Development and Planning of Urban Underground Space of Shanghai and Proposals for Further Improvement

Yangliang Li*
Department of Construction Management, Ande College, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, 710311, China
*Corresponding author’s e-mail: 1005854635@qq.com

Abstract. The paper introduces the background and development of urban underground space of Shanghai as a necessity, discusses its present situation in Shanghai, proposes the overall strategy and measure underlying the layout characteristics, and points out the existing problems in the process. Finally, the paper comes up with three suggestions for further improvement.

1. The necessity of developing urban underground space of Shanghai and its present situation

1.1 The necessity of developing urban underground space (e.g. Shanghai) in major cities of China

Since the reform and opening-up, China has made great progress in urbanization, with its urbanization rate rising rapidly from less than 20% in 1989 to 60.60% in 2019, and the number of cities growing from 193 to 672, including 17 megacities with an urban population of more than 5 million. With the continuous development of urbanization, the urban construction is bound to advance, with increase in the number of cities is bound to increase and expansion in the size of cities. According to the established strategy of “sustainable development” both socially and economically, China's urban construction should take the route of “concentration”. However, the reality of urban construction is far from the original blueprint. According to Qian Qihu, a scholar from the Chinese Academy of Engineering, the construction and development of China's cities in the early stage still follow the extensive model of “scattering”, far behind the developed countries in terms of GDP per square meter, with the main focus concentrating on the above-ground construction [1]. This extensive model, simply focusing on plane expansion, not only causes great damage to the environment and urban congestion, but also consumes a lot of land resources, hampering sustainable development.

The rapid urban expansion in China has led to the so-called “urban disease” among cities, characterized by land resource scarcity, population congestion, traffic jam, green resource shortage, and worsening eco-system, all of which contributed to the dilemma where China's urban development is being trapped. Many researches and practices have shown that these problems are rooted in the conflict between the need for urban expansion and the shortage of land resources [2].

To explore the possibility of healthy and sustainable development of urbanization in China, scholars have proposed a route featuring “density, dimension and concentration” that China should follow based on experiences of the developed countries. The past experiences of those countries showed that a full utilization of underground space would be an ideal option for urban expansion.

Also, the social and economic development of cities and the growing need of urban dwellers for better life have urged urban administrators to evaluate their performances beyond population and economic index, and focus on the construction of an eco-friendly city. The developed countries, like
Japan and Germany, have managed to integrate infrastructures such as pipelines, large-scale energy supply system, large-scale rainwater collection system and sewage system in the underground space, thus markedly promoting urban functions and benefiting its citizens. According to Shao Jizhong, full three-dimensional utilization of urban underground space would make urban road network and other infrastructure more sustainable [2], thereby promoting the overall development of cities.

To sum up, in order to increase the capacity of cities in a healthy and sustainable way, it is essential to develop underground space in major Chinese cities such as Shanghai.

1.2 The present situation of underground development of Shanghai

Shanghai has long started underground development, which could be traced back to the civil defense engineering projects in the 1970s. Since the 1990s, the expansion and renovation of the city along with the rapid development of underground railway transit system have helped form a well-planned underground transportation system, driving the construction of surrounding underground network with various functions.

Since 2000, there has been a marked acceleration of underground development in Shanghai, while international events such as EXPO further boosted the construction of rail transit and underground tunnel, thus promoting the development of underground space. With the development of underground infrastructure like subway, underground space has become a hot topic in the urban development of Shanghai. At present, the scale of underground space in the city has increased from 25 million square meters in 2004 to more than 100 million square meters now [3]. In terms of the functions, the existing underground space is dominated by traffic facilities, accounting for about 71%, including garage, bicycle garage, rail transit and ancillary facilities, linkage corridor, etc. Public service facilities underground account for about 5%, including hotels, shopping malls, catering venues, entertainment venues, conference venues, cultural and sports venues, hospitals, sunken plazas, etc. Underground municipal utilities account for about 4%, and underground storage facilities account for about 3%[4]. Through 676 kilometers of rail transit connections, Shanghai has formed a network of multi-core underground city.

2. Principles and planning features of underground space development in Shanghai

2.1 Principles of underground space development of Shanghai

Based on the characteristics and reality of Shanghai, Shanghai Municipal Commission of Urban Development has proposed the following six principles of underground space development:

1. Integration of above-ground and underground development, with the two complementing each other in collaboration
2. Integration of short-term and long-term development for consistent planning by stages
3. Integration of peacetime and wartime development based on functions and facility reservation
4. Integration of system and space for full development
5. Prioritize transportation system while developing civil projects and disaster prevention facilities, with emphasis and moderate exploitation
6. Coordinated development between human and nature under the people-oriented principle [5]

Meanwhile, the government also put forward an underground layout consisting of one center and four deputy center, eight key areas, and seventeen transport hubs as the key point, as well as a rail transit line with a total length of 500 km as the major network. A layered development strategy was carried out, integrating near-surface layer (0 to 15 m), middle layer (-15 to -40 m), and deep (-40 m) for vertical space planning. In the planning and integration of underground space, Shanghai has also made strategic planning for the development of underground infrastructure such as underground transportation system, underground municipal pipeline system, civil defense engineering and underground disaster prevention system, large-scale underground complex system and underground logistics and storage facility system.

