Key Issues and Strategies for the High-Quality Development of High-Speed Rail Passenger Hubs

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Abstract. A review of urban development stages and passenger travel characteristics indicates that the future planning, construction, and operation of high-speed rail passenger hubs must place greater emphasis on sustainability, integrated efficiency, and passenger experience. With high-quality hub development as the overarching objective, this paper defines the requirements for greater sustainability, higher efficiency, and a better passenger experience, and proposes corresponding strategies. First, the siting of integrated hubs should be coordinated with the urban center system; the scale and functional mix of integrated development should be determined prudently; and spatial layouts should retain flexibility for future adaptation. Second, scientific site selection, compact layouts, refined design, and intelligent operations should be used to shorten travel distances and waiting times at every stage of the passenger journey. Third, passenger experience should be improved through appropriate spatial scales, convenient transfer organization, diversified facilities and services, nature-oriented place-making, and precise information provision. Continuous improvement of hub planning, construction, operation, and management through digital and intelligent technologies will be an important direction for future development.

Keywords: transportation planning; high-speed rail passenger hub; sustainability; high efficiency; passenger experience; intelligent operation.

Chinese Library Classification: TU984. Document code: A. DOI: 10.16361/j.upf.202405007. Article number: 1000-3363 (2024) 05-0047-08.

After nearly two decades of rapid growth, China has made remarkable achievements in high-speed rail, greatly improving the convenience of intercity travel. Between 2012 and 2022, the share of high-speed rail passengers in total railway passenger traffic rose from 20.5% to 76.2% [1], making high-speed rail the dominant mode of railway passenger transport. By the end of 2022, the operational network had reached 42,000 km and included 1,188 high-speed rail passenger stations. By 2035, the network is expected to reach 70,000 km, with more than 2,000 passenger stations [2]. In addition, several conventional railway stations built at an earlier stage and located in central urban areas, including Guangzhou and Chongqing stations, now face opportunities for renewal. China will therefore remain in a period of substantial opportunity for high-speed rail passenger hub construction.

For multiple reasons, however, some existing hubs display evident deficiencies. Certain stations are located far from the main urban area; the development performance of high-speed rail new towns varies considerably; and some hubs are oversized or provide inconvenient access and transfers [3-4]. In light of evolving urban and transport conditions, it is necessary to identify systematically the key issues and strategic responses associated with high-quality hub development, thereby guiding future construction and operation.

1 Development Trends and Requirements

1.1 Cities have entered a stock-oriented development stage, while travel characteristics continue to change, requiring sustainable hub development

After more than four decades of rapid growth, Chinese cities have, on the whole, entered a stock-oriented stage of development. At the same time, urban travel characteristics continue to evolve under the combined influence of economic conditions, public policy, and technological change. High-speed rail hub planning and construction must therefore emphasize sustainability: hubs should respond to the requirements of urban development in the stock era while remaining adaptable to future changes in transport demand and behavior.

1.1.1 Stabilizing urban populations and construction land, together with tighter fiscal constraints, require rational decisions on hub location and scale

As cities enter the stock-oriented stage, population and construction land are tending toward stability. According to the National Bureau of Statistics, during the 13th Five-Year Plan period China's population growth rate declined from 0.7% in 2016 to 0.1% in 2020, and the national population gradually stabilized [1] (Figure 1). Meanwhile, the delineation of the three control zones and three control lines has largely fixed urban development boundaries, strictly limiting new urban land. Large-scale development of new districts beyond existing built-up areas is therefore unlikely. In addition, as the national economy has entered a new normal, fiscal pressure on governments at all levels has increased. During the 13th Five-Year Plan period, the share of transport expenditure in total public expenditure declined progressively [1] (Figure 2). Under tight fiscal constraints, cost reduction and efficiency improvement have become general requirements across sectors, and urban infrastructure investment must give greater attention to economic returns.

The stock-development context raises two questions for high-speed rail passenger hubs. On the demand side, the stabilization of population and construction land makes it uncertain whether high-speed rail demand can continue to grow at earlier rates. On the supply side, simultaneous constraints on land and public finance require tighter control over land take and investment. New hubs should therefore not be located far from the main urban area, and their scale should not be excessively ahead of actual demand, so as to avoid inefficient investment.

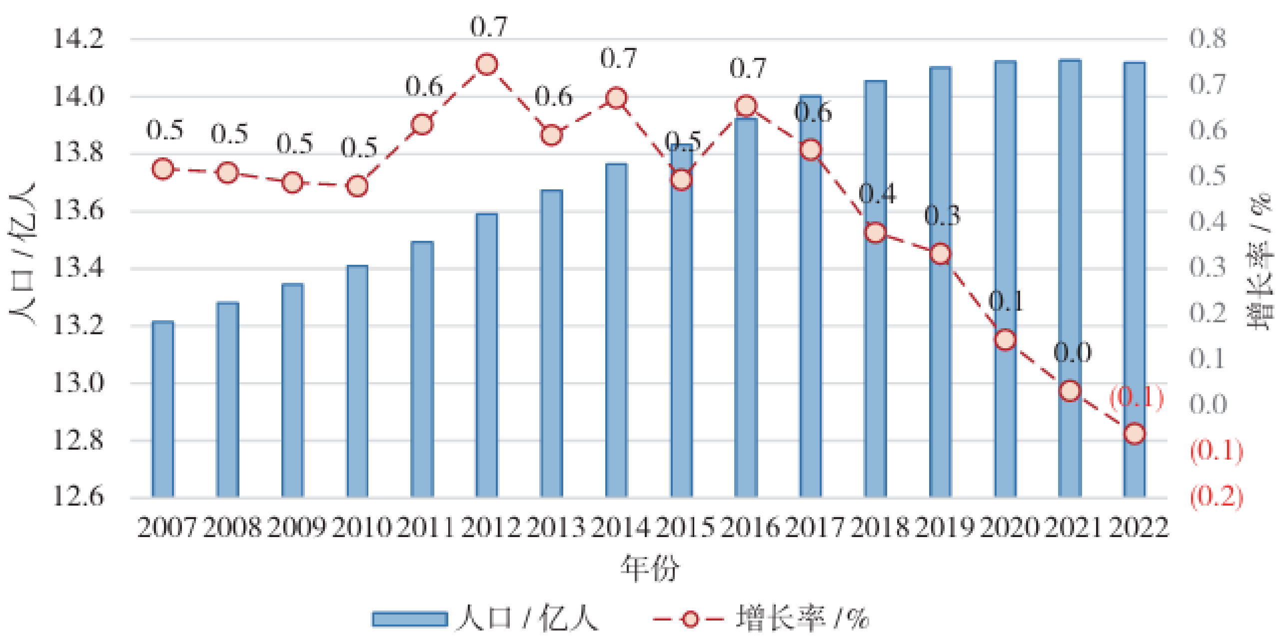

Figure 1. Trend in China's total population, 2007-2022

Source: compiled from the China Statistical Yearbook 2022 [1].

