Planning Research on China's Urban Underground Spaces: Evolution and Prospect

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Abstract: As a critical means of optimizing spatial structure, improving infrastructure, and enhancing urban resilience, the development of urban underground space plays an indispensable role in achieving cities' low-carbon and sustainability goals, and its scientific planning has drawn increasing attention. Against this backdrop, this study employs CiteSpace software and the China National Knowledge Infrastructure (CNKI) database to systematically review the research progress, hotspots, and trends in urban underground space planning in China from 1995 to 2024. The findings reveal a concerted evolution among spatial planning, its upstream comprehensive evaluation, and downstream management and implementation. The development can be broadly divided into three stages: the "exploratory stage" (up to 2007), focused on foundational planning research and practical experience accumulation; the "rapid growth stage" (2008–2018), marked by advances in system construction, spatial coordination, and technical upgrading in planning methodologies, alongside concentrated efforts in rail transit, ecological energy conservation, and safety assurance; and the "high-quality development stage" (from 2019 onward), characterized by research on integrating underground space planning into the national territorial spatial planning system to serve urban renewal, and explorations of human-oriented, green, intelligent, and resilient underground space planning. Building on these findings, the paper discusses future prospects for urban underground space planning from the perspectives of functional compounding, embedding, and facility sharing.
Keywords: urban underground space; urban planning; literature review; development period

Urban underground space generally refers to the space below the ground surface. From the perspective of urban construction, it mostly denotes underground spatial engineering that uses space as its carrier — i.e., underground space in the narrow, traditional sense[1].

As an essential component of territorial spatial resources, China's urban underground space has played a crucial role across different periods and development stages. From the 1950s to the 1980s, urban underground space primarily served civil defense purposes. Since the reform and opening-up, the development and utilization of urban underground space have gradually transitioned from a stage primarily combining peacetime and wartime uses centered on civil defense construction to an orderly development stage aimed at serving urban construction. Since the beginning of the 21st century, underground space has played an increasingly important role in improving ecological environments, optimizing spatial structures, and enhancing urban resilience[2-4], progressing from exploratory development into a phase of rapid growth, with research presenting an increasingly diversified trend.

Since 2019, under the new territorial spatial planning system, urban underground space planning, as a specialized plan, must balance resource protection and development, emphasizing macro-level guidance and intensive utilization of underground space resources[2]. Underground space also plays an irreplaceable role in achieving the "dual carbon" goals and is a vital instrument for cities to achieve sustainable development[3,5], with its contributions to high-quality urban development increasingly recognized by the public.

Therefore, analyzing the evolutionary trajectory of China's urban underground space planning research is conducive to grasping its development direction, fully integrating research achievements in underground space planning within the territorial spatial planning framework in practice, adapting to developments in socioeconomic conditions, institutional mechanisms, and planning technologies, and better serving the creation of livable, resilient, and intelligent cities.

1 Research Methodology and Data

1.1Data Sources

This study employs CiteSpace for bibliometric analysis. The literature was sourced from the CNKI Chinese database, with search terms combining themes such as "urban underground space development and utilization" and "urban underground space planning." The search period spans from January 1995, when a relatively stable output of publications began, to December 2024. Considering the overall quality and impact of the sample, data from Chinese core journals (Peking University Core) and the Chinese Social Sciences Citation Index (CSSCI) were selected, totaling 896 papers.

1.2Research Theme Definition and Data Screening

The development and utilization of urban underground space primarily involve stages including "exploration, evaluation, planning, construction, and operation and maintenance," encompassing multiple intersecting disciplines such as geological resources and geological engineering, surveying and mapping science and technology, urban-rural planning, architecture, and civil engineering, with varying emphases across different studies. This study focuses on the "spatial planning" perspective for literature screening, selecting data related to territorial spatial planning and urban-rural planning for analysis.

After one by one screening and verification, removing duplicates and irrelevant literature, a total of 674 relevant papers were identified. Using one-year intervals as time slices for bibliometric analysis, the annual publication distribution and trends are shown in Figure 1.

