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Measuring urban spatial interaction in Wuhan Urban Agglomeration, Central China: A spatially explicit approach

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ABSTRACT

In the context of globalization and integration, urban agglomeration gradually becomes the basic unit of regional competitions. In addition to urban agglomeration system, spatial interaction has become a popular topic and a key element for sustainable urban development. This paper investigates the typical agglomeration area in Central China-Wuhan Urban Agglomeration (WUA) and uses a spatially explicit approach based on the data field to analyze urban spatial interaction inside the region. Four years of cross-section data are used as case studies to analyze the spatial structure of urban interactions and the dynamic interaction variations. The results indicate that the spatial patterns of "one nucleus and multitude weak" and "the east is stronger than the west" exist in the study area. Spatial interactions among non-core cities were small during the study period. Due to the "Rise of Central China" strategy and integrated construction in the WUA, spatial interactions have increased since 2006. Notably, spatial interactions have become more integrated, and the narrow trend of interaction differences has been represented. Regional spatial interaction gradually develops in a positive direction and leads the urban development into a sustainable way.

1. Introduction

The spatial distribution and organization of cities around the world evolve and transform with globalization, integration and networking in different countries and areas (Gu & Shen, 2003). In the process of urbanization, urban agglomeration gradually replaces the single city as a basic regional unit in global competition and labor division. Recently, the development of urban agglomerations has significantly impacted the international competitiveness of a country more than ever (Gaitani et al., 2014; Scott, 2002; Tan, Liu, Liu, He, & Ming, 2014). Since the implementation of market-oriented economic liberalization reform in 1978, China has undergone and is experiencing an unprecedented degree of urbanization (Fang, Song, Zhang, & Li, 2005; He et al., 2016; Khanna, Fridley, & Hong, 2014; Madlener & Sunak, 2011). In 2007, the urban agglomerations' areas accounted for 21.13% of the total national area of China, while their urban and the associated population and economic contribution accounted for 51.4% and 78.78% of Chinese totals, respectively (Fang et al., 2011). Urban agglomerations have the largest growth potential and have become the most dynamic areas in Chinese economic development. In 2014, the National New Urbanization Plan (2014–2020) was established, in which the development of urban agglomerations and small-medium cities was emphasized (Shan & Huang, 2013).

Along with the transformation of the basic regional competition units, the importance of spatial interaction has been further highlighted. The conversion of research object from the single city to urban agglomeration is also the switching from individual research to systematic research. In addition to concerning the individuals inside the system, spatial interactions among them also deserve attention (Bourne, 1982; Wan & Zeng, 2013). This attention is warranted precisely because of the spatial interactions that make the cities, which are spatially separated from each other, constitute an urban agglomeration system with certain structure and function (Xu, Zhou, & NIng, 2009). In the practical research of urban agglomeration, urban spatial interaction represents the exchange of multiple regional elements, which cover various aspects of production activity and daily activities, including material, energy, population, and information (Hagerstrand, 1968; Ullman & Boyce, 1980). The integration development of urban agglomeration can be promoted though regulating and guiding the relation of urban spatial interaction (Fotheringham, 1983; Haynes & Fotheringham, 1984; Porell & Hua, 1981; Sen & Smith, 2012; Shen, 2002). Relevant regional policies, which play an important role in the regional development (Wu, Zhang, & Shen, 2011), can be adjusted based

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on the analysis of the strength of spatial interaction between different areas to promote healthy regional development. To further reveal the evolution of regional spatial structure and enhance regional development efficiency, more studies of spatial interaction in urban agglomeration area are urgently needed.

Focusing on the regional spatial interaction, a growing body of literature has attempted to measure and evaluate its structure and characteristics (Abreu, De Groot, & Florax, 2004, Balbo & Marconi, 2006, Ekpenyong, Zhang, & Xia, 2015). A series of methods in exploring spatial interaction has developed. The gravity model, which applies Newton's law of gravitation to sociology, is the earliest developed method and first be used to discern the range of retailer's control areas (Reilly, 1929). A wide range of application also happened in subsequent spatial interaction researches. In 1967, Wilson (1970, 1971) proposed the maximum entropy model which reference to statistic mechanics to quantitative analyze the interaction strength between two local areas in a closed system. Microstates statistical characteristic was used to describe macrostates interactive motion in this model. Alonso's Theory of Movements (ATM), which is an alterable and flexible model, describes regional interaction through linking the multidirectional interactions by balancing factors (Alonso, 1973). Population particle pattern method explained the spatial interaction as macroscopic manifestation of the Brownian movement of population, capital and others in two-dimensional space (Wang & Ding, 1994). Along with the emergence and development of artificial intelligence, the artificial neural network was introduced into spatial interaction research and neural spatial interaction model (NSIM) was proposed (Fischer & Gopal, 1994; Fischer & Leung, 1994)

