 $km \cdot h^{-1}$ or higher) have irreplaceable advantages in providing large-scale trans-regional intercity transportation services. It is necessary to guarantee the corridor supply to such transportation mode with high timeliness, especially in terms of strengthening direct connections between central cities in the enhancement region. According to Figure 8, high-speed rail corridors are reasonably arranged in the Yangtze River Delta to give play to their timeliness. They will meet the connection needs of the major central cities in the Yangtze River Delta through the 2.5 h time-space circle, and should be used as the dominant transportation mode for large-scale trans-regional travel in urban agglomerations.

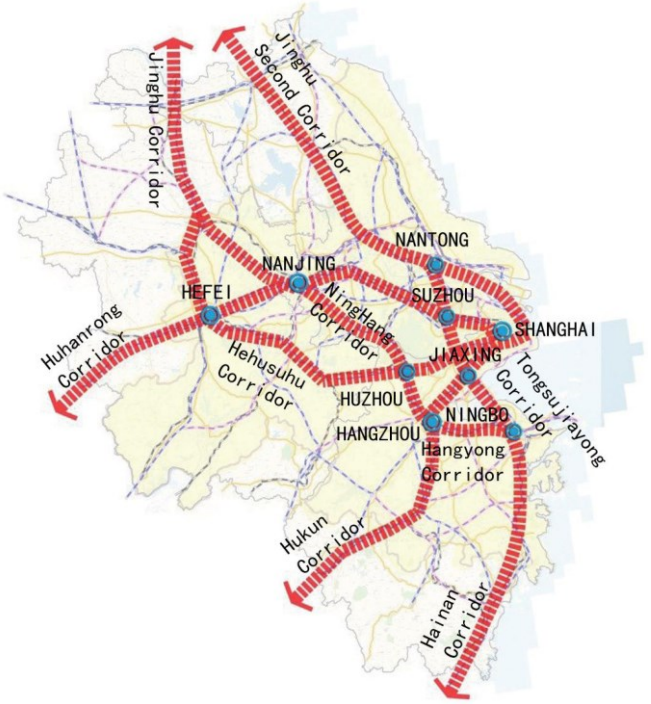


Figure 8 High speed cross-regional corridor layout in Yangtze River Delta

The corridors that should be guaranteed with a higher priority include the Beijing–Shanghai corridor, the Shanghai–Kunming corridor, the Shanghai–Wuhan–Chengdu corridor, the Nanjing–Hangzhou corridor, the Hefei–Huzhou (Hangzhou)–Suzhou–Shanghai corridor, and the Beijing—Shanghai 2nd (northern coast)–Nantong–Suzhou–Jiaxing–Zhoushan—Southern Coast corridor. Regarding the functional organization, high-speed rails should dominate, and their short-distance intercity function should be moderately separated to release their carrying capacities and guarantee long-distance travel to reflect their high timeliness.

With the Beijing–Shanghai high-speed rail as an example, its current carrying capacity from Shanghai to Nanjing (including) and further cities is about the same as that from Shanghai to Nanjing and closer cities. In addition, as a key section for operational organization, the Shanghai–Ningbo section is almost running on full capacity, which leads to inadequate carrying capacity for short-distance sections and the difficulty to further improve the timeliness of long-distance sections. If short-distance intercity railways are put into operation in the future and carry some of the short-distance passenger flow after optimizing and guiding their functions, it is estimated that at least 8 million

passengers capacity can be released to serve long-distance passenger flow each year. In addition, it is possible for this part of carrying capacity to further improve its timeliness.

4.2.2 Intercity travel in metropolitan circles

Intercity travel within metropolitan circles should follow the principle of radial corridor and layered organization (see Figure 9). The radius of the business close-interaction layer of a metropolitan circle is generally 50 km. This layer mainly serves cross-regional business passenger flow with 1-hour as its basic constraint, and is dominated by intercity railways and highways. Regarding planning guidance, it is necessary to enhance the connection and transfer functions of the radial road network and transportation hubs, promote the unified planning, construction and cross-border operation of intercity rails and urban (suburban) rails, and build the main body of intercity passenger transportation for metropolitan circles.

