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Integrated development of intercity railways and urban (suburban) railways in the Shanghai Metropolitan Area

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Abstract: The integration of intercity railway network and urban (suburban) railway network is an important measure to address the growing demand for internal coordination in metropolitan areas. Focusing on coordinated planning, construction, design, and operation of the integration of intercity railways and urban (suburban) railways in the Shanghai Metropolitan Area, this paper analyzes the construction and operation mode of private railways in the Tokyo Metropolitan Area and proposes a development mode of two-network integration in the Shanghai Metropolitan Area. In terms of rail transit network, the paper proposes a pattern featuring "integration of trunk railways, secondary extension, and supplementation by region" in the metropolitan area to adapt to the diversified intercity mobility demand in the Shanghai Metropolitan Area. With regard to construction, it is crucial to establish rail transit corporations in the metropolitan area and promote systematic top-down planning, construction, and operation. At the operation and management level, bus transit operation and high/regular-speed railway lines should be adopted to ensure the competitiveness of the two networks. Finally, the paper concludes that the integrated development of the two networks should serve as the basis to build a reasonable rail transit network with flexible operation and to meet the demand for diversified connections in the metropolitan area.

Keywords: rail transit; two-network integration; intercity railways; urban (suburban) railways; Shanghai Metropolitan Area

Introduction

In February 2019, the National Development and Reform Commission issued *Guidance for Fostering and Developing Modern Metropolitan Areas*, proposing that the network layout of metropolitan area rail transit should be coordinated to promote the integration between trunk railway, intercity railway, urban (suburban) railway, and urban rail transit. Since then, four-network integration has become a state-level top-down development priority. A series of state-level plans have been rolled out, including *Outline for Building China's Strength in Transport*, *Outline of Integrated Development of Yangtze River Delta*, and *Development Plan for Guangdong-Hong Kong-Macao Greater Bay Area*.

Compiled and issued jointly by the Shanghai Municipal People's Government, Jiangsu Provincial People's Government, and Zhejiang Provincial People's Government, *Spatial Cooperative Plan of Greater Shanghai Metropolitan Area* specifies that the Shanghai Metropolitan Area consists of Shanghai, Suzhou, Wuxi, Changzhou, Nantong, Jiaxing, Huzhou, Ningbo, and Zhoushan. Amid the trend of high-quality regional integration, it is difficult for a self-contained rail transit development mode to meet the requirements of efficient and convenient intercity travel and satisfy the increasingly expanding communication demands of the Shanghai Metropolitan Area and the Yangtze River Delta urban agglomeration [1]. Consisting of intercity railway and urban (suburban) railway, the rail transit of a metropolitan area underpins regional multi-center, multi-node, and multi-layer spatial coordinated development [2], which has become an inevitable trend. It also provides a practical path for accelerating regional integration. First, metropolitan rail transit promotes collaboration among multiple centers and multiple nodes in the Shanghai Metropolitan Area, as well as mutual reinforcement between urban functions. Second, characterized by flexibility, fast speed, and low price, it will play a leading role in multi-level rail transit in the Shanghai Metropolitan Area in the future. Therefore, when planning the rail transit network in the Shanghai Metropolitan Area, it is necessary to break through the limitations of administrative division and plan for the healthy development of rail transit from various perspectives, such as regional integration and urban area integration.

1 The composition of metropolitan area rail transit

1) Intercity railways in the metropolitan area

Intercity railways in the metropolitan area are a type of passenger rail transit system, like high-speed railway and urban (suburban) railway, that connects major urban centers within the metropolitan area. Its speed is generally set at

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160–200 km ħ$^{-1}$, and the distance between stations exceeds 5 km. It also links counties and districts along the line. For example, the Suzhou-Wuxi-Changzhou Intercity Railway, which is to be constructed in Jiangsu province in the near future, aims to connect the city centers of Suzhou, Wuxi, and Changzhou, as well as the districts and counties along the line, such as Kunshan, Wuzhong, Suzhou New Area, Taihu New Town, Huishan, and Wujin.

2) Urban (suburban) railway

Urban (suburban) railways mainly connect key functional zones and the urban area, with relatively small station spacing. The train can stop at each station. There are both high-speed and regular-speed trains. Moreover, urban (suburban) railways can run independently or cross trunk railway, intercity railway, or urban rail transit line in accordance with the demand [3].

Shanghai Jinshan Railway is the first urban (suburban) railway that adopts bus transit operation in China. Passengers can take it by swiping their public transport cards or buying train tickets. There is no fixed train number, no fixed seat, and no fixed departure time. Similar to an urban rail transit line, it is equipped with a reminder announcing the arrival of a stop. It also adopts a long-short route operation. The train can run non-stop, stop at major stations, and stop at each station. Its whole trip can take 32 minutes (the fastest) and 60 minutes (the slowest) (Fig. 1). Passengers can choose their trips according to their specific demands.

