Land Use Policy 69 (2017) 12–24

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Monetary valuation of urban underground space: A critical issue for the decision-making of urban underground space development

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ARTICLE INFO

Keywords:
Urban underground space (UUS)
Value
Monetary valuation
Decision-making
Replacement cost method

ABSTRACT

Urban underground space (UUS) has attracted more and more attention worldwide, but its value, external value particularly, is often ignored or underestimated, which will influence or even change the trade-offs in the decision-making processes of UUS development. This paper employed service replacement cost method (SRCM) to access the value of urban underground space. Since the precise estimate of the value of urban underground space is almost an impossible task, this paper can only provide a crude approximation, in other words, a relative magnitude of the value of urban underground space. The case study of Changzhou City in China manifested that urban underground space provided an important portion of urban economy, which reached up to, but not be limited to, 1.8% of its GDP. This paper should aid in giving urban underground space more weight in urban decision-making process.

1. Introduction

Urban underground space (UUS) has been consistently used to address urban problems, and with the rapid spread of urbanization, it has been attracting more and more attentions worldwide (Bobylev and Sterling, 2016). For instance, China, as an emerging market of UUS (Zhao et al., 2016), has established an inspiring objective in the 13th Five-Year Plan for Urban Underground Space Utilization and Development (2016–2020), pointing out that at least 50% of the total cities should complete UUS planning (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2016).

However, in most cases, underground space is resorted to just because it is the only possible solution instead of considering its benefits and advantages. What lead to the situation is that there are still a number of controversial issues remaining to be solved regarding underground space use, and this can result in various pressing problems in the process of underground space development. In China, for instance, the ownership of underground land has not been made clear in the national legislative framework, and the underground land price mechanism is far from mature, only established in some provinces such as Zhejiang. Moreover, due to the lack of underground space planning, underground solutions will have to face potential technical problems and the induced financial problems because their construction will influence the existing surface and underground buildings. Among these issues, the most primary one is the high construction cost of underground structures. Generally, the construction cost of underground structures is 2–10 times that of surface structures (Kaliampakos et al., 2016), which is intuitively unfavorable to UUS development. The cost issue has taught us lessons in the urban development process, as learnt from Lujiazui Business District in Shanghai which lost the best opportunity of inter-connecting major buildings via underground passageways due to considerable financial pressure, and has to afford much more cost to make up the inter-connections in recent years (Qiao and Peng, 2016).

The turning point of UUS development with regard to the trade-offs between surface and underground solutions will come if the benefits of UUS use are taken into consideration in the decision-making process (Godard and Sterling, 1995; Almansa et al., 2012). Nevertheless, it is by no means an easy task to persuade the decision-makers to select underground solutions just by qualitative analysis of benefits or advantages of UUS use, although sometimes we can to some extent improve strategic decision-making in complex systems only with qualitative information (Corral-Quintana et al., 2016). For example, in order to map out the long-term overall layout of UUS development in the master planning of UUS, urban underground land will be evaluated qualitatively to determine which part of the city will derive more social benefits while affording less construction cost (Zhao et al., 2016), but unfortunately, the evaluation results play little role in changing the decision-makers' cognition toward UUS. Thus the monetary valuation of UUS use, that is, the quantification of UUS benefits in monetary

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http://dx.doi.org/10.1016/j.landusepol.2017.08.037
Received 26 June 2017; Received in revised form 27 August 2017; Accepted 28 August 2017

terms, may be literally the determining factor in the decision-making process.

The value of UUS can be broadly divided into two categories, i.e., internal value and external value. The internal value, also called intrinsic value, comes from the direct benefits of UUS use, such as leasing fees, renting fees, etc. The external value, also called instrumental value, can be derived from the indirect benefits that UUS impose on society, environment, and other aspects. The value of UUS, for this sake, is different from the 'price' of underground land because the major components of UUS value are 'externalities' which are largely external to the market and thus not reflected in market prices (van der Heide et al., 2010), and this is exactly where the obstacle of monetary valuation of UUS lies.

The aim of this paper is to develop a practical method for the monetary valuation of UUS. Given that the precise estimate of the value of UUS is almost an impossible task, this paper can only provide a crude approximation of the value of urban underground space, but it is still valuable for awareness raising (Marre et al., 2016) of UUS and further influencing the trade-offs in the decision-making process of UUS development. Following the analysis of Section 2 on available techniques and urban services that UUS offers, the method of service replacement cost method (SRCM) is thoroughly presented in Section 3, then applied to Changzhou City in China in Section 4 to highlight the contribution of UUS to urban welfare. The valuation process and results are further discussed in Section 5 and conclusion are drawn in Section 6.

2. Literature review: economic approaches and valuation indicators

2.1. Economic approaches

To date, monetary valuation of UUS is far from mature. For a better understanding of the methodology of SRCM, it is necessary to review the previous literature on economic approaches of monetary valuation. Moreover, SRCM is an integrated method which combines a number of other techniques, so a thorough review is helpful for a comprehensive apprehension of this method.

