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CHINA SUSTAINABLE CITIES
INTEGRATED APPROACH PILOT PROJECT

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NINGBO
SUMMARY REPORT

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SUMMARY REPORT

GEF-6 CHINA SUSTAINABLE CITIES INTEGRATED APPROACH PILOT PROJECT

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Preface

The Sustainable Cities Integrated Approach Pilot was a worldwide program established by the multinational Global Environment Facility in its sixth funding round (GEF-6). As implemented in China, it was aimed at helping Chinese cities use the principles of transit-oriented development (TOD) to achieve sustainable land-use policies and transit plans at the levels of city, transit corridor, and transit station. The five-year China project (GEF-6 China TOD) ran from December 2017 to March 2023. It was managed by the World Bank and implemented by China's Ministry of Housing and Urban-Rural Development (MoHURD) and seven representative large cities: Beijing, Tianjin, Shijiazhuang, Ningbo, Nanchang, Guiyang, and Shenzhen. . This report contains only city and station levels of analysis.

The Ningbo GEF-6 Project Management Office (PMO), set up under the Ningbo Housing and Rural-Urban Development Bureau, was led and coordinated by the Development and Reform Commission of Ningbo. Several city agencies participated in the activities of the PMO, including the Natural Resources and Planning Bureau, the Transportation Bureau, and the Finance Bureau; also participating were district governments and the Ningbo Rail Transit Group. The planning and design of the Ningbo project were undertaken by several consulting technical organizations.* This report is prepared by the team from Beijing Jiaotong University, it summarizes and evaluates the technical outputs of the project.

* The Shenzhen Urban Transport Planning Center and Deloitte Consulting (Chengdu) were responsible for the city-level technical content. . Beijing Urban Construction Design and Development Group, Shanghai Jianke Engineering Consulting, and Shanghai Jibang Investment Consulting were responsible for the financial and investment aspects and pilot project technical content.
China Metro Engineering Consulting was responsible for the station-level technical content.

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Abstract

Ningbo is an important port city on the southeast coast of China and a central city in the southern wing of the Yangtze River Delta. It is renowned for its historical and cultural significance as well as its manufacturing and innovation districts. The urban space of the Ningbo metropolitan area exhibits a "1 + 3" cluster pattern: It consists of Sanjiang, which is the urban center and undergoing renewal, and three other clusters—Beilun, Zhenhai, and Fenghua. All four clusters are the city's centers of commercial and industrial activity as well as areas of cultural and social appeal.

Land acquisition and development along Ningbo's rail transit lines have been active since the 2006 release of the *Ningbo Rapid Rail Transit Network Planning* document. However, the metropolitan area suffers from an inadequate alignment between rail transit and urban spatial structure, insufficient public transport connections, and low levels of population and employment around transit stations.

As one of the seven pilot cities selected for the GEF-6 China TOD project, Ningbo focused on TOD at the city, corridor, and station levels. In response to the city's problems of urban structure and transportation, the Ningbo project promoted improvements in the structure and performance of public transit as the foundation for successful urban renewal and development in Ningbo. The project advanced designs, policies, and implementation strategies that will be incorporated into Ningbo's construction policies and future urban and transportation planning.

The project's technical team has fashioned two different types of TOD based on variations in the functional characteristics of rail transit stations and the potential for urban renewal. The team has also provided suggestions regarding spatial zoning, land use, transportation modes, and development intensity and explored the integration of above-ground and underground TOD to promote commercial prosperity. More specific discussions regarding urban renewal will be included in the report on urban regeneration, one of the special topic reports in the GEF-6 China TOD series. An evaluation system and optimization and improvement strategies for TOD stations in urban renewal areas have also been established and serve as a reference for cities with similar demands.


NINGBO

Part 1: TOD Strategy at the City Level

Ningbo is an important coastal port city in southeastern China, located in Zhejiang Province within the prosperous Yangtze River Delta region. It is also a key city in China's Belt and Road initiative and one of the country's 15 subprovincial cities. As of the end of 2022, Ningbo had a total resident population of 9.6 million, including 6.2 million registered residents, and 79 percent of the population of the city as a whole was urbanized.

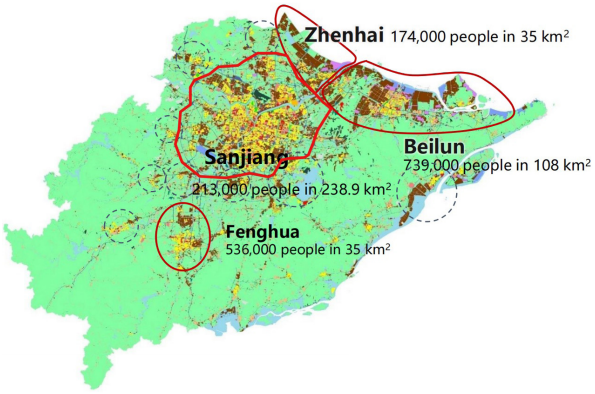
The city, with one of the strongest economies in the province, has high per capita disposable income and thus strong consumer spending power. Over the period from 2021 to 2022, the city had a positive in-migration population flow equal to about 5.7 percent of the city's total population.

The more developed urban space of the city proper—with a population of 2.25 million— consists of four clusters: Sanjiang, which is the urban center and is undergoing renewal, Beilun, Zhenhai, and Fenghua. These clusters are centers of commercial and industrial activity as well as areas of cultural and social appeal. Of the four clusters, population and population growth are centered in Sanjiang, while jobs are concentrated in Sanjiang, Zhenhai, and Beilun (figure 1).[1]

Ningbo has a solid industrial foundation, with various industrial parks distributed along rail transit lines in suburban areas, especially Zhenhai and Beilun. The total value of the tertiary (services) sector's output surpassed that of the secondary sector (including manufacturing, construction, and food processing) for the first time in 2019, but the secondary sector still accounts for nearly 50 percent of the city's overall economic output.

1 Beilun, Zhenhai, and Fenghua are also three of the city's six districts; the other three are in the Sanjiang cluster: Haishu, Jiangbei, and Yinzhou.

Figure 1: Land Use and Spatial Structure of Ningbo City



Source: China Metro Engineering Consulting, *Study on Improvement of Existing Rail Transit Stations Based on TOD, Task 1: Background Investigation Report, June 2020.*

1. Transportation Characteristics of Ningbo

Line 1, Ningbo's first rail transit line, opened in May 2014, and Line 2 opened in September 2015. During the years of the GEF-6 China TOD project in the city (December 2017 to March 2023), phase 2 of transit construction created Lines 3, 4, and 5. Currently the five lines serve a total of 127 distinct stations in the four clusters, and the combined length of the lines totals 185.2 kilometers (figure 2).

Figure 2: Ningbo Urban Rail Transit Lines

Source: Ningbo Rail Transit, http://www.nbmetro.com/fast-track.php.

Within each of its four clusters, Ningbo has a relatively balanced mix of residential and occupational areas. Throughout the city, short-distance travel is predominant, with an average travel distance of 4.7 kilometers and an average one-way commuting time of about 24 minutes in the city. The mode accounting for the highest proportion of short-distance travel is walking, followed by bicycles, electric bicycles, and automobiles.

The five rail lines mainly attract passengers for long-distance travel—14.5 kilometers per trip on average. Thus, the lines have not reached the multiuse goals outlined in the 2006 network planning document, leaving them with a relatively low proportion of transportation usage by residents.

