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Spheres of Urban Influence and Factors in Beijing-Tianjin-Hebei Metropolitan Region Based on Viewpoint of Administrative Division Adjustment

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Abstract: The coordinated development of Beijing, Tianjin and Hebei has been elevated as China's important strategy. And, the priority in considering how to bring the maximum effect of their coordinated development into play is to delineate the spheres of urban influence with regard to the cities in the Beijing-Tianjin-Hebei Metropolitan Region. By building an evaluation index system of urban comprehensive strength, this paper applies the principal component analysis method to determine centrality strength of the cities, and the breakpoint theory and weighted Voronoi diagram to identify the spheres of urban influence in all central cities of the region. Results show that 13 central cities within the region greatly differ in strength, which can be classified into four tiers and that the spheres of urban influence do not have a high goodness of fit with administrative jurisdiction scope. Cities like Beijing, Tianjin, Shijiazhuang and Handan have larger spheres of urban, spheres of urban influence in Tangshan and Qinhuangdao are basically consistent with their administrative jurisdiction scopes, and seven cities including Langfang and Baoding have smaller spheres of urban influence. So according to these cities' comprehensive strength and spheres of influence, the region can be divided into five plates: Beijing, Tianjin, Shijiazhuang, Tangshan and Handan. The major influence factors for inconsistency between spheres of urban influence and spheres of jurisdiction include difference in urban administrative ranking, small number of central cities with weak strength, discrepancy in the number of counties under jurisdiction, unreasonable spheres of jurisdiction and diversity in topographical conditions. In order to solve the imbalance in the spheres of urban influence and those of jurisdiction and better facilitate the coordinated development of the region, it is advised to adjust administrative areas so as to obtain more optimized urban spatial layout and more reasonable urban scale hierarchy system.

Keywords: spheres of urban influence; urban comprehensive strength; adjustment of administrative divisions; weighted Voronoi diagram; Beijing-Tianjin-Hebei Metropolitan Region

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1 Introduction

With the rapid development of social economy, the urban comprehensive strength of the region has improved. Nevertheless, the spheres of urban influence of all cities are classified on the basis of relative strength and the centrality strength of each city is a relative index, so such spheres keep stable to some extent. The delineation of the spheres of urban influence is an important aspect in the study of the interaction among a city and its surrounding cities and regions, which has become a hot issue in recent years (Xie *et al*., 2009). Also known as

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urban hinterland, the sphere of urban influence means the areas where the attraction and radiation of cities play a leading role in the social economic interaction of surrounding areas and it is formed due to the balance of cities spatial interaction at the same level in the region (Wang and Zhao, 2000). The spheres mainly depend on centrality strength and distance among different cities (Liu and Xie, 2011).

The spheres of urban influence are based on Central Place Theory, Breakpoint Theory and Urban Filed Theory and have been studied by the methods like influence attenuation curve, Rd chain, field intensity model, gravity model and weighted Voronoi diagram. Early in the 1920s to 1930s, Reilly (1929; 1931) became the first to propose the Law of Retail Gravitation, which then provided theoretical basis for delineation of spheres of urban influence. On the basis of the theory, Converse (1949) put forward the Breakpoint Theory to interpret the interaction between a city and its surrounding areas. Christaller (1933) illustrated the spheres of urban influence of cities at different levels under ideal conditions in his Central Place Theory. Later, Losch (1954) and Isard (1956) gradually perfected this theory based on the original information. Additionally, Isard (1967) applied the gravity model to analyze the spheres of urban influence and regarded urban population as a major influence factor. On such basis, Wilson (1967) developed the model into the double-restriction gravity model by maximizing entropy functions. Huff *et al*. (1973; 1995) analyzed the spheres of urban influence and urban system for Ireland with gravity model. Aoyama and Kondo (1993) found the shortening of travelling duration caused by the rapid development of Japanese expressways and then they calculated the changes in the spheres of urban influence of major cities by modeling. Boots (1980) and Okabe *et al*. (1997; 2000) believed that the regional structure of the spheres of influence for central areas of a city is a Thiessen Polygon.

The spheres of urban influence also remain a hot topic for researches in China. Chen (1987) calculated the spheres of urban economic influence with influence attenuation curve and analyzed the process of attenuation for the influence of cities with different tiers and scales due to the effect of distance. Wang (2001) applied the gravity model to analyze the spheres of urban influence in 17 major cities. Gu (2002) used the breakpoint model, Rd Chain and other methods to generate a boundary line for the spheres of influence between any two adjacent cities. Wang and Chen (2004) applied the breakpoint model and the field intensity model to make a comparative analysis of the spheres of influence of major cities in the Yangtze Delta. Feng *et al*. (2006) employed the breakpoint model to analyze the spheres of radiation influence of different factors for Zhengzhou. Wang and Guo (2003) analyzed the dynamic changes in the spheres of urban influence of 14 cities in the Yangtze Delta from 1985 to 2000. Pan *et al*. (2008) classified the spheres of influence of the cities at the prefecture level and above with field intensity model and found the poor goodness of fit between spheres of urban influence and spheres of jurisdiction with overlay analysis. Deng *et al*. (2010) analyzed the spheres of urban influence of six provinces in central China with field model. Wang *et al*. (2011) incorporated the regional accessibility factor to improve the traditional field intensity model. Deng *et al*. (2013) and Wang Hao *et al*. (2014) made a comprehensive comparison between the gravity model and the improved field model, two methods for measuring the spheres of urban influence. Wang Kaiyong *et al*. (2014) analyzed the spheres of urban influence of cities in China with time-distance and improved gravity models.