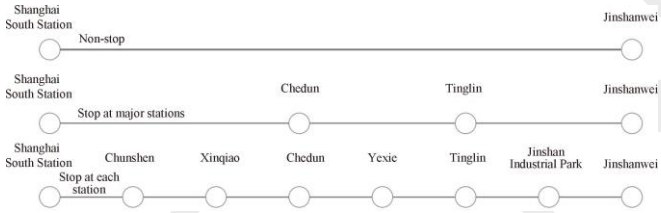


Fig. 1 Stations and schedule of Shanghai Jinshan Railway

Data source: the schedule of Shanghai Jinshan Railway

2 Challenges facing the rail transit development of the Shanghai Metropolitan Area

Upholding the concept of "one intercity network" [2], all cities within the Shanghai Metropolitan Area are working hard to promote the integration of the intercity railway network and the urban (suburban) railway network. For example, the Suzhou-Changshu-Zhangjiagang line, an urban (suburban) railway planned by Suzhou, can be connected with the Rudong-Nantong-Suzhou-Huzhou line [4]. When planning the urban (suburban) railway, Wuxi, Nantong, and other cities emphasize a standardized system and network connectivity with the intercity railway in the metropolitan area. However, in practice, problems concerning coordination remain to be addressed.

1) Incoordination between provinces and cities in planning

First, different cities have different functional positioning and design standards for metropolitan area rail transit. For example, Wuxi municipal government expects the Suzhou-Wuxi-Changzhou railway to realize non-stop connection between Taihu New Town and Shanghai, with minimal stations and a speed up to 160 to 200 km ħ$^{-1}$. Changzhou municipal government expects the said line to coordinate with urban rail transit, suggesting a low-level design standard. Disputes exist among cities about whether the urban (suburban) railways interconnected with the intercity railways in the metropolitan area should be incorporated into the urban rail transit express line system or the intercity network. Second, provinces and cities often have different opinions on the layout of rail transit lines in the metropolitan area. Provinces hope that the intercity railway in the metropolitan area will be located at the city center and cover the largest number of passengers along the line. With the existing railway passenger stations in the city center, cities hope to promote the development of peripheral new towns using new lines.

2) Inconsistent system of metropolitan area rail transit between provinces and cities

Shanghai municipal government has built, is building, and is planning to build urban (suburban) CRHF EMU system with a speed of 160 km ħ$^{-1}$. Jiangsu provincial government has built and is planning to build subway B size train with a speed of 120 km ħ$^{-1}$and CRHF EMU system with a speed of 160–200 km ħ$^{-1}$. The railways built by Zhejiang provincial government use B size train or AH size train systems with a designed speed of 100 to 120 km ħ$^{-1}$. The planned Shanghai-Jiaxing railway will adopt CRHF EMU system with a speed of 160 km ħ$^{-1}$ (Table 1).

Table 1 Rail transit systems in metropolitan areas of China

Province/ municipality	Metropolitan area rail transit	Line condition	System	Designed speed /(km·h^{-1})
Shanghai	Jinshan Railway	Built	CRH6A/6F EMU	160
	Airport connection line	Being built	CRHF EMU	
	Jiamin Line	Planning to build	CRHF EMU	
Jiangsu	Nanjing Metropolitan Intercity Line S	Built	Subway B size train	100–120
	Wuxi Urban Line S1	Being built	Subway B size train	120
	Suzhou-Wuxi-Changzhou Intercity Line	Planning to build	CRHF EMU	160–200
Zhejiang	Hangzhou-Haining Intercity Line	Built	Subway B size train	120
	Hangzhou-Fuyang Intercity Line	Built	Subway AH size train	100
	Shanghai-Jiaxing Intercity Line	Planning to build	CRHF EMU	160

3) The administrative barriers between railway departments and local governments make coordination difficult.

Railway management is mainly divided into management at the levels of national railway, joint venture railway, and local railway. National railway and joint venture railways are mainly controlled by railway companies and operated by railway bureaus or railway companies. Railway departments and local governments have different responsibilities,

demands, and mechanisms. The boundaries between railway and urban land are well-defined, which makes it difficult to realize the integrated development of stations and cities and the flexible operation of lines.

To promote the integration of intercity railway and urban (suburban) railway network in the metropolitan area, local governments should take greater initiative in the construction of rail transit. In recent years, apart from provincial governments, which have increased capital to rebuild, merge, and reorganize railway investment corporations, municipal governments also have started to establish intercity railway corporations responsible for the investment, financing, construction, operation, management, and development of intercity railway projects. In the future, local governments should play a leading role in the construction and operation of intercity railways and urban (suburban) railways in metropolitan areas, promoting the cooperation between railway departments, urban planning and transportation departments, and metro enterprises in terms of cooperation mechanism, technical operation, and commercial development.

3 The rail transit operation in the Tokyo Metropolitan Area

The private railway in the Tokyo Metropolitan Area (hereinafter referred to as "private railway") is similar to the intercity railway and urban (suburban) railway in the Shanghai Metropolitan Area in function, both serving close and frequent connection with short and medium distances in the metropolitan area. Lessons can be learned from Tokyo's network format, diversified construction modes, and connected operations between rail transit at all levels.