2. Challenges in TOD Development

Transportation and land development in Ningbo have exhibited some key weaknesses: (1) low ridership on the five transit lines with both temporal and spatial imbalances, (2) low density of the rail network relative to population and employment centers, (3) low density of land development along the rail lines, (4) poor pedestrian access to rail stations, and (5) inadequate affordable housing near stations.

Low Intensity of Rail Passenger Flow

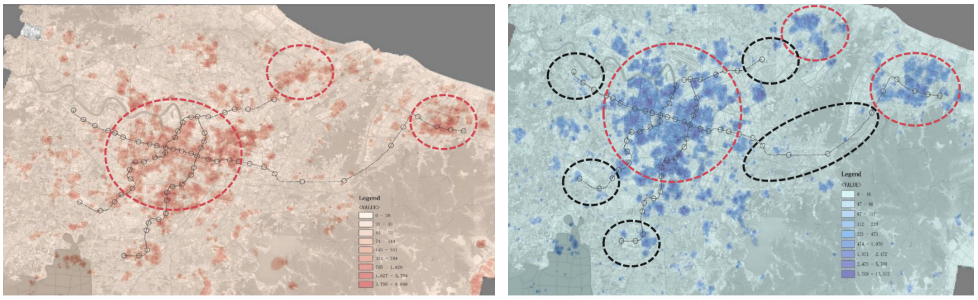
The current modal share of rail transit in Ningbo still needs to be higher. Public transportation accounts for 18 percent of travel, and urban rail, mainly serving longer-distance travel, accounts for only 4 percent. Likewise, the daily number of passengers served by urban rail in Ningbo per kilometer (roughly 5,250) is lower than in similar-sized cities and about one-fourth lower than the national average of 7,100.

Station passenger flow is imbalanced, being significantly higher in the city center than at the end stations. Flows are heavily weighted to morning and evening rush hours, especially so on the western section of Line 1.

The locations of stations generally need to match the distribution of employment and population; such alignment in Ningbo is weak and produces insufficient passenger flows (figure 3). Seven residential centers are outside the 800-meter coverage of existing rail stations, and approximately 12 employment centers are outside the 800-meter coverage, indicating a need for further optimization of employment coverage.

Figure 3: Population and Employment around Rail Transit

a. Population b. Employment



Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report, October 2021.*

The rail transit stations need to attract more passengers living within a 500-meter radius. For about 70 percent of stations, the "coverage rate" at that distance (the proportion of the population within that range that use the station) is less than 40 percent. Suburban stations mainly rely on passenger flows from a radius of 500–1,000 meters. And about one-third of all stations primarily rely on passengers from beyond the 1,000-meter range.

Weak Coverage of the Commuting Population

Ningbo's rail transit construction started relatively late and has yet to serve as large a population as was expected (table 1). After completing the second phase of rail transit planning at the end of 2021, the total operating mileage in Ningbo reached 175 kilometers. The coverage rate of commuting within an 800-meter radius of urban rail transit stations was 20 percent before the completion of the second phase and increased to 32 percent afterward.

However, at the cluster level, in urban central areas such as the Sanjiang District with relatively dense rail transit networks, the coverage rate of commuting within an 800-meter radius of urban rail transit stations was 40 percent and 61 percent, respectively, before the completion of the second phase. These rates were lower than the rail coverage rates in similar urban central areas elsewhere in China.

Table 1: Comparison of Rail Network Construction Status and Planning Goals

Planning Period	Network Length (km)	Sanjiang Area Network Density (km/km^2)
End of 2019	96	0.13
Phase 2 completion, end of 2021	175	0.25
2020 planning goal	272	0.44
Long-term planning goal	409	0.68

Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report, October 2021.*

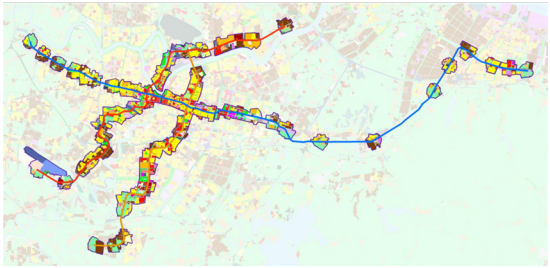
Low Intensity of Land Use along the Rail Lines

The current average floor-area ratio (FAR, the ratio of total building floor area to lot size) within 500 meters of the city's rail transit stations is generally low. Only eight of the 117 stations have a FAR within 500 meters that is greater than 1.5; these stations account for about 7 percent of the total. Stations with a FAR between 0.5 and 1 account for 34 stations, making up 29 percent of the total.

Within 1 kilometer of the stations, the proportion of ground made up of undeveloped construction land plus nonconstruction, logistics, warehousing, and vacant land—at roughly 20–25 percent—is relatively high. In contrast, the ratio of land suitable for TOD purposes, such as commercial and public service facility land, at roughly 15 percent, is relatively low.

A statistical measure of how well land use is diversified within 800 meters of rail stations is relatively low.[2] The intensity of land use and the level of matching that use with the TOD of stations need further optimization (figure 4).

Figure 4: Land Use around Rail Transit Stations



Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report, October 2021.*

2 The average functional mix index within 800 meters of rail transit stations in the entire city is 0.65, lower than 0.72 in Shenzhen.

Inefficient Station Connectivity

Pedestrian and bus connectivity at Ningbo's stations need improvement.

- The average number of entrances and exits at Ningbo's rail transit stations is relatively low, with 84 percent of stations having three or fewer.[3]
- Pedestrians should generally be able to reach a station in 10 minutes from a distance of about 1,250 meters.

In Ningbo, the average distance to a station covered by a 10-minute walk is about 500 meters. The difference is significantly attributable to the low density of roads around stations.

- About 35 percent of rail transit stations have no conventional bus connections within 50 meters of an entrance or exit.

Insufficient Affordable Housing around Stations

The construction of rail lines has increased the number of land transactions along the construction corridor, resulting in higher land transfer prices. From 2016 to now, 13 large-scale affordable housing projects have been approved and constructed in Ningbo, with only five located along the rail transit corridor. Most of these projects are in suburban areas far from the city center.

3. TOD Strategies

To address the issues and challenges, the technical team in Ningbo proposed TOD strategies and guidance. At the macro level, the strategy emphasizes integrating urban rail transit with urban development in different locations, phased guidance, and close integration. At the intermediate level, the strategy focuses on implementing high-density rail networks in the city center and integrated TOD-driven urban renewal. Policy suggestions focused on land control mechanisms and organizational improvements in city government.

Macro-Level Guidance

At the macro level, the principles are based on spatial reshaping and the leveraging of underused resources. The planning and guidance models adopted for the urban center differ from those for the suburbs. In the city center, rail transit construction is the engine for urban renewal, while in peripheral areas, rail transit stations are used to guide development of the surrounding land. Different development and construction methods are employed for different regions.

The urban planning structure is closely integrated with the staged construction plan of the rail transit network, emphasizing the high level of unity between the rail transit network structure and the urban planning structure. This guides urban development in a clustered direction, enhancing the coupling of the rail network framework with the urban spatial system to support dual main centers and the development of secondary centers in the periphery.

Intermediate-Scale Guidance

At the intermediate level, the focus is on accelerating the construction of a high-density rail network in the city center. Multistation linkage—jointly developing their underground spaces— is implemented in densely populated areas, supporting the development of underground space. Priority is given to TOD urban renewal or redevelopment projects in rail transit peripheral areas. Additionally, 49 urban bus hubs are planned around rail transit stations to promote integrating the bus system with multiple networks.

