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Review and Outlook on 30 Years of Development of Guangzhou's Rail Transit Station Complexes

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Abstract: The planning and construction of rail transit station complexes are critical in raising funds for rail transit construction, promoting the development of rail transit network, enhancing the development intensity around stations, and avoiding inefficient land use. This paper provides a comprehensive review of the development history of Guangzhou's rail transit station complexes over the past 30 years, summarizing the evolution characteristics and implementation effects of the rail transit network and station complexes at each stage. The policies, mechanisms, theories, and practical methods related to station complexes have gradually matured, with the achievement of significant economic, social, and transportation benefits. The paper highlights the new opportunities and challenges faced by Guangzhou's urban rail transit construction in the context of developing the Guangdong–Hong Kong–Macao Greater Bay Area. The paper also explores new trends and ideas for the future development of rail transit station complexes, including extending from network nodes to four-network integration, transitioning from point-based to area-based continuous development, transforming, renovating, and utilizing existing resources, growing attention on quality and benefits as well as sustainable development, and expanding applications from cities to metropolitan areas. The continuous exploration of the evolution characteristics, mechanisms, policies, and compilation of planning of station complexes has effectively ensured the planning and construction of Guangzhou's rail transit and driven the city's socio-economic development. **DOI:** 10.13813/j.cn11-5141/u.2024.0201-en

Keywords: rail transit; station complexes; transit-oriented development (TOD); rail transit + property; four-network integration; Guangzhou

Guangzhou has experienced comprehensive economic, social, and population growth over the past three decades since the 1990s, leading to a rapid increase in transportation demand. To address traffic issues and drive urban development, Guangzhou has mobilized all resources in the city to construct urban rail transit systems. A 621 km urban rail transit network [1] had been completed by the end of 2022, generating a significant demand for construction funding. The rail transit station complex (hereinafter referred to as the "station complex") is a form of complex under the transit-oriented development (TOD) model with rail transit as its core. It is a general term for the development complexes located above rail transit depots (yards) and rail transit stations [2]. The original intention behind the construction of the station complexes is to address the funding needs for rail transit construction, avoid the disorderly sprawl of large cities, and enhance the development intensity around stations. The city can integrate resources and explore potential development spaces to achieve efficient land use, promote a multifunctional and diverse urban environment, and foster prosperity and equitable sharing of resources by leveraging the efficient and rapid rail transit system. With the inclusion of the Guangdong–Hong Kong–Macao Greater Bay Area in the national development strategy, Guangzhou's rail transit sector and the construction of station complexes face new opportunities and challenges. Reflecting on the past 30 years of station complex development and considering the experiences, lessons learned, and implementation outcomes from this evolution, are of significant importance in guiding the planning, design, construction, and management of rail transit.

1 1990s: exploratory phase

1.1 From the "cross" rail transit network to the completion of metro line 1

The planning for Guangzhou's urban rail transit network began in the 1960s, incorporating both transportation and underground air defense functions in response to national defense needs at the time [3]. After nearly 30 years of repeated deliberation, a "cross" rail transit network plan was finalized in the late 1980s. This plan included Metro Line 1 (Xilang–Guangzhou East Railway Station) and Metro Line 2 (Chigang–Xinshi), with Metro Line 1 selected as the first line to be constructed. In May 1992, the Guangzhou Metro Corporation (hereinafter referred to as "Metro Corporation") was established. In March 1993, the original State Planning Commission approved the project proposal and feasibility plan for Metro Line 1. Construction of Metro Line 1 officially began in December 1993. In June 1997, the first section of

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Metro Line 1 was opened for operation, making Guangzhou the fourth city in mainland China (excluding Hong Kong, Macau, and Taiwan) and the first in Guangdong Province to open a metro line. By June 1999, Metro Line 1 was fully operational with a total length of 18.5 km.

1.2 Exploration of the “rail transit + property” model

1.2.1 An inevitable choice under the realities and challenges of urban development

Guangzhou’s urban space in the early 1990s was characterized by a single-center and high-density layout. The city’s production and living activities were primarily concentrated in the old urban districts with high population density, chaotic organization, low environmental quality, and severe traffic congestion. Such a situation manifested in several ways: 1) high population density: the built-up area of the old urban districts (Yuexiu District, Dongshan District, Liwan District, and parts of Haizhu District) covered only 54.4 square kilometers but housed a permanent population of 2 million. Additionally, there was a floating population of over 1.2 million, leading to an extremely high population density of 58 800 people per square kilometer, which severely strained various urban facilities [4]. 2) Low environmental quality: 56% of the factories in the city were densely packed in the old urban districts, leading to significant environmental pollution, including noise and industrial waste. Industrial emissions of gas and wastewater accounted for up to 40% and 48% respectively of total emissions in this city. 3) Severe imbalance between road supply and demand: The rapid increase in bicycles and motorcycles exacerbated traffic issues. There were approximately 3 million bicycles by the late 1980s, double the number from a decade earlier [5]. There were 363 000 motorcycles in 1993, making up 64.4% of the total motor vehicles. Bicycles made up 60% of road traffic, motorcycles 25%, and other motor vehicles 15% in the early 1990s. Bicycles and motorcycles frequently occupied lanes designed for motor vehicles and caused chaotic conditions of lane use [4]. 4) Severe shortage of parking supply: Parking facilities in the city could only meet 15%–30% of the parking demand in 1992. As a result, most bicycles and motorcycles were parked on sidewalks, further congesting the already narrow pedestrian paths [5].

In response to the challenges and constraints hindering urban development, Guangzhou decided to build Metro Line 1 in the 1990s to promote public transit, ease traffic congestion, revitalize old urban districts, and support new district development. The plan aimed to optimize the old urban districts by reducing residential functions and enhancing non-residential functions while widening Zhongshan Road from 18 meters to 36 meters. The Metro Line 1 construction and road expansion extended the old urban area into the new districts of Tianhe and Fangcun, aiming to lower population density, alleviate traffic congestion, increase public spaces, and improve environmental quality [6].

The biggest challenge in constructing Metro Line 1 was securing the necessary funds. The budget of the project was 14.6 billion yuan, which represented 20.6% of the entire GDP of Guangdong in 1993 [7], far beyond what the municipal budget could cover. Additionally, large-scale demolition in the old city districts required substantial relocation funds. Unlike provinces, including Beijing, Tianjin, and Shanghai, that had received central government financial support for metro projects, both the central and Guangdong provincial governments clearly confirmed that Guangzhou’s metro construction would not receive supporting funds. This situation forced Guangzhou to draw references from Hong Kong and adopt the “rail transit + property” model to raise funds. By selling the land use rights above metro stations along Line 1 to raise funds, Guangzhou became the first city in mainland China to implement the “rail transit + property” model.

1.2.2 Introduction of foreign enterprises for joint development

The integrated development project along Metro Line 1 adopted a cooperative development strategy primarily focused on attracting foreign-invested enterprises. The metro company collaborated with partner enterprises (mainly Hong Kong-invested companies) to form a project company (joint venture) for joint development [6]. The development strategy and model (Fig. 1) mainly included

1) The metro company was responsible for handling the land use rights procedures, while the partner enterprises were responsible for raising the necessary funds for the project, as well as organizing project design, construction, and operation.

