19th WORLD CONFERENCE OF THE ASSOCIATED RESEARCH CENTRES FOR THE URBAN UNDERGROUND SPACE
Belgrade, Serbia, November 4-7, 2025.

ACUUS BELGRADE 2025

Paper No: 1.9.85
DOI: 10.46793/ACUUS2025.1.9.85

EXPLORATION OF IMPLEMENTATION PATHWAYS FOR UNDERGROUND SPACE PLANNING IN KEY URBAN AREAS

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Abstract: The rational development and utilization of urban underground space is a crucial approach to optimizing spatial resource allocation. This study focuses on key urban districts, drawing on the characteristics of underground space development in internationally exemplary regions. Combining practical insights from China, it summarizes existing issues encountered during the planning and implementation process of underground space projects. Four key influencing factors—regulatory systems, organizational management, spatial information, and technical methods—are identified. An integrated pathway for enhancing urban underground space planning is proposed, comprising top-level design, organizational management, information coordination, and technical execution. The analysis of international case studies broadens research perspectives, and the proposed implementation strategies offer valuable insights for the planning and management of similar urban key district development projects.

Keywords: urban underground space planning, regulatory systems, organizational management, spatial information, technical methods

1. INTRODUCTION

Under the era of high-quality development, China's urban planning and construction are transitioning from incremental expansion to the enhancement of existing stock. In recent years, China has successively issued several policy documents, including the "Opinions of the Central Committee of the Communist Party of China and the State Council on Establishing a Land and Space Planning System and Supervising Its Implementation," the "Opinions of the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council on Comprehensively Strengthening Resource Conservation," and the "Guiding Opinions of the Ministry of Natural Resources on Exploring and Promoting the Development and Utilization of Urban Underground Space." These documents set higher standards for underground space development, planning, and implementation.

Globally, the development of underground space originated in 18th-century Britain with the construction of subways. Countries and regions such as Japan and Canada have accumulated extensive experience in policies, regulations, planning systems, and practical applications related to underground space development. In mainland China, underground space development began in the 1950s with the construction of bomb shelters and underground storage facilities for wartime preparedness. This evolved from the opening of Beijing's subway in 1969 to large-scale development driven by rail transit during the "Twelfth Five-Year Plan" period, and further into networked development during the "Thirteenth Five-Year Plan." Currently, the utilization of urban underground space in China exhibits multi-layered spatial characteristics and diversified functional features [1].

Numerous scholars have built a substantial research foundation around urban planning implementation. However, most existing studies focus on traditional urban planning aspects, with limited in-depth exploration from the perspective of underground space. This paper concentrates on the planning and implementation of underground space in key urban districts. Based on an international perspective and the analysis of typical cases, it identifies

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the complex characteristics and implementation challenges of underground space development. A planning and implementation pathway is proposed, encompassing "top-level design, organizational management, information coordination, and technological support," aiming to provide a reference for similar district development projects..

2. CHARACTERISTICS OF UNDERGROUND SPACE DEVELOPMENT IN KEY URBAN DISTRICTS

2.1. Attributes of Major Engineering Projects

The concept of key urban zones originates from the "Central Place Theory" proposed by German geographer W. Christaller in 1933, emphasizing the significance of transportation location and influence on surrounding areas. Projects within these zones exert extensive impacts on regional economic development, environmental sustainability, and social progress, classifying them as significant local infrastructure projects [2].

Given that underground urban space is formed through artificial development of structures within subsurface rock or soil layers beneath the surface, its development possesses inherent engineering attributes [3]. In Chinese provincial and municipal regulations concerning underground space planning and management—exemplified by the "Shenzhen Underground Space Development and Utilization Management Measures"—the definition of key urban zones refers to areas designated as city centers, comprehensive transportation hubs, and similar regions. Projects for underground space development in these zones are characterized by strategic importance, advantageous transportation location, substantial land development potential, rapid progress requirements, and high-quality integrated presentation. Such development constitutes a vital approach to expanding urban spatial capacity.

