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STRENGTHENING UNDERGROUND SPACE CONNECTIVITY TO ENHANCE THE EFFICIENCY OF UNDERGROUND SPACE UTILIZATION: A CASE STUDY OF BEIJING PRACTICES

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Abstract: In the context of rapid urban development and increasingly scarce land resources, the efficient development of underground space has become a crucial strategy for enhancing a city's sustainable development capabilities. In particular, strengthening underground space connectivity has a significant impact on reducing surface traffic pressure, optimizing urban spatial layout, and improving the quality of life for citizens. As the capital of China, Beijing's underground space development and utilization have formed a large scale. How to strengthen underground space connectivity and enhance the overall utilization efficiency of underground space is an important issue facing Beijing's underground space development in the new era. This paper discusses Beijing's practical to promote connectivity within underground spaces, focusing on the establishment of an underground vehicular connectivity system, the facilitation of underground connections between subway stations and surrounding areas, and the enhancement of systemic connectivity in urban key functional areas. It proposes the necessity of strengthening underground space connectivity and its role in promoting urban development.

Keywords: Underground Space Connectivity, Utilization Efficiency of Underground Space, Beijing Practices

1. INTRODUCTION

With the rapid urban development, megacities generally face severe challenges such as increasingly scarce land resources, worsening traffic congestion, and an urgent need to expand public spaces. Against this backdrop, seeking space underground and pursuing benefits through depth has become a critical pathway to enhance urban carrying capacity and sustainable development. Meanwhile, based on the growth of demand and the advancement of science and technology，underground space development has shifted from a single function to comprehensive and networked. Among them, connectivity has become a key strategy to improve the efficiency of underground space utilization. Beijing, the capital of China, has formed a large scale of underground space with decades of rapid urban construction. In the new development phase, how to strengthen underground space connectivity and create integrated aboveground-underground urban spaces has become an important issue for the city's development. This paper focus on Beijing's practical exploration in strengthening underground space connectivity. By analyzing the experiences and challenges of typical cases in planning, design and construction models, it evaluates the multi-dimensional benefits of underground space connectivity. These findings aim to provide valuable insights for advancing underground space connectivity in other megacities like Beijing.

2. NECESSITY AND MULTIFACETED BENEFITS

The underground space connectivity is an inevitable requirement for modern urban development at a certain stage. By establishing an efficient and convenient underground connectivity network, cities can not only effectively alleviate surface traffic pressure and optimize urban functional layouts, but also significantly improve

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commuting experiences and quality of life for urban residents, thereby injecting new vitality into urban development.

The underground space connectivity, far more than simple physical passage linkages; it represents a multidimensional and systematic conceptual connotation. At the physical level, the underground space connectivity primarily refers to the direct spatial linkage and convenient transition between different underground spaces, as well as between underground spaces and above-ground buildings, achieved through various forms such as underground pedestrian walkways, vehicular tunnels, and underground public spaces. On a deeper level, the underground space connectivity also have multi-dimensional and systematic core value. Through physical connectivity, it achieves functional synergy, promoting the complementary and organic integration of different underground space functions such as commercial, office, cultural, entertainment, and transportation, forming a multifunctional underground zone and elevating the overall service level.

The benefits and positive impacts of underground space connectivity can be summarized as follows:

2.1. Enhancing Spatial Efficiency

The scattered underground space can be integrated by connectivity. This not only revitalizes existing underground assets but also provides broader systemic access possibilities for the development of new underground spaces. As a result, it significantly enhances the comprehensive utilization efficiency of urban land and spatial resources.

2.2. Enhancing Urban Resilience

An interconnected underground space network can serve as critical pathways, shelters for evacuation, material transport, and emergency refuge in urban emergency situations, thereby improving the city's capacity to respond to natural disasters and emergencies.

2.3. Stimulating Economic Vitality

The connectivity can create new economic benefits for underground space. In particular, strengthening the seamless connection between underground space and the surrounding subway systems can significantly attract passenger flow, enhance commercial value, and drive regional economic development.