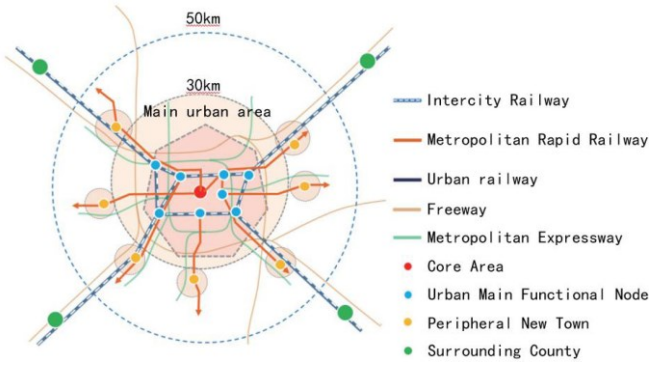


Figure 9 Space and intercity transportation organization of typical metropolis circle

The radius of the commuting interaction layer of a metropolitan circle generally is less than 30 km. This layer mainly serves daily commuters with 1-hour door to door as its basic constraint, and its travel demand is not different from urbanized passenger flow. Regarding planning guidance, urban (suburban) rails and urban rapid rails should dominate, supplemented by expressways and customized bus system to enhance the integration of transportation hubs and urban functional centers, as well as the transfer function of urban rail transportation network.

4.2.3 Intercity travel in dense urban areas

Dense urban areas should meet the diversified and networked travel demand, and actively seek multi-mode and multi-level network connections and continuous operations. The travel demand of medium and long distance between major urban centers should be met based on intercity railways and transportation hubs. Between secondary centers or towns, intercity railways (if conditions permit) or urban (suburban) rails may be considered to expand the service coverage. The network operation of intercity trains can be organized in dense urban areas (rather than corridor operation). In major corridors, efforts should be made to operate and organize intercity railways as buses. In particular, frequent intercity trains should be in operation between districts with high demand.

In areas with unique features, the connection and sharing of different transportation modes should be realized, and the quality of cross-region transportation should be improved through cross-regional public transportation, road connection and tour-line organization.

4.2.4 Intercity travel in adjacent urban areas

Adjacent urban areas should consider integrated transportation organization, and organize travels across administrative boundaries according to the same standard. Bus priority should be extended to the cross-border area. The connection and sharing of different bus systems should be realized through the transfer at railway hubs, the cross-regional operation of regular buses and the integration of ticket systems. Regarding the roadway network, road connection should be achieved at the planning and construction stages, and the cross-border coordination should be enhanced in aspects such as road functions, construction standards and implementation timings and orders.

4.3 User perspective: model innovation of transportation hubs

While paying attention to the overall benefits and functions of the intercity transportation system, we should optimize the organization and services of intercity transportation from the perspective of users, namely intercity travelers. With the expansion of intercity travel population, the convenience of intercity transportation has received more and more attention. What is currently criticized the most is the connection issue at both ends of intercity trips. The time spent in the urban transportation system is often much longer than the time on high-speed rails. Hence the negative effect of "half an hour on high-speed rails and two hours at both ends" is prominent. As the most reliable connection mode for intra-city trips, rail transit faces several restrictions, including repeated security inspections, entrance gates, ticket validations and transfers, which make it difficult to predict the travel time. Intercity business commuters who make frequent and regular intercity trips require easy travel and transfer, and the reduction of the dwell time spent at stations. The solution to the aforementioned difficulties actually places revolutionary requirements on the services and organization mode of existing external transportation hubs.

In the past, the planning and construction of external railway hubs emphasize the centralized layout, which is favorable for maximizing the benefits of the railway operation system. The passenger traffic at Hongqiao Station in Shanghai was as high as 120 million in 2017, which accounted for nearly 60% of railway passenger traffic of the city. The corresponding numbers are 112 million and 80% at the East Station in Hangzhou. The centralized layout of hubs has led to some significant negative effects, such as long transfer time and the deficiency of corridor and hub

resources. On the other hand, as a hub region that is oriented to the regional integration is formed around the hub (the Hongqiao Business District in Shanghai is the most typical case), the activity trajectories of passengers show a clear trend of integration between transportation hubs and surrounding functional space. In the hub region, businesses are mostly corporate headquarters, exhibitions and trade companies; regional intercity travelers account for a high proportion; and the surrounding region is highly dependent on the hub (see Figure 10). Because of the large scale of the transportation hub and the traditional construction mode, the interface separation effect between the hub and the space is prominent. The gathering and distribution of passengers rely mostly on motorized vehicles and rail transit through transfer at the departure and arrival levels, whereas the connections to the area within one kilometer, or even 500 meters, around the transportation hub have become the most difficult blind point, which contradicts to the trend of integrated development in the hub region.

