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Study on the demand and driving factors of urban underground space use

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ABSTRACT

For sustainable development of Urban Underground Space (UUS[1]), determination of the desirable volume and function share of UUS is of vital importance. However, prediction of demand for UUS remains a rather challenging task. Very little quantifiable information, which is a basis for comparative study and improvement of prediction methods, is currently available pertaining to UUS. Xinjiekou, the center of Nanjing city, is called the first commercial center of China. Employing precision mapping on site and inquiring with a variety of organizations concerned, all the developed UUS in the area of Xinjiekou has been investigated in detail. On the basis of the quantitative investigation, the development modes and functional ratios are compared with other Chinese and foreign cases. By quantitative and comparative studies, the demand and driving factors of UUS have been identified. It is also found that the study area has the potential to be further developed and improved. It is hoped that this paper will enhance knowledge about the quantitative characteristics of UUS use, and be helpful for the demand prediction and planning of UUS development.

1. Introduction

In recent decades, many cities have entered into a period of rapid development of Urban Underground Space (UUS) use (Admiraal, 2006). On one hand, it is found that the developments in some areas are not sufficient to address the problems faced. Some of the important potential functions have not been involved. Many underground areas are overcrowded. On the other hand, some of the developed underground spaces are left unused or even abandoned. Flower City Square, the new city center in Guangzhou, has an area of UUS of about 500,000 m^2, among which the commercial part of UUS, named the Mall of the World, is about 150,000 m^2. After opening, the flow of customers was far lower than expected, so that about two-thirds of the shops were closed.

Once an underground opening is created, it is difficult to expand its volume or alter its use (ITA, 1991; He et al., 2012). Because the subsequent development of UUS might be prevented by the need to preserve ground conditions (stress and hydrogeological state of geological body) so that existing aboveground and underground structures would not be endangered.

Therefore, determination of desirable volume and function share of UUS is of vital importance (Monnikhof et al., 1999).

However, prediction of demand for UUS remains a rather challenging task (Chen et al., 2007; Zheng and Dai, 2007). Estimation of urban space needs is an important topic to be studied (Scobotka et al., 1991). Influence factors in UUS need are complex. Little work has been done to gain insight into the intrinsic controls on desirable volume and function share of UUS.

A major difficulty in developing prediction method comes from the lack of quantitative information that can be used for comparison. UUS use, its benefits and drawbacks, as well as UUS role in a city, have been very well studied descriptively (e.g. Belanger, 2007; ITA WG 4, 2000; Carmody and Sterling, 1993). However, there is still some lack of the study on the quantitative characteristics of UUS (Bobylev, 2010).

This paper analyses the quantitative characteristics of UUS use in the city center of Nanjing, named Xinjiekou, and compares it with other Chinese and foreign cases. It aims to identify the demand and driving factors of UUS. These quantitative data of UUS in Xinjiekou are gained by precision mapping on site and inquiring with a variety of organizations concerned. The case study provided in this paper can also be used as a reference for future comparative studies.

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[1] UUS means Urban Underground Space.

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2. Methodologies

2.1. Systematic and detailed investigations in a typical city center

In order to obtain accurate first-hand information, understand the actual operational status and internal demand of UUS. Field investigation, observation as well as inquiry in the studied area were needed.

2.1.1. Field measurement and calculation

Based on the drawing documents and information provided by the planning authority, field investigations have been carried out in Xinjiekou. For each underground space project, investigating and mapping were conducted floor by floor. In terms of statistics, functions of UUS are divided into following kinds: commerce, transportation and parking functions. In particular cases where a floor is used for commercial development, the whole of the floor would be treated as commercial form including internal facilities such as lifts, stairs, and toilets. Therefore, a certain degree of error exists between the area in calculation and the actual usable area.

2.1.2. Observation and statistic

The utilization efficiency of UUS in different time periods has been recorded and analyzed. The types of users were also distinguished in the observation of flow of people.

2.1.3. Inquiring

By inquiring at a variety of institutions, some information and drawings were collected, especially some underground structures that cannot be observed directly.

