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# An evaluation of China's urban agglomeration development from the spatial perspective

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A B S T R A C T

While Chinese governments used UAs (urban agglomerations) as a policy tool to gain an advantageous position in global and regional competition and made ambitious plans to build up dozens of national, regional and local-level UAs in the next decade, the criteria of UAs from the spatial perspective have been overlooked thus far, and the proposed UAs have been defined approximately by the authority of jurisdiction of clustered cities and towns. This paper argues that rational spatial planning of UAs is impossible without consistent criteria for them and that a solid method is necessary to identify the spatial extension of UAs. Based on the theory of economic geography that views UA as a phase expression of the mature 'pole-axis' urban system, a stepwise approach is proposed: firstly, to identify central cities in a region; secondly, to assess the completeness of the city system and analyse the social and economic relationship of the cities and towns; and thirdly, to evaluate the degree of evolution of the urban system. With this approach being applied to five national-level UAs proposed by the national plan, the paper proves that the number and extension of UAs are greatly exaggerated in the current strategic plan.



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## 1. Introduction

As Gottmann (1957) raised the concept of the *megalopolis* and Geddes (1968) coined the term *conurbation*, a variety of related terms such as *world city region* (Friedmann, 1986; Scott, 2002), *uninuclear* and *polynuclear conurbations* (Mayhew, 2004), *extended metropolitan region* (EMR), *metropolitan area* (MA), and *standard metropolitan area* (SMA) used by the US government, *mega urban region* (Gavin, 2001), and *unité urbaine* proposed by the French Statistical Institute have been proposed. Among them, *urban agglomeration* (UA) refers to extended city and town areas comprising the built-up area of central areas and suburbs linked by continuous urban areas. The UA has become a hot research topic in recent years.

In contrast to previous findings in developing regions of Africa and Latin America (Brockerhoff and Brennan, 1997) that big city residents were disadvantaged, there is a large body of literature about Asian countries since 1990s showing big cities as 'engines of growth', where productivity was much higher than elsewhere in the country and where economies of agglomeration were celebrated (Choe, 1996; Patsy, 1997; Gavin et al., 2000). This may partly be interpreted by the effect of deepening globalisation and regional integration, and the governance structure of developing Asian countries. Indeed, while the world's largest UAs such as the northeast coast of the US, the Great Lakes region in North America, the Pacific coast of Japan, northwest Europe and the Greater London area are growing more mature and increasingly complex, most of the new large agglomerations including Shanghai, Singapore, Jakarta, Manila and so on are located in the Asian-Pacific region. It was argued that the optimal city size may be beyond any size achieved thus far in the world (Mera, 1973; Marelli, 1981). The linkage of city size with high ranking and advantageous status in the world urban system has made a great impact on spatial planning in different countries and regions, where the UA was adopted as a policy tool to improve regional or national competitiveness and promote cross-border cooperation.

From the opening up and reform of China in 1978 to the mid-1990s, the Chinese urbanisation policy shifted from 'anti-urbanisation' in the pre-reform era to 'boosting the development of small cities and towns and controlling the growth of large cities'. During the 10th Five-year Plan (2000–2005), the strategy of 'coordinated development of large, medium and small cities' was implemented. Later, in the 11th Five-year Plan (2005–2010), policy emphases switched to large cities again, intending to make megalopolises the leading cities, to assert the function of central cities and to form new megalopolises with less land utilisation, more employment, a strong element of concentration ability and rational population distribution (Chen, 2008). Led by the turn in policy, many blueprints were proposed for cities and regions to achieve higher hierarchical status. In 2014, the National New Urbanisation Plan for 2014–2020 (NNUP2020) was released, claiming that UAs would be the main spatial carrier of China's urbanisation in the following decade. A so-called '5 + 9 + 6' pattern of UA strategy was proposed in NNUP2020, demonstrating that China would have five national, nine regional and six local level UAs in 2020, lying on the three horizontal and two vertical axes of urbanised areas, set via the national plan, of Main Function Oriented Zones (MFOZ). With regard to the appropriate number and distribution of UAs, researchers presented different views of spatial structure of UAs, such as the '5 + 6 + 11', '3 + 3 + 7', '10 + 6', '10 + 3' and '3 + 7 + 17' patterns (ISPRE, 2015; see appendix for details), most of which are constructed from the perspective of the national, regional and local levels. It can be seen that five national-level UAs were commonly agreed by scholars, but views about regional-level and local-level UAs were very different. There are plenty of studies in the literature attempting to show the importance of implementing the UA strategy in certain areas and to justify the appropriateness for cities and towns to be incorporated.

The debate on the number and organisation plans of UA reflects the fact that few consensuses on the concept and evaluation standard of UA have been reached. Because of the differences in definition of what does and does not constitute an 'agglomeration', as well as variations and limitations in statistical or geographical methodology, there is no scientific consensus between academia and government and UA strategy may lack objectivity. It may not be clear, for instance, whether an area should be considered as a satellite and part of an agglomeration, or a distinct entity by itself. The size of a UA may also be vague, because the proximity and social and economic (sometimes cultural) connection of cities and towns were usually studied based on the statistics of the 'points' representing cities and towns, but the 'plane' jurisdiction area of cities and towns with close relationships were excluded from UA research without detailed justification. Consequently, the spatial definition of a UA is inaccurate, which makes it difficult to support further discussions, for instance, on the population capacity of a UA constricted by resources and the environment of the region, and the function and development direction of different cities, towns and areas in between. It is thus concerning that the lack of a uniform standard and objective methodology to define a UA is leading UA strategy to become a political football, and that the planning of UAs may suffer from long-term instability and lack of continuity (Wang, 2012). With this background, it is vital to develop a scientific methodology to define UAs from a spatial respective.