3.1 The rail transit system in the Tokyo Metropolitan Area

In the main corridors of the Tokyo Metropolitan Area, Japan Railway Shinkansen (hereinafter referred to as "JR bullet train") and JR regular-speed railway form a rail transit trunk network that extends outward. Large private railway companies build regional sub-trunk networks to weave the main corridors. In remote suburban areas, short-distance lines are used as links between trunks and secondary trunk lines [5], distributing passengers for trunk lines. Thus, radial short private railway lines are formed in a small area and the service scope of trunk stations is expanded (Fig. 2).

Unlike China's stratified rail transit network system, all levels of rail transit in the Tokyo Metropolitan Area can meet the commuting demands within the capital area, and the rail transit providing internal travel services accounts for about 80% of the total network [5]. On the lines with JR bullet train, only the medium- and short-distance JR regular-speed trains in the metropolitan area are run, with a service radius of no more than 150 km. Even in the sections without JR bullet train services, the running distance is no more than 300 km. Private railways are mainly responsible for running cross-region trains in the metropolitan area and short-distance trains in the urban area. In addition, the subway can be directly connected to the railway. Private trains can directly enter the city center, thus serving the centripetal passenger flow in the metropolitan area.

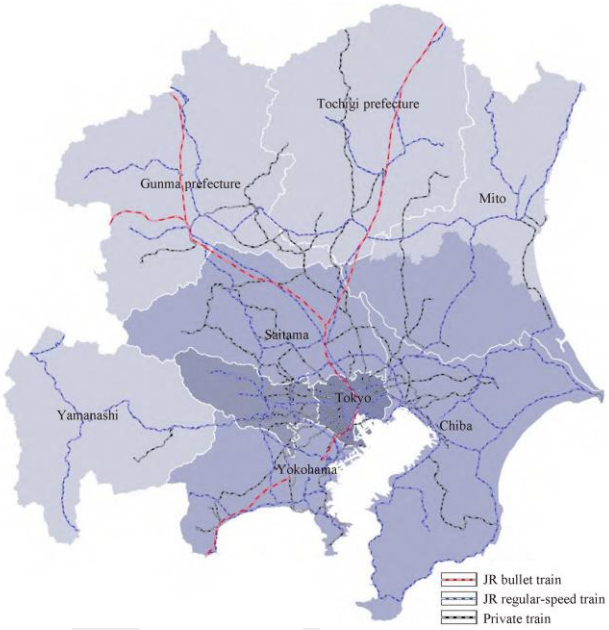


Fig. 2 Layout of multi-level rail transit network in Tokyo Metropolitan Area

Data source: the rail transit network of the Tokyo Metropolitan Area in 2020.

The flexible operation of rail transit in the Tokyo Metropolitan Area is mostly attributed to its diversified construction modes. JR bullet train and JR regular-speed railway are operated and managed by six railway passenger transport companies. Among the six companies, JR East, Central Japan Railway Company, JR West, and Kyushu Railway Company have been fully transformed into private-run companies although they are affiliated to the national railway. To increase revenue, railway passenger transport companies will improve service quality and develop new service domains while offering public welfare services to the urban area. As private companies, private trains can provide transport services in the metropolitan area and the urban area. They are equipped with multiple stations, which are located in the city center or the center of functional sections, such as the urban life section, industrial section, tourism section, etc. They boast accessibility and convenience, and their price is lower than that of JR railway. Therefore, private railways can attract and maintain many passengers.

3.2 The construction and operation mode of private railways

In function, the private railway in the Tokyo Metropolitan Area is similar to a network consisting of intercity

railway and urban (suburban) railway. Its construction and operation modes can provide a reference for the integrated development of the two networks in the Shanghai Metropolitan Area.

The construction mode of private railway is not subject to administrative division. Major and minor private railway companies jointly form a "trunk line plus network" (Fig. 3). Major private railway companies construct trunk lines based on direction, with their function similar to that of intercity railway in the metropolitan area. Minor private railway companies are responsible for the construction of connection lines and intensification lines, which function as the cross-region extension and intensification of urban (suburban) railways. The distribution of private railway lines in the Tokyo Metropolitan Area is shown in Fig. 4.

Private trains have diversified operation patterns. Multiple options are available for the same line, such as limited express, semi-express, urgent, fast, and stop at each station, meeting passengers' various travel demands. Moreover, private railway, JR railway, and subway systems are integrated. After paying Japan Railway Company, private railway companies can adopt cross-line operations or run to the urban center using the subway track (Fig. 5). Since there are too many constructors for private railway and each line is basically operated independently with trains on its own line, passengers from outside the metropolitan area have to frequently transit between cities. Given the single-center structure of the Tokyo Metropolitan Area, its disadvantages often go unnoticed. However, this mode is not applicable to the Shanghai Metropolitan Area characterized by multiple centers.

