

Research Article

# Integrated Land Use-oriented Design Practice for Rail Transit Complexes: The Yuhuazhai TOD Project (Hyper Park)

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## Abstract

Against the dual backdrop of stringent land resource constraints and low-carbon urban development, Transit-Oriented Development (TOD) has emerged as a core pathway for spatial restructuring and sustainable growth in high-density cities. This paper takes the Yuhuazhai Depot Overbuild Development Project along Xi'an Metro Line 3 - the Yuhuazhai TOD project (Hyper Park) - as a case study of community-scale TOD practice. It elaborates on how the project, under the guidance of three-dimensional integrated land utilization principles, realizes the integration of "Station-City-People-Ecology" through structural engineering innovation, spatial organization optimization, and integrated ecological technologies. The project addresses key challenges in metro overbuild developments, including functional integration, spatial connection, vibration isolation, and ecological construction, through specific design approaches. The outcome is a 24-hour vibrant community integrating living, working, shopping, entertainment, mobility, and recreation, which enhances land-use efficiency, promotes jobs-housing balance, and strengthens ecological and health attributes. This paper presents relevant technical frameworks and design strategies for similar TOD developments in high-density urban contexts.

## Keywords

TOD Model, Integrated Land Use, Metro Depot Overbuild Development, Structural Integration, Spatial Efficiency, Smart Ecology, Regional Adaptability, Sustainable Design, Community Placemaking

## 1. Introduction

The Transit-Oriented Development (TOD) model, a critical strategy to combat urban sprawl, traffic congestion, and environmental degradation, profoundly influences modern urban planning and architectural practice. In the 1990s, in order to solve problems such as the shortage of urban resources caused by the rapid expansion of cities, American scholar Peter Calthorpe proposed the development of the TOD model. [1] Emphasizing high-density, mixed-use, pedestrian-friendly

development anchored around public transit nodes, reshaping urban form and lifestyles. In the densely populated East Asian region, such as Japan, Singapore and China's Hong Kong, the TOD model has long been applied very maturely, and a large number of successful cases of comprehensive development of transportation land have been formed. For example, Tokyo's Shibuya Station, Hong Kong's Admiralty MTR Station, and Singapore's Punggol New Town have all generated consid-

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erable social and economic benefits. [2].

Contemporary Chinese megacities face severe challenges: escalating land scarcity, diminishing ecological spaces, inefficient sprawl leading to fragmented urban structures, and the homogenization of regional identity amidst rapid construction. In this context, the TOD model, leveraging its potent spatial integration and resource efficiency capabilities, demonstrates significant adaptive value. Its core essence has evolved from an initial focus on transportation functions to constructing a quintessential integrated spatial system encompassing "Station-Urban Space-Human Activity-Landscape Environment-Smart Technology." This transformation emphasizes strengthening organic linkages between urban functional zones through three-dimensional, networked spatial organization, and elevating station areas into vital urban hubs. In recent years, China has been continuously promoting the TOD development model of "rail transit + property", marking that the Chinese mainland has gradually entered the TOD era, and people's lifestyles and travel modes have become more convenient. [3] China's "14th Five-Year Plan" explicitly advocates building a modern integrated transportation system, positioning rail transit as the core skeleton for rapid transit network development, providing national strategic backing for widespread TOD implementation. In 2015, the Ministry of Housing and Urban-Rural Development issued the Guidelines for Planning and Design of Areas Along Urban Rail Transit Lines to promote the coordinated development of rail transit and cities. Potential cities across China have been actively advancing TOD development, formulating local policies, and carrying out TOD pilot projects. [4].

## 2. Master Planning: Community-level Exploration Under the TOD 5.0 Concept

### 2.1. Urban Dimension: Regional Catalyst and Spatial Synergy

The TOD model, with rail transit hubs or clusters of rail stations as its core, forms a polycentric cluster structure, and the corresponding population density distribution has shifted from a unimodal pattern to a multimodal one. In the populous East Asian region, represented by Japan, Singapore, and Hong Kong, China, there are numerous successful cases of integrated development of transportation and land use. [5].

