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## Strategic Optimization of Guangzhou Comprehensive Transportation Hub from the Perspective of the Guangdong–Hong Kong–Macao Greater Bay Area

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**Abstract:** This paper offers an extensive summary of the direction and strategies for function optimization and improvement of Guangzhou. The summary concentrates on the significant preposition of determining how to further optimize and improve the function of Guangzhou as a comprehensive transportation hub in the context of the coordinated development of the Guangdong–Hong Kong–Macao Greater Bay Area. The summary is based on the development experience in New York, London, Tokyo, and other world-class bay areas and the characteristics of different construction and development stages of Guangzhou as a hub. Firstly, the paper identifies four major shifts in the function of the comprehensive transportation hub in the new era, through an analysis of the flow characteristics of population, economy, industry, and other elements in the Guangdong–Hong Kong–Macao Greater Bay Area and Guangzhou. The four major shifts include the shift from competition and cooperation to coordinated development, the shift from scale expansion to quality improvement, the shift from facility connection to integrated services, and the shift from an emphasis on efficiency to a focus on effectiveness. Secondly, by summarizing the urban development experience of world-leading bay areas, the paper proposes that six aspects of comprehensive transportation hub function improvement should be prioritized: global connection capability, hub carrying capability, interconnection capability, capability to provide integrated services, capability to support the urban economy, and sustainable development capability. Finally, the paper establishes an indicator evaluation system with 18 key indicators of the function optimization and improvement of Guangzhou as a comprehensive transportation hub based on the six capabilities. The proposed method can help evaluate the challenges faced by Guangzhou and put forward corresponding suggestions, including improving the city level of Guangzhou as a hub, co-building and sharing resources, innovating integrated services, and strengthening the hub economy. The measures are expected to facilitate the high-quality development of Guangzhou. **DOI:** 10.13813/j.cn11-5141/u.2022.0407-en

**Keywords:** comprehensive transportation hub planning; functional evaluation; function optimization; Guangzhou; Guangdong–Hong Kong–Macao Greater Bay Area

### 0 Introduction

The Guangdong–Hong Kong–Macao Greater Bay Area <sup>[1]</sup> is one of the areas with the highest degree of openness and economic vitality in China, playing a leading role in implementing China's Belt and Road Initiative (BRI) and in building China's strength in transportation. Guangzhou should give full play to its leading role as a national central city and comprehensive gateway city to comprehensively enhance the function of an international comprehensive transportation hub, thus driving the Greater Bay Area to move towards the medium and high ends of the global value chain and industrial chain. The *National Comprehensive Three-dimensional Transportation Network Planning Outline of China* <sup>[2]</sup> proposed to build the international comprehensive transportation hub cluster of the Guangdong–Hong

Kong–Macao Greater Bay Area with Guangzhou, Shenzhen, and Hong Kong at the core to link cities such as Zhuhai and Macao. Specifically, Guangzhou carries the function of an international comprehensive transportation hub, serving as an international railway hub, international seaport hub, and international aviation (freight) hub.

As the south gate of China, Guangzhou is at the forefront of China in terms of passenger and freight volume, and its function as a comprehensive transportation hub is enhanced constantly. Therefore, under China's strategic orientation and the development background of the Greater Bay Area, we should respond to opportunities and challenges faced by the whole world and the whole country, explore strategies for optimizing the function of Guangzhou as a comprehensive transportation hub, plan major transportation facility projects and innovate systems and mechanisms in advance, and comprehensively enhance Guangzhou's global competitiveness

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and influence. In this way, we can ensure that Guangzhou plays a core driving role in the high-quality construction of the Guangdong–Hong Kong–Macao Greater Bay Area.

## 1 New connotation of comprehensive transportation hub from the perspective of the Guangdong–Hong Kong–Macao Greater Bay Area

### 1.1 Development background and demand of the Guangdong–Hong Kong–Macao Greater Bay Area

#### 1) New pattern and mission: participating in international cooperation and competition.

China's gross domestic product (GDP) in 2019 reached 14.4 trillion USD (1 USD is about 6.75 CNY), with a growth rate of 6%. This made China the second largest economy in the world. Specifically, the GDP of the Guangdong–Hong Kong–Macao Greater Bay Area was 1.68 trillion USD (see Table 1), accounting for 11.7% of China's total, with a growth rate of 6.6%. The economy of this area was of a large scale with strong growth. Compared with the economic scale of international bay areas, the economy scale of the Guangdong–Hong Kong–Macao Greater Bay Area was larger than that of the San Francisco Bay Area (0.88 trillion USD) and close to that of the New York Bay Area (1.72 trillion USD) or the Tokyo Bay Area (1.77 trillion USD) [3]. With its economic growth far ahead of that of the three major bay areas, the Guangdong–Hong Kong–Macao Greater Bay Area has become a new economic growth pole in the world.