4 The integrated development mode of rail transit networks in the Shanghai Metropolitan Area

4.1 Network layout pattern

Considering the multi-level, multi-center, and multi-node spatial structure of the Shanghai Metropolitan Area, *Spatial Cooperative Plan of Greater Shanghai Metropolitan Area* has developed an intercity network composed of state-level trunk railway, metropolitan rail transit, and cross-region subway. Among them, the metropolitan rail transit, consisting of intercity railway and urban (suburban) railway, plays a leading role in serving intercity travel in the metropolitan area. It is expected to meet about 80% of intercity travel demands in the future.

To better satisfy the diverse intercity mobility demands in the Shanghai Metropolitan Area, this paper proposes a network layout pattern featuring "integration of trunk railways, secondary extension, and supplementation by region" based on the private railway layout in Tokyo Metropolitan Area.

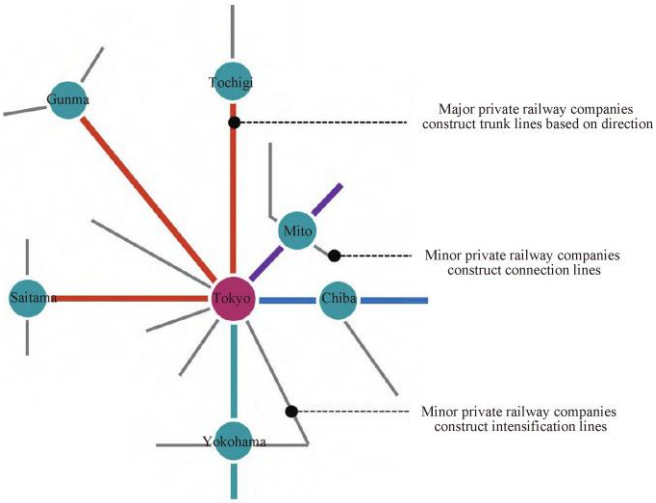


Fig. 3 Private railway network structure in Tokyo Metropolitan Area

Data source: the private railway network of the Tokyo Metropolitan Area in 2020.

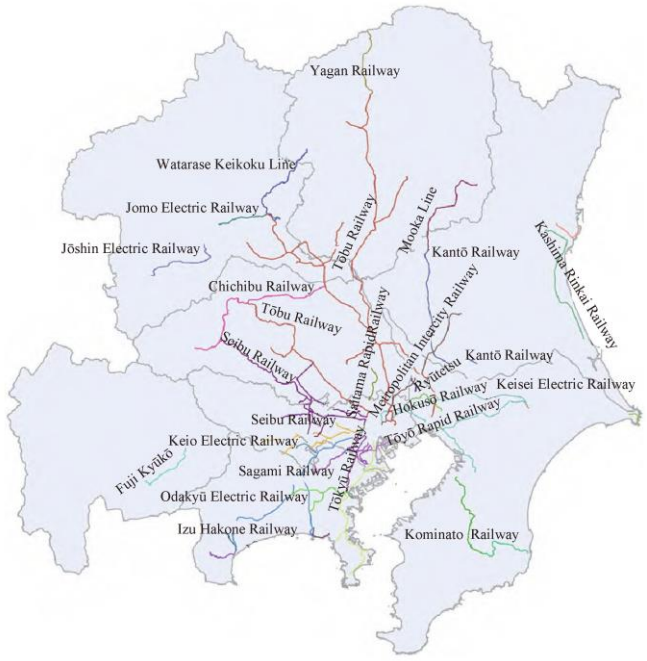
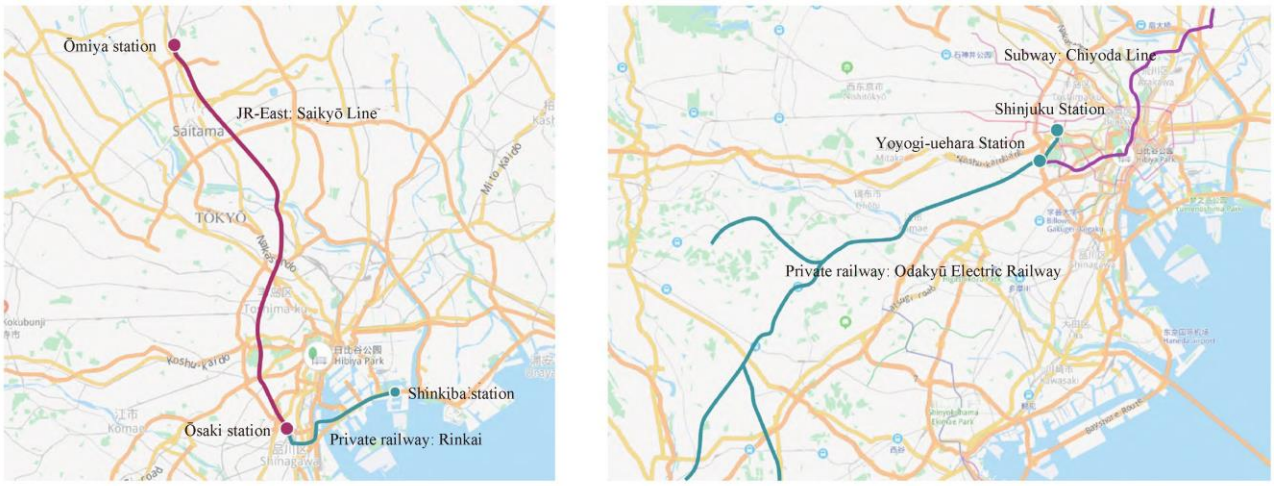