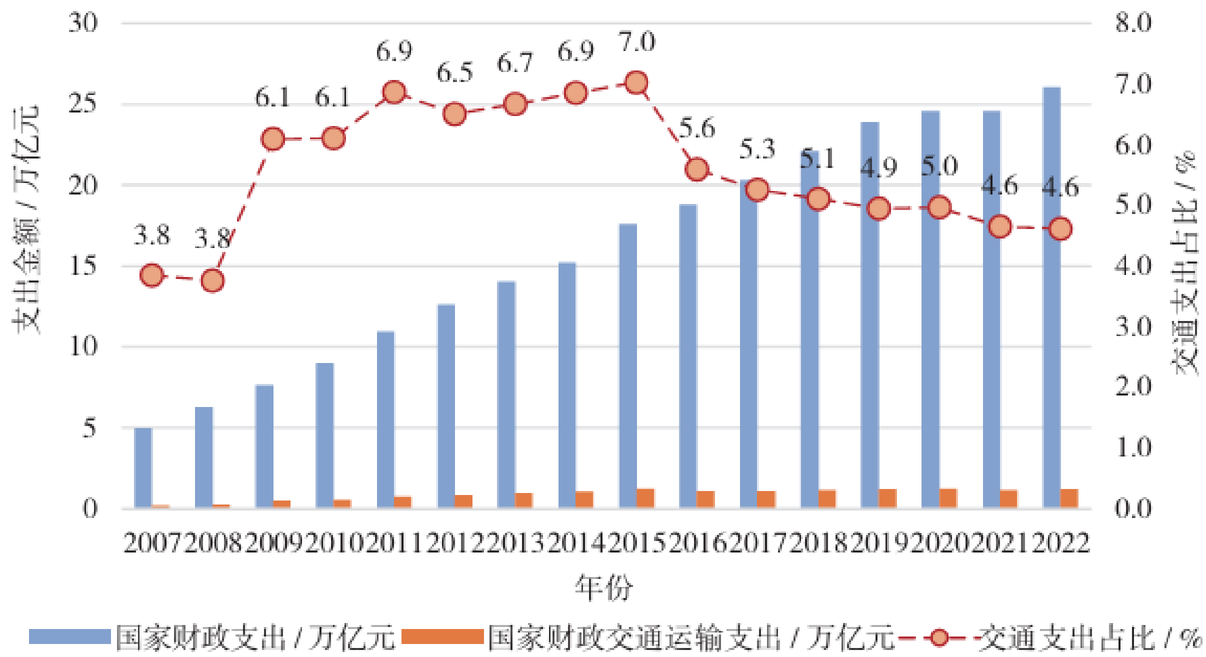

Figure 2. Share of transport expenditure in China's total fiscal expenditure, 2007-2022

Source: compiled from the China Statistical Yearbook 2022 [1].

1.1.2 Dynamic travel characteristics require hubs to retain flexibility for change

Continuing changes in travel patterns arise principally from three sources. First, shifts in regional economies, industrial distributions, and population patterns alter the total volume of regional transport demand. Second, new regional transport infrastructure induces changes in the scale and structure of demand. Third, changes in urban economic activity, transport infrastructure, technology, and policy reshape travel behavior; examples include expansion of metro networks, rapid growth in shared mobility, and changes in parking-pricing policy. Hub layouts and facility capacity should therefore retain sufficient flexibility to accommodate future changes in access modes and passenger flows.

1.2 New-type urbanization is generating frequent intercity travel, placing higher demands on hub service efficiency

As economic and social development proceeds and the railway network improves, the frequency of rail travel in major cities is generally increasing (Figure 3). This increase, together with the rising share of high-speed rail in total railway passenger traffic [1], demonstrates the growing importance of high-speed rail in everyday travel. Integrated hubs are critical to the efficiency of passenger transport. Only by improving their operating efficiency can the speed advantage of high-speed rail be fully realized across the entire door-to-door journey.

China's urbanization has also entered a stage in which urban agglomerations constitute the principal spatial form. The regionalization of economic activity has generated substantial cross-city commuting and business travel, creating a large and increasingly routine market for frequent, short- and medium-distance intercity journeys. Surveys show pronounced cross-city commuting in China's three largest urban agglomerations: approximately 100,000 trips per day between Beijing and Tianjin [5], 137,000 between Shanghai and Suzhou [6], and 200,000 across Shenzhen, Dongguan, and Huizhou [7]. Railway passenger statistics further show that between 2019 and 2023, the share of Shenzhen's outbound rail passengers traveling within Guangdong Province or to Hong Kong and Macao rose by 6.5 percentage points (Figure 4). This suggests that intercity demand will continue to increase with regional integration. Because such travelers are highly sensitive to time costs, they demand particularly efficient hub services.

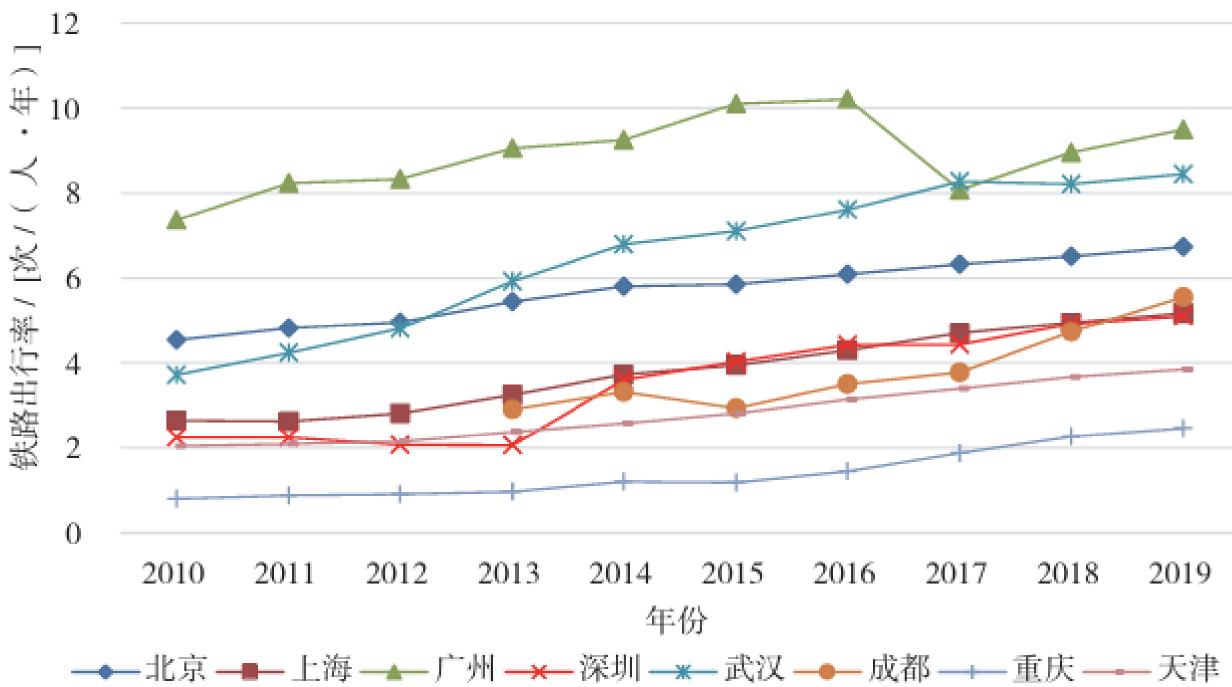

Figure 3. Trend in per capita railway travel frequency in selected cities

Source: compiled from municipal statistical yearbooks and statistical bulletins.

