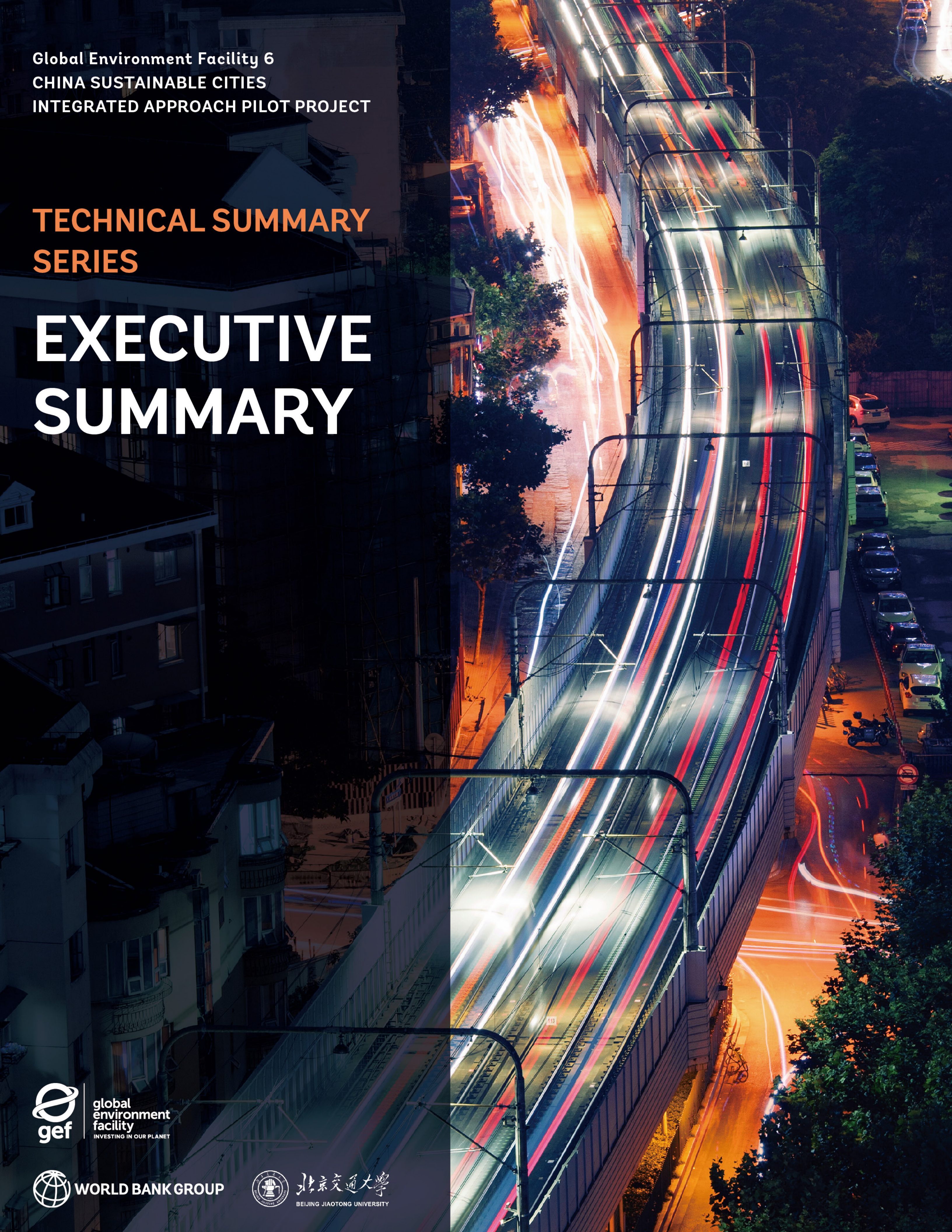

Global Environment Facility 6
CHINA SUSTAINABLE CITIES
INTEGRATED APPROACH PILOT PROJECT

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EXECUTIVE SUMMARY

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 document provides an overview of the eight technical summary reports produced by the project: the report on the National Platform for TOD Information Management created for the GEF-6 China TOD project and seven city reports. The prefaces to the city reports list the principal city departments and consulting technical organizations that participated in the work. Another report, Special Topics in TOD, covers the urban regeneration, public participation, and financing aspects of the China TOD project. The series of summary reports are prepared by the team from Beijing Jiaotong University.


BEIJING

Abstract

In China, the Sustainable Cities Integrated Approach Pilot Project aimed to assist seven Chinese cities—Beijing, Tianjin, Shijiazhuang, Ningbo, Nanchang, Guiyang, and Shenzhen—absorb the principles of transit-oriented development (TOD) into their urban policies and transportation planning. The World Bank developed a national web-based platform for TOD information management to monitor and help coordinate city plans. China's Ministry of Housing and Urban-Rural Development implemented the platform and integrated it with similar city-level platforms. Each pilot city conducted multidimensional TOD research at the levels of city, corridor, and transit station. To conduct context-specific TOD studies tailored to the characteristics of pilot cities, the project built a methodological system and technical standards for TOD classification assessment, issue diagnosis, and planning strategies.

The research results helped guide urban planning in the context of rapid growth of rail transit during the project implementation period (late 2017 to early 2023). At the city level, it addressed how TOD could integrate with urban structure and functional layout; at the corridor level, it explored land use and spatial layout models that promote a balance between job and housing and produce financially supportive increases in land values; at the station level, it focused on integrating bus and slow modes of travel to create walkable, multiuse areas around stations. Three studies addressed the special TOD topics on urban regeneration, public participation. and urban rail financing. Outreach to the public and participation by residents and other stakeholders in developing and monitoring local TOD projects were an integral part of the project.

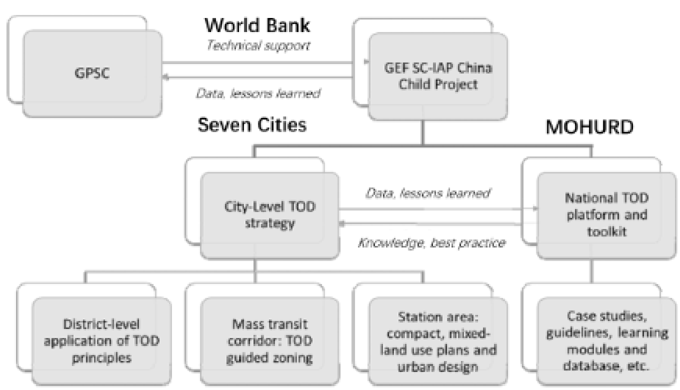
The insights and lessons drawn from the project for China and other developing countries are primarily as follows: TOD's creation of dense, multiuse neighborhoods accessible by mass transit, walking, and bicycling directly improved urban travel and commuting, promoted urban economic prosperity, enhanced social equity, and fostered a low-carbon urban environment.

BEIJING

Part 1: Background and Objectives

From 2014 to 2022, the urbanized portion of China's permanent population increased from 57 percent to 65 percent, and urban rail transit expanded dramatically. From 2015 to 2023, the number of cities operating rail transit about doubled, to 57, and the total operating length of urban rail increased from about 4,500 kilometers to 10,600 kilometers. Against this background, the philosophy and techniques of transit-oriented development have become important requirements of high-quality urbanization in China. China chose transit-oriented development (TOD) as the focus of its participation in the Sustainable Cities Integrated Approach Pilot Project, a multinational effort funded during GEF-6 (the sixth round of grants from the Global Environment Facility). China's project, "GEF-6 China TOD," was conducted from late 2017 to early 2023 at the national level and in seven large pilot cities—Beijing, Tianjin, Shijiazhuang, Ningbo, Nanchang, Guiyang, and Shenzhen. The World Bank provided technical support to China's Ministry of Housing and Urban-Rural Development at the national level. The pilot cities conducted TOD research and planning at three scales: city, transit corridor, and transit station (figure 1).

Figure 1: Project Architecture



Note: GPSC = Global Platform for Sustainable Cities; GEF SC-IAP = Global Environment Facility Sustainable Cities-Integrated Approach Pilot; TOD = transit-oriented development; MOHURD = Ministry of Housing and Urban-Rural Development.
Source: Project Appraisal Document of the GEF-6 China TOD project.

1. The Role of Urban Rail in TOD

The major modes of urban public transportation are urban rail transit (above- and below-ground rail lines typically known as "metro"), light rail ("trams" or "trolleys"), conventional buses, bus rapid transit (BRT), and public bicycles. Historically, urban sprawl has arisen from a failure of conventional urban planning to link land development to the integrated growth of public transit modes. And historically, conventional planning has nearly completely disregarded the value of walkability as the ultimate environmentally and socially sound principle of urban design. Nonetheless, in the pursuit of equitable, environmentally sound planning of walkable urban spaces in and around large cities, urban rail has unique advantages and unique problems.

On one hand, urban rail is unmatched in its ability to support shifts of populations to new, self-sustaining, walkable urban communities while efficiently connecting them to each other and to the central city On the other hand, urban rail requires massive investments to build; its construction imposes disruptions on existing communities that are difficult for a single jurisdiction to manage; the low income generated by rail operations impose heavy burdens on public finances; and even if profitable, creates long payback periods unattractive to investors. Therefore, although urban rail holds the key to managing the ongoing urbanization of China in an era of climate crisis, it is the most difficult mode to execute under conventional modes of planning and finance.

Transit-oriented development is a planning concept that was formalized in the United States in the early 1990s as a set of planning tools enabling localities to manage urban growth without car-centric sprawl.[1] The goal of TOD is to absorb growth into hubs that combine employment, housing, retail business, education, urban amenities, and nature. Much of the day-to-day commuting and other travel for residents can be done by walking or bicycling, with shopping or longer trips facilitated by bus and urban rail, and with urban rail connecting to long-distance ("heavy") rail. The growing experience with TOD in China and worldwide made it practical to be the centerpiece of China's participation in GEF-6.

The GEF-6 China TOD project aimed to expand the national and local capacity for urban development and transportation planning that would improve the quality of urban life, promote economic prosperity, combat climate change, and increase urban resilience. The means to achieve those goals was TOD planning to design new or renovated urban spaces in the pilot cities that enhance "slow modes" of travel (walking and bicycling) within a larger fabric of public transportation.

