The main characteristics of urban underground space regulatory plan from the perspective of China’s spatial planning: A practice in Beijing Sub-Center

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Abstract: In order to better solve the new problems encountered in the national development, China is gradually establishing a new national territory spatial planning system. It can implement the requirements of whole-area and multi-element control of land and space. Underground space planning is a special planning in the new spatial planning system. We will explore how to scientifically and reasonably prepare underground space planning. Combined with the planning practice of Beijing and Sub-Center, we propose that the underground space planning system should be further improved, especially at the regulatory planning level. It can not only refine the master planning requirements of underground space, but also effectively guide the detailed planning and project construction of underground space. This paper attempts to put forward the main characteristics of underground space regulatory planning, hoping to provide reference for other cities' underground space planning. The first is ecological priority and limited utilization. Detailed geological survey is the basis of underground space planning. In the Sub-Center, we evaluated the requirements of geological ecological protection and the impact of geological disasters, and delineated the three-dimensional utilization boundary of underground space and the influence scope of geological disasters. The second is the improvement of space management and space vitality. We explore the allocation method of underground space covered area, and divide the covered area into each construction site, giving priority to the key areas such as Universal Studios and metro station areas. The third is multi-dimensional utilization and planning integration. The underground facilities are planned in depth and intensively. The plan puts forward detailed in-depth layout guidance, focusing on the construction of Facility Service Ring, and coordinating the intensive construction of underground tunnels, metro and underground municipal facilities. The fourth is to encourage the application of new technologies. The planning will reserve sufficient
space for future development, such as the construction of underground logistics, multistage rainwater collection and underground heat utilization in the Sub-Center.

1. Introduction

Beijing is gradually establishing a new national territory spatial planning system, which promotes the protection and utilization of land and space resources from the perspective of whole-area, multi-elements and three-dimensional, and better solves the new problems encountered in the national development. The spatial planning system includes three levels of city, district and town, and three types of general planning, detailed planning and related special planning. Underground space planning is one of the special plannings in the new spatial planning system. It is worth noting that Beijing is the first city in China to propose the reduction of construction land, so how to make good use of the "Built-up area" has become the main work of urban construction, and how to make more ecological, efficient and multidimensional use of underground space is a new challenge we are facing. Therefore, in the new spatial planning system, it is the core content for us to scientifically build the underground space planning system.

In Sub-Center, we have initially established the underground space planning system covering the master plan and detailed planning, and transferred the underground space control requirements from the master plan to the detailed planning. In particular, the regulatory detailed planning of underground space of Beijing Sub Center (block level) is the first medium level underground space planning in China. It has achieved the full coverage of the Sub-Center’s underground space in the 155 square kilometers’ area. The underground space construction requirements and indicators are fully included in the detailed planning, directly guiding the construction of key projects.

Based on the planning practice of Sub-Center, this paper reviews the exploration of regulatory planning of underground space, and puts forward four main characteristics of urban underground space planning. It includes: ecological priority and limited utilization, spatial management and vitality improvement, multi-dimensional utilization & planning integration and new technology application.

2. Adhering to the planning concept of ecological priority and sustainable utilization

Geo-ecological conditions are the basic and decisive factors of urban underground space utilization. In-depth study of geo-ecological environment and geological disasters is the premise of underground space planning, and also an important basis for determining the underground available resources. Compared with the central urban area and the western part of the city, the geo-ecological environment and groundwater system of the Sub-Center are more complex, which puts forward higher requirements for the utilization of underground space.

