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Spatial and temporal distribution of expressway and its relationships to land cover and population: A case study of Beijing, China

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ABSTRACT

The interaction between urban transport, land cover change and the distribution of population is a typical manifestation of the urbanization process. As high-grade road, expressway plays a significant role in promoting resource circulation and economic development. Based on the road distribution, land cover and population census data, this study specifically probed the relationship between the expressways and the land cover and population of Beijing. The results show that: (1) as the distance from an expressway increases, the amount of built-up land gradually decreased, and the transfer of land cover near the expressway was more intensive and frequent when compared with that of the whole city; (2) In 2010, a district that was less than 3 km from both sides of the expressway and which occupies one-quarter of the entire city had concentrations of 42% industrial land, 58% of settlement land, and 76% transportation land of the entire city; (3) As for Beijing, the population density was positively correlated to road density, and population density declined with a corresponding increase in buffer distance; (4) The ring area between the Fifth and the Sixth Ring Road featured the greatest density of expressways and the most dramatic changes in both land cover and population. According to our study, there's a positive interactive feedback relationship between the expressways, land cover and population of Beijing. Also, due to the concentration of population, industry and transport system around the expressways, special attention should be paid to environmental pollution and the inhabitants' health in this area.
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Introduction

Many studies indicate that interactive circular feedback relationships exist between urban transport, land cover and population (Voss and Chi, 2006; Iacono and Levinson, 2009). The construction of transport facilities and an improvement in transport conditions will increase the accessibility of some urban regions, making available the enhanced influences of human activities. Increased access will also promote the emergence of new commercial and residential centers and lead

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to an increase in population (Chi, 2010, 2012; Kotavaara et al., 2011; Ratner and Goetz, 2013). In turn, the changes in land utilization and cover also bring about variations in people's travel activities. Travel demand increases, which in turn induces the formation of transport policies, stimulates road planning and exerts an important influence on the extension and improvement of the transport network (Cervero, 2003; Iacono and Levinson, 2009; Liu, 2009; Wang, 2009). The process of interaction between urban transport, land utilization and cover and population is, in fact, the process of urbanization.

In studies that analyze changes in land cover and population, spatial information technologies, represented by Geographical Information System (GIS) and Remote Sensing (RS), have been commonly used (Weng, 2002; York et al., 2011). Land cover and its changes can be obtained via the interpretation and comparison of remote sensing images taken over time, while GIS provides a spatial statistic tool and mapping tool for the quantitative analysis of such changes (Aljoufie et al., 2013). Meanwhile, GIS not only provides the differences in population in terms of an administrative unit scale, but also shows the distribution and change of the researched population on an even smaller scale (e.g. 1 km or hundreds of meters) (Langford and Unwin, 1994; Gallego, 2010). In addition, when analyzing the influence of transport activities on the natural environment or social economy, the road buffer zone extracted by GIS serves as a common analysis unit. The approach of comparing a specific index within various buffer zones to evaluate whether spatial regularity exists in road influence has been applied in studies of roads on subjects such as ecological influence and heavy metal accumulation, etc. (Larsen and Parks, 1997; Zhang et al., 2002; Schelhas and Sanchez-Azofeifa, 2006).

With the acceleration of China's urbanization process, its urban population has also experienced rapid growth. According to the data obtained from the third to sixth nationwide population censuses, the urban population of China grew from 207 million in 1982 to 666 million in 2010. The latter accounted for 49.68% of the total population of China. As the capital, and also as one of China's largest cities, Beijing is a typical example of the rapid growth of an urban population. By 2010, the urban population of Beijing accounted for 86% of its total population, and had increased in population by 6.336 million people, compared to the year 2000. With the expansion of the city, newly-built urban areas, suburbs and edge cities have become the areas experiencing the most rapid population growth. In order to satisfy the travel demands of people living in these areas, Beijing is striving to develop its rail transit and expressway systems. The improvement in transport conditions has increased the glamour of these areas for more people, leading to increased population concentrations. For the process of interaction between transportation and population, in cases of imbalances and mismatches between transport resources and population distribution, travel demands will not be satisfied, which results in further traffic jams (Aljoufie et al., 2013). Despite the 228 km of metro lines and 900 km of expressways, Beijing still suffers from severe traffic jams (Yu, 2012). The average driving speed on expressways is actually below 20 km per hour during rush hours and on holidays (Beijing Municipal Commission of Transport, http://www.bjjtw.gov.cn/).

As a high-grade road type in the transport system, the expressway exerts obvious influences on both city expansion and population distribution (Wang et al., 1975; Kim, 2007). In this paper, GIS is used to research the spatial and temporal characteristics of expressways in Beijing. The results reveal the basic rules of land cover and the population distribution of the areas around expressways. This study probes the relationship between the expressway and land cover and population. The results of this study are expected to be a theoretical reference for expressway management, urban planning, population sampling surveys and subsequent studies.

Material and methodology

Study area

Beijing is situated at the northern tip of the North China Plain, with its center located at 39°54′20″N and 116°25′29″E. The city covers a land area of 16,411 square kilometers, including 14 districts and 2 counties (Fig. 1). The western, northern and northeastern parts of the area are mountainous and hilly, which accounts for about 61.4% of the city; the remaining part is a plain. According to the urban planning of Beijing, both Dongcheng and Xicheng are traditional inner-city districts. Chaoyang, Haidian, Fengtai and Shijingshan are urban expansion districts. Tongzhou, Shunyi, Fangshan, Daxing and Changping are new urban development districts. Huairou, Pinggu, Mentougou, Miyun and Yanqing are districts dedicated to ecological conservation. According to the fifth and sixth population censuses, the permanent resident population of Beijing in 2000 was 13.57 million people. This increased to 19.61 million by 2010.

Data collection and processing

In this study, both statistical and spatial data of Beijing were gathered and sorted, including road, land cover, population, administrative boundary and DEM. Spatial and mathematical statistical analysis was carried out in ArcGIS 10.0 (ESRI Inc.) and SPSS 18.0 (SPSS Inc.), respectively.

Road

The road data used in this study is the vector data of roads covering the whole city of Beijing in 2010. It is noteworthy that due to the considerable levels of urban traffic flow, the second, third and fourth ring roads, which have a speed limit of no more than 80 km per hour, are not treated as expressways in this study.

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