In general, previous studies took two approaches to define the spatial scope of UAs or continuous urbanised areas. The first is an indices-based approach. Based on preset indices and analyses of the statistics of its spatial units, usually at the prefecture, county or township levels, the spatial units of the UA were identified and the border of jurisdiction were adopted as that of the UA. In the 1960s, Japan set the standard of its Metropolitan Areas, involving the indices of the urban population, the proportion of the population commuting to the central area of the metropolis and the proportion of cargo transportation (Zhang, 2003). Zhou and Shi (1995), Yao et al. (2006), Ni (2008) and Fang (2009) proposed indices and standards of UAs in China based on the number and density of the population, the population urbanisation level, regional location and communications, and the connection between central cities and peripheral counties. Another kind of study took a land use-based approach to identify the boundary of the UA. For example, Fragkias and Seto (2009) studied the coverage of the Yangtze River Delta UA of China via the Hoshen–Kopelman algorithm, which is a method to label and identify clusters of urbanised areas on a grid of land use cells. Dong et al. (2008) investigated the spatial pattern of China's UAs based on fragmentation theory. Huang et al. (2010) studied the area of economic influence of cities in Heilongjiang province, China, with a weighted Voronoi method. Some other methods were used to ascertain the morphological border of the UA with remote sensing land-use data and nightlight DMSP/OLS data (Imhoff et al., 1997; Henderson et al., 2003). The former approach enabled identification of central cities and consideration of the relationships between different spatial units with, for instance, statistics on transportation and the commuting population, but the precise boundary of the UA was unclear. In most cases, the methods for the selection and integration of indices were unavoidably subjective. Simplification and abstraction of spatial data is fundamentally weak in itself. The latter method, on the other hand, could distinguish continuous urbanised areas, but the structure of the UA was ignored. As both approaches have some advantages and disadvantages, methods were developed to integrate the results obtained from the two approaches; for example, by overlapping the indices with results obtained from the gravity model and potential model (Wang et al., 2013), or by combining indices to select central cities with analysis of the accessibility of cities to each other (Zhang et al., 2012).

However, the questions of how UAs should be defined and on what standard are yet to be answered. Factors such as the centricity of cities, the transportation and communication of cities, proximity of spatial units, the similarity and supplemental role of cities in socio-economic, cultural and industrial aspects, and urban land use patterns should be comprehensively addressed. In this paper, we attempt to elaborate on the concept of the UA from the perspective of economic geography, and propose a methodology to identify the spatial scope of the UA. Based on these, we try to evaluate the appropriateness and feasibility of the UA strategy of China.

With regard to the spatial boundary of the UA, we will focus on the actual growth boundary of continuous urbanised areas. Compared with many other terminologies related to the UA, such as the boundary of the UA planning area, the growth boundary of the UA and the boundary of the urbanised area within the UA, what concerns us is the evaluation of development of the UA. In order to set a rational strategy for UA development, firstly, identification of the actual boundary of the urbanised area is required, based on which the resource/environmental carrying capacity and regional development planning may be evaluated and proposed properly. Without understanding of the actual boundary, it makes no sense to devise plans about how many UAs are to be constructed and which cities and towns are to be included.

## 2. Theoretical base for identifying the boundary of the UA

### 2.1. 'Pole-axis theory'

Agglomeration and diffusion of regional economic activities are widespread phenomena that exist all over the world. As a result of the impact of the growth pole, the effects of agglomeration and diffusion are the main interactions within regional economic activities. To facilitate the interaction, social and economic entities cluster in cities and towns, and along with further development, higher level economic connections take place. According to the pole-axis theory, a region experiences four steps in its evolution towards an agglomeration (Lu, 2002). At first, there are only randomly distributed settlements. Then, the preliminary structure of the pole-axis forms, i.e. due to the benefit of economic agglomeration and scale effect, some central places or settlements providing goods and services for both themselves and other areas (Openshaw and Veneris, 2003) emerge, and the development 'axes' of the region are constructed between central places via infrastructure bundles such as trunk transportation lines, energy pipes or waterways. In the third step, as social and economic factors flow along the axes, at some distance to the existing central places, new centres gradually emerge and the system grows until it becomes a network system of settlements consisting of connected hierarchical central places and axes. In the fourth step, with further social and economic development, the network system of the pole and axes develops as an agglomeration, providing a basic regional factor that yields the UA (Lu, 2002). The UA is a mature outcome of a pole and axis system.

### 2.2. Methodology to identify the boundary of the UA

Based on the pole-axis theory, the identification of a UA should include three steps: first, to discover whether there are some well-developed cities and ascertain if they are the central places of the region; second, to assess the completeness of the city system and analyse the social and economic relationship of the cities and towns in order to judge the socio-economic basis of these areas to develop as a whole; and third, to identify the actual growth boundary of the pole-axis system, to evaluate the development degree to which it has become a UA.

Step 1: Identify central cities. The central city is the core of the UA. In addition to providing comprehensive services to the whole UA region, they function as the hub of various economic factors via their close relationship to other cities, towns and villages in the UA (Tan et al., 2000). They are also the main attractors of advantageous resources, and play an important role in improving the rank of the UA and leading its orderly development. The status of individual cities in an UA can be measured by a centrality index (Christaller and Baskin, 1966), an indicator for how much a city provides services for the region outside itself (Zhou et al., 2001). The services of central cities range from the business and service industry, transportation, manufacturing, and so on. Zhou et al. (2001) pointed out that the concept of centrality is the basis for the evaluation of the city's rank in an urban system, the division of the urban hierarchy system, the description of the interacted network structure of the urban system and the determination of the areas over which the city has influence. The centricity index is widely used for horizontal or vertical comparison of urban systems, and in regional analysis.

Preston (1970) noted that the centrality of a city is different from its nodality, which shows the importance of the city in a region. He presented the theoretical model of centrality ($C$), nodality ($N$) and locality ($L$) representing the local consumption of a city; i.e. $C = N - L$. According to Preston, if a city is large in size, but closed, and fails to provide higher-level goods and services for the region, its centrality is small. Theoretical and empirical studies in spatial economics have demonstrated that centrality is a significant driving force of population and industries, and cities of higher centrality are usually more competitive if there are no strict external constraints. Along with the trend of economic globalisation, this is more and more evident. Therefore, centrality provides a proper index to evaluate the comprehensive strength of each city and determine the central cities. The centrality index can be calculated by integrating one or several single factors which represent the size, economic strength and quality of life of the central cities. Christaller (1933) for instance, even used telephone call data to measure centrality. Preston (1970) and Marshall (1989) used data from the retail and service sectors.

Ning and Yan (1993) considered the non-agricultural population, industrial production, and size of post and telecommunication data in urban areas. Yu and Lu (2005) used the indices of gross domestic product, non-agricultural population and total retail sales of consumer goods in urban areas. Zhou et al. (2001) proposed to measure the centrality of a city by urban employment data in the commercial, service, transportation and information sectors and manufacturing industries, and proposed nine factors to reflect these, whereby the centrality index of 223 prefecture-level cities in China was calculated and classified into five levels. To integrate different indices, expert knowledge, the Delphi method, the analytic hierarchy process (AHP), principal component analysis, the entropy method and the variation coefficient method are often used to determine the weight of each factor.