3 Shenzhen has an average of four, and Hong Kong an average of six.

Policy Optimization Strategies

Optimize Control Mechanisms for Rail Stations and Surrounding Land

Focus on enacting land management measures and policies specific to the city and clarify the functions in the TOD comprehensive development process. This will allow control of the land resources along transit lines and around stations across multiple stages, from large-scale planning and management to project-level land reserves, supply, and transfer.

Encourage Participation of Multiple Stakeholders

Construct a diversified cooperation pattern for comprehensive TOD of rail transit. Include construction and operation entities and subsidiaries, local government platform companies, and other market-oriented development and operation companies.

Support Market-Oriented Development

Market-oriented measures are needed to effectively cope with the significant financial pressure that will be created by the planned arrival in 2035 of an enlarged rail network. They include supporting Ningbo Rail Transit Group in obtaining comprehensive TOD resources and establishing diversified business models and forms.

Policy Optimization Suggestions

To support a healthy TOD regulatory environment in Ningbo City, the Ningbo City Project Office has formulated a series of TOD supporting policy proposal lists (table 2).

Table 2: Policy Recommendations for Comprehensive TOD

Policy Document	Responsible Unit	Key Policy Points
Regulations for the Comprehensive Development and Land Management of Ningbo Rail Transit	Ningbo Municipal Natural Resources and Planning Bureau	Strengthen organizational leadership, clarify the scope of comprehensive development, optimize the implementation mechanism of control and planning, strengthen underground space reserve engineering construction, improve land reserve mechanism, determine land supply methods, explore land classification pricing mechanisms, explore new models for property transfer, and other key content points.
Special Planning for Comprehensive Development along the Rail Transit in Ningbo	Ningbo Municipal Natural Resources and Planning Bureau (lead), Ningbo Rail Transit Group (specifically responsible)	Clarify the developable land resources, sort out the usable underground space, and determine the scale of fund-raising.
TOD Integrated Urban Design Guidelines in Ningbo	Ningbo Municipal Natural Resources and Planning Bureau (lead), Ningbo Rail Transit Group (specifically responsible)	Provide differentiated guidance for different levels and layers of stations in terms of functional positioning, land layout, development intensity, urban form, open spaces, underground spaces, slow traffic systems, and transportation connections.
Regulations for Parking Facilities and P+R Construction Management in Ningbo	Ningbo Municipal Transport Bureau (lead), in conjunction with Ningbo Municipal Housing and Urban-Rural Development Bureau	Specify requirements and regulations for the location of P+R parking lots, P+R parking facilities construction requirements, and the interlinked charging mechanism between P+R and rail transit.
Guidance for the Promotion of Green Building in TOD Projects in Ningbo	Ningbo Municipal Housing and Urban-Rural Development Bureau	Encourage the implementation of green building standards in TOD demonstration projects, explore the establishment of high-star green building incentive measures, and standardize green construction and safe construction in rail transit construction projects.
Guidance on the Proportion of Affordable Housing and Talent Apartments in Ningbo	Ningbo Municipal Housing and Urban-Rural Development Bureau	Provide support for the location layout and construction methods of new affordable housing and talent apartments along rail transit, as well as support for urban renewal involving the reconstruction of existing buildings.

Source: Shenzhen Urban Transport Planning and Design Research Center, Deloitte Consulting (Chengdu), and Nikken Sekkei Research Institute, *Ningbo TOD Strategic Study, Task 6b: Research Report, 2022.*

4. TOD Station Typology

Station classification supports the spatial and functional TOD strategy at the city level. The technical team used multiple factors to detail the TOD classification of all existing urban rail transit stations in Ningbo. They classified the stations into four major types according to their need and potential for urban renewal and transformation of the surrounding land. Corresponding TOD guidelines were proposed to aid research for existing stations. The four-level classification provides a good basis for setting Ningbo's development sequence and the optimization of station function.

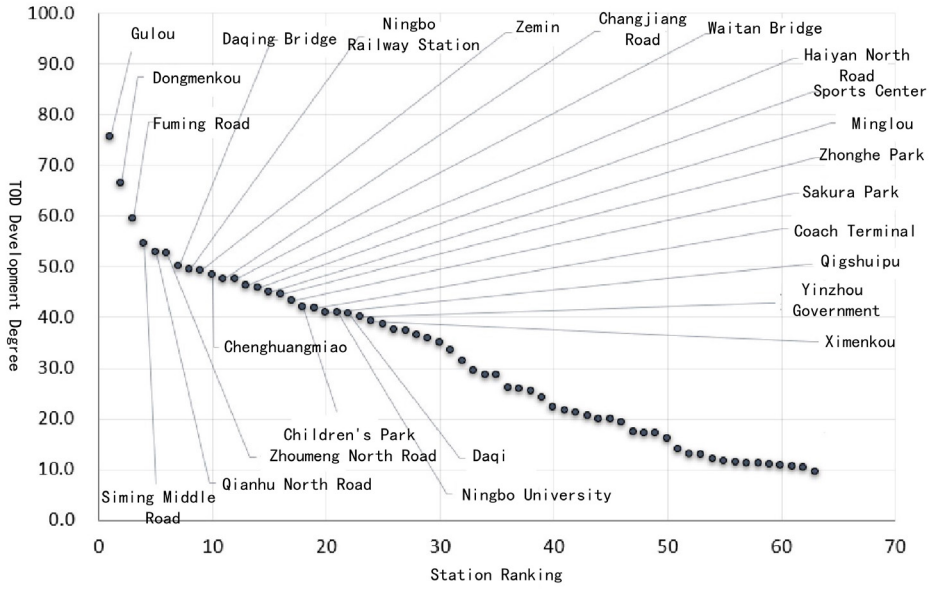
Calculation Method for TOD Development Level

The TOD evaluation system for Ningbo's existing urban rail transit stations was based on the internationally accepted "node-place" model and local investigations. The model encompasses three dimensions (encompassing eight categories and 39 indicators):

- the node traffic capacity of the station
- the place capacity around the station
- public willingness to optimize stations, as measured in opinion surveys

Calculation of the indicator weights was based on model data (entropy), a method that avoids the influence of expert composition, subjective judgment, and time factors. The TOPSIS analysis method, suitable for multiobjective decision-making, was applied to the varying levels of TOD at the stations to obtain a comprehensive ranking of all stations (figure 5). Applying the stations' indicator scores to the node-place model facilitates a comparison with other cities domestically and internationally to identify development gaps and deficiencies.

Figure 5: TOD Rail Station Level and Ranking Results



Source: China Metro Engineering Consulting, *GENB-3 Research on Improvement of Existing Rail Transit Stations Based on TOD, Task 3: Research Plan Comparison for Key Stations*, August 2021.

Four Development Categories for Stations

Four categories—A, P, I, and N—were created to indicate the TOD potential of the stations and the degree of long-term TOD improvement they need, which in turn define the long-term development needs of rail transit in Ningbo (figure 6):[4]

A-TOD (Already achieved TOD)

Stations with mature development in the city's traditional core areas. Basic features include traditional commercial centers with mature urban development. TOD effects have already been formed, and passenger flows are relatively high. The surrounding area has a high population density and land development is well formed, featuring a high level of commercial and public service facilities.