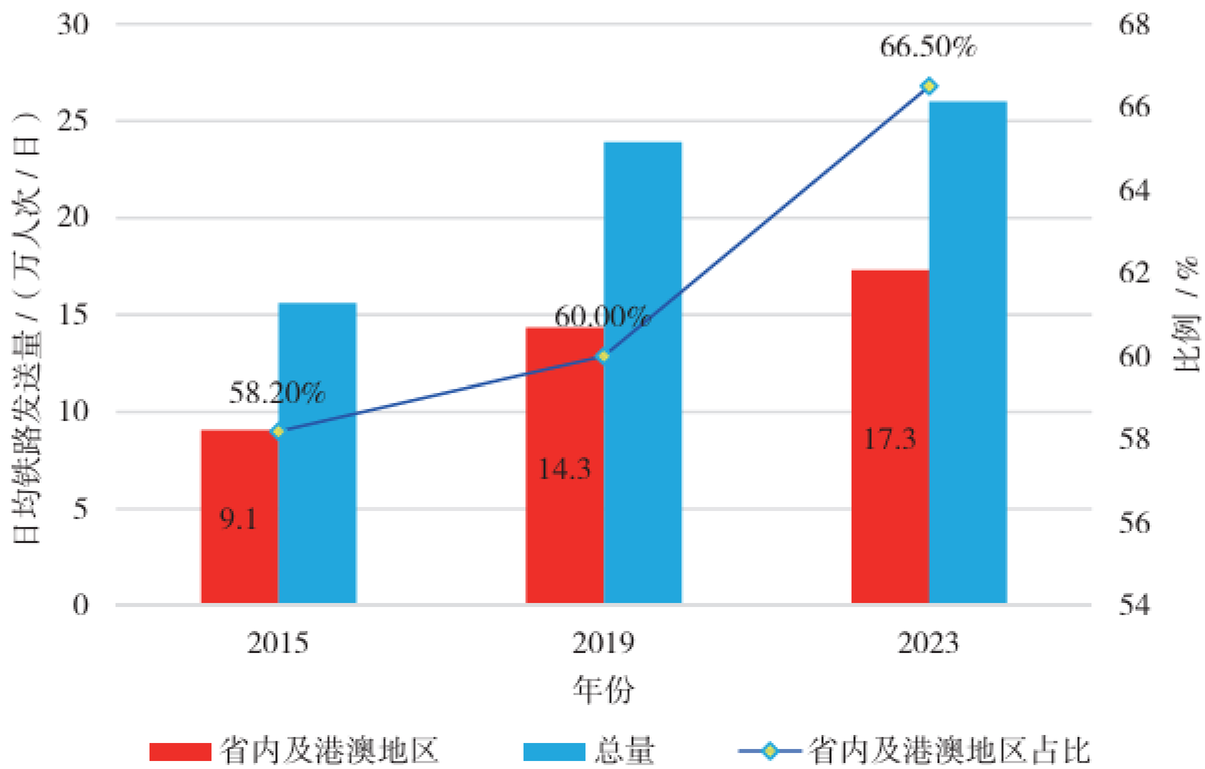

Figure 4. Average daily outbound railway passenger volume in Shenzhen and the share traveling within Guangdong, Hong Kong, and Macao

Source: compiled from data supplied by China Railway Guangzhou Group.

1.3 Diversified passenger groups and service needs require varied services and stronger attention to passenger experience

The diversity of high-speed rail passengers leads directly to diversified service requirements. On the one hand, China's high-speed rail network covers regions that differ greatly in economic conditions, population structure, and transport services. Passenger groups therefore vary in travel distance, frequency, and other characteristics (Figure 5). On the other hand, high-speed rail serves business travel, tourism, family visits, commuting, and migrant work. Different groups have increasingly varied needs regarding access modes (Figure 6), supporting services, and the overall travel experience [8-9].

Hub development and operation must accordingly place greater emphasis on differentiated services and passenger experience. Improvements are required not only in architectural layout and physical facilities, but also in operating models. In response to the new technological revolution led by digitalization and its transformation of transport infrastructure, hubs should expand pathways for digital governance and innovate organizational models of operation [10]. Intelligent technologies can support innovation in the concepts, models, and instruments of hub construction, operation, and management, thereby improving service quality and passenger experience.