The Yuhuaazhai TOD project (Hyper park) is a pioneering application of this advanced concept at the community scale. The site is tightly constrained by the Metro Line 3 Yuhuaazhai Depot, surrounded on three sides by the stabling yard.

*Suturing the Urban Fabric:* Carefully configured building masses and public spaces effectively mend the urban fabric severed by the depot, integrating the isolated transportation facility into the urban functional network.

*Driving Regional Vitality:* High-density development

concentrates diverse populations (residents, workers, shoppers), significantly boosting day-night population density and economic activity intensity, establishing the project as a vital engine for the Software New City district.

*Integrating Ecological Networks:* Through the design of landscape corridors and visual axes, internal green spaces seamlessly connect and interpenetrate the city's ecological network. This greatly enhances regional ecological service efficacy and resilience, marking an evolution from "individual building greening" to "systemic ecological resilience."

### 2.2. Functional Dimension: Multiplicity, Mixing, and Smart Enablement

The public spaces in TOD areas need to undergo two transformations: sharing and characterization. Functionally, they should meet the activity needs of innovative groups, and spatially, they should reflect unique identifiability. [6].

Within an irregular trapezoidal plot of only approximately 15.72 hectares, The Yuhuaazhai TOD project (Hyper park) transcends traditional residential mono-functionality. It integrates a diverse mix of functions: residential, retail, office, kindergarten, community service center, and senior care center. This composite design actively responds to the TOD core area principle of a "5-10 minute living circle."

*Vertical Mixed-Use Model:* The design employs an advanced vertical mixed-use model. Commercial, office, and public service facilities (e.g., community center, senior care) occupy the lower levels and podiums, while mid-to-high-rise levels house residences. This vertical stacking maximizes functional mix and efficient organization within limited land, effectively activating 24/7 community vitality and significantly shortening residents' daily service access distances.

*Full Life-Cycle Service Provision:* Supporting facilities cater to needs from childcare to senior care, precisely serving the project's diverse residential and working populations, strongly underpinning social sustainability and community cohesion.

### 2.3. Community Dimension: Placemaking and Vitality Co-creation

A community is more than a physical collection of spaces; it is an organic entity fostering emotional identity and social interaction. In outdoor spaces, setting up places for people to talk, stay, and engage in activities helps enhance interpersonal communication and foster a community atmosphere; indoor spaces are divided into multiple functional areas such as community public services, leisure and entertainment services, and commercial shopping services. [7].

The Yuhuaazhai TOD project (Hyper park) prioritizes crafting place identity and refining spatial experience.

*Hierarchical Public Space System:* A layered public space system is constructed, ranging from a highly identifiable main entrance plaza, through a central community landscape axis,

to group courtyards, and finally extending to semi-private doorstep spaces. Through spatial permeability, composition, and transition, this fosters a "refined, warm, and human-scale" atmosphere for neighborly interaction, enhancing community belonging and interaction.

**Healthy Environment Creation:** At the micro-environmental level, design integrates considerations of sunlight, ventilation, and acoustic performance with landscape sightlines. Combined with green, low-carbon technologies, this fosters a healthy, comfortable, and environmentally harmonious living and working experience, demonstrating deep concern for occupant well-being.



**Figure 1.** The Yuhuaizhai TOD project's site plan aerial perspective.

### 3. Transportation Dimension: Three-dimensional Integration and Efficient Commuting

#### 3.1. Rail Transit Integration

From the perspective of TOD, the development of land use around stations can realize functions and vitality by means of guiding hierarchical layout and differential density, and agglomerate towards stations to strengthen the public center function of stations and their surrounding areas, as well as give play to the agglomeration effect. [8].

In addition to ensuring the efficiency of residents' travel, the traffic design in the station should also comply with the implementation of traffic improvement plans proposed in the traffic impact assessment. [9].