Step 2: Evaluate the urban system and analyse the social and economic connections of cities. The urban system is a mutually restricted dependent system composed of cities and towns of different sizes and functions lying on the transportation network (Bournel and Simmons, 1978). A good urban system is the product of mature regional development and is a basic requirement for the healthy development of the UA. The urban system is very important for the formation of supplementary functions, networking relationships and the integration of cities. A good and complete urban system in the UA not only plays the role of connecting different parts of the region and strengthening mutual communication, but also effectively enhances the attraction and radiation effect of individual cities, which is indispensable for the integration of spatial resources and the coordinated and healthy development of the UA.

Within an urban system, the intensity of social and economic connections of cities and towns plays an important role in the functioning of the UA. Close interrelationships enhance the core effect of central cities, and foster the spin-off effect of the UA. To measure this, the flow of population, cargo transportation, information and capital in two or multiple directions is often used. Some scholars suggested taking land transportation for two hours as the threshold of one-way traffic in the UA, because within this time period it is highly likely that people would make a round trip in a single day for business activities (Deng et al., 2005), and the connectivity, direction and amount of land transportation such as highways and railways is more important in the analysis of social and economic connections. For instance, Miao and Wang (2006) quantitatively studied the economic relationships of cities within and outside Henna province with the amount of passenger transportation by road and rail. Liu and Lu (2007) used the information from nodal data to analyse the location and size of the area of influence of certain cities. The use of an index is also proposed to indicate the intensity of regional economics (Li et al., 2001).

Step 3: Assess the development of the 'pole-axis' system. According to the 'pole-axis' theory, a well-developed pole and axis urban system characterised by coordinated urban activities and land use is a necessary condition for the formation of a UA. It is thus indispensable to investigate the structure of the pole and axis urban system when studying the maturity of UA development.

We proposed identifying the boundary of UA areas based on POI (Point of Interest) data from web maps, which involve the name, type and coordinates of map features, whether this be a place, a building, a park or a map annotation. POI data are instantly updated to meet the needs of map searching and navigation and their size is enormous. The Baidu map (http://map.baidu.com) incorporates more than 20 million POIs over urban and rural areas in China. Comparing the distribution of POIs between 2008 and 2014, we found that in large cities and surrounding areas, the number of POIs was fairly stable, while in small towns and rural areas, the number of POIs increased distinctively, because the map data service is new in those areas. This observation designates POI as a reliable data source for analysing the spatial characteristics of large UA areas. In contrast to an urban population in China in 2015 of 55.9%, the proportion of POIs in urban areas is 75.5%. For all categories except administrative organisation, the POI ratio in urban areas is significantly higher than that in rural areas (Table 1). The result confirms the strong correlation of the distribution of POIs with urban activities.

Density estimation is an effective way to quantify the distribution of POIs from the spatial perspective. On the contour map of density estimation, closer iso-density lines represent higher density areas and longer distances represent lower density areas. The boundary of the UA can be recognised by searching for the exact position where the density of POIs changes significantly. To

**Table 1**
The proportion of different categories of POI data in urban and rural areas.

| POI type | Overall % | Urban % | Rural % |
|---|---|---|---|
| Administrative building | 9.0 | 53.3 | 46.7 |
| Traffic | 10.6 | 80.8 | 19.2 |
| Bank | 5.7 | 72.8 | 27.2 |
| Commercial | 0.6 | 90.1 | 9.9 |
| Retail | 21.4 | 77.7 | 22.3 |
| Hotel | 2.8 | 73.1 | 26.9 |
| Restaurant | 15.0 | 82.2 | 17.8 |
| Hospital | 3.3 | 72.1 | 27.9 |
| Academic institute | 5.4 | 66.6 | 33.4 |
| Company | 12.8 | 82.6 | 17.4 |
| Park | 0.2 | 79.2 | 20.8 |
| Residence | 3.1 | 87.4 | 12.6 |
| Others | 10.1 | 71.4 | 28.6 |
| Total | 100 | 75.5 | 24.5 |

do so, the kernel density estimation is firstly introduced, which is given as the following equation:

$$P_i = \frac{1}{n\pi R^2} \times \sum_{j=1}^{n} K_j \left(1 - \frac{D_{ij}^2}{R^2}\right)^2 \tag{1}$$

where $i$ is the indicator of specific points, $R$ is the radius (bandwidth) of the kernel, $j = 1$ to $n$ is an indicator of POIs within the kernel, $d_{ij}$ is the distance between $i$ and $j$, and $K_j$ is the weight of $j$ calculated by Gaussian function.

Here, the bandwidth $R$ has a significant impact on the result of estimating kernel density. It should be appropriately determined on the real distribution of points. Hinneburg and Keim (1998) empirically studied the relationship between the bandwidth and the number of density attractors, and found that a good bandwidth is where the number of density attractors remains constant with the largest interval. They therefore suggested selecting a bandwidth within this interval. Liang et al. (2012), in their study on urban green space, considered the size of the study area and recommended to take 1/30 of the length of the smaller lateral as the kernel bandwidth. Upon analysis of Baidu POIs, we found that at the UA scale, with vast urban and rural areas, the appropriate kernel bandwidth is much smaller than 1/30 of the lateral length of the region, otherwise the internal spatial structure of cities and towns would not be clear. Based on the standard of Hinneburg and Keim (1998), a bandwidth of 15,000 m was set, where the number of kernel density centres was stable, and pattern of kernel density distribution was scarcely affected by the spatial differentiation of POIs inside cities.

Fig. 1 gives an example of the spatial pattern of POIs, rendering a set of iso-density lines circling density attractors. In close-knit and aggregated cities and towns, the density of POIs was significantly higher than that in outer areas. Consequently, it becomes possible to determine where integrated UA areas are by studying the trend of iso-density lines.