**Table 1** Indicator comparison of major world-class bay areas and China's urban agglomerations in 2019

Region	Total area/ 10 000 km <sup>2</sup>	Total GDP/ trillion USD	Total population/ 100 million	Per capita GDP/ 10 000 USD	Number of invention patents % 10 000 pieces
New York Bay Area	3.45	1.72	0.23	7.35	4.3
San Francisco Bay Area	1.79	0.88	0.08	11.5	6.1
Tokyo Bay Area	3.67	1.77	0.35	5.05	14.7
Guangdong–Hong Kong–Macao Greater Bay Area	5.59	1.68	0.73	2.30	35
Beijing–Tianjin–Hebei urban agglomeration	21.8	1.23	1.13	1.09	
Yangtze River Delta urban agglomeration	35.8	3.44	2.27	1.52	

1) According to the *Report on Collaborative Innovative Development of Guangdong–Hong Kong–Macao Greater Bay Area (2020)*, the number of invention patents in the Greater Bay Area in 2019 was 2.38 times that of Tokyo Bay Area, 5.72 times that of San Francisco Bay Area, and 8.16 times that of New York Bay Area, ranking first in the world. Data sources: China's data came from the National Bureau of Statistics and Guangdong Statistical Information Network, while other data came from References [2–3].

In the post-epidemic era, with accelerated adjustment of the global economic pattern, China's economy has shifted to high-quality development. The Guangdong–Hong Kong–Macao Greater Bay Area undertakes the historical mission of building a world-class urban agglomeration,

further implementing the BRI construction, building China's strength in transportation, participating in international co-operation and competition at a higher level, and expanding international living space. In recent years, the Fourth Industrial Revolution, represented by information technology and digital technology, has become the most important new momentum of global economic growth. Relying on a large manufacturing basis and a strong innovation capacity, the Guangdong–Hong Kong–Macao Greater Bay Area has become the vanguard of the Fourth Industrial Revolution through the integration of “scientific and technological innovation + intelligent manufacturing + high-end services.”

#### 2) New opportunities and challenges: an urgent need to strengthen regional coordinated development and win-win cooperation

Compared with other major urban agglomerations in China and the three major bay areas in the world, the Guangdong–Hong Kong–Macao Greater Bay Area is at the forefront in terms of air passenger and freight throughput [4–6] and port container throughput [7]. Hong Kong International Airport and Guangzhou Baiyun International Airport (hereinafter referred to as Baiyun Airport) ranked 5th and 39th in the World's Best Airports of 2019 [8]. The Port of Hong Kong and Guangzhou Port ranked 2nd and 16th in the Xinhua–Baltic World's Port List [9] (see Table 2). Both transportation facility scale and integrated service capacity lead the world. However, compared with the international first-class bay areas, the Guangdong–Hong Kong–Macao Greater Bay Area shows a multi-center development trend, with homogeneous competition in some fields and to-be-strengthened cooperation. Guangdong Province, the Hong Kong Special Administrative Region, and the Macao Special Administrative Region are under the framework of “one country, two systems, and three separate customs territories.” Due to different social and legal systems, they belong to different customs territories, and the interconnection of their infrastructure and market rules needs to be improved.

### 1.2 Connotation of comprehensive transportation hub

A comprehensive transportation hub refers to a transition center of passenger and freight flow formed on a comprehensive transportation network node [10]. It has a well-connected network extending in all directions, a strong traffic radiation capacity, a collection of various transportation modes, and traffic transfer and supporting services. From the perspective of the Guangdong–Hong Kong–Macao Greater Bay Area, a comprehensive transportation hub should have not only traffic functions but also the following three characteristics.

1) A carrier of the national will and a gateway to the world. Transportation is a basic, leading, and strategic industry in the national economy, serving as an important service industry [2]. A comprehensive transportation hub is not only

an important carrier to speed up the building of China's strength in transportation but also an important means to implement the national strategic intention and optimize resource allocation.

**Table 2** Indicator comparison of airports and ports in the world-class bay areas and China's main urban agglomerations in 2019

Region	Name of airport	Ranking of World's Best Airports	Passenger throughput/100 million	Freight and mail throughput/10 000 tons	Port name	Ranking of Xinhua-Baltic World's Ports	Container throughput/10 million TEU
New York Bay Area	John F. Kennedy International Airport	74	0.62	143	Port of New Jersey	8	0.75
San Francisco Bay Area	San Francisco International Airport	48	0.57	54	Port of Auckland		0.25
Tokyo Bay Area	Haneda Airport	2	0.85	129	Port of Tokyo	11	0.36
	Narita International Airport	9	0.44	211			
	Hong Kong International Airport	5	0.61	459			
Guangdong-Hong Kong-Macao Greater Bay Area	Guangzhou Baiyun International Airport	39	0.74	192	Guangzhou Port	16	2.28
	Shenzhen Baoan International Airport	65	0.53	128	Shenzhen Port	22	2.57
Beijing-Tianjin-Hebei urban agglomeration	Beijing Capital International Airport	72	1.00	196	Tianjin Port	24	2.08
Yangtze River Delta urban agglomeration	Shanghai Hongqiao International Airport	16	0.46	42	Shanghai Port	4	4.33
					Ningbo Port	13	2.75

Data sources: References [5-9].

2) A base of regional coordinated development to promote the interaction of high-end elements. A comprehensive transportation hub provides collection-distribution and transfer services for personnel and material exchanges. It can promote accelerated aggregation and efficient interaction of passenger flow, freight flow, information flow, capital flow, and innovation elements, activate regional innovation capacity and vitality, and drive and support regional economic development.