2) The municipal land administration department transferred the land use rights of the project to the metro company at a market-assessed land price. After the metro company entered into a cooperation contract with the partner enterprises and established a project company, through the project company, the partner enterprises paid the metro company a comprehensive land development fee. Once the metro company obtained approval from the municipal development and reform department, the funds were directly used for the construction of Metro Line 1.

3) The project land provided by the metro company was divided into two types: raw land (resettlement uncompleted) and cultivated land (resettlement completed). The partner enterprise relied on the project company to organize the resettlement of raw land and would cover the expenses. The cost required for the resettlement of the cultivated land organized by the metro company shall be paid by the partner enterprise to the metro company as a lump sum.

4) Regarding profit distribution, given the high intensity of capital usage during the construction of Metro Line 1, a

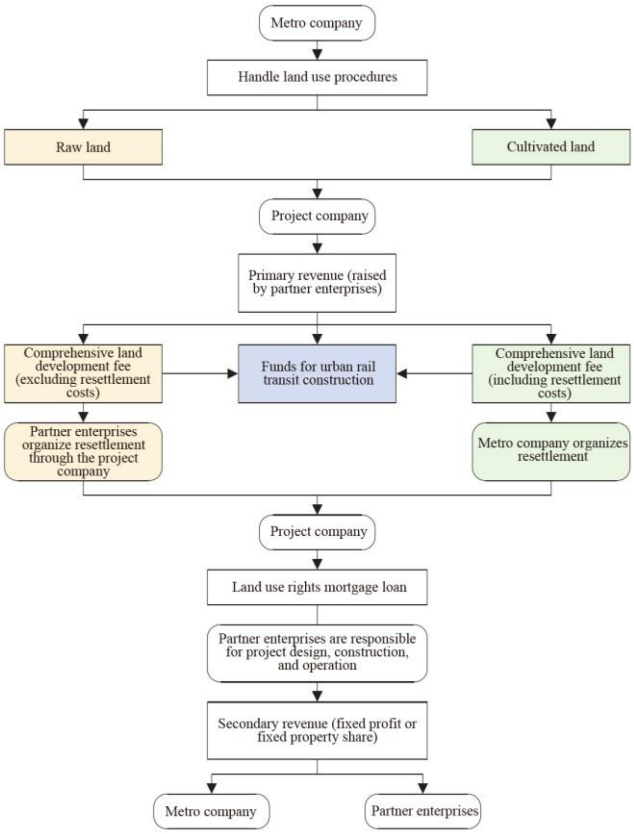

Fig. 1 Development strategies and models for station complex projects in Guangzhou in the 1990s

Source: compiled based on references [6, 8].

distribution method with a larger proportion in the short term and a smaller proportion in the long term was adopted. One part of the income of Guangzhou was reflected in the short term as a comprehensive land development fee, while the other part came from property rental income that was reflected in both the short and long term as fixed profits or fixed property shares and paid by the partner enterprises to the metro company according to the contract.

5) After the partner enterprises paid the comprehensive land development fee, the metro company assisted in transferring the land ownership to the project company. The project company can then utilize the land use rights as collateral for loans.

Regarding the development scale, after repeated evaluations of the current status, planning conditions, development value, and demolition difficulty along Metro Line 1, 28 plots along the line were selected for the integrated station complex development (Fig. 2). The total construction area amounted to 2 million square meters, with a total investment exceeding 20 billion yuan. The project aimed to raise 3 billion yuan excluding the capital in construction funds for urban rail transit, which was referred to as the "3 Billion Project". A total of 900 000 square meters of buildings needed to be resettled, and the original property owners on these plots were to be relocated either through permanent resettlement in different locations or through cash compensation after relinquishing their properties. The goal was to alleviate the excessively high population density and severe traffic congestion in the old city districts. This also necessitated that the newly constructed station complexes along Metro Line 1 primarily served non-residential functions, with commercial and office spaces making up 60% of the total construction area (1.2 million square meters), while residential functions account for 40% (800 000 square meters) [8].

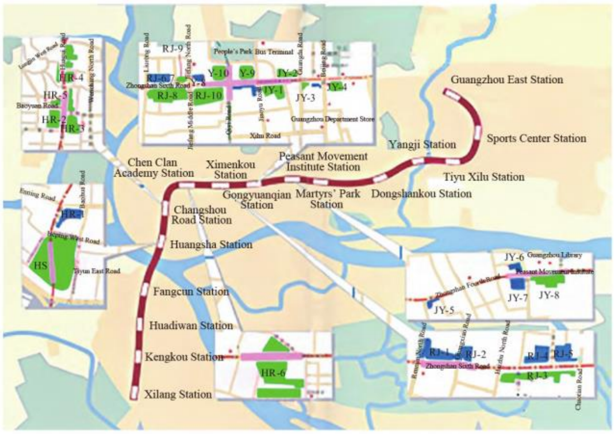

Fig. 2 Planning of station complexes along Guangzhou Metro Line 1 in the 1990s

Data source: reference [8].

1.3 Implementation effects: significant economic, social, and transportation benefits

After the development strategy and construction scale were determined, Guangzhou fully committed to advancing the integrated station complex projects along Metro Line 1. The implementation results primarily include

1) Economic benefits: by the end of 2002, out of the 28 development projects, 4 were completed; 3 were under construction, and 2 were converted into greening projects, while the rest were temporarily stalled [6]. The direct economic benefits from the integrated station complex development along the line amounted to approximately 2.4 billion yuan, with property rental income exceeding 10 million yuan a^{-1}. The completion rate of the "3 Billion Project" reached 80.3%, effectively achieving the fundraising goal for the construction of Metro Line 1.

2) Social benefits: the project has driven the renovation and upgrading of the old city areas, alleviating the high population and building densities in old districts and facilitating the relocation of factories and industrial upgrades. Over 30 000 citizens moved from the old city districts to the new districts, with the average living area increasing from 7.9 square meters per person to 10.8 square meters per person, a 36.7% improvement that significantly enhanced living quality and well-being. Factories in old districts gradually relocated to the new districts for renovation and

reorganization after receiving resettlement compensation, achieving industrial upgrades.

3) Transportation benefits: the resettlement along Metro Line 1 facilitated the expansion and renovation of roadways. For instance, Zhongshan Road was widened from 18 meters to 36 meters and expanded from two lanes to six lanes, transforming it into a major thoroughfare connecting the old and new districts, which greatly alleviated traffic congestion. Since the opening of Metro Line 1 in 1997, citizens have gradually shifted their travel habits and modes of transportation with more people opting for urban rail transit. This shift has led to an increase in the proportion of public transportation use and a significant reduction in surface road traffic congestion.

2 The First decade of the 21st century: systematic planning phase

2.1 Initial network development of urban rail transit

From 2001 to 2010, Guangzhou was approved for a total of 11 urban rail transit lines, covering a distance of 237.3 km. From 2001 to 2005, metro projects were approved as independent lines under the national policy at the time, with Guangzhou securing approvals for two metro lines totaling 56.3 km, including Metro Line 2 (Sanyuanli–Wanshengwei) and Line 3 (Panyu Square–Guangzhou East Station and Tiyu Xilu–Tianhe Coach Terminal Station). From 2005 to 2010, through the *Approval of the National Development and Reform Commission on the Recent Construction Planning of Urban Rapid Rail Transit in Guangzhou*, six extra metro lines were approved, totaling 127.6 km [9]. In 2009, the *Approval of the National Development and Reform Commission on the Adjustment Plan of the Recent Construction Planning of Urban Rapid Rail Transit in Guangzhou* led to the approval of three additional lines, totaling 53.4 km, including Phase II of Metro Line 6, Phase I of Line 7, and Phase I of Line 9. By the end of 2010, Guangzhou had built nine metro lines, including Lines 1, 2, and 3, the North Extension of Line 3, Phase I of Line 4, Line 5, and Line 8, as well as the Guangfo Line and the APM Line. The operational length of the urban rail transit network reached 236 km, with an average daily passenger volume exceeding 4 million passengers per day [1].