P-TOD (Potentially achieved TOD)

Stations in a city center that have almost reached a mature level of TOD. Basic features include being in new city centers or hub nodes with relatively good development around the stations but with inadequate transit coverage of nearby populations.

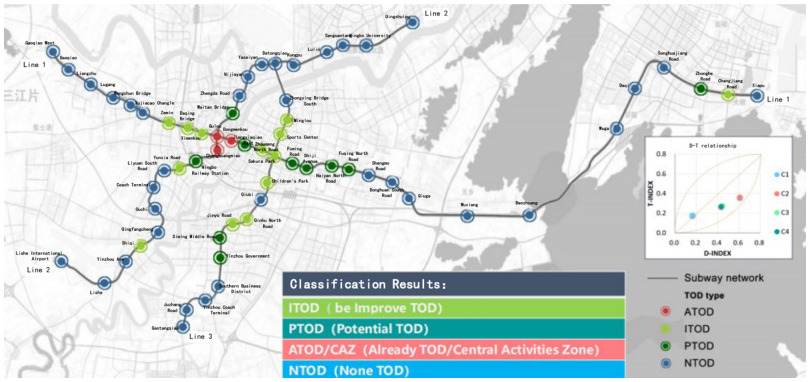
I-TOD (Improve TOD)

Stations with apparent shortcomings. Basic features include high current and planned population density in the surrounding areas. The land has available development space and good planning conditions. The evaluation indicators need to be improved in one or more dimensions to exceed average rail transit passenger flow. The potential for improvement is significant, and the effect will be substantial.

N-TOD (No TOD)

Stations that need comprehensive reshaping and improvement. Basic features include being located on the edge of the city center. The surrounding land could be more efficiently used, with low development density, incomplete land development, and single service functions. The land intensity is low, and the surrounding population and employment coverage is low. The comprehensive TOD development score is relatively low.

Figure 6: Station TOD Categories as Applied to Rail Transit Lines 1, 2, and 3



Source: China Metro Engineering Consulting, *GENB-3 Research on Improvement of Existing Rail Transit Stations Based on TOD, Task 3: Research Plan Comparison for Key Stations*, August 2021.

Development Guidelines for the Four Categories

TOD guidelines for future development and functional optimization were formulated for each station category. The guidelines are drawn from various dimensions of the indicator system to generate strategic results.

4 K-means clustering was used to classify the levels of TOD needed at the stations.

A-TOD

Considering that ATOD stations are already mature in terms of current development, the focus is on enhancing quality. The strategy emphasizes improving quality and efficiency, precisely designing services for rail transit users, and thoroughly exploring service details and quality. Renewal of residential land can be obtained organically through local government plans for older residential areas. Use of underground spaces can be explored further, leveraging the potential value of history, culture, and other characteristics for the development of those spaces.

Traffic congestion can be eased by improving the walking environment, creating more green transportation connections, restricting car access, improving the operational management of rail transit stations, and strengthening integration with surrounding above-ground and underground spaces.

P-TOD

The basic land development around these stations has already been completed, and they have some potential to improve their attractiveness to the surrounding population. The suggested development strategy is to avoid launching large-scale urban renewal and planning changes because these stations already have a higher level of TOD planning, no severe shortcomings, limited potential for designed improvement, and a high value for the region. The TOD effect will therefore gradually emerge naturally with urban development and the realization of better transportation facilities.

The focus should be on maintaining the stability of existing planning policies. At the same time, close attention should be paid to the dynamic evolution of rail transit and urban development. Joint development of underground space by the transit system and stakeholders in the surrounding area should be deeply explored, and relevant services should be provided around the station to enhance the level of supply and service provided by these stations.

I-TOD

These stations have relatively good land planning conditions, moderate passenger flow, and some development space. Suggested guiding strategies include consolidating and exploring options for the developable land, enhancing functional mixtures, forming a land-use structure of high-density centers and low-density periphery, and further enhancing the attractiveness of the area to the local population.

Public service facilities should be provided according to the characteristics of the surrounding area, and multiple transportation methods and green transportation should be integrated. The level of supply and service of urban rail transit should be enhanced, and the shortcomings in the station evaluation indicators should be addressed.

At the same time, as the surrounding land development gradually improves, transportation access facilities should be gradually standardized and fixed. Given their proximity to new regional centers, consideration should be given to introducing other types of rail transit, such as intercity rapid transit.

N-TOD

These stations are characterized by low efficiency of the surrounding land use, low development density, incomplete land development, and single service functions. Comprehensive studies should be carried out in conjunction with suburban and regional planning. Specific development strategies should focus on overall planning and development to adjust the inefficient use of land around the station and form a concentric structure of development.

The construction of commercial facilities around the station should emphasize overall shaping and value enhancement, increasing the floor-area ratio, and supporting public service facilities. Rail transit should be fully supplied, and transportation access facilities of various types should be developed to form new urban attraction points.


NINGBO

Part 2: TOD Strategy at the Station Level

The technical team in Ningbo has created a set of eight station types, or profiles, based on the assessment of the range and type of development suitable for the city's existing stations. These types can guide the spatial planning and design of different rail transit stations and strengthen the linkage between the city and individual stations.

The stations are further divided into three levels of TOD transformation for their respective types—low, medium, and high.

1. Classification of Existing Urban Rail Transit Stations for TOD

Ningbo's existing urban rail transit stations have been categorized into eight types on the basis of indicators such as location and surrounding land use.

- *Gateway Hub*: Stations that serve as transportation hubs for Ningbo's external traffic
- *Urban Service*: Stations located in or near city public service facilities, such as hospitals.
- *Industrial Park*: Stations located in or near industrial development areas with industrial land dominance
- *Research Park*: Stations located in or near science and technology research and development zones with industrial land dominance
- *Central Business*: Stations located in central and subcentral areas with concentrated employment (example in figure 7)
- *Central Commercial*: Stations located in central and subcentral areas with large commercial complexes
- *Mature Community*: Stations dominated by residential land use and without large-scale transformation potential
- *New Community*: Stations dominated by residential use with potential for development in the surrounding areas

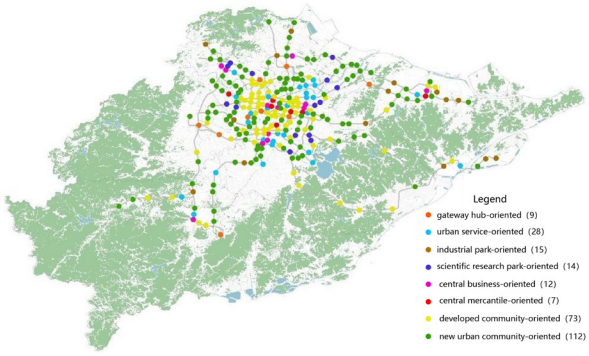
In the station-level TOD classification, the technical team used the node-place model, selecting three node indicators: centrality degree, proximity centrality, and transport accessibility. And they selected three place indicators: development intensity, development mix, and connectivity convenience. The team first screened for four station types: unique, park, central, and community. The station-level TOD classification method focuses more on station capacity represented by regional and transportation factors. In contrast, the city-level TOD classification method mentioned above (A, P, I, N) highlights the potential for future urban renewal, with different objectives and research outcomes from different technical teams.

Using the model with node and place indicators, the technical team evaluated 270 current and planned stations within the rail network of Ningbo's six districts and identified the number of stations for each of the eight types (figure 8). In the node-place model, 72 percent of the stations exhibit characteristics of balanced nodes and places, while 22 percent have subordinate features.