As a space division method, the weighted Voronoi diagram is applicable to accurate measurement of the spheres of influence at the levels of point, line and surface (Gong *et al*., 2012; Kang *et al*., 2013; Tian *et al*., 2014) and has been widely used in the research on the spheres of urban influence. Wang *et al*. (2003) proposed to construct a weighted Voronoi diagram with centrality intensity as weight and then delineate the spheres of urban influence. Based on the above theory, Li *et al*. (2004) made an improvement, proposed the combination of Breakpoint Theory and weighted Voronoi diagram. Quite many scholars applied the weighted Voronoi diagram to separate the spheres of urban influence of all regions (Wu and Yan, 2009; Zhao *et al*., 2010; Gu *et al*., 2014).

In 2014, the coordinated development of Beijing, Tianjin and Hebei has elevated as China's significant strategy. President Xi Jinping proposed that we should break the administrative barriers and emphasized coordinated development of different administrative areas, which reflected the thought of integration. It is urgently required that the administrative barriers should be bro-

ken in the coordinated development. Thus, the determination of the spheres of urban influence in major cities of Beijing, Tianjin and Hebei has become an important basis for administrative division adjustment.

Most of the previous researches on the spheres of urban influence focused on the classification of urban economic regions and metropolitan areas rather than the adjustment of administrative divisions. Based on Breakpoint Theory and weighted Voronoi diagram, this paper classifies the spheres of urban influence in 13 central cities of Beijing, Tianjin and Hebei and analyzes if the spheres of urban influence are consistent with those of jurisdiction. This paper may provide guidance with the optimized integration, rational resource allocation, adjustment of administrative divisions and perfection of urban system of Beijing-Tianjin-Hebei Metropolitan Region.

2 Materials and Methods

2.1 Study area

Beijing, Tianjin and Hebei are the third metropolitan region of China, with a total area of approximately 217 000 km^2 and total permanent resident population of 1.09×10^8 (Fig. 1). By the end of 2013, the region had 13 central cities including Beijing, Tianjin and the other 11 cities at the prefecture level. Besides, there were 118 counties and 27 cities at the county level in the region. Although the region currently includes two municipalities and one province in terms of administrative division, it was under the jurisdiction of Zhili Province in the Ming and Qing Dynasties with close culture, connected areas and closely linked social and economic development. As an inseparable unit, the region was pinned great hopes on its integrated development. The *National New-type Urbanization Plan* (2014–2020) and the *Outline for Planning of Coordinated Development of Beijing*, *Tianjin and Hebei* explicitly identify Beijing, Tianjin and Hebei as a world-class metropolitan region and propose that populations and industries should be encouraged to be transferred from metropolises to adjacent cities and towns. Hebei will gradually get rid of the siphoning effect brought by Tianjin and Beijing and produce the influence of radiation. With Beijing- Tianjin-Hebei Metropolitan Region as research focus, this paper is able to provide a better reference for improving the comprehensive strength and influence of Chinese cities, coordinated development of urban clusters and optimization of urban system.

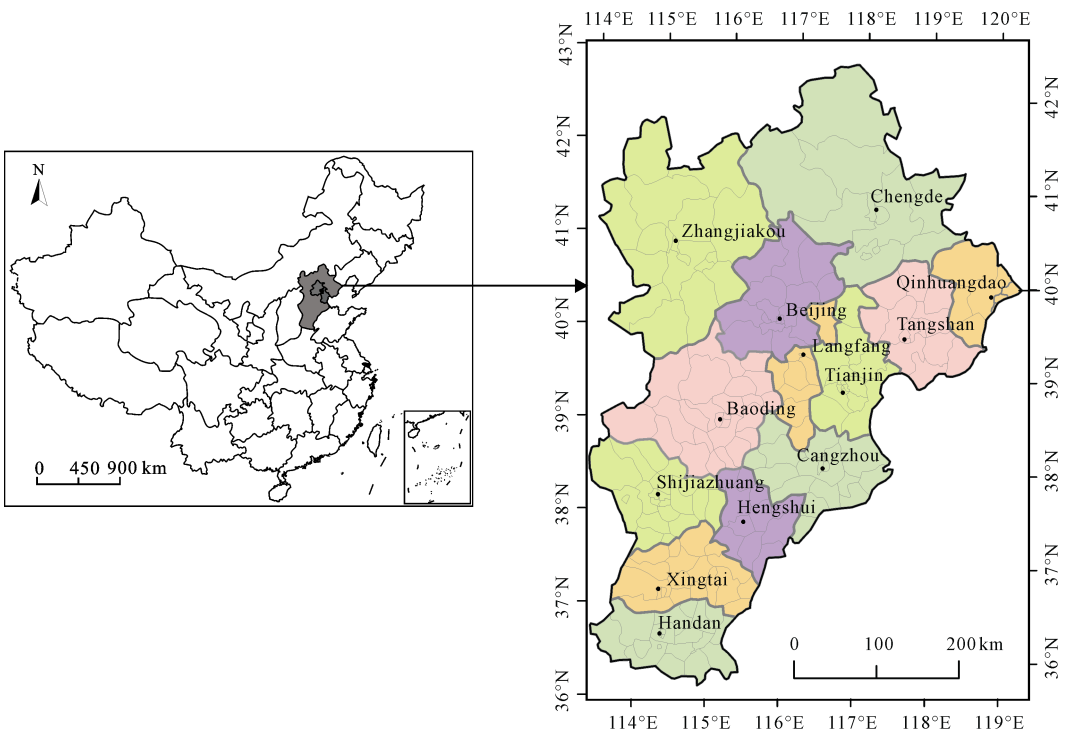

Fig. 1 Location map of Beijing-Tianjin-Hebei

2.2 Data sources

The index data cited in this paper are the data of the cities at the prefectural level and above of Beijing, Tianjin and Hebei as of late 2013, directly from China City Statistical Yearbook 2014 (National Bureau of Statistics, 2014). Map data come from the Center for Resources and Environmental Sciences, of Chinese Academy of Sciences. County-level administrative divisions of Beijing-Tianjin-Hebei Metropolitan Region in 2013 are regarded as base map and government residents of all central cities as their central positions.