2.2 Systematic land reserve planning along urban rail transit lines

In July 2004, Guangzhou was awarded the right to host the 16th Asian Games in 2010. It poured resources into the whole city to improve the urban landscape and environment and vigorously advance infrastructure development. A total of 109 billion yuan was invested in infrastructure projects over the next six years, with 54.7 billion yuan allocated to urban rail transit construction [10]. These special funds for the Asian Games were entirely sourced from the municipal budget. Guangzhou adopted a “rapid expansion” philosophy for urban rail transit construction, utilizing municipal fiscal resources to aggressively build new lines. This approach differed from the “rail transit + property” financing model used in the 1990s during the construction of Metro Line 1. Given this context, Guangzhou did not engage in detailed planning or systematic construction of integrated station complexes along the new urban rail transit lines. However, the focus during these 10 years was on exploring land reserve planning around stations of new urban rail lines and the underground space development around stations along Metro Line 1 from an overall network perspective.

Guangzhou organized the preparation of the *Land Reserve Planning for Metro Lines 1–9* [11]. This plan involved conducting research on land reserves around stations along the urban rail transit lines, with a total planned reserve area of 4 601 hm^2 (Fig. 3 and Table 1). The main contents of the plan included

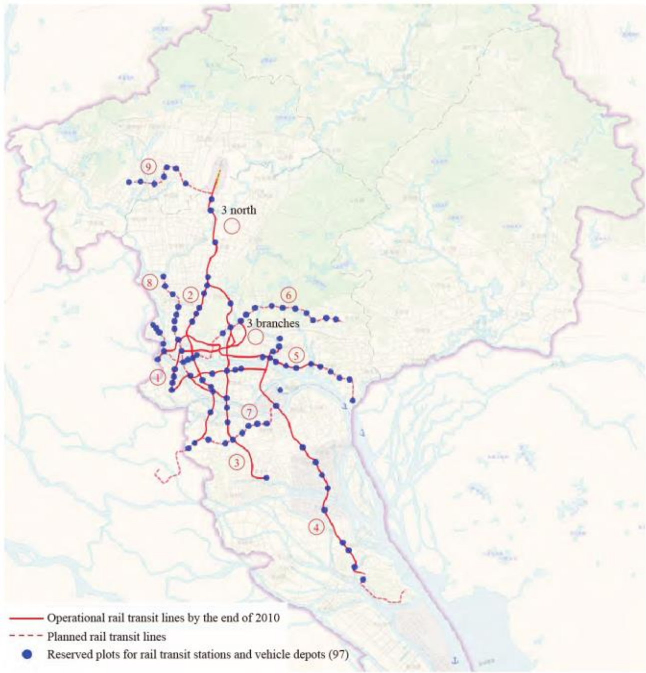

Fig. 3 Land reserve planning along Guangzhou Subway Lines 1–9 in the first decade of the 21st century

Source: compiled based on reference [11].

1) Regarding the overall interests of rail transit and urban development, Guangzhou drew on the successful experience of Hong Kong’s “rail transit + property” model. The plan involved investigating, verifying, and organizing land resources around the stations of Metro Lines 1–9 that could be comprehensively developed. All relevant information about the land was collected, including current conditions, location attributes, planning nature, plot size, and land price, so as to conduct a preliminary reserve of key plots along the lines, providing a foundation for following steps like

Table 1 Land reserve planning and land area of stations along Guangzhou Subway Lines 1–9 in the first decade of the 21st century

Project	Urban rail transit lines									Total
	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7	Line 8	Line 9	
Number of reserved plots for rail transit stations and vehicle depots	5	10	7	13	12	21	8	13	8	97
Reserved land area/hm^2	111.7	332.7	197.2	1 781.4	186.4	452.7	530.2	359.4	649.3	4 601.0

identifying reserve targets, delineating land boundaries, and making physical land reserves.

2) Regarding the sequencing of land reserves, it was acknowledged that land reserve work possesses a proactive and forward-looking nature. To prevent the loss of land benefits and to ensure adequate land supply for various important urban facilities and key projects, exploratory studies were conducted on the timing of land reserves around stations along Metro Lines 1–9. By considering the construction schedules of urban rail transit and overall urban development trends, land reserves were planned and implemented in both short-term and long-term phases.

3) Regarding the plan implementation, efforts were made to explore the establishment of a reserve information database and a dynamic tracking and updating mechanism and align with the construction cycles of urban rail transit and the evolving needs of urban development. By dynamically adjusting land reserve plans around stations and providing regular updates on planning changes promptly, the plan aimed to maximize the role of rail transit in expanding and optimizing urban spaces.

2.3 Implementation outcomes: exploring underground space development and enriching TOD concepts

Building on the planning exploration and theoretical research of the 1990s regarding integrated station complex development along Metro Line 1, the project entered a significant construction phase in the 21st century. The main construction activities and implementation outcomes include: 1) The development of the 28 integrated station complex projects established in the 1990s along Metro Line 1 continued. By the end of 2007, 10 projects were completed, including Jietai Plaza, China Travel Commercial City, Xinbaoli Building, and Mayflower Plaza, fulfilling the goals of raising funds for urban rail transit construction, providing resettlement solutions, and effectively addressing the funding needs for Metro Line 1 construction. 2) To alleviate the surface traffic burden and enhance urban functional layouts, the underground space development of stations along Metro Line 1 was explored. Underground space development was initiated at seven stations, including Fangcun Station, Chen Clan Academy Station, Gongyuanqian Station, and Tiyuxi Station, with a total construction area exceeding 260 000 square meters. Centering around the stations, focuses were laid on creating underground commercial spaces and traffic relief corridors [12]. By integrating metro entrances with above-ground commercial buildings, public service facilities, and landscape nodes, the project achieved a truly three-dimensional urban rail transit TOD model.

3 “12th Five-Year Plan” period: expansion and acceleration phase

3.1 Further densification of urban rail transit network

With the approval of the *Guangzhou Urban Rail Transit Recent Construction Plan (2012–2018)*, seven new lines were approved in 2012 with a total length of 228.9 km, including the northern extension of Line 8, Phase I of Line 13, Phase I of Line 14, Line 21, the southern extension of Line 4, Line 11, and the branch of Line 14. During the “12th Five-Year Plan” period, Phase I of Line 6, the post-Phase I extension of the Guangzhou–Foshan Line, and the Haizhu Tram Line were completed, adding 30 km to the network. By the end of 2015, a total of 11 urban rail transit lines had been completed with a total length of 266 km. Additionally, there were 10 lines under construction, totaling 282.3 km with a total investment of 146.8 billion yuan, 45% of which was covered by Guangzhou’s fiscal funds. The remaining funds were secured through bank loans and land development. The massive fiscal spending and bank loans used by Guangzhou in preparation for the Asian Games in the first decade of the 21st century indirectly led to a tight financial situation in the post-Asian Games era. Consequently, the vast funding needs for urban rail transit construction during the “12th Five-Year Plan” period necessitated continued exploration and deepening of the “rail transit + property” financing model, propelling station complex construction into a rapid expansion phase.