Fig. 4 Private railway lines in Tokyo Metropolitan Area (distributed by company)

4.1.1 Integration of trunk railways

Trunk corridors, which connect global cities of all levels, undertake the largest cross-region passenger flows in the metropolitan area and are the main corridors integrating intercity railways and urban (suburban) railways. Trunk corridors consist of lines planned by the upper level and existing lines (Fig. 6) and are mainly supported by intercity railways in the metropolitan area. In the presence of other urban (suburban) railways in the corridor, it is necessary to integrate passages and stations with the intercity railways in the metropolitan area, thus realizing the integration of the two networks.



a Private railway and JR regular-speed railway

b Private railway and subways

Fig. 5 Connected operation of private railways with JR regular-speed railways and subways in Tokyo Metropolitan Area

Data source: the rail transit network of the Tokyo Metropolitan Area in 2021.

As the main corridors of rail transit in the metropolitan area, trunk corridors need to balance efficiency and coverage. It is suggested that the design standard of rail transit in the trunk corridor should be upgraded, with the design speed within the range of 160–200 km h^{-1}. By running express trains at major stations with a spacing of 10–20 km, the efficiency of the connection between the functional sections in the corridor can be ensured. Meanwhile, additional urban stations can be built upon demand. Trains should be accessible in the urban area and overtaking lines are needed for urban train stations. Thus, the running of express trains at major stations will not be affected while the coverage of stations is expanded.

For example, it is planned to build two lines in the section from the downtown area of Suzhou city to Changshu in the Rudong-Nantong-Suzhou-Huzhou railway corridor, namely Rudong-Nantong-Suzhou-Huzhou intercity line and the Suzhou-Changshu-Zhangjiagang (within the Suzhou urban/suburban railway). However, the two lines are not consistent with each other in specific line location. To allow the two lines to share passages and station facilities, the line location of Rudong-Nantong-Suzhou-Huzhou should be adjusted to serve as the trunk line of the railway corridor. Three intercity stations should be set at Suzhou North Station, Yangchenghu Station, and Changshu Station to guarantee efficient connections within the corridor. The line location of Suzhou-Changshu-Zhangjiagang should also be partially adjusted. A line should be constructed from Changshu to Zhangjiagang, serving as the extension of the trunk line. Three urban stations should be added between Suzhou North Station and Changshu Station (Fig. 7) [4]. The Suzhou-Changshu-Zhangjiagang line and the Rudong-Nantong-Suzhou-Huzhou line should adopt the same EMU system. Changshu Station has the condition for cross-line operation.

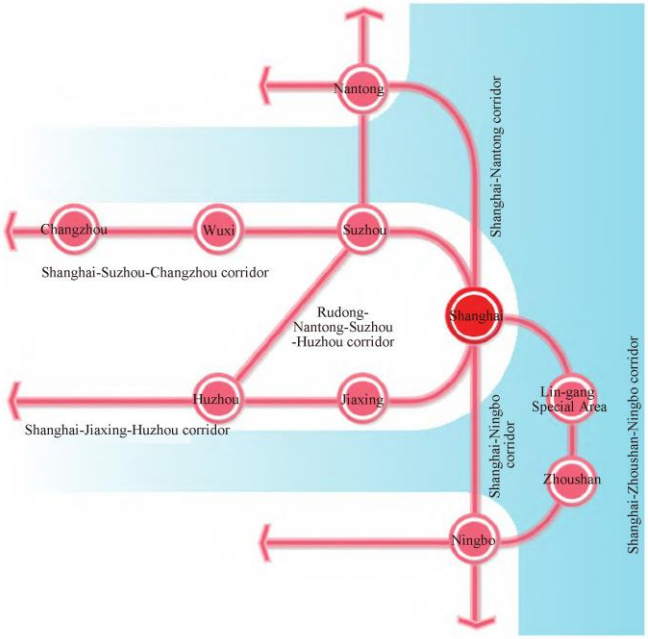


Fig. 6 Layout of rail transit corridors in Shanghai Metropolitan Area

4.1.2 Secondary extension

Secondary corridors connect global cities and global functional and supporting nodes. They can be divided into two types. One refers to the secondary passenger flow corridor covering the metropolitan area without passing the primary city, such as the West Taihu Corridor in the Shanghai Metropolitan Area. The other serves as the extension of the trunk corridor. For example, the Shanghai-Ningbo Railway Corridor extends westward from the Jinshan node and can offer non-stop trains from Shanghai to the north shore districts and counties of Hangzhou Bay, covering this region

(Fig. 8). It is an important way for global cities to release their non-core functions by using secondary corridors to extend outward. To this end, the interconnectivity with hubs in railway corridors should be guaranteed.