2.3 Methods

2.3.1 Building urban comprehensive strength index system

Urban comprehensive strength involves influence and effects in terms of economy, society, culture, technology and transport. The traditional evaluation methods tend to adopt a single index (such as population and economy) or only a few indexes, which fail to reflect urban influence in a complete, objective and comprehensive manner. Based on the principles of systematicness, comparability and operability, this paper analyzes the influence of 13 central cities of Beijing, Tianjin and Hebei with comprehensive index system and measures the actual level of urban comprehensive scale in a complete and objective manner with variables of 30 indexes on economic growth, social development, urban construction and foreign exchanges (Table 1). Among them, economic growth indexes reflect cities financial strength; social development indicators show the living quality of residents covering employment, school, hospital and library; urban construction indicators reflect the scale of infrastructure including housing, road, and greenbelt; and foreign exchanges indicators show flow of personnel, goods and information to the outside.

Table 1 Comprehensive strength evaluation index system of Beijing-Tianjin-Hebei

Index class	Index
Economic growth	GDP (X_1)
	General local fiscal budget revenue (X_2)
	Urban investment in fixed assets (X_3)
	Actual utilization of foreign capital in the year (X_4)
	Total retail amount of social consumables (X_5)
	Deposits of banking system national at year-end (X_6)
	Loans of National Banking System at Year-end (X_7)
Social development	Totalpopulation as of the end of the year (X_8)
	GDP per capita (X_9)
	Persons Employed in Various Units at Year-end (X_{10})
	Full-time teachers in regular institutions of higher education (X_{11})
	Students in regular institutions of higher education (X_{12})
	Collection of books in public libraries (X_{13})
	Number of doctors (X_{14})
	Number of Beds of Hospitals and Health Centers (X_{15})
Urban construction	Area of built-up area (X_{16})
	Area of Land Used for Urban Construction (X_{17})
	Area of residential land (X_{18})
	Area of roads (X_{19})
	Area of green land (X_{20})
	Number of buses (X_{21})
	Power consumption (X_{22})
	Water supply (X_{23})
Foreign exchanges	Passenger capacity (X_{24})
	Freight gross (X_{25})
	Telecommunication traffic (X_{26})
	Post service volume (X_{27})
	Number of Internet users (X_{28})
	Number of Subscribers of Local Telephones (X_{29})
	Number of Subscribers of Mobile Telephones (X_{30})

2.3.2 Breakpoint Theory

Breakpoint Theory is a theory regarding interaction between a city and a region, which is developed by Converse based on the Reilly's Law of Retail Gravitation. The theory believes that the influence of a city over its surrounding areas is proportional to its scale and inversely proportional to the square of distance. The breakpoint (or cut-off point) of influence areas of two cities is expressed in the following formula:

$$d_A = \frac{D_{AB}}{1+\sqrt{\frac{P_B}{P_A}}} \quad d_B = \frac{D_{BA}}{1+\sqrt{\frac{P_A}{P_B}}} \tag{1}$$

where d_A and d_B mean distance from breakpoint to two cities respectively; D_{AB} and D_{BA} mean distance between cities A and B; and P_A and P_B mean the populations of the two cities.

However, in reality, population is only one of the multiple factors for urban influence. By building a set of comprehensive index system, this paper applies the principal component analysis method to calculate the comprehensive strength of central cities, and obtain the value of centrality intensity by means of data conversion as substitute for urban population.

The following inferences can be obtained through

analysis of breakpoint formula:

Inference 1: The Euclidean distance of any two adjacent cities is equal to the sum of the Euclidean distance of the two cities to the breakpoint.

$$d_A + d_B = D_{AB} \tag{2}$$

Inference 2: The distance of the breakpoint to two adjacent cities is proportionate to the square roots of centrality intensity of the two cities, which is expressed as follows:

$$\frac{d_A}{d_B} = \sqrt{\frac{P_A}{P_B}} \tag{3}$$

Inference 3: Within a homogenized planar region, with each city as element of generation, the speed of its influence expansion is proportionate to the centrality roots of two adjacent cities. a_1 and a_2 mean expansion speed of two adjacent elements of generationfor a given planar point, which is expressed as follows:

$$\frac{a_1}{a_2} = \sqrt{\frac{P_A}{P_B}} \tag{4}$$

2.3.3 Weighted Voronoi diagram

The Voronoi diagram was first proposed by Voronoi, a Russian mathematician, in 1908. In 1911, Thiessen, a meteorologist of the Netherlands, applied the diagram in meteorologic observation. The extensive application of Voronoi in spatial analysis represents a common method for delineation of the spheres of influence by target space. The regular Voronoi believes that within the a homogenized planar region, if each city has the same influence (or weight of space target), the breakpoint will be the midpoint for the line connecting two adjacent cities and the dividing line for the spheres of influence will be the perpendicular bisector for the line connecting the two cities. However, in reality, cities have different centrality intensity and expand towards surrounding areas at the speed of their influence, thus forming the spheres of their influence. The dividing line is a circular arc. The above is just the basic ideas of the weighted Voronoi diagram. The definition of the diagram is described as follows:

Let P_i (i =1, 2, …, n) be n points in a 2Deucli-deanspace and λ_i (i =1, 2, …, n) are the n real numbers given. The plane is divided into n parts. The division of the plane determined by $V_n(P_i, \lambda_i)$ is called the Voronoi diagram for the weighted point and$\lambda_i$is called as weight of P_i.

$$Vn(P_i, \lambda_i) = \bigcap_{j \neq i} \{P \mid \frac{d(P, P_i)}{\lambda_i} < \frac{d(P, P_j)}{\lambda_j}\} \ (i = 1, 2, \ldots, n) \tag{5}$$

Formula (5) indicates Voronoi polygon with larger weighthas even larger area.