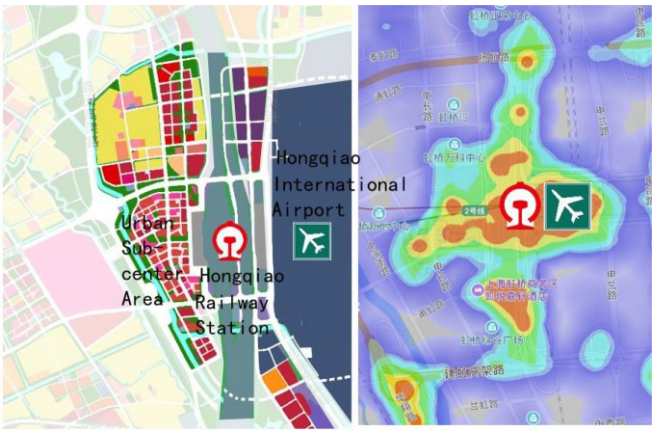


Figure 10 Thermodynamic activity chart of the crowd around Hongqiao Hub

Source: Based on Baidu's thermodynamic map of population.

As the key interface of intercity transportation, a hub determines the service level of intercity transportation to a large extent. It is therefore necessary to carry out service-oriented model innovation of intercity transportation hubs. This innovation should not only consider the macroscopic layout, but also pay attention to the functional organization of the hub itself.

4.3.1 Mode 1: moderate separation of hub functions

The future intercity corridors will present a hierarchical layout. Especially for super-large cities and megacities, intercity corridors need not only the large-scale, trans-regional and high-speed railway system, but also the intercity rail transportation system that serves metropolitan circles and dense urban areas. As the intercity transportation network continues to improve, intercity hubs that differ from tradition gateway hubs will emerge.

Such intercity hubs are primarily targeted at the Yangtze River Delta and metropolitan circles. They serve the frequent regular intercity business and commuting trips in the groups or districts where they are located. These hubs are separated spatially and functionally from the gateway hubs serving the whole city. Compared with traditional gateway hubs, these intercity hubs are favorable for a scattered and balanced spatial layout. It is possible for these hubs to achieve seamless station-city integration with adjacent functional space, making it easier to operate and organize intercity transportation in the same way as operating and organizing buses (see Figure 11a). Regarding the construction mode of railway lines and hubs, underground laying can be selected (such as the Futian Station in Shenzhen, Guangdong Province) to achieve the three-dimensional and compound layout with the urban center and to improve the distribution efficiency of passenger flow by using non-motorized transportation to realize seamless connection.

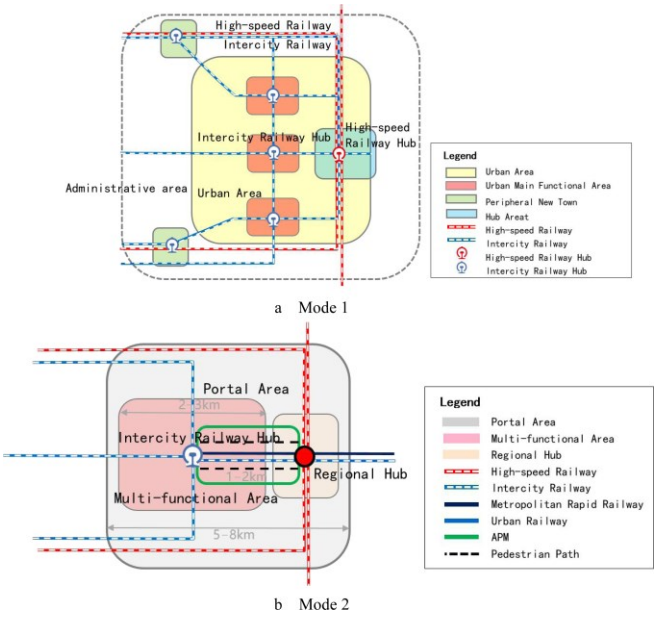


Figure 11 Layout pattern of intercity hubs

With Suzhou as an example, based on the condition of completed intercity railway network, a relatively scattered layout mode is adopted for intercity hubs, which integrates intercity hubs into the layout of the urban center system. Eight intercity hubs are planned, and they will serve the fast connection demand between functional areas, such as the industrial park zone, new district, Gushu and Wujiang, and other regions in the Yangtze River Delta. According to a rough calculation, the scattered layout mode that integrates functional centers will save the intercity transfer and connection time by 40%–60%, and will substantially improve the efficiency and experience of intercity transportation.

4.3.2 Model 2: the union hub in gateway hub zone

The gateway hub zone is a typical area in super-large cities and megacities. Functional groups that serve the region have often been formed around airports and high-speed rail hubs.