3.2 Planning and construction of station complexes under the urban-rural co-construction model

3.2.1 Phase I: proposal of a 50 billion yuan fundraising target

To alleviate the financial burden on the municipal government during the “12th Five-Year Plan” period and to raise more funds for the construction of new urban rail transit lines, Guangzhou implemented bold reforms and innovations in land policy, offering supportive policies to the metro company, which was tasked with the land reserve and development along the urban rail transit lines. Guangzhou established the funding plan for urban rail transit construction during the “12th Five-Year Plan” period in April 2010. Based on the estimated funding needs from the urban rail transit network construction plan, after deducting capital (fiscal funds) and debt financing, the remaining funding gap needed to be filled through the development revenue of station complexes along the urban rail transit lines. A target was set to raise 50 billion yuan within five years, a goal later referred to as the “50 Billion Project”.

3.2.2 Phase II: establishment of “20 + 8” land reserve scheme

Guangzhou formulated the *Guangzhou Plan for Promoting Land and Property Development Along Rail Transit Lines* and the *2012–2016 Guangzhou Rail Transit Land Reserve Plan (First Batch)* in November 2012. This plan selected the “20 + 8” land reserve scheme for rail transit lines, defining the land reserve tasks allocated to each district (county) and establishing the organizational structure, land revenue sharing ratios, and reserve procedures. The first batch of land reserve planning includes 20 rail transit stations and eight vehicle depots, covering a total area of 439 hm^2, with a total development scale of 13.48 million square meters. The expected net land revenue is 17.65 billion yuan, with a post-deduction revenue of 16.82 billion yuan after sharing with various districts (counties). The remaining portion of the “50 Billion Project” funding target was achieved through two channels: the first is gradually increasing the land parcels included as the initial reserve work progresses and demonstration effects become apparent by rolling adjustments to the land reserve plan; the second one is earning revenue by the metro company participating in the property development.

The main contents of implementation model and planning include:

1) Organizational structure: a working group composed of the municipal land reserve department and the metro company was responsible for a land reserve along the rail transit lines.

2) Task division: the municipal government was responsible for the unified planning, reserve, and transfer of land and property along the rail transit lines. It utilized the strong credit and financing capabilities of the metro company to raise the necessary funds for the land reserve. Each district (county) was responsible for land acquisition, demolition, and resettlement, with costs included in the land reserve development expenses.

3) Planning and land reserve: by considering the functional layout of the lines and station conditions, plots within a 300 meter radius around the stations were selected, and land and property development plans were developed. The working group would handle the physical reserve of these plots.

4) Land transfer methods: the land use rights for underground commercial spaces were directly connected to and built simultaneously with the urban rail transit stations which cannot be implemented separately, would be transferred to the metro company through an agreement-based transfer method. The land use rights for above-ground commercial properties would be transferred through a public auction process. The metro company can acquire these land use rights through bidding and auction based on its own advantages.

5) Land transfer revenue: the net revenue from land transfers in the six central districts (Yuexiu, Liwan, Haizhu, Tianhe, Baiyun, and Huangpu) was divided between the city and district. 80% of the revenue will be used to offset the land development revenue tasks assigned to each district, while 20% will be allocated to district finances. For the four outer districts and two county-level cities (Huadu District, Panyu District, Nansha District, Luogang District, Zengcheng City, and Conghua City), the net revenue from land transfers would be used to offset the land development revenue tasks that each district or county was required to complete.

6) Management of development revenues: the operating revenues generated from properties directly connected to and constructed simultaneously with urban rail transit stations, as well as the profits from joint development projects between the metro company and other enterprises, would be considered as the operating income of the metro company and be fully allocated to urban rail transit construction and to cover any operational deficits.

3.2.3 Phase III: adjustment to 39 reserved land areas

In response to the practical issues encountered during the implementation of the “20 + 8” land reserve plan such as boundary lines, land ownership, and demolition, coordination with various districts (counties) led to the removal of some plots that were not feasible for development. As a result, the land available for the development of station complexes was reduced to 12 urban rail transit stations and seven vehicle depot sites. Throughout the implementation process, continuous adjustments were made and after multiple rounds of optimization, 20 additional plots were added, increasing the total number of reserved plots to 39 (Fig. 4), including 31 urban rail transit stations and eight vehicle depot sites, with a total land area of 1 037 hm^2 and a total development scale of 20.48 million square meters. The phase planned to raise 47.984 billion yuan (see Table 2), with the remaining 2.016 billion yuan to be obtained through the metro company participating in property development.

Fig. 4 Planning of station complexes in Guangzhou during the "12th Five-Year Plan" period

Source: Compiled based on the Implementation Rules and Working Mechanism for Promoting Land Reserve Work along Urban Rail Transit Lines in Guangzhou.

Table 2 Funding of station complexes in Guangzhou during the "12th Five-Year Plan" period

District	Number of station complexes	Fundraising task/ 100 million yuan	Fundraising completion status/ 100 million yuan	Fundraising completion rate/%
Zengcheng	6	40.32	109.4	271.3
Panyu	7	40.32	43.8	108.6
Huangpu	2	24.19	77.0 1)	79.6
Luogang	3	72.58		
Tianhe	4	52.42	4.0	7.6
Baiyun	2	84.68	46.2	54.6
Liwan	6	44.36	66.1	149.0
Nansha	1	28.23	Unsold reserved plots	0
Haizhu	1	40.32		0
Huadu	5	32.26		0
Conghua	2	20.16		0
Yuexiu 2)				
Total	39	479.84	346.5	72.2

1) On February 12, 2014, the State Council approved the dissolution of Huangpu District and Luogang District, merging them into the new Huangpu District. The fundraising completion status and completion rate for these two districts are calculated under the statistics of the new Huangpu District. 2) Considering the limited number of reserved land plots in Yuexiu District, the municipal government has exempted its fundraising task of 2.016 billion yuan, which will be obtained through the metro company participating in property development. Source: Compiled based on the *Implementation Rules and Working Mechanism for Promoting Land Reserve Work Along Urban Rail Transit Lines in Guangzhou*

In February 2015, Guangzhou City formulated the *Implementation Rules and Working Mechanism for Promoting Land Reserve Work Along Urban Rail Transit Lines in Guangzhou*, which further clarified the working model: 1) Land reserve authority: The land reserve function was removed from the metro company and centralized under the city land reserve department. 2) Land reserve costs: The city land reserve department was responsible for the expenses related to land acquisition and demolition for urban rail transit station plots, while the metro company was responsible for the costs associated with vehicle depot sites. 3) Division of responsibilities between city and districts: The city land reserve department was tasked with organizing planning site selection, planning compilation, and funding, while each district (county) was responsible for land approval, land acquisition, and demolition, handling the physical land reserves. 4) Planning compilation: For projects requiring adjustments to the detailed regulatory plan, the city land reserve department was responsible for applying for these adjustments based on the specific circumstances and functional layout of the plots. 5) Incentive mechanism: Districts (counties) that completed land reserve tasks on time were rewarded with 5% of the land acquisition compensation fee. Those who completed tasks ahead of schedule and achieved higher land revenues were rewarded with 10% of the compensation.