3 Results

3.1 Measurement of urban comprehensive strength

30 characteristic parameters of 13 central cities of Beijing, Tianjin and Hebei were built into a 13 × 30 raw data matrix. In order to the eliminate the impacts by order and dimension and prevent the negative values of the indexes after normalization from going against the following operations, this paper makes a standard treatment of raw data for indexes by Maximum difference normalization method. Let X_{ij} be the original statistical data of variable j in city i, then:

$$M_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{6}$$

SPSS software was applied to make an analysis of main components, the factor with characteristic value larger than 1 was selected as theprincipal factor. Moreover, first two major factors were selected to replace 30 indexes. Then, the integrated score of main components was calculated and cities were sorted with the variance contribution rate as weight.

It can be observed that the integrated scores of some cities are negative. Therefore, the minimum-maximum normalization method was adopted to carry out data conversion of the raw data column and map it in a new data interval to form a new data column. The formula is shown as follows:

$$v' = \frac{v - \min A}{\max A - \min A}(\text{new\_}\max A - \text{new\_}\min A) + \text{new\_}\min A \tag{7}$$

where v' refers to the data after normalization; v means raw data; max$A$ and min$A$ mean the maximum and minimum values of the raw data column; and new max$A$ and new_max$A$ mean the maximum and minimum values of the mapping interval.

As the maximum value of the major indexes for 13 cities is around 20 times of their minimum value, data

Table 2 Comprehensive strength and orders of 13 central cities

City	Beijing	Tianjin	Shijiazhuang	Tangshan	Baoding	Handan	Cangzhou	Qinghuangdao	Langfang	Xingtai	Zhangjiakou	Chengde	Hengshui
Integrated score	2.493	1.276	0.051	–0.015	–0.231	–0.271	–0.340	–0.428	–0.463	–0.485	–0.502	–0.534	–0.550
Centraliy intensity index	20.00	12.40	4.76	4.34	2.99	2.75	2.31	1.76	1.54	1.40	1.30	1.10	1.00
Order	1	2	3	4	5	6	7	8	9	10	11	12	13

conversion was conducted on the integrated scores of these cities within the closed interval of [1, 20]. The result of calculation is shown in Table 2. The 13 cities are divided into four tiers according to the centrality intensity indexes of these cities.

First-tier central city: Beijing and Tianjin. The centrality strength index of the two cities is larger than 12. Both cities are not only municipalities with higher administrative ranks directly under the central government, but also classified into megacity behemoths with a population of more than 10 million in terms of scale. All indicators are far higher than those of the other cities. Thus, they are core cities of the region.

Second-tier central city: Shijiazhuang and Tangshan, two cities with the greatest strength in Hebei Province. The centrality intensity index of each city lies between 4 and 5 and are classified into Type I metropolises in terms of scale. They are two central cities located in the north and south of Hebei Province respectively.

Third-tier central city: Baoding, Handan and Cangzhou. The centrality intensity index of each city is around 3. Baoding and Handan are classified into Type II metropolises and Cangzhou is a coastal port city, with strong comprehensive strength. Thus, the three cities are classified into sub-central cities in the region.

Fourth-tier central city: Qinhuangdao, Langfang, Xingtai, Zhangjiakou, Chengde and Hengshui, with centrality intensity index being lower than 2. They are classified into Type I medium-sized city in terms of scale and belong to node cities of the region.

3.2 Overlap analysis of spheres of urban influence and spheres of jurisdiction for central cities

The spheres of urban influence are delineated with the cities at the prefecture level according to centrality strength and distance of cities. Fig. 2 shows the intensity of radiation influence of central cities over each point in the region. It can be seen that the nearer each point gets to central cities, the greater influence it will receive. Beijing, Tianjin and Tangshan are under the greatest urban influence, followed by Baoding, Shijiazhuang and Handan, *etc*., which are located along the Beijing-Guangzhou Railway Line. Both southwest and southeast parts of the region are weakly influenced as the southwest part is mostly mountainous area, far away from central cities, and in the southeast part, Hengshui and Xingtai, *etc*. have a low centrality strength and do not cause a high influence over surrounding areas.

Nevertheless, only the intensity of influence of all cities over surrounding areas can be observed and the spheres of influence by these cities fail to be accurately delineated. By the function module of Weighted Voronoi Diagram in the ArcGIS software, the weighted Voronoi diagram with multiple closed boundaries (or spheres of spatial influence of each city) was constructed, with the government residents of 13 cities at the prefecture level of Beijing, Tianjin and Hebei and square roots of centrality

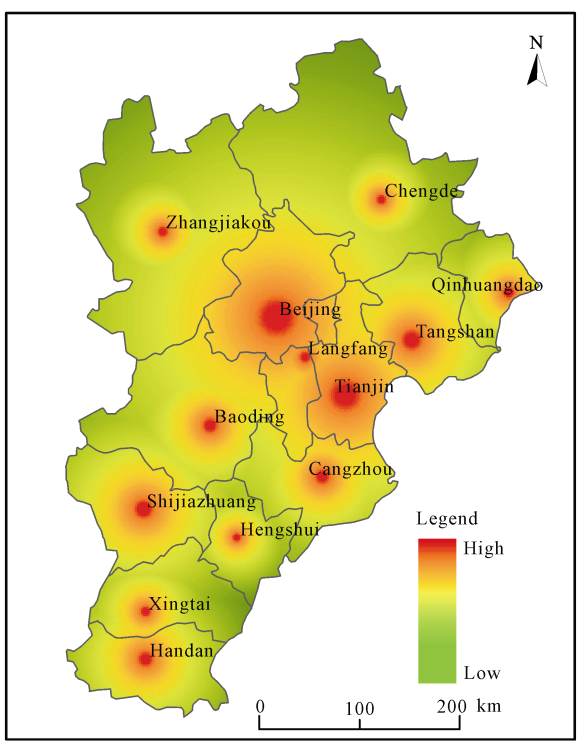

Fig. 2 Urban influence intensity of Beijing- Tianjin-Hebei

intensity as weight. The boundaries of enclosed unit are just the fault arcs of influence among adjacent cities (Fig. 3). It can be found that for two adjacent spheres of influence, the bending orientation of fault arc always points to the cities with larger centrality intensity.