A Densi-Graph proposed by Xu and Gao (2016) was used to search for the threshold of iso-density lines between those that were close to each other and those that were more distant. If the area within the contour line associated with density $d$ is defined as $S_d$, then $r_d$ is the theoretical radius of the defined area $S_d$ (i.e. $r_d = S_d \wedge (1/2)$). The basic idea of the Densi-Graph proposed by Xu and Gao (2016) was to see the change or derivation of the theoretical radius $r_d$ against $d$. In theory, if

$$\lim \frac{d(\triangle S_d \wedge (1/2))}{d(d)} = 0, \tag{2}$$

the density of the POI changes homogeneously, and the iso-density lines are evenly distributed; if

$$\lim \frac{d(\triangle S_d \wedge (1/2))}{d(d)} > 0, \tag{3}$$

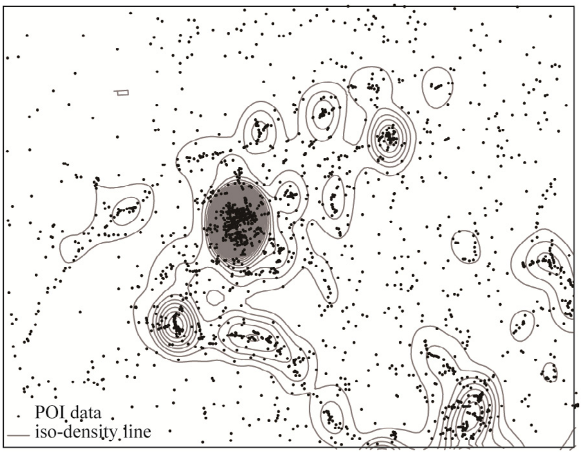


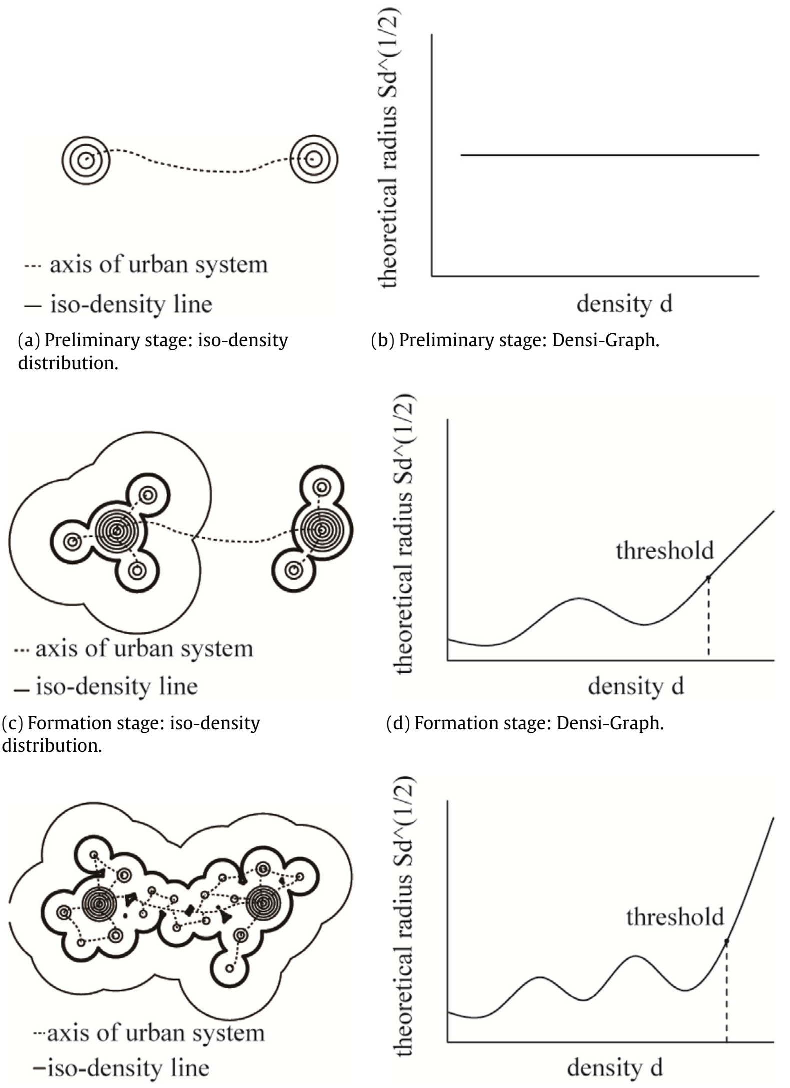

**Fig. 1.** An example of the iso-density map of POIs at regional scale.

then the iso-density lines become loosely distributed towards the outer areas. In the case of real cities, the Densi-Graph curve may swing up and down, with fluctuations of POI density in urban areas. We define a positive value of $r$ as the tolerance of the fluctuation. If the left side of Eq. (3) exceeds $r$ and the trend is irreversible, the corresponding density $d$ is considered as a global inflection point of the Densi-Graph curve, i.e. the density threshold of UA. The tolerance $r$ is determined pragmatically by the growth rate of Densi-Graphs for different UAs and a 5% growth rate is recommended based on the research of Xu and Gao (2016).

In Fig. 2, we analysed the structure of a pole-axis urban system in different development stages with the Densi-Graph method. We theoretically hypothesise that there are three stages for the development of a UA: the preliminary stage, the formation stage and the mature stage, corresponding to the second, third and fourth stages of the pole-axis theory. In the preliminary stage, the central city and town emerge and expand evenly towards the outer areas with unlimited development (Fig. 2(a)), which represents a homogeneous change of POI density and the iso-density line. Therefore, the corresponding Densi-Graph looks like a horizontal line (Fig. 2(b)). As the pole and axis system gradually forms (Fig. 2(c)) and becomes mature (Fig. 2(e)), the iso-density lines of the POIs expand and merge with each other. In the corresponding Densi-Graph curve (Fig. 2(d) and (f)) we may see that the patterns of density distributions inside and outside the pole-axis system are quite different. Inside the system, whenever the lines merge, the Densi-Graph curve fluctuates but tends to be horizontal, but outside the system, a global increase trend will be detected, where the threshold density implies the boundary of the UA.

## 3. Case study in the capital UA region

The capital region is often called the Beijing–Tianjin–Hebei UA and is a loosely defined area with Beijing and Tianjin, the two municipalities directly controlled by the central government that are megacities with populations in 2014 of 21.52 million and 15.17 million respectively, and Hebei province, which surrounds them. Some tend to think that the UA covers all three provincial-level units. With regard to the classification of the region, many terms have been raised, such as Beijing–Tianjin–Tangshan urbanised areas, Capital Economic Region, and Bohai Rim Economic Region, but each term has a different spatial range and units. In fact, Beijing, Tianjin and Hebei province is a vast area involving two provincial cities, Beijing and Tianjin, and 11 prefecture-level cities or 206 county-level jurisdiction units. To determine where the UA boundary should be, we took the whole region within the boundary of the three provincial units as the study area. After merging adjacent central districts of each city, 176 basic units are obtained.




(a) Preliminary stage: iso-density distribution.

(b) Preliminary stage: Densi-Graph.

