

Patterns, Characteristics and Enlightenment of Urban Underground Complex Practices in China

Rusi ZENG, School of Architecture and Design, Southwest Jiaotong University, China

Zhongwei SHEN, School of Architecture and Design, Southwest Jiaotong University, China; College of
Architecture and Urban Planning, Chongqing Jiaotong University, China

Abstract

Urban underground complex (UUC) appears in urban underground space with three-dimensional redevelopment of the city. It is a public transit-oriented underground architecture, integrating with more than two functions such as commerce, entertainment, office and parking, etc. As an important part of urban space, UUC assumes part of the urban functions. Also, Independence, connection, and blurred boundaries are the basic features of UUC. It has advantages in effectively alleviating the problems of land tension, traffic congestion, and environmental pollution in urban centres, and can improve the quality of urban space and environment. In China, UUC is mainly characterized by large-scale development and rapid construction. However, the theoretical attention related to the planning and design of UUC is far from enough, resulting in extensive construction and failure of meeting the needs of users, which is also a waste of resources. Therefore, the current construction background of UUCs in China was introduced, the connotation, characteristics, and value of UUC were analysed. Representative UUCs were analysed for summarizing the practical patterns. Recommendations were made from the urban level, the neighbourhood level and the architectural level. The research results may provide references and value for the planning, design, construction and operation of UUC.

Keywords

Urban underground complex, China, Connotation, Characteristics, Value, Pattern

1. Introduction

In the process of rapid urbanization, problems such as traffic congestion, shortage of land resources, and environmental pollution have become increasingly prominent. In order to seek space for survival and development, people have changed the traditional two-dimensional development pattern to downward development, and to three-dimensional space. The Tokyo Declaration in 1991 stated that 'the 21st century is the century for development and utilization of underground space.' Utilization of underground space has become the main approach for urban sustainable development, and one of the effective methods to solve urban issues. With the development of social economy, the advancement of science and technology, and the diversification of human needs, the connotation of urban underground space continues to expand. It is developing towards integration, intensification and systematization, Thus Urban Underground complex (UUC) has emerged. Its core value is to realize the three-dimensional development of urban space through complex and intensive organization, efficient transport and transfer services, and high-quality environment. It also offers a solution for the problem of land shortage in urban centre, traffic congestion, thus improves land value and environmental quality.

Japan started relatively early in the utilization and research of UUC, and has made great achievements (Liu, 2007), including analysing and summarizing the development history, stage and policy of underground shopping malls in UUC, summarizing the types of underground shopping malls and

comparing them through case studies, analysing the indoor lighting effects of underground streets, as well as the environmental psychology and behaviour research of users. In the monograph 'Geo-Space Urban Design', the concept of underground city was introduced, which laid a theoretical foundation for the development of modern urban underground space in the direction of integration and systematization (Golany & Ojima, 1996). In addition, due to the cold weather conditions in Canada, research on underground space has more regional characteristics. Underground cities promoted the development of urban centres and bring huge economic benefits (Zacharias, 2007).

Developed countries such as Japan and Canada have made great achievements in utilization of underground space, as well as UUCs. However, in China, there is a difference in public ownership of land, policy and administrative system. Therefore, the experience and research products from developed countries can't be simply duplicated. The public ownership of land in China makes the overall planning and systematic design of UUC possible. However, there are few studies of UUC in planning and design. In particular, the attention paid to the characteristics and patterns of UUC is far from enough, which has caused extensive construction of UUCs in some cities, and has also resulted in a waste of resources. Hence, based on the current construction background of UUCs in China, the connotation, characteristics, and value of UUCs which have been built was analysed, and the practical patterns are summarized. Recommendations on planning and design of UUC are made from urban level, neighbourhood level and architectural level. The research results can provide references for the planning, design, construction and operation of UUCs.

2. Connotation, characteristics and value of UUC

2.1. Connotation of UUC

In China, many scholars have defined UUC. The term 'Urban Underground Complex' first appeared in the monograph 'Underground Architecture' (Tong, 1994). Its definition emphasized on the transition from a Building Complex to an Urban Complex. It was emerged through the three-dimensional redevelopment of cities, with the utilization of urban underground space. This definition emphasizes the evolution of UUC, and the expansion of its urban functions.