**Pedestrian Network Optimization:** Under the concept of TOD planning, the standards adopted for walking scales in current domestic and international planning practices are the average values of walking time and distance acceptable to "most people", such as a walking time of 5 minutes or 10 minutes, and a distance with radii of 400m, 600m, 800m, or 1km, etc. [10].

Leveraging its unique proximity to the metro station and depot, the project establishes a three-tiered "Station-Community-City" integrated transportation system, focused on seamless, convenient, and safe transfers and internal circulation.

**Vertical Layering Strategy:** The core innovation of this

project's traffic organization is the adoption of a clear vertical layering strategy. The ground level primarily serves as the interface with municipal roads, featuring drop-off areas and emergency vehicle access points. The below-ground level consists mainly of a large underground parking garage (meeting substantial parking demands) and ancillary equipment rooms. The above-ground level is exclusively pedestrian-focused, accommodating residential entrances and a central landscape park. Vertical circulation cores connect the above-ground level with both the underground garage and ground level. Home-access hubs are strategically positioned at key locations on the eastern, western, and southern sides of the development, enabling convenient pedestrian circulation while maintaining complete separation of vehicles and pedestrians.

**Pedestrian-Vehicle Segregation:** This layered design achieves complete pedestrian-vehicle and passenger-freight separation. Vehicle movement is strictly confined to Ground Level entrances and the Deck-Under level, while the Deck-On level forms a car-free pedestrian sanctuary, vastly improving internal safety and environmental comfort.

#### 3.2. Local Traffic Coordination

##### 3.2.1. Dynamic Traffic Organization

Slow traffic spaces that are green, low-carbon, comfortable and safe are the distinctive calling cards of people-oriented cities. Taking advantage of the opportunity of large-scale rail transit development, creating such slow traffic spaces provides the possibility to trigger new spatial agglomeration in station areas. [11].

Traffic organization is reconfigured based on "human-centric, resilient" principles, featuring clear functional zoning and resolving the relationships between various flows, with a strong emphasis on humanized design throughout the site.

**Vehicular System:** Employs an "outer ring, inner dispersal" model. Internal ground-level roads prohibit general vehicle traffic. All resident and visitor vehicles access the large Deck-Under garage via entrances on the north, east, and west sides, proceeding directly to underground levels via ramps ("zero ground-level crossings"). Internal service vehicles use strictly time-limited dedicated routes with management protocols.

**Pedestrian System:** By integrating the slow traffic system with civil services, green spaces, and park facilities, a street system suitable for walking and slow traffic in TOD communities can be constructed. [12] An "One Axis, Three Loops" pedestrian network centered on the central landscape promenade is established on the Deck-On level. The "Axis" is the core community spine; the "Three Loops" connect residential entrances, encircle groups, and link public facilities. Abundant rest nodes integrated with roof gardens and platform greenery encourage walking and interaction.

**Emergency System:** A full ring fire lane and adequate fire

appliance access points are strictly provided on the Deck-On level according to codes, ensuring unimpeded emergency access and rescue efficiency. Specific ground-level routes can be activated in emergencies per plan.

### 3.2.2. Static Traffic Configuration

Parking utilizes a "Fully Underground + Elevated Deck"

composite model. The underground garage has 3 entrances connecting to Keji West Road and planned roads via site roads. Parking provision: 661 underground spaces, 3491 Deck-Under spaces. Emergency fire lanes and required fire appliance hardstandings are provided. A 1.5 m soil layer atop the garage deck supports low-carbon landscape planting.