In our work, we carried out a more detailed geological survey work to find out the geological and ecological background, including basic geological conditions, dynamic groundwater conditions, ecological and geological environment cycle analysis, etc. Comprehensively evaluating the geological and ecological conditions, we analyzed the plane and vertical distribution of engineering-geological conditions, such as sand soil layer (aquifer), cohesive soil layer, gravel layer and rock layer. On the other hand, we integrated hydrogeological data with geological borehole data to identify the main types of geological disasters and carry out
the impact assessment of geological disasters. The types of geological disasters include seismic fault, land subsidence, sand liquefaction and karst collapse. It is worth noting that the number of boreholes in this geological survey is more than 300, the plane precision scale is 1:5000, and the vertical accuracy within 50m underground reaches 1m. The accuracy of geo ecological background assessment can meet requirements of regulatory detailed planning.

With the comprehensive geological survey data and geological disaster assessment work, we built a three-dimensional geological ecological evaluation model. According to the calculation of the model, the planning can define the preconditions for the utilization of underground space in different areas and depths, and delineate the "ceiling" of the available resources of the underground space in three-dimension, so that the public can understand the utilization requirements of underground space more intuitively.

![Image: Three Dimensional Geological Model of Sub-Center](image)

**Figure 1.** Three Dimensional Geological Model of Sub-Center

We comprehensively analyzed the basic ecological circulation path of "water, soil and gas". According to the geo-ecological evaluation model, it is found that the "water cycle" safety of Sub-Center has the greatest impact on the construction of underground space, which should be paid more attention to. Dynamic groundwater is the most active factor of geological environment and should be the focus of planning. The underground water layer of Sub-Center can be divided into four main levels: shallow groundwater, sub-shallow groundwater, sub-deep groundwater and deep groundwater. The utilization of underground space should not destroy the geological structure of the aquicludes between the water layers, so that it can avoid groundwater pollution and channeling.

The plan proposes to take the distribution of the first aquiclude as the three-dimensional red line of the utilization of the underground space, which ensures that the depth of underground utilization should not damage the aquiclude, so as to protect the ecological filtration function of aquiclude and the quality of the groundwater.
3. Implementing the requirements of covered area control and enhancing the vitality of underground space

Due to different geological conditions and utilization modes, there is no common requirements of the covered area control of underground space. In China, the covered area control of underground space is also a frontier topic of few cities. In recent years, the covered area of underground buildings often exceeds that of above ground buildings in Beijing. Due to the lack of research on the covered area control of underground space, it is difficult to determine the rationality of the planning and management. <Development Control Planning For The Sub-Center Of Beijing (2016-2035)> defined the total covered area of underground space in Sub-Center. But how to further subdivide the total covered area of underground space into each block and each plot is a difficult problem that we must solve. Combined with the previous planning experience, we have preliminarily explored the method of Sub-Center underground space covered area subdivision.

We collected the information of Beijing's underground building function, the number of above ground floors, the number of underground floors, and the covered area of above ground and underground buildings for comprehensive analysis. By analyzing the variable relationship between the ratio of underground space to above ground space and the number of building floors of different functional land, we find that the proportion of underground space benchmark covered area has strong correlation with land use function and building floors of above ground. We then analyzed the covered area proportion of underground buildings in different regions and summarized the reference value of underground space covered area control.

In order to ensure the rationality of the covered area prediction, we studied the probability of underground space construction of different functional types of land, combined with the experience of Beijing urban construction in recent years. The conclusion is that the construction probability of underground space of residential land is the highest, followed by industrial land, public service land, public management land and infrastructure land, and the construction probability of underground space of industrial land is the lowest.

To ensure the demand of underground space of the dynamic areas such as the surrounding areas of railway stations and the land for public service facilities, the planning proposes that the underground space covered area can be increased. For example, in order to ensure the integrated construction of rail transit stations, the planning proposes that the underground space covered
area of the surrounding land of rail transit the hub stations can be increased by a certain proportion based on the benchmark covered area. This requirement supports the construction of key projects such as the Universal Studios and the Sub-Center railway station, improves the quality of underground space construction, and promotes the integration of new development and urban renewal.