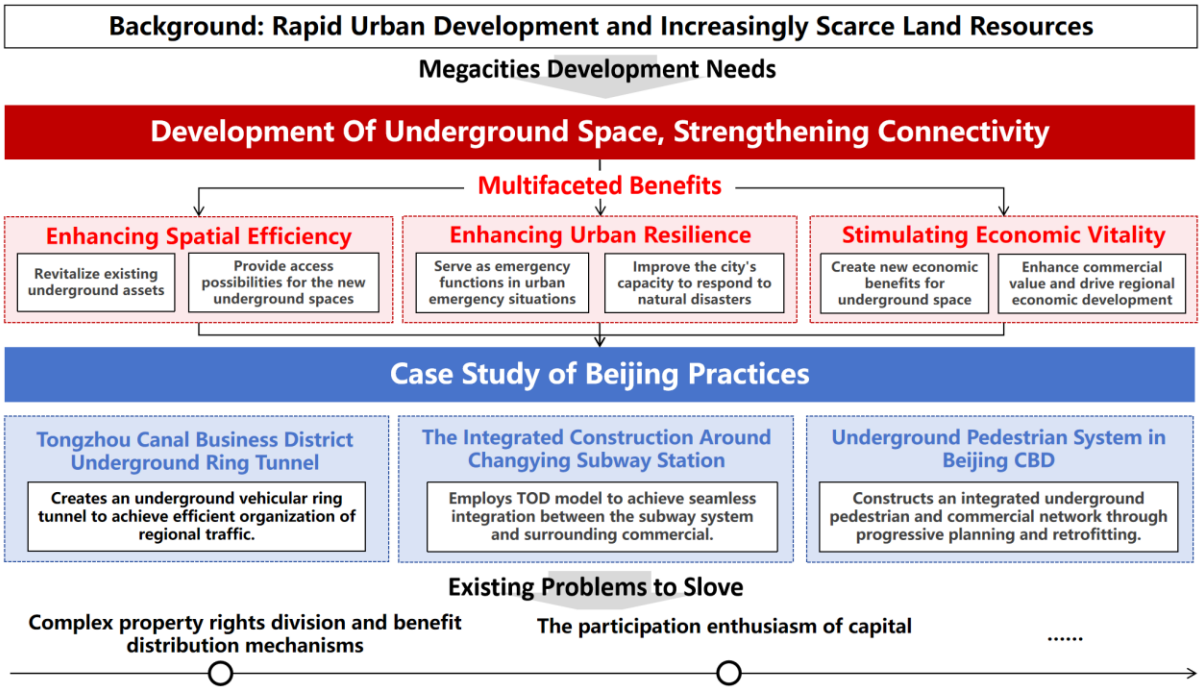

Figure 1. *Technical Framework Diagram*

3. TONGZHOU CANAL BUSINESS DISTRICT UNDERGROUND RING TUNNEL

The Tongzhou Canal Business District is located within the sub-center of Beijing's Tongzhou District. The area has a high building density, heavy pedestrian and vehicular traffic, and likely to cause surface traffic congestion. To improve the ground traffic environment and achieve interconnection among plots, a 1.5-kilometer underground ring tunnel was constructed approximately 10 meters below the surface, with a width of 14 meters and a height of 4 meters. This tunnel interconnects all 22 plots within the district. It guides vehicular traffic underground and leaves the road surface for pedestrians and bicycles to use. This design forms an efficient dual-layer transportation system, effectively separating fast and slow traffic system.