Figure 7: Typical Example of a Central Business Station: Government Station, Yinzhou District

Source: Beijing Jiaotong University TOD team.

Figure 8: Long-Term Station Planning: TOD Classification Results



Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report*, October 2021.

Index System Construction

Using the aforementioned eight-type station classification, the technical team proposed the overall development vision for Ningbo TOD: to create a vibrant, compact, and attractive city and support a green and rewarding lifestyle. The vision of compactness is reflected in the place value within the node-place model, and the green transportation vision is reflected in the node value.

The TOD principles discussed in the World Bank's 2017 report, *Transforming the Urban Space through Transit-Oriented Development: The 3V Approach*, include coordinating population and economic density to improve transport accessibility, and promoting compact development and work-life balance. To account for the social and economic impacts of TOD implementation, the technical team constructed an evaluation framework for station potential using the 3V (3 values) in the World Bank report: the values of node, place, and market potential (with market divided into economic and social). This framework is used to assess the level of integrated development between transportation and land use in station areas and evaluate their future potential.

The indicators selected by the team for the three values are as follows (table 3):

Table 3: Evaluation Indicators of TOD Station Potential in Ningbo

Dimension	Connotation	Indicator	Calculation/Explanation	
Node	Station carrying capacity	Centrality degree	Number of lines passing through the station (count)	
	Network connectivity	Proximity centrality	Average distance to other stations in the network (km)	
	Transport accessibility	Number of stations reachable within 30 minutes	Total number of stations reachable within a 30-minute travel time (count)	
Place	Land development potential	Floor-area ratio	Ratio of total building floor area to land area within an 800m radius	
	Land use diversity	Land use mix	$M = \frac{-\sum_{i}^{k} p_i * \ln p_i}{\ln k}$	Pi represents the proportion of the i-th land use type to the total land area. k is the number of land use types.
	Pedestrian accessibility	Intersection density	Number of intersections within an 800m radius (count/km²)	
Market	Land development potential	Potential land area	Total area of potential development land within an 800m radius (m²)	
	Land development revenue	Potential land price	Net income from potential land sales within an 800m radius (100 million yuan)	
	Investment attractiveness	Average current housing price in the area	Average current housing price in the area (yuan)	
	Industrial support	Industrial platform level	Level of the industrial platform in the spatial planning	
	Population value	Population density	Ratio of total population to area within an 800m radius (10,000 people/km²)	
	Employment value	Job density	Ratio of total jobs to area within an 800m radius (10,000 jobs/km²)	
	Work-life value	Number of jobs reachable within 30 minutes	Total number of jobs covered by stations reachable within 30 minutes (10,000 jobs)	
	Community value	Road network density	Ratio of total road network length to area within an 800m radius (km/km²)	

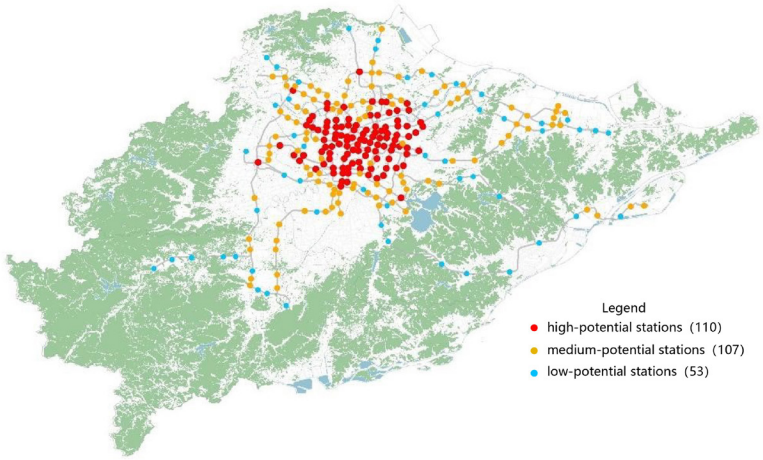
Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report*, October 2021.

- Node: centrality degree, proximity centrality, and the number of stations reachable within 30 minutes
- Place: floor-area ratio, land use diversity, and pedestrian accessibility
- Market potential
  - Economic: potential land area, potential land price, average current housing price in the area, and the industrial platform level
  - Social: population density, job density, the number of jobs reachable within 30 minutes, and road network density.

Scores for Station Potential

By using these indicators and weighting each station's scores, a comprehensive potential score was assigned to each station. The five stations with the highest comprehensive scores were Min'an East Road, Ningbo Railway, Haiyan North Road, Jiangsha Bridge East, and Ailu . Furthermore, the technical team divided the stations into three potential categories: high, medium, and low (figure 9).

Figure 9: Distribution of Stations, by TOD Potential



Note: The three categories were calculated with k-means clustering.
Source: Shenzhen Urban Transport Planning Center, *Ningbo TOD Strategic Study, Task 4: Results Report*, October 2021.

The high-potential stations are predominantly concentrated within Ningbo's inner ring road, particularly in the city center. Overall, the distribution of high-potential stations, by type, is as follows:

- Gateway Hub: 4
- Urban Service: 16
- Industrial Park: 2
- Research Park: 3
- Central Business: 8
- Central Commercial: 5
- Mature Community: 45
- New Community: 27

Of these 110 stations, 55 are already operational, 39 are in the final phase of construction, and 16 are planned.

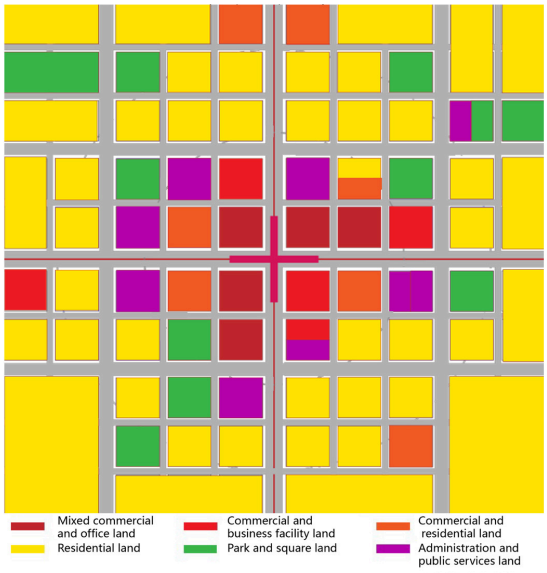
2. Optimization Guidelines by Station Type

Classification and guidance strategies have been proposed to aid the application of the station TOD classifications and potential evaluations to future TOD and construction. The guidance includes design optimization recommendations consisting of indicators within the TOD system such as area function positioning, land attributes, mixture degree, and floor-area ratio. The guidance system is based on station grading and classification; it targets park, central, and community-type stations, providing differentiated guidance based on the functional characteristics and current conditions within each regional spatial plan.

Central Business and Central Commercial Stations

Central stations, whether in concentrated business or commercial areas, are typically important economic centers of city centers and subcenters. The future development of central stations should encourage a greater mix of land uses to create a blend of commercial, office, residential, and public service functions (figure 10). Efforts should also be made to improve the convenience and other service aspects of transportation facilities at these stations. The optimization guidelines for central stations encompass (1) spatial zoning, (2) transportation systems, (3) land use, (4) development intensity, and (5) spatial design, among others.

Figure 10: Land-Use Guidance for Central Stations



Source: Shenzhen Urban Transport Planning Center, *GENB-1 Ningbo TOD Strategic Study Task* 5, September 2022.

