Research on the development and utilization of underground space in Beijing Old City

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Abstract. As a concentrated embodiment of urban historical sites, cultural relics and cultural heritage, the old city of Beijing has the most intensive historical and cultural resources and the most stringent requirements for historical protection. At the same time, it also faces a series of development problems to be solved, such as insufficient development space, lagging public service facilities, and urgent improvement of living environment. How to effectively utilize the underground space resources and coordinate the relationship between historical protection and urban renewal is an important issue for the sustainable development of the old city of Beijing. In this paper, the development and utilization strategies of the underground space in the old city of Beijing are systematically studied, as well as the reasonable utilization methods of the underground space in the historical protection areas. Through the development and utilization of underground space, we can make up for the shortage of public service and better improve the ground space environment. In addition, this paper also discusses the integrated development of underground space and metro stations, so as to enhance the urban renewal and development of the station areas. The relevant data and conclusions are from the latest planning and practical experience of Beijing old city, in order to provide useful reference for the sustainable development of historical urban areas and the scientific utilization of underground space resources.

1. The urgent demand of underground space utilization in old city
Effective excavation and utilization of underground space resources is of great significance to promote the sustainable development of the old city of Beijing. At the same time, the development of underground space in the old city is also faced with many constraints, such as high requirements for historical protection, engineering safety constraints and insufficient available space. How to effectively coordinate the demands of historical protection and urban space development is an important issue for the development of underground space in Beijing old city.

2. Current situation and challenge of underground space utilization in old city
The current situation of underground construction in the old city of Beijing is complex. The large number of early underground projects and the newly constructed underground space exist at the same time, mainly distributed in 5-10 meters underground. The construction density is very high, and there are certain engineering safety risks.

The underground cultural relics are widely distributed, and there are a large number of proven and unproved underground cultural relics burial areas. These underground cultural relics can be traced back
to the Yuan Dynasty, mainly distributed within 10 meters underground, with the underground water well deep to 11-12 meters.

The space of streets and alleys is narrow and difficult for the construction of municipal pipelines. There are also abandoned pipelines of different periods underground, which makes the construction of underground space more difficult.

The protection requirement of traditional buildings is strict. In the historical blocks, traditional buildings with brick and wood structure are mainly used, the underground foundation of which is generally shallow and need to be reinforced before the underground development of surrounding areas so as to ensure the safety of the building structure.

The property right of courtyards is complex. Due to historical reasons, there are many forms of property rights in the same courtyard, which makes the underground development process more complex.

Figure 1. Examples of basement in the old city.

3. Utilization mode of underground space in old city

3.1. Utilization of underground space in historical protection area

The old city of Beijing is one of the areas with the most abundant historical and cultural resources. The historical and cultural blocks, characteristic areas and other traditional areas account for 40% of the total.

The development and utilization of the underground space in the historical protection area is not only subject to certain objective constraints, but also faces urgent development demands. Combined with different architectural features and development modes, underground space often shows different construction forms and functional types.

3.1.1. Residential quadrangle. For residential quadrangles, the development and utilization of underground space is mainly for the needs of living supplement functions, which is often spontaneous and small-scale. In order to ensure the safety of the adjacent buildings and infrastructure, the underground construction scope of residential quadrangle generally does not exceed the scope of the ground buildings, and should withdraw a certain distance from the adjacent boundary of the courtyards or buildings. The underground construction depth of residential quadrangle is generally no more than the corresponding building height, generally 5-6 meters, and no more than 1 floor. The underground space is mainly of functions such as storage room, reading room, etc. Functions that have big noise or affect the neighborhood, such as video room or chess room, are not suitable.
3.1.2. Public quadrangle. Compared with residential quadrangles, the construction scope and depth of underground space is relatively flexible. Considering the spatial demand, the underground construction depth of public quadrangle can reach 5-10 meters, but should not exceed 2 floors underground. To ensure the safety of adjacent projects, infrastructures and to guarantee a certain proportion of solid soil, the construction scope of underground space generally does not exceed 50% of the courtyard area. The underground space functions mainly include community service, recreational and sports room, shared parking, underground municipal station or other public welfare facilities.

No.21 courtyard of Sanjing hutong is located in the Dashilan historical and cultural district, with an area of 993 m². It is planned to increase the underground space with the renovation of the courtyard to form a public performance venue serving the surrounding communities. The core space for performance includes 180 seats, and the height of audience and stage can be adjusted by lifting modules. The basement boundary retreats 1.2m from the first floor building axis.