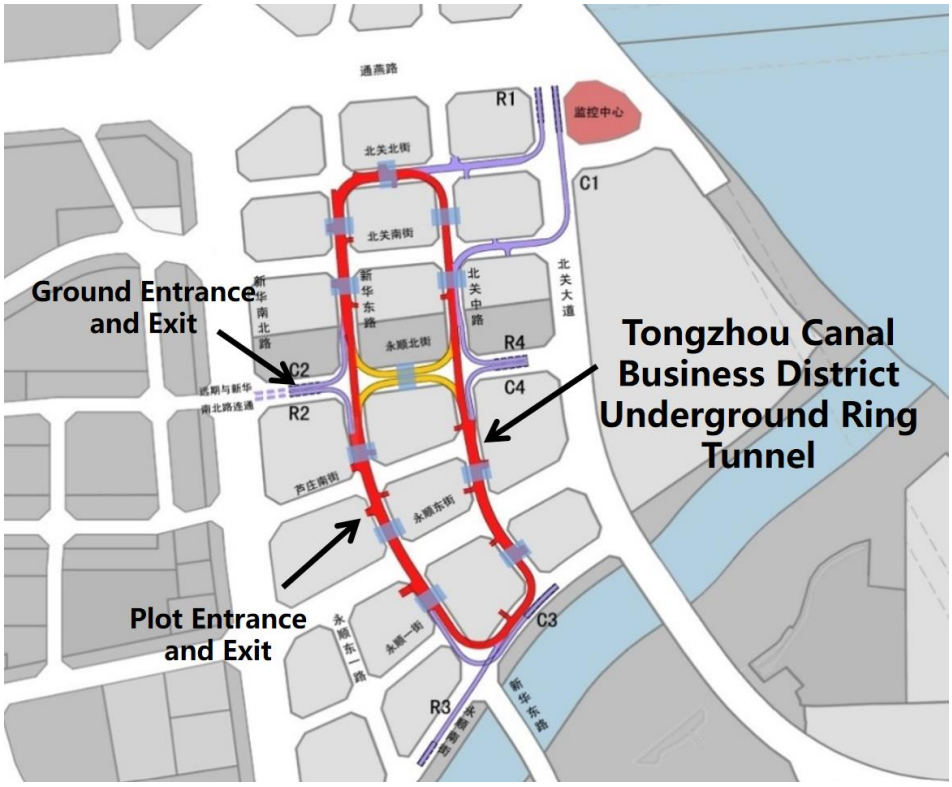

Figure 2. *Schematic Diagram of Tongzhou Canal Business District Underground Ring Tunnel*

Figure 3. *Interior Scene of Tongzhou Canal Business District Underground Ring Tunnel*