UUC refers to the underground building that is built below the surface of the city and can provide people with places for transport, public activities, living and working, and correspondingly equipped with supporting integrated comprehensive facilities. It is an ambiguous concept with unclear extension (Geng & Zhao, 2001). With the three-dimensional redevelopment of cities, underground buildings and structures of various types and functions are gathered together to form a comprehensive underground space which is unified in planning, complementary in functions, and integrated in space (Tong, 2005). UUC is a network that connects, transports and transfers the aboveground and underground systems, and developed in a three-dimensional direction. It combines commerce, storage, business, entertainment, disaster prevention, municipal (including public and private) facilities together, which constitutes a comprehensive facility to organize people's activities and improve the efficiency of the city (Li, 2006).

UUC began with the development and utilization of underground space by human beings. It evolved from the initial single function of sheltering from wind and rain, to a public transit-oriented urban underground building, which integrated multiple functions such as commerce, office, entertainment, etc. With the rapid development of the city and the diversified needs of users, the connotation of UUC continues to expand. The morphology of UUC is also constantly changing.

2.2. Characteristics of UUC

(1) Opened to urban spaces

The basic feature of UUC is its openness to the city. UUC belong to the category of underground public buildings, which assume urban functions, especially in the compact and three-dimensional areas such as urban centres. It has become a key component of three-dimensional space organization of cities. Therefore, openness to the city is its basic feature. 'Openness' includes two levels of connotation: one is open to an architectural space, which means the publicization of space. The other is the ambiguity of boundaries, emphasizing the integration with surrounding urban elements.

Firstly, UUC covers urban functions such as public underground transport, commerce, entertainment, parking, whose customers are mainly composed of people using rail transit. There is also a considerable part of citizens enter UUC for consumption, entertainment and other activities. These behaviours and activities have contributed to the increasing publicization of the internal space of UUC, and provided a basis for the convenience of travel of citizens. For example, an underground street carries the function of a street on the ground, sharing the responsibility of pedestrian walkway on the ground, and connecting the surrounding underground space. The underground atrium becomes a gathering space for public transportation, which plays an important role in transferring and dispersing pedestrian flow.

Secondly, UUC integrates the public space with surrounding urban space, and conducts overall planning and design with urban elements such as urban roads (including aboveground and underground), plazas, green spaces, and parks. UUC emphasizes on the integration of urban space. Thus, its boundaries are often difficult to determine and vague. Sunken plazas, atriums, entrances and exits, vertical traffic facilities and other constituent elements have become important media for its integration with the surrounding urban space.

(2) Comprehensiveness of functions

The comprehensiveness of functions is another important feature of UUC. The underground complex is an urban complex, whose core value needs to reflect the synergy effect of '1+1>2' (Wang, 2018). 'Comprehensive' contains the concept of 'Mixed-use Development'. When UUC contains three or more functions that can provide revenue and support each other (such as transport, retail, entertainment, office, leisure, and public activities, etc.), it can form a complementary and symbiotic relationship and attract more people. It generates a value of 'place' and external effects through the agglomeration of different functions, which also brings vitality to surrounding areas. Specifically, it includes the integration of multiple urban transportation modes, the combination of commercial and service facilities, as well as combined with civil defense facilities in China.

In addition, the comprehensiveness of functions also underlines the mixed-use of different time periods, that is, 'full-time functions' (Wang, 2010). The passenger flow of rail transit has peak hours both in the morning and evening, which can bring a large number of passengers to UUC. However, in other periods, the effect brought to retail, catering, entertainment and other profitable businesses is relatively weaker. In order to realize the '24-hour' operation of UUC, different functions are combined in diverse periods according to their own attributes. For example, a UUC that is dominated by business purposes on weekdays will drop in popularity at weekends. On this occasion, it is necessary to supplement functions such as entertainment and leisure which citizens prefer during weekends, hence bringing vitality to UUC during weekends and realizing 'full-time function'.

(3) The organization of space through vertical dimension

The organization of space through vertical dimension is another important feature of UUC. The vertical composition of space is divided into 9 levels: super high-rise level, high-rise level, middle level, near-surface level, ground level, surface level, shallow underground level, middle underground level, and deep underground level. The closer to the ground level, the denser and more opened of the space, and the higher the value (Han & Feng, 1999).