(c) Formation stage: iso-density distribution.

(d) Formation stage: Densi-Graph.

(e) Mature stage: iso-density distribution.

(f) Mature stage: Densi-Graph.

**Fig. 2.** Densi-Graph analysis of the evolution of pole-axis urban system.

### *3.1. Centrality of cities*

For the analysis of centrality, we took general fiscal revenue (GFR), total fixed asset investment, total retail sales of social consumer goods, gross domestic product (GDP), and the proportion of third industry in GDP of different spatial units as the basis indices. With an entropy method, the weight matrix of each index was determined (Table 2). The highest weight was placed on GFR (0.31), suggesting that this term has the biggest deviation among the six indices.

The comprehensive centrality index of each spatial unit was calculated (Fig. 3). Table 3 only lists those with a centrality index higher than 2. Table 3 shows that the central districts of Beijing, including Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai and Shijingshan, have the highest comprehensive strength in the whole region, with a centrality index of 99.62. This is followed by Binghai, a new district

**Table 2**
Entropy weights of the cities' centrality indices.

| Index | Weight $(w)$ |
|---|---|
| GFR (general fiscal revenue) | 0.31 |
| Total retail sales of social consumer goods | 0.26 |
| GDP (gross domestic product) | 0.21 |
| Total fixed asset investment | 0.14 |
| Residential population (in 2013) | 0.07 |
| Proportion of 3rd industry in GDP | 0.01 |

**Table 3**
The centricity score of cities in the Beijing–Tianjin–Hebei region.

| Spatial unit | Centrality | Spatial unit | Centrality | Spatial unit | Centrality |
|---|---|---|---|---|---|
| Central districts of Beijing | 99.62 | Wuan city, Tianjin | 3.73 | Dingzhou city, Hebei | 2.47 |
| Binhai, new district of Tianjin | 39.45 | Baodi district, Tianjin | 3.67 | Central districts of Xingtai city, Hebei | 2.46 |
| Central districts of Tianjin | 23.51 | Central districts of Tangshan city, Hebei | 3.67 | Luquan city, Hebei | 2.37 |
| Central districts of Shijiazhuang[a] | 13.76 | Jixian county, Tianjin | 3.51 | Huairou district, Beijing | 2.36 |
| Shunyi district, Beijing | 8.08 | Zunhua city, Hebei | 3.23 | Laoting county, Hebei | 2.33 |
| Changping district, Beijing | 6.36 | Fengnan district, Tangshan | 3.20 | Hejian city, Hebei | 2.32 |
| Tongzhou district, Beijing | 5.91 | Jinghai district, Tianjin | 3.18 | Luanxian county, Hebei | 2.31 |
| Daxing district, Beijing | 5.90 | Fengrun district, Tangshan city, Hebei | 3.16 | Luannan county, Hebei | 2.28 |
| Dongli district, Tianjin | 5.68 | Renqiu city, Hebei | 3.12 | Yutian county, Hebei | 2.27 |
| Xiqing district, Tianjin | 5.54 | Central districts of Zhangjiakou city, Hebei | 3.08 | Central districts of Chengde city, Hebei | 2.27 |
| Fangshan district, Beijing | 5.30 | Gaocheng city, Hebei | 3.05 | Cixian county, Hebei | 2.22 |
| Central districts of Qinhuangdao, Hebei | 5.29 | Xinji city, Hebei | 2.74 | Shexian county, Hebei | 2.18 |
| Wuqing district, Tianjin | 5.17 | Central districts of Langfang city, Hebei | 2.72 | Qianxi county, Hebei | 2.12 |
| Jinnan district, Tianjin | 5.12 | Central districts of Cangzhou city, Hebei | 2.68 | Zhengding county, Hebei | 2.11 |
| Qianan city, Hebei | 4.98 | Ninghe county, Tianjin | 2.57 | Huanghua city, Hebei | 2.07 |
| Beichen district, Tianjin | 4.83 | Zhouzhou city, Hebei | 2.54 | Cangxian county, Hebei | 2.04 |
| Central districts of Baoding, Hebei | 4.31 | Bazhou city, Hebei | 2.52 | Pinggu district, Beijing | 2.03 |
| Central districts of Handan, Hebei | 3.94 | Miyun district, Beijing | 2.51 | | |
| Sanhe city, Hebei | 3.90 | Yongnian county, Hebei | 2.47 | | |

[a] Shijiazhuang is the capital city of Hebei province.

of Tianjin (39.45), and the central districts of Tianjin (23.51). As the capital city of China, the central districts of Beijing surely have a huge potential to be the strongest centre of the region. Binhai new district, known as 'the third growth pole of the Chinese economy' is the international shipping and logistics centre in north China. A comparison of the centrality index implies that its importance has surpassed the central districts of Tianjin. As the centralities of central Beijing and Binghai district are significantly higher than that in other areas, we chose them as the central places of the capital UA.

### 3.2. *Social and economic connections between spatial units*

Upon identification of the central places of the capital UA, the social and economic connections between spatial units were analysed to evaluate the integration level of the urban system.