3) An engine of high-quality urban development and a state-of-the-art platform of economic development. Transportation hubs such as airports, ports, and railways are important carriers of urban functions. Centering on the construction of comprehensive transportation hubs, we can reshape urban spatial and industrial layouts, work towards new heights of urban economic development and public services, and develop the "hub economy"<sup>[11]</sup>.

### 1.3 Functional shifts of comprehensive transportation hub

Given the interpretation of the connotation of the comprehensive transportation hub from a new perspective and the requirements of building a world-class bay area and an urban agglomeration for coordinated and win-win development, the comprehensive transportation hub should undergo four major shifts.

1) A shift from competitive cooperation to coordinated development. We should break through boundary barriers of

the Guangdong-Hong Kong-Macao Greater Bay Area to integrate and give full play to the resource advantages of various administrative regions. Moreover, we should promote the co-construction and sharing of major transportation infrastructure, the integration of cross-border (boundary) transportation services (passenger and freight flow), and the interconnection of market rules. Hence, we can promote economically and socially integrated development across administrative regions.

2) A shift from scale expansion to quality improvement. The establishment of a high-level, multi-layer, and modern comprehensive three-dimensional transportation system should not be limited to the construction of traffic hardware facilities. More attention should be paid to the direct interconnection of transportation networks, high-quality construction of facilities, integration of operation and management, and application of new transportation and digital technology.

3) A shift from facility connection to integrated service. We should realize zero-distance transfer for passenger transportation and seamless connection for freight transportation. Moreover, we should promote integrated passenger transportation services on the basis of travel experience, as well as multimodal logistics transportation services on the basis of supply chains. In this way, we can realize integrated services in different regions, with different modes of transportation and under different systems.

4) A shift from emphasizing efficiency to focusing on effectiveness. By integrated development of transportation, space, and industry, we can improve the unit input-output efficiency of transportation and utilization efficiency of land resources, promote green transportation development, and cultivate new momentum of urban development.

## 2 Determination of key indicators for functional evaluation of Guangzhou comprehensive transportation hub

New York, London, and Tokyo are core cities in the world-class bay areas. Their transportation development strategies and key indicators (see Table 3) can be used for reference to formulate transportation policies for the Guangdong-Hong Kong-Macao Greater Bay Area. These cities focus on the optimization of transportation systems in the aspects of safety, health, fairness, and sustainability. New York and London pay more attention to public traffic coverage and accessibility, traffic safety, traffic carbon emissions, green travel, the construction of healthy and dynamic neighborhoods, as well as the improvement of services rendered to residents by overall transportation systems. Moreover, London's Plan also proposes continuously strengthening the capacity of cross-regional, national, and intercity connections to enhance strategic highway networking. Tokyo emphasizes the internationalization of

airports and ports, the world's top high-density railway networking, the integrated transformation of stations and the surrounding environment, and the construction of logistics infrastructure networks. Thus, it put forward control indicators at international, regional, and urban levels.

Beijing and Shanghai have also formulated urban transportation development strategies and key indicators (see Table 4). Focusing on aspects such as regional transportation, city-transportation coordination, and travel quality, Beijing puts forward the control indicators of regional transportation effectiveness, urban road network density, transportation structure, and green transportation construction. Focusing on the construction of a more open international hub, Shanghai puts forward corresponding indicators from the aspects of international competitiveness, national and regional radiation, and the development of urban public transportation. Its

goal is to build itself into a city of innovation, culture, and ecology and an excellent global city.

As an international comprehensive transportation hub and international logistics center, Guangzhou is an important carrier for constructing the hub cluster of the Guangdong–Hong Kong–Macao Greater Bay Area. Guangzhou has complete infrastructure for sea, land, and air transportation, with a national leading scale in the transportation industry (see Table 5). In 2019, Guangzhou's passenger volume and freight volume accounted for 48% and 45% of those of the Pearl River Delta region, respectively. Thus, Guangzhou has a solid foundation for building itself into a world-class international transportation hub. From the aspects of enhancing the global influence, promoting the free flow of regional factors, and supporting the construction of dynamic cities, with a focus on the six capabilities of global connectivity, hub

**Table 3** Transportation development strategies and key indicators of New York, London, and Tokyo

City	Name of plan	Year of release	Development strategy	Key indicator
New York	<i>PlaNYC: A Greener, Greater New York</i> <sup>[12]</sup>	2007	Efficient and sustainable	Promoting the use of bicycles to realize bicycle lanes of 1 800 miles (about 2 900 km) by 2030 Trial implementation of traffic congestion charges
	<i>One New York: The Plan for a Strong and Just City</i> <sup>[13]</sup>	2015	Reliable, safe, sustainable, and accessible	Population and employment coverage within commuting time of 45 min Quarterly bicycle commuting index Traffic safety level
	<i>The Mayor's Transport Strategy 2010</i> <sup>[14]</sup>	2010	More efficient, integrated, and secure	Strengthening the capability of cross-regional, national, and intercity connection Improving the accessibility of public transportation and employment Reducing the impact of transportation on climate change and improving resilience Encouraging green ways of travel such as walking and bike riding Improving road safety in a community
London	<i>The Mayor's Transport Strategy 2018</i> <sup>[15]</sup>	2018	Healthy streets	Adjusting transportation structure to make the proportion of green transportation reach 80% Reducing traffic volume in the central urban area to reduce the overall traffic volume by 10% to 15% Ensuring zero emission in transportation and no casualty in traffic accidents Continuously promoting the construction of suburban railways in London.
	<i>Tokyo 2020: Leading the Regeneration of Japan over the Great Earthquake (Tokyo 2020 for short)</i> <sup>[16]</sup>	2011	City of safety, city of inclusiveness, and city of wisdom	Strengthening the construction of multiple passages. Strengthening the role of Port of Tokyo as a logistics center in and outside Japan Promoting the expansion and internationalization of Haneda Airport. Ensuring that everyone can be respected and well treated, e.g., good accessibility of roads). Intensive construction of urban functions, e.g., integrated transformation of important downtown stations and their surrounding environment.
Tokyo	<i>Great Design of Urban Construction: Creating the Future of Tokyo (Tokyo 2040 for short)</i> <sup>[17]</sup>	2017	Safe, colorful, and smart city	Strengthening functions of airports. Rebuilding road space to promote contact and prosperity. Improving the world's top high-density railway network. Building a free-travel city on the basis of railway networks, and shaping the image of the city with the station as the center to turn a transportation hub into a street center. Forming a regional logistics infrastructure network.