They not only carry the function of transportation gateways, but also bring in intensive contacts with surrounding regions (see Figure 11b). In this situation, unilaterally requiring the centralized arrangement of hubs is actually harmful to the effectiveness of both functions. Hence the union hub mode in the large gateway hub zone becomes an effective solution. Apparently, the function of a gateway hub is to enhance the super long-distance passenger flow from or to the entire country and even the whole world. It serves the whole city and even the region, and pursues higher timeliness. Conversely, an intercity hub is primarily targeted at the Yangtze River Delta and serves intense and frequent passenger flow in the hub zone. Both the gateway hub and the intercity hub form a combination relationship in the hub zone, which not only effectively relieves the passenger flow and corridor organization pressure of the gateway hub, but also ensures the organization efficiency of intercity rails. The necessary transfer and complementary relationship between them can be achieved through mass rapid transit or pedestrian paths, and they can be connected with other important functional nodes in the hub zone.

With the union hub of the King's Cross Railway Station in London as an example, it consists of St Pancras Station, King's Cross Railway Station and Euston Station, which are the terminal of Eurostar, a domestic railway hub and the terminal of a commuting rail serving the metropolitan circle, respectively. The surrounding area is concentrated with corporate headquarters, business office buildings, universities, creative parks and residential building. The stations are connected by urban rails, and can also be reached on foot (see Figure 12).

Figure 12 Hub area case of King's Cross station in London

Source: Based on network data.

The union hub should leave enough space between stations, which is helpful for expanding the hub–space interface and diversifying the hub space. Regarding the rail line access, the gateway hub should focus on high-speed railways, while the intercity hub should be oriented to intercity rails. At the same time, the connectivity between the railway networks should be ensured. The most important thing is to give priority to the walking connection between the intercity hub and functional centers, and the distance, size and quality should meet the requirement to walk into and out of the hub.

5 Conclusions

The higher-quality integrated development of the Yangtze River Delta cannot be separated from the support of a high-quality intercity transportation system. Therefore, a new round of improvement of the intercity transportation system should be service-oriented, rather than being limited to the scale and standards of channel and hub facilities, and should focus on the improvement of the service quality throughout the intercity transportation process. In the meantime, the functional organization of the intercity transportation system should pay more attention to differentiated spatial hierarchy and diversified demands of the population, and should reflect the functionality and experience of intercity transportation services. In this context, the role played by intercity hubs will be more prominent. Certainly, the construction of the intercity transportation service system still faces numerous institutional and industrial barriers. It is urgent to innovate and reform mechanisms across administrative systems, which is also the aspect that needs continuous attention and research in subsequent studies.

References

[1] Cai Runlin, Zhang Cong. New Transportation Development Strategies for the Cluster of Urban Areas in Yangtze River Delta Area [J]. Urban Transport of China, 2017, 15(4): 35–48 (in Chinese).

[2] Luo Zhendong, He Heming, Geng Lei. Analysis of the Polycentric Structure of Yangtze River Delta Based on Passenger Traffic Flow [J]. Urban Planning Forum, 2011(2): 16–23 (in Chinese).

[3] Duan Jin. National Grand Infrastructure Construction and Urban Spatial Development: a Case Study on High Speed Railway and Urban Comprehensive Transport Hub [J]. Urban Planning Forum, 2009(1): 33–37 (in Chinese).

[4] Chen Weijin, Ma Xueguang, Cai Lili, et al. Characteristics of Regional City Connection's Spatial Pattern Based on Intercity Passenger Traffic Flow in Pearl River Delta [J]. Journal of Economic Geography, 2013, 33(4): 48–55 (in Chinese).

[5] Chen Xiaohong, Zhou Xiang, Qiao Yingyao, et al. Coordination and Optimization of Multilevel Rail Transit Network and Multi-scale Spatial Layout: a Case Study of Shanghai Metropolitan Area [J]. Urban Transport of China, 2017, 15(1): 20–30+37 (in Chinese).

[6] Deng Runfei, Guo Xiucheng. Study on the Classification and Function of Rail Transit System in Urban Agglomeration Based on Trip Characteristics [J]. Modern Urban Research, 2013(12): 113–120 (in Chinese).

[7] JIN An. Characteristics Evolution Trend and Development Countermeasures of Inter-City Transit Under City Integration [J]. Railway Transport and Economy, 2017, 39(4): 84–89 (in Chinese).

[8] Shanghai Urban and Rural Construction and Transportation Development Institute. Shanghai Transportation Annual Report 2017 [R]. Shanghai: SURTDI, 2017 (in Chinese).

[9] Cai Runlin, Zhao Yixin, Li Bin, et al. Suzhou Metropolitan Rail Transit Development Within Megalopolis [J]. Urban Transport of China, 2014, 12(6): 18–27 (in Chinese).

[10] China Academy of Urban Planning & Design. Suzhou Comprehensive Transportation System Planning [R]. Suzhou: Suzhou Planning Bureau, 2018 (in Chinese).