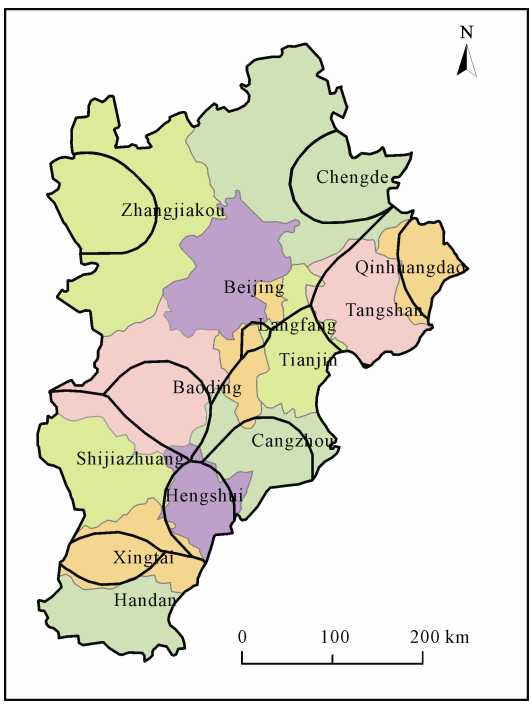

Fig. 3 Spheres of Influence with Regard to cities of Beijing-Tianjin-Hebei

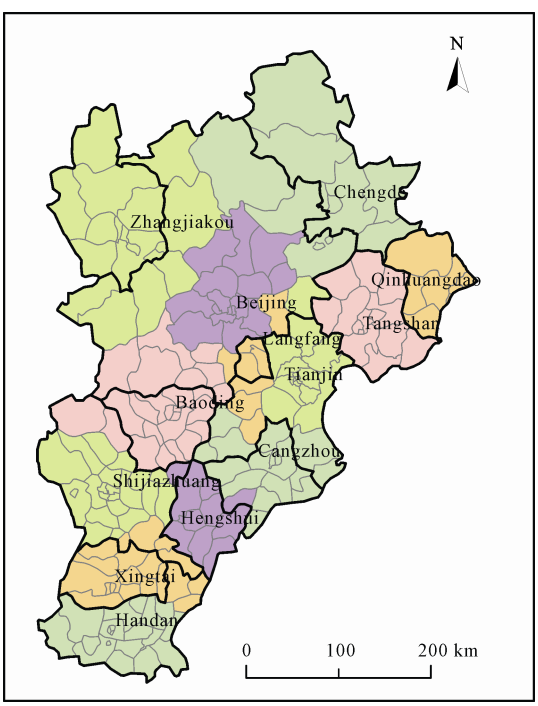

Fig. 4 Spheres of Influence with Regard to cities of Beijing-Tianjin-Hebei based on county boundary

It can be seen according to the area of spheres of influence for each central city, Beijing has an overwhelming advantage, with an 83 500 km^2 area of influence, 38.9% of the total area of the region. And Langfang has the smallest area of influence with only 993 km^2, 0.46% of the total area of the region. The size of the spheres of influence of the former is 84 times of that of the latter, with a huge gap.

However, the size of spheres of a city's influence is not completely proportionate to its centrality intensity as spheres of urban influence also depend on the distance with adjacent cities in addition to centrality intensity of a city. For example, Tianjin ranks the second place in terms of overall strength but the size of its influence is slightly smaller than Shijiazhuang. It is mainly due to the fact that Tianjin is surrounded by Beijing, Tangshan, Cangzhou and other cities with strong strength and is highly constrained in terms of the expansion of its influence towards the outside. Another important reason is that Tianjin is a coastal city near the southern Bohai Sea. There is no way for its urban influence to radiate towards the direction. And Shijiazhuang is surrounded by no city with strong strength and far away from its surrounding cities. Also, as an inland city, the city can make its influence radiate towards the surrounding areas, thus producing a larger urban influence. In addition, although Hengshui has the lowest centrality intensity among the 13 central cities, the size of the spheres of its spatial influence is more than 7 times of that of Langfang. That is due to the fact that no cities with strong strength are located around Hengshui while Langfang is located between the powerful Beijing and Tianjin and affected by their 'shadow', thus having narrow spheres of influence.

However, the Voronio diagram regarding the spheres of urban influence shown in Fig. 3 is completely ideal and can not fully reflect the true conditions. The integrity of county-level administrative divisions and influence of the terrain factor should only be taken into account in the overlap analysis. Thus, it is required that the result of the spheres of urban influence initially delineated should be modified (Fig. 4). It is found through overlap comparison between spheres of influence and those of jurisdiction of all central cities, they do not have a high goodness of fit but deviate from the ideal model proposed in the Central Place Theory.

As the top city in the region, Beijing does influence

all of its administrative divisions and 22 counties and cities as well, including Jixian county in Tianjin; Huailai, Zhuolu, Chicheng, Guyuan, Yuxianand Yangyuan in Zhangjiakou; Fengning, Luanping, Xinglong and Yingshouyingzi in Chengde; Sanhe, Dachang, Xianghe and Gu'an in Langfang; Zhuozhou, Yixian, Laishui, Laiyuan, Gaobeidian, Dingxing and Xiongxian in Baoding. The size of spheres of urban influence for Beijing is 3.86 times of the spheres of its jurisdiction. And there are more than 30 million permanent residents in its spheres of urban influence.