Another motivation for pursuing TOD: Apart from integrating transit modes and designing complete, walkable communities, TOD entails comprehensive land-use enhancement along rail lines that increases land values. That aspect addresses urban rail's financial liabilities that weigh on local public budgets. In joint ventures of government and the private sector to build urban rail, those increased values can be the source of public revenues not previously available from public transit.

The 11 studies produced by the GEF-6 China TOD project show how it navigated these intersecting elements of TOD. Eight of the reports are technical summaries; one covers construction and use of the nationwide TOD monitoring and evaluation platform, and seven others discuss TOD efforts in each of the seven pilot cities. Three special discussion reports cover the ways TOD supported urban regeneration; the cities' extensive use of public participation to help shape planning and execution; and the workings of land development and public-private consortiums to help sustainably finance TOD projects. This executive summary gives an overview of the eight technical summary reports.

1 Peter Calthorpe, *The Next American Metropolis: Ecology, Community, and the American Dream* (Princeton, NJ: Princeton Architectural Press), 1993.

2. Project Design

As early as the 1990s, Chinese cities gradually began to introduce elements of the TOD concept in their planning. The more rapid urbanization of China beginning around 2000 drove the construction of more urban rail transit and made TOD an engine for urban development. Under TOD, urban rail transit more consistently developed and integrated above-ground and underground areas, concentrating travel and transforming urban land use. TOD also helped orient spatial growth away from a single-center design and toward a hub-and-spoke or multicenter layout. However, the rapid growth of TOD construction in the early 2000s still focused on the construction of physical space to the neglect of a comprehensive development of social, economic, and environmental assets; and most of TOD construction focused on individual stations or local spaces, with less consideration of corridor and city-level perspectives.

The GEF-6 China TOD project engaged both national and local governments to show that, under a more robust TOD approach, cities, with national level support, could address the shortcomings of preceding development efforts. China's Ministry of Housing and Urban-Rural Development (MoHURD) was selected as the implementing national-level agency for the project.

MoHURD's Municipal Transportation Office is responsible for the approval of transit-related above-ground and underground spaces. MoHURD is also the collector and repository of data related to urban rail transit, a valuable resource for comparisons between cities and for analyses involving other indicators of urban development and construction. Finally, MoHURD's work includes the approval of overall urban planning, urban renewal, and affordable housing projects. As such, the agency was well placed to play a top-down guiding role for city planning.

A major goal of the GEF-6 China TOD project was the creation of a computerized system for guiding, monitoring, and evaluating projects in the pilot cities. That goal was accomplished with a web-based National Platform for TOD Information Management, initially built by the World Bank. MoHURD's deep involvement in urban development made it the natural choice for implementing, augmenting, and managing the use of the platform at the national level. Complementary platforms that could interact with the national platform were developed in the pilot cities. The platforms maintain a database, select key indicators, and conduct monitoring and diagnosis of TOD issues; the national platform conducts the monitoring and evaluation across all the pilot cities.

The selection of the seven pilot cities was guided by the requirements of China's new urbanization strategy. Selected cities were meant to represent a range of geographic locations, urban scales, economic development levels, and urban rail development levels.

The populations of the seven cities range from 2 million to 190 million. The cities are distributed as follows across China's regions: Beijing, Tianjin, and Shijiazhuang are in the Beijing-Tianjin-Hebei multicity complex; Ningbo is in the Yangtze River Delta urban agglomeration; Nanchang is in the middle reaches of the Yangtze River agglomeration; Guiyang is the representative of the western provinces; and Shenzhen is in the Guangdong-Hong Kong-Macao Greater Bay Area cluster. During the project execution period, these cities, to varying amounts, each had rail transit lines operating or under construction and each represented a range of regional characteristics and development levels.

The innovation in the design of the GEF-6 China TOD project lay in its attention to the multiscale characteristics of TOD (city, corridor, and station). The approach overcame the limitations of traditional TOD practices, which were mostly focused on research limited to station areas.

In the seven representative cities at the level of citywide analysis, the focus was on the compatibility of TOD principles with existing urban development strategies, the spatial distribution of the population and economy, station type classification, and the relationship between TOD and planning implementation.

At the corridor level, cities emphasized the relationship between living and working spaces along selected rail transit corridors and the potential for new development along the corridors to generate both community benefits and economic return. At the station level, the focus was mainly on the compact development of station area space, the spatial design of mixed functions, and the integration of slow modes of travel with other modes of public transit.

3. The Pilot Cities and Rail Transit Construction during the Project

The seven representative cities—Beijing, Tianjin, Shijiazhuang, Ningbo, Nanchang, Guiyang, and Shenzhen—all had urban rail transit lines that were already in operation or under construction before the project began (table 1).

Table 1: Key Indicators of the Seven Pilot Cities

City	Built-Up Area, 2022 (square km)	Population in Built-Up Area, 2022 (thousands)	GDP per Capita, 2022 (CNY)	Rail Transit Length, 2017 (km)	Rail Transit Length, 2022 (km)	Number of Rail Transit Stations in 2022
Beijing	1,469	19,128	190,300	608.0	864.1	511
Tianjin	1,264	11,601	119,200	175.3	293.9	225
Shijiazhuang	335	3,494	63,000	30.2	76.4	63
Ningbo	397	2,247	163,900	74.5	185.2	127
Nanchang	377	2,920	111,000	7.9	128.3	103
Guiyang	369	2,195	79,900	0	75.7	57
Shenzhen	962	17,660	183,000	302.5	564.8	388

Source: China National Bureau of Statistics, *China Urban Statistical Yearbook 2023, 2023; China Urban Rail Transit Association, Urban Rail Transit 2022: Statistics and Analysis Report, 2023; MoHURD, China Urban Construction Statistical Yearbook*, 2017, 2018, 2022, 2023.

Beijing, the capital of China, is a megacity located in the Beijing-Tianjin-Hebei urban agglomeration. As of 2022, he population in the built-up area of Beijing was about 19.1 million. Beijing was the first city in China to begin building a subway. From 2017 to 2022, the total operating length of its urban rail transit increased from 608 kilometers to 864 kilometers. Under the "population alleviation" goal of the 2017 edition of the urban master plan, Beijing was exploring adjustment of its population and industrial space through the construction of urban-rural (suburban) railways, promoting a multicenter urban spatial structure.

Tianjin is a directly administered municipality in the Beijing-Tianjin-Hebei urban agglomeration and is also the largest port city in northern China. The total permanent population of the city's built-up area is 11.6 million. The first urban rail transit line in Tianjin was officially opened in 1984. From 2017 to 2022, the total operating length increased from 175 kilometers to 294 kilometers. The passenger flow intensity of urban rail transit in Tianjin is at a medium to low level among cities of similar scale. Its rail system is notable for the long length of its suburban routes.

Shijiazhuang, the capital of Hebei Province, is located in the southern part of the Beijing-Tianjin-Hebei urban agglomeration. The total population of the city's built-up area is 3.5 million. The first subway line opened for trial operation in 2017, and the city is developing its urban rail transit system rapidly in the context of its overall development strategy—"reduction within the Second Ring Road, multiplication outside the Second Ring Road." ; The current total operating length of its rail system is about 76kilometers.

Ningbo is an important node in the Yangtze River Delta urban agglomeration and an important river and seaport city on the southeast coast. The total population of the city's built-up area is about 2.2 million. The first subway line officially opened in 2014. From 2017 to 2022, the total operating length increased from about 74 kilometers to 185 kilometers. Urban rail transit lines cover the urban area and also radiate to surrounding clusters including Fenghua, Beilun, and Zhenhai.

Nanchang, the capital of Jiangxi Province, is the central city of the urban agglomeration in the middle and lower reaches of the Yangtze River. The total population of the built-up area is 2.9 million. The first subway line opened for operation in 2015; from 2017 to 2022, the total operating length increased from about 8 kilometers to 129 kilometers. Nanchang's urban rail system guides the expansion of the city's spatial structure, supporting the coexistence of old and new areas and the development of clusters across the river.

Guiyang, the capital of Guizhou Province in southwestern China, has characteristics of a mountainous city, and its urban space exhibits characteristics of cluster development. The population of the built-up area is about 2.2 million. The old central urban area has a population density of more than 30,000 people per square kilometer. It faces the development dilemma of high population density and scarce available land resources in a mountainous environment. The first subway line opened for trial operation in 2017, and by 2022, the total operating length reached 76 kilometers. The development of urban rail transit plays an important role in improving travel in mountainous cities and connecting various clusters in the city.

Shenzhen is an important node in the Guangdong-Hong Kong-Macao Greater Bay Area. it was designated as an economic special zone in the "reform and opening up" period. The population of the built-up area in Shenzhen is about 17.7 million. The first urban rail transit line opened for operation in 2004, and from 2017 to 2022 its total operating length increased from 302 kilometers to 565 kilometers. As a city at the forefront of China's economic development, Shenzhen absorbed the earlier rail construction experience of the Hong Kong Special Administrative Region (SAR) and innovatively formed a development model of "railway + property." The passenger flow in Shenzhen's urban rail system accounts for more than 60 percent of the city's total public transport passenger flows.


SHENZHEN

Part 2: The National Platform for TOD Information Management

The objective of the National Platform for TOD Information Management was to create a web-based program with a variety of modules suitable for the distinct needs of decision-makers and the general public for oversight data and for educational material. It was designed both to maintain an up-to-date TOD knowledge repository and to gather and process city TOD data that could inform the projects in real time as well as guide future projects.

