International Journal of Geographical Information Science

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713599799

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First published on: 04 November 2008


To link to this Article DOI: 10.1080/13658810802363614

URL: http://dx.doi.org/10.1080/13658810802363614

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Research Article

Research on the Urban Influence Domains in China

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(Received 22 February 2008; in final form 21 July 2008)

Through research on the gravity model, the paper studies the geometric characteristics of urban influence domain and the principles for the change of urban influence domain along with the evolution of distance decay index, calculates the distribution of the gravitational field by using ARCGIS, establishes a spatial cluster system for the megalopolis in china, delineates urban influence domains by dissolving spatial features, and compartmentalizes China into 13 economic regions based on the megalopolis clusters and urban influence domains combining with the physical and economic locations. Major conclusions are: the distribution of urban gravitational field is the manifestation of regional unbalanced development; the spatial structure and characteristic of urban system can be studied through the distribution situation of urban gravitational field; the urban influence domains in China have not formed the mosaic structure of a standard regular hexagon; the economic region with weak urban gravitational field may be compressed by the region with stronger urban gravitational field.

Keywords: gravity model; urban agglomerations; urban influence domain; China

1. Introduction

To this day, the theory involving urban system and urban influence domain is relatively matured, and there are also lots of empirical researches. Famous theoretical contributions to this research field are the Central Place Theory (Christaller 1933), the extension to the Central Place Theory (Losch 1954), and the modification to the Central Place Theory (Isard 1956). Empirical researches are grading for the villages of England and Wales (Smailes 1944), research on China’s rural market and social structure (Skinner 1964), research on China’s urban influence domain compartment for Henan Province (Li et al. 2004), theoretical analysis on dividing urban influence domains (Yin 2005), reparation of metropolitan areas and megalopolis areas in China (Wang and Ye 2009).

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2004), and geographic information system (GIS) method study on dividing urban influence domains (Wang et al. 2004). This paper will calculate high-accuracy spatial distribution pattern of urban gravitational field for 670 cities, including Xianggang (Hong Kong), Aomen (Macau) and cities in Taiwan, delineate the influence domain of the cities, define the core urban areas by using gravity model and GIS technology, and delineate the city group, urban system, and economic zones.

Previous work defined the urban influential domain mainly by polygons, such as the central place studies by Christaller and Isard. The unique contribution of this paper to the literature is to confirm the theoretical shape of urban influential region, and show the detailed mosaic pattern of urban influential system in China by applying advanced GIS technology. It is different from early version definitions for urban influential region and economic zones, for it applies computer drawing based on unbiased theory and data instead of manually drawing based on personal experiences. It is also different from recent version definitions for urban influential region and economic zones, for it is a nationwide systemic study based on theory instead of theoretical research at limited regional scale.

2. The law of universal gravitation and its application

Newton’s laws of universal gravity in physics described the attraction between two objects generated by mass, and its basic formula is as follows:

\[ F = K \times \frac{m_1 \times m_2}{d^2} \] (1)

where \( F \) is the attraction between object 1 and object 2; \( K \) is a constant; \( m_1 \) and \( m_2 \) are the mass of object 1 and object 2; \( d \) is the distance between two objects.

In the nineteenth century, many scholars had noticed that the law and measurement methods established in physics can be applied to social issues, and thus the subject of social physics was established (Carry 1858). The British scholars applied firstly the Newton’s Law of Universal Gravitation on the research of population migration (Ravenstein 1885), and later on gravity models are widely used to explain mathematical models with the type of flowing in human geography, such as migration, telecommunication, passenger traffic and cargo flow, etc.

The gravity model was applied to describe the attraction between the two cities generated by population or economic strength in social physics, and its basic formula is as follows:

\[ F = K \times \frac{Q_1 \times Q_2}{d^a} \] (2)

where \( F \) is the attraction between city 1 and city 2, \( K \) is a constant; \( Q_1 \) and \( Q_2 \) are the population or economic strength (such as GDP) for city 1 and city 2; \( d \) is the distance between two cities; \( a \) is the friction coefficient for distance, and it is positive. \( a \) equals 2 in physics, and it decreases with the improvement of traffic situation. \( a \) is greater than 2 in the case of extremely underdeveloped traffic situation, and \( a \) is less than 2 in the society with developed traffic conditions. Scholars have studied the economic foundation of the gravity model and the method to derive the value of \( a \) in the gravity models (Wang 2006).