The spatial hierarchy of UUC is based on vertical cascading, and has its own particularity. The passenger flow brought by public transport is an important factor of its spatial distribution (Jia, 2015). Therefore, its vertical spatial composition is different from that of urban complexes or aboveground buildings. Normally, it is based on the level of rail transit. Considering the value of the ground level, in order to ensure the convenience of transport and transfer, the spatial organization shall be conducted according to the principle of the strong or weak connection with the rail transit. Functions more closely related can be arranged in the adjacent level with rail transit, such as fast-food restaurants, convenience stores, parking, etc. The closer to the ground floor, the greater the openness and publicity of the space. Functions such as catering, retail, entertainment can be arranged.

(4) 'Strong' in space and 'Weak' in forms

With no external facade and no requirements for the combination of building shapes, the indoor environment of UUC is the key point, which is also the unique feature of UUC. For architects and urban designers who are used to building facade modelling and exterior space design, adjustment and revision of design methods are also needed (Shen, 2019). With the development and utilization of urban underground space and UUC, interiorization in urban design has become an inevitable trend, and it is also the result of redevelopment of urban space. The quality of the internal environment directly affects the value and benefits of UUC.

2.3. Value of UUC

(1) Relieve the issues of shortage of urban land, and expand urban space

In high-density urban areas such as urban centres, the problem of land shortage is becoming more and more prominent. Affected by high-rise buildings, high density, streets and other factors, the space aboveground is quite limited. In this context, underground space has natural advantages. UUC can effectively connect various functional spaces, such as underground commerce, underground public transport, underground municipal facilities, etc., through rational organization of space. Hence, an integrated underground pedestrian system that connects urban functions is formed, an underground 'node' is established, which will maximize the effect of each function, so as to bring both social and economic benefits.

(2) Improve urban transportation and stimulate urban vitality

The utilization of UUC is driven by urban transportation. Meanwhile, the advantage brought by the development of UUC is to improve urban transportation. For example, through public transportation such as subways, a layered and three-dimensional transportation system integrated with ground transportation and pedestrian bridges is established. Thus, more space on the ground is left for green and pedestrians. For example, the context of both old part with high density and new part of the city with new texture is sewed up through the design strategy of underground railway station. Only urban functions are left aboveground (Zeng & Shen, 2020).

On the ground level, the regional pedestrian system is integrated through the roof with landscape of the complex that can be accessed by citizens (Figure 1). The underground space is connected to metro

stations through underground pedestrian walkways, which forms a multi-level and three-dimensional transportation system, effectively improves the quality of urban space, and brings vitality to the region (Figure 2).



Figure 1. The landscape on the roof of West Kowloon Station. Source: Author.



Figure 2. Interior space of West Kowloon Station. Source: Author.

(3) Save energy and resist severe cold weather conditions

In terms of energy saving, underground space has natural advantages. Since ancient times, humans have begun to use underground space in the form of cave dwellings (Tong, 1994). Underground space can resist the severe cold weather conditions and has the unique feature of staying comfortable both in winter and summer. In China, underground space has been used for about 4,000 years. In the loess areas of Shaanxi, Gansu, and Shanxi, about 35-40 million people live in underground dwellings: Sunken cave dwellings and Hillside Type Dwellings (Golany & Ojima, 1996).

UUC has become one of the major approaches to solve weather issues in cold regions of China, by providing convenient access facilities for pedestrians through an underground networked pedestrian system. Harbin is located in the northern part of Northeast China. It has an extreme cold weather condition with a minimum temperature of minus 37.7°C in the winter. The Harbin Metro is the first subway system constructed in cold regions, in China. The Museum Station UUC driven by metro construction is the largest example with diversified functions, and has become the centre of urban activities.

(4) Protect historical buildings, streets and ancient cities

The level of urbanization in China has accelerated. Urban development has entered an important period of urban renewal. According to the seventh national census data, the urbanization rate of the permanent population in China has reached 63.89% in 2020, which made an increase of 14.21 percentage points over 2010 (Zhu & Zhang, 2021). Relevant policies are clearly proposed to implement urban renewal actions (Wang, 2020). The development and utilization of underground space resources has become one of the important approaches to achieve the goal of high-quality urban renewal.