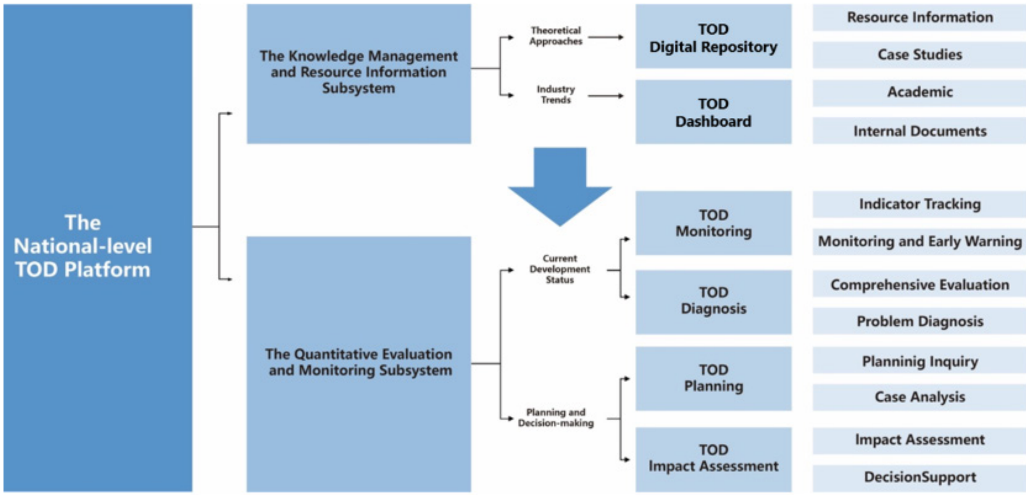
As a knowledge platform, it consolidates relevant policies across time and space to extract and summarize the characteristic practices of pilot cities. This helps clarify the experiences and issues related to planning, design, construction, development, and policy mechanisms, providing valuable insights for TOD construction in other cities nationwide.

As a data processing platform, it contains indicator criteria for monitoring and evaluation of construction at the city, line (corridor), and station scales. The platform provides basic data and comparability for the multidimensional assessment and analysis of the relationship between urban rail construction and urban space.

1. Format and Architecture

The TOD platform is divided into two basic subsystems and six basic modules (figure 2). The two major subsystems are the Knowledge Management and Resource Information Subsystem; and the Quantitative Evaluation and Monitoring Subsystem. Two of the six modules are in the knowledge management subsystem: the Digital Repository and the Dashboard. Four are in the evaluation and monitoring subsystem: Monitoring, Diagnosis, Planning, and Impact Assessment (table 2). Depending on user permissions, the platform can provide visualization, querying, and other services to meet the national-level monitoring and diagnosis functions. And it can offer customized planning and impact assessments according to local needs.

Figure 2: **Architecture of National TOD Platform**



Source: China Academy of Urban Planning and Design, *Technical Report at the End of 2021.*

Table 2: **Modules of the National TOD Platform**

Module	Description
Digital Repository	A repository of domestic and international policies, regulations, and industry standards related to TOD. Technical guidelines, manuals, toolkits, research reports. Academic papers, monographs, relevant website links, etc.
Dashboard	Information on policy making, project practices, and the seven GEF- 6 China TOD project cities. Information on TOD-related research and practices in the cities
Monitoring	Monitor the short-term or long-term effects of TOD-related projects implemented in various cities; showcase the achievements
Diagnosis	Assessment and diagnosis of the current level of TOD development in various cities and showcasing of achievements
Planning	Case reports of TOD-related projects both domestically and internationally; presentation of TOD strategic research and practical achievements in seven GEF- 6 China TOD project cities
Impact Assessment	Local cities conduct impact assessments of their respective urban projects under the TOD evaluation system's standard framework provided by the national platform; results are showcased

Source: China Urban Planning and Design Research Institute, *Research Background and Tasks of the Project.*

2. Evaluation and Monitoring Subsystem

The design of the evaluation and monitoring subsystem is guided by four principles: consistency, local variability, low-carbon development, and value feedback. On that basis, more than 20 indicators from three levels (station, corridor, and city) and eleven dimensions (indicator categories) were selected to establish a unified framework for monitoring, diagnostics, planning, and impact assessment.

The big-data resource library systematically integrates or accesses data resources and outcome resources from seven pilot cities. The indicator system offers specific data that is measurable and updatable at regular intervals.

The selection of 11 basic indicators (table 3) primarily considers two factors: data availability and clarity. The chosen indicators reflect the core goal of promoting coordinated development of urban land and transportation.

Table 3: National TOD Platform Indicators

Indicator	Station Level	Corridor Level	City Level
Urban Rail Transit Facilities	Number of entrances and exits.	Average number of entrances and exits.	Average number of entrances and exits. Number of stations. Total track mileage. Number of urban rail lines.
Urban Rail Transit Operation	Average daily passenger flow at stations.	Average daily passenger volume per line. Passenger flow intensity. Rail passenger load factor.	Average daily rail passenger volume. Passenger flow intensity. Rail passenger load factor.
Land Development	Intensity of building development Gradient of building development intensity	Intensity of building development Gradient of building development intensity	Average daily rail passenger volume. Passenger flow intensity. Rail passenger load factor.
Mixed-Use	Degree of mixed-use functionality Density of functionality	Degree of mixed-use functionality Density of functionality	Degree of mixed-use functionality. Density of functionality.
Connectivity	Number of transferable rail lines. Number of transferable bus routes. Centrality of rail network.	Number of transferable rail lines. Number of transferable bus routes.	Number of transferable rail lines. Number of transferable bus routes.
Transportation Environment	Bicycle riding speed. Road operating speed.	Bicycle riding speed. Road operating speed.	Bicycle riding speed. Road operating speed.
Jobs-Housing Commuting	Density of residential and employment population. Gradient of residential and employment density. Intensity of OD commuting coverage.	Density of residential and employment population. Gradient of residential and employment density. Intensity of OD commuting coverage.	Density of residential and employment population Gradient of residential and employment density. Overall residential and employment coverage rate. Overall commuting coverage rate. Intensity of OD commuting coverage.
Cost of Living	Residential housing price level Suitability of residential housing prices	Residential housing price level Suitability of residential housing prices	Residential housing price level. Suitability of residential housing prices.
Neighborhood Environment	Green view rate Road network density	Green view rate Road network density	Green view rate. Road network density.
Low Carbon Energy-Saving	n.a.	Per capita turnover total energy consumption. Per vehicle turnover traction energy consumption.	Per capita turnover total energy consumption. Per vehicle turnover traction energy consumption.
Resource Management	n.a.	n.a.	Resource management income. Station commercial income.

Note: n.a. = not applicable.

Source: China Urban Planning and Design Research Institute, *Monitoring and Evaluation Indicator System for TOD Development.*

3. Summary

The national TOD platform consolidates and assesses monitoring data on the development of urban rail TOD nationwide. It enables station-, corridor-, and city-level assessments across in 11 categories, including rail facilities, land development, functional diversity, and job–housing commuting balance. In support of environmentally friendly development, the national and local TOD platforms contain low-carbon indicators in the monitoring and assessment modules. The local platforms consolidate data related to urban rail TOD in their respective cities. Some data resources of the local platforms can be linked with the national platform to provide continuously updated nationwide data related to TOD development.

The GEF-6 China TOD experience with the national TOD platform can assist other cities in China and in other developing countries in releasing TOD policies and urban management tools and in conducting TOD monitoring and evaluations.

With the completion of the GEF-6 China TOD project, the local and national platform operations will still need active policy and financial support from government at all levels as well as from development organizations. Keeping the platforms up-to-date with further TOD projects will help ensure that TOD will continue to benefit from the guidance, analysis and evaluations the platforms can provide.

Part 3: Summary of TOD Studies in Seven Pilot Cities

The seven pilot cities reported on TOD analyses at the city level. Published reports from most also discussed rail transit corridors and areas in the immediate vicinity of rail transit stations as objects of study for implementing transit-oriented development.

At the city level, the pilot cities, guided by the national information management platform, conducted TOD studies based on the city's positioning, development goals, and current issues. These studies integrated TOD into the overall urban development strategy. Multiple technical teams analyzed TOD development issues based on land use status, city master plans, and urban rail plans, and they developed TOD classification models. These teams provided strategies and technical guidance that took into account the population, economy, and industrial layout of each city.

At the corridor level, Beijing, Tianjin, Shijiazhuang, Nanchang, and Guiyang reported on the use of selected rail transit lines to formulate policies coordinating other transit modes and land development. Their approaches varied, including the use of existing railways, upgrading lines, or working with newly added lines. The research focus on TOD corridors reflects the distinctive characteristics of each city. Some cities concentrate on the rail transit lines themselves to better balance work and home life. Others shift the research focus to the development of land resources along transportation corridors. These differentiated studies enrich the multidimensional understanding of the scale, function, and development form of TOD corridors.

At the station level, the pilot cities conducted TOD studies of rail transit hubs, stations, and station area spatial ranges, providing guidance for the development of TOD sites of different levels and types. Some cities chose contiguous areas with several stations as their research scope. Shijiazhuang and Nanchang selected metro Line 1 and the eastern section of Line 2, respectively, studying how several operational rail transit stations could promote urbanization in peripheral areas. In Tianjin, the focus was on the traditional industrial communities in the suburbs, and how urban renewal could be initiated under the influence of rail transit stations, igniting new urban vitality.

Some cities chose individual stations or rail transit hubs as their research subjects, focusing on how stations and hubs affect the density and function of surrounding city spaces and land use. Beijing examined the Life Science Park Station, a subway interchange hub in the Changping District's Life Science Park Cluster, where integrated above-ground and underground development could drive the new city development. Shenzhen chose the upcoming Bainikeng Station hub area as a case study, exploring how TOD could guide sustainable transformations of urban villages and logistics centers. Guiyang mainly conducted theoretical research to explore the spatial layout of TOD communities that support "low-carbon sustainability" transportation.

Although the emphasis of these station-level studies varied, the common result was that the planning of TOD sites can be highly localized, and there is no best model. Different planning and design schemes should be formulated based on specific locations and functions. Tailored development will result in the best choice that aligns with local interests and development.