Fig. 7 Two-network integration of the Rudong-Nantong-Suzhou-Huzhou corridor (the section from Suzhou urban area to Changshu)

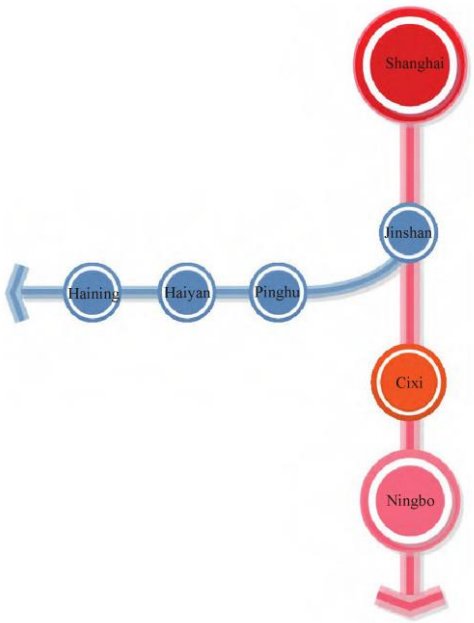


Fig. 8 Interconnectivity of Jinshan-Haining secondary corridor and Shanghai-Ningbo corridor

4.1.3 Supplementation by region

Trunk corridors and secondary corridors can only cover relatively important sections in the metropolitan area. Therefore, based on actual demands, cities can use urban (suburban) railways to connect important supporting nodes to major corridors for supplementation. Meanwhile, cities with existing trunk railways can first make use of them to run intercity city trains from the downtown area to sub-level districts, counties, and urban (suburban) trains. The design speed for urban (suburban) railways in the connection corridor should be 160 km h^{-1} since a low standard will affect service quality and operation efficiency [6].

For example, Tongzhou Bay Port Area is an important strategic part of Nantong's development blueprint, but it is far away from the city and is not included in the rail transit corridor of other metropolitan areas. Therefore, urban (suburban) railway can be used to connect this area to the railway passenger transport hubs of the city, such as Nantong Station, so as to improve traffic accessibility. Although Qidong, Haian, and Rugao are not covered by the rail transit corridor of the metropolitan area, they are located along the existing Nanjing-Qidong Railway. In this case, the existing railways should be first used to run urban trains, so as to avoid waste caused by repeated railway construction (see Fig. 9).

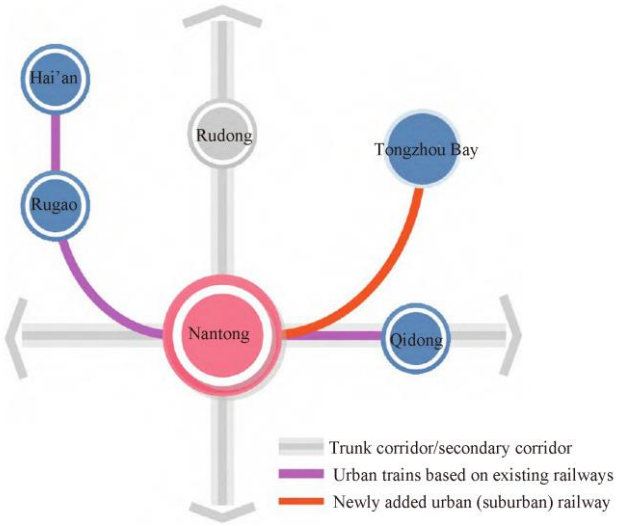


Fig. 9 Categorization of connection corridors in urban area of Nantong

Rail transit systems should be standardized to ensure the integration between trunk corridors, secondary corridors, and connection corridors. First, efforts should be made to ensure that the systems of intercity railway in the metropolitan area and urban (suburban) railways are standardized so that the two networks can share passages. Thus, the functions of the two networks supplement each other and the urban (suburban) railways in the connection corridors can be connected with the urban (suburban) railways in the hubs of the metropolitan area. Second, the two networks should be integrated with the existing trunk railways so that the existing railways can be partially used to run cross-region non-stop trains.

4.2 Construction and operation modes

4.2.1 Organization establishment & construction and operation parties

Metropolitan area rail transit should coordinate the construction and operation of the two networks in a top-down manner from trunk and branch lines to connection lines. Therefore, "two provinces and one city" and each prefecture-level city within the metropolitan area should jointly establish a metropolitan area rail transit corporation responsible for the investment, financing, construction, management, and operation of trunk and branch lines of the metropolitan area, as well as land development along the line. China Railway can participate in the construction and operation, but the rail transit corporation should be jointly controlled by "two provinces and one city" and local railway investment companies.