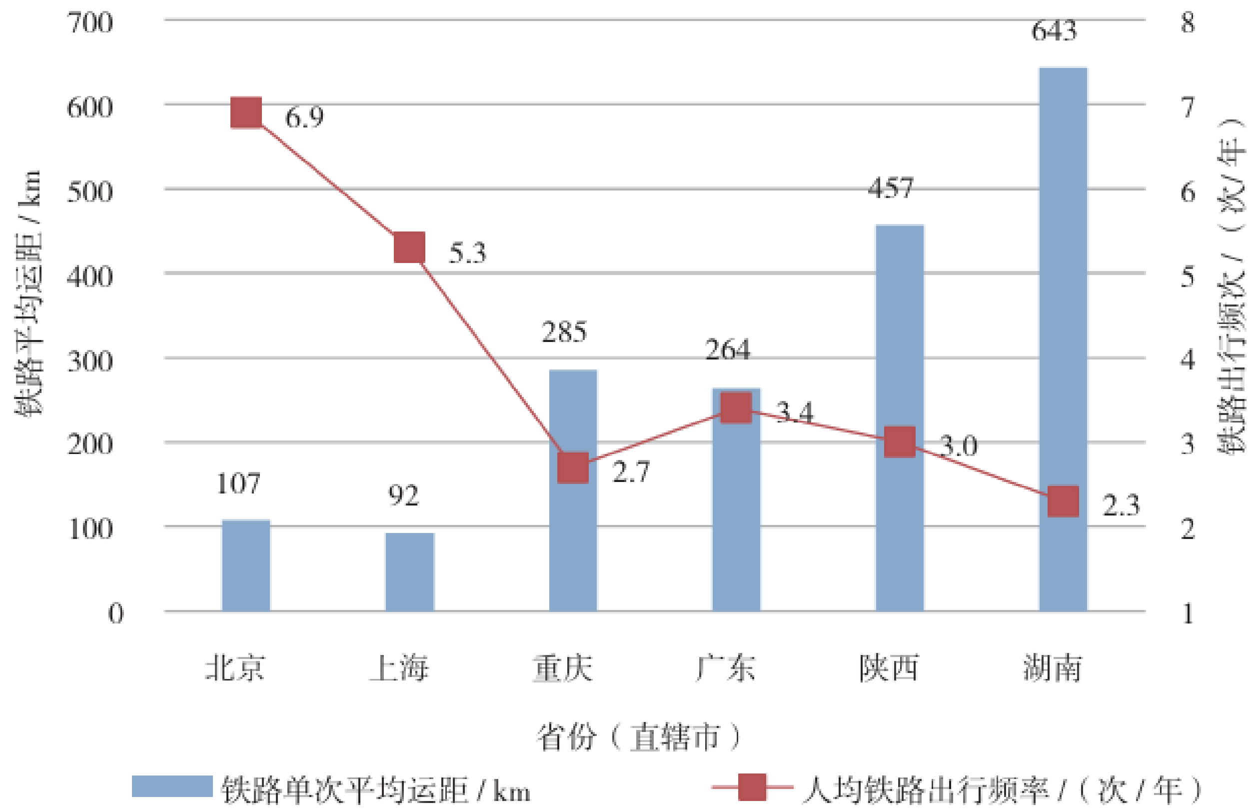

Figure 5. Average railway travel distance and per capita travel frequency in selected regions in 2019

Source: compiled from data published by provincial and municipal statistical bureaus in 2019.

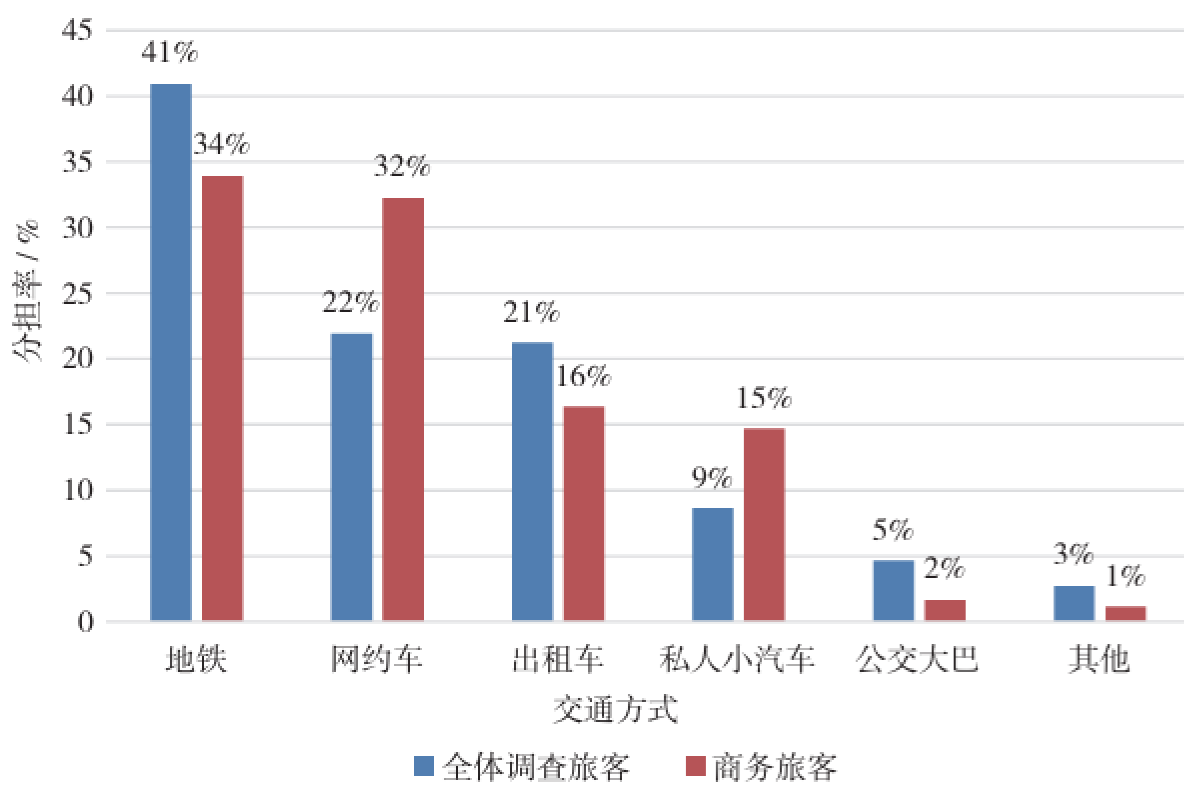

Figure 6. Mode shares for departing high-speed rail passengers at Shenzhen North Station by passenger group

Source: questionnaire survey conducted in November 2023.

2 Key Issues and Strategic Responses

Under the new conditions, the development logic of high-speed rail passenger hubs must shift from rapid, large-scale construction and experience-based operation toward refined construction and intelligent operation. It must also respond to the differing concerns of stakeholders. Government agencies and operators focus on investment efficiency, operational sustainability, and performance, whereas passengers expect efficient services and a good experience. High-quality hub development must therefore address three central issues: sustainability, operational efficiency, and passenger experience.

2.1 Developing more sustainable hubs

Sustainability is the foundation of high-quality hub development. To maximize the social benefits of hub investment and maintain viable long-term operation, scientific siting and development strategies are essential. Hubs should correspond to the city's stage of development and remain capable of adapting to future change. The following discussion focuses on siting, integrated development, and resilience (Figure 7).

2.1.1 Coupling hub locations with primary and secondary urban centers provides the basis for sustainable development

The location of a high-speed rail passenger hub directly determines its effective service area and the scale of the passenger market it can attract, and is therefore fundamental to sustainability. Coordinated development between high-speed rail hubs and urban centers has become a broad professional consensus [11-12]. New hubs should be located, wherever possible, within existing primary or secondary urban centers, avoiding the passenger-demand risk and investment waste associated with remote suburban sites.

2.1.2 Development scale and functional mix should be determined prudently

High-speed rail new towns and three-dimensional integrated station development have become prominent topics, but successful examples remain limited. The key is to understand objectively the meaning and internal logic of station-city integration and transit-oriented development (TOD) [8, 13]. China's national high-speed rail hubs primarily serve infrequent, medium- and long-distance trips with diverse purposes. They differ from intercity and urban rail hubs, which mainly serve frequent short- and medium-distance commuting and business travel and thus provide the principal foundation for urban TOD.