Spatial Zoning

The spatial range is influenced by the level, nature, and scale of the service area and by the structure of the road network. Under the plan, the coverage area around the station will vary in size and exhibit irregular spatial boundaries. The region around the central station can be divided into three layers: the portal area, the core area, and the transition area, each with different spatial forms.

Transportation Systems

In the densely populated and complex transportation systems of city centers, the overall transportation system should be centered around rail transit stations characterized by high accessibility and transfer efficiency. With rail as the primary mode and regular bus systems as auxiliaries, the plan should also seek ways to optimize slow modes and limit private traffic.

Land Use

The composition of land use is mainly focused on business, commerce, administrative offices, and public services (table 4). The layout of land functions often presents functional aggregation horizontally and functional mixture vertically. Promoting integrated development of commercial, service, transportation, and municipal facilities in both above-ground and underground spaces is encouraged and will help create a comprehensive whole around the central station.

Development Intensity

Development intensity typically includes high density, with density decreasing in a concentric pattern from the core area outward.

Spatial Design

The spatial environment should create a diverse and rich cultural atmosphere, showcasing regional cultural characteristics, providing humanized facilities, and creating a vibrant central area.

Table 4: Land-Use Reference Standards for Central Stations

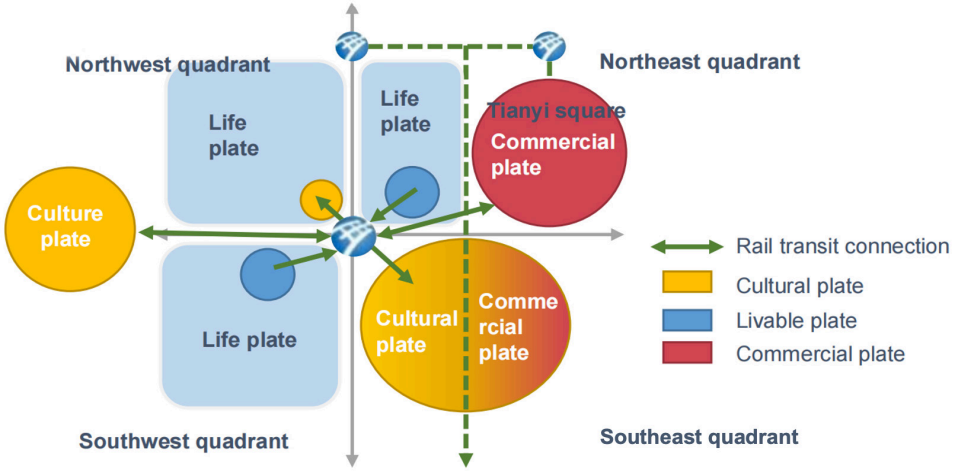
Station Zone	Range (approximate meters)	Land Use Proportion Reference Standard (approximate percent)	
Station core	0-300	Commercial and office mix	20-40
		Commercial services	5-10
		Public management and services	10-15
		Residential and commercial mix	10-15
		Residential use	10-15
		Roads and transportation	15-25
Rail transit radiation	300-500	Public management and services	5-10
		Commercial services	0-5
		Residential use	50-65
		Roads and transportation	10-15
		Green spaces and plazas	5-15

A typical example of a Central Commercial type of station is Chenghuangmiao, on Ningbo Rail Transit Line 2, located in the core area of Sanjiangkou (figure 11). The area belongs to Ningbo's traditional commercial district, characterized by a mature commercial atmosphere and dense population. Its transformation plan focuses on using bus and slow-mode transit connections to tie together life and cultural functions with existing commercial zones (figure 12).

Figure 11: Tianyi Square, at Chenghuangmiao Station

Source: Beijing Jiaotong University TOD team.

Figure 12: Overall Planning of Chenghuangmiao Rail Transit Station



Source: China Metro Engineering Consulting, *GENB-3 Study on Improvement of Existing Rail Transit Stations Based on TOD, Task 4-1: Planning and Design of Key Rail Transit Stations in Ningbo*, August 2021.

Mature Community and New Community Stations

Residential functions are the focus of community-type station areas, and they are equipped with relatively complete public service facilities appropriate to the population size of the community. Optimization of the layout should prioritize residential function and establish corresponding and well-developed commercial, public service, and municipal facilities that match the scale and characteristics of the residential population. The transportation system should revolve around rail transit as the core, with efficient connections to other modes. The aim is to create an attractive environment with abundant and convenient public facilities in a diverse neighborhood culture. The optimization recommendations for community-type stations cover (1) spatial zoning, (2) transportation systems, (3) land use, (4) development intensity, and (5) environmental design, among others.

Spatial Zoning

The spatial range is the area within 700–800 meters from the station, with the gateway area blending into the surrounding environment without clear boundaries. The core area generally refers to the 300–400-meter zone around the station entrances and exits. In contrast, the transitional area extends from the core area to the main arteries on the periphery.

Transportation Systems

Community-type stations are often located in the middle of main roads or at intersections and are suitable for underground concourse design with multiple station entrances and exits. The core area of the station area has a higher road network density compared to the transitional area, with road network spacing of, at most, 300 meters to form a small-scale and dense network structure. The station is closely integrated with city roads, and multiple conventional public transportation stops are set in the vicinity, but parking lots are generally not provided (table 5).

Land Use

Areas near community-type stations are suitable for developing high-density residential communities and mixed-use complexes combining residential and commercial functions (figure 13 and table 5). Land should be allocated for public service facilities. Residential land and public green spaces are suitable for planning in the transitional area.

Figure 13: Land-Use Guidance for Community Stations

Source: Shenzhen Urban Transport Planning Center, *GENB-1 Ningbo TOD Strategic Study Task 5*, September 2022.

Table 5: Land-Use Reference Standards for Community Stations

Station Zone	Range (approximate meters)	Land Use Proportion Reference Standard (approximate percent)	
Station portal	0-200	Commercial and office mix	10-15
		Commercial services	15-20
		Public management and services	25-30
		Residential and commercial mix	0-10
		Residential use	20-35
		Roads and transportation	5-15
Station core	200-400	Public management and services	15-25
		Commercial services	0-5
		Residential and commercial mix	5-10
		Residential use	45-50
		Roads and transportation	10-15
		Green spaces and plazas	5-15
Rail transit influence	400-800	Public management and services	5-10
		Commercial services	0-5
		Residential use	50-65
		Roads and transportation	10-15
		Green spaces and plazas	5-15

Development Intensity

The core area should receive high-intensity development of commercial facilities, public service facilities, and mixed-use complexes, while the transitional area should see medium-intensity development of residential areas. The development intensity of the core and gateway areas is 30 percent to 100 percent higher than that of the transitional area.

Environmental Design

Commercial and public service facilities should be well-equipped and concentrated in the core area. Large public green spaces should be located outside the station area or in the transitional area. The core area should be improved through street and cluster green spaces, and walking environments should be enhanced through greenways.

A typical example of a community-type station is the Jinhai Road Station, in Xincheng, Fenghua District (figure 14).

Figure 14: Typical Example of a Community Station: Jinhai Road Station, Xincheng

Source: Beijing Jiaotong University TOD team.

Gateway Hub Stations

Gateway Hub station areas are designated in higher-level plans as transportation hubs serving external transportation services, such as train stations, airports, ports, and long-distance bus stations. The optimization recommendations for Gateway Hub stations cover (1) spatial zoning, (2) industrial functional positioning, (3) transportation systems, and (4) environmental design, among others.