The following information was asked of lessors and renters: rents, rental rate and operating situation.

2.2. Three typical centers selected for comparison

Berlin-Alexanderplatz and Shanghai People's Square were selected for the comparison with Nanjing Xinjiekou Area. The three city centers have similar areas, about 0.5 km^2, and all are transportation junctions.

Alexanderplatz Square is a distinct landmark in the center of Berlin, which is the capital and largest city of Germany. It is also a busy transport hub and highly frequented shopping area (Bobylev, 2010). Shanghai People's Square is a large public activity center as well as an administrative and cultural center, which is located in the east coast regions and the most economically developed city of China. The land use types of People's Square include underground rail transport, ground public transport, underground parking, an underground pedestrian system and underground commerce (Zhu and Tang, 2010).

Field investigations have also been carried out in Shanghai People's Square to verify and supplement the data obtained from references (Table 1). Information on Berlin-Alexanderplatz can be found at www.stadtentwicklung.berlin.de; Bobylev (2010).

Many factors have impact on UUS use in a city, including population, economic activity, urban area size, ground conditions, climate, geographical location, etc. (Bobylev, 2016). Table 2 shows some socioeconomic and climatic information of the 3 cities. (For easy comparison, all the GDP data are converted into US$ according to corresponding annual average exchange rates.) It can be seen that the GDP per capita of Nanjing and Shanghai are similar. The GDP of Nanjing is close to Berlin. However, the GDP per capita and GDP per km^2 of Berlin are much higher than the two Chinese cities. Besides, as to weather condition, the difference of annual temperature between Nanjing and Shanghai is small. But the temperature of Berlin is a little lower than Nanjing and Shanghai. Based on the above, we can include that the driving force of UUS development between Nanjing and Shanghai is similar and the driving force of Berlin UUS development is stronger than Nanjing and Shanghai.

2.3. Factor analysis combined with comparative cases

Data of many other cases have been collected for comparative study on function ratio and driving factors of UUS.

3. Data on the Xinjiekou area, the city center of Nanjing

3.1. Study area

Xinjiekou area is the center of Nanjing city (see Fig. 1), which is also called the first Chinese commercial center. The history of the commercial center dates back to 100 years ago. Today, nearly 700 stores are gathered here, of which about 30 large and medium-sized commercial enterprises are more than 10,000 m^2. About 100 Fortune 500 companies have set up branches here. Large public crowds aggregate and disperse every day, especially during

Table 1
UUS by function in Shanghai People's Square.

Category of functional use	Utilities	Parking	Rail transit	Pedestrian	Commerce	Total
Area (m^2)	15,900	70,200	65,960	300	54,080	206,440
Ratio (%)	7.7	34	32	0.1	26.2	100

Table 2
Information about Nanjing, Shanghai and Berlin.

	Area (km^2)	Population ('000)	Population density (person/km^2)	GDP (billion $)	GDP per capita ($/person)	GDP per km^2 (million $/$km^2$)	Weather condition	
							Annual temperature (°C)	Average highest–lowest (°C)
Nanjing	6587.0	8187.8	1243.0	129.364	15799.6	19.6	15.4	20.2–11.6
Shanghai	6340.5	24151.5	3809.1	348.804	14442.3	55.0	17.05	20.58–14.14
Berlin	891.8	3517.4	3944.1	145.015	41227.6	162.6	9.67	13.36–5.88

*Berlin: The data of city area and population (2013) come from *"Bevölkerungsstand in Berlin am 31. Dezember 2013 nach Bezirken".Amt für Statistik Berlin-Brandenburg (in German). 18 February 2014. Retrieved 20 August 2014.* The GDP data (2013) come from *Federal Statistical Office of Germany*. The climate data (1876–2015) come from en.wikipedia.org.
*Shanghai: The data of city area, population and GDP (2013) are from *Shanghai Statistical Yearbook*; the climate data (1991–2010) are from *China Meteorological Administration*.
*Nanjing: The data of city area, population and GDP (2013) are from *Nanjing Statistical Yearbook*; the climate data (1971–2010) are from *China Meteorological Administration*.