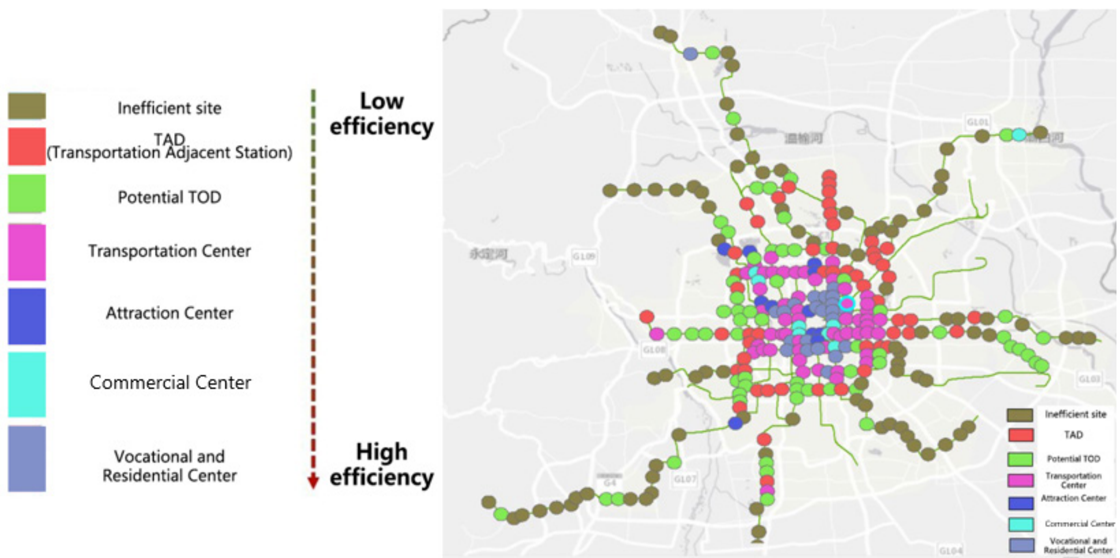
1. Beijing

Beijing was the first city in China to incorporate "reduced development" into its overall urban plan. Adhering to international TOD development best practices in its work, the technical team published a report on its analysis of city-, corridor-, and station-level issues and challenges. The team proposed a planning response that aligns with Beijing's development characteristics and trends, reflecting international TOD experience and local features of how rail transit supports a "reduction and enhancement" development strategy.

City Level: Developing the Microcenter and Leading Urban-Rural Integration

For the city center, the team presented a strategy for developing urban rail transit stations. In line with the objectives required for reduced development—green transportation and organic congestion relief—they emphasized a differentiated development strategy. Beijing still faces the problems of uneven distribution of passenger flows and limited coverage of commuting populations. The team proposed a classification of seven station functions (figure 3). From high efficiency to low, they were jobs and housing; commercial; cultural, scenic, and entertainment attraction; transportation complex; potential for TOD; potential for transit-adjacent development (TAD); and low efficiency. By developing strategies in line with the rail microcenter construction concept that the city advanced in 2018, the technical team aimed to enhance the effectiveness of rail transit stations.

Figure 3: **Location of Beijing Rail Transit Stations, by Function**



Note: TAD = transportation-adjacent development.
Source: Beijing Urban Planning and Design Institute, *TOD Strategic Report*, 2023.

For the outskirts of the city Beijing emphasized the "suburban railway + rail transit" model to construct a rail transit commuting circle. The suburban railway network closely connects major city nodes, forming a network-style development pattern that allows various transportation modes to be coordinated and complement each other in key new areas, promoting the decentralization of nongovernmental functions.

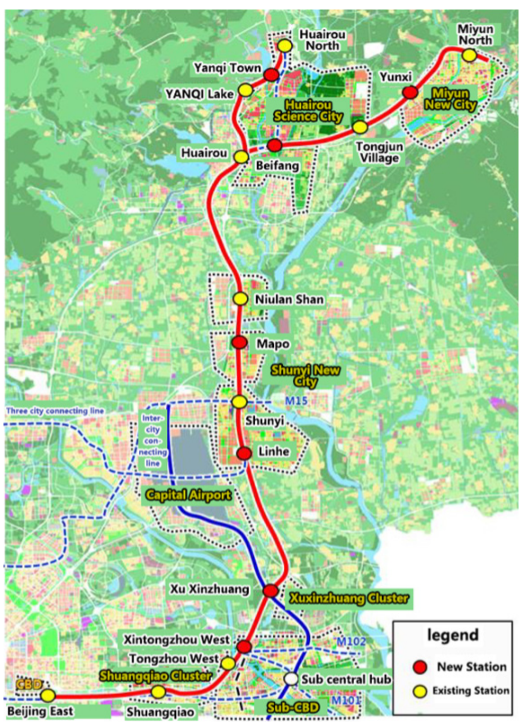
Corridor Level: Optimizing Land Use along the Suburban Railway Line

The technical team selected the Beijing suburban railway Tongmi Line for corridor-level research, with the goal of effectively optimizing the urban structure with microcenters to promote urban development through reduction and improvement. The main part of the line relies on the existing Jingcheng railway line, connecting Tongzhou, Shunyi, Huairou, Miyun, and other four urban areas (figure 4). Through the analysis of current issues such as low passenger flow and distance from densely populated areas, the team proposed planning strategies such as a mixed urban land layout, urban function enhancement, comprehensive traffic coordination, and land function analysis around key stations. By establishing a metropolitan commuting route, it supports the development of Alitongzhou Sub-Center, Shunyi New City, Huairou Science City, and Shunyi New City, realizing optimization of the urban spatial structure and high-quality development.

Station Level: Life Science Park Station Promoting High-Quality New City Construction

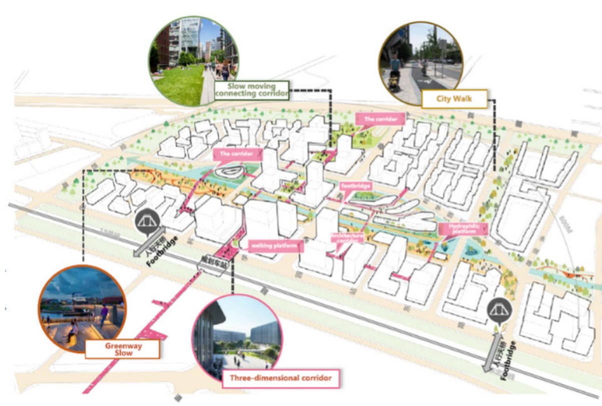
Beijing selected the Life Science Park Station in the Changping District for research and practice at the station level. The research aimed to promote high-quality development of the Life Science Park Cluster new city and support the city's multicenter spatial pattern. In the research team's station-level TOD scheme, livable community construction was carried out in conjunction with a multilevel slow transit system (figure 5). The design created a "rail transit system with a slow transit system," focusing on supplementing the rail corridor there by weaving around it the slow transit system, creating greenways and cycling paths that facilitate slow transit connections and integrated transfers.

Figure 4: Distribution of Microcenters along the Beijing Suburban Railway Line



Source: Beijing Municipal Engineering Design and Research Institute, Kaida Global (Asia), and Beijing Shili Junhui Real Estate Consultants, *Research on Rail Transit and Land Optimization Based on TOD Concept: Final Report*, 2023.

Figure 5: Beijing Slow Transit System at Life Science Park Station



Source: Beijing Urban Construction Design and Development Group and Yuheng Sustainable Transportation Research Center Consortium, *Completion and Summary Report of the Demonstration Project for Comprehensive Planning and Construction of Urban Renewal Areas based on the TOD Concept*, 2023.

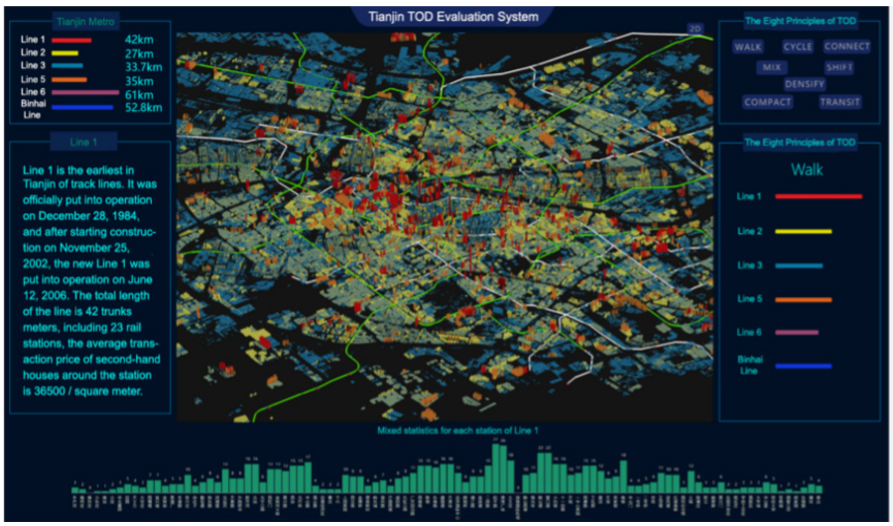
2. Tianjin

Tianjin reported on its TOD work at the city, corridor, and station levels of analysis.

City Level: Development Potential and Integration with Pedestrian Spaces

At the city level, Tianjin's technical team created a multidimensional system for assessing TOD potential using social, economic, and transportation data (figure 6). In response to the current issues in Tianjin of low rail transit passenger density and long rail transit lines, the team began station evaluation and classification, dividing all rail transit stations into three categories: regional and urban core stations, key stations, and general stations. For each type, the team proposed strategies for zone-classified development based on factors such as land use, transportation facilities, development intensity, and station space organization. The goal was to improve market value, optimize road transportation, and enhance the built environment in ways appropriate to each station type. The team also considered the residents' desire for a high-quality living environment and stressed the connection between rail transit and slow transportation, focusing on walkability in the areas around the stations to enhance urban spatial quality.

Figure 6: **TOD Information and Evaluation Platform in Tianjin**



Source: Transportation and Development Policy Research Institute, *Urban TOD Strategy Report*, 2021.