**Table 4** Transportation development strategies and key indicators of Beijing and Shanghai

City	Name of plan	Development strategy	Key indicator
Beijing	<i>Beijing Urban Master Plan (2016–2035)</i> <sup>[18]</sup>	Promoting coordinated development of transportation and cities, attaching equal importance to public transportation precedence and demand management, and improving travel quality	1. Establishing a multi-circle transportation development model to create a one-hour transportation circle. 2. Improving the density and implementation of the planned road network to realize a road network density of up to 8 km km <sup>-2</sup> in the centralized built-up area. 3. Reducing the proportions of passenger car trips and average trip intensity of vehicles by 30%. 4. Building a walking- and bicycle-riding-friendly city, with an urban green-travel proportion of 80%.
Shanghai	<i>Shanghai Urban Master Plan (2017–2035)</i> <sup>[19]</sup>	Building a more open international hub	1. Strengthening the status of an aviation gateway in the Asia-Pacific region, with designed annual passenger and freight throughput of the aviation hub reaching 180 million and 6.5 million tons, respectively. 2. Promoting functional upgrading of the international seaport hub to improve port container throughput. 3. Enhancing the radiated service capacity of railway hubs. 4. Developing diversified modes of public transportation, with public transportation accounting for 40% of all modes of travel. 5. Building a city-wide rail transit network to realize a proportion of 80% of public transportation trips between the new town and the central urban area and rail-transit travel time of less than or equal to 40 min between hubs.



carrying capacity, interconnection, integrated services, economic driving, and sustainable development, this paper established 18 key indicators according to the principle of feasible quantification and easy access (see Table 6). On this basis, the functions and main problems of the Guangzhou comprehensive transportation hub were evaluated.

**Table 5** Comparison of passenger and freight volumes of major cities in China

City	Passenger volume/100 million			Freight volume/100 million tons		
	2018	2019	2020	2018	2019	2020
Guangzhou	4.80	4.98	3.27	12.77	13.61	9.24
Beijing	6.76	7.21	3.62	2.10	2.29	2.23
Shanghai	2.15	2.22	1.19	10.74	10.96	13.92
Shenzhen	1.99	2.12	1.37	3.28	4.35	4.15
Chongqing	6.36	6.35	3.99	12.82	11.27	12.19

Data sources: statistical bulletins of national economic and social development of various cities in China from 2018 to 2020.

### 3 Functional evaluation of Guangzhou comprehensive transportation hub

#### 3.1 Construction status quo of Guangzhou comprehensive transportation hub

Guangzhou is located at the junction of the Pacific Ocean

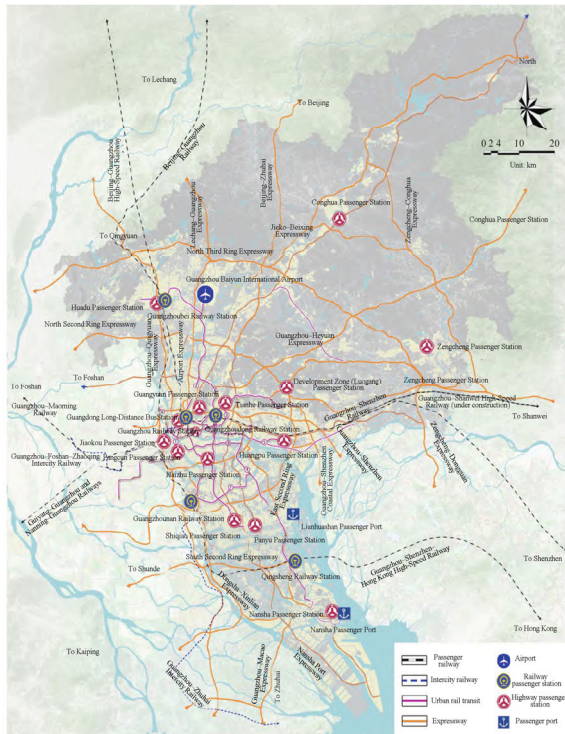
and the Indian Ocean. It is also at the intersection between the Beijing–Guangzhou transportation channel, the main artery of communications between north and south in China, and the coastal thoroughfare. Guangzhou is one of the three major hub cities in China. It has basically formed a comprehensive transportation hub pattern with Baiyun Airport and Guangzhou Port as the leaders, Guangzhou Railway Station, Guangzhoudong Railway Station, Guangzhounan Railway Station, and Jiangcun Railway Marshalling Station at the core, and expressway passenger and freight transportation hub stations and rail transportation hub stations as the supplements (see Fig. 1).

