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The transformation of urban industrial land use: A quantitative method

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Abstract

A large number of cities around the world today owe their land use growth to the rapid development of industrial areas. The spatial structure of industrial distribution in cities shape urban spatial morphology linking with land use, transportation, economic activities, and housing. Meanwhile, growth and expansion of city population and land use reconfigure the spatial structure of industrial distribution. Research into urban industrial spatial distribution and its transformation process may help urban planners and decision makers understand the land use and population dynamics of a city. Genetic algorithms are believed to be one kind of the promising methods to simulate this dynamic process. In this paper, we propose a novel method to simulate urban industrial spatial distribution and its transformation process in Shanghai, China. The results show that along with increasing urban land price over time, industries are going to move outward from the city center. However, the maximum profit of a firm tends to decrease, which could lead industrial factories to move beyond city boundary. The analysis of the current industrial spatial distribution in Shanghai indicates that, when land price in a city rises above a specific threshold, new government policies and other competitive advantages need to be enacted if the city wants to retain industrial firms within the city boundary.

Keywords: Industrial spatial structure; Spatial analysis; Genetic algorithm; Shanghai

1. Introduction

The expansion of urban land use and transformation of industrial space are two conspicuous phenomena revolving around the development process of cities (Angel et al., 2005). On the one hand, industrial growth and agglomeration are major driving forces of urban land use change and expansion (Walker, 2001). The start-up and concentration of industrial plants lead to the convergence of residential, economic and social activities due to agglomeration effects. Spatial restructuring of industries may also reshape spatial configuration of a city (Clark & Burt, 1980; Viehe, 1981; Walker, 2001). On the other hand, residential population growth, in-migration and expansion of residential space also affect the spatial distribution of industries due to the shifting of land price and local labor market (Hudalah, Viantari, Firman, & Woltjer, 2013; Ning & Yan, 1995). The reconfiguration of urban industrial spatial distribution and urban

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land use expansion are therefore two complementary close-knitting processes determining the spatial trajectory of urban transformation.

It can be argued that appropriate and balanced urban industrial spatial structure is imperative to steady urban growth (Anas, Arnott, & Small, 1998; Fischer & Nijkamp, 2012; Fujita & Thisse, 2013). During the process of rapid urbanization and suburbanization, any ad hoc and unplanned spatial distribution and allocation of industries may bring about undesirable consequences, including high energy consumption and waste, excessive loss of prime agricultural farmland, heavy traffic congestion, and degraded quality of life (Berrigan, Tatalovich, Pickle, Ewing, & Ballard-Barbash, 2014; Brueckner, 2000; Ewing, Meakins, Hamidi, & Nelson, 2014). In China, for example, heavily concentrated manufacturing factories around city center have brought about severe traffic congestion and air pollution, while unorderly industrial diffusion has greatly accelerated the removal of prime agricultural land during the past ten years (Chan & Yao, 2008; Tian & Zhu, 2013). Therefore, understanding the relationship between land use change and industrial spatial distribution and their co-transforming processes can help urban planners and decision makers develop a more sustainable and livable city.

Studies on industrial spatial structure can be dated back to the study of industrial structure of American cities in the late 1950s (Alexandersson, 1956) and Alfred Weber's industrial location theory (Weber & Friedrich, 1962). Economic geographers attempt to explain spatial distribution of industrial factories based on land price theory (Alonso, 1964; Isard, 1956; Muth, 1961). For example, Weber pointed out that an industry is usually located where the transportation cost of raw materials and final products is the lowest. Alonso found that manufacturing factories choose to be located close to both market and labor in a city. These pioneering studies lay a basic foundation for the contemporary research on industrial spatial distribution. However, classic location theories say little about the transformation process of industrial structure from a dynamic perspective.

While evolutionary economic geographers have explored evolving spatial structure and distribution of industries using theoretical frameworks based on agglomeration effect, technology innovation, knowledge spillover, and industry life cycle theories (Iammarino & McCann, 2006; Krugman, 1991; Peltoniemi, 2011), most of them only focus on industrial structure alone while neglecting urban spatial process. There is a lack of exploration into how urban land use change is linked with the spatial transformation of industrial activities. Frenken and Boschma (2007) proposed a theoretical framework to investigate industrial dynamics and urban growth, but no specific industrial space is presented or delineated although such understanding of spatial transformation is essential to urban planning and city management. In a practical sense, urban land use change is a continuous transmitting process. Industrial redistribution and residential land use transformation are critical part of urban growth. Reconfiguration of land price space can lead to a redistribution of industrial and residential land use patterns. Likewise, restructuring of industrial and residential land use can alter the spatial structure of land price. This co-transforming process can be better understood through a dynamic simulation perspective.

Drawn on biological metaphors to create computer programming systems, evolutionary algorithm is believed to be one of the promising methods to simulate dynamic transformational problems (Manson, 2005). This paper develops a dynamic simulation method for simulating the spatial transformation process of urban industries. A novel model

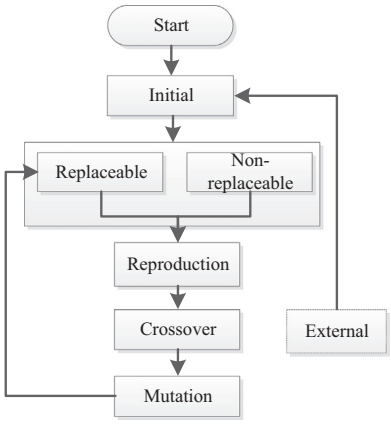

Fig. 1. Framework of GA.