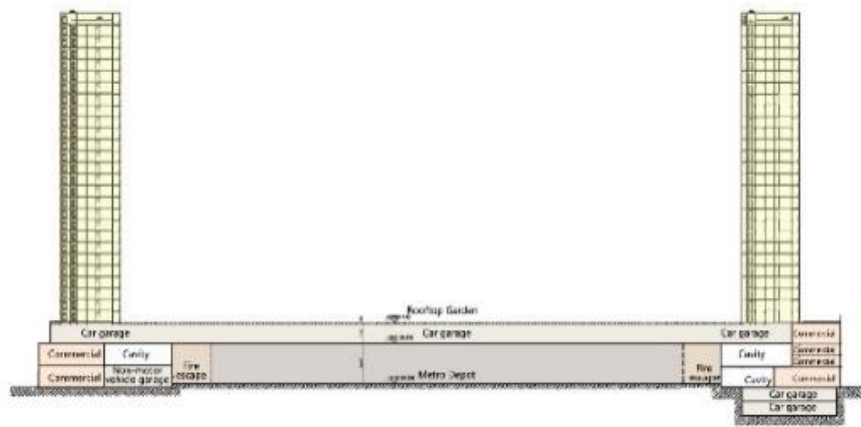


Figure 2. the Yuhuaazhai TOD project 's architectural section.

## 4. Structural Integration: Engineering Synergy to Address Loads, Vibration, and Sustainability

### 4.1. Differentiated Structural System Adaptation

The structural design of The Yuhuaazhai TOD project (Hyper park) is the cornerstone supporting the feasibility and safety of its overbuild development, confronting three core challenges: complex load transfer, vibration transmission from metro operations, collapsible loess foundation treatment and sustainable construction requirements. Innovative structural integration strategies successfully achieved synergy between engineering and architecture.

### 4.2. Collaborative Vibration Mitigation System

To resolve the conflict between vibration transmission and efficient land use, the project innovatively implements a "Three-Tier Collaborative Energy Dissipation System," embodying structure-energy-environment integrated design:

Tier 1: Isolation Layer - 300mm thick recycled rubber bearings installed atop the depot tunnel roof attenuate ~30% of vertical vibration while reducing material carbon footprint.

Tier 2: Terminal Noise Reduction - Floating floors and

constrained layer damping walls integrated within residential levels significantly enhance acoustic comfort.

### 4.3. Geological Adaptation and Sustainable Structure

Addressing Xi'an's characteristic collapsible loess, composite foundation treatment techniques are employed, combined with scientific waterproofing and drainage design, effectively mitigating risks from collapsible settlement coupled with metro vibration - offering valuable experience for similar geological TOD projects.

Responding to carbon neutrality goals, the project utilizes recycled aggregate concrete in main structures, industrial waste-recycled terracotta panels for cladding, and promotes bio-based materials like straw gypsum board for partitions. This creates a "Structural Dissipation-Material Circulation" low-carbon loop, significantly reducing the project's embodied carbon.

## 5. Landscape Design: Multi-tiered Ecological Scenario Creation

### 5.1. Synergy with Regional Green Network

The project deeply integrates with the city's "One Core, Multiple Points" park system (1 ecological park + 13 comprehensive parks + 40 pocket parks), contributing to the "300



m to Green, 500 m to Park" goal. Landscape corridors effectively link metro station exits and community entrances, providing visual and behavioral guidance. These corridors also serve as potential wildlife movement paths, creating a bidirectional permeable "City-Community" ecological interface that enhances regional connectivity.

## 5.2. Community-serving Landscape Spaces

**Central Axis & Hierarchy:** Leveraging the expansive east-west central space, a human-scale, multi-functional community landscape axis is created. This axis serves as both a visual corridor and the primary setting for daily activities. Landscape clusters are strategically concentrated along the axis and at key intersections, establishing a clear hierarchy to accommodate social and recreational needs at various scales.



**Figure 3.** the Yuhuaizhai TOD project 's neighborhood garde.

**All-Age Inclusive Landscape:** Garden design integrates points and lines, featuring a central internal garden as a social hub formed along the landscape axis. Refined group landscapes are developed along this axis, connected by a network of leisure pathways. Catering to seniors, adults, and children, it utilizes the large park for jogging paths, integrates fitness areas under mature trees, provides children's play and nature education spaces, and features interactive light/sound installations tailored to different user groups, creating a truly all-age community park.