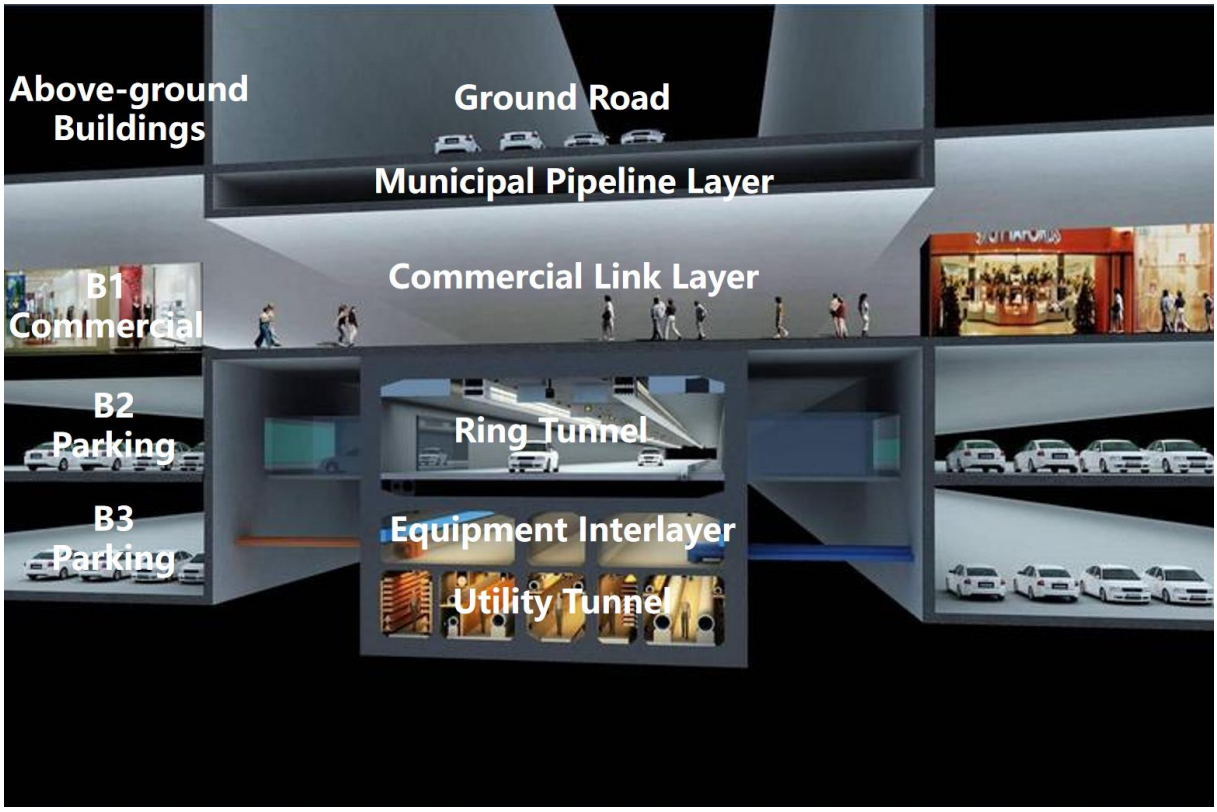

Figure 4. *Schematic Cross-section of Tongzhou Canal Business District Underground Ring Tunnel*

3.1. Underground ring Tunnel Enhances Regional Vehicular Connectivity and Shared Parking Resources to Optimize Surface Traffic Conditions.

The tunnel has built 22 entrances and exits, connecting the underground parking lots of surrounding commercial buildings, office buildings and residential apartments, achieving complete underground connection within the area and sharing underground parking resources. The tunnel is equipped with traffic monitoring devices, electronic display screens, and intelligent traffic signals to dynamically optimize traffic flow efficiency in real time.

3.2. The B1 Level is Designed as an Integrated Underground Walkway System Enhancing Area Accessibility.

The tunnel designed a pedestrian level (B1) above the vehicular traffic layer, which is connected to the surrounding office buildings, commercial complexes and subway stations, and also has commercial spaces. People can move between subways and different buildings without going to the ground, unaffected by the weather, and carry out activities such as commuting, dining and social activities. The system establishes a safe, comfortable, and efficient underground pedestrian circulation network.

4. THE INTEGRATED CONSTRUCTION AROUND CHANGYING SUBWAY STATION

The Changying Station of Beijing Subway Line 6 is located in Chaoyang District, Beijing. The station is close to the shopping center on the south side. To effectively disperse passenger flow and organic integrate with surrounding commercial areas, the station adopted an integrated development model during construction. This design seamlessly connects the station concourse with the underground levels of the commercial complex, providing a comfortable and convenient shopping experience for subway passengers and shoppers.