The Chunxi Road UUC in Chengdu has the Daci Temple within its station area. The Daci Temple was built between the 3rd and 4th centuries, which has been more than 1,600 years. The temple is magnificent and is a famous ancient temple in Chengdu (Figure 3). Presently, a well-known commercial complex with a block style has been built around Daci Temple: Taikoo Li. The underground space of commercial complexes in Chunxi Road area such as Silverstone Plaza and IFS are organized through the integration of underground commerce (Figure 4), pedestrian walkways, underground parking, and metro stations. The Chunxi Road UUC is a typical 'Urban center' style UUC. The Daci Temple was retained on the ground and repaired to incorporated with the surrounding functions, thus improving the spatial quality and cultural connotation of that area.



Figure 3. The Daci Temple and its surroundings.

Source:

<https://you.ctrip.com/sight/chengdu104/4344.html>.



Figure 4. Underground commercial street of Taikooli near Daci Temple. Source: Author.

3. Practice and patterns of UUCs in China

The Utilization of underground space in China started with the construction of civil air defense projects. In the early decades, the underground space in China is scattered, lacking overall planning and humanized design. Recently, in order to reduce the conflict between population growth and limited urban space resources, and to ensure the sustainable development of cities, China has begun to build UUC, seeking for new ideas of a more compact and reasonable urban development. Until 2017, the number of large-scale UUCs in China (including completed, under planning, and under construction) has reached 120. Among them, 81 are in the eastern region, 27 in the central and western region, and 13 in the northeast region (Liu, Qiao, & Peng, 2017). Large-scale UUCs such as The Culture Wave City in Hangzhou Qianjiang New CBD, the core area of Guangzhou Zhujiang New CBD, Shenzhen Futian Station and other large-scale UUCs have been built one after another. The practical patterns of UUC are divided into 2 major types based on the principle of its leading function (Table 1).

3.1. Transit hub-oriented type

Based on the construction of an urban transportation hub, the Transit hub-oriented type of UUC combined railways, subways, light rails and ground transportation together. With transportation connection and transfer services as the leading functions, it can effectively reduce transfer time and the ground level traffic flow. Typical cases are Shanghai Hongqiao Transportation Hub, Beijing South Railway Station, Chengdu East Railway Station UUC (Figure 5).

3.2. Urban centre type: integrated with plazas, green spaces, streets, High-rises

Generally, this type of UUC is located in urban centres, CBDs and other prosperous areas, and is constructed underneath urban green spaces, plazas and streets. It can ease traffic problems, space congestion and other urban issues, which is a practical pattern driven by urban public transportation such as subways. Typical cases are Chengdu Tianfu Square UUC (Figure 6), Shanghai Renmin Plaza UUC, etc.



Figure 5. Chengdu east station UUC. Source: Author.



Figure 6. Chengdu Tianfu Square UUC. Source: Author.

Table 1. Practice and characteristics of typical UUCs in China. Source: Auhtor.

Pattern	Connotation	Project name	Time of construction (year)	Characteristics
Transit hub-oriented type	Railway station-oriented, integrated with railways, subways, light rails, and ground transportation. The major function is urban transfer. Usually utilize the underground space of railway station plaza to combine multiple transportation modes, with supporting facilities implemented.	Lanzhou Zhongchuan Transportation Hub	2021	Built based on airport-oriented transportation hub
		Chongqing Shapingba Railway Station	2018	Make full use of the underground space and constructed 8 floors underground. Adopting a full three-dimensional layout in the urban centre
		Chongqing East Railway Station	2018	With a total of 5 floors, the ground floor is a station building, with a ticket hall and a station hall. A total of 4 floors underground, rail transit lines are connected underground. Combined with the 'traffic core', natural light is invited
		Lanzhou West Railway Station North Square UUC	2016	Including about 66,000 m ² of commercial area and a total number of 1,900 underground parking spaces. The three-dimensional space is used for systematic layout to realize the 'zero-distance transfer' between high-speed railway and urban transit
		Shanghai Hongqiao Transportation Hub	2010	Combining High-speed railway, intercity railway, urban rail transit, magnetic levitation, public transportation, civil aviation, commerce, catering, entertainment, parking, and municipal pipelines