Guangzhou has large-scale regional transportation infrastructure. Its current transportation land area reaches 221 km<sup>2</sup>, accounting for 12.4% of the city's total construction land area and far exceeding the transportation land areas of Shenzhen (103 km<sup>2</sup>) and Dongguan (45 km<sup>2</sup>). Baiyun Airport is one of the three major international aviation hubs in China. It had a passenger throughput of 73.37 million and a freight–mail throughput of 1.922 1 million tons in 2019, ranking 11th and 17th in the world, respectively [5–6]. Guangzhou Port is a major coastal hub port and container trunk-line port in China. It had a freight throughput of 626 million tons and a container throughput of 23.24 million TEU in 2019, ranking fifth globally in both aspects [7]. Guangzhou Railways are important super-large railway hubs in south China, with three high-speed railways, five general-speed railways, and three

**Table 6** Key indicator system for evaluating functions of Guangzhou comprehensive transportation hub

Primary indicator	Secondary indicator	Connotation interpretation	Tertiary indicator
Global influence level	Global connection capability	Utilizing rich international and national routes of airports, ports, and railways to build a sea–land–air comprehensive three-dimensional transportation network accessible to the whole world and expand the global transportation network and logistics supply chain system	International and regional destinations
			International container liner route
			International railway express
Regional factor flow level	Hub carrying capability	Improving the overall operational efficiency of the hub by the expansion of large transportation hub facilities and the increase in investment in intelligent facilities; deepening transportation openness and cooperation to attract more passenger and freight flow to enhance global influence and competitiveness	Air passenger throughput
			Air freight and mail throughput
			Container throughput of port
Dynamic city construction level	Interconnection capability	Improving cooperation and co-construction mechanisms of transportation infrastructure with surrounding cities, speeding up the construction of cross-regional rail transit and road networks, and improving regionally coordinated trunk and branch transportation networks to promote optimal allocation of regional resources and support regional coordinated development	Access time to Beijing–Tianjin–Hebei, Yangtze River Delta, and Chengdu–Chongqing urban agglomerations
			Access time of urban rail transit in the Greater Bay Area
			Mutual arrival time of Guangfo and Guangqing central urban areas
Dynamic city construction level	Capability to provide integrated services	Elevating the level of zero-distance transfer and seamless transshipment to speed up the development of multimodal transportation and building an operation platform of smart transportation to reduce travel costs and improve travel efficiency	Transfer distance and time of major passenger transportation hubs
			Proportion of sea–rail intermodal transportation volume to port container throughput
			Overall clearance time of port
Dynamic city construction level	Economy-driving capability	With the rail transit hub, the logistics hub, and the bus and trolleybus hub at the core, popularizing the mode of “transportation + logistics + industry + community” to promote the deep integration of transportation with the city and the industry; innovating investment and financing modes of hub construction and cultivating new momentum of hub construction to promote high-quality urban development	Population or employment coverage within 800 m of rail transit stations
			Proportion of total logistics cost to GDP
			Ratio of logistics added value to total logistics cost
Dynamic city construction level	Capability of sustainable development	Coordinating transportation development and safety, strengthening the capacity building of transportation safety and emergency support, and encouraging the popularization and application of new energy and public transportation to promote the green and low-carbon development of transportation	Road traffic mortality per ten thousand vehicles
			Proportion of public transportation to motorized travel in the central urban area
			Carbon emission from transportation

intercity railways. Guangzhou Highway System is the largest main highway hub in south China, forming an expressway network of three beltways and 19 radial roads. Guangzhou has opened 18 urban rail transportation lines with a total operating mileage of 515 km.



a Passenger transportation hub



b Freight transportation hub

**Fig. 1** Status quo of passenger and freight transportation hubs in Guangzhou

In 2020, under the impact of COVID-19, Guangzhou's comprehensive transportation services still showed strong resilience, with both passenger and freight volumes ranking third in China. In 2020, Baiyun Airport had a passenger throughput of 43.768 million, ranking first in the world, and a freight-mail throughput of 1.7595 million tons<sup>[20]</sup>, ranking second in China. Guangzhou Port completed a container throughput of 23.51 million TEU and a freight throughput of 636 million tons, with a year-on-year growth of 1.2% and 2.6%, respectively<sup>[21]</sup>. The number of China-Europe Railway Express trains increased by 63.24% year on year, and the number of transported TEU containers increased by 67.89% year on year<sup>[22]</sup>.

### 3.2 Functional evaluation

**1) Global connection capability: The sea-land-air transportation network with direct access to world-class cities needs to be strengthened.**

Baiyun Airport has a total of 95 international and regional destinations, of which 21 are in Europe and America. In terms of this proportion, it is lower than that of Tokyo (146/55), Beijing (153/60), Shanghai (139/42), and Hong Kong (155/39). The few direct flights to major cities in Europe and America can hardly meet the demand of rapid growth in international passenger and freight transportation. Guangzhou Port has 120 international container liner routes, about half of those in Hong Kong and Shenzhen. Its role as an international passage to sea has not been fully played. Guangzhou has much fewer China-Europe Railway Express trains than Chengdu, Chongqing, or Zhengzhou and has no trains to Southeast Asia.