2.2. Project Complexity

The concept of project complexity was first introduced by Baccarini, who defined it as the heterogeneity and interdependence among interacting components [4]. Qing hua He and colleagues developed a multidimensional model of complexity for major Chinese engineering projects based on grounded theory qualitative research, encompassing six aspects: institutional, environmental, organizational, technical, task-related, and social complexity [5]. Due to their large scale, numerous subcomponents, multifunctionality, open spatial design, and shared facilities, underground space development projects in key urban zones exhibit significant complexity in planning, design, construction, and operational management.

1) Spatial Facility Complexity

The functional facilities within urban underground spaces are diverse, including underground transportation, municipal utilities, public services, storage, and disaster prevention facilities. These encompass rail transit systems, tunnels, underground garages, municipal pipelines, pedestrian passages, and commercial spaces. The necessity to arrange multiple functions within confined environments requires precise assessment of construction conditions and spatial layout—both horizontal and vertical—resulting in elevated safety risks and technical challenges.

2) Complexity of Stakeholders

The multifaceted nature of underground space facilities in key urban zones leads to numerous involved parties. Stakeholders include government agencies, developers, design firms, construction enterprises, consulting agencies, and suppliers. Different phases of project development involve varying stakeholders, and the complexity is further compounded by issues of property rights, investment, and operational responsibilities related to underground facilities, thereby increasing planning and implementation difficulties.

2.3. Irreversibility

Subterranean space constitutes an irreversible spatial resource, underscoring the critical importance of scientific planning and sustainable development [7]. Compared to surface development, underground space exploitation exerts long-term impacts on adjacent terrestrial and subterranean infrastructure and environmental conditions. Unsystematic development of underground space may result in irrevocable losses to urban future growth. Therefore, proactive planning of underground space layout and moderate development are of paramount significance.

2.4. Economic Correlation

1) High Development Costs

Relative to conventional above-ground construction, underground engineering presents increased complexity in hydrological, geological, and environmental conditions, introducing significant uncertainties into design and implementation processes. Typically, underground space development incurs substantial costs. Recent trends favor compact neighborhood configurations characterized by small blocks and dense street networks [8]. However, such small parcel divisions, intricate architectural structures, and deep excavations lead to large-scale foundation pits and support difficulties, indirectly elevating development costs. Additionally, underground construction is constrained by the sequence of land transfer on the surface, complicating the synchronization of foundation pit excavations [9].

In key urban districts with high surface building development intensity, the corresponding underground space development scale is proportionally larger. Large-scale, complex foundation pit groups exhibit varied excavation depths and shapes, with interwoven interfaces forming complex load-bearing support systems and numerous shared enclosures. These projects pose substantial engineering risks, present numerous construction challenges, and demand extensive management and coordination efforts from project stakeholders, with high requirements for technical expertise.

2) Influence of Regional Economic Development

The development of underground space is significantly correlated with regional economic levels. Market research indicates that, geographically, regions such as East China and South China—areas with higher economic development—exhibit larger scales of underground space utilization and more mature development experience, exemplified by cities like Shanghai, Beijing, and Shenzhen. These regions also demonstrate a strong association with urban rail transit infrastructure. Cities with robust economic growth generally achieve higher standards in underground space development, characterized by integrated utilization, combined civil and military functions, and multifunctionality.

3. CHALLENGES IN THE PLANNING AND IMPLEMENTATION OF UNDERGROUND SPACE IN KEY URBAN DISTRICTS

3.1. Institutional Framework

The management mechanisms require further refinement, and the planning system necessitates enhancement [10,11]. The primary issues within the underground space regulatory framework include ambiguities in legal definitions concerning operational rights and ownership, unclear legal entities, and inconsistent management standards. Although many major Chinese cities have established foundational plans for underground space utilization, their planning systems and content remain underdeveloped. The hierarchical clarity of underground space planning is insufficient, particularly at the level of control detailed planning that serves as the basis for administrative permits, where relevant provisions are notably lacking. Furthermore, the implementation of planning faces challenges due to inadequate safeguard mechanisms, incomplete supporting policies and regulations, disjointed planning, construction, and management processes, and a tendency to prioritize plan formulation over execution and evaluation.