In accordance with the principles of social physics, a city gravitational field can be expressed by the following formula:

\[ F_R = \frac{Q}{R^a} \] (3)
where $R$ is the distance between settlements and urban center, and the unit is km; $Q$ is the city’s population with unit 10,000 persons or economic strength (such as GDP) with unit 10,000 Yuan; $F_R$ is the city’s influence strength to the settlements at $R$ km away.

It can be proved that the influence domain for smaller city under the shield of bigger cities is an eccentric circular region. The smaller city does not locate on the center of the circular area, but locates on the extended line from the bigger city to the smaller city.

Let $A$ and $B$ stand for the two cities with the population of $Q_A$ and $Q_B$, respectively, and suppose $Q_A > Q_B$, and the distance between the two cities is $d$. Establish a rectangular plane coordinate system, take $A$ as the origin point, take $A \rightarrow B$ as $x$-axis, and the influence domain of $B$ meet the following terms:

$$Q_A / R_A^a \leq Q_B / R_B^a$$
with the critical state being:

$$Q_A / R_A^a = Q_B / R_B^a$$

Let

$$(Q_A / Q_B)^{(2/a)} = E$$

$E$ is determined by the friction coefficient of distance and the relative size of the two cities, and can be called the social characteristics index for the city influence domain. As $a$ is a positive closer to 2, and $Q_A > Q_B$, so $E > 1$, and thus formula (5) can be written as:

$$R_A^2 = E \times R_B^2$$

The equation for the circular trajectory can be expressed by rectangular plane coordinates as:

$$x^2 + y^2 = E \times [y^2 + (d-x)^2]$$

With the circular center locates at $(E \times d(E-1), 0)$; the radius equals $E^{0.5} \times d(E-1)$; the nearer critical point locates at $(E^{0.5} \times d(E^{0.5} + 1), 0)$; and the further critical point locates at $(E^{0.5} \times d(E^{0.5} - 1), 0)$.

Through study on the decisive role of the value of $a$ to the value of $E$, we notice that, with all other conditions remain unchanged, the stronger the friction of distance, and the greater the distance decay index $a$, the greater the circular radius of influence domain; the more shift of the circular center away from the large city; the more shift of the nearer critical point to the direction of smaller city to larger city; and the more shift of the further critical point to the direction of larger city to smaller city.

Actually, with the development of transportation in the real world, the friction of distance is reducing and the distance decay index $a$ is declining, the radius of influence circular for the smaller cities decreases; the circular center shifts to the larger city; the nearer critical point between two cities shifts further away from the larger city; and the further critical point shifts toward the two cities.
This principle of change in critical points can perfectly interpret the phenomenon that the development of modern transportation can increase the centripetal force to the border provinces and regions, and help to form an integrated economic system in a large country. The impact of Southern Xinjiang Railway to Kashgar region and the impact of Qing-Zang Railway to Xizang (Tibet) are two typical examples in China.

The urban gravitational field theory can be applied to the study on the influence domain of cities. If a settlement is influenced by several cities, the settlement belongs to the influence domain of the city possessing the largest influence force, and the total urban influence force for a settlement is the sum of the gravitational field for all the cities. City influence domains are circular area mosaic in the real world. In the circumstance of cities possessing the same amount of population, the influence domains are Thiessen polygons; when the cities are evenly distributed on the earth surface, and the transportation frictions are constant, the influence domains are hexagons as shown in the Central Place Theory by Christaller. Through calculating the gravitational field of cities, the high-value area of urban gravitational field can be defined, which can be further utilized to do spatial clustering analysis for the cities and to define the core areas for city groups.

3. China’s urban gravitational field and city groups

The criteria to define city is different among nations, such as Japan defines a town as a residential place with a population more than 50,000, and USA demands central city population must surpass 50,000 for a Metropolitan Statistical Area. China’s city definition changes over time; the current criteria was defined in 1993. It is a complex definition system with the basic demand of non-agricultural population surpassing 80,000. The appropriate conditions for setting up a city in China can be relaxed in some cases, such as an important trade port along the coastal and border areas.