4. Multi-integration of spatial plannings and multi-dimensional utilization of land resources

The regulatory planning of underground space is a platform for planning integration. Through planning, the underground control requirements of other special plannings of land use, municipal administration, transportation and engineering are further coordinated to realize the multi-dimensional utilization of underground space.

To coordinate the reasonable layout of public service facilities, infrastructure and security facilities in the vertical dimension, the underground space of 0-10 meters should give priority to the public activities, including commercial, cultural, sports, education, public space, utility tunnel, parking and other facilities; The underground space of 10-30 meters underground and the sub-deep underground space of 30-50 meters underground should give priority to underground track, underground municipal facilities, underground parking, ground source heat pump and other facilities; Deep underground space (30-50m underground) should be reserved for underground logistics, garbage treatment, fast track, safety, data storage, river regulation and storage facilities.

We encourage the compound utilization of underground space in rail stations, shopping malls, office, culture, sports and other facilities, where the underground space is connected with subway and transportation hub, forming a comprehensive pedestrian system.

The construction of key projects such as Facility Service Ring will promote the integration of above-ground and underground distribution of public service facilities and infrastructure and form a circular complex system of various facilities. With a total length of 36.5 km, it integrates large-scale infrastructure and urban public service facilities, and runs through 12 Construction-Groups and 36 Residential Hubs through green belts, roads, tracks and pipe corridors.
The underground part of Facility Service Ring is mainly located under the road, including rail transit, utility tunnel, invisible municipal facilities, underground logistics, emergency refuge and other functions. The Facility Service Ring also enhances the transportation system, including improving the level of integrated development of rail stations, increasing the proportion of underground parking lot, and creating a comfortable and orderly environment for walking and bicycle connection.

5. Encouraging the application of new technologies

With the rapid development of science and technology, a variety of new technologies are emerging. The planning also provides space for future urban development, and actively encourages the application of new technologies in underground space, including underground logistics, underground renewable energy, multi-level rainwater collection, etc.

The planning has reserved space for the construction of underground logistics system. Combined with the rail transit network, the planning explores the construction scheme of efficient and intensive underground logistics system with passenger and freight sharing, and constructs a complete underground logistics system. The plan initially puts forward the rail transit scheme of passenger and freight sharing, and reserves the space for underground city distribution center, underground group distribution center and terminal distribution network.

The utilization of underground for renewable energy includes ground source heat pump heating system, solar energy storage heating system and so on. New public buildings can be provided with renewable energy such as ground source heat pump and water source heat pump according to the conditions. Heat energy collection, storage and utilization system shall be built in the main functional areas of the city. The underground space of regional rivers and most buildings can be used as the buried pipe area of heat pump to provide regional energy guarantee.

Figure 3. The Effect Picture of The Underground Part of The Facility Service Ring of Sub-Center
The long-term planning also considers the construction of underground multi-stage rainwater collection and reuse system to improve the urban flood control and drainage capacity. The use of shallow underground space to set up rainwater collection and storage facilities can effectively reduce surface runoff and reduce the risk of waterlogging. The deep underground space can be used for the storm water regulation and storage system, where flood control and drainage should be taken into account.

In the future, the plan will make full use of the characteristics of underground space to resist disasters, apply cutting-edge science and technology, explore the construction of emergency refuge, data center, dangerous goods processing center and other disaster prevention & security facilities in deep underground space, and build a comprehensive underground disaster prevention system.

6. Conclusion
With the establishment of China's land and space planning system, the underground space development will pay more attention to the concept of "ecology", "economy", "people-oriented" and "multi-dimensional composite". We hope that the exploration of regulatory planning of underground space in Sub-Center can provide useful help for related urban underground space planning. Urban underground space is an important land space resource. How to make more scientific and reasonable use of underground space is still the direction we should continue to explore.

Reference
[1] Beijing Municipal Master Planning (2016-2035)
[2] Development Control Planning For The Sub-Center Of Beijing (2016-2035)
[3] Beijing Underground Space Planning (2018-2035)