Major national high-speed rail hubs should give priority to transport functions and approach high-speed rail new town development cautiously, avoiding the introduction of excessive urban functions and additional passenger flows. Where integrated development is undertaken, its scale should correspond to the population and industrial base of the service area, and its functional mix should respond to actual local demand. Excessive development places substantial pressure on hub construction and operation, while homogeneous commercial programs may lead to vacant buildings and inefficient investment.

2.1.3 Hub facilities should be resilient to future change

Urban economic development, demographic change, technological innovation, and transport-policy adjustment may all alter passenger volumes and access characteristics. Current facility capacities and layouts may therefore not match future needs. Hub planning and construction should explicitly incorporate resilience, minimize fixed and rigid barriers, and reserve flexibility for low-cost adaptation.

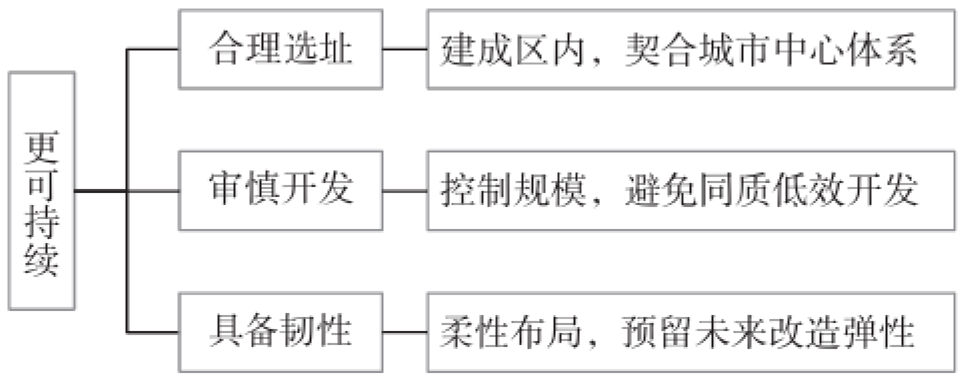

Figure 7. Goal-measure-technology roadmap for developing a more sustainable hub

2.2 Developing more efficient hubs

Efficiency is a core component of high-quality hub development. Three factors largely determine integrated hub efficiency. First, site selection affects the distance and time of urban access and is the basic determinant. Second, spatial layout and transfer organization determine walking distances and transfer times between the high-speed rail concourse and access terminals, as well as the processes and time required to enter and leave the station; these are the core determinants. Third, the scheduling and organization of access services determine waiting times between modes. Efficient hubs therefore require scientific siting, compact facility layouts, fine-grained transfer design, and intelligent operational control, so that travel distances and waiting times are reduced at every link of the complete journey (Figure 8).

2.2.1 Planning and design

At the macro scale, hubs should be located close to primary or secondary urban centers, allowing passengers to use nearby stations and reducing access distance and time within the city. At the meso scale, hub capacity should be appropriate and the layout compact, minimizing walking distances and times for entry, exit, and transfer. At the micro scale, access facilities and transfer routes should be designed around human needs; routes should be clear, direct, and short.

2.2.2 Operation and management

First, intelligent operational dispatch should be implemented. An integrated smart dispatch platform should monitor real-time travel demand and capacity on both the railway and urban-access sides. High-precision passenger-flow warnings and multimodal contingency plans can support timely dynamic scheduling and improve overall operating efficiency. Second, multi-actor collaborative management should be strengthened. Operating and management policies for the various modes within a hub should be coordinated, and management requirements and service standards should be made as consistent as possible across terminals.

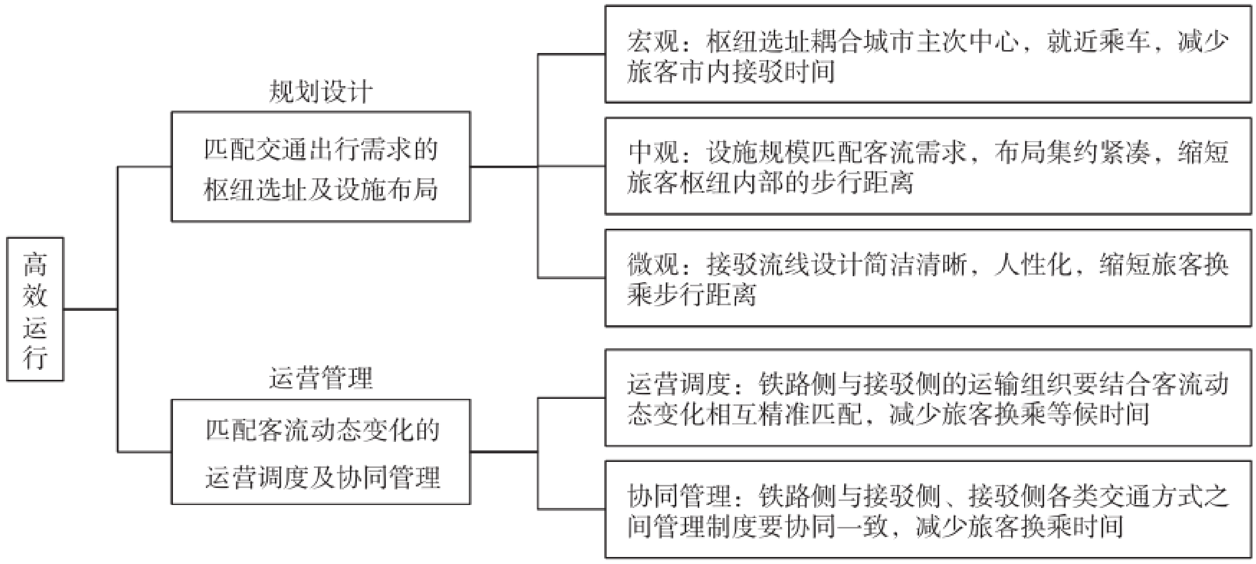

Figure 8. Goal-measure-technology roadmap for developing a more efficient hub

2.3 Developing hubs that provide a better passenger experience

Creating a good travel experience is the ultimate objective of high-quality hub development. Passengers frequently criticize oversized stations, long walking distances, prolonged queues, repeated security screening, inefficient transfers, and unclear guidance. Improving experience requires a differentiated understanding of how passenger groups perceive the hub environment and comprehensive improvement in spatial scale, facility layout, information services, and place-making (Figure 9).

2.3.1 Hub design should maintain appropriate spatial scales and passenger densities

Appropriate spatial dimensions and reasonable passenger densities help passengers feel safe and comfortable. Overly large spaces create a sense of emptiness, and visual blind spots may pose safety risks. Passenger sightline simulation can identify such residual spaces in advance and support targeted improvements. Excessive crowding in congregation areas creates anxiety, undermines dignity, and may produce stampede risks. Comfortable density standards differ among transport environments. High-quality international airport waiting areas, for example, provide substantially more space per passenger than railway waiting halls (Table 1). Pedestrian simulation can visualize spatial densities and support optimization of hub layouts.