In this section, I will draw the distribution map of gravitational field for China through designing gravitational units and calculating the gravitational field. I divided the country into cells striding 0.02° of both latitude and longitude (equivalent to 2.2 km along meridians). Supposing friction coefficient of distance decay $a$ equals 2, I calculated the gravitational field, or influence force by supposing the cell population is 1, for each cell from each of the 670 cities by using ARCGIS. As the calculation is complex, the cities and cells can be grouped into regions, and each city and cell is given a serial number for identification, and then the Excel spreadsheet has been used to define the city influence domain for each cell in accordance with the largest gravitational force principles; in the meantime, calculate each cell’s total gravitational field for urban influence force by summing up the gravitational field of 670 cities. Finally, through table joint function in ARCGIS, chart the total gravitational field for urban influence force according to the value assigned to the cell, and draw the distribution maps of influence domains for 670 cities by dissolving the city influence attribute for each cell in ARCGIS.

The specific calculation formulae are:

$$F_i = \sum_j \frac{Q_j}{R_{ij}^2}$$  \hspace{1cm} (9)

$$j_i = \left\{ j \in N_+ : \max_{j=1}^i \left( \frac{Q_j}{R_{ij}^2} \right) \right\}$$  \hspace{1cm} (10)
where $F_i$ is the total gravitational field for $i$th gravitational cell generated by city $1\rightarrow J$; $Q_j$ is $j$ city’s total urban population; $R_{ij}$ is the distance between gravitational cell $i$ and city $j$; $j$ is serial number for cities generating gravitational force to cell $i$, $j$ equals 1 to 670; and $j_i$ is the influence domain of city $j$, which cell $i$ belongs to.

To show the distribution of gravitational field, the city gravitational grades are standardized, the author converts the value of urban gravitational field into urban gravitational grades by natural logarithmic transformation, and the conversion formula is:

$$G = \text{int}[2.6 \times \ln(F) - 15.44] + 5$$

(11)

where $G$ is gravitational field grade; and $F$ is sum of gravitational field value for each cell, the unit is persons/km$^2$.

The result is that for the national distribution of urban gravitational force, the urban gravitational force grades are between $-3$ and 39, grades for low value area are less than or equal to 5, grades for high value area are equal to or more than 16, and grades for medium value area are between 6 and 15. Normally the urban gravitational force is higher at regions with higher city density in China, and the grade is more than 6. Conversely regions with the grade greater than 16 have the highest urban gravitational force, and they are generally located at large cities and their vicinity, and failed to form contiguous high-value zone. Therefore, the internal structure and spatial distribution of urban gravitational field can be analyzed by studying the distribution of the regions with gravitational force grade between 6 and 15.

Through reading the distribution map of the gravitational field in China, we can find that China’s urban gravitational field distribution characteristics are: (1) high-value regions are concentrated in the southeast part of China, while the grades for northwest part of China are relatively low; (2) the concentrated distribution of city groups is combined with the scattered distribution, and large city groups always form contiguous regions with high gravitational force value; (3) regions with harsh natural conditions, such as the Gobi desert, plateau and mountain areas, and cold regions in the north, have lower gravitational force value for the city is scarce; (4) regions with favorable natural conditions, such as coastal areas, the great plains and large basins, have higher gravitational force value for the city density is high, the regions near the mega-cities have the strongest gravitational field; and (5) the difference between the low and high value areas is larger, according to the grading by natural logarithmic: the grade difference is generally 24 or so.

City gravitational field can also be used in spatial clustering analysis to determine the structure and spatial distribution of city groups. Theoretically, each grade of the urban gravitational field can be used to analyse urban clusters in different levels, while the medium value range with grade between 6 and 15 is more suitable for the spatial clustering research of China’s existing urban system. Particularly, the medium value range with grade between 11 and 14 is the best range for spatial clustering research of China’s urban system. This paper studied the spatial clustering for China’s urban system at the grade level of 12, and takes the contiguous regions with urban gravitational field grade equals 12 as the base for city spatial clustering and definition for mega-cities, and sorts the urban clusters according to the total urban population in the contiguous regions.