3.2. Organizational Management

Issues of fragmented authority and management gaps are prevalent, necessitating further research into property rights. Currently, there is a consensus among Chinese cities that urban underground space planning and management fall under the jurisdiction of municipal urban and rural planning authorities. However, in practice, issues such as sectoral segmentation, multiple management entities, and unclear responsibilities are prominent. Effective utilization of underground space requires standardized regulation and coordination of various underground facilities, including construction requirements, sequencing, and interrelations. The complexity of planning, management, and implementation underscores the need for clear delineation of responsibilities among supervisory agencies to ensure integrated oversight across departments.

3.3. Spatial Information

Given the unique nature of urban underground spaces as enclosed environments beneath the surface, limitations of traditional surveying technologies, and the historical lack of unified planning and coordination for development zones and surrounding underground areas, there are notable deficiencies in early-stage statistical standards and fundamental survey data. Challenges include inadequate integration and application of foundational underground space data. The primary difficulty in managing underground space development information lies in acquiring reliable baseline data, compounded by the underground environment’s inaccessibility to direct observation,

incomplete urban underground information archives, and multi-agency management. Currently, only a few Chinese cities maintain comprehensive and accurate databases on underground space utilization. Some cities have incorporated underground space information management into local regulations to support refined urban governance. For example, Chengdu and Kunming's "Urban Underground Space Development and Utilization Management Measures" explicitly assign responsibility for underground space information management to urban planning administrative departments.

3.4. Technical Methods

Standardization of technical norms remains urgent, alongside the enhancement of management and technical personnel capabilities. For most Chinese cities, underground space utilization remains a relatively unfamiliar domain, requiring multidisciplinary expertise for effective management. Urban underground space planning is characterized by spatial coordination and comprehensive integration. Due to the absence of unified methodologies and technical standards, current practices are primarily exploratory at the local level, resulting in significant disparities in planning outcomes. The lack of relevant policies, regulations, and detailed management guidelines further complicates implementation. It is essential to strengthen legal guidance, supervision, and training for urban planning authorities to familiarize them with emerging trends in underground space development, recognize the importance of standardized planning and management under new conditions, and clarify departmental responsibilities. Additionally, targeted professional training for administrative and planning personnel across regions remains an urgent need.

4. EXPLORATION OF IMPLEMENTATION STRATEGIES FOR UNDERGROUND SPACE PLANNING BASED ON CASE STUDY ANALYSIS

4.1. Top-Level Design Pathway

By analyzing typical international case studies focusing on the development of distinctive features and management mechanisms for underground space development, it is evident that the integrated utilization of underground space underpins the high-precision development orientation of the district. The management mechanisms require support from relevant policies and regulations, as outlined in Table 1.

Table 1. *Top-Level Design of International Typical Cases in Subterranean Space.*

Representative project	Area	Develop distinctive features	Underground space management mechanism
Tokyo Shinjuku	Japan	Highly intensive integrated development of stations and cities	Mature management regulations system, complete underground space planning system
Montreal	Canada	The world's largest underground pedestrian network	The integrated management system and operational mechanism jointly established by the government and private enterprises; Integrating underground pedestrian network into statutory planning
Canary Wharf	Britain	One of the most important financial regions in the world	Funding from higher-level governments and policy incentives for special development zones; Developer prepares development plan
Chicago Pedway	America	An underground colorful dungeon unaffected by weather and motor vehicles	Land spatial rights, spatial laws, and incentives for building public passages with plot ratio; Regional regulations provide construction guidelines
Paris La D é fense	France	The world's first urban complex that combines underground transportation with underground space	Government functional departments have no overlapping powers or superior subordinate relationships; Mature planning system