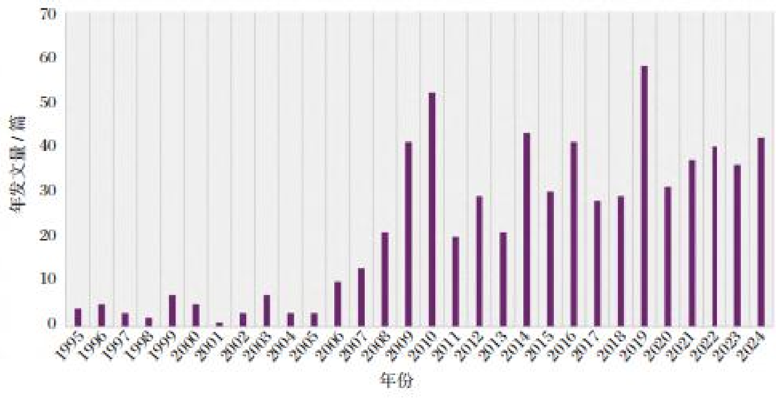

Fig.1 The number of related papers published in each year from 1995 to 2024

2 Overall Statistical Analysis

2.1Publication Time Distribution

China's urban underground space development and utilization began to integrate with urban construction from 1987. In 1997, the "Regulations on the Management of Urban Underground Space Development and Utilization" were promulgated, stipulating that "people's governments at all levels shall, when organizing the compilation of master urban plans, formulate plans for urban underground space development and utilization in accordance with the needs of urban development"[5]. Comprehensive research on urban underground space planning also began from this period.

Since 1995, China has consistently produced a certain number of research publications annually, though the total volume remained limited. From around 2008, the number of publications began to increase steadily, maintaining a relatively high level, with fluctuations appearing around the years of major events or the promulgation of significant policies.

2.2Distribution of Research Institutions

The distribution of research institutions reflects the degree of attention different academic organizations devote to urban underground space planning research. Through global analysis using the adjusted software g-index, the 674 papers involved 239 academic institutions across multiple fields, with 111 inter-institutional collaborative network links and a network density of 0.0039. Considering only the top 5% of institutions by frequency in each time slice yields 88 institutions and 67 inter-institutional network links, with a network density of 0.0175. This indicates a considerable number of institutions engaged in underground space planning research, yet the significantly higher network density among the top 5% suggests that collaboration tends to concentrate among "leading" institutions, indicating relatively limited cooperation among ordinary research institutions.

As shown in Table 1, regarding institutional publication volume, 7 institutions have published 10 or more papers, primarily universities and research institutes. These institutions account for 2.9% of the total, with their cumulative publications representing 17.4% of the total output, indicating that underground space planning research exhibits a "long-tail distribution" in institutional terms.

Table 1. Frequency statistics of top institutions in related research (≥10 publications)

No.	Institution	Frequency	First Publication Year
1	Tongji University Underground Space Research Center	32	1995
2	Tongji University Underground Space Research Center	29	2007
3	Tongji University Department of Underground Architecture and Engineering	13	2003
4	Nanjing Geological Survey Center, China Geological Survey	12	1999
5	Shanghai Municipal Engineering Design and Research Institute (Group) Co., Ltd.	11	2004
6	Underground Space Research Center, PLA University of Science and Technology	10	2010

7	College of Architecture and Urban Planning, Beijing University of Technology	10	2016

2.3Distribution of Research Scholars

In terms of total publication volume, scholars with more than 10 papers include PENG Fangle, SHU Yu, QIAO Yongkang from Tongji University, and CHEN Zhilong from the PLA Army Engineering University. Analysis of the co-occurrence network among scholars with higher publication volumes (≥5 papers) reveals that scholars within a collaborative network mostly belong to the same institution, with cooperation spanning different years. Beyond the most prolific scholars, other researchers show relatively limited collaboration and have not formed other close co-occurrence networks.

The temporal distribution of research scholars shows clear 阶段性 characteristics: early representative scholars include QIAN Qihu, CHEN Zhilong, GUO Dongjun, and SHU Yu, who have long been engaged in urban underground space research. Their publications evolved from early explorations of underground space development to research on disaster prevention, composite development, and underground space planning, laying the cornerstone for underground space planning research and continuing to contribute. Around 2010–2020, representative scholars such as YUAN Hong and QIAO Yongkang emerged: the former's research focuses on management systems and planning strategies for underground space planning; the latter conducts research combining technological developments and demand trends, covering urban renewal, transformation trajectories, and model algorithms.