2.2 Layout and characteristics of underground development of Shanghai

At present, an underground network system with functional integration and layer utilization has been
basically formed based on the strategic requirements. Specifically, it has the following three characteristics:

2.2.1 Plane layout with clear priorities and highlights
The overall regional framework of underground space in Shanghai consists of the city center of People's Square that extends toward the surrounding area. Relying on underground transportation facilities and other urban infrastructure, a comprehensive underground project is established, harboring sub-center, regional center and new underground city with distinct features [6].

As to the implementation of the project, the overall pattern has been basically formed, with the network of urban underground space based on the rail transit system initially in place. Except 11 confirmed key areas in the overall planning of underground space, a new round of development and utilization of underground space has been launched in the latest five years to form a new regional center, including backshore and foreshore of Expo Garden, the comprehensive transport hub of Xinzhuang, SuHu, North Bund, Yangpu Binjiang, etc.

2.2.2 A vertical layout of layer utilization
The existing plan determines a vertical layout of the underground space, including development sequence of individual layers, projects involved and principles of mutual coordination. At present, the underground space in Shanghai mainly focuses on layers at -40m and above, consisting of municipal pipeline and subway below the road and underground complex, subway, underground road, building foundation and special engineering in layers beyond the road.

In addition, there are also a few underground projects that are difficult to develop, such as the 500kv Jingan power transmission and transformation project of Shanghai World Expo (up to 34m underground), the basement of Star Harbor International Centre at Shanghai North Bund (up to 36m underground), and part of the North Cross Interchange has reached a depth of -48m.

2.2.3 Interconnected functional systems
The rail transit-based underground space is designed to integrate transportation with commercial center to maximize the functions of the project. Under this principle, Shanghai rail transit system focuses on effective connection with surrounding businesses, allowing the integration of above-ground and underground functions, thus greatly enhancing the vitality of the region with more benefits.

At present, there are seven types of properties connecting underground rail transit stations with surrounding underground spaces in Shanghai, including underground commerce, underground parking, underground office, bus hub, cultural and sports facilities, external traffic and residential communities [7]. Underground commerce is the most important among all properties, accounting for 68%, followed by the bus hub connection, accounting for 11%; cultural and sports facilities, external traffic, underground parking and residential communities accounted for a relatively lower proportion. As to the rail transit stations, about one third of the current rail transit stations have been effectively connected with the surrounding areas (mainly the city center), allowing active interaction between rail transit stations and regional development as well as sustainable development of these areas.

3. Problems in underground space development in Shanghai and proposals for further improvement

3.1 Problems in underground space development in Shanghai

3.1.1 Lack of overall planning, especially for non-central areas
Although Shanghai has basically established a complete system of underground space, it fails to fully identify the development of individual areas as part of the overall planning, with part of the system being developed in disorder or not fully utilized. In addition, there are inconsistencies between underground space planning and resources such as land, municipal administration, rail transit, pipelines and civil air
defense, indicating problems in the coordination of underground space development and other construction activities by municipal departments. Besides, the underground space development in Shanghai is mainly centered on the regional center and transportation hub, without enough attention to the underground space planning of non-central areas.

3.1.2 “Layer-based development” that requires further implementation

Since the development of underground space is irreversible, the development sequence and layout of underground space should be carefully studied before being carried out. The principle of “layer-based development” is to ensure the efficiency of underground space development in a step by step manner from easy to difficult. However, the principle has not been well followed in practice, with many efforts concentrating on the near-surface underground projects. This leads to the excessive occupation of shallow underground space in Shanghai, a practice of inefficiency with possible difficulties for further development of underground space.

3.1.3 Inappropriate timing sequence of underground space development

There are documents, such as the Concept Planning of Underground Space in Shanghai, which have offered far-sighted suggestions for the overall planning of underground space. However, as these plans were proposed long time ago (2008), they have been outdated in the rapid expansion of urbanization featuring constantly changes in the construction and space layout of the city. Also, the lack of detailed guidance in these plans makes it difficult to fully implement the overall planning in practice. This has caused problems in the timing planning of underground projects. For example, the inefficient connection of many underground railway stations is causing inconveniency for the passengers when taking a transfer, leading to a decline of passenger travel efficiency.