According to the total urban population in the contiguous regions, the result of sorting for China’s megalopolis clusters are: the Chang (Yangtze) River Delta, the
Zhu (Pearl) River Delta and the Beijing–Tianjin–Tangshan region are the three largest; Wuhan, Jinan–Zibo, Shenyang, Chongqing are the 4th–7th largest; Xi’an, Shantou, Zhengzhou, Xuzhou, Qingdao, Changsha, and Harbin are the 8th–15th largest; Nanchong, Dalian, Changchun, Taiyuan, Wenzhou, Taipei, Guiyang, Shijiazhuang are the 16th–23rd; Haikou is the 50th, Yinchuan is 121st (figure 1, table 1). The urban group rank in Figure1 represents the rank of China’s megalopolis clusters by total urban population in the contiguous regions. According to Jean Gottmann’s definition in 1957, total population must be more than 25 million for megalopolis; China have three megalopolises that have surpassed this criterion.

4. Spatial patterns of China’s urban influence domain

The distribution map of urban influence domains in China (figure 2) is generated through dissolving and merging of the influence domain attribute for each cell in GIS. Through reading the map, we can find the distribution characteristics for the city influence domains in China:

1. The city influence domain in the regions with more developed urbanization is closer to the standard Christaller hexagon, such as the Chang (Yangtze) River Delta region (figure 3). The urban population of adjacent cities, Suzhou, Wuxi and Changzhou, are close to each other. The division lines for urban influence domains are perpendicular straight lines between the neighborhood cities.

Figure 1. Distribution map of urban gravitational field, megalopolis clusters, and economic zones in China. Urban group rank refers to the total urban population in the contiguous regions for China’s megalopolis clusters. Data source: China City Statistical Yearbook 2004.
Table 1. The largest 15 megalopolis clusters in China sorted by population (source: China City Statistical Yearbook 2004).

<table>
<thead>
<tr>
<th>Rank of megalopolis clusters</th>
<th>Population for megalopolis clusters, 10,000</th>
<th>City number</th>
<th>Head city</th>
<th>Other major cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5121.0</td>
<td>50</td>
<td>Shanghai</td>
<td>Nanjing, Hangzhou, Suzhou, Wuxi, Ningbo</td>
</tr>
<tr>
<td>2</td>
<td>4216.7</td>
<td>19</td>
<td>Guangzhou</td>
<td>Hong Kong, Dongguan, Shenzhen, Foshan</td>
</tr>
<tr>
<td>3</td>
<td>2695.8</td>
<td>8</td>
<td>Beijing</td>
<td>Tianjin, Tangshan</td>
</tr>
<tr>
<td>4</td>
<td>1364.1</td>
<td>11</td>
<td>Wuhan</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1279.8</td>
<td>13</td>
<td>Jinan</td>
<td>Zibo</td>
</tr>
<tr>
<td>6</td>
<td>1197.9</td>
<td>12</td>
<td>Shenyang</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1127.4</td>
<td>4</td>
<td>Chongqing</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>839.9</td>
<td>5</td>
<td>Xi'an</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>752.6</td>
<td>9</td>
<td>Chengdu</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>655.5</td>
<td>4</td>
<td>Shantou</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>511.9</td>
<td>12</td>
<td>Zhengzhou</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>424.4</td>
<td>3</td>
<td>Xuzhou</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>416.3</td>
<td>5</td>
<td>Qingdao</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>392.2</td>
<td>3</td>
<td>Changsha</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>337.7</td>
<td>2</td>
<td>Harbin</td>
<td></td>
</tr>
</tbody>
</table>

(2) With less developed urbanization, the shape of city’s influence domain for the western, northern, and north-western regions in China is dominated by circular. The size and shape of the domains are affected by the distribution pattern of the large cities nearby, such as Beijing, Chongqing, and Urumqi.

Figure 2. Distribution map of urban influence domains in China. Source: China City Statistical Yearbook 2004.
(3) The influence domain of mega-cities is larger, and it often compresses the domains for adjacent small and medium-sized cities; the compression effects to the vicinity small and medium-sized city domains by Chengdu, Wuhan are obvious.

(4) Large cities adjacent to the Qing-Zang Plateau, deserts, mountains and high latitude regions have extreme large domains, such as Xining, Lhasa, and Korla in Xinjiang.