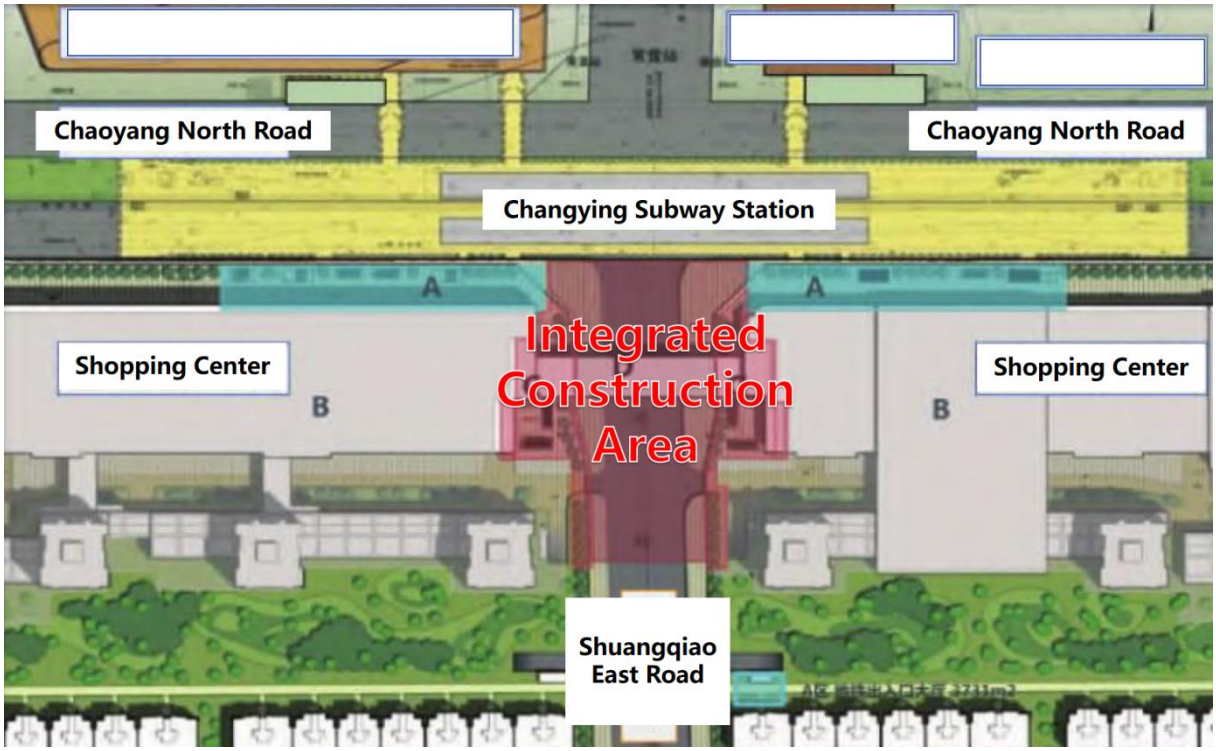

Figure 5. *Schematic Diagram of Underground Connectivity Construction Mode at Changying Subway Station*

Figure 6. *Rendering of Underground Connectivity at Changying Subway Station*

4.1. Connect the Subway Systems with Commercial Spaces and Utilize the Flow of Traffic to Enhance the Value of Commercial Spaces.

The integrated design model fully opens the southern space of the subway station concourse, connecting it with the underground commercial area. At the same time, the underground space of the road is integrated to form a "T"-shaped structure. The total underground construction area of the integrated development is 7,477 square meters, including 4,000 square meters of commercial facilities, effectively converting subway passenger flow into commercial customer flow.

4.2. Clarify the Construction Funds and Settlement Methods to Ensure that the Integrated Construction is Implemented Simultaneously.

In the integrated construction of subway, funding sources is often a significant challenges. The Changying Station project stipulates that construction funds for the integrated area will be advanced by the subway company first, and then paid by the property management unit after settlement. This operational model not only solves construction financing issues, but also provides a strong guarantee for the simultaneous planning, design and construction of subway facilities, underground passageways, and commercial spaces.

5. UNDERGROUND PEDESTRIAN SYSTEM IN BEIJING CBD

Beijing Central Business District (CBD), located in the central part of Chaoyang District, is a strategically planned zone that integrates commercial, financial, technological, office, entertainment, and residential functions. As a pivotal gateway for Beijing's international engagement and a nationally significant business district. The CBD is currently the area with the largest development scope, utilization depth and construction scale of underground space in Beijing. Through the comprehensive underground integration, the underground space serves as a shared platform, achieving resource sharing in the high-density built environment.