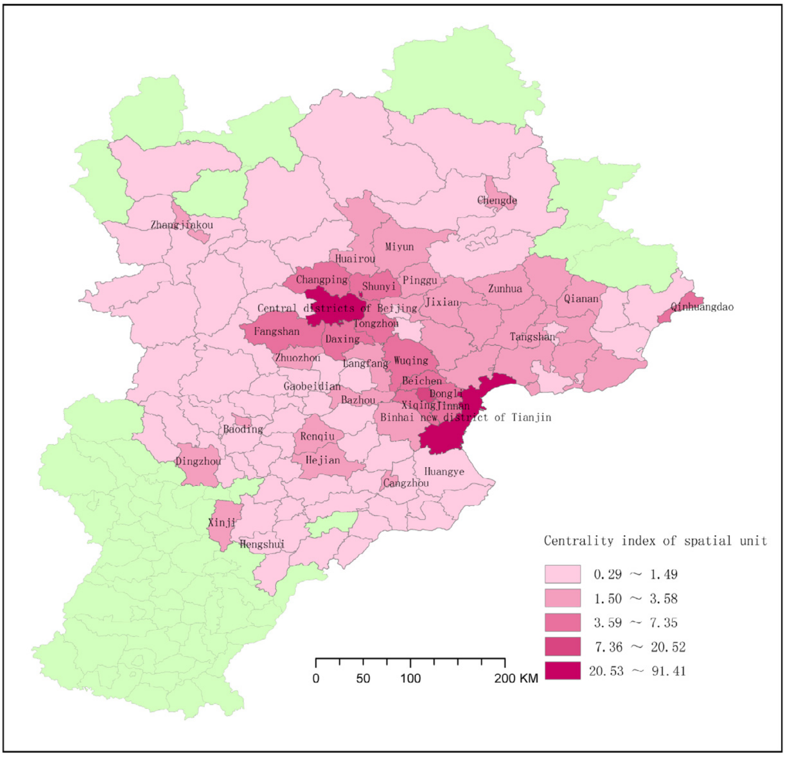



**Fig. 3.** Centrality of spatial units in the Beijing–Tianjin–Hebei region.
*Source:* Niu et al. (2015).

Theoretically, the social and economic connections between two units are strongly related to the distance between them and their scale: the closer the distance and the larger the scale, the closer connection there will be. The social and economic connection is usually evaluated by the flow between two units such as the commuter flow, cargo flow, technology flow, information flow, finance flow, etc. Chen and Song (2010) adopted spatial distance and passenger and cargo transportation volume to represent the strength of economic connections. Some calculated the strength of connection of different areas by the social network. We selected four commonly used indices to calculate the social and economic connections between spatial units, including road network distance, road passenger transportation volume, railway passenger transportation volume and pairwise internet search results.

Transportation distance is defined as the minimum time cost of two spatial units computed by the length of highway or high-speed railway divided by the average speed between different urban hierarchies. If there are several paths between a spatial unit and central cities, the topological map is created firstly by overlapping different road networks; then, the time distances between any two nodes on the network are calculated. The path associated with the minimum time cost of two spatial units is chosen. The resulting transportation distance reveals the convenience of transportation between each pair of spatial units.

We collected road passenger transportation data from the statistical yearbook of 2014. The volume of road passenger transportation is comprised of long-distance passenger volume and cross-border public transportation volume. Likewise, railway passenger transportation volume is comprised of direct trains and cross-border trains between different spatial units. The cross-border transportation volumes are used. With the prevalence of internet usage, the information volume of the internet has grown quickly and conveys a variety of social and economic information. In the Baidu search engine (http://www.baidu.com), which is the largest web search engine in China, we input the names of any

**Table 4**
The weight of socio-economic connection indices.

| Index of social and economic connections | Weight |
|---|---|
| Railway passenger transportation volume | 0.36 |
| Road passenger transportation volume | 0.35 |
| Baidu information index | 0.27 |
| Time distance of road transportation | 0.02 |

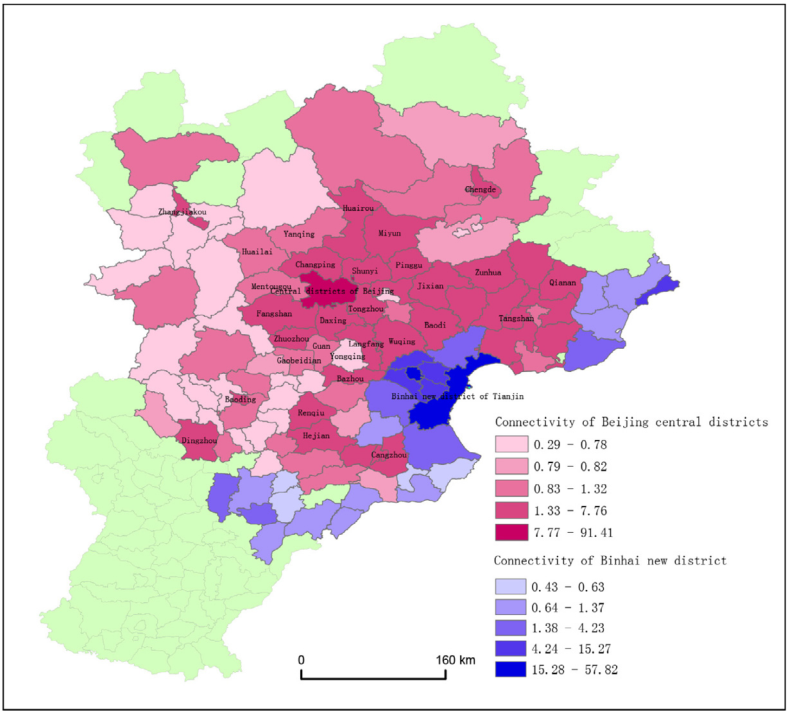
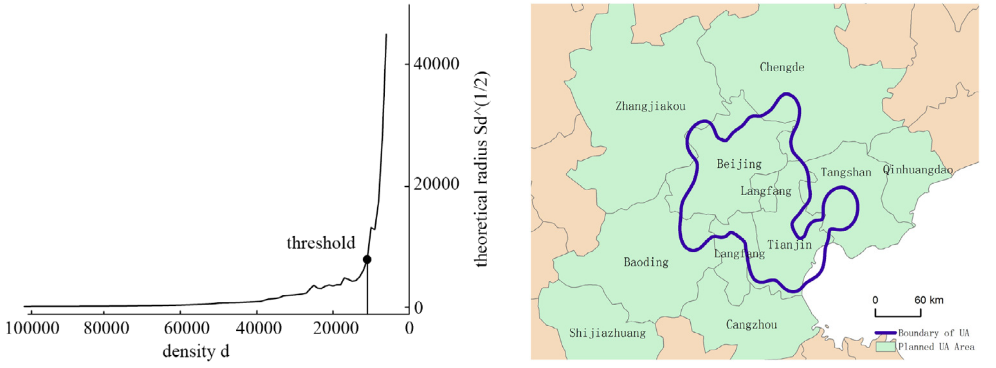



**Fig. 4.** Connectivity of cities and towns with central cities in the Beijing–Tianjin–Hebei region. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

two places. With such a pairwise internet search method, for example, inputting 'Beijing' and 'Tianjin', we obtained the number of text pages including both terms. The number of search results is a proxy indicator of the comprehensive intensity of the connection of two spatial units, which supplements the other three indices from the social perspective.

The four indices representing the connection of spatial units are strongly correlated. For instance, time distance is significantly correlated with road and railway passenger transportation volumes, and the Pearson's correlation coefficients of pairwise internet search results with the other three indices are significant. Therefore, we calculated the entropy weight of the indices (Table 4) and then computed the social and economic connection strength of spatial units with the two central cities one by one. In general, the highway and railway networks in Beijing and Tianjin are quite developed. From Fig. 4, we can see that connectivity generally attenuates outside the Beijing central districts and Binhai new district, but the trend is not evenly distributed. There are some enclaves between strongly connected nodal cities such as Yongqing county in Hebei province, and Zhuolu county and Huailai county in northwestern Hebei province. This may be explained by relatively poor trunk road and railway accessibility in these areas.