3.1.3. Traditional street space. The traditional streets and hutongs in the old city are an important part of the traditional historical features. Due to the early construction, the width of the traditional streets is relatively narrow, mostly 1.5-3 meters. The underground space usually has problems of poor municipal facilities and backward infrastructures, which restrict the new development and renovation of the old city area. It is difficult for traditional streets and hutongs to alleviate the lack of space resources through simply widening the road or reconstruction under the strict policy conditions. It is necessary to introduce more intensive space utilization strategies and innovation of new technologies or materials, so as to improve the infrastructure service level of historical protection areas.
Figure 4. Cases of municipal pipelines in Hutong.

Shoubi street is a secondary trunk road located in the old city of Beijing. The total length of the road is about 907 meters, and the width of the planned red line is 35-40 meters. With the renewal of the road, a new utility tunnel with a length of about 850 meters is built under the road, with which four underground mechanical garages and an integrated monitoring center are built. The project will effectively improve the service level of the municipal network in the old city area and supplement the parking space of the surrounding areas.

Figure 5. Case study of three-dimensional parking lot combined with urban road.

3.1.4. Urban renewal & reconstruction area. The urban renewal & reconstruction areas in the old city are also the key areas for the development and utilization of underground space. The coordinated development of aboveground and underground space can improve the quality of urban public environment beyond the scope of the project. In order to enhance the comprehensive benefits of underground space, the utilization of underground space in renewal & reconstruction areas should generally take into account the construction of major urban facilities and public welfare facilities, and to strengthen the interconnection of underground public space and the integrated construction with metro stations. The Gulou street weaving project is located in the historical and cultural block, which adopts the traditional quadrangle form to coordinate with the historical features. The project uses the underground space to build cultural facilities, social parking and other urban public welfare facilities, which can better alleviate the parking pressure and the shortage of public service facilities.
3.2. Integrated construction of underground space with metro station

Metro transit is an important factor to promote the development and utilization of underground space in the old city of Beijing. By 2018, the density of the existing metro network in the old city of Beijing has reached nearly 0.9 km/km², and the coverage rate of 750m radius of stations has reached over 75%. By 2035, the number of metro stations will increase by nearly 80%. It is an important direction for the development of underground space in the old city of Beijing to promote the integrated development of aboveground and underground space, optimize the overall quality of station space and improve the level of urban public service.

3.2.1. Renovation of existing station. The early projects of metro stations in the old city of Beijing have problems of insufficient space and outdated facilities, which makes it crucial to update and reconstruct the stations according to the new traffic demand. Beixinqiao metro station is the west extension of the airport line. The renovation project will improve the underground crossing conditions by adding non paid passages of the station. Bicycle parking garages, tourist service centres, post office, community service centres and other facilities are added in the underground space of green space around the station to improve the level of public service facilities. The project will also increase the urban public green area and public activity space by putting the metro auxiliary facilities and NIMBY facilities underground, so as to improve the urban living environment of surrounding areas.
3.2.2. Integrated development of new station. With the densification of the metro network in the old city, the construction of new stations can not only improve the service level of metro transit, but also promote the renovation of urban space & functions so as to improve the comprehensive land efficiency and urban environmental quality around the station. Wangfujing Commercial District is one of the municipal commercial centers in Beijing, with a total planned area of 3.7 million square meters, including 1.1 million square meters underground. Combined with the construction of Metro Line 8, a utility tunnel will be constructed simultaneously to release the shallow underground space for underground commercial street. The underground commercial street will connect the commercial buildings on both sides to the metro station to form a continuous underground commercial pedestrian environment. Driven by the passenger flow of the metro station, the economic value of the underground space of the commercial buildings has been significantly improved. The extensive underground pedestrian network system also provides convenient and comfortable walking environment and shopping experience for pedestrians and tourists as well.

3.2.3. On-site protection of underground cultural relics during the construction of metro station. There are many underground cultural relics buried in the old city of Beijing. With the rapid development of metro transit, cultural relics are frequently excavated in construction sites. In order to ensure the construction of metro transit and take into account the protection of historical relics, the old city of Beijing has adopted the strategy of on-site protection and exhibition of cultural relics, so as to promote the integration of history and modernity. Through rescue excavation and construction of exhibition facilities, cultural relics are protected to the greatest extent and people can occasionally stop to glance at the traces of history in the busy city life.
4. Prospect of underground space utilization in old city
As the area with the most concentrated historical context, construction intensity and functional types, the underground space of the old city is not only restricted by many current and historical factors, but also has great development potential and urgent demand. The development of underground space in old city is a complex and systematic project, which requires both general planning and comprehensive laws & regulations. Meanwhile, it is also necessary to sum up experience and methods from the specific practice. This study, with the latest planning and practical experience of the Beijing old city, explores the development strategies and functional characteristics of underground space in different regional types. At the same time, by focusing on the renovation of historical protection areas and the integrated development of metro transit, the study also provides a useful reference for the underground space planning and the improvement of underground space management system in the old city.

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