Corridor Level: Investment Estimation and Conceptual Planning for Corridor along Rail Transit Line 4 North Section

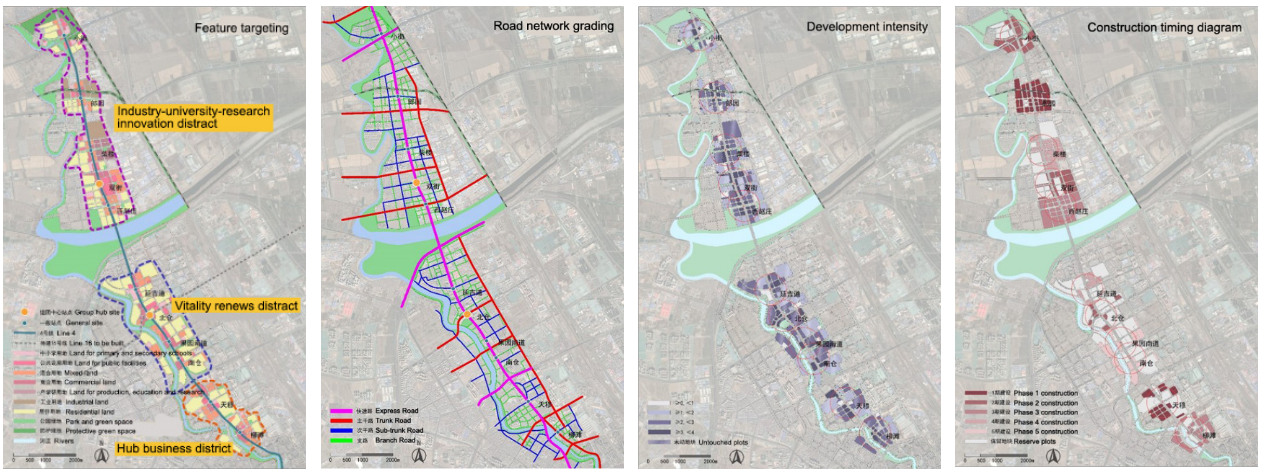
Tianjin selected the under-construction northern section of Line 4 for research to conduct conceptual, financial, and implementation planning applicable to rail corridors (figure 7). In the conceptual planning phase, the technical team established station categories and proposed measures for road optimization, land structure adjustment, and development timing. The conceptual planning allowed the team to predict passenger flow after the corridor's opening. They were then able to use const-benefit analysis to study suitable financing schemes to alleviate the local budgetary pressures on rail transit construction and operation. Finally, based on Tianjin's actual financial situation and budget constraints, they provided optimization suggestions for land use schemes along the corridor, including floor area ratio, function, and density.

Station Level: TOD Driving Renewal of Old Communities in Jianchang Road Area

Tianjin selected Siyuan Road Station, Jianchang Road Station, and Jinzhonghe Street Station in the Jianchang Road area along Line 5 for study. The technical team proposed a TOD diagnosis and evaluation method for the stations and surrounding area, exploring the integrated development mode of urban renewal (figure 8). The work focused on the interchange between rail transit and buses as well as the integration of slow transit systems and the supplementation of public service facilities.

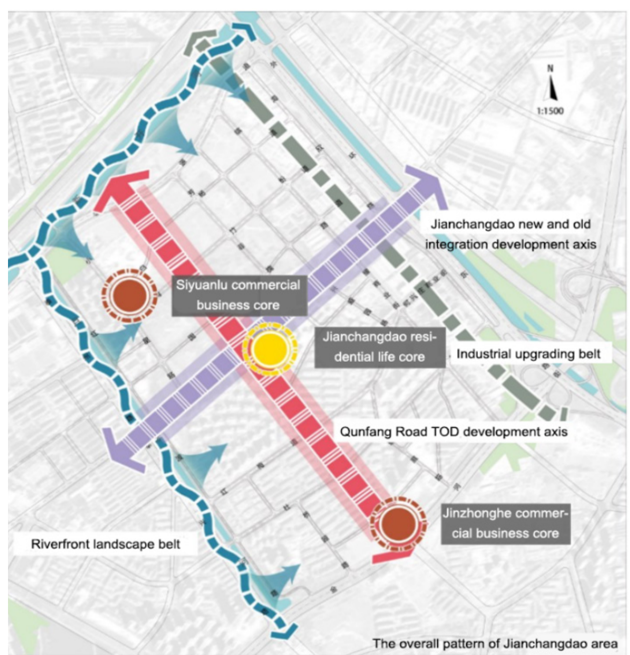
Figure 7: Planning for the Northern Section of Line 4

a. Existing land-use types | b. Roads | c. Land-use adjustment | d. Development timing



Source: Yuheng Sustainable Transportation Research Center, *Summary Report on Financing Research for Urban Rail Transit Corridors Using TOD Model*, 2021.

Figure 8: Spatial Pattern Planning of the Jianchang Road Area, Tianjin



Source: Tsinghua University Transportation Research Institute, *Research Report on Public Space and Urban Quality Enhancement*, 2022.

3. Shijiazhuang

Shijiazhuang reported on its TOD work at the city, corridor, and station levels of analysis.

City Level: Enhancing Urban Function and Optimizing Land Use Efficiency around Rail Transit

At the city level, Shijiazhuang's TOD strategy was shaped by regional integration with Xiong'an, the city's plan for four new city clusters, and the development of the Hutuo River area. The strategy involved using TOD policy tools to improve the urban spatial framework and land use efficiency (figure 9). Facing slow regional integration, a lack of overall planning in old and new urban areas, and inadequate functionality along the rail transit corridor, the technical team proposed a general development strategy: "reduction within the Second Ring Road and enhancement beyond it." They also offered specific TOD planning recommendations.

The key was to establish an integrated transportation network for regional integration and enhance Shijiazhuang's connection to the Beijing-Tianjin-Hebei urban agglomeration. Outside the main urban area, the technical team planned to build high-quality TOD new towns along the rail transit network. Within the main urban area, they recommended restructuring land-use functions along the rail transit corridor to improve public service facilities and enhance integration with various slow transportation modes, such as bicycles and pedestrians. These suggestions aimed to promote regional and citywide TOD development.

Corridor Level: Harnessing Urban Renewal and New Area Development with Line 4

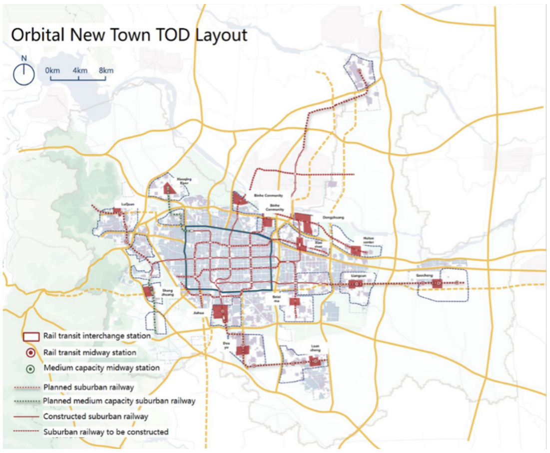
The technical team chose Shijiazhuang metro Line 4 for research on how to approach the dual tasks of revitalizing the old city and activating the development of new areas. Current issues included lagging land functionality and low utilization rate of Line 4. The team proposed planning strategies to address the disconnection between the old city and the new area, improve the efficiency of construction and enhance market performance along the corridor, and boost connectivity around key points. Implementation included differentiated construction along the corridor, balancing "rail + property" investment returns, and leveraging environmental benefits.

Given the city's existing travel structure and financial situation, the technical team proposed a "rail + slow transit" construction plan. Rather than emphasizing the density of the rail transit network, the plan focuses on the integration of the rail system with slow transit along the corridor to improve connectivity and increase the proportion of green travel. The specific measures for constructing the slow transit system include creating pocket-shaped slow transit lanes in key areas along the corridor, establishing TOD slow transit zones, and creating a friendly built environment for slow transit connections.

Station Level: Urbanization of Rural Areas along Line 1

In Shijiazhuang, four stations along Line 1, north of Shijiazhuang East Railway Station, were taken as a demonstration of TOD station area construction for urbanization of a rural area. This area is a core node connecting the old city with Zhengding New City, promoting the development of the Yonghe River. It is currently dominated by agriculture and rural industries, with significant advantages in regional transportation connections and the interweaving of blue-green resources. However, it also faces issues such as weak infrastructure, monotonous settlements, and risks of flooding. Therefore, the technical team proposed a range of planning and design schemes: integrating industry, residence, and recreation; resilient ecological construction with blue-green integration; and TOD life circle planning with spatial grading (figure 10). The mixed-use urban-rural space design combines transportation speed and slowness and serves as a model of driving rural revitalization through TOD.

Figure 9: **Layout of TOD New Towns in Shijiazhuang**



Source: China Urban Planning and Design Research Institute, *Shijiazhuang Rail Transit TOD Development Strategy and Connecting Transportation Study*, 2022)

Figure 10: **Shijiazhuang TOD Life Circle Concept**

Source: Shenzhen General Institute of Comprehensive Transportation, Municipal Engineering Design Research Institute, and Shenzhen Urban Planning and Design Research Institute, *Task 4 - Comprehensive Development Research: Results of the Project*, 2022.

4. Ningbo

Ningbo reported on its TOD work at the city and station levels of analysis. Summarized here is the city-level portion of its report.

City Level: Implementing TOD Improvement Strategies for Urban Renewal

The technical team evaluated the potential of urban renewal through TOD around rail transit stations. Relevant issues were low rail transit passenger density, weak integration with the city's spatial system, and low land development intensity along the rail corridors. To address them, the technical team proposed TOD strategies and policy guidance at both macro and intermediate levels. The approach was effective in making the rail transit network radiate to the suburbs and supports the expansion of Ningbo's metropolitan spatial structure.

Considering the demands of urban renewal within the inner city, the technical team conducted a detailed classification of TOD development levels for all the city's stations using multifactor indicators. They categorized stations into four types—A, P, I, N—according to their potential for supporting urban renewal and the transformation of their surrounding areas (figure 11), as follows:

A—Already achieved TOD

TOD effects have already been formed, and passenger flows are relatively high.

P—Potentially achieved TOD

Relatively good development around the stations but with inadequate transit coverage of nearby populations.

I—Improve TOD

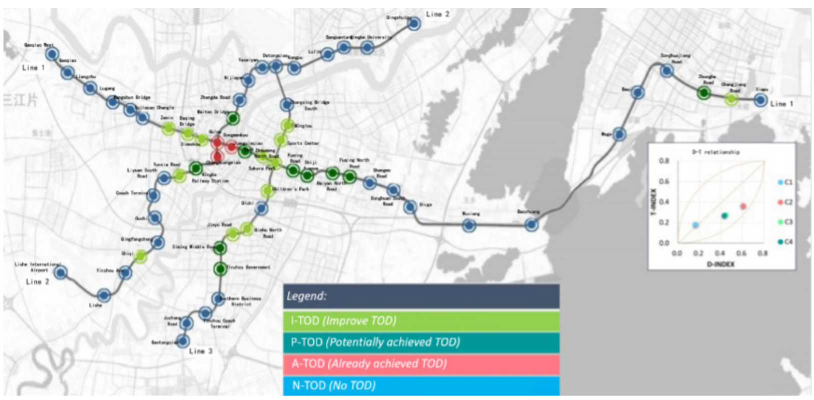
The evaluation indicators need to be improved in one or more dimensions to exceed average rail transit passenger flow.