CityLink Mall	Singapore	Singapore's first air-conditioned underground shopping mall, subway commercial	Land spatial rights, spatial laws, and incentives for building public passages with plot ratio; Draft plan for underground space connectivity in the central urban area and overall blueprint for urban development

After years of exploration and practice, China has essentially established a legal and policy framework for underground space development. Most cities have enacted regulations for the management and utilization of underground spaces, providing detailed provisions for each specific issue. However, comparative analysis of legal policies related to underground space in representative regions reveals that cities with relatively mature experience in underground space development, such as Beijing and Shanghai, lack dedicated management regulations, such as Beijing's relevant administrative measures and Shanghai's Planning and Construction Regulations, as shown in Tables 2 and 3.

Table 2. *Chinese laws and regulations concerning the development and utilization of underground space.*

Classification	**Name**
national laws	Civil Air Defense Law of the People's Republic of China (October 1996), Land Administration Law of the People's Republic of China (1998/2004), Property Law of the People's Republic of China (October 2007), Urban Real Estate Administration Law of the People's Republic of China (Revised) (August 2007), Urban and Rural Planning Law of the People's Republic of China (January 2008)
National regulations	Regulations on the Management of Urban Underground Space Development and Utilization (Ministry of Housing and Urban Rural Development 1997/2001/2011), Urban Planning Compilation Measures (Ministry of Housing and Urban Rural Development 2006.04), Land Registration Measures (Ministry of Land and Resources 2007.12), Housing Registration Measures (2008.02), Guiding Opinions on Promoting the Construction of Urban Underground Comprehensive Pipe Corridors (General Office of the State Council, November 2015), 13th Five Year Plan for Urban Underground Space Development and Utilization (Ministry of Housing and Urban Rural Development, June 2016), Guiding Opinions on Strengthening Urban Geological Work (Ministry of Land and Resources, September 2017)

Table 3. *Regulations on the Management of Underground Space in Typical Regions of China.*

Region	**Management Measures for Underground Space**	**Representative project**
Beijing	Management Measures for the Safe Use of Civil Air Defense Projects and Ordinary Basements in Beijing	Xiong'an Station Hub Area
Shanghai	Regulations on the Planning and Construction of Underground Spaces in Shanghai	Shanghai Hongqiao, Expo Zone B, West Bund Media Port
Shenzhen	Shenzhen Underground Space Management Measures	Qianhai, Baishizhou, Chao-zong
Nanjing	Management Measures for the Utilization of Underground Space in Nanjing City	Jiangbei New City
Suzhou	Management Measures for the Utilization of Underground Space in Suzhou City	Suzhou Center
Jinan	Management Measures for the Utilization of Underground Space in Jinan City	Hanyu Golden Valley
Fuzhou	Management Measures for the Development and Utilization of Urban Underground Space in Fuzhou City (Trial)	new coastal city

In summary, China has initially established a comprehensive institutional and regulatory management framework for urban underground space development at both national and local levels. However, standards for urban underground space development and management remain inconsistent. Compared to the policy support mechanisms in developed countries and regions internationally, there is still a notable gap. It is therefore necessary to further refine and systematically improve the urban underground space legal and regulatory system.

4.2. Organizational Management Pathways

The development of urban underground spaces involves numerous stakeholders, necessitating a robust leading authority to coordinate regional development and construction. Taking the Shanghai West Coast Media Port underground space development project as an example, the government's political characteristics, social influence, and its discourse power in major construction projects—particularly those driven by government investment—render governmental administrative governance as equally vital as market regulation. This results in a governance framework that synergistically integrates "government plus market" mechanisms, which effectively promotes the planning and implementation of construction projects, as illustrated in Figure 1 [12].