At the same time, there were not enough entrances and exits reserved to connect surrounding underground space due to the lack of the overall planning awareness in the construction of some early underground projects in Shanghai, leading to gaps between individual underground spaces.

3.1.4 Lack of incentive and information management

Compared with the aboveground space, the development of underground space requires a large investment and a long duration, making it riskier with diminishing returns. In order to encourage the development of underground space, the government should launch appropriate preferential incentives. However, according to Shi Zheng and Dai Miaomiao, the Shanghai municipal government lacks relevant preferential measures, especially in the connection between above-ground facilities and underground space [8]. Shanghai began the construction of computer-based underground space management system at the end of the 20th century. However, due to the lack of overall consideration, whenever the number of underground space projects increased to a certain extent, the government needed to coordinate issues such as technical standard inconsistency, gaps between goals and reality, and unclear responsibilities of subjects involved in the system. The above-mentioned problems indicate that the administrative departments of Shanghai still have a long way to go in terms of information management of the underground space development.

3.2 Proposals for further improvement in the development of underground space in Shanghai

3.2.1 Improve the planning system, with more emphasis on the non-central areas

The preliminary planning of underground space development must be far-sighted to ensure the orderly and efficient progress of the project considering the time duration and scale of such project. Also, the preliminary planning should be detailed in guidelines to ensure that the overall planning is practical and flexible enough, allowing constant adjustment. Therefore, the administrative departments of Shanghai should make sure that the underground space planning can be implemented in all areas at all levels, ensuring consistency between short-term and long-term planning.

Since the development of underground space is irreversible, once the project is completed, it will
cost a fortune for adjustment in the later stage. Therefore, it is necessary to ensure that the time sequence of the project in each stage is taken into account, ensuring sufficient vacant space is reserved for the connection and interaction with the surrounding underground space in the future. In addition, the underground space planning in Shanghai should start from the overall situation with balanced consideration between central and non-central areas.

3.2.2 Strengthen the integration of rail transit and surrounding ground space and increase the degree of development informatization

The underground space in Shanghai is based on rail transit, so the important nodes of urban underground rail transit will significantly promote the development of surrounding commercial plots, and provide a prerequisite for the expansion of surrounding underground space. It is of great significance for the development of urban economy to strengthen the planning and guidance to promote the full connection between subway stations with the surrounding plots, thus giving a full play to the role of rail transit system in promoting the development of the surrounding areas.

Though Shanghai has been taking a lead in the information system, part of the underground projects has not been incorporated into the database. In the context of computer-based urban planning, the underground space planning should also learn from the experience of the above-ground planning in the establishment of a database to promote the cooperation of departments and resource sharing, thus ensuring efficient and scientific development of the underground space.

3.2.3 Reasonably determine the development scale of underground space

The cost and difficulty in developing deep underground space makes it economically necessary to ensure the proper utilization of near-surface underground space. Therefore, before the development of underground project, the necessity, scale and development depth of the engineering project should be studied carefully instead of rushing to a conclusion. The administrative departments of Shanghai should take the occupation of the near-surface underground space as an additional cost when approving the project, making sure that the most valuable near-surface space is reserved for the most important projects.

Acknowledgments
In the process of writing, the author of this paper is under the guidance of Dr. Lai Yu from Xi’an University of Architecture Technology. Prof. Liu Hua put forward many constructive suggestions. The author is very grateful to them

Reference
[1] Qian Q.H. (1998) The Climax of Urban Underground Space Development in China. J. Geote. Eng. 01: 112-113.
[2] Shao J.Z., Wang H.F. (2014) Status and Trend of Underground Space Planning in China. J. Research on Modern City. 28: 87-89
[3] Chen J.W. (2019) Experience of Overseas Underground Space Development and Utilization and Its Enlightenment to Shanghai. J. Scientific Development, 12: 83-85
[4] Chen J.X., Bai Y., Liu Z., Fan Y.Q. (2018) Study on the Evaluation of Deep Underground Space Resources in Shanghai. J. Modern Tunnel Technology. 55(S2): 1243-1254.
[5] Shen G., Tang H. (2017) Study on the Development and Utilization of Underground Space in Shanghai. J. Regional Development. 21: 22-23
[6] Liu X.H. (2016) Review and Analysis of Urban Underground Space Planning and Construction in Shanghai. In: 2016 China Urban Planning Annual Meeting. Shanghai: 547-556.
[7] Zhao Y. (2016) Study on Connection Planning of Shanghai Rail Transit Station and Surrounding Underground Space. J. Modern Tunnel Technology 43: 150-155
[8] Shi Z., Dai M.M. (2015) On the Feasible Structure of Functional Coupling of Underground Space. J. Land and Resources of Shanghai. 36(02): 71-73.