N—No TOD

Stations that need comprehensive reshaping and improvement.

The categories and associated planning and design guidelines laid the analytical foundation for the subsequent development and continuous optimization of station functions in Ningbo.

Figure 11: **Classification of TOD Potential for Rail Transit Stations in Ningbo**



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.

5. Nanchang

Nanchang reported on its TOD work at the city, corridor, and station levels of analysis.

City Level: Clarifying a Consistent Indicator System and Timely Rail Development

At the city level in Nanchang, the technical team established a relatively comprehensive TOD framework encompassing factors such as land use, industry layout, and the impact on strategic zones. The framework aimed to coordinate and link the relationships between urban planning and transportation planning. Currently, Nanchang faces challenges in its TOD development, such as the limited scale of the rail transit network, inadequate support for the city's spatial structure, and relatively low passenger density. In response to the ongoing growth of population and motor vehicle use in the midst of limited land resources, the technical team provided recommendations for optimizing the rail transit network to support Nanchang's urban spatial expansion and achieve transportation development goals. The result was a multimodal, integrated public transportation plan that supported crucial transportation corridors and strategic development zones (figure 12).

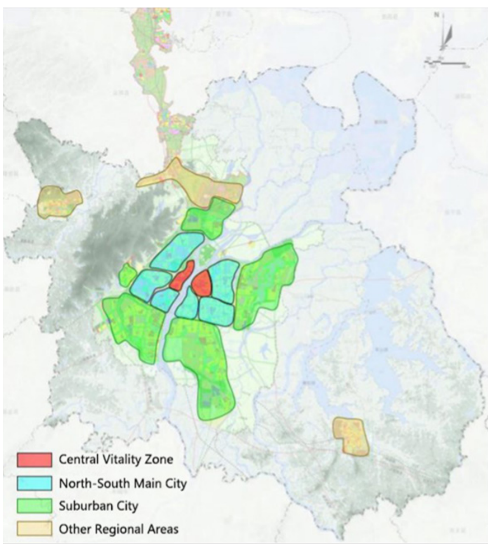
The team's TOD framework offers concise and adaptable indicators that support TOD strategic goals. A TOD assessment system, which includes macro, intermediate, and micro assessments (figure 13), corresponds to the city's own framework of general, regional, and detailed planning.

The plan extended the rail transit network in a measured fashion. The study emphasized a tight integration between existing rail transit lines, the city's spatial structure, and bus and slow transit systems.

Corridor Level: Promoting Comprehensive Development in the New Urban Area

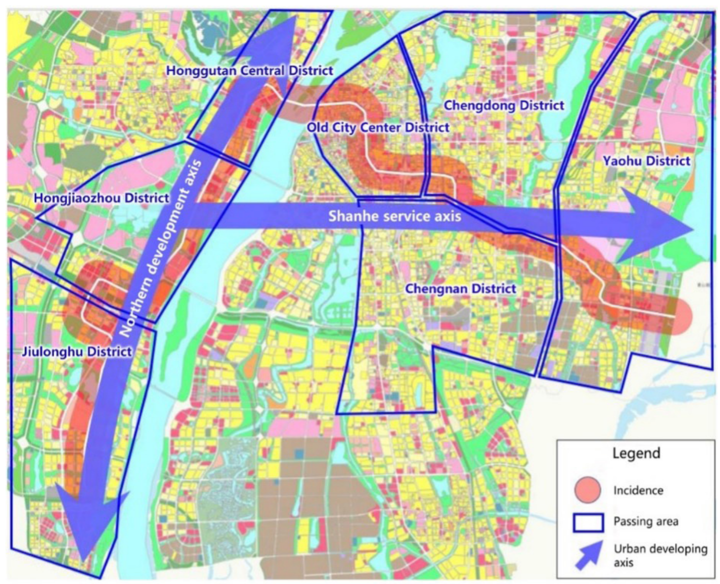
Nanchang chose metro Line 2 as the subject for corridor-level TOD research. development goal of ensuring the effective guidance of the line in promoting the construction of the new urban area, relieving population density in the old city center, and supporting the center area's transformation. Through the analysis of functional positioning and land use along Line 2, the technical team developed guidance to boost the land development value along the corridor and support new areas of industrial and economic development (figure 14). At the corridor level, the rail transit's effective service radius has been extended. Large commercial facilities and leisure and recreational areas have been developed along the corridor, forming a new mode of "rail + cultural tourism." Additionally, affordable housing has been arranged along the south section of Line 2 to ensure job accessibility for low- and middle-income populations and residents moving from the city center to the outskirts.

Figure 12: Nanchang's Macro Strategic Zones



Source: Shenzhen Urban Transportation Planning and Design Research Center and Nikken Sekkei Research Institute, *Urban Development at the City Level with Public Transit-Oriented Development (TOD) Strategy: Formulation, Implementation, and Project Management Support.*

Figure 14: Urban Functional Zones and Development Axes in Nanchang



Source: Shanghai WSP Consulting and Shanghai Yisheng Management Consulting, *Final Report and Summary of Rail Transit TOD Planning and Design Study.*

Figure 13: Nanchang's Macro, Intermediate, and Micro Analysis Framework

Source: Shenzhen Urban Transportation Planning and Design Research Center and Nikken Sekkei Research Institute, *Development and Implementation of Transit-Oriented Development (TOD) Strategies Guided by Public Transit at the Urban Level, and Project Management Support.*

Station Level: Urban Space Expansion

At the station area level, the main focus was on the eastern extension of metro Line 2, exploring the integrated model of urban transportation construction and land development management around the stations. Using the example of the 10 stations involved in the eastern extension of Line 2, the technical team defined the functional positioning and classification of research stations, designing different development models (figure 15).

First, by clarifying the key development areas around the station through resource sorting, they provided market positioning and property portfolio suggestions for the industrial development around the station. Second, they designated key stations, formulating urban design control elements, and proposing spatial planning and design schemes. Finally, based on the development types, they staged implementation plans.

6. Guiyang

Guiyang reported on its TOD work at the city, corridor, and station levels of analysis.

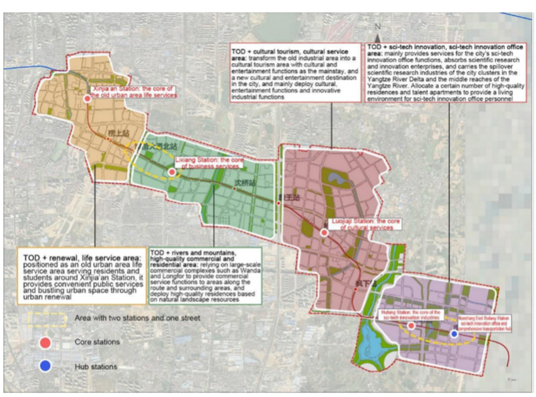
City Level: Adapting a Multinetwork System to Mountainous Urban Features

At the city level, TOD in Guiyang faces the challenges of traffic congestion and the city's mountainous terrain. The technical team developed a city-level TOD strategy to address both internal and external transportation.

For external transportation, they proposed the construction of a ring-shaped high-speed rail system to promote the integrated development of the Guiyang–Gui'an urban agglomeration (figure 16). This would achieve a one-hour commuting circle and a one-hour economic circle, providing transportation support for the goal of becoming a "strong provincial capital."

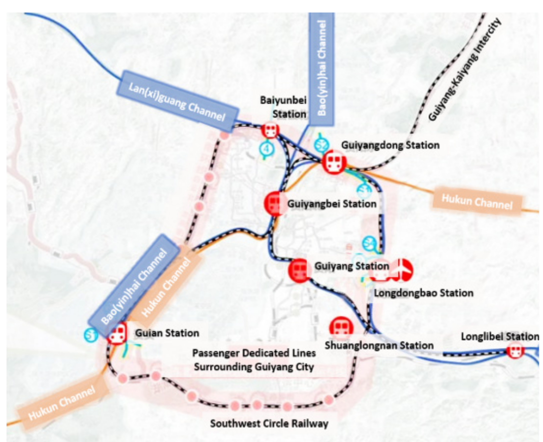
Regarding internal transportation, the team classified urban stations into four levels (city, cluster, zone, and neighborhood) and six types (commercial, industrial, residential, transportation, scenic-leisure, and multiuse). They connected city clusters separated by mountainous terrain and explored urban development resources around the stations. This approach effectively reduces urban transportation emissions and promotes intensive land development while aligning with Guiyang's development concept of "low-carbon, eco-civilization, and sustainability."

Figure 15: Functional Zoning of the Line 2 Eastern Extension in Nanchang



Source: China Sustainable Transportation Center and Beijing Urban Construction Design Group, *Research Report on Station Area Planning Based on TOD Concept of Rail Transit.*

Figure 16: External Transfer Connections of the Guiyang Ring Rail System



Source: Tsinghua University Institute of Transportation Research, *Classification, Grading, and Functional Positioning of City Ring Rail Transit Stations.*

Corridor Level: Population Relocation and New Cluster Development

At the corridor level, the Guiyang study focused on the issue of population relocation away from the main urban area and promoted the development of new clusters guided by two new rail transit corridors. The technical team selected the planning of the upcoming metro lines 3 and S1 as the research case proposed an integrated plan for land development and transportation along the first phase of rail S1 and Line 3 (figure 17).

S1 is an important corridor to drive the integration of Guiyang and Gui'an, guiding the population and urban functions from the main urban area to the new area. Line 3 can alleviate areas with high population density and open up an important corridor for southward development across the mountainous terrain.