3 Analysis of Research Trends and Hotspots

3.1Overview of Research Hotspots

The co-occurrence and timeline distribution of keywords can reflect the academic development trajectory of the urban underground space planning field, enabling the division and summarization of developmental stages. There are 10 keywords with co-occurrence frequency ≥5 (Table 2), of which — aside from "underground space" — keywords such as "development and utilization," "rail transit," and "civil defense engineering" exhibit relatively high centrality. Considering their duration (Figure 2), these keywords have maintained continuous research attention since their emergence, suggesting they remain core research areas in underground space planning.

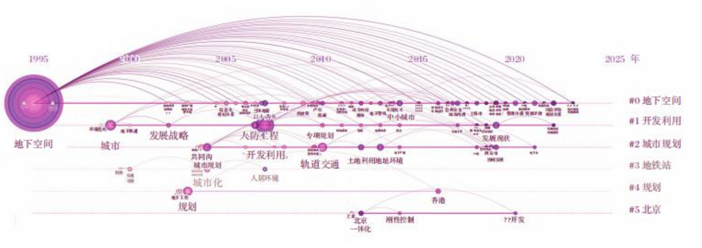

Fig.2 Timeline view of keywords in the research

Table 2. Frequency statistics of hot keywords in the research (frequency ≥5)

No.	Keyword	Frequency	Centrality	First Appearance
1	Underground space	279	0.93	1995

2	Development and utilization	38	0.07	2007
3	Planning	16	0.05	2003
4	City	12	0	1999
5	Urban planning	8	0	2004
6	Urban planning	8	0.07	2010
7	Rail transit	6	0.04	2016
8	Utility tunnel	5	0.07	2007
9	Civil defense engineering	5	0.05	2008
10	Public space	5	0.03	2009

As shown in Figure 3, further clustering of keywords reveals: Modularity Q = 0.59, indicating significant cluster structure; Mean Silhouette = 0.98, reflecting high confidence in clustering results. There are 6 representative clusters, broadly consistent with the keyword distribution mentioned above [Figure 3(b)]. At the intra-group level, keyword distribution is more diverse, with secondary keywords such as utility tunnels, development strategies, urban renewal, coordinated development, and planning strategies emerging. This demonstrates that implementation pathways and research approaches in underground space planning have become diversified, involving coordination with other urban spaces and planning systems rather than treating underground space as an isolated system.

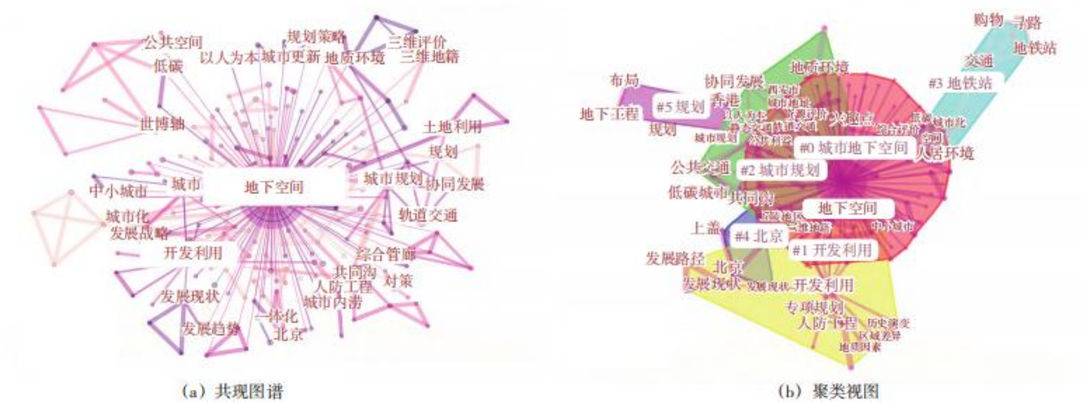

Fig.3 Keywords co-occurrence map and clustering view

3.2Development Trends of Research Hotspots

Building on the preliminary exploration of hotspots, burst keyword analysis is introduced to further trace the development trajectory of underground space planning. By retaining high-impact literature nodes in the timeline diagram (Figure 2), combined with word frequency analysis for representative years (Table 3) and burst word analysis (Figure 4), and comprehensively considering annual publication volume changes, timeline patterns, and policy guidance trends, the research content for years with fewer publications or less significant word frequency characteristics was re-examined. China's urban underground space planning research can thus be divided into three stages.

