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Measuring urban sprawl and exploring the role planning plays: A shanghai case study

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ABSTRACT

Measuring the degree of urban sprawl largely depends on the local context and available data. This research establishes a multidimensional index which combines city expansion, urban compactness and urban form to measure sprawl. Urban planning, as part of the state-led growth approach, has exerted dramatic impact on city growth in China. Recent studies have discussed the role of planning in city growth. However, measuring the impact of planning on sprawl, has not been conducted. Taking Shanghai as a case study, this paper builds a multidimensional index to measure the spatio-temporal characteristics of urban sprawl in Shanghai from 1990 to 2010. It finds that urban sprawl was more serious in 2000s than in the 1990s, and the sprawl also presents spatial heterogeneity within different areas of the city. While quantifying the role of planning in urban sprawl, this study adopts the Geo-Detector based on spatial variation analysis of the geographical strata in order to assess the impact of planning on urban sprawl. It finds that planning is strongly correlated with urban sprawl, in other words, urban sprawl is kind of a "planned sprawl" in Shanghai. The research concludes with future planning policies necessary for a more sustainable and compact development pattern.

1. Introduction

As China has become increasingly urbanized, most of its cities have exhibited high growth rates and fragmented patterns of urban expansion, especially at the city outskirts (Yeh and Wu, 1996; Yu et al., 2007). When first introduced to China in the 1980s, (Fung, 1981), the notion of urban sprawl was often referred to as rapid urban growth (Wu and Yeh, 1997,1999). The concept was then extended to the inefficient spatial development pattern on the urban fringe (Deng and Huang, 2004; Wei and Zhao, 2009). Different from sprawl seen in Western cities, which is mainly driven by lifestyle changes (Squires, 2002), sprawl in China is significantly influenced by the state. In the context of an imperfect land market and decentralization process, local governments have become the de facto facilitator to guide market forces and achieve economic growth (Zhu, 2005). Driven by the incentive to maximize benefits from land leasing and pressure from developers to acquire land, local governments have tended to oversupply land, leading to urban sprawl problems (Tian, 2014).

There has been a wealth of literature documenting the methods for measuring sprawl and comparing the degree of sprawl among a diverse set of cities (Galster et al., 2001; Lopez and Hynes, 2003; Tsai, 2005; Jiang et al., 2007; Schneider and Woodcock, 2008; Bhatta et al., 2010a, 2010b; Zhang et al., 2014). Studies on sprawl have focused primarily on U.S. cities, but recent studies across the globe have emerged, such as in Europe (Antrop, 2004; Kasanko et al., 2006), China (Deng and Huang, 2004; Zhang et al., 2013; Jiang et al., 2016), India (Bhatta et al., 2010b) and Israel (Frenkel, 2004).

Given the varying contexts, indicators measuring sprawl differ from country to country. Direct comparisons among global cities from different geographical settings have also appeared using remotely sensed data and census information (Schneider and Woodcock, 2008). In China, some studies on urban sprawl have examined the spatio-temporal change of landscape based on time-series data (Yu et al., 2007; Jiang et al., 2016; Zhang et al., 2016), but studies on the complexity of sprawl and its driving forces have been fairly scarce (Yue et al., 2007; Zeng et al., 2014; Yue et al., 2016). Moreover, given the difficulty of obtaining sufficient social, economic and land use data, the indicators which are applied in developed countries are not easily applied in developing countries. For instance, in China, information on employment, residential unit, and land use data at the street community (*Jiedao*[1] in Chinese) or township is not available. How planners can design a

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[1] *Jiedao*/township is the smallest geographic unit where census data can be achieved in China, and *Jiedao* is located in the urban area, while township is located in the rural area.

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method to accurately identify the degree of sprawl based on limited data in the local context remains a critical issue.

In China, a city master plan has significant impact on city growth and the real estate market because the arrangement of infrastructure facilities can change land values in certain areas. A city master plan forecasts the size and boundary of a city built-up area and its population over a 20 year period, designates areas for various types of land use, such as residential, commercial, industrial and farmland, and arranges major infrastructure and citywide social amenities (Tian and Shen, 2011). Different from population growth, the growth boundary designated by the master plan has been an essential and tangible tool to guide city growth. During the past three decades, Chinese urbanization took a formal form of industrial zones and planned new towns, and planning was used by local governments to maximize land income or to open up new spaces for growth in order to generate taxes, and was a powerful tool for growth. Therefore, planning contributes to the operation of the local growth machine (Wu, 2015; Tian et al., 2017). To what extent planning has curbed or accelerated urban sprawl is worth further research.

In this research, we select Shanghai as a case study, and three temporal satellite images at 10 years intervals (1990, 2000 and 2010) have been classified to determine urban growth. We develop a multi-dimensional index method combining the evaluation of city expansion, urban compactness, and urban form to measure the degree of urban sprawl at the spatial level of the *Jiedao* or township, and analyze the spatio-temporal characteristics of urban sprawl from 1990 to 2010. Then, we adopt geographical detectors proposed by Wang et al. (2010) based on spatial variation analysis of the geographical strata to assess the impact of planning on urban sprawl.

This paper is organized as follows: the first section reviews literature on methods of measuring urban sprawl and characteristics of Chinese urban sprawl. The following section provides a method for measuring city growth and compares the change of degree of sprawl in Shanghai from 1990 to 2000 and 2000 to 2010. Next, this research applies the Geo-detector to examine the impact of planning on urban sprawl. The paper concludes with future policies necessary for a more sustainable and compact development pattern.