**2) Hub carrying capability: Existing airports, ports, and railway stations have an insufficient comprehensive carrying capacity.**

Baiyun Airport's passenger throughput is 91.7% of its designed capacity, and its operation saturation of the international freight station is 83.3%. Frequent delays and warehouse cramming occur. Guangzhou Port has a wharf design capacity of only 370 million tons and 15.76 million TEU, which can hardly meet the needs of port production and development. In terms of railways, the designed daily average dispatched passenger volume of Guangzhou Railway Station is 30 000, but the actual number is 68 600, which indicates the capability of the station has been overused. The locations of the railway freight stations are mismatched with the layouts of industries with large logistics demand, such as the manufacturing industry and the commerce industry. As a result, the potential of railway freight transportation has not been fully exploited.

**3) Interconnection capability: "One-hour life circle" in the Guangdong-Hong Kong-Macao Greater Bay Area has not yet been truly realized.**

Guangzhou and the major cities in the Greater Bay Area



have preliminarily realized an inter-station “one-hour rail transit circle” (see Table 7). However, the capacity of the Guangzhou–Shenzhen–Hong Kong Railway on the east side of the Greater Bay Area is close to saturation, with an urgent need for expansion. Guangzhou–Zhuhai Intercity Railway on the west side of the Greater Bay Area has a low technical standard (design speed of 200 km·h<sup>-1</sup>), with no direct high-speed rail line to Macao. For intercity transportation, transferring within the city is time-consuming. It takes 40–50 min to transfer from the municipal government to Guangzhounan Railway Station by car and 30 min by subway. As a result, the actual total travel time between cities in the Greater Bay Area is more than one hour.

**Table 7** Travel time by urban rail transit between major cities in the Guangdong–Hong Kong–Macao Greater Bay Area

City	Rail transit connection/line	Running time/min	Running time
Hong Kong	Guangzhou–Shenzhen–Hong Kong High-Speed Railway and Guangzhou–Kowloon Railway	60	The utilization capacity of the Guangzhou–Shenzhen–Hong Kong High-Speed Railway and Guangzhou–Shenzhen Railway is basically saturated.
Shenzhen	Guangzhou–Shenzhen–Hong Kong High-Speed Railway, and Guangzhou–Shenzhen Intercity Railway (under construction)	30	
Dongguan	Guangzhou–Shenzhen–Hong Kong High-Speed Railway and Xiamen–Shenzhen Railway	24	
Huizhou	Guangzhou–Shenzhen–Hong Kong High-Speed Railway	72	
Foshan	Guangfo Metro, Guangzhou–Zhuhai Intercity Railway, and Guangzhou–Foshan–Zhaoqing Intercity Railway	24	Within 30 min in the vicinity of Guangfo and more than 40 min in other areas
Zhongshan		30	
Jiangmen	Guangzhou–Zhuhai Intercity Railway	32	
Zhuhai		66	
Zhaoqing	Nanning–Guangzhou Railway and Guangzhou–Foshan–Zhaoqing Intercity Railway	32	Only 17.5 pairs of trains are operated daily on Guangzhou–Foshan–Zhaoqing Intercity Railway on average.

Data source: travel information from 12306 China Railway and Baidu Map.

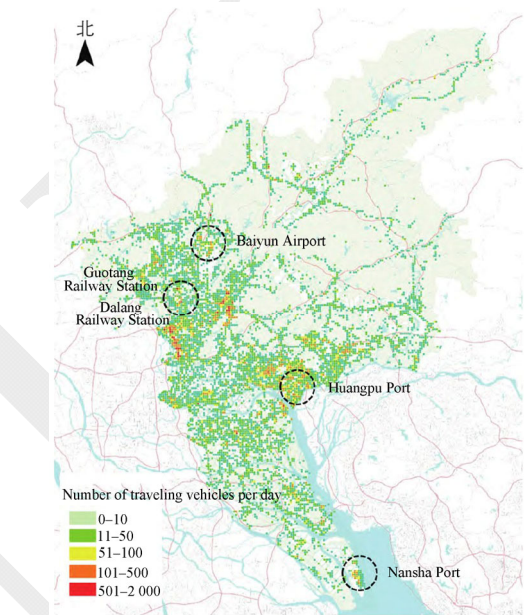
#### 4) Capability to provide integrated services: There is still much room for improvement in the service level of zero-distance transfer and multimodal transportation.

Supporting facilities of Guangzhounan Railway Station were completed late. The lack of unified planning and staged implementation of reserved projects results in the current scattered layout, insufficiency in three-dimensional compact construction, and low transfer efficiency. In the city, only Huangpu New Port has realized sea–rail intermodal transportation. Its sea–rail intermodal transportation volume accounts for 0.46% of the container throughput of the port [22]. The proportion is far lower than 29% of the Port of Hamburg [23] and 6.63% of the Qingdao Port [24].

#### 5) Economy-driving capability: The transportation hub is poorly connected and coordinated with urban space and industrial layout.