The scope of influence in Tianjin is 1.5 times of that of its administrative area. Although Jixian is under the influence of Beijing, Tianjin influences Bazhou, Wenan and Dacheng in Langfang; Huanghua, Haixing, Renqiu, Hejian and Suning in Cangzhou with its strong comprehensive strength.

The scope of influence in Shijiazhuang is 1.4 times of that of its administrative area.It influences all of its administrative divisions and Fuping and Quyang in Baoding; Anping in Hengshui; and Baixiang, Ningjin, Xinhe and Nangong in Xingtai as well.

The scope of influence in Handan is 1.2 times of that of its administrative area. It influences all of its administrative divisions and also Linxi, Qinghe and Weixian in Xingtai.

What is worth mentioning is that the spheres of influence of Tangshan and Qinhuangdao are basically consistent with the spheres of their jurisdiction, indicating rational jurisdiction. So the two cities have fully produced their influence.

Langfang, with the smallest spheres of influence, only constitutes over 26% of its administration divisions and radiates towards three counties and other seven cities are highly influenced by Beijing and Tianjin. The size of spheres of urban influence of Baoding is 42% of that of spheres of its jurisdiction and some counties in its southern and northern parts are highly influenced by Beijing and Shijiazhuang respectively. The size of spheres of urban influence of Zhangjiakou and Chengde is 51% and 60% respectively of that of its spheres of their jurisdiction as the two cities are located on the northwest to the northeast of Beijing and a lot of counties are highly influenced by Beijing. Additionally, the size of spheres of urban influence of Cangzhou, Xingtai and Hengshui is smaller than that of their jurisdiction, showing insufficient comprehensive strength.

According to the comprehensive strength and spheres of influence of cities in the region, five central cities may be selected and each acts as one independent plate according to the spheres of their influence (Table 3). The spheres of influence of the five central cities are shown in Fig. 5.

It can be shown from Table 3 and Fig. 5 that Beijing is absolutely a core city in the region and has the largest area of plate, nearly half of the total area of the region. Tianjin is the second largest plate in the region; however, its influence is greatly restricted due to its small distance from Beijing and Tangshan, neighboring from Bohai Sea so that the spheres of its influence only cover part of Cangzhou, Langfang and Hengshui. Tangshan

Table 3 Delineation of spheres of urban influence of five central cities

Central city	Spheres of urban influence
Beijing plate	Beijing, Zhangjiakou, Chengde, northern Langfang, northern Baoding, Jixian (Tianjin)
Tianjin plate	Tianjin (except Jixian county), Cangzhou, southern Langfang, eastern Hengshui
Tangshan plate	Tangshan, Qinhuangdao
Shijiazhuang plate	Shijiazhuang, western Hengshui, southern Baoding and northern Xingtai
Handan plate	Handan, southern Xingtai

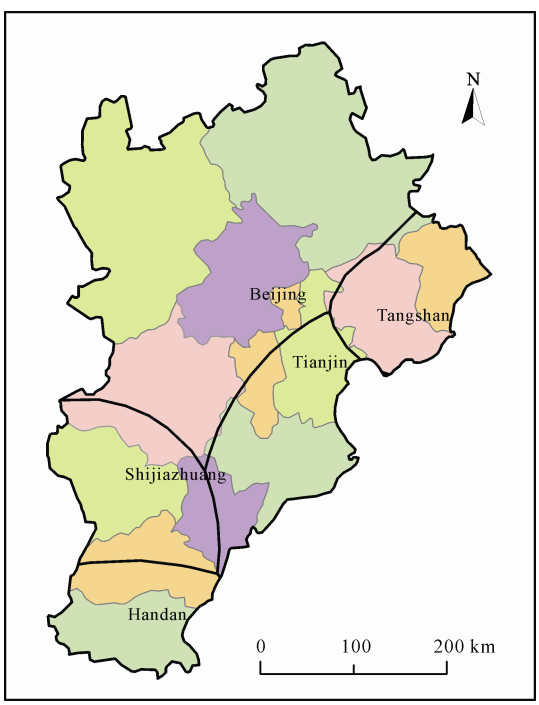

Fig. 5 Spheres of urban influence of five central cities in Beijing-Tianjin-Hebei

ranks the third place in terms of comprehensive strength; nevertheless, it can only cover Qinhuangdao due to the fact that it is located in the northeast. As the capital city of Hebei, Shijiazhuang ranks the fourth place in terms of comprehensive strength and the spheres of its influence are mainly distributed in the middle and southern parts of the region. Handan, as the southernmost central city of the region, covers the whole city and half of Xingtai due to its unique location conditions.

4 Influence Factors and Suggestions on Adjustment of Administrative Divisions

4.1 Influence factors regarding inconsistency between spheres of urban influence and Jurisdiction

4.1.1 Influence Factors for spheres of urban influence larger than spheres of jurisdiction

Beijing, Tianjin, Shijiazhuang and Handan influence more areas than their own administrative regions, in which administrative ranking is an important influence factor. Beijing is not only a municipality directly under the central government but also the capital of China. It attracts talents and resources from the whole country and enjoys the strongest comprehensive strength in the region. However, it only has two counties under its jurisdiction, equivalent to a city at the prefecture level. Also acting as a municipality directly under the central government, Tianjin has only three counties under its jurisdiction. Therefore, the spheres of influence of the two cities are far larger than their jurisdiction, typically 'big horse pulling a small carriage'. While as the capital city of Hebei Province, Shijiazhuang enjoys higher administrative regions and more distinct advantages in terms of resources allocation than other cities, thus obtaining even larger spheres of influence. It is studied that the higher the administrative rank is, the larger the urban population and the better social-economic development will be (Chan and Zhao, 2002). And Handan, located in the southernmost of Hebei, takes unique location advantage and has a larger urban scale compared with its surrounding cities. Thus, it can be developed into a sub-central city with larger spheres of influence.