Table 1. Passenger-comfort design standards for transport spaces

Relevant standard	Facility or space	Area standard (m^2/person)
Code for Design of Metro (GB 50157-2013)	Platform	0.33-0.75
Quality of Service for Civil Transport Airports (MH/T 5104-2013)	Terminal waiting area	≥1.0
Quality of Service for Civil Transport Airports (MH/T 5104-2013)	First-class and business-class lounge	≥5.0
Code for Design of Railway Passenger Stations (TB 10100-2018)	Waiting area (hall or room)	≥1.2
IATA airport level-of-service indicator	Terminal waiting area	≥1.9

2.3.2 Hub layouts should provide convenient transfers and diverse services to meet varied passenger needs

Transport service is the fundamental function of a hub, and efficient transfer is the core passenger requirement. Food and beverage, shopping, rest, temporary work, and other services are also derived needs. In response to the diversity of passenger groups, hubs should introduce an appropriate mix of consumption, rest, entertainment, and public-service functions. This allows passengers the freedom to leave immediately or remain in the hub and makes services easier to access.

2.3.3 Intelligent technologies should provide precise information and improve the travel experience

Precise information services allow passengers to obtain real-time hub information quickly and to choose access modes and station routes with confidence. First, dynamic access-information systems should display walking distances, queue conditions, and waiting times for each mode, guiding passengers toward appropriate choices. Second, hubs should develop three-dimensional panoramic visualization and guidance systems. Through mobile apps, passengers can check the operating status of entrances and exits, security areas, concourses, transfer corridors, and access facilities, and choose faster routes. Third, Mobility as a Service (MaaS) reservation platforms should match urban access services more precisely with high-speed rail operation and shorten transfer waiting times.

2.3.4 Hub environments should integrate natural ecology and create high-quality places

Green and low-carbon principles are important directions in hub architecture. Introducing daylight, fresh air, and vegetation enables passengers to engage with nature and reduces travel-related tension and fatigue. Comfortable seating, artworks, sculpture, and other elements can create warm, high-quality environments and overcome the monotonous spatial character of many early railway stations.

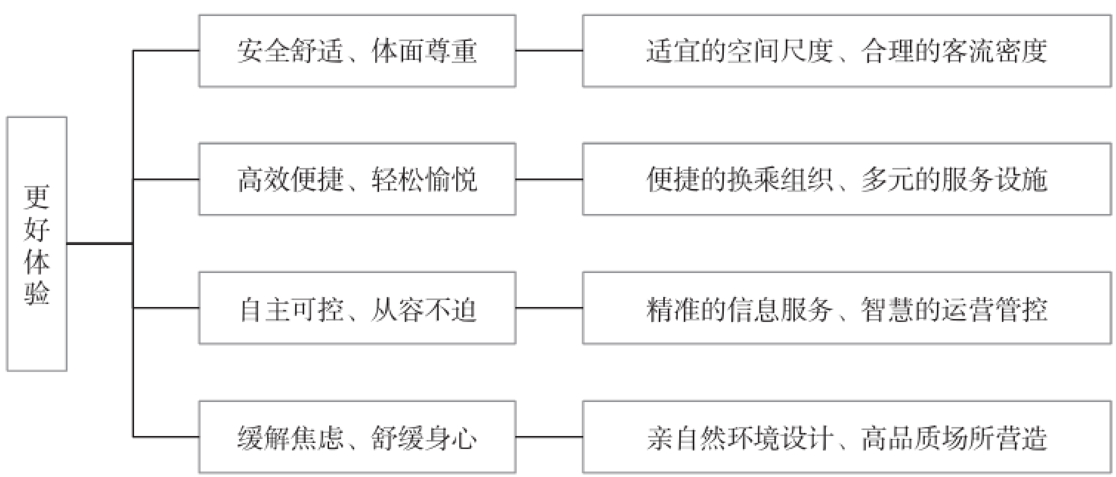

Figure 9. Goal-measure-technology roadmap for developing a hub with a better passenger experience

3 Practical Experience and Exploration

3.1 Practices for developing sustainable hubs

3.1.1 Hub siting coordinated with the urban spatial structure and center system

Shenzhen has long emphasized the interaction between railway hubs and its urban center system, and hub construction has effectively supported the development of primary and secondary centers. The reconstruction of Shenzhen Railway Station around 1990 promoted Luohu, the city's earliest central area. Shenzhen North and Futian stations, selected and built after 2000 [14], are located respectively in the Longhua secondary center and the Futian primary center. The 2021 Shenzhen Territorial Spatial Master Plan proposed a railway passenger hub system of five primary and five supporting hubs [15]. The ten hubs are closely coordinated with urban centers at different levels (Figure 10), providing a foundation for sustainable development.

Some high-speed rail hubs elsewhere in China were never opened after completion or were closed after only a short period of operation, failing to produce timely benefits. Remoteness from urban centers, delayed surrounding development, and weak passenger demand are major reasons. A review of twenty completed but unused high-speed rail or intercity stations shows that twelve are more than 20 km by road from their city centers (Table 2). Future hub siting should avoid this problem.

Figure 10. Coupling relationship between Shenzhen's railway hubs and urban center system

Table 2. Distance from the city center of twenty completed but unused or subsequently closed high-speed rail stations in China

No.	Station	Location	Service line	Operational status	Road distance to city center (km)
1	Hele	Hele Town, Wanning	Hainan Eastern Ring High-Speed Railway	Completed but never opened	26
2	Shushan East	Shushan District, Hefei	Hefei-Fuzhou High-Speed Railway	Completed but never opened	2

No.	Station	Location	Service line	Operational status	Road distance to city center (km)
3	Zijinshan East	Qixia District, Nanjing	Shanghai-Wuhan-Chengdu High-Speed Railway	Completed but never opened	16
4	Jiangpu	Pukou District, Nanjing	Shanghai-Wuhan-Chengdu High-Speed Railway	Completed but never opened	37
5	Lile	Jianghai District, Jiangmen	Guangzhou-Zhuhai Intercity Railway, Jiangmen branch	Completed but never opened	5
6	Jianghai	Jianghai District, Jiangmen	Guangzhou-Zhuhai Intercity Railway, Jiangmen branch	Completed but never opened	13
7	Jinning East	Jinning District, Kunming	Kunming-Yuxi High-Speed Railway	Completed but never opened	23
8	Yangzong	Yangzong Town, Kunming	Nanning-Kunming High-Speed Railway	Completed but never opened	35
9	Yizhuang	Beijing Economic-Technological Development Area	Beijing-Tianjin Intercity Railway	Completed but never opened	28
10	Shenyang West	Yuhong District, Shenyang	Beijing-Shenyang High-Speed Railway	Opened briefly, then closed	46
11	Wulanmutu	Fumeng County, Fuxin	Beijing-Shenyang High-Speed Railway	Opened briefly, then closed	50
12	Nailingao	Chaoyang County, Chaoyang	Beijing-Shenyang High-Speed Railway	Opened briefly, then closed	67
13	Dandong West	Zhenxing District, Dandong	Dandong-Dalian Express Railway	Opened briefly, then closed	12
14	Huaqiao	Kunshan, Suzhou	Shanghai-Nanjing Intercity Railway	Opened briefly, then closed	12