(a) Densi-Graph of the kernel density of POI.

(b) Boundary of the capital UA.

**Fig. 5.** Identification of the boundary of the capital UA.

For simplicity and clarity, we classified the cities and counties by their connectivity to central places: high, medium, low, and those outside the two-hour time distance circle (Fig. 4). The last classification is made for the reason that two hours is generally believed to be an appropriate threshold for a UA as it allows commuting and one-day business trips within the region. The red layer in Fig. 4 shows the classified connectivity with the Beijing central districts, and the blue layer shows the connectivity with the Binhai new district uncovered by the red layer.

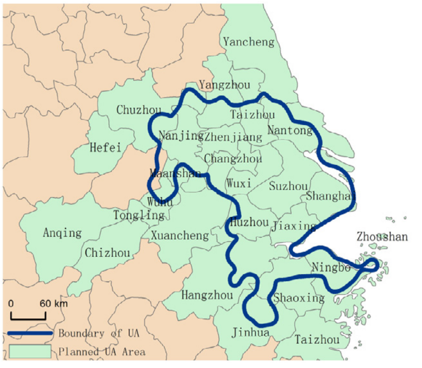
### *3.3. Development degree of UA*

With the POI data of the 2011 Baidu map, we plotted the Densi-Graph of the capital UA (Fig. 5(a)). With the method related in Section 2.2, the threshold point of the curve was recognised, whereby the boundary of the capital UA was plotted in Fig. 5(b). The development degree of the capital UA was objectively demonstrated, from which we understand that the integration of Beijing, Tianjin, and Langfang city, Tangshan city, and part of Baoding city and Chengde city is substantial, but cities in the southwestern part of Hebei province including Zhangjiakou, Shijiazhuang, Qinhuangdao, and Cangzhou are still distinct entities in themselves.

The result in Fig. 5 confirms the polarisation of the region. Specifically, the primary functions of the whole region agglomerate in Beijing, Tianjin and a limited part of Hebei province, but those of the surrounding hinterlands are barely driven up by them. On the other hand, the roles played by Shijiazhuang, Zhangjiakou and Qinhuangdao cities in the capital UA are indistinct, making it difficult for them to absorb the industrial transfer from the central cities. If the capital UA is to be implemented to the expected scope, the local governments must maintain an open mind and the administrative boundaries of the municipalities must be disregarded, so that more nodal cities can be absorbed into the UA system and a new balance can be achieved among cities on a larger terrestrial scale. To this end, the construction of an integrated infrastructure and road network is essential, which may facilitate the outward dispersal of urban functions in central cities. In addition, it is necessary to reinforce the radiation and driving function of sub-central cities by upgrading the industrial structure and adjusting the spatial structure, to accelerate the gradient shift of industries in the region.

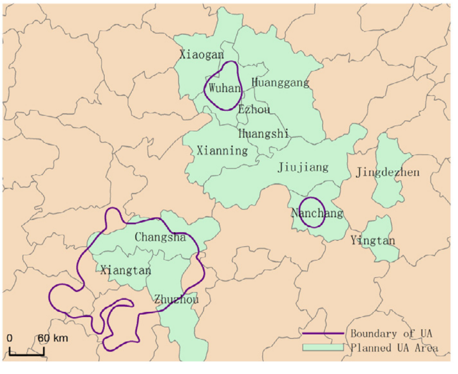
## 4. Comparison of the development degree of major UAs in China

With a similar approach to the above, we analysed the other four national UAs proposed by NNUP2020; namely, the Yangtze River Delta UA, the Pearl River Delta UA, the Middle and Upper Reaches of Yangtze River UA, and the Chengdu–Chongqing UA. The polygons of green colour in Fig. 6 represent prefecture-level cities which have been included in the UA in NNUP2020. As their

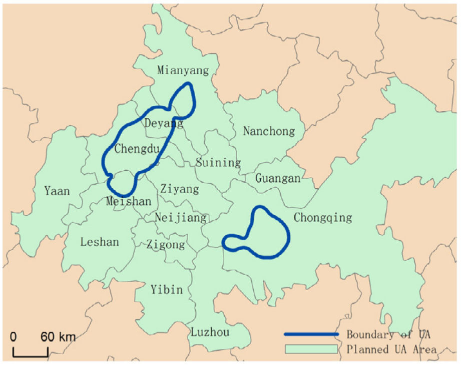



(a) Yangtze River Delta UA.


(b) Pearl River Delta UA.




(c) Middle and upper reaches of Yangtze River UA.




(d) Chengdu–Chongqing UA.

**Fig. 6.** Development of the other four proposed national UAs. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

boundaries in Fig. 6 show, the Yangtze River Delta and Pearl River Delta agglomerations are relatively mature. In the former, Shanghai, Nanjing, Hangzhou and 15 other prefecture-level cities are well incorporated. In the latter, Guangzhou, Shenzhen, and eight other prefecture-level cities are integrated in the UA. A comparison of them with the capital UA in Fig. 5(b) demonstrated that the development degree of the capital UA has been left far behind. In addition, the agglomerations in the middle and upper reaches of the Yangtze River and Chengdu–Chongqing regions are both in the formation stage, as some important central cities in these regions are independent.

It may be supposed that, compared with these five national agglomerations, the proposed UAs in other regions are actually underdeveloped. Even though this fact does not refute China's UA strategy of building dozens of agglomerations in one decade, the results may at least suggest that the current spatial definition of the UAs is too strict.

The UA is the product of a mature regional urban system that is different from the regional policy demanded by the government. It should not be fully determined by administrative instructions or policy interventions; otherwise, the UA plan may lead local governments to blindly enclose more areas without considering the true purpose of the strategy in practice.

The UA strategy requires huge investment of capital, land and other resources. With only three to five mature agglomerations, whether or not China should invest in 20–30 UAs at the same time is in question. Therefore, it is essential to create a better national master plan for UAs based upon the general architecture at the top level, and objective and accurate assessment of the geographic condition. Meanwhile, the economic development level and potential of different regions should be made when they compete for the status of UA, to avoid the UA strategy becoming a political tool for local governments to scramble for government and social investment.