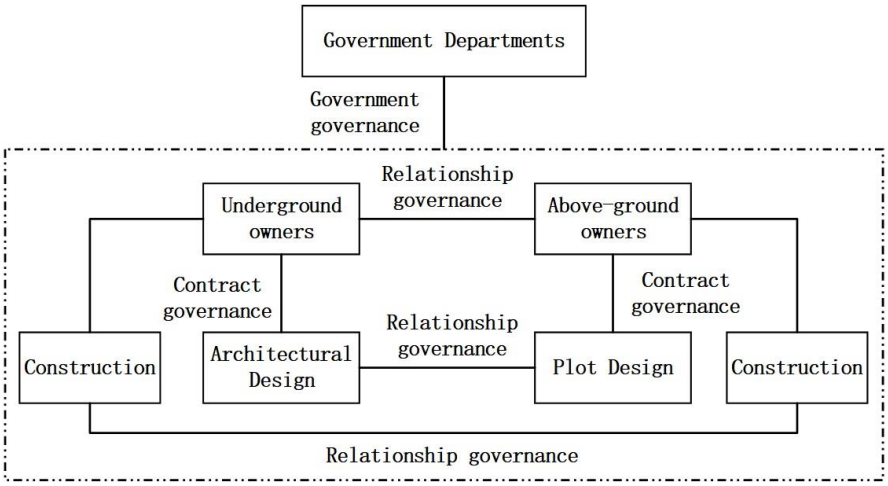

Figure 1. *Governance Mechanism of the Shanghai West Bank Media Port Project[12].*

Underground space development projects in key urban districts typically exhibit a dual collaborative structure involving government and enterprise entities, with coordinated participation from planning agencies, master design units, consulting firms, and overall control organizations. Regarding project stakeholders, the principal can be the government, a platform company, or a land parcel developer. Taking the Shenzhen Bay Super Headquarters Base as a case study, the project initiates development and construction mechanisms during the decision-making phase by establishing a command center and designating a comprehensive development and operation entity—namely, a municipal state-owned enterprise—and forming a strategic implementation platform company for the district. The process involves identifying appropriate construction models to balance the interests of government, investors, builders, operators, and users, thereby establishing an efficient decision-making framework.

4.3. Information Integration Pathways

In the context of the digital economy era, to thoroughly implement the Chinese government's strategic directives for building a "Cyber power," "Digital China," and "Smart Society," most Chinese cities have introduced strategic plans to advance digital and smart city development. The most representative achievement is the application of underground space information management through BIM, GIS, and CIM digital platforms during project design, construction, and operational maintenance phases, as illustrated in Figure 2.

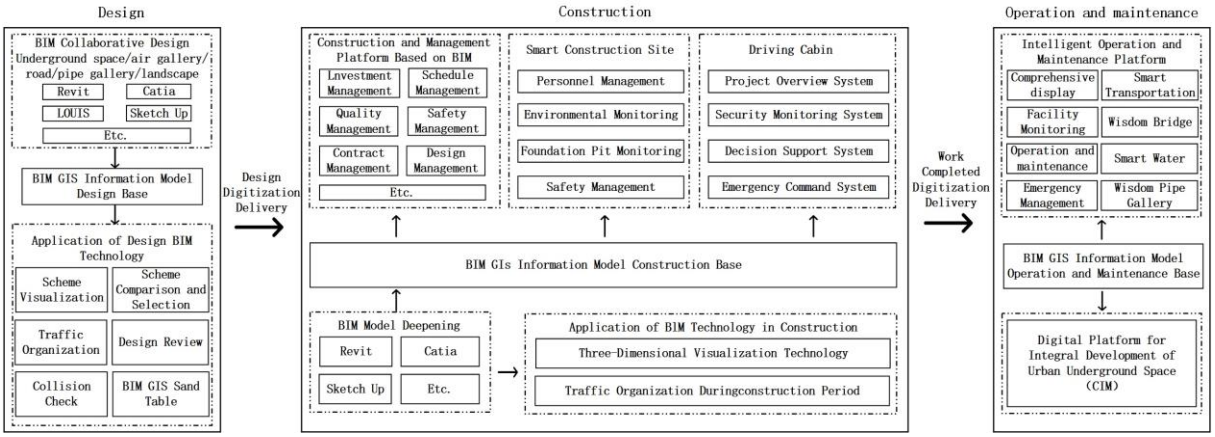

Figure 2. *Comprehensive digital management of the entire process of urban underground space design, construction, and operation and maintenance.*