Station Level: Low-Carbon, Ecological, and Sustainable Model

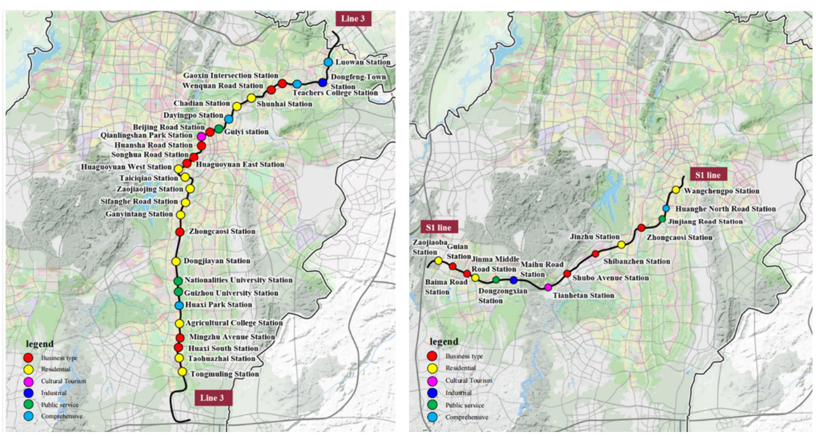
At the station level, TOD rail transit construction in Guiyang demonstrates how it can alleviate traffic congestion, achieve intensive land development, and embody the "low-carbon, ecological, and sustainable" development philosophy of Guiyang. The challenge for Guiyang is the concentration of population, jobs, and public service facilities in the old city area and a surrounding mountainous terrain.

The contradiction between the rapid growth of motor vehicle use and the shortage of road resources is becoming more pronounced. Cross-regional travel is a bottleneck that exacerbates traffic congestion in the old city area. The technical team adopted a differentiated approach to regional connection, designating traffic-coordinated development strategies for the old city area, the Wudang area, and the Gui'an New Area. The plan for the old city, for example, primarily enables citizens to make greater use of slow transit by increasing road network density and reducing block scale (figure 18).

Figure 17: Classification of Stations, Line 3 and S1 Line

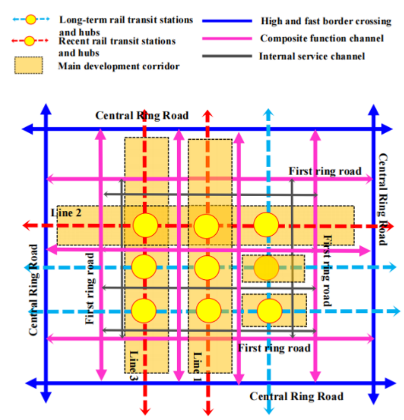
a. Line 3

b. S1 Line



Source: China Academy of Urban Planning and Design, *Research on Comprehensive Development Planning of TOD in Guiyang Rail Transit S1 Line Phase 1 and Line 3 Phase 1 Areas.*

Figure 18: Traffic Planning in Guiyang's Old City Area



Source: Hyder Consulting (Shanghai), *Comprehensive Development Planning Study of TOD in the Areas along the Phase 1 of Guiyang Rail Transit Line S1 and Line 3.*

7. Shenzhen

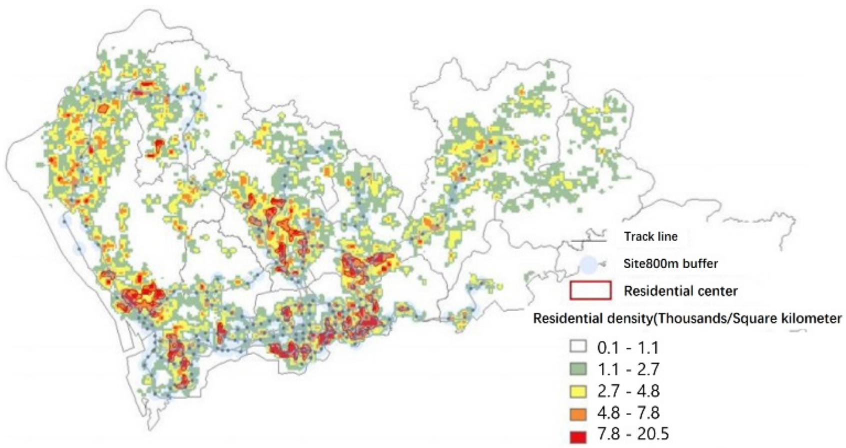
Shenzhen reported on its TOD work at the city and station levels of analysis.

City Level: Emphasizing Job-Housing Coverage and Improving the Bus System

At the city level, Shenzhen's technical team addressed current issues such as the need to improve the efficiency of the existing public transportation system, the inadequate alignment of the rail transit network with urban development, and the bottleneck period in the development of the "rail + property" model. For example, the coverage of rail transit for residential and employment centers is primarily concentrated in the southern regions, such as Nanshan, Futian, and Luohu and is weaker in the northwest and northeast areas (figures 19 and 20).

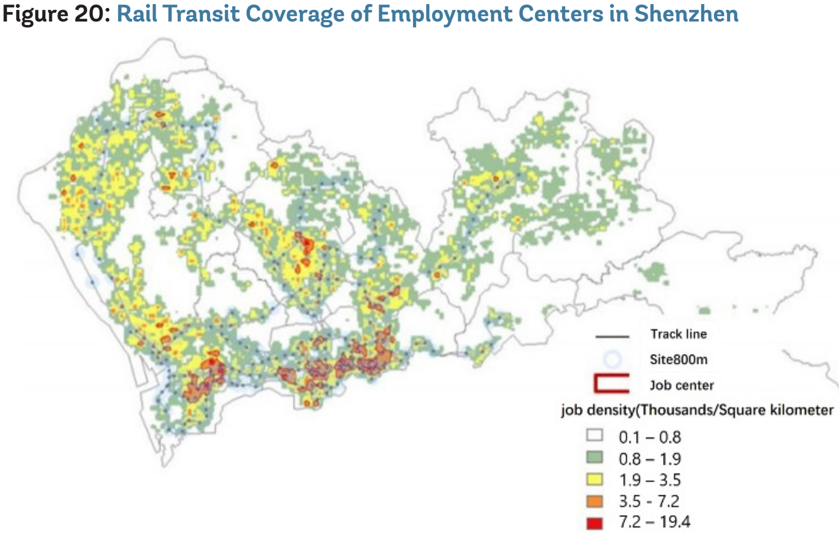
They formulated a TOD strategy based on existing city and transportation plans and policies and evaluated the service level of the rail transit system in the context of current issues. They proposed a TOD strategy that included optimizing the rail transit network, improving the bus system, promoting green travel, driving land development, and integrating rail infrastructure with vertical urban development.

Figure 19: Rail Transit Coverage of Residential Centers in Shenzhen



Source: Shenzhen Urban Transport Planning Center, *Shenzhen Urban TOD Strategy: Overall Report*, 2023.

Figure 20: Rail Transit Coverage of Employment Centers in Shenzhen



Source: Shenzhen Urban Transport Planning Center, *Shenzhen Urban TOD Strategy: Overall Report*, 2023.

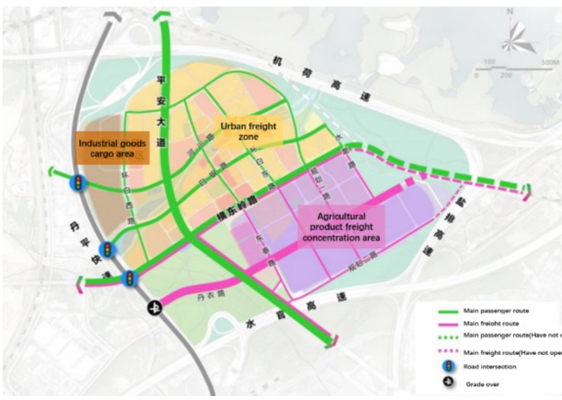
Station Level: Bainikeng Area—Urban Village Transformation

Shenzhen selected the Bainikeng area, located in the border region of the city, as the station-level TOD unit of study. The Bainikeng area is bounded—and isolated—by four fast roads. It will become a hub where railways and urban rail transit intersect, making it an example of urban village transformation in a suburban area.

The technical team found that the current problems in Bainikeng included difficult traffic connections inside and outside the area, a conflicting mix of passenger and cargo transportation inside, and a lack of life service facilities. In response, the team established a comprehensive transportation network plan based on concepts oriented to the convenience of residents (figure 21). They strengthened hub-intensive development and constructed a three-level community living circles as a solution for enhancing community quality (figure 22).

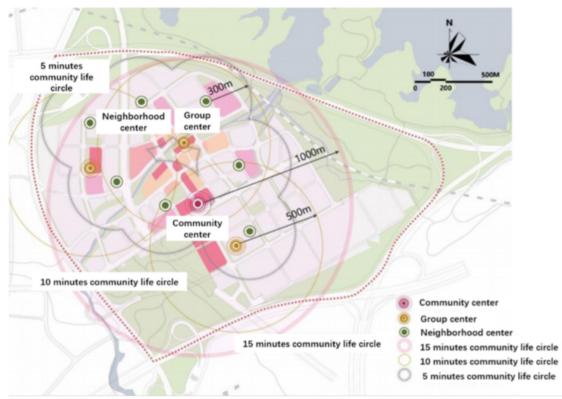
The Bainikeng project provides relevant experiences for the development and upgrade of suburban areas, for urban village renewal, and for public participation in areas facing the challenges of transformation.

Figure 21: Concept of Passenger Traffic Organization, Bainikeng Area, Shenzhen



Source: Shenzhen Branch of the China Academy of Urban Planning and Design *Shenzhen Bainikeng TOD Planning Report*, 2023.

Figure 22: Design for Community Living Circles, Bainikeng Area, Shenzhen



Source: Shenzhen Branch of the China Academy of Urban Planning and Design *Shenzhen Bainikeng TOD Planning Report*, 2023.

SHIJIAZHUANG

Part 4: Challenges, Achievements, Benefits, and Outlook

With the support of the GEF-6 China TOD project, research at the national level and in the seven pilot cities has enriched and expanded TOD theory. The advances encompass social, economic, and environmental aspects as well as the use of spatial scales represented by the city, corridor, and station levels of analysis. Educationally, the project has broadened the understanding of TOD among government agencies, planning departments, related enterprises, and the public. Rather than being confined to the narrowly conceived development of physical space, the project has shown that urban revitalization and urban growth are best seen as a systematic mindset for improving quality of life and environmental sustainability. These theoretical enrichments are critical for managing the rapid urbanization and growth of transportation infrastructure faced by developing countries, including China.

The project developed a system capable of generating measurable goals that could be monitored and a process by which outcomes could be evaluated. It produced economic benefits and improvements in the quality of life and environmental sustainability.

Looking ahead, the economic and environmental conditions and metropolitan landscapes in developing countries have evolved since the start of the project. Tightened budgets, more suburbanized metropolises, and greater environmental threats, make continued work on the goals and possibilities of TOD ever more relevant.