Spatial Zoning

The number of Gateway Hub station areas is limited, but they play a crucial role in urban and regional transportation services and economic development. The spatial scope of these areas should be determined on the basis of the influence range of external transportation hubs in Ningbo.

Industrial Functional Positioning

Gateway Hub stations and the surrounding urban design should be integrated for development, with supporting functions including office spaces, residential areas, cultural and entertainment facilities, commercial and hotel functions, and exhibition centers. The composition and proportion of transportation and urban functions should be based on the station's planning positioning, operational model, throughput, service scope, and target users.

Transportation Systems

The overall development of Gateway Hub stations should be intensive. The station area should be mainly focused on transportation functions, while the specific functions of the station area should be determined through special planning and design. Newly built Gateway Hub stations should be developed into integrated facilities that combine multiple functions, such as residences, commercial spaces, and services and entertainment venues.

Gateway Hub stations should be built with multiple floors of mixed-use development above them. The station and the city should be integrated, and various urban functions should be incorporated within the high-rise hub complex, making it a city landmark. Horizontally separated hubs can be connected to high-rise buildings through underground and above-ground pedestrian systems.

Environmental Design

The environmental design and service facilities should promote convenient and efficient transfer and highlight the role of urban gateways.

Research Park Stations

Research Park station areas feature relatively large-scale and homogeneous research facilities (which can include warehousing). The optimization recommendations for Research Park stations include (1) spatial zoning, (2) transportation systems, (3) land use, and (4) development intensity, among others.

Spatial Zoning

The spatial scope is determined by the influence range of higher education institutions and other factors. The core area of the station should be located within a walking distance of about 5 minutes (400 meters) and consists of critical management, service, or exhibition facilities with significant passenger flow, and commercial and office facilities closely related to the work and life of the research park staff.

Transportation Systems

Stations and entrances/exits should be connected to the main pedestrian entrances/exits of the research park and be connected to their pedestrian systems or public transportation nodes. Transit hubs can be set up near the rail entrances/exits to create a transportation node for interchanging between rail transit, conventional public transit, and nonmotorized modes (table 6).

Land Use

In the gateway area of the station, plazas and transportation facilities should be provided for transportation distribution and transfer. Public and commercial service facilities related to the research park's functions or serving the park staff should be concentrated in both the gateway and core areas. For Research Park stations affiliated with higher education institutions, sufficient recreational spaces and public service facilities should be provided for surrounding residents, and the proportion of surrounding green spaces and public service land should be appropriately reduced (figure 15 and table 6).

Development Intensity

Development intensity should be influenced by the characteristics of the research park itself, and it should comply with both the intensity and building height requirements of the surrounding area.

Figure 15: Land-Use Guidance for Research Park Stations

Source: Shenzhen Urban Transport Planning Center, GENB-1 *Ningbo TOD Strategic Research, Task* 5, September 2022.

Table 6: Land-Use Reference Standards for Research Park Stations

Station Zone	Range (approximate meters)	Land Use Proportion Reference Standard (approximate percent)	
Station portal	0-200	Industrial use land	20-25
		Commercial services	25-30
		Public management and services	10-15
		Mixed use land	10-15
		Roads and transportation	20-25
		Green spaces and plazas	0-5
Station core	200-400	Industrial use land	30-35
		Public management and service	10-15
		Commercial services	0-5
		New industry use land	25-30
		Roads and transportation	15-20
		Green spaces and plazas	5-10
Rail transit influence	400-800	Industrial use land	30-35
		Public management and service	5-10
		Commercial services	0-5
		Commercial services	30-35
		Roads and transportation	10-15

Source: Shenzhen Urban Transport Planning Center, *GENB-1 Ningbo TOD Strategic Research, Task 5*, September 2022.

Urban Service and Industrial Park Stations

For Urban Service and Industrial Park stations, optimization guidelines were given for (1) land value capture, (2) urban renewal, (3) motor vehicle and parking management, (4) low-carbon and green initiatives, (5) safety and risk management, (6) private car and taxi management, (7) transportation connections, and (8) underground space layout, among others.

Land Value Capture

Encourage the concentration of land resources around rail transit areas based on the floor-area ratio (FAR) to enhance the regional land value. Surrounding areas should be used for mixed land-use, adhering to the principles of "high intensity, high value, and high agglomeration," leveraging land resources to support industrial development and enrich the potential sources of tax revenue. Through land value capture, the external benefits of rail transit can be internalized, alleviating the substantial financial pressure of rail transit construction, operation, and maintenance, while laying a foundation for diversified business development.

Urban Renewal

Adopt a comprehensive, government-led approach for urban renewal. Encourage use of various transformation models, including government-led initiatives, voluntary transformation by land rights holders, and single-entity commercial developments, to stimulate the participation of market entities and accelerate the urban renewal process.

Priority should be given to comprehensive, mixed-use, and residential projects, as well as new industrial and urban integration projects that positively impact the economic and social development of local towns or districts. The expected property appreciation on these projects supports their economic feasibility. Seek innovation in financial policies, reform systems, spatial policies, and land policies, and address issues related to fund-raising, spatial utilization, governance models, and operational management.

Motor Vehicle and Parking Management

Emphasize the development of green travel modes, establish an integrated transportation system with multiple modes of transportation, improve multilevel and differentiated public transportation systems, and vigorously promote pedestrian and bicycle transportation system construction. Strengthen green transportation management, reasonably allocate the scale of parking lots around rail transit stations, reduce private car traffic, and use intelligent transportation systems to improve transportation efficiency. Advocate for green transportation design, create an ecologically friendly transportation environment, and promote the intensive use of transportation facilities with a priority on public transportation and slow transportation.

Low-Carbon and Green Development

Encourage low-carbon economies and innovative low-carbon technologies around the station areas, promote lifestyle changes, minimize urban greenhouse gas emissions, and foster healthy, cost-effective, and low-carbon living and consumption patterns. On the other hand, employ carbon capture and offset principles to establish public green spaces, plant green trees, and achieve near-zero carbon emissions in the vicinity of stations.

Safety and Risk Management

Reduce the number of lanes around the station area, control lane width and intersection scale. Limiting the vehicle speed to 20–30 kilometers per hour is advisable to ensure the safety of pedestrians and cyclists. Proactive management of streets around the station should be based on usage different periods.

Private Car and Taxi Management

Introduce speed limit strategies around the station to manage traffic and parking demand and encourage passengers to opt for sustainable transportation. To reduce the need for private cars and taxis, implement measures such as congestion charges, license fees, and assigning more road rights to high-quality public transportation services. To control parking, set the number of parking spaces in the core area of the station to no more than 70 percent of the standard minimum and encourage the promotion of shared parking. For interchanges with rail transit, adopt a bay platform approximately 100 meters from the rail transit station and place it upstream of bus stops. Passenger pickup and drop-off facilities by private cars and taxis should be integrated with building entrances or placed nearby using bay platform parking.

Transportation Connections

Prioritize public transportation and slow transportation measures. Set the distance between traditional public transportation and bicycle stations to within 200 meters. Each station should have multiple entrances/exits directly integrated with commercial and public buildings or connected through underground passages, aerial walkways, and so on to seamlessly link with commercial and public buildings.