						together
				Beijing South Railway Station	2008	The transfer space on the first underground level connects with the north-south square, and forms a three-dimensional efficient transfer place with the elevated waiting hall, the ground platform, the second and third underground level of subway lines
				Shanghai South Railway Station	2006	Underground commerce is introduced in the North-South Plaza, and passengers are transferred through the underground space of the railway station
				Shenyang North Railway Station	1990	The first large-scale transportation hub style UUC in China, covering functions such as station basement, pedestrian walkways, underground commercial streets, parking, and civil defense
Urban centre type: integrated with plazas, green space, streets, High-rises	Plaza type	Use the underground space of the plazas in urban centres to supplement the ground functions, and preserve the green space on the ground, meanwhile providing space for public activities	the	Chengdu Tianfu Square UUC	2010	Connected with the Grand Theatre and the Art Palace, the underground space of Metro Line 1 and 2, forming an underground pedestrian network. Combining commercial, cultural, and entertainment facilities to create a regional centre of vitality
				Chengdu Jincheng Station UUC	2010	Use the ground plaza to build several entrances and exits, as well as light wells, integrating subways and underground commerce to form a distinctive underground space
				Shanghai Wujiaochang UUC	2010	Located in one of the four sub-centres of Shanghai, with the iconic sunken plaza as the core, metro stations and lines as the axis, combined with its surrounding functions, the UUC has a regional influence
				Shanghai Jinan Temple UUC	2000	Built within a 'high-quality commercial business district', with comprehensive utilization of commercial facilities and underground subway space, integrating commercial, office, cultural with entertainment functions
				Shanghai Renmin Plaza UUC	1995	Use the underground space of plazas and green spaces in the urban centre, combined with the reconstruction and expansion of metro stations,

					integrated commerce, transportation, parking, with municipal administration
			Shanghai Xujiahui UUC	1993	The first comprehensive development project of underground space in Shanghai, including three-line transfer hub, underground parking, commercial and other functions
High-rise type	Use and transport facilities to combine the basements of high-rise buildings in urban centres, forming a systematic and efficient network for pedestrians both above and underground.	urban spaces and urban	Shanghai Lujiazui UUC	2016	The underground commercial district is directly connected to the metro line, and passengers can go directly through the underground walkways without leaving the station, supported by functions including leisure, entertainment and business facilities
			Chengdu Chunxi Road UUC	2012	Located in the commercial centre of the city, the underground space of surrounding high-rise buildings is integrated through the construction of metro stations to form a three-dimensional traffic system for underground and aboveground passengers and vehicles

4. Discussion

Through the analysis of the connotation, characteristics, value, and practical patterns of existing UUCs in China, this paper proposes planning and design strategies and enlightenments based on the dimensions of cities, neighbourhoods, and buildings.

4.1. Urban level recommendation

At the urban level, the planning and site selection of UUC should conform to the overall urban planning and development direction of the city. UUC is featured by a large scale and a fast construction speed. At the same time, due to the large-scale construction of subways and other rail transit, the practical pattern of UUC oriented by subway stations plays an important role in guiding the direction of urban space, promoting urban structure, improving land value and economic development. Therefore, UUC should be planned and considered as a whole, and left enough space for future development, which can enhance the sustainability of underground space utilization and urban resilience.

Meanwhile, UUC should be aimed to improve the image of the city and strengthen the identity of itself. Due to its enclosed feature, underground space is difficult to be recognized aboveground by users. Lacking identities leads to the less willingness to go inside for the users. UUCs underneath plazas and green spaces are good opportunities for improving the image and spatial quality of the city. Therefore, UUC that enhances the image of the city should be built in accordance with the urban environment. At the same time, its identity can be addressed by connecting the ground entrances and exits, sunken plazas, etc., thus its attractiveness is enhanced.

4.2. Neighbourhood level recommendation

At the neighbourhood level, the functional configuration of UUC should match the surrounding functions to realize the complementation for the function the neighbourhood, which can stimulate neighbourhood vitality. The underground complex has been evolved from the concept of a single independent public building, and has the character of 'border ambiguity'. It is an important part of urban space. Therefore, its functions have a subordinate nature. This means not only its own internal needs should be satisfied, but also the requirement of the neighbourhood should be satisfied, in order to provide high-quality urban public space and service facilities. Simultaneously, it should also form a complementary, coordinated and corresponding relationship with the functions of the aboveground buildings, to realize the integrated development of both the aboveground and underground.