3.3 Implementation effects: maturity of "rail transit + property" model

By the end of 2020, the "50 Billion Project" had completed the land transfer for 14 sites (excluding Yuexiu District), raising 34.65 billion yuan for urban rail transit construction, achieving a funding completion rate of 72.2%. The remaining sites will proceed with land acquisition, transfer, and development according to the plan. The main effects of implementation include:

1) Economic benefits: The project essentially met the goal of raising funds for urban rail transit construction during the "12th Five-Year Plan" period. It explored and established a financing and operational mechanism for urban rail transit construction.

2) Transportation benefits: During the "12th Five-Year Plan" period, 30 km of urban rail transit lines were completed, bringing the total operational mileage to 266 km by the end of 2015. This facilitated the networked operation of urban rail transit. By 2015, urban rail transit accounted for 17.1% of motorized trips, a 3.7-fold increase from 2005 [1].

3) Urban development: The construction of station complexes realized the concept of rail transit leading urban development. It promoted the integration of urban rail transit

with land development along the lines, enhanced the ability of rail transit to optimize urban space and improve land use efficiency, and spurred the development of new districts.

4) Resource allocation: The project achieved synchronized planning, design, and construction of urban rail transit and land development along the lines, optimizing resource allocation efficiency.

5) Mechanism model: The project established a unique and well-structured “rail transit + property” model in Guangzhou, creating a sustainable development and stable funding mechanism for the construction and operation of urban rail transit. It achieved the organic integration of rail transit functions with urban space and increased the intensity of land development around stations.

4 “13th Five-Year Plan” period: comprehensive development stage

4.1 Urban rail transit achieves networked operation

In 2017, the *Urban Rail Transit in Guangzhou Entered a New Phase of Expansion with the Approval of the Guangzhou Urban Rail Transit Phase III Construction Plan (2017–2023)*. This plan included 10 new lines: the east extension of Line 3, the east extension of Line 5, Phase II of Line 7, the north extension of Line 8, Line 10, Line 12, Phase II of Line 13, Phase II of Line 14, Line 18, and Line 22. The total length of these lines amounts to 258.1 km, with a total investment of 219.6 billion yuan [13]. Besides the capital (fiscal funds) and self-raised funds by enterprises, the remaining 148.1 billion yuan needed to be raised through the “rail transit + property” model, known as the “150 Billion Project”. This project aimed to raise 79.3 billion yuan through primary land transfer proceeds, with the remaining funds supplemented by secondary development profits and comprehensive development of surrounding land. By the end of 2022, Guangzhou had completed 16 metro lines with 263 stations, covering a total length of 621 km. Over 30 years of development, the urban rail transit in Guangzhou evolved from a single line to a multi-line network, expanding from the central area to the outer districts, thus achieving networked operation in a real sense (Fig. 5).

4.2 Comprehensive development of “two main lines + two main entities”

4.2.1 Formulation and implementation of guidelines to promote systematic development

In March 2017, *Guangzhou City formulated the Implementation Rules for the Construction of Rail Transit Station Complexes and Comprehensive Land Development in Surrounding Areas (Trial)* (hereinafter referred to as the *Implementation Rules*). This document served as the primary guiding framework for the construction of station complexes during the “13th Five-Year Plan” period [2], marking the entry of Guangzhou urban rail transit comprehensive development into a phase of full-scale development.

The *Implementation Rules* were structured around two main lines: the construction of station complexes and the comprehensive land development in surrounding areas. The station complex construction was developed in parallel with the urban rail transit projects, while the surrounding land development was carried out separately according to urban development needs. This approach ensured both coordinated planning and individual progression of the two components (Fig. 6). The main content of the *Implementation Rules* included:

1) Land use and development scope: The station complexes encompassed stations, vehicle depots, transportation connection facilities, etc., aiming to achieve seamless transfer and integration. The surrounding land development area covered a radius of 800 meters centered on the station, creating a mixed-use area that integrates transportation, commercial, residential, and other functions.

2) Implementation entities: There were two main entities responsible for the implementation: the metro company and the city land reserve department. The metro company was responsible for the planning, design, and construction of the station complexes. This included organizing the conceptual design and planning proposals, handling land and property acquisition, and managing the overall development of the station complexes. The city land reserve department oversaw

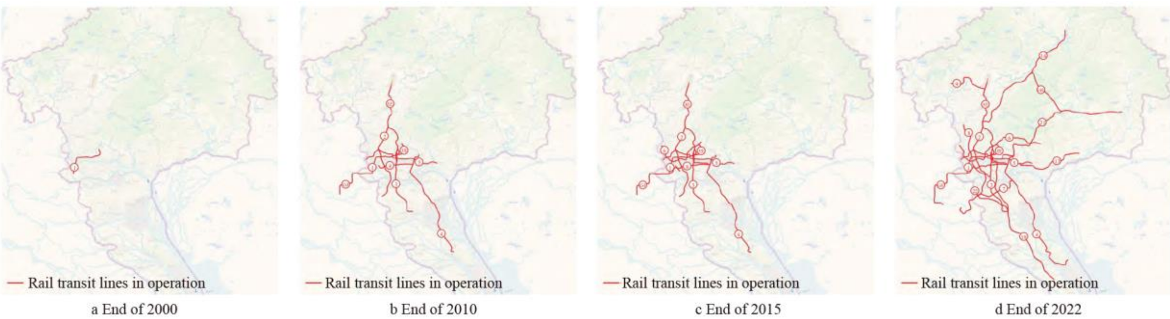

Fig. 5 Evolution of Guangzhou’s urban rail transit network

Source: compiled based on Reference [1].

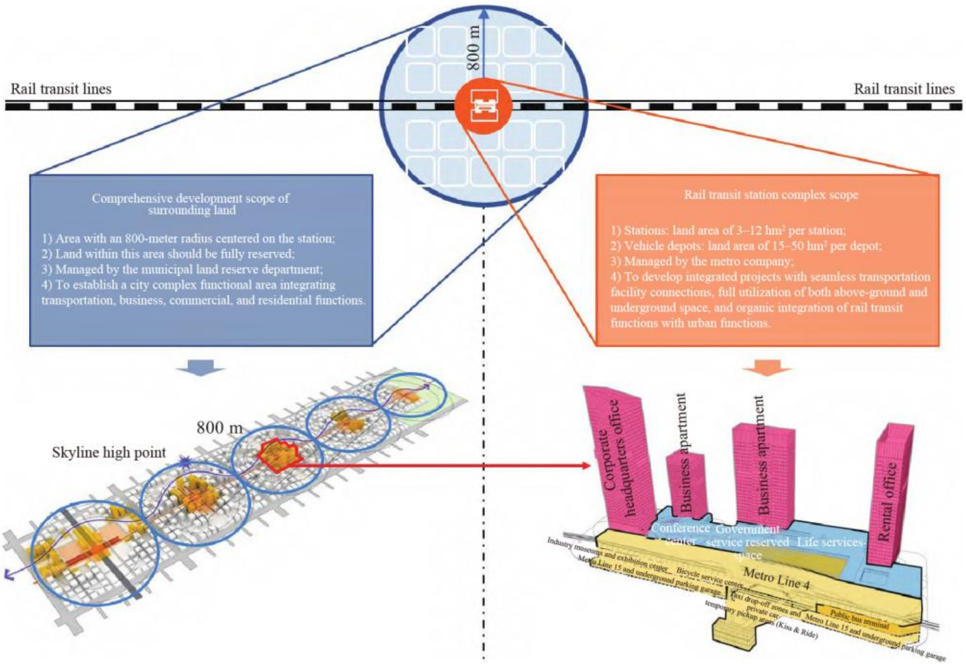

Fig. 6 Strategies for construction of station complexes and comprehensive development of surrounding lands in Guangzhou during the "13th Five-Year Plan" period

Source: compiled based on Reference [2, 15].

the comprehensive land development surrounding the stations, including managing land reserves, organizing planning development, and coordinating with various administrative districts to ensure effective implementation.