## 5. Concluding remarks

According to the theory of economic geography, the UA should be an agglomeration of cities with a limited spatial scope, where the natural and social environments are highly integrated, with large scales of population and economy, high levels of urbanisation and industrialisation, and advanced infrastructure and public service networks. It is the product of pole-axis urban system development at a mature stage. These conditions are being accepted gradually. Clearly, the proposal for UAs in the national strategy should comply with these standards. Spatial adjacency of cities is just one condition, but not the only one. In a sense, the integration of functions is more important, which may be represented by the intensity of social and economic ties and the development degree of the pole-axis urban system of the region.

Developing this argument, we doubt the rationality of the proposed UAs in the national plan for UAs and previous studies related in the first part of this article. The procedure presented in this paper includes three steps of recognition of central cities, analysis of the regional urban system and the social and economic connections of cities, and assessment of the development degree of the urban system. The results of the case areas supported the conclusion that only three to five UAs are currently mature, and most others being proposed are underdeveloped. This implies the necessity of considering the ability of the Chinese government to accomplish the plan, especially if the national government intends to play a primary role in the construction of national and regional UAs. According to the experience of existing agglomerations in the world such as New York, London and Tokyo, most take decades to move from individual cities to highly interactive urban systems. The development of China's Yangtze River Delta UA, which is centred on Shanghai, Nanjing and Hangzhou, took advantage of the opening up and reform of China and accelerated from the early 1980s, and the Pearl River Delta UA benefitted from the preferential regional policy that set up the Shenzhen Special Economic Zone in 1992 and the return of Hong Kong to China in 1997. Its formation took also more than 20 years. The idea of the capital UA was proposed at the beginning of the 21st century and planning for the Greater Beijing region covering Beijing, Tianjin, and North Hebei province (Wu, 2002, 2006, 2013) and for the Beijing–Tianjin–Hebei region (Fan, 2008) have been studied ever since. But it is commonly accepted that the construction of the capital UA is slower than expected as a result of conflicts among the three municipalities. Past experience suggests that the construction of the UA is a time-consuming and costly programme, subject to many factors besides the wishes of government or a top-down plan. Objectively speaking, to achieve the goal of 20 or so UAs in five years is impossible, and a more realistic plan with a solid base of comprehensive scientific research from the geographical, fiscal and political perspectives is imperative.

In this paper, we advanced previous studies by adopting development degree analysis to the procedure of UA identification and stressed that this is one of the most important criteria for a UA. This understanding is of great significance for an objective review on the UA strategy.

We demonstrated that, to resolve the basic concept and criteria of UAs, an investigation from the spatial perspective is essential. At present, the core issue with regard to the debate on the number and range of UAs lies in the specious definition of the spatial boundary. Our proposal of using POI data and the Densi-Graph method offers a clear answer to the question. As the results of analysis that are more objective and accountable, they tend to be reliable references for spatial planning policies.

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**Table A.1**
Different views about the number and spatial structure of UA in China.
*Source:* ISPRE (2015). Organised by author.

| Spatial pattern of UA | | Specification of UA strategy |
|---|---|---|
| 5 + 6 + 11 (by Xu K D) | 5 national-level | Pearl River Delta, Yangtze River Delta, the capital region, Chengdu–Chongqing cluster, middle reach of Yangtze River |
| | 11 regional-level | Shandong peninsula, mid-southern Liaoning, Central plains, Guanzhong–Tianshui cluster, Beibu Gulf, Central Guizhou, Taiyuan, Hubaoeyu-Region, middle reach of Yellow river in Ningxia, Lanzhou–Xining cluster, Huaihai plain area |
| | 6 support-level | West coast of Taiwan Strait, Hainan, northern slope of Tianshan Mt., Harbin–Changchun cluster, Central Yunnan, south and mid-Tibet |
| 5 + 9 + 6 (by Fang C L) | 5 national-level | Pearl River Delta, Yangtze River Delta, the capital region, Chengdu–Chongqing cluster, middle reach of Yangtze River |
| | 9 regional-level | Harbin-Changchun cluster, Shandong peninsula, mid-southern Liaoning, West coast of Taiwan Strait, Central plain, Guanzhong, Yangtze–Huaihe river, Beibu Gulf, northern slope of Mt. Tianshan |
| | 6 lower regional-level | Hubaoeyu-Region, the Central Shanxi, middle reach of Yellow river in Ningxia, Lanzhou-Xining cluster, central Yunnan, central Guizhou |
| 3 + 3 + 7 (by Gu C L) | 3 UAs | Pearl River Delta, Yangtze River Delta, capital region |
| | 3 urban clusters | mid-southern Liaoning, along Jiaoji railway, southeast Fujian |
| | 7 conurbations | Jianghan plain, Central plain, Songnen plain, central Hunan, Sichuan basin, Three Gorges area, Guanzhong area |
| 10 + 6 pattern (by Xiao J C) | 10 developed | UAs in the Pearl River Delta, Yangtze River Delta, capital region, mid-southern Liaoning, Shandong peninsula, middle reach of the Yangtze River, Chengdu–Chongqing cluster, west of strait, central plains, Guanzhong |
| | 6 developing | Beibu Gulf, Yangtze–Huaihe river, eastern Hubei, central Jilin, Harbin–Daqing–Qiqihar cluster, northern slope of Mt. Tianshan |
| 10 + 3 pattern (by Ning Y M) | 10 double-centre | Pearl River Delta, Yangtze River Delta, capital region, Shandong peninsula, mid-southern Liaoning, Harbin–Qiqihar cluster, Changchun–Jilin cluster, central plain, southern Fujian, Chengdu–Chongqing cluster, |
| | 3 mono-centre | Wuhan cluster, Changsha–Zhuzhou–Xiangtan cluster, Guanzhong cluster |
| 3 + 7 + 17 (by Wu T H) | 3 first-class | Pearl River Delta, Yangtze River Delta, capital region |
| | 7 second-class | Chengdu–Chongqing cluster, central plain, Wuhan cluster, Shandong peninsula, west coast of Taiwan strait, mid-southern Liaoning, Jinan cluster |
| | 17 third-class | Changsha–Zhuzhou–Xiangtan cluster, Xuzhou cluster, Shijiazhuang cluster, Fuyang cluster, Guanzhong cluster, Chaoshan cluster, Beibu gulf, Hefei cluster, Nanchang cluster, Wenzhou–Taizhou cluster, Harbin cluster, Guiyang cluster, Changchun cluster, Xiangyang cluster, Qiongzhou Strait, Taiyuan cluster, Lanzhou cluster |

## Appendix

See Table A.1.

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