2. Measuring urban sprawl

Urban sprawl is an inefficient spatial pattern of urban expansion, representing one end of the continuum in contrast with the “compact” city form (Ewing, 1997). Despite the ambiguous and controversial definition of urban sprawl, common agreement exists as to its specific characteristics: low density or single-use development; scattered or leapfrog expansion; excessive spatial growth; segregated land use; and auto-dependency (Gordon and Richardson, 1997; Ewing, 1997; Brueckner, 2000; Galster et al., 2001; Lopez and Hynes, 2003). During recent decades, planners have widely studied and documented the socio-economic costs and the negative impact of urban sprawl such as increasing loss of land resources, environmental degradation, and the growing lack of accessibility to jobs, etc. (Burchell et al., 1998; Kahn, 2000; Johnson, 2001). Particularly, the land-consumptive and inefficient nature of sprawl is well acknowledged (Hasse and Lathrop, 2003).

In order to quantify the dimension and degree of urban sprawl, several new indices have emerged. They are usually one or two dimensional, focusing on population density (Fulton et al., 2001; Lopez and Hynes, 2003), land expansion (Yu et al., 2007; Burchfield and Overman, 2006) and job accessibility (Weitz and Crawford, 2012). For instance, researchers compare the growth ratio of urban land conversion in conjunction to population change to quantify the relative intensity of sprawl (Fulton et al., 2001; Kasanko et al., 2006). Sprawl has also been measured by the degree of equal distribution of built-up areas, using methods like the relative entropy or Gini coefficient (Tsai, 2005; Bhatta et al., 2010a; Martellozzo and Clarke, 2011; Hu et al., 2015). While these single dimensional measures are easy to calculate with existing available data, they seldom consider the negative social and environmental impact associated with sprawl (Ewing and Hamidi, 2015).

Recently, studies have conceptualized urban sprawl as a multi-dimensional phenomenon (Frenkel and Ashkenazi, 2005), and a number of multidimensional indices have been developed. In general, sprawl measures can be divided into five major independent dimensions which identify different types and extents of sprawl, including growth and change rates, density, spatial-geometry such as fragmentation, accessibility, and land resource loss (Galster et al., 2001; Frenkel and Ashkenazi, 2005; Hasse and Lathrop, 2003; Cutsinger et al., 2005; Tsai, 2005). In the first of the multiple indices, this one developed by Galster et al(2001), sprawl is defined as a pattern of land use that presents low levels in at least one of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity. Then, Ewing et al. (2002) extend the indices with a wider degree of variability and use the principal component analysis (PCA) to cluster the sprawl areas. Similarly, Frenkel and Ashkenazi (2005) identify three dimensions of sprawl: density, scatter (or fragmentation), and mix of land-uses. Hasse and Lathrop (2003) developed a series of five indicators to measure the costs and negative externalities of sprawl on land resources.

Despite some drawbacks such as redundant information (Schneider and Woodcock, 2008; Bhatta et al., 2010b), multidimensional measures of sprawl based on pattern metrics are useful to analyze the complex nature of sprawl (Ewing and Hamidi, 2015). In recent studies, many researchers have further updated and refined the original indices and conducted empirical analysis to capture changes in sprawl patterns over time in different areas (Sarzynski et al., 2014; Hamidi and Ewing, 2014). Nevertheless, the main problem associated with sprawl measurement is the failure to define the threshold between sprawling and non-sprawling (Bhatta et al., 2010b). Unfortunately, sprawl is still a relative concept today and its measurements vary from region to region.

3. Chinese urban sprawl and its causes

Chinese urban sprawl presents several similar characteristics with the U.S. context such as dispersed and fragmented development, a main pattern of new development zones and semi-urbanized villages, urbanized areas growing faster than actual population, and a significant loss of critical cultivated and forested land resources (Zhang, 2000; Deng and Huang, 2004; Yu et al., 2007; Tian et al., 2017). The differences, however, are quite apparent. For instance, low-density and commercial strip development are not characteristics of sprawl in most Chinese cities (Zhang, 2000). On the contrary, sprawl is sometimes accompanied with a fairly high population density, especially in some fringe villages (Schneider and Woodcock, 2008; Wei and Zhao, 2009). Additionally, the Chinese central city is still a booming area rather than a declining one as seen in many large U.S. cities. These differences reveal distinct driving forces behind the sprawl pattern in China.

As a result of suburbanization, urban sprawl in Western cities is derived from a combination of both market and government failures (Ewing et al., 2015). Given the externality of land markets, government reactions may aggravate market distortions by providing subsidies for automobiles and establishing land-use regulations to control outcomes (Ewing, 1997). In other words, sprawl is not simply a natural response to market forces, but a product of market imperfections and government actions. Similarly, Chinese urban sprawl is also the result of a combination of market forces and government actions (Zhang, 2000; Yu et al., 2007). Both state-led growth and the bottom-up model have significantly contributed to scattered and fragmented development (Zhu and Hu, 2009; Tian and Zhu, 2013).

Urban sprawl in China takes root in the imperfect and uneven land market reform (Yeh and Wu, 1996; Ding, 2003; Deng and Huang, 2004). Since the land reform in the 1980s, a dual system of land