In addition, UUC needs to be coordinated with the neighbourhood environment to realize the sustainable development of the region and the city. The utilization of underground space is an effective approach to protect natural environment and resources. The popularity of the plaza-type UUC in urban centres is a proof. Meanwhile, in the historic block, underground space is also developed and utilized, and UUC is gradually formed. The coordination with the aboveground environment is mainly carried out through 'Node', such as entrances and exits, sunken plazas, and atriums. Therefore, the design of the 'Node' type of space should be more cautious.

4.3. Architectural level recommendation

At the architectural level, the vertical organization and design of UUC should be optimized to avoid the isolated development of traditional underground space, and to improve the compactness and integration of urban space, in order to realize the sustainable development of both UUCs and cities.

In addition, the rationality of functional configuration should be improved. Commercial-based UUCs have become the main trend for a long time. However, in some areas, there is not enough passenger flow to support the operation of underground commerce. On this occasion, other functions such as culture, leisure, and entertainment should be considered to improve the attractiveness of the UUC itself and the functions of the aboveground buildings. Blindly large-scale utilization of UUC should be avoided.

Furthermore, UUC has no external facade, and the internal space will directly affect the users' experience. Therefore, the design quality of internal space should be strengthened. Buildings serve for people, and their fundamental purposes are to meet users' requirements. The design can be optimized from the aspects of comfort of internal environment, orientation, and humanized facilities.

To sum up, this paper attempts to put forward some suggestions through the analysis of the concepts, characteristics, value, and practical patterns of UUCs in China. These suggestions have value for the planning, design, construction, and operation of UUCs.

5. References

- Golany, G. S., Ojima, T. (1996) *Geo-Space Urban Design*. John Wiley & Sons.
- Tong, L.X. (1994) *Underground Architecture*. Jinan: Shandong Science & Technology Press.
- Liu, J. Y. (2009) *Urban development in three dimensions-Design and theory of underground streets*. Nanjing: Southeast University Press.
- Zacharias, J., Xu, M. (2007) 'The Underground System as Economic Generator for Montreal's Central City', *Urban Planning International*, 06, p28-34.
- Geng, Y.C., Zhao X. H. (2001) *Urban underground architecture*. Harbin: Harbin Institute of Technology Press.

-
- Tong, L. X. (2005) *Underground space and development of urban modernization*. Beijing: China Architecture & Building Press.
- Li, X. (2006) 'Discussion on multiple issues of planning urban underground space', *Life & Disaster*, Suppl. 1, p61-67.
- Wang, Z. D. (2018) *Research on the synergy of mixed-use complex*. Beijing: China Architecture & Building Press.
- Wang, Z. D. (2010) *Study on contemporary urban mixed-use complex*. Beijing: China Architecture & Building Press.
- Han, D. Q., Feng, J. L. (1999) *Holistic Design on Urban Architecture*. Nanjing: Southeast University Press.
- Jia, J. (2015) *Design and Practice of Urban Underground Complex*. Shanghai: Tongji University Press.
- Shen, Z. W. (2019) 'Architecture of Underground space', *Time + Architecture*, 05, p20-23.
- Zeng, R. S., Shen, Z. W. (2020) 'The Modern Railway Complex from a Multi-dimensional Perspective: A Case Study on Hong Kong West Kowloon Station', *New Architecture*, 01, p88-92.
- Zhu, Y. L., Zhang, B. (2021) 'The Future Trend of China's Consumption Under the Change of Demographic Structure-Analysis Based on the Data of the Seventh National Census', *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition)*, 50(04), p149-162.
- Wang, M. H. (2020) 'Implement Urban Renewal actions', *China Engineering & Consulting*, 12, p6-9.
- Liu, Y. P., Qiao, Y. K., & Peng, F. L. (2017) 'Investigation and analysis of construction status of large urban underground complexes', Proceedings of the 2017 Annual Conference of China Civil Engineering Society, 2017, Shanghai. China Civil Engineering Society, 51-62.

Funding

This research was funded and supported by the National Natural Science Foundation of China [Grant number 51778529 and number 51978573].