Figure 7. *Schematic Planning Diagram of Underground Space System at B1 Level in CBD*

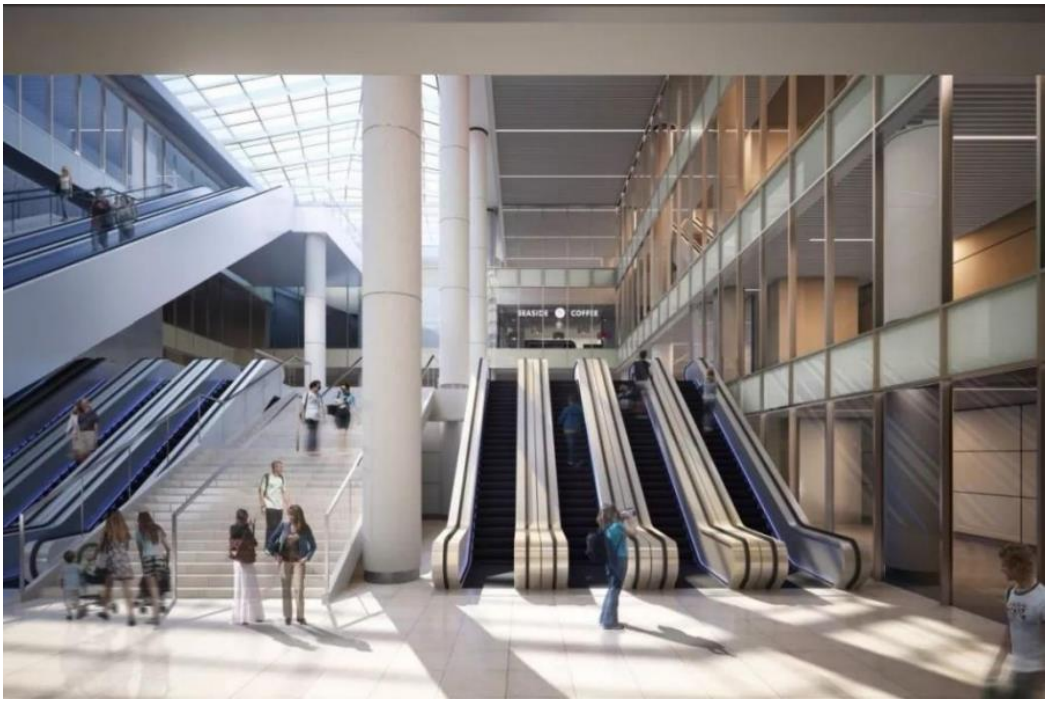

Figure 8. *Rendering of CBD Subway Transfer Hall*

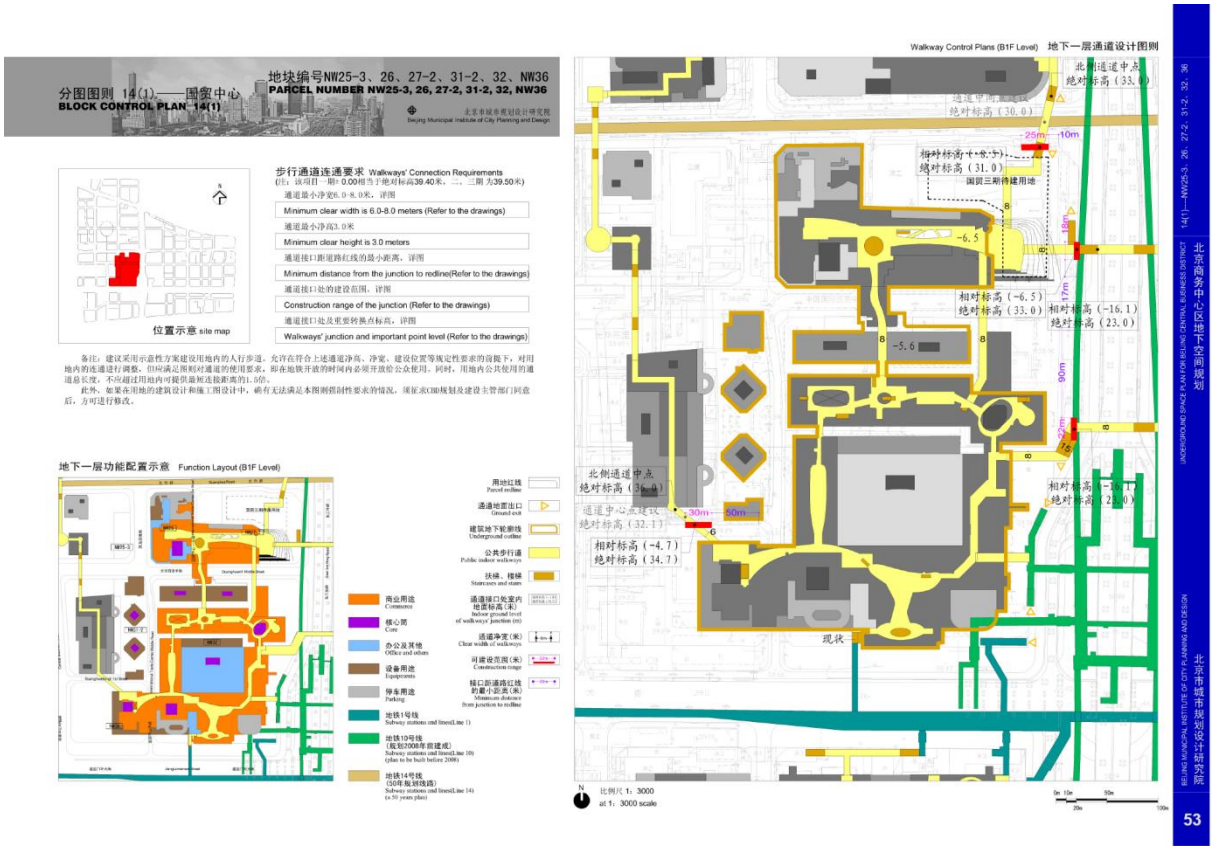

Figure 9. *Block Control Plan in Underground Plan For Beijing Central Business District*

5.1. Developing an Underground Pedestrian System to Establish a Networked Public Space Framework Below Ground.

The CBD has developed an approximately 10-kilometer underground pedestrian system at the B1 level, connecting commercial facilities, public spaces, and subway stations. This network links 6 subway stations and 5 bus terminals, covering about 221 hectares in the most densely developed business area with the highest pedestrian flow of CBD. The pedestrian walkways are lined with commercial, cultural and recreational amenities, creating comfortable all-weather environments for walking, shopping and entertainment.

5.2. Formulated Master Planning and Coordinated Implementation of Underground Space Development.

In 2005, the CBD formulated the Underground Plan For Beijing Central Business District, which specified technical parameters such as connectivity locations, vertical, widths, and heights for both project sites and public areas. The plan established detailed zoning regulations that effectively guided the specific design and implementation of each project, and also provided predictive guidance for future development.

6. EXPERIENCE AND SUMMARY

These three cases exemplify the critical role of underground connectivity from different perspectives. Taking the new district development as an opportunity, Tongzhou Canal Business District creates an underground vehicular ring tunnel to achieve efficient organization of regional traffic and optimization of above-ground space. Changying subway station employs a Transit-Oriented Development (TOD) model to achieve seamless integration between the subway system and surrounding commercial and residential functions, enhancing district vitality and resident accessibility. As a high-density urban core, Beijing CBD constructs an integrated underground pedestrian and commercial network through progressive planning and retrofitting, seamlessly linking transportation hubs with major buildings.

From the three cases, we can also summarize valuable practical experience from Beijing in underground space connectivity. First, tailored approaches should be adopted based on local conditions and project categories. Different planning concepts, construction models and technical solutions should be applied to new urban districts, built-up area redevelopment, and subway stations to enhance the relevance and effectiveness of underground connectivity. Second, it is essential to strengthen planning guidance and policy support, as scientific top-level design and consistent policy frameworks form the critical foundation for promoting orderly development of underground spaces connectivity.

However, Beijing's current underground space connectivity work still face many challenges. For instance, cross-parcel and cross-ownership underground connections involve complex property rights division and benefit distribution mechanisms. Additionally, the high construction costs and long return periods of underground projects have dampened the participation enthusiasm of social capital. Therefore, subsequent efforts should focus on improving legal frameworks and establishing long-term mechanisms to promote the connectivity and efficient utilization of underground spaces.

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