The plot ratios of the areas around the three major railway stations in Guangzhou are between 0.68 and 1.04, much lower than the average plot ratio (about 6.6) in the TOD range of Tokyo Railway Station. The coverage rate of the population within 800 m of rail transit stations in the central urban

area of Guangzhou is 41.2%, lower than that of Beijing (85%). The highly compound and centralized development mode centered on the hub remains to be promoted. Logistics parks in the city are in a layout of “large ones concentrated and small ones scattered” (see Fig. 2). Logistics warehousing land has an average development intensity of 0.41 and a tax output rate of 149 CNY per square meter, the lowest in all industries. The connection among hubs, logistics parks, and industrial bases is highly insufficient, and the scale effect of the development of the hub economy has not yet been formed.



**Fig. 2** Hotspot distribution of Guangzhou heavy-duty trucks. Data source: It is plotted according to the track data of Guangzhou heavy-duty trucks in 2017.

#### 6) Capability of sustainable development: It is urgent to build a green and safe travel environment on the basis of new infrastructure.

Guangzhou has fully utilized big traffic data for early warning of road safety, reducing road traffic mortality to 2.93 persons per ten thousand vehicles. However, the mortality in Guangzhou is still much higher than that of 0.77 persons per ten thousand vehicles in Shenzhen. Public transportation (excluding taxis) in the central urban area of Guangzhou accounts for 61.1% of the motorized travel modes. This share is lower than that in the central urban area of Tokyo (86%).

Table 8 compares functional indicators of comprehensive transportation hubs between Guangzhou and other cities.

### 4 Measures for function optimization of Guangzhou comprehensive transportation hub

Given the above functional evaluation of Guangzhou comprehensive transportation hub, this paper proposes some

optimization suggestions from the aspects of improving the city level as a hub, co-building and sharing resources, innovating integrated services, and strengthening the hub economy. This aims to build Guangzhou into a first-class international transportation hub radiating globally in an all-round manner by sea, land, and air.

**Table 8** Comparison of comprehensive transportation hubs between Guangzhou and other cities

Secondary indicator	Key indicator	Guangzhou in 2020	Comparison with other cities
Global connection capability	Number of international and regional destinations	95	Tokyo: 146
	Number of international container liner routes	120	Shenzhen: 226
	Number of international railway trains	106	Chongqing: 2 177
Hub carrying capability	Air passenger throughput/10 000	7 338 (2019)	Ranking 11th in the world
	Air freight and mail throughput/10 000 tons	175.95	Shanghai: 368.35
	Port container throughput/10 000 TEU	2 351	Shanghai: 4 350
Interconnection capability	Access time to the Yangtze River Delta and Chengdu–Chongqing urban agglomerations/h	4	
	Access time of urban rail transit in the Greater Bay Area/h	≥1	Shanghai to cities in the Yangtze River Delta: ≤1
	Mutual arrival time of Guangfo and Guangqing central urban areas/h	≥1	Shanghai to Jiaying: 0.5
Capability to provide integrated services	Transfer distance and time in major passenger transportation hubs	The average transfer distance is over 200 m, and the transfer time is more than 5 min	For Tokyo and Hong Kong, the average transfer distance does not exceed 200 m, and the transfer time does not exceed 5 min
	Proportion of sea–rail intermodal transportation volume to port container throughput	0.46%	Port of Hamburg, Germany: 29%
	Overall clearance time of port/h	Import: 12.53 Export: 0.87	Shenzhen import: 5.7
Economy-driving capability	Population or employment coverage within 800 m of rail transit stations	41% (2019)	Beijing: 85%
	Proportion of total logistics cost to GDP	13.62%	Shenzhen: 10.7%
	Ratio of logistics added value to total logistics cost	0.6	Shenzhen: 0.83
Capability of sustainable development	Road traffic mortality per ten thousand vehicles	2.93 (2019)	Shenzhen: 0.77
	Proportion of public transportation (excluding taxis) to motorized travel in central urban areas	61% (2019)	Tokyo: 86%
	Carbon emission from transportation/(10 000 t person <sup>-1</sup> a <sup>-1</sup> )	1.9	International: 1.5 (0.9–2.5)

#### 4.1 Continuously expanding sea–land–air mutually-aided international three-dimensional passage network

With a focus on BRI countries and regions, in terms of international aviation, Guangzhou should actively explore more destinations and lines to Europe, America, Oceania, and Africa, strive for more airspace resources and freight–mail flight time, and vigorously develop all-freight flights. These efforts are conducive to building a dense “International Air Silk Road” with Guangzhou as an important node. In terms of international shipping, Guangzhou should speed up the expansion of European and American ocean container liner routes and strengthen cooperation with international shipping alliances and liner companies to broaden the “Maritime Silk Road.” In terms of international railways, Guangzhou should

extend international passenger and freight train services to Southeast Asia to increase the number and enhance the efficiency of China–Europe and China–Asia Railway Express trains and improve land outbound thoroughfares.