3) Planning preparation and review: The station complex conceptual plan mainly included the scope of land use, functional layout, architectural design, transportation integration, landscape design, and economic assessment. The comprehensive development plan for surrounding land primarily encompassed the scale of reserved land, detailed planning adjustment schemes, transportation-specific planning, and economic assessment.

4) City and district division of responsibilities and revenue distribution: the city land reserve department was responsible for project approval and funding for the station complexes, while each district carried out the specific land acquisition. Revenue from land sales was divided between the city and district at a ratio of 95:5. For surrounding land comprehensive development, the districts handled all land reserves. After allocating 10% of the land sale revenue for urban rail transit construction, the remaining revenue was split between the city and district at a ratio of 15:85.

4.2.2 Planning for comprehensive development of station complexes

Guided by the *Implementation Rules*, Guangzhou organized the development of the *Guangzhou Urban Rail Transit Phase III Construction Plan (2017–2023) New Line Station Complex Building Concept Plan*. This plan involved land surveys and research for 113 stations along 10 metro lines, resulting in the planning of 33 station complexes [14] (Fig. 7 and Table 3).

Fig. 7 Planning of station complexes in Guangzhou during the "13th Five-Year Plan" period

Source: compiled based on Reference [14].

Table 3 Overview of station complexes in Guangzhou during the "13th Five-Year Plan" period

Urban rail transit lines	Station complexes	Number	Land area for station complexes/ hm²	Gross floor area for station complexes/ 10 000 m²	Revenue from primary land transfer for financing by the end of 2022/billion yuan
Line 18	Pazhou West District Station	4	0.7	9.7	
	Hengli Station		10.3	25.2	
	Wanqingsha Depot		50.7	86.9	
	Panyu Square Station		7.2	5.5	
Line 22	Xilang Station	6	10.6	45.0	
	Chentougang Parking Lot		28.8	64.5	63.7
	Qifu New Village Station		6.4	6.8	
	Bai'e Tan Station		8.3	32.9	
	Jiaomen Station		6.6	29.5	
	Qingsheng Station		4.5	22.6	2.6
Phase II of Line 13	Huanggang Parking Lot	6	32.8	58.3	
	Chaoyang Station		8.9	22.1	
	Chatou Station		12.1	36.9	43.2
	Xizhou Station		5.2	16.2	
	Shipa South Station		3.7	4.7	
	Huangjinwei Station		3.6	12.0	
Phase II of Line 14	Xinshixu Station	2	4.1	4.8	
	Jiahe Wanggang Station		8.9	33.2	
Line 10	Guanggang New City Depot	2	33.9	79.1	
	Daganwei Station		7.6	30.0	
Phase II of Line 7	Shangtang Parking Lot	2	14.0	33.0	
	Yufengwei Station		3.8	10.7	
East Extension of Line 5	Shuanggang Parking Lot	4	17.7	36.9	
	Miaotou Station		5.4	12.3	33.4
	Huangpu Passenger Port Station		5.2	14.1	5.6
	Yuancun Station		4.5	24.8	
Line 12	Chatou Depot	3	33.2	38.9	37.9
	Chisha Depot (Chisha Station)		56.8	121.9	176.9
	Chigang Station		9.0	35.1	
East Extension of Line 3	Guangzhou New City West Parking Lot	3	18.1	35.5	
	Panyu Passenger Station		10.0	39.1	58.1
	Jinguang Avenue Station		11.2	34.3	
North Extension of Line 8	Jiangfu Station	1	7.9	19.6	
	Total	33	451.7	1 082.1	421.4

Source: compiled based on Reference [14].

The main content of the station complex building concept plan included

1) Development scale: The 33 projects covered a total land area of approximately 452 hm^2 with a total construction volume of about 10.82 million square meters, including 25 station complexes and eight vehicle depot complexes. The land area for the former ranged from 3 to 12 hm^2 per site, while the latter ranged from 15 to 50 hm^2 per site.

2) Land compatibility: In the planning and control, the land use for the station complexes was designated as transportation facility land compatible with comprehensive development functions, including commercial, business, residential, and other functions.

3) Floor area ratio: The floor area ratio (FAR) for the rail transit station complexes was ≤ 5.0, while for the vehicle maintenance depots, it was between 2.0 and 3.0. The actual FAR needed to be determined based on factors such as traffic capacity, environmental capacity, and geological conditions. The station body, transportation connection facilities, and municipal facilities were not included in the FAR of the complexes and are calculated separately.

4) Subsequent approval procedures: For sites that comply with the aforementioned floor area ratio specifications, the integrated development plans would be directly included in the statutory detailed control plans after review and public notice by the planning department. Sites with a higher floor area ratio than specified must be submitted to the Municipal Planning Committee for review according to the established procedures.

5) Construction implementation: The principles of environmental friendliness, green and low-carbon development, and livability for both residence and work were upheld, while the concept of zero-transfer transportation and one-stop service was implemented. One station complex from each district was selected as a pilot project, and construction and implementation were gradually advanced.

4.3 Implementation effectiveness: policy mechanisms and planning methods further refined

By the end of 2022, 8 out of the 33 planned station complex projects had been completed, including the Chatou Station, Chisha Vehicle Depot (Chisha Station), and Chatou Vehicle Depot. The primary land grant revenue for urban rail transit construction reached 42.14 billion yuan, achieving a fundraising completion rate of 53.1%. Secondary development and the remaining station complex projects are still underway.

During the "13th Five-Year Plan" period, the development of station complexes was carried out for the first time under the guidance of the *Implementation Rules*, introducing four innovations in planning, design, and construction compared to previous practices.

1) Development concept: The process promoted the simultaneous execution of station site selection, planning, design, and construction in urban rail transit. This included completing the investigation and selection of developable land during the site selection phase, reserving land for over-station development during the feasibility study phase, finalizing the design of the over-station complex during the station architectural design phase, and constructing the station complex during the station construction phase, ultimately achieving true integration of the station and the city.

2) Planning approach: The implementation of the 33 station complex projects followed a “two main lines” development strategy, which not only fulfilled Guangzhou’s strategic requirement of building a hub-based network city but also elevated the urban rail transit network beyond the pure transportation function, creatively integrating transportation, economic, and service functions into a unified system.