No.	Station	Location	Service line	Operational status	Road distance to city center (km)
15	Baohuashan	Jurong, Zhenjiang	Shanghai-Nanjing Intercity Railway	Opened briefly, then closed	41
16	Yunlianghe	Longting District, Kaifeng	Zhengzhou-Kaifeng Intercity Railway	Opened briefly, then closed	12
17	Jialuhe	Zhengdong New District, Zhengzhou	Zhengzhou-Kaifeng Intercity Railway	Opened briefly, then closed	26
18	Nancao	Zhengzhou Economic-Technological Development Zone	Zhengzhou-Airport Intercity Railway	Opened briefly, then closed	26
19	Mengzhuang	Zhengzhou Airport Economy Zone	Zhengzhou-Airport Intercity Railway	Opened briefly, then closed	34
20	Jiulangshan	Shifeng District, Zhuzhou	Changsha-Zhuzhou-Xiangtan Intercity Railway	Opened briefly, then closed	15

3.1.2 Sustainable development and retrofit of Shenzhen North Station Hub

Shenzhen North Station Hub is a very large high-speed rail hub that entered operation in 2011. Its compact layout and public-transport-oriented access became influential examples for hubs built during the same period. As development and passenger volumes around the station exceeded expectations and access patterns changed, however, the area developed several problems, including concentrations of office buildings, local congestion, and underused terminals. Government departments and the hub operator subsequently implemented differentiated land development, diversified operation, and transfer-terminal retrofits. These measures provide useful lessons for other Chinese high-speed rail passenger hubs.

(1) Differentiated development of land around the hub. Construction of Shenzhen North Station strongly stimulated urban development in the surrounding area. Within 2 km², approximately 3.5 million m² of floor space was developed, principally for offices and housing. Development exceeded expectations, placing heavy pressure on local roads and reducing the efficiency of passenger distribution. At the same time, Shenzhen's office stock has continued to increase while occupancy rates have declined. To avoid excessive transport pressure and resource waste caused by homogeneous development, municipal and district governments changed part of the commercial-office land originally planned on the east square into public-facility land and green space and introduced municipal cultural facilities, thereby differentiating land uses.

(2) Full use of spatial resources for diversified operation and self-financing. On the one hand, the hub operator continues conventional activities, including management of supporting car parks and leasing commercial space on the east square, generating relatively stable revenue. On the other hand, it has expanded revenue channels to offset operating deficits. In June 2024, taking advantage of Shenzhen's promotion of the low-altitude economy, Shenzhen Metro Group and a general-aviation company developed China's first low-altitude-plus-rail air-rail intermodal project on the deck above the taxi terminal on the east square [16]. The project provides one-stop connections between aviation and rail, while the hub operator receives income from site leasing and ticket sales.

(3) Low-cost retrofit of access terminals. In response to rapid growth in ride-hailing and the marked decline of long-distance coach demand, Shenzhen North Station converted the central section of the basement public car park beneath the west square and part of the surface coach terminal into ride-hailing pick-up areas. This low-cost retrofit improved ride-hailing access while avoiding inefficient use of the car park and coach terminal, thereby adapting the hub to new access conditions.

3.2 Planning and design experience for efficient hubs

Experience and lessons from the planning, design, and operation of Shenzhen North and Futian hubs, together with recent exploration at Xili Hub, offer useful references for the construction and operation of high-speed rail passenger hubs in China.

3.2.1 Appropriate scale and compact layout

Shenzhen North Station has eleven platforms and twenty tracks and adopts a vertically layered arrangement [17]. Transfer distances between access terminals and the high-speed rail concourse are generally kept within 200 m, and transfer times within five minutes. Scale control and compact organization therefore secure convenient passenger transfers.

3.2.2 Fine-grained design of access and transfer organization

(1) Urban rail access. Large hubs should limit the number of connecting urban rail lines to avoid concentrating multiple lines at a single point and creating operational safety risks. Where several lines are introduced, their stations should form a network of distributed interchange points in the surrounding area. Shenzhen North Hub is served by metro lines 4, 5, and 6 [17]. The interchange between lines 4/6 and line 5 at Shenzhen North is also a structural interchange in the citywide network (Figure 11). Because both high-speed rail and metro demand exceeded expectations, high-speed rail access flows and internal metro interchange flows each exceed 200,000 passengers per day. The overlap of these two large flows creates severe crowding during peak periods, requires flow-control measures, worsens passenger experience, and increases operational complexity. By contrast, the urban rail network around Futian High-Speed Rail Hub forms a distributed, multipoint interchange pattern [18], avoiding the concentration of structural metro interchange flows and high-speed rail access demand (Figure 12).