#### 4.2 High-quality construction of port-type and airport-type national logistics hubs

Guangzhou Port is one of the first 23 national logistics hubs. In addition to expanding the comprehensive wharf operating capacity of Nansha Port, we should also speed up the construction of the Nansha Port Railway and sea–rail intermodal logistics park to promote coordinated development with ports on the west bank of the Pearl River, enhance the shipping services of Guangzhou Port, and improve Guangzhou’s capability to allocate resources in the high-end value chain of global shipping. In addition, efforts should be made to speed up the third-phase expansion of Baiyun Airport and the construction of the northern airport-related industry, improve the comprehensive bonded function of the airport, and introduce the characteristic industrial brands of aviation equipment and manufacturing, biomedicine, intelligent equipment, and airport-related logistics. On this basis, integrated development of traffic facilities, logistics facilities, and industrial groups inside and outside the airport can be promoted to build a benchmark for the development of global aviation metropolitan areas.

#### 4.3 Reconstructing the railway hub pattern featuring “multi-point layout, and multi-point arrival and departure”

It is necessary to build a strategic railway passage radiating in 10 directions across China and put emphasis on the construction of high-speed railways such as Guangzhou–Qingyuan–Yongzhou and Guangzhou–Heyuan. In this way, we can realize three-hour access from Guangzhou to the Yangtze River Delta and the Chengdu–Chongqing urban agglomerations. In accordance with the principle of “passenger trains on inner lines while freight ones on outer lines, bullet trains on inner lines while ordinary ones on outer lines, multi-point layout, and multi-point arrival and departure”, a pattern of 12 railway passenger transportation hubs is formed. The pattern takes Guangzhou Railway Station, Guangzhoudong Railway Station, and Baiyun Railway Station as the central hubs, Guangzhounan Railway Station, Guangzhoubai Railway Station, Nansha Railway Station, and Xintang Railway Station as the gateway hubs, and New Huangpu Passenger Station, Zengcheng Railway Station, Airport Station, Knowledge City Station, and Qingsheng Railway Station as the functional hubs. Hence, it is ensured that there is basically one high-speed railway station in each district. The function of general-speed railways will be transferred by the newly built Guangzhou Baiyun Railway Station. Moreover, Guangzhou Railway Station and Guangzhoudong Railway Station should be expanded to introduce high-speed railway lines into the city.



#### 4.4 Building a one-hour intercity transportation network in the Greater Bay Area with Guangzhou as the center

On the west side of the Greater Bay Area, by speeding up the construction of the Guangzhou–Zhongshan–Zhuhai–Macao High-Speed Railway, Guangzhou can make up for its weakness in transportation to Zhongshan, Zhuhai, and Macao. For neighboring cities such as Guangfo, Guangguan, and Guangqing, a dense cross-city high-speed and fast subway network with Guangzhou at the core should be built to enhance direct interconnection between Guangzhou and its surrounding cities. For Guangzhou, it is necessary to build a high-speed subway network that efficiently connects Baiyun Airport, 12 railway passenger transportation hubs, and the main functional areas of the city to realize the rapid direct interconnection between large transportation hubs, as well as between the hubs and the main functional areas of the city.

#### 4.5 Innovating the integrated services of zero-distance passenger transfer and multimodal freight transportation

We should innovate mechanisms of intermodal transportation between Guangzhou and its surrounding cities, as well as between Guangzhou and Hong Kong and Macao, and explore network integration of national railways, intercity railways, and urban rail transit. Moreover, we should promote ticketing interconnection, mutual recognition of security checks, cross-line transportation, and information exchange among different cities, as well as among different modes of transportation. Thus, “Lingnan Pass” can be developed into the “Bay Area Pass”, and the “Universal Public Transportation Card” can be developed into the “Universal Transportation Card.” Relying on the developed transportation advantages of Guangzhou, we should promote sea–rail, air–rail, highway–rail, waterway–waterway multimodal transportation. On the basis of the new models such as network freight transportation, high-speed railway logistics, general aviation logistics, and trucking services, we should explore integrated freight transportation and service and trade management rules. New technologies such as the Internet of Things (IoT), unmanned aerial vehicles (UAVs), and radio frequency (RF) identification should be introduced to improve the construction of digital and intelligent logistics.

#### 4.6 Promoting the integrated development of transportation hubs with urban spatial and industrial layouts

Centering on rail transit hubs, we should highly aggregate diversified urban functions such as offices, commerce, residence, and culture to meet the traveling, living, working, and entertaining service needs of citizens, turning a station into a destination. Moreover, we should promote the “hub + community + industry” development model to deeply integrate the transportation hub with urban functions to stimulate the

new vitality of the region. Layouts of logistics parks and freight depots in the central urban area of Guangzhou should be optimized, and the “transportation + logistics + industry” coordinated development mode should be promoted by the construction of modern and three-dimensional logistics hubs.

## 5 Conclusion

As the basic support of urban social and economic activities, transportation is an important condition for shaping a new pattern of urban space and even regional development. From the perspective of the Guangdong–Hong Kong–Macao Greater Bay Area, Guangzhou should actively respond to global and national opportunities and challenges and promote the transformation of urban construction from focusing on increments to optimizing stock. In addition, with the guideline of “being based on Guangzhou, benchmarking relevant international and domestic development, leading regional coordination, and innovating integrated services”, Guangzhou should plan major transportation infrastructure and corresponding supporting measures to further consolidate and enhance its functions and status as a comprehensive transportation hub. On this basis, Guangzhou can play the important role of a core engine in constructing the Greater Bay Area.

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