3) Policy mechanism: The policy was led by the development and reform departments, with the planning and resources departments guiding the planning, the rail transit departments organizing the scheme preparation, and the districts handling land acquisition. This clear division of responsibilities facilitated collaboration among various departments and between the city and districts, achieving integrated, full-process, and platform-based planning. The connection mechanism between urban planning and rail transit construction was streamlined.

4) Development model: the development of the station complex was closely linked with the construction of the rail transit project, proceeding simultaneously. The land for the station complex was included in the land acquisition scope of the main rail transit project, acquired and implemented together with the rail transit project land. This approach allowed the metro company to participate in the secondary development of the complex through cooperative development (Fig. 8).

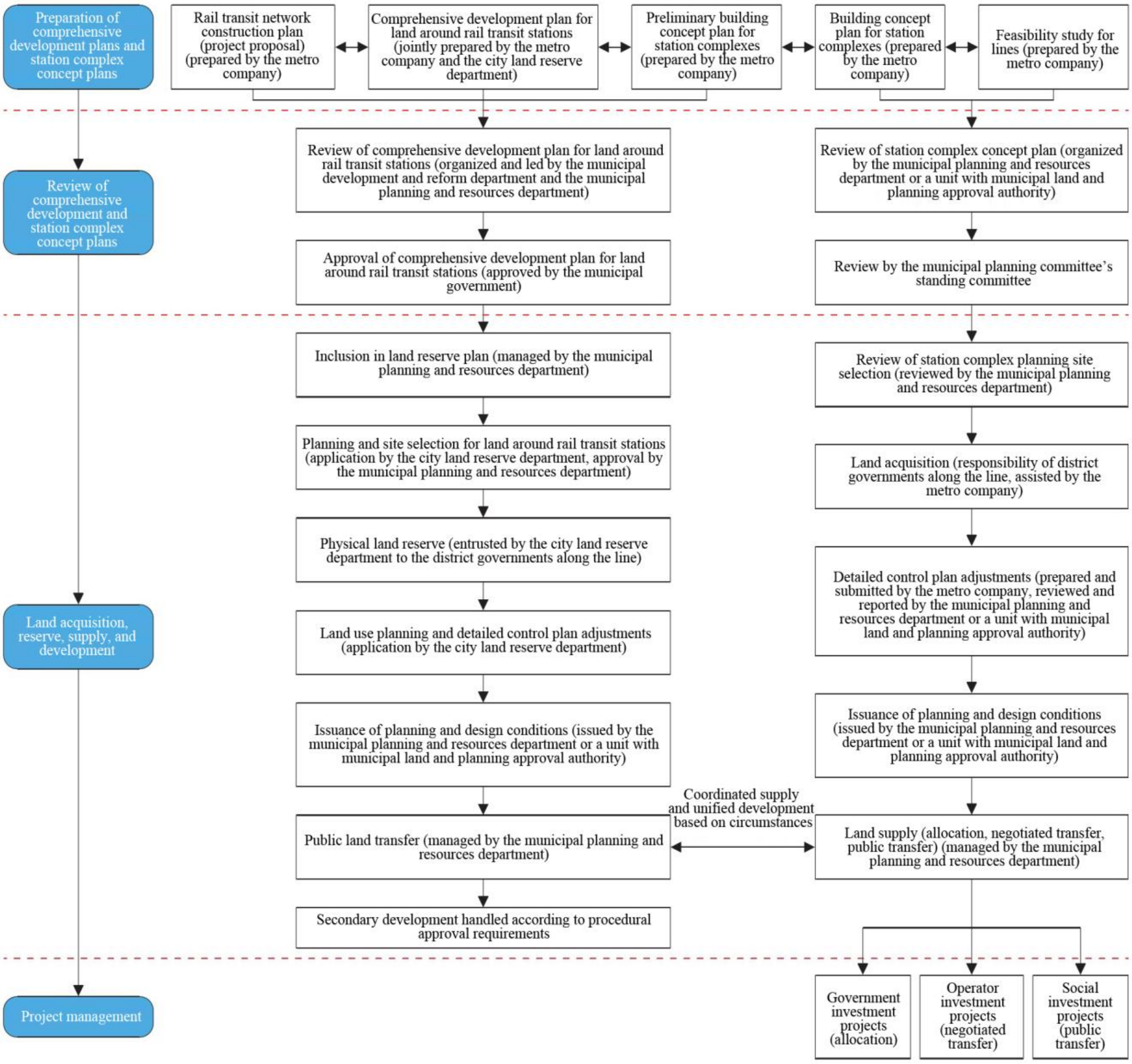

Fig. 8 Process of comprehensive development of station complexes and surrounding lands

Source: compiled based on Reference [2].

5 Future development outlook

5.1 From single-station complex to integrated four-network station complex

Starting from the exploration of the “rail transit + property” model during the construction of Metro Line 1, Guangzhou has utilized station complex development to fund urban rail transit construction, address traffic issues in old city areas, and optimize urban spatial layout. This evolved into the formulation of the *Implementation Rules* during the “13th Five-Year Plan” period. Over 30 years of continuous practice and development, the policies, supporting systems, and planning and design methods for station complex development in Guangzhou have gradually matured, successfully implementing a more diverse range of station complex projects. With the approval and implementation of the *Guangdong–Hong Kong–Macao Greater Bay Area Intercity Railway Construction Plan*, Guangdong Province designated Guangzhou Metro Group Co., Ltd. (renamed from Guangzhou Subway Corporation in June 2015) to undertake the construction and operation of intercity railways within the Guangzhou metropolitan area [15], achieve intercity railway transit-oriented operation, and participate in the construction of regular-speed and high-speed railways. By the end of 2022, Guangzhou had more than 800 km of rail transit lines completed or under construction. During the “14th Five-Year Plan” period, in addition to accelerating the construction of metro lines outlined in the *Guangzhou Urban Rail Transit Phase III Construction Plan (2017–2023)*, the focus will also be on building intercity railways like the Nanzhu-Zhong and Foshan-Guangzhou-Dongguan lines in the Greater Bay Area, with an aim to establish a “cross-shaped” main axis of the rapid transit network in the Guangzhou metropolitan area, enabling 0.5–1 h fast commutes between Guangzhou’s central district and cities such as Foshan, Dongguan, Zhuhai, and Macau. By 2030, the network is expected to exceed 1 500 km, integrating trunk railways, intercity railways, suburban railways, and urban rail transit. The future trend of rail transit development is inevitably toward an integrated four-network system, and Guangzhou’s station complex development must also keep pace and diversify, expanding from single station complexes to integrated four-network station complexes.

5.2 From “single-station” complexes to “station + surrounding area” integrated development

Most of the completed and under-construction station complexes in Guangdong are scattered “single-station” projects, lacking integrated development with the surrounding areas. This is especially evident in the absence of effective coordination with urban village renovations, old city areas and factory transformations, and key functional zones around the stations, leading to challenges in aligning transportation connectivity, functional layout, and spatial design with the surrounding areas. One challenge is the complex land ownership around the stations, making land acquisition difficult. The other challenge is that since land parcels farther from the stations are less influenced by the transit network, their economic value is consequently reduced. As Guangzhou enters a phase of stock development, the comprehensive development of land around transit stations needs urgent attention, especially as large-scale station complex developments are near completion. Such a shift in focus is a core consideration behind the “two main lines” development strategy outlined in the *Implementation Rules*. Moving forward, there is a need to promote integrated and large-scale development based on the city transportation strategic plan, the implementation of the rail transit network, and the construction of station complexes. This should be combined with land reserves around transit stations, urban renewal projects, and key functional zone planning to establish a new development model. This model would integrate “rail transit stations + station complexes + public service facilities + comprehensive land development”, further enhancing the value-adding effect of the transit network on urban development. This approach is essential for sustainable urban development, creating new growth points, and achieving the integration of stations and cities.