Remarkable achievements have been made by those methods in advancing the analysis of regional interaction. Thereinto, the gravity model based on the concise model structure and precise model indicators has become the most popular method and has a wide scope of empirical application (Cervero & Kockelman, 1997; Graham, 1997; Jang & Kang, 2015; Zhang, 2005). On this basis, related researches have involved the improvement of gravity model from different perspectives. Converse (1949) proposed the breaking point method, which introduce the breaking point into gravity model to explore the location of balance point in regional interaction. It has been diffusely applied in the interaction-based regional segmentation. Potential model based on the basis framework of the law of gravitation to obtain urban total interaction by calculating the interregional interaction between the special city and all of other cities (Geertman and Ritsema Van Eck, 1995; Guagliardo, 2004; Hansen, 1959). Huff model (De Beule, Van den Poel, & Van de Weghe, 2014; Huff David, 1964) was developed to analyze the marketing area of regional interaction by calculating the interaction proportion of each single area in the whole region. Lowry combined the economic base model with gravity model to construct Lowry model (Lowry, 1964), which with higher operational ability and widely used in analyzing interactive influence of urban change on regional scale. Combined with the field theory, data field based spatial interaction approach was proposed with explicit spatial information to measure the strength of spatial interaction based on Euclidean distance (Friedmann, 1986; Wu, Zhang, 2009).

Those improvements further extended the application of gravity model and specially offered efficient solution on regional spatial interaction research. However, parts of which could be improved still exist. The deficiencies mainly reflected in three aspects. First, the spatial interaction is often investigated based on single regional element, such as population or material. The expression of regional comprehensive interaction is incomplete. Second, they measure the multidirectional spatial interaction in an isotropic way: the outward interaction is same as the inward interaction. There is obvious spatial heterogeneity with regional interaction actuality. Third, most of the above models express regional spatial interaction in a statistics way, more attention has not been paid on the spatial explicit of regional interaction in grid level. Data field can achieve the spatial implementation of regional interaction, and it realizes the radiation interactions from the data object to each point in the field by measuring the diffusion effect of urban potential influence following the law of distance decay, however, existed data field based model measures the spatial interaction based on Euclidean distance. The spatial anisotropy of interactive distance inside the region is neglected. Negative influence will be put on the interaction analysis. In order to further analysis the spatial pattern and heterogeneity of spatial interaction, there is an urgent need to improve the data field approach.

The purpose of this paper is to explore the structure and characteristic of spatial interaction inside urban agglomerations. We focus more specially on the Wuhan urban agglomeration (WUA), Central China. A spatially explicit approach based on improved data field is developed. In order to get a spatially explicit result, an improvement on data field was carried out from three aspects: (1) we construct a comprehensive measurement system to obtain urban potential influence which is viewed as field potential of urban object in a regional interaction field. A series of indicators are selected from three aspects, including economy, society and environment; (2) the interaction field of each urban object is respectively established in urban agglomeration area, the directional interaction from the specific urban object to any point in the field can be measured and expressed spatial explicitly; (3) we assess regional accessibility based on regional comprehensive traffic network, which is the noticeable passage of spatial interaction, to catch the spatial anisotropy character. Influences on spatial interaction from different types of traffic modes are effectively considered. Railways, highways and harbors are taken into account. Finally, the spatially explicit approach is employed to explore the whole-cover spatial interaction of WUA in grid level, and to further analyze the interactive characteristic and spatial pattern of regional spatial interaction.

2. Spatially explicit of urban spatial interaction

Spatial interactions are representation of exchange of material, information, funds, and population among different areas, which act over a wide range of temporal and spatial scales. Different areas which are spatially separated can be linked by spatial interactions in many aspects as society, economic, culture and so on (Arlinghaus, 1985; Batty & Longley, 1994; Chen & Zhou, 2001). It plays a significant role in supplying each other's needs, expanding developing space and obtaining developing chances in the whole area. Spatial interaction between two points can be measured straightforwardly with interaction structure of point-line. However, it is difficult to show these interactions cover the whole area, even more challenging is the exhibition of regional interaction in a spatial explicit way. Spatial explicit assessment can identify critical areas of spatial interaction change and give insight in the change of spatial interaction pattern. In order to further understand urban spatial interaction in a comprehensive way, a spatial explicit approach is needed to realize the spatialization of urban spatial interaction.

As a typical spatially explicit method, data field express the full-coverage interaction and its historical change through surveying the radiation differences which come from each data object and influence on the whole area. Better spatially explicit effect will obtain by combining spatial interaction character with location information. In the urban spatial interaction research, relevant improvement on data field will be made based on the differences and similarities between physical space and geographic space. We viewed the Central Business District (CBD) of each city as field source in the spatial interaction field; field potential is represented by the potential influence of urban data object through comprehensive measurement of regional development condition; spatial interaction, which be viewed as field intensity and highly correlated to field potential and spatial distance, is measured based on the actual regional traffic network. The total spatial interaction situation is acquired by field superposition of every single city. The research framework is shown as Fig. 1.

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