(5) Small and medium-sized cities locating in the regions with high city density have smaller domain extent, the small cities in the vicinity of large cities have the smallest domain extent, such as the influence domain for small and medium-sized cities in the Zhu (Pearl) River Delta are compressed by regional large cities, the domain for Langfang is compressed by Beijing and Tianjin, and the domain for Zhangqiu is compressed by Jinan and Zibo in Shandong.

As the urban population and economic strength are different, and the spatial distribution of cities also have no geometric regularity, thus the influence domain for each city is not the same. The geometry appearance for each city’s influence domain can be broadly classified into three categories:

(1) In the circumstances where the adjacent cities have about the same population and economic strength, the two influence domains have perpendicular bisector boundaries, such as Suzhou and Wuxi.

(2) In the circumstances where the population and economic strength difference between adjacent cities is not large, the influence domain for the larger city
semi-sieges the influence domain for the smaller city, such as Guangzhou semi-sieges Dongguan, and Beijing semi-sieges Tianjin.

(3) In the circumstances where the population and economic strength difference between adjacent cities is large, the influence domain for the larger city entirely surrounds the influence domain for the smaller city, such as Beijing surrounds the domains for Zhangjiakou, Chengde and Baoding.

Based on the basic shape mentioned above, many geometric shapes for influence domain can be derived in accordance with different city size and specific spatial pattern of the cities: (1) the shape of influence domain for a smaller city locating in the middle of two larger cities may be convex lens-shaped, such as Xingtai between Shijiazhuang and Handan, and Yangquan between Shijiazhuang and Taiyuan; (2) the shape of influence domain for a medium-sized city locating in the middle of a larger city and a smaller city may be crescent-shaped, such as Zhangye between Jiuquan and Wuwei, Aksu between Urumqi and Kashgar; (3) the influence domains for three cities with different size magnitude may form the phenomena of medium-sized domain surrounding smaller domain, while it is surrounded by larger domain, for example the influence domain of Urumqi surrounds Kuitun’s, and the Kuitun’s surrounds Wusu’s, the domains of Chengdu, Mianyang and Jiangyou also have the phenomenon of double surrounding; and (4) the extension of some large cities’ influence domain may lead to the formation of dumbbell-shaped geometry for their influence domains, such as Handan in Hebei and Guigang in Guangxi.

The economic zone’s boundary can be delineated based on the urban influence domain through GIS. Firstly, we dissolve and merge the urban influence domains into 34 regions in accordance with the provincial boundaries, then merge the provincial domains into 13 economic zones according to their natural and economic locations. The economic zones delineated according to natural conditions in China are normally eight regions as Northeast, Northern, Central, Southern, Southwest, Midwest, Qing-Zang, and Xinjiang. Five regions are divided into two parts according to their economic locations. For example, Northeast, Northern, Central are divided according to their relative location to the coast, Southern is divided according to their relative location to Taiwan and Xianggang, and Southwest is divided according to their access to Chang River navigation route.

Finally the boundary between adjacent zones can be modified through integrating and trimming, based on the principle of dissolving the completely encircled domains, and by taking account of the transportation lines’ effect on the delineation of economic zones.

The economic zone delineation results can be read in table 2. According to the sorting sequence of the economic zones, the zones from large to small by area are Northern Southwest (NSW, 2.24 million km²), Far West Inland (FWI, 1.62 million km²), Northern Northeast (NNE, 0.96 million km²), Midwest Inland (MWI), Coastal North China (CNC), Inland Central China (ICC), Inland North China (INC), Western South China (WSC), Southern Southwest (SSW), Coastal Central China (CCC), Qing-Zang Plateau (QZP), Southern Northeast (SNE), and the smallest Eastern South China (ESC, 0.13 million km²). The zones from more to less by population are Coastal Central China (CCC, 84.39 million persons), Coastal North China (CNC, 72.93 million persons), Western South China (WSC, 72.18 million persons), Inland Central China (ICC), Inland North China (INC), Northern Southwest (NSW), Northern Northeast (NNE), Southern Northeast (SNE), Eastern South China (ESC), Midwest Inland (MWI), Southern Southwest
(SSW), Far West Inland (FWI), and the least Qing-Zang Plateau (QZP, 1.43 million persons). The zones from high to low by population density are Coastal Central China (CCC, 241.7 persons/km²), Western South China (WSC, 152.2 persons/km²), Eastern South China (ESC, 137.6 persons/km²), Southern Southwest (SSW), Far West Inland (FWI), Coastal North China (CNC), Inland Central China (ICC), Inland North China (INC), Northern Northeast (NNE), Southern Southwest (SSW), Western South China (WSC), Coastal North China (CNC), Inland Central China (ICC), Inland North China (INC), Northern Northeast (NNE), Southern Southwest (SSW), Far West Inland (FWI), Coastal North China, Northern Northeast, and Southern Northeast. Qing-Zang Plateau is an economic zone in the process of formation. It has scarcely distributed