5.3 From “new line construction + station-city integration” to “relocation and renovation + stock renewal”

Over the past 30 years, Guangzhou rail transit network has experienced tremendous growth. Station complexes have been developed alongside new lines, significantly enhancing transit services and driving the development of new districts and urban construction. In July 2023, the *State Council General Office issued the Guiding Opinions on Actively and Steadily Promoting the Renovation of Urban Villages in Mega Cities*. In September 2023, the *Ministry of Natural Resources released the Notice on the Pilot Work of Redeveloping Inefficient Land* (Document No. 171 [2023]), deciding to launch a new round of urban village renovations and inefficient land redevelopment in major cities like Guangzhou and Shanghai. This aims to improve people’s livelihoods, expand domestic demand, and promote high-quality development. As major cities in China enter a stage of stock development, land resources are becoming increasingly scarce. The development of station complexes should focus more on updating and utilizing existing resources to adapt to changing times. Future trends and strategies for the development of station complexes in Guangzhou should include: 1) The relocation and renovation of old depots and the development of overhead structures should be promoted. This includes depots such as Jiahe Wanggang, Yuzhu, and Xilang. 2) The renovation of surrounding old city areas through existing stations in older urban districts should be driven to enhance spatial quality and living environments. This approach aims to inject vitality into the old city, with examples including the Bai'e Tan Area of Fangcun Station, the Luochongwei Area of Songxi Station, and the Guangzhou Railway Station area. 3) Stock renewal around new line stations crossing old urban areas should be promoted. By using the construction of rail transit stations as an opportunity to improve public space quality and implement planned roadways, the urban landscape can be enhanced. Examples include the Binjiang East Road Station, Memorial Hall Station, and Martyrs' Cemetery Station.

5.4 From speed and scale to quality, efficiency, and sustainable development

Since the "11th Five-Year Plan", Guangzhou has consistently added more than 200 km of rail transit network every five years, effectively supporting social and economic development and meeting the growing travel demands of citizens. Large-scale and high-intensity rail transit network construction requires substantial funding, which has been primarily raised through the "rail transit + property" model, driving the rapid and large-scale development of station complexes over the past 30 years. To quickly gather the necessary construction funds, past station complex developments often focused more on speed and scale, with an emphasis on residential, commercial, or office buildings. However, as the Chinese economy has shifted from a phase of rapid growth to high-quality development, the development of station complexes must evolve correspondingly. The focus should shift from merely pursuing speed and scale to prioritizing quality and efficiency, transitioning from a purely "land-for-rail and fundraising" purpose to promoting high-quality urban development, practicing the TOD concept, and integrating public resources. Specific strategies include: 1) Modern rail transit integrated transfer systems should be constructed to achieve seamless, zero-transfer integration between rail transit stations and station complexes. 2) Low-efficiency land around stations should be revitalized and redeveloped to promote intensive and efficient land use and to shape a new urban landscape. 3) More reliance should be placed on secondary development revenues and surrounding land development to raise funds for rail transit construction and operations. 4) Policy mechanisms should be further explored and innovated to establish an integrated investment and financing mechanism for rail transit investment and development.

The "rail transit + property" model, which relies primarily on the one-time revenue from the sale of land in station complexes for financing rail transit construction, cannot ensure the long-term sustainability of rail transit development. In the future, it is essential to explore sustainable development strategies for the entire life cycle of rail transit: 1) TOD sustainability: It is necessary to continue to advance and deepen the planning and construction of station complexes, ensuring that rail transit construction and urban development are mutually supportive, promoting smart growth in cities. 2) Financial sustainability: Future efforts should focus on revenue from secondary development, including income from leasing properties and operating self-held properties. The former mainly refers to high-quality commercial buildings and office spaces in the overlying properties, while the latter includes retail commercial spaces and advertising revenue within stations. 3) Operational sustainability: Guided by a transit-oriented operation model, efforts should be made towards the rapid implementation of an integrated rail transit network under the four-network integration framework, building a cohesive system across the Greater Bay Area with "one network and one ticket to connect cities". This approach aims to continuously increase passenger flow intensity and scale, converting flow into economic benefits and ultimately achieving self-sustaining operations. 4) Social sustainability: In the future, it is necessary to take on more social responsibilities by using rail transit to stimulate the integrated development of land along the routes, guiding a shift in urban development models and creating more high-quality communities that are convenient for transportation and environmentally friendly, which in return will provide a sustainable, high-intensity passenger flow that supports both rail transit operations and property management.

5.5 From Guangzhou to the Greater Bay Area

As the Guangdong–Hong Kong–Macao Greater Bay Area becomes an integral part of the national development strategy, the barriers posed by administrative boundaries within the Greater Bay Area will gradually diminish, leading to a trend of boundary-less integration. Driven by industrial developments, the integration of major hubs with urban areas, and intercity rail connectivity, the boundaries between Guangzhou and its neighboring cities will gradually blur. Concurrently, with Guangzhou Metro Group Co., Ltd. fully undertaking the Pearl River Delta intercity railway projects, including 13 lines such as the Guangfo Ring Intercity Railway, Guangzhou–Dongguan Intercity Railway, Guangzhou–Zhongshan–Zhuhai Intercity Railway, and Guangzhou–Qingyuan Intercity Railway, the total intercity rail mileage in the Guangzhou metropolitan area is expected to exceed 550 km, which will lead to greater integration between Guangzhou and other cities in the Greater Bay Area, forming a unified rail transit network across the region. Therefore, the future construction strategies, concepts, methods, and experiences of Guangzhou station complexes need to be promoted and adopted in other cities in the Greater Bay Area such as Foshan, Dongguan, Zhuhai, and Zhongshan. Guangzhou must effectively integrate the land resources surrounding high-speed rail, intercity rail, and urban rail transit stations within the metropolitan area to foster passenger flow along the rail lines, advancing the integrated operation of rail transit across the Greater Bay Area and the orderly development of station complexes, so as to establish a sustainable "rail transit + property" model and development mechanism, enhancing the passenger and economic benefits of the Guangzhou metropolitan rail network. By leveraging the “Guangzhou model” of station complex development, the city can lead the coordinated and unified development of cities in the Greater Bay Area.

6 Conclusions

The planning and construction of station complexes play a crucial role in raising funds for rail transit development, promoting the expansion of the transit network, enhancing the development intensity around stations, and preventing inefficient land use. Over the past 30 years, Guangzhou has continuously explored development mechanisms and policies, studied evolving trends, and iteratively updated its planning strategies, which effectively ensured the timely and efficient planning and construction of rail transit, significantly alleviating urban transportation issues and driving social and economic development in the city. As Guangzhou fully integrates into the development of the Guangdong–Hong Kong–Macao Greater Bay Area, it is essential to continue in-depth research on the development patterns, mechanisms, policies, and planning of station complexes to maximize the role of station complex planning and construction in driving both rail transit and urban development.

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