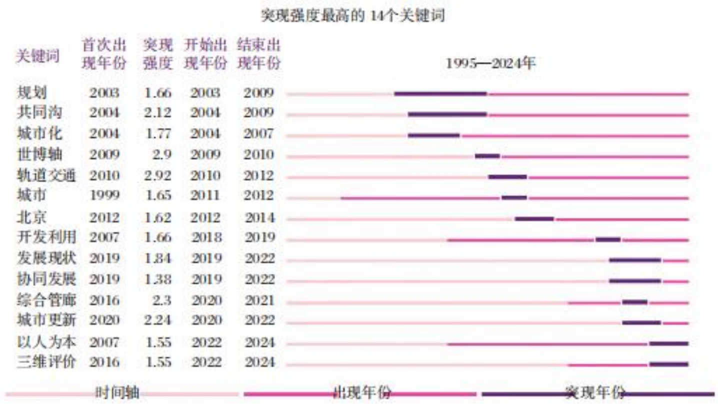

Fig.4 Burstness view of keywords in the research

Table 3. Research hot keywords in various periods

Stage	Representative Year	Main Keywords (Frequency)
Stage I	2004	Underground space (7); Planning (3); Urban square (2)
	2009	Underground space (16); Development and utilization (4); Investment and financing (3)
Stage II	2010	Underground space (16); Development and utilization (4); Investment and financing (3)
	2013	Underground space (30); Expo Axis (4); Development and utilization (3); Rail transit (3); Natural lighting (2); Ecology (2)
	2016	Underground space (10); Disaster prevention (4); Metro station (2)
	2020	Underground space (16); Utility tunnel (3); Smart city (2)
Stage III	2021	Underground space (9); Utility tunnel (3); Management system (3); Urban renewal (2)
	2022	Underground space (12); Development and utilization (4); Resource evaluation (3); Utility tunnel (2)
	2023	Underground space (15); Planning strategy (5); Urban renewal (3); Planning system (3); Suitability (2)
	2024	Underground space (15); Disaster prevention and reduction (3); Resilience enhancement (3); 3D cadastre (2); Urban waterlogging (2)

3.2.1Up to 2007: Exploratory Stage

This stage spans from the emergence of domestic urban underground space planning research to approximately 2007.

With the construction and opening of metro systems in multiple cities, from 2001 China explicitly designated rail transit as the priority of urban transport construction, positioning the "Tenth Five-Year Plan" period as the launch phase for "planning and constructing metro, light rail, and other rail transit"[6]. Subsequent policies reiterated the requirement for orderly development of urban rail transit and formally incorporated it into the "public transport priority" strategy[7]. Metro construction directly drove the rapid growth of China's urban underground space scale, creating an urgent need for scientific planning to regulate development. As this field had previously been largely uncharted, this stage primarily involved drawing on international experience, including the planning and construction of Montreal's underground city in Canada[8], Tokyo's underground space development and utilization in Japan[9], and deepening into the borrowing of planning guiding principles, regulatory standards, and incentive measures[10].

Foundational research remained the focus of planning compilation throughout this period. Given the poor visual intuitiveness and high complexity of underground space, specific resource evaluation methods were required. During this period, foundational research was conducted on urban underground space development capacity assessment[11], evaluation indicator systems were constructed[12], the concept of "resource quality assessment" was introduced, and work on fuzzy comprehensive evaluation and 3D visualization was promoted[13].

Serving management and implementation is the purpose of planning compilation, requiring legal system support. While drawing on the achievements of countries such as Japan in underground space development legislation[14], domestic cities like Shenzhen began exploring underground space utilization legislation, particularly the establishment of local regulatory systems[15].

At the core spatial planning level, alongside the determination of urban underground space development strategies and objectives[16], China began researching planning concepts and technical approaches for underground space resource development and utilization[4], establishing indicator systems to evaluate underground space planning, particularly regarding sustainable development[17]. During the same period, practice began on underground space planning for entire cities or key areas, including the conceptual plan for Shanghai's underground space[18], the conceptual plan for the core area of Hangzhou's Qianjiang New City[19], planning control for Qingdao's Huangdao Central Business District[20], and the "well-shaped" underground passage plan for Shanghai's CBD core area[21].

3.2.22008–2018: Rapid Growth Stage

In 2008, the "Urban and Rural Planning Law" was promulgated, filling the gap left by the previous "City Planning Law" regarding underground space planning, stipulating that "the development and utilization of urban underground space shall…follow the principles of overall arrangement, comprehensive development, and rational utilization, fully considering the needs of disaster prevention and reduction, civil defense, and communications." Alongside major events such as the 2008 Beijing Olympics and the 2010 Shanghai World Expo, China's urban development entered a fast track, with underground space development following closely. The "Property Law" promulgated in 2007 stipulated that "construction land use rights may be separately established on the surface, above, or below the land surface," further safeguarding and promoting underground space development. As a new component of urban development, underground space utilization gained increasing recognition and acceptance[22]. By around 2014, China had become a major player in global urban underground space development and utilization[23].