In addition to ensuring the effective utilization within the industry sector by government agencies and related operational maintenance units, there is also significant potential to leverage underground space information in other domains such as project development, design, construction, safety, and disaster prevention. Under the premise of safeguarding data security and confidentiality, it is recommended to maximize public access to information regarding underground spaces that impact people's livelihoods. Collaborative research with relevant scientific and educational institutions on underground space information management, along with the development of new systems and the adoption of innovative technologies, represents the future direction of underground space information management.

4.4. Technical Support Pathway

For design entities with strong comprehensive capabilities, the introduction of centralized control, along with adherence to guiding principles and regulatory frameworks, is essential. Taking the Guangzhou Mingzhu Science Park project as a case study, a detailed underground space planning approach was employed. The approved "Textual and Graphical Regulations" serve as the legal basis for underground space planning approval and land transfer. Additionally, relying on the detailed underground space plan as a preliminary negotiation platform facilitates horizontal coordination among government departments, landowners, and project implementers, while vertically integrating various professional design teams to ensure consistency of objectives and synchronization of technical standards.

5. RECOMMENDATIONS FOR IMPLEMENTATION PLANNING

5.1. Enhancement of Policy Mechanisms for Subterranean Space Development and Utilization

Firstly, streamline and integrate existing operational procedures for development and utilization, establishing a comprehensive workflow encompassing planning, project initiation, approval, construction, acceptance, operation, and maintenance of underground space projects. Secondly, for development models lacking clearly defined procedures, conduct innovative research on mechanisms related to property rights attribution, investment and financing modes, and operational maintenance frameworks.

5.2. Strengthening Organizational Management of Underground Space Development

From planning formulation and approval to the selection of design entities, project development, and post-construction operational management, reinforce the guidance of government authorities and foster market-oriented collaboration, thereby forming context-specific organizational management models. Conduct in-depth studies on interface delineation, rights management, and cost allocation among organizational elements.

5.3. Establishment of a Three-Dimensional Underground Space Information Management System

Utilize multi-modal digital technologies such as BIM, GIS, and CIM to develop information databases and system platforms, enabling comprehensive mapping of urban underground space development status. Effective information recording and data management are crucial for collecting, organizing, storing, and sharing underground space information. Additionally, address issues related to data ownership and sharing, clarifying the responsibilities and rights of data custodians.

5.4. Enhancement of Technical and Management Training Programs

Implement specialized training mechanisms targeting government agencies, project owners, developers, design firms, construction entities, and operational management units. Use benchmark demonstration projects as case studies to systematically analyze and disseminate key challenges and focal points in underground space development and management processes, thereby elevating the technical and managerial competencies of relevant personnel.

6. CONCLUSION

Currently, in the era of stock renewal and digital economy, large-scale district-based development projects are gradually declining. How to optimize and efficiently utilize urban three-dimensional space resources has become a critical issue for urban planning, construction, and management authorities. This paper examines urban underground space development projects from an international perspective, integrating practical project development experiences. Using case study methodology, a strategic framework comprising "top-level design, organizational management, information coordination, and technological support" is proposed. The development and construction of underground spaces in key urban districts constitute a complex systemic engineering task. Effective implementation of planning requires policy support and the concerted efforts of developers and project stakeholders. The adaptability of organizational management models for underground space development remains a subject warranting further in-depth research.

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