As seen from figure 1, the distribution map of economic zones are delineated according to the urban influence domains; many economic zone boundaries coincide with the provincial boundaries and the zones in between city groups with weak gravitational field. For example, Far West Inland economic zone coincides with the boundary of Xinjiang Autonomous Region, and the economic zone boundaries of Inland North China, Eastern South China, Western South China, Inland Central China and Southern Southwest fit with the corresponding provincial boundaries well. However, the provincial boundaries are remarkably different from economic zone boundaries for Qing-Zang Plateau, Northern Southwest, Inland Central West, Coastal North China, Northern Northeast, and Southern Northeast. Qing-Zang Plateau is an economic zone in the process of formation. It has scarcely distributed

<table>
<thead>
<tr>
<th>Economic regions</th>
<th>Provinces included</th>
<th>Area, 10,000 km²</th>
<th>Urban population, 10,000</th>
<th>Urban population density, persons/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Central China (CCC)</td>
<td>Shanghai, Jiangsu, Zhejiang, Anhui</td>
<td>34.9</td>
<td>8438.7</td>
<td>241.7</td>
</tr>
<tr>
<td>Coastal North China (CNC)</td>
<td>Beijing, Tianjin, Hebei, Shandong</td>
<td>71.5</td>
<td>7293.2</td>
<td>102.0</td>
</tr>
<tr>
<td>Western South China (WSC)</td>
<td>Guangdong, Guangxi, Hainan, Xianggang, Aomen</td>
<td>47.4</td>
<td>7218.4</td>
<td>152.2</td>
</tr>
<tr>
<td>Inland Central China (ICC)</td>
<td>Hubei, Hunan, Jiangxi</td>
<td>51.9</td>
<td>4869.5</td>
<td>93.8</td>
</tr>
<tr>
<td>Inland North China (INC)</td>
<td>Henan, Shanxi, Shaanxi</td>
<td>51.3</td>
<td>4188.8</td>
<td>81.7</td>
</tr>
<tr>
<td>Northern Southwest (NSW)</td>
<td>Chongqing, Sichuan</td>
<td>224.0</td>
<td>3644.9</td>
<td>16.3</td>
</tr>
<tr>
<td>Northern Northeast (NNE)</td>
<td>Heilongjiang, Jilin</td>
<td>96.2</td>
<td>2660.2</td>
<td>27.7</td>
</tr>
<tr>
<td>Southern Northeast (SNE)</td>
<td>Liaoning</td>
<td>18.3</td>
<td>2235.3</td>
<td>121.9</td>
</tr>
<tr>
<td>Eastern South China (ESC)</td>
<td>Fujian, Taiwan</td>
<td>13.2</td>
<td>1810.8</td>
<td>137.6</td>
</tr>
<tr>
<td>Midwest Inland (MWI)</td>
<td>Gansu, Inner Mongolia, Ningxia</td>
<td>89.2</td>
<td>1563.6</td>
<td>17.5</td>
</tr>
<tr>
<td>Southern Southwest (SSW)</td>
<td>Guizhou, Yunnan</td>
<td>46.9</td>
<td>1249.4</td>
<td>26.6</td>
</tr>
<tr>
<td>Far West Inland (FWI)</td>
<td>Xinjiang</td>
<td>161.8</td>
<td>606.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Qing-Zang Plateau (QZP)</td>
<td>Qinghai, Xizang (Tibet)</td>
<td>30.2</td>
<td>142.7</td>
<td>4.7</td>
</tr>
</tbody>
</table>
cities and weak urban gravitational field. A large piece of urban influence domain for Qing-Zang Plateau economic zone is seized by Northern Southwest economic zone, so that the whole region was divided into three parts, but the opening of the Qing-Zang Railway is beneficial to the integration, development, and expansion of this economy zone. Northern Southwest economic zone is much larger than its provincial administrative area. It not only occupies a large area of the Qing-Zang Plateau economic zones and adjacent to the Far West Inland zone, but also extends to western Hubei and northeastern Guizhou, caused by the strong influence of Chongqing. The eastern part of the Mid West Inland economic zone was taken by Coastal North China, Southern Northeast, and Northern Northeast, because of the urban underdevelopment in mid and eastern Inner Mongolia.