Continuing the trends from the previous stage, and responding to the large-scale development of underground space during this period, foundational research incorporated development evaluation alongside resource assessment, including studies on characteristics and limiting factors of underground space resource development[24], development potential evaluation[25], and development suitability assessment[26].

At the management and implementation level: based on regulations such as the "Property Law," key discussions focused on the attributes and ownership of underground space[27], the integration of underground space rights with three-dimensional land utilization rights[28], reviewing the process of legal system construction for China's urban underground space and expectation in future trends[29], and calling for accelerated underground space utilization legislation to enhance urban sustainable development capacity[30]. Building on legal research, comprehensive management and its component systems for underground space development were proposed[31], and directions for management system reform were explored[32].

At the spatial planning level, alongside the construction boom, large-scale underground space development urgently required planning guidance, and related research flourished.

Planning system construction. Based on discussions of underground space planning compilation systems and development operation strategies[33-34], a three-tier system took initial shape: first, proposing conceptual shifts, system integration, work priorities, and main content for underground space planning within master plans[35]; second, focusing on the integrated development of underground space with other specialized plans, particularly civil defense engineering[36], achieving "two-plan integration" and expanding toward "multi-plan integration"; third, facing the development wave, focusing on underground space development control[37], with case studies of key urban areas such as the first phase of Shanghai Hongqiao Business Core Area[38], Shenzhen Bao'an Central District[39], and Xiamen Maluan Central Island[40], exploring methods for underground space development control.

Spatial coordination in planning. Underground space planning cannot treat underground space in isolation. Theories of multiple coupling between underground and above-ground space[41] and methods for integrated above-ground and underground design[42] became strategies for effective underground space development — for example, using underground space to proactively compensate for and coordinate with above-ground historical and cultural district protection and urban renewal[43-44]. While coordinating above-ground and underground space development, it was necessary to seek unification between underground space and various specialized plans, improve underground space management mechanisms and legal construction, build underground space information platforms, and summarize and propose China's urban underground space planning development strategies[5].

Planning technology advancement. Frontier planning technologies gradually extended from above-ground to underground space planning, attempting to apply BIM technology in urban underground space development[45], achieving underground space data standardization alongside information platform construction[46], and developing 3D visualization underground space auxiliary planning systems[47].

Alongside the maturation of underground space planning systems, spatial coordination, and technology, this stage also formed several mainstream research directions.

Rail transit-led development. Rail transit station areas are the leading edge of underground space development and the focus of planning research. Based on evaluation of comprehensive development levels of underground space in metro station areas[48], research explored underground space planning models and development control brought by rail transit development, including underground space planning models based on TOD core concepts[49], unified planning models for underground stations and underground space[50], urban metro and other underground space systems such as shared utility tunnel systems[51], and development control of underground space along metro lines[52].

Ecological and energy-saving innovation. The 2010 Shanghai World Expo promoted innovation in underground space planning concepts. During the construction of the Expo Axis and underground complex, site resources and energy were utilized to the maximum extent[53], embodying green ecological and energy-saving, low-carbon characteristics[54]. Advanced means were extensively employed to achieve ecological and energy-saving goals — introducing greenery and sunlight into underground levels through Sun Valleys and grassy slopes[55] — organically integrating multiple park functions and transferring them underground in a scaled, systematic, and orderly manner[54], improving land use efficiency and spatial environment quality.

Spatial safety assurance. With the rapid development of China's underground space and the concentration of human flows, safety issues have assumed increasing importance[56]: on one hand, urban underground space flood prevention measures and countermeasures needed improvement[57], and scientific, reliable fire protection design for underground spaces — particularly large underground spaces — needed assurance[58]; on the other hand, underground space could be utilized for comprehensive urban disaster prevention[59], strengthening inherent urban safety and improving urban disaster prevention spatial systems[60].