**Site Constraint Resolution:** Limited soil depth atop the deck garage constrained large tree planting. Design solutions include creating localized landform variations and strategically placed planting beds to accommodate large trees, fostering an open and comfortable spatial atmosphere.

## 6. Green Ecological Strategies

The Yuhuaizhai TOD project (Hyper park), guided by the core principles of ecological priority and low-carbon circularity, establishes a community-scale TOD green development paradigm through a three-tier system: land-efficient planning, energy structure optimization, and resource cycling.

**Land-Efficient Ecological Space Creation:** Leveraging the

overbuild characteristic, a remarkable 40% green ratio is achieved: Ground Level utilizes micro-topography and native vegetation to form ecological corridors; The Deck-Under level features a 1.5 m soil layer creating ecological parking with carbon-sequestering plants; Roofs and terraces implement modular vertical greening, forming energy-saving thermal buffer zones. This three-dimensional system reduces the urban heat island effect by  $\geq 2^{\circ}\text{C}$  and enhances stormwater retention capacity.

**Energy Structure Transformation:** Building-Integrated Photovoltaics (BIPV) technology can achieve an energy efficiency gain of 12%-18% through the functional coupling of 'power generation - sunshading - enclosure'. [13] Extensive photovoltaic (PV) panels are deployed on commercial, office, and residential communal roofs, projected to cover over 40% of public area energy consumption (lighting, elevators, pumps). The construction of a community microgrid must conform to the theory of the integration of the "energy-information-facility" networks, and realize the temporal and spatial matching of energy production/consumption through intelligent regulation. [14] PV louvre systems are innovatively applied to select facades, enhancing energy yield by  $\sim 15\%$  while providing shading. A community-scale smart microgrid integrates rooftop PV, energy storage, and intelligent power management, enabling dynamic monitoring and optimized dispatch of energy production, storage, and consumption, increasing local renewable energy utilization and enhancing community energy resilience.

**Water System Resilience Enhancement:** Tailored to Xi'an's rainfall patterns, a dual "Sponge Cells - Reclaimed Water Network" system is implemented: Permeable paving and bio-retention achieve 85% annual runoff volume control; Rainwater harvesting and reclaimed water treatment provide 80% irrigation substitution, supplemented by greywater systems for toilet flushing, further reducing municipal water dependence - forming a "Collection-Purification-Reuse" closed-loop water system.

**Material Circulation & Low-Carbon Construction:** Large-scale use of recycled aggregate concrete, industrial waste-recycled terracotta panels, and straw gypsum boards significantly reduces lifecycle material carbon emissions. Local stone and timber are prioritized in landscaping to minimize transport emissions. Waste sorting and recycling systems are implemented throughout construction and operation phases.

## 7. Conclusion: Towards a Future-oriented Sustainable TOD Paradigm

The ultimate goal of TOD sustainable development is to achieve a three-dimensional balance of 'spatial efficiency-ecological resilience-social equity', avoiding the erosion of humanistic values by technical rationality. [15].

The Xi'an Yuhuaizhai project demonstrates that successful

community-scale TOD construction relies on the deep synergy of five key objectives: three-dimensional land efficiency, systemic ecological resilience, lifecycle-integrated smart technology, manifestation of regional identity, and human-scale refinement.



**Figure 4.** the Yuhuaazhai TOD project 's street view.

Looking ahead, TOD development will accelerate into a new phase characterized by deep intelligence and regional coordination. Efficient and intensive land use is the foundation; healthy ecological resilience is the safeguard; inclusive and accessible smart technology is the tool; the innovative inheritance of regional culture is the distinctive feature; and the meticulous implementation of human-centered care is fundamental. The exploration of The Yuhuaazhai TOD project (Hyper park), where nature, culture, transportation, experience, and local ingenuity intertwine, demonstrates how innovation creates new possibilities for the integrated development of people, industry, and the city.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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