4.1.2 Influence factors for spheres of urban influence smaller than spheres of jurisdiction

(1) The number of central cities is small and their strength is weak. Although the two provinces and one municipality in the Yangtze River Delta (namely Shanghai, Jiangsu and Zhejiang) are similar to Beijing-Tianjin-Hebei Metropolitan Region in size, they have 25 central cities at the prefecture level under their jurisdiction, about twice of the Beijing-Tianjin-Hebei Metropolitan Region. Additionally, although Shandong and Henan have a smaller population than Beijing, Tianjin and Hebei, they have 17 central cities under their jurisdiction, far more than the number of cities of Beijing, Tianjin and Hebei. Also, most of the cities in the region have weak comprehensive strength and the centrality intensity of half of the cities is not more than 1/10 of Beijing, thus producing a low influence.

(2) Large number of counties with small area. By the end of 2013, there were 135 counties (county-level cities) in Hebei Province, and ranked the second place in terms of number of counties, only one county less than Sichuan. Except the northern mountainous area, most of the counties have a small area and the smallest county, Dachang, only has an area of 176 km^2. There are 25 counties whose administrative area is smaller than 500 km^2. The issue that there are a number of counties with small area in the middle and southern plain area of the region is caused by historical factors to a large extent. However, under the background of market economy, fragmented administrative divisions at the county level lead to low economic competitiveness of counties and difficulty in forming large cities.

(3) Unreasonable jurisdiction of central cities. Baoding ranks the fifth place in the region in terms of comprehensive strength but has 22 counties and county-level cities, but it can only influence half of these cities. Besides, Lanfang, Hengshui and Xingtai, *etc*. are typically of the case. In the Central Place theory of Christaller, the highest efficiency will be obtained if each central city at higher level (city at the prefecture level) in the plain administrates six sub-central cities (cities at the county level). However, each city at the prefecture level has 12.3 counties (county-level cities) under its jurisdiction on average, far beyond the optimum spheres of jurisdiction proposed in the theory.

(4) Large difference in terrain conditions of the region. The region is surrounded by Yanshan Mountains on the north, Taihang Mountains on the west, Bohai Sea on the east and North China Plain on the middle and south. Chengde and Zhangjiakou in the north are located in mountainous areas and have a small density of popu-

lations, with a small scale and spheres of urban influence. However, they have a large area of jurisdiction, namely 39 500 km^2 and 36 300 km^2, more than one third of the total area of the region. While the middle and south parts of the region are located in the North China Plain, they have a large density of populations and a dense distribution of cities and each central city has relatively small spheres of jurisdiction. So it can be shown that the difference in terrain conditions of the region is also an important factor.

4.2 Suggestions on administrative divisions adjustment of region

4.2.1 Cultivating new central cities

The farther central cities are from center, the lower influence they will produce. It is advised that spatial plan and urban system plan should be prepared as soon as possible based on the Outline for Coordinated Development Plan of Beijing, Tianjin and Hebei and new central cities should be built to drive the development of surrounding county-level cities. These cities may undertake some functions of the Beijing and ease the resource and environmental pressure faced by the capital. Also, new central cities should be built into traffic hubs and their radiation capacity should be enhanced so as to ease the traffic pressure of Beijing and optimize spatial layout.

For example, as central cities produce a low influence over counties like three counties (Sanhe, Dachang and Xianghe) in the north of Langfang, Zhuozhou and other counties in the north of Baoding, new central cities or prefecture-level cities should be developed. It is advised to change Sanhe and Zhuozhou into prefecture-level cities and make Dachang and Xianghe under the jurisdiction of Sanhe and Laishui, Laiyuan, Yixian, Dingxing, Gaobeidian and Xiongxian under the jurisdiction of Zhuozhou. After such incorporation, the pattern of spheres of influence would be better optimized (Fig. 6). It can not only solve the problem of low centrality of Langfang and Baoding and the difficulty in radiating towards all areas under their jurisdiction but also ease the excessive pressure caused by Beijing's influence. Also, the building of the two new prefecture-level cities would better take over the non-capital functions of Beijing, better facilitate the coordinated development of Beijing and Tianjin and bring about great opportunities to their own development.

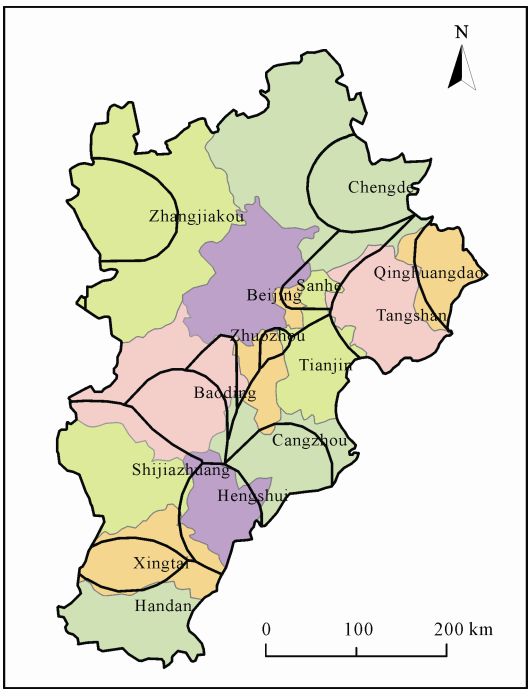

Fig. 6 Spheres of urban influence of Beijing-Tianjin-Hebei, after Sanhe and Zhuozhou were upgraded to the prefecture level cities