3.2.32019 Onward: High-Quality Development Stage

In 2019, the "Opinions of the CPC Central Committee and the State Council on Establishing the Territorial Spatial Planning System and Supervising Its Implementation" proposed integrating underground space planning into the territorial spatial planning system. In the same year, the "Standard for Urban Underground Space Planning" was promulgated, standardizing underground space planning compilation. Subsequently, a series of policies including the "Guiding Opinions of the Ministry of Natural Resources on Exploring and Promoting Urban Underground Space Development and Utilization" were issued, providing effective guidance for the scientific development of underground space. As urban development shifted from extensive expansion to intensive exploration, and from quantitative growth to qualitative improvement, underground space — guided by high-quality urban development and aimed at fulfilling the people's aspirations for a better life — has become an important growth pole for urban development[61].

As a pioneer of high-quality development, pre-planning evaluation for underground space has expanded in comprehensive and three-dimensional directions. A comprehensive evaluation system for underground space resource investigation was proposed[62], integrating 3D geological models and 3D spatial analysis methods[63], achieving automatic fusion of 3D geological models and underground structure models, and conducting 3D modeling for urban underground space resource evaluation[64], applied in specific practice. Shanghai, Shenzhen, Hangzhou, Nanjing, and other cities have established "3D cadastres." To achieve full and scientific utilization, research has been conducted on problems faced by underground space development in cities with special geological conditions[65].

At the planning management level, greater attention is paid to investment returns and operational management, integrating scientific rigor with operability. Underground space development requires comprehensive management, overall planning, and innovative investment, financing, and revenue models[66], strengthened urban underground space operational management[67], improved underground space management technical systems, establishment of complete administrative management institutions, sound urban underground space laws and regulations[68], and accelerated advancement of underground space governance system construction[69].

At the spatial planning level, research focuses on how to improve urban underground space planning compilation and integrate it into the territorial spatial planning system[70]. Based on understanding the current status and implementation effects of underground space planning in China, planning theories and methods are further refined[71], advocating the concepts of "fourth territorial space" and "underground red line"[72]. On the other hand, urban renewal[70] has received increasing attention. The "Guidelines for Urban Renewal Planning and Land Policies (2023 Edition)" encourages full underground space utilization in compliance with regulatory requirements, strengthening coordinated construction and composite utilization of above-ground and underground space, and improving land conservation and intensive utilization levels. Underground space innovation focuses on urban renewal and refined management[73]. Given the "above-ground first, then underground" development sequence in urban renewal areas, new planning strategies must be proposed[74], promoting high-quality development and sustainable utilization of China's urban underground space[75], with emphasis on four aspects:

Human-oriented underground space. Addressing issues such as underutilization of underground space in some cities, poor user experience, short 停留 times, and monotonous underground business formats[76], proposals have been made for ecological and humanized trends in underground space internal environments[77], hoping that China's underground space development will advance further in visual aesthetics and comfort pursuit[78].

Green underground space. Urban underground space development is an important measure for alleviating "urban diseases" and achieving sustainable urban development[79]. It is necessary to delineate 3D ecological red lines for underground space and conduct underground space resource potential assessment[80], focusing on land conservation, geothermal energy utilization, water conservation, and green urban infrastructure, assisting the development of green buildings and green cities through underground space[81].

Intelligent underground space. Combined with the aforementioned "3D cadastre" construction, urban underground space surveys and information management are conducted[82]. Centered on block data and edge computing, targeting all urban elements and spaces, collection facilities, transmission facilities, and processing facilities covering various intelligent application scenarios above and below ground are constructed[83]. Urban underground space information sharing platforms and scientific technology innovation are improved[67], and underground space intelligent management systems are accelerated, with forward-looking deployment of underground space science and technology development strategies[75].

Resilient underground space. Moving from spatial safety to resilience enhancement, addressing safety issues in underground space construction, operation, and management requires multi-dimensional prevention from management and technical perspectives, regulatory perspectives, and legal perspectives[68]. Disaster prevention strategies and measures are formulated with the goal of "building resilient cities"[84], constructing a comprehensive resilience and disaster prevention framework for urban underground space[85]. Particularly, urban high-density areas exhibit significant vulnerability, and their three-dimensional spatial characteristics — especially the disaster prevention properties of underground space — should be fully utilized to enhance urban resilience[86].