N
0 1 2 5 km
6号线
4号线
深圳北站
5号线
运营线路

Figure 11. Layout of urban rail lines at Shenzhen North Station Hub

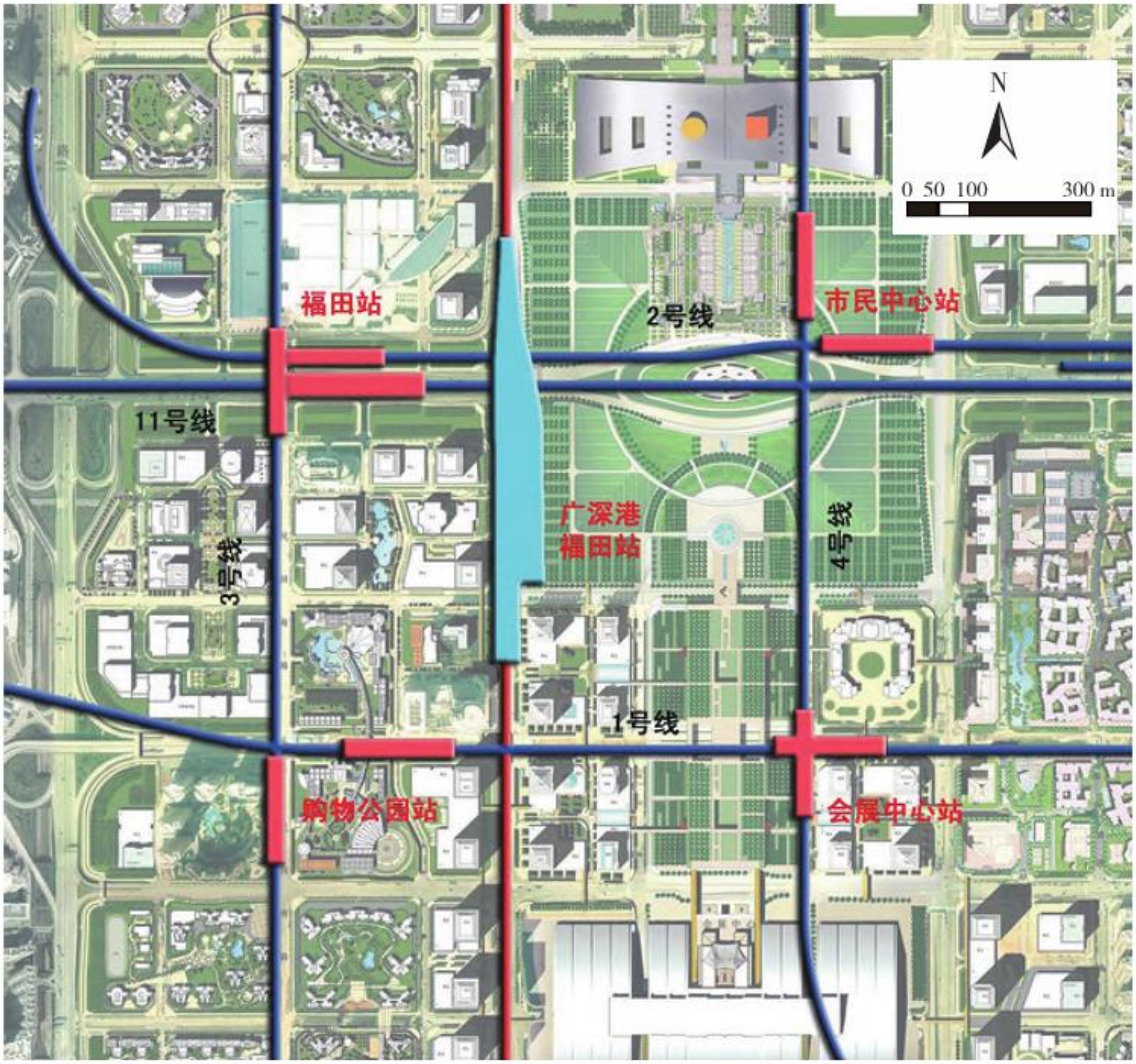

Figure 12. Layout of urban rail lines in the Futian High-Speed Rail Hub area

(2) Pedestrian access. Level entry and exit, which reduces vertical transitions and shortens walking distances, is critical to efficient transfer. Major access facilities should be placed, wherever possible, on the same level as the high-speed rail concourse. At Xili Hub, metro access is expected to account for 68% of high-speed rail passengers. The design places the high-speed rail arrival hall, the reserved express departure hall, and the metro concourse on the same level [19], allowing the principal transfer flows to move horizontally.

(3) Private-vehicle access. Private cars are an important means of access and should be accommodated rationally around the core requirements of rapid entry and exit and brief drop-off and pick-up. Xili Hub includes dedicated access ramps connecting directly to expressways and major roads, ensuring rapid access (Figure 13). Separate kiss-and-ride drop-off lanes are arranged on the east and west squares to allow convenient passenger entry [19].

Figure 13. Layout of dedicated rapid-access ramps at Xili Hub

(4) Bus access. Space in the hub core is limited and should primarily serve passengers. Xili Hub abandons the traditional model of a large combined bus terminal. It does not include a long-distance coach station; its bus terminal retains principally boarding and alighting functions, while the main vehicle-storage areas are located outside the core. The layout thus shifts from a large multifunctional terminal to a separation between bus terminus and bus layover yard [19].

3.3 Exploration of hubs with a better passenger experience

Chinese high-speed rail passenger hubs have undertaken extensive experiments to improve passenger experience, particularly through human-centered services, diversified services, and intelligent operation.

3.3.1 Providing human-centered operational services to facilitate travel

Many human-centered measures have been widely adopted, including assistance for passengers with special needs, nursing rooms, and convenient in-station transfers. Since 2010, Chinese cities have progressively introduced security screening for metro entry in accordance with laws and regulations. Although this increases perceived safety, it also reduces convenience. Passengers broadly expect transfers between high-speed rail and metro without repeat screening. Many hubs now allow high-speed rail passengers to enter the metro without additional screening. Tianjin West and Beijing Qinghe stations have implemented two-way screen-free transfers [20], significantly improving experience. During holiday peaks, Shenzhen North uses temporary measures to permit arriving high-speed rail passengers to transfer to the metro without re-screening and is studying permanent retrofits. The Xili Hub design reserves the spatial conditions for two-way screen-free transfer: screen-free high-speed rail-to-metro transfer can operate from opening, and two-way implementation can be introduced later as security policy evolves.

3.3.2 Creating high-quality places and providing diversified services

Today's large high-speed rail hubs provide not only transport transfer but also commercial consumption, public activity, cultural exchange, and urban image functions. Recent practice has explored how design can create high-quality places that offer comfortable environments and diversified services. Hangzhou West Station Hub, opened in 2022, uses the separation of the railway tracks to create a central transfer space known as Cloud Valley. Landscaping, a Party-mass service center, a high-speed rail museum, and other urban public facilities have been introduced, turning the area into a permanent exhibition space and a venue for regular events [21]. The Xili Hub design places public and cultural facilities at the ends of the station building [19], creating conditions for future cultural activities and public exchange, enriching hub services, and giving concrete form to station-city integration.

3.3.3 Implementing intelligent operational services to improve passenger experience

Intelligent hub operation covers passenger service, information monitoring, operational dispatch, and facility control. Shenzhen has recently explored intelligent operation in several hubs. At Shenzhen North, the city is promoting a dynamic passenger-information system that upgrades the static signage network with real-time access information, including walking distances, waiting times, and queue conditions for each mode, thereby guiding passengers toward appropriate choices. Shenzhen is also developing a MaaS travel-reservation platform for hubs, which will match supply and demand more accurately between railway services and urban access and shorten transfer waiting times.

4 Conclusion

Over the past two decades, China's high-speed rail network and passenger hubs have made major contributions to national mobility and urbanization. By identifying the key issues facing hub development, this paper proposes a systematic strategy for high-quality development across three dimensions: greater sustainability, higher efficiency, and a better passenger experience. Practical cases provide further lessons for future hub construction. As the new technological revolution led by digitalization transforms the transport sector, information and intelligent technologies will be increasingly important for improving hub planning, construction, operation, and service. Their continued application is a central direction for the high-quality development of China's high-speed rail passenger hubs.

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Revised: August 2024

AI-assisted translation