Since trunk and branch lines are the main body of rail transit networks, their construction and operation level will have a direct impact on the operation of the whole network. Therefore, Shanghai should lead the urban planning departments of other cities to formulate a standardized rail transit network plan for the metropolitan area. Rail transit companies should be responsible for investment, financing, and construction. The construction can be funded by the cities in proportion to the mileage of the line within the boundary. For the sections with engineering difficulty and high construction cost, a special fund for rail transit construction can be subsidized, and private capital investment is encouraged. After the line is completed, the metropolitan area rail transit corporation will carry out standardized network operations. It will also be responsible for the coordination and communication in the cross-line operation of the trunk railway.

The rail transit connection line can be planned and constructed by cities independently in accordance with the demand. The planning scheme should be incorporated into the rail transit network planning of the metropolitan area. Compared with trunk and branch lines, the investment and operation modes of the connection lines are more diversified. New lines can be constructed solely by local governments or with the cooperation between local governments and China Railway or other private capital. Overall, non-government capital is encouraged to invest. Existing trunk railways can be used to run urban train lines. This service can be purchased by local governments from China Railway.

Then, connection lines can be operated by municipal governments, railway authorities, or private companies, depending on the specific constructors. The urban (suburban) railways wholly owned or jointly constructed by local governments shall be operated by the urban railway investment corporation of the city. The lines using existing railways to run urban trains can be entrusted to local railway bureaus. Urban (suburban) lines constructed by private capital can be operated by private railway companies. For the connection lines with strong demand for cross-line operation with rail transit trunk and branch lines in the metropolitan area and national trunk railway, they should be handed over to the metropolitan area rail transit corporation for overall network operation (Fig. 10).

4.2.2 Bus transit operation and high/regular-speed railway line patterns

Bus transit operation and high/regular-speed railway line patterns are the keys to ensuring the competitiveness of the two networks. All metropolitan area rail transit including trunk and branch lines and connection lines should adopt the bus transit operation mode. High/regular-speed operation should be guaranteed for trunk and branch lines.

Compared to state-level trunk railways, metropolitan area rail transit is more service-oriented. Different from trunk railways, the train models of metropolitan area rail transit boast larger capacity, higher density, multiple running routes, and integrated transportation card. Rail transit in the metropolitan area needs to serve a certain scale of cross-region commuter passenger flow. It is necessary to develop a new bus type with a design speed of 160–200 km h^{-1} (Fig. 11) to meet the requirements of large capacity, fast start and stop, fast boarding and landing [7], and large standing space.

With the bus transit operation mode, the frequency of train departure should be increased to ensure that the shortest departure interval does not exceed 10 minutes during peak hours. The multi-route network operation mode should be adopted to enable passengers to choose different trains according to their demands, such as non-stop, stopping at major stations, and stopping at each station. Meanwhile, integrated transportation cards should be launched in metropolitan area rail transit, urban buses, and urban rail transit, enabling passengers to enter a station by swiping a card. In addition, low fare and transfer preferential policies should be carried out to attract routine commuters and cross-region leisure passengers.

To maximize the composite functions of metropolitan rail transit, attempts can be made to replace urban rail transit services with metropolitan rail transit. The key is to set stations with a differentiated section-based approach and adopt a long-short route pattern (Fig. 12). For example, in the urban area, the distance between rail transit stations in the metropolitan area can be reduced to about 2 km, with overtaking lines set up. In the suburban area, the distance between stations should be increased to more than 5 km. With high/ regular-speed railway line mode, passengers can transfer to a short route at an urban rail transit hub station, or take a non-stop train from a hub station to a minor station in an urban area. Lines between short routes can also be run in the urban area in place of urban rail transit services.