5. Conclusions, questions and discussions

Theoretical contributions of this paper to urban geography society are that it delineates the real world’s circular pattern of urban influence domain system. It is an improvement to the Central Place Theory. For the Central Place Theory is the ideal situation demanding homogenous distribution of cities and the same amount of population for cities. Through applying GIS, this paper calculates the spatial distribution of breaking points defined by Reilly’s Law. By using GIS, this paper also calculates the distribution of city gravitational field generated by urban system in China, which shows the distribution pattern of rural-urban migration potential. It sets base for future study on simulating the dynamic process of urbanization in China, given the current urban system pattern, rural population distribution, and rural-urban migration growth rate.

Major conclusions in this study are: (1) natural conditions and the enormous differences in economic development levels determine the uneven spatial distribution of the urbanization levels in China, and the uneven distribution of urban gravitational field is the form of performance for such regional differences; (2) the city groups can be defined by studying the distribution of urban gravitational field, through which further study on spatial structure and characteristics for China’s urban system can be conducted, currently the top seven largest urban groups by population are Chang (Yangtze) River Delta, Zhu (Pearl) River Delta, Beijing–Tianjin–Tangshan region, Wuhan, Jinan–Zibo, Shenyang and Chongqing; (3) caused by complex terrain, relatively low overall urban development level, the urban influence domain in most parts of China has not taken the shape of a hexagonal mosaic; and (4) China can be delineated into 13 economic zones by taking provincial level administrations as basic blocks, in accordance with the natural and economic locations, and the boundary of economic zones is defined by the influence domain of the cities in the core areas; the domain for economic zones with weak urban gravitational field could be seized by stronger economic zones.

To study the spatial pattern of city group and urban influence domain by using gravitational theorems is just one of the research subjects in social physics. Actually the law of gravity is widely used in urban geography. For example, inter-city transport network design can refer to the gravitational field of city to determine the route for high-speed railways, inter-city rail transportation and express highways. The city gravitational field can be used in urban development planning to determine the city’s development axis and potential development axis. The distribution of weak gravitational field can serve as an indicator for urban planning and designing agencies to establish new cities in accordance with the principle of gap-filling. The
research result for newspapers distribution, cargo traffic, telephone calls, and peasant worker floating in social physics can be used in the planning for transportation, communication, and post and telecommunication systems. Population density and total population in the urban influence domain can be used to measure and estimate regional urban development potentials. The urban economic zones can be delineated by different grades in accordance with the core region and their influence domain at different hierarchy levels. The shape of the urban gravitational field and influence domain can be used to merge adjacent cities and design the prefecture level administrative boundaries.

Urban population is taken as the indicator to calculate urban influence force in this study, but it is not the single candidate in the selection of indicator for the urban influence force. According to different research purposes, non-agricultural population, total economic output, urban resident’s income, economic openness and scale of foreign-funded enterprises can also be the source of city attractive force. Wang’s study on the probability of choosing the Cubs in Chicago and hinterlands for four major cities in northeast China by Huff model also reflects the circular shape of influence domains (Wang 2006). We look forward to having more scholars to study the spatial principles for urban issues and economic development by applying social physics in the future.

We can learn from the results that the theoretical shape of urban influential domains is proved to be circular mosaic by assuming homogenous plain background, but caused by changing of natural terrain condition and transportation situation the real shape is much more complex than a simple model can deal with. With the development of GIS technology, the model result can be improved further to represent the real world patterns more accurately.

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