There have been several tentative research projects or outcomes on UUS valuation in the past few decades. Godard and Sterling (1995) provided some general considerations regarding the assessment of UUS benefits. Kaliampakos et al. (2016) put forward principles and basic approaches for social cost benefit analysis (SCBA). Nishi et al. (2000) and Lin and Lo (2008) used willingness to pay (WTP), a common proxy of the contingent valuation method (CVM), to value the underground interior design and underground metro malls respectively. Pasqual and Riera (2005) analyzed the characterization of underground space as a particular good and further established a methodological approach for underground land value via shadow price. Fu and Yang (2009) adopted the hedonic pricing method (HPM)[1] to estimate underground land price. ITA Working Group (1990) described and compared methods used for cost-benefit analysis of urban transportation systems in four western countries. In China, the comparison method is usually employed for the monetary assessment of indirect benefits of underground projects (Jiang and Chen, 2003; Cui et al., 2008; Long et al., 2004; Jiang et al., 2004; Wang, 2012; Wang and Peng, 2014; Wang and Peng, 2015), and these research efforts render valuable references to this study.

In addition to the aforementioned CVM and HPM, there are several alternatives available for the monetary valuation of such non-market goods as UUS. Principally, they can be disaggregated into non-demand approaches and demand approaches (van der Heide et al., 2010). Non-demand approaches value an asset on the assumptions that the value equals at least the costs people have to pay to replace or to avoid the services of goods, such as opportunity cost approach, averting behavior approach, the replacement cost approach. Demand approaches basically include the revealed preference method and the stated preference method. The former one, such as HPM, travel cost method (TCM), uses market information to estimate the value, whereas the latter one, e.g., CVM, choice modelling (CM), establishes a hypothetical market and deeming willingness to pay (WTP) or willingness to accept (WTA) as the value of goods (Cameron and James, 1987), usually by survey questionnaires.

When valuing UUS as an exceedingly complex urban system, demand approaches lack in reliability as there are so many market factors for HPM that will make the valuation process extremely sophisticated, while the success of CVM depends, to a great extent, on the subjective questionnaire designing and respondents' familiarity (Eom and Larson, 2006) with UUS. For simplicity and practicality, this paper adopted the non-demand approach to value UUS in monetary terms. Here a modified replacement cost method is employed, namely service replacement cost method (SRCM). As a less data and resource intensive method (Notaro and Paletto, 2012), SRCM values UUS by assessing the cost that society has to pay if people want to replace the urban services that UUS contributes by other means. In order to do so, all relevant urban services and the corresponding replacement cost should be included. The replacement cost in the valuation process can be obtained from the existing relevant research efforts, also called benefit transfer. The methodology of SRCM will be further explained and discussed in Section 3.

2.2. Urban services provided by UUS: valuation indicators for UUS

Prior to the quantitative valuation, urban services of UUS should firstly be determined, so that the replacement cost can be obtained based on each kind of service.

As a kind of special resource (Parriaux et al., 2007; Bobylev, 2009), UUS bears various intrinsic natural resources which can be called as "special resource services", such as physical space, materials, groundwater, energy, etc. Considering these "special resource services" are literally irreplaceable and are not prime concerns for the decision-making process of current urban problems, this paper refers to UUS service herein as the urban social services or functions that the developed physical underground space can offer, which is an 'incremental' or 'marginal' concept in monetary valuation process. In this respect, considerable efforts have been made to demonstrate the UUS services. First and foremost, UUS alleviates land use pressure for densely packed cities (Hunt et al., 2016; Sterling, 1997; Broere, 2016; Admiraal and Cornaro, 2016), and the extra urban space can bring cities direct benefits from leasing fees, renting fees of underground commercial facilities and parking facilities and also release lands for other uses (Barker and Jansson, 1982; Ronka et al., 1998; Working Group No. 4, International Tunnelling Association, 2000; Sterling et al., 2012). As another critical starting point of UUS development, underground transportation facilities such as road tunnels and metro tunnels work to improve the urban traffic condition by improving traffic efficiency and reducing the accident rate (Barker and Jansson, 1982; ITA Working Group, 1990; Sterling, 1997; Broere, 2016). In the meantime, the increase in real estate values in the vicinity of UUS transportation facilities is a not insignificant sum of money (Bobylev, 2009). With respect to environmental benefits, UUS is perceived not only to be an ideal insulation media for noise pollution (ITA Working Group, 1990; Sterling, 1997; Broere, 2016), but to be very helpful to air pollution (ITA Working Group, 1990; Broere, 2016) and energy-saving issues (Hunt et al., 2016; Broere, 2016) as regards motor vehicle reduction. This, to some extent, will further influence social health care services and productive activities (ITA Working Group, 1990). From the perspective of city resiliency, economic losses related to wars, natural disasters and lifeline

[1] Hedonic pricing method assumes that the price of a product is determined, more or less, by embodied characteristics which are not necessarily valued by market prices, and derives the product value using regression analysis of the variables reflecting the characteristics.