4.2.2 Expanding the spheres of jurisdiction of Beijing and Tianjin

Zhangjiakou and Chengde in the north of the region have a low influence without strong county-level city under their jurisdiction. It is advised to put some county-level cities of the two cities adjacent to Beijing under Beijing's jurisdiction. There are about 2 000 000 poor residents and a lot of state-level poverty counties surrounding Beijing. After the incorporation of some county-level cities, the ecological compensation mechanism and the powerful radiation influence of Beijing can better drive the development of these counties. Similarly, it is also advised to incorporate some counties under the jurisdiction of Langfang and Cangzhou to Tianjin. Such delineation is not without precedent in history. Hebei delineated eight counties including Yanqing, Miyun, *etc*. into Beijing in 1958 and five counties like Jixian and Baodi to Tianjin in 1973. With the increasingly enhanced strength of Beijing and Tianjin, proper expansion of jurisdiction will bring about benefit to the overall development of the region.

4.2.3 Establishing municipal districts by removing some counties (county-level cities) to enhance strength of central cities

A lot of prefecture-level cities in Hebei Province have

poor strength and small area under their jurisdiction, with insufficient population agglomeration. Also, the urban areas of these cities are surrounded by suburb counties and even a lot of such counties have thesame names as the prefecture-level cities, such as Handan Country in Handan, Cangxian County in Cangzhou, Xingtai County in Xingtai, and Chengde County in Chengde. It is advised to change these suburb counties to districts. It can facilitate the expansion of development space of central urban areas and optimization of spatial structure of urban areas. Also, all the central cities can develop their characteristic industries according to their functional orientation in the region so as to improve the influence of these cities.

4.2.4 Shifting counties with larger populations and strong comprehensive strength to county-level cities

Some counties with strong strength may be developed into sub-central cities under the jurisdiction of prefecture-level cities, which would enhance development vigor and drive regional economic growth. Also, these small cities may take over some functions of large cities so as to realize industrial connection between two types of cities and full matching in development. The increase in the number of small cities in the regions would help to optimize urban layout and form a network-like multi-layered urban system with a combination of small-, medium- and large-sized cities.

4.2.5 Moderately incorporating county-level administrative divisions and reducing their number

There are many districts under the jurisdiction of prefecture-level cities and they are completely surrounded by suburb counties, for example, Jingxing Mining District and Jingxing County, Yingshouyingzi Mining District and Xinglong County. The integration of districts and counties does not only enhance the strength of county-level administrative divisions and optimize the spatial structure of urban areas but also help to improve the efficiency of jurisdiction. The incorporation of some adjacent small counties would help to simplify organizations and reduce administrative costs. Also, it can enhance the economic strength of the counties and lay a foundation for the direct administration of counties by province.

5 Discussion and Conclusions

By building a set of comprehensive index system measuring the comprehensive strength of cities, this paper applies the principal component analysis method to calculate the comprehensive strength of central cities and then employs the Breakpoint Theory and weighted Voronio diagram to delineate the spheres of urban influence of 13 central cities. The following conclusions are reached:

Four tiers of cities are divided according to their overall strength. First-tier cities, Beijing and Tianjin, are core cities of the region; second-class central cities including Shijiazhuang and Tangshan, are two cities with the greatest strength in Hebei Province; third-tier cities, including Handan, Baoding and Cangzhou, belong to sub-central cities in the region; fourth-tier central cities like Qinhuangdao, Langfang, Xingtai, Zhangjiakou, Chengde and Hengshui, are node cities of the region.

The spheres of influence with regard to all central cities of Beijing, Tianjin and Hebei do not match the spheres of their jurisdiction. Beijing, Tianjin, Shijiazhuang and Handan have larger spheres of urban influence; both spheres for Tangshan and Qinhuangdao are basically consistent; Langfang, Baoding, Zhangjiakou and Chengde have smaller spheres of urban influence. Beijing has the largest spheres of influence, 84 times of the spheres of Langfang. The region is thus divided into five plates according to their comprehensive strength and spheres of influence: Beijing, Tianjin, Tangshan, Shijiazhuang and Handan.

Finally, this paper analyzes the major influence factors regarding inconsistency between spheres of urban influence and of jurisdiction and makes five pieces of suggestions on the irrational administration divisions of the region. 1) Cultivating new central cities, like Sanhe and Zhuozhou; 2) moderately expanding the spheres of jurisdiction of Beijing and Tianjin; 3) establishing districts by removing some county-level cities to enhance the strength of central cities; 4) changing the counties with larger populations and stronger comprehensive strength to county-level cities; and 5) moderately incorporating county-level administrative divisions and reducing their number.

It is important for the research of spheres of urban influence to optimize regional spatial layout and urban system. Administrative division adjustment plays an important role in regulating the spheres of urban influence and helps to optimize the spatial layout of urban areas, accelerate balanced urban-rural development,

perfect urban scale hierarchy system and better promote the coordinated development of Beijing, Tianjin and Hebei Region.

Due to the complex delineation of spheres of urban influence, we are still at the stage of exploration. The conclusions of this paper are only approximate classification of the spheres of influence of Beijing- Tianjin-Hebei region under ideal conditions. First, further optimization needs to be conducted regarding the building of urban comprehensive strength index system; indexes selection and principal component analysis are subjective process and the methods for measuring comprehensive strength of cities are quite simple. Second, this paper ignores the heterogeneity of the region and only takes the integrity of county-level administrative divisions into account. In the future, we should consider incorporating terrain conditions, traffic accessibility, regional culture recognition and other factors into the research on the spheres of urban influence so as to make the results more scientific.

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