A three-dimensional, networked, and multifunctional walking corridor consisting of underground, ground-level, and above-ground layers should be formed on the basis of horizontal and vertical traffic at the station. Rail transit station halls should be combined or connected with distribution plazas, building spaces, and underground spaces. Pedestrian bridges, underpasses, and walkways should be arranged according to the locations of the station hall space, platform entrances/exits, and surrounding functional spaces. Entrances/exits should be placed in densely populated areas, and various pedestrian-friendly facilities should be set up to connect rail transit entrances and exits with surrounding buildings and streets. Prominent and clearly labeled walking guidance systems should be installed on major roads around rail transit stations, indicating the direction and distance of the station.

Underground Space Layout

Establish controlled development zones, including priority, moderate, and restricted development areas, according to the demand level for underground space.

Priority development areas include important commercial and business centers, and public service centers, major transportation hubs (such as airports and high-speed rail stations), and the surroundings of key rail transit stations (such as hub stations and interchange stations).

Moderate development areas include residential, administrative office, industrial and warehousing, and educational use areas.

Restricted development areas encompass primary water source protection zones, related control zones, important mountainous areas, and the core protection ranges of cultural preservation units and points.

The development of underground space in rail transit station areas should follow the principles of hierarchical development, with development intensity and functions determined by the nature of the city's gateway, core, and radiating functions. Central and gateway hub stations are suitable areas for development in Ningbo.

The commercial format in station areas should comply with the random characteristics of passenger flows and emphasize the convenience of commercial operations. Commercial spaces should include various layouts, such as integrated point-style station halls, linear underground streets, and block-style underground malls. The station interior should be arranged with three main sections: retail, dining, and services. The underground commercial street should focus on leisure, dining, and fashion-related businesses.

The underground public space of stations should be integrated with the above-ground public building space and open green plaza nodes, facilitating the flow of pedestrian traffic. Underground public spaces should be set up at the intersections and transitions of underground pedestrian trunk routes to enhance pedestrian flow aggregation and dispersion. At major attractor points in the underground, such as the main entrances of underground commercial complexes, sunken plazas or spatial nodes should be established to facilitate spatial transitions. At the same time, underground spaces should meet disaster prevention and evacuation requirements, minimizing the number of staircases and beautifying the ground landscape.

Part 3: Summary of Achievements and Future Directions

Among its key experiences, the Ningbo project developed differentiated analyses of TOD related to urban renewal and to the development of individual stations. For the future, the project recommends focusing on improving policies, collaboration, and the sustainability and inclusivity of TOD.

1. Summary of Key Experiences

The Ningbo project established city-level (urban renewal oriented) and station-level (location oriented) classification schemes for urban TOD, crafted guidelines tailored to the two classifications systems, and developed design strategies appropriate to both levels of classification.

Establishment of TOD Evaluation Methods

In the Ningbo project, two TOD classification methods for urban rail transit stations were established by technical teams—city level and station level. Both methods used the node-place model. The main difference lay in their focus: the city-level method established four types that provide a reference for selecting areas with the most potential for future urban renewal. The station-level method established eight types defined by current urban functions and location characteristics.

The city-level method used a local survey as well as the node-place model to form a three-dimensional evaluation system with eight categories and 39 indicators. Indicator weights were calculated using the entropy weight method, which overcomes the problems of subjectivity and time dependence typically present in studies that rely on subjective weighting by experts.

The station-level method developed an indicator system comprising node, place, and market values and assigned weights to specific indicators to identify the types and potential values of existing TOD stations. The resulting classifications help prioritize future TOD development and are used to formulate spatial optimization guidelines for areas around the stations.

TOD Classification Guidelines

At the city level, the transformation direction and optimization focus for the four types of station were developed in the classification guidelines, laying the foundation for their "site-specific, classified" TOD in the context of future urban renewal.

Station-level guidelines recommended differentiated spatial zoning, transportation systems, land use, development intensity, and environmental design policies for the eight types of station..

Integration of Rail Transit Construction and Urban Renewal

The study was tightly integrated with the urgent needs of the city and the ongoing urban renewal efforts, addressing issues such as inadequate spatial layout, congested roads, encroached pedestrian spaces, traffic congestion, and outdated commercial formats.

The project team specified improvements to the linkage between stations and the surrounding buildings by considering the addition of new entrances/ exits for the rail transit stations. By enhancing the internal space of the rail transit system and its connection with the urban space, the recommendations increased passenger flow, driving urban commercial opportunities and promoting the renewal of the inner city.

Recommendations for improvements in public transportation around the stations, minimizing the intertwining of motor vehicles, nonmotor vehicles, and pedestrian traffic. In addition, by promoting the development and utilization of underground space, the plan introduced additional passenger flows in underground commercial spaces to ease passenger movements in periods of inclement weather.

Integrated Design of Underground Space and Station Connectivity

The Ningbo project office and the technical team carried out the integrated design of above-ground and underground spaces around TOD rail transit stations. For example, in the city center, opportunities were found for multiple underground levels, with one for business and commercial uses and one below that for parking and utilities. Pedestrian walkways could be connected through escalators, sunken courtyards and plazas, optimizing the organization of pedestrian flow.

In addressing rail connectivity, the goal was to improve the bus, bicycle, and pedestrian transfer capabilities of stations, optimize transfer routes, and enhance the experience of slow modes on these routes. Access points were increased in areas with high commuting demands. Priority for slow modes was advocated to provide shortcuts for pedestrians and cyclists and additional facilities for nonmotorized vehicle parking. Furthermore, the connection with surface public transportation stations was strengthened, setting up transfer shortcuts and optimizing the slow-mode environment and bus station functions.

2. Directions for Continued Optimization

Future activities are best directed at updating and standardizing policy documents, improving collaboration among TOD project stakeholders, building up the green character of TOD, and promoting affordable housing and work-life balance.

Continuous Improvement of Existing Policies

The Ningbo project office formulated suggestions for the optimization of TOD policies and developed an action manual with guidance for several policy documents. The optimization suggestions and action manual aim to promote efficient division of labor and collaboration among various departments and provide more standardized references for TOD construction and development. Continuously optimizing existing policies is critical for accommodating new trends in urban rail and for incorporating higher-level policy documents and plans.

Enhanced Collaboration Among Diverse Stakeholders

As it guides TOD development, the government should also focus on further harnessing the role of the market and encouraging diverse stakeholders—social groups, property owners, residents, developers, operators, and other market entities—to participate. Efforts along these lines include promoting the participation of market entities in construction and development; establishing dynamic consultation to give market entities space for planning adjustments; and exploring how to allow market entities to invest in municipal construction in exchange for concessions such as volume rate rewards.

Meanwhile, mechanisms for public participation should be strengthened to learn from the public's concerns and to increase transparency and access to information throughout the life cycle of projects, to ensure sustainable funding, and secure smooth implementation of TOD projects.

Focus on Sustainable and Inclusive TOD Development

TOD should emphasize sustainability such as by introducing green and energy-saving technologies and using durable and environmentally friendly materials. Integrating the development of stations with their surrounding areas increases multifunctional underground space and improves urban safety and public facilities.

To enhance social fairness and inclusivity, projects should promote overall work-life balance in the area and avoid excessive commercialization that might affect the daily life of residents. Constructing affordable housing along subway lines is a priority, as is resettling displaced residents near their original location and preserving the area's social structure. TOD must accommodate the diverse needs of special groups such as women, older people, children, and people with disabilities. Inclusivity also means creating public spaces that are friendly to the entire population within the station area, including barrier-free designs and accessible elevators.

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