1. Challenges

Cities in China and other developing countries face great financial pressure and complex social and environmental challenges in addressing urban dynamics. In that context, TOD as a spatial model alone cannot serve as an effective policy tool. It must encompass a multidimensional, multiscale approach if it is to address urban challenges common to rapidly developing cities :

1. The urgent need for effective financing of TOD while simultaneously reducing the costs associated with TOD development, construction, and operation.
2. Balancing the commuting efficiency of the majority of the workforce with ensuring social equity in travel for vulnerable groups.
3. Balancing the ecological resilience of public transportation infrastructure with protecting fragile and sensitive ecological environments.

2. Conceptual Achievements

Shifting focus from physical space to comprehensive development in various dimensions such as social, economic, and environmental aspects.

Early Chinese urban TOD projects understood and practiced TOD as a "development tool." This project broadens the meaning of TOD to include land-transport integration, transit corridor-supported job-housing balance, land value appreciation, transit social equity, and public transit environmental benefits.

Transitioning from a focus on a single-level space to the integration of multiple scales such as city, corridor, and station.

At the city scale, the project emphasizes driving overall accessibility and employment, enhancing transportation equity for vulnerable groups and impoverished communities.

At the corridor scale, it places greater emphasis on the appreciation of property values along the corridor, balancing job-housing relationships along the corridor, and the impact on biodiversity in sensitive ecological areas.

At the station scale, it places greater emphasis on improving walkability in station areas, enhancing commercial vitality, and comprehensively enhancing the built environment in the surrounding areas.

Shifting focus from developmental increment to multiple urbanization challenges under various transportation modes.

The GEF-6 China TOD project conceives of TOD as "公交导向发展" (public transit-oriented development), distinguishing it from the traditional Chinese translation of it as " 公交导向开发 " (transit-oriented development). This emphasizes new topics beyond the development of physical space and with a multiplicity of transportation modes.

3. Methodological Achievements

Measurement indicators adaptable to different scales and local issues

The selection of indicators was based on the interaction between the implementation and management of TOD at the national level and the availability of local data in pilot cities. They serve as the basis for diagnosing problems and challenges faced by urban TOD and provide the most basic data source for measuring "good TOD" at different scales (table 4).

Table 4: TOD Measurement Indicators at Multiple Levels

<table>
<tr><th>Level</th><th>Research Object</th><th>Problem Solving</th><th>Measurement Indicators</th></tr>
<tr><td>Station</td><td>Quality of station area
Study on station types
Accessibility of facilities
Efficiency of land use</td><td>Physical space and built environment
TOD station types
Traveler groups and mode selection</td><td>Location and distance of transportation stations
Number of bus stations
Development compactness
Diversity of points of interest and facilities
Distance to public service facilities
land use density
Distance to passenger hubs
Transfer distance for different modes of transportation
Population coverage within 800 meters of the station
Land use coverage within 500 meters of the station</td></tr>
<tr><td rowspan="2">Corridor</td><td rowspan="2">Prosperity of commerce and employment
Changes in real estate value</td><td>Employment accessibility
Employment success rate</td><td rowspan="2">Direction and location of bus routes
Residential population
Employment positions
Ratio of employment and residential population along rail lines
Density of ground-floor shops
Urban road network
Housing and land prices</td></tr>
<tr><td>Land value appreciation
Housing affordability</td></tr>
<tr><td rowspan="3">City</td><td rowspan="3">Environmental and climate resilience
Social equity in transportation</td><td>Urban space and transportation coordination</td><td rowspan="3">Diversity of land use
density of roads
density of rail networks
traffic flow
pollution emissions
carbon emissions
interview data
biodiversity
public participation of citizens</td></tr>
<tr><td>Urban form and carbon emissions</td></tr>
<tr><td>Transportation social equity</td></tr>
</table>

Source: Beijing Jiaotong University, based on Zhang and Li (2023).

Multiple classifications of rail transit station types

- Based on the built environment of stations
- Based on the combination of built environment and passenger flow
- Based on travel behavior of target groups

The definition of station domain space varies from 400 meters to 1,500 meters. The variations limit the comparability of TOD in different cities.

4. Economic, Social, and Environmental Benefits

The principles and concepts of TOD have been expanded from a focus on transportation modes to a more comprehensive urban-scale understanding that has the ability to deliver economic benefits, job creation, reduction of greenhouse gas emissions, and improved level of social equity. These multidimensional benefits can be measured with specific indicators (table 5).

Table 5: TOD Indicators of Economic, Social, and Environmental Benefits

Economic Dimension	Land use value	Residential property prices
		Commercial property prices
	Fiscal sustainability	Investment in TOD design area
		Area of commercial and residential buildings constructed in TOD design area
		Tax revenue generated in TOD design area
Social Dimension	Accessibility and diversity	Density of rail network
		Population density within 500m buffer zone
		Number of enterprises and government institutions within 500m buffer zone
		Coverage rate within 500m buffer zone of stations
		Population coverage rate within 800m buffer zone of stations
		Number of points of interest (poi) within 250m (300m-500m) of stations
		Pedestrian-friendly environment
		Distance to job positions, commercial facilities, schools, and municipal services
	Protection of vulnerable groups	Average commuting time
		Average commuting distance
		Average commuting cost
		New job opportunities created in TOD design area
Environmental Dimension	Greenhouse gas emissions	Per capita commuting-related greenhouse gas emissions
	Local pollution levels	Reduced levels of PM2.5/ PM10

Note: PM2.5/PM10 = inhalable particulate matter that is 2.5 or 10 micrometers in diameter or smaller.
Source: Project Appraisal Document of the GEF-6 China TOD project.

Economic Benefits

The achievement of economic goals is mainly measured by indicators of land use values that leading to fiscal sustainability: residential and commercial property prices, new investment and construction, and tax revenue in the TOD design area. After the opening of rail transit during the project execution period, the appreciation effects on commercial and housing real estate have been prominent in many pilot cities.

However, the cost-benefit analysis of TOD corridors is crucial in avoiding excessive construction of rail transit in the “new normal” context of tightened macroeconomic and regulatory conditions. For example, many cities with an average housing price of CNY 20,000 per square meter do not have the ability to support TOD construction and operation through the appreciation of land values after construction.

Social Benefits

The social benefits of TOD encompass a wide range, particularly with the input from public participation: quantitative, such as a more balanced work-life relationship and a higher accessibility and greater diversity of service facilities; and qualitative, such as creating a more inclusive city through attention to the needs of low-income and minority populations and other vulnerable groups. Case studies in pilot cities have shown that, especially for low-income areas, public transit improvements have increased the accessibility of jobs, education opportunities, and medical facilities.

- In the Bainikeng area of Shenzhen, public participation helped guide the improvement of public service facilities.
- Beijing and Shenzhen have combined TOD with the construction of affordable housing while enhancing land use efficiency.
- In Guiyang, research on minority ethnic communities in Huaxi District provided a solution for improving accessibility in the Miao ethnic community.
- In Nanchang and Guiyang, newly planned land for affordable housing was reserved along newly constructed rail transit lines.

Environmental Benefits

The environmental value of TOD has only been gradually accepted by Chinese cities in recent years. By supporting public transit and slow modes of travel, TOD directly reduces greenhouse gas emissions from car use and the amount of fine particulate matter in the air. The positive environmental benefits of TOD include a more diverse urban space that integrates parks and green walkways.

Research yielded measures to prevent or alleviate the impact on sensitive ecological areas through scenario simulation analysis.

- At the corridor scale in Tianjin, a carbon emission model provided a method for calculating carbon emissions within a certain range along the rail transit.
- In Guiyang at the city level, a low-carbon spatial development model for central urban areas, suburban areas, and edge areas was put forward.

TOD is an important research direction in the effort to reduce greenhouse gas emissions. However, compared with the economic and social dimensions, the methods for collecting and measuring the environmental benefits of TOD are still relatively limited, and further research is needed.

5. Outlook

The GEF-6 China TOD project was initiated at a critical stage of urbanization in China. Through research, it promoted TOD development strategies and related planning guidance at the national and pilot city levels. The project's outcomes have incorporated these TOD concepts into urban development strategies and enhanced public understanding and support through public participation. TOD theory has been expanded, deepening the theoretical depth of addressing localized issues in developing countries within the context of TOD tools. At the same time, a more systematic TOD methodology has been established, facilitating the replication of standardized data indicators, evaluations, and forecasting methods in other developing countries.

In addressing the three fundamental issues related to TOD urban rail transit construction—Where does the funding come from? What new changes will it bring to the old city? What benefits does it bring to the public?—this work has gradually helped industry stakeholders form a consensus on what constitutes "good TOD."

Research revealed that there is almost no replicable spatial pattern for the application of TOD in different cities due to differences in urban scale, geographical features, and socio-economic development levels. “Good TOD” is more a way of thinking for solving comprehensive urban problems based on local conditions.

During the project execution period, China’s economy entered a “new normal” in which policies for local government debt and urban rail transit construction continued to tighten. These changes were not considered in the initial design of the project, which focused on vigorous construction of urban rail transit in the service of economic growth, social equity, and environmental protection. But in 2018 and again in 2021, the National Development and Reform Commission tightened the approval threshold for urban rail transit construction, which has limited the issuance of new rail construction permits. As a result, large-scale, high-intensity construction of urban rail transit has been forced to gradually cool down.

However, this does not mean that TOD in Chinese cities has come to an end. The municipal (suburban) railway, which connects city clusters in the new national urbanization strategy, will become a focus of development in the next stage. Conventional bus systems need rethinking in the context of alleviating social and policy burdens. Further inquiry is needed on forms of public transportation in cities that have not yet met the conditions for constructing rail transit. In some smaller cities with strong economies, the tram has become a low-capacity, low-cost transportation solution with both commuting and sightseeing value.

Yet, more broadly, in the context of coping with global climate change, many issues confronted in the GEF-6 China TOD project will become even more salient:

- How to use TOD as a policy tool to combat poverty and provide fair travel services for more women, ethnic minorities, and the elderly
- How to reduce the environmental impact during the construction of large-scale transportation infrastructure
- How to evaluate the long-term impact of completed TOD projects on cities and regions.

These issues drive the necessity of continuous research on TOD in developing countries and await further exploration.

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