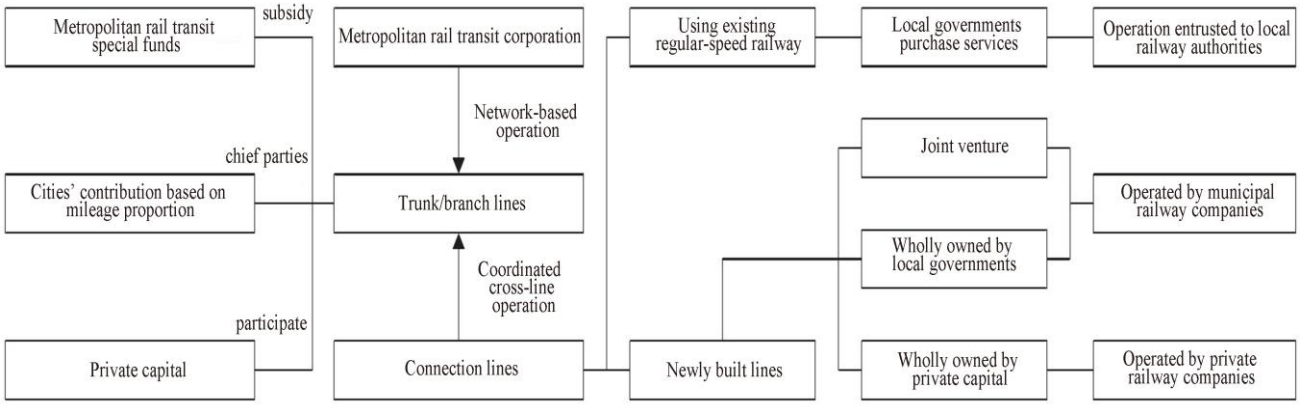


Fig. 10 Construction and operation mode of rail transit in metropolitan area

a Widen carriage doors on both sides

b Expand standing space

Fig. 11 Train model sample of metropolitan rail transit with bus transit operation mode

Data source: CRH6F-A intercity EMUs of CRRC Qingdao Sifang Co., Ltd

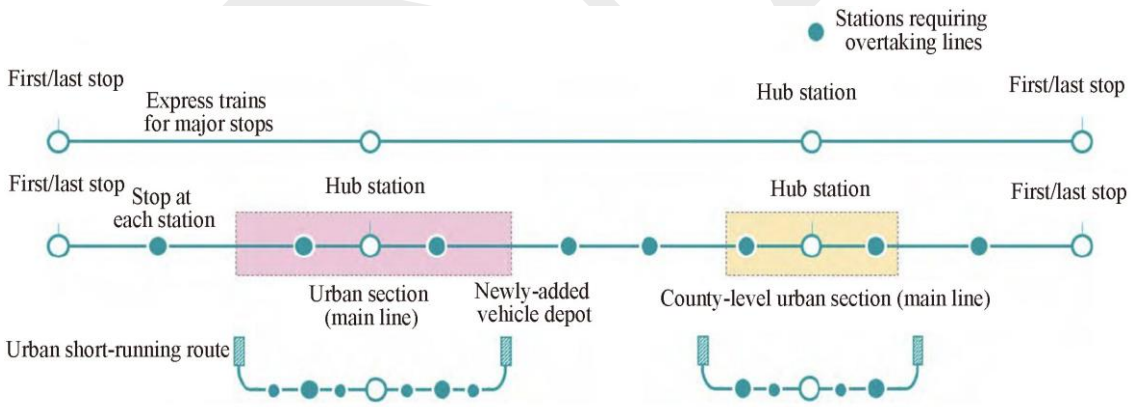


Fig. 12 Organization mode of rail transit lines with urban rail transit replaced by metropolitan area rail transit

5 Conclusion

The integration of intercity railway and urban (suburban) railway in a metropolitan area will be an inevitable trend. With two-network integration, an optimal spatial format can be achieved to promote multi-center and multi-node transportation distribution. What is more, metropolitan area rail transit is the most flexible, economical, and convenient means of rail transit for cross-region medium- and short-distance mobility. With one network, intercity railways and urban (suburban) railways can complement each other, achieving higher operation benefits. Based on two-network integration, a reasonable and flexible metropolitan area rail transit network should be constructed. In terms of network layout, emphasis should be placed on the pattern featuring "integration of trunk railways, secondary extension, and supplementation by region". Rail transit systems within different levels of corridors should be standardized to realize interconnectivity. In terms of construction and operation mode, both the top-down approach and the bottom-up approach should be adopted to promote

the healthy and rapid development of the two networks and meet the demands for diversified connections in the metropolitan area and the urban area.

References

[1] CAI R L, ZHANG C. 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] Leading Group Office of the Spatial Cooperative Plan of Greater Shanghai Metropolitan Area. Spatial Cooperative Plan of Greater Shanghai Metropolitan Area [R]. Shanghai: Shanghai Municipal Bureau of Planning and Natural Resources, 2021. (in Chinese)

[3] National Railway Administration of the PRC. Code for design of suburban rail: TB 10624—2020 [S]. Beijing: China Railway Publishing House Co., Ltd., 2021: 1–2. (in Chinese)

[4] Shanghai Branch, China Academy of Urban Planning. Plan for State-level High-speed Railway Pivotal Cities and Four-network Integration [R]. Suzhou: Suzhou Municipal Bureau of Natural Resources and Planning, 2021. (in Chinese)

[5] Railway characteristics and implications of Tokyo Metropolitan Urban (suburban) railways [EB/OL]. (2019-06-20) [2021-10-08]. https://www.sohu.com/a/321902473_281835. (in Chinese)

[6] Shanghai Branch, China Academy of Urban Planning. Plan for multi-layer rail transit integration in Wuxi city [R]: Wuxi: Wuxi Transportation Bureau, 2021. (in Chinese)

[7] DOU X. The first 160 km/H intercity EMU rolled off the production line [J]. Electric Drive for Locomotives, 2013 (4): 31. (in Chinese)

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