4 Conclusions and Prospects

4.1Research Conclusions

Through overall statistical and trend hotspot analysis, China's urban underground space planning research is increasingly maturing, with its upstream comprehensive evaluation and downstream management and implementation showing interactive development. The exploratory stage (up to 2007) was in the initial research phase, focusing on foundational planning research and accumulating practical experience. The rapid growth stage (2008–2018), driven by comprehensive urbanization and major events, saw underground space planning research enter a prosperous phase. Alongside planning methodology research on system construction, spatial coordination, and technical upgrading, the field concentrated on rail transit, ecological energy conservation, and safety assurance, achieving a leap from basic exploration to comprehensive research. The high-quality development stage (2019 to present), under the backdrop of the territorial spatial planning system, has brought underground space planning research into a new phase of quality improvement and efficiency enhancement: first, researching how to integrate underground space planning into the territorial spatial planning system and serve urban renewal; second, exploring human-oriented, green, intelligent, and resilient underground space planning, making planning more comprehensive, scientific, and pragmatic.

4.2Future Prospects

With the establishment of the territorial spatial planning system and the delineation of urban development boundaries, cities have entered a new stage focused primarily on stock renewal. Combined with development trend research, urban underground space planning and its upstream comprehensive evaluation and downstream management and implementation will undergo the following changes.

Underground space comprehensive evaluation will become a component of urban physical examination. Beyond natural and environmental element research, greater attention will be paid to construction, cultural, and other elements in renewal area underground spaces and above-ground built spaces, analyzing how underground space development can avoid impacts on adjacent underground and upper spaces. This requires more precise spatial information and development suitability evaluation. Simultaneously, through physical examination and renewal of existing underground spaces to activate stock, a dual approach will satisfy urban — particularly renewal area — demand for underground space.

At the management and implementation level, greater attention will be paid to underground space function introduction and comprehensive benefits. Future urban renewal will be a priority. The "Urban Renewal Planning Compilation Guidelines" propose clarifying design management requirements at different scales, organically integrating urban renewal specialized plans, district planning, and project implementation plans throughout the entire process, incorporating financial calculations and operational models into project implementation plans. Underground space construction costs are high, particularly underground space development in urban renewal areas, which must consider the safety of surrounding adjacent and upper spaces, resulting in even higher costs that necessitate thorough research on investment returns and future operations.

Against this backdrop, facing more pragmatic underground space management and implementation requirements, based on more advanced comprehensive evaluation methods and comprehensively improved construction technologies, urban underground space planning is expected to exhibit the following development trends.

Compounding. Underground space has been incorporated into the territorial spatial planning system at all planning levels, requiring that above-ground-oriented spatial control requirements be comprehensively extended underground. Combined with "3D cadastre" and comprehensive evaluation, on the basis of above-ground and underground spatial coordination and major specialized system coordination, facing the deep expansion of underground space, attention should focus on the coordination of deep and shallow underground spaces. Incorporating temporal factors, attention should focus on the coordination of underground space renewal and development timing, constructing its unique spatial indicator system and planning model, forming a "single map" integrating above-ground and underground spaces, underground levels, major underground systems, and their development timing.

Embedding. Based on comprehensive evaluation in urban physical examinations, research should be conducted on urban — particularly renewal area — demand for underground space. Combined with the "Property Law" definition of underground space development rights, and 借助 relatively mature underground space suitability evaluation methods and their conclusions, adapting to local conditions and proceeding step by step, underground space should be embedded into above-ground areas — primarily functions difficult to satisfy in urban renewal areas such as transport, logistics, municipal services, and civil defense — to alleviate the contradiction of insufficient above-ground space, releasing more space for public activities or greenery. Simultaneously, attention should be paid to the impact of embedded underground space on the underground environment and the overall spatial environment, achieving coordinated development and protection, and serving the creation of human-oriented, green cities.

Sharing. Underground space planning should research spatial sharing of diverse functions to reduce costs, enhance vitality, and increase benefits. On this basis, research should explore how to promote active joint construction and sharing of underground space facilities among adjacent plots or multiple entities, forming an interconnected urban underground space network that can both enhance urban resilience and extend vitality and benefits throughout the city. Sound cross-departmental underground space management systems and shared information platforms should be established, underground space utilization legislation strengthened, efficient use of underground space big data promoted, information silos eliminated[5], information asymmetry resolved, and the refinement and intelligence levels of underground space planning, construction, and management comprehensively improved.

In summary, facing future spatial supply and conditional constraints, development demands and comprehensive benefits, the compounding, embedding, and sharing underground space planning model will help promote underground space planning toward diversified integration, intensive efficiency, pragmatic operability, and green sustainable development goals, serving the overall planning of three-dimensional territorial space.

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