Research Paper

The Spectrum of Metropolitan Areas across the World, and Detection of Potential Metropolitan Areas with Chinese Characteristics

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Abstract

When people talk about the Metropolitan Area (MA), they mean differently in different parts of the world with different contexts. Based on its spatial extent, internal structure, socio-economic function, and network characteristics, an MA can refer to various entities from a metropolis to a Megacity-region. In an effort to clarify the MA concept, we review the origin of the MA concept and its development in various parts of the world, especially the United States, Japan and China, so as to propose a spectrum of MAs, and their relationship with specific human and natural geographical contexts. Particularly, we find MAs in China typically have a unique three-circle structure, which is composed of a core circle, a commuting circle, and a functional metropolitan circle. By international comparable standards which include factors such as population density, facility density, and economic activity intensity, and adjusted with reasonable context-dependent considerations in China, the three circles are designated as follows: the spatial extent with the highest development intensity and assuming a central regional role is identified as the core circle; the districts and counties around the core circle with a commuting rate greater than 10% are identified as the commuting circle; and the districts and counties within an one-hour accessible zone are identified as the functional metropolitan circle. To test the model, we utilize eight sources of big data covering ecological background, population, economy, transportation, real estate, land use, infrastructure, and culture characteristics, and with a fusion analysis of the data we show how the factors combined give rise to the three-circle structure in typical Chinese MAs, and why the combination of the same factors in the US and Japanese contexts works otherwise to fill different niches in the spectrum of MAs mentioned above. For a further inquiry, within the framework of the same model and using the same dataset, we identify 32 cities from all 338 prefecture-level cities in China that would qualify as an MA or potential MA, which we call "the Metropolitan Areas with Chinese Characteristics", and designate the spatial extent of the three circles within each of the MAs. Additional analyses are also conducted to locate the main development corridors, key growth poles, and currently underdeveloped regions in each of the MAs. We conclude the paper with discussions of potential challenges of MA development in China vis-a-vis current policies, such as cross-administration collaboration between jurisdictions within the same MA, and cross-scale collaboration between MAs, cities, and city groups. Placing the research in the global context, and considering the vast similarities between China and other developing countries in terms of population density, land resources, urbanization

level, and socio-economic development status in general, we argue that China's model of MAs may be also applicable to other developing countries. Therefore, this research may shed lights to planning researchers and practitioners around the world, especially in developing countries in understanding the development conditions of MAs in their own contexts, and also in methods for identifying and planning potential MAs to achieve their specific policy objectives.

Keywords

Metropolitan Area, Spatial Planning, Geospatial Information Systems, Big Data

1. Introduction

1.1. Metropolitan area concepts

Metropolitan area is a complex spatial system. Urban geography, population geography and urban planning provide theoretical support for summarizing the development of the metropolitan area from the perspective of regional differences and spatial structure evolution. In 1961, Jean Gottman first mentioned the concept of "Megalopolis" in the book "Megalopolis: the urbanized northeastern seaboard of the United States ", which refers to the phenomenon of urbanization in the northeastern United States (Gottman,1961). The first naming of the phenomenon, that is, a central city or a few large cities that play a central role, plus an urban economic region surrounded by areas with strong connection from the central city (Gottman,1957; 1978). In the 1950s, Japanese scholars proposed the concept of "Toshiken" and applied it to regional urban planning (Tomita,1975). In 1951, the Japanese scholar Kiuchi Shinzo proposed that the metropolitan area should be composed of three parts: the central area, the surrounding area of the city and the vast hinterland of the suburbs by studying the cross-sectional changes and regional structure of urban population increase and decrease (Kiuchi,1954). His ideas were further developed into the metropolitan area concept of Japan, and as one of the important spatial organization characteristics of Japan, western countries and other urban areas. The definition of the metropolitan area in Japan basically refers to the American standards, and then sets various metrics according to the specific national conditions such as the population and area of Japan (Kanemoto,2002). Because China and Japan belong to the East Asian Chinese character culture circle, Japan's theoretical exploration and successful practice in the metropolitan area has been widely quoted in China. Chinese scholars, including Yixing Zhou, Shimou Yao, Chaolin Gu, Chuanqing Wu, etc., began to study the concept of urban agglomeration (Zhou,1986; Yao,2005; Gu,1994). There is never a unified academic definition about metropolitan area. However, most definitions indicate that the metropolitan area is an interconnected whole formed by cities of different grades, types and sizes, with the help of regional transportation networks. Combining the existing concepts of metropolitan area, metropolitan area in this paper is defined as a region consisting of a densely populated urban core and its less-populated surrounding territories, sharing industry, infrastructure, and housing. This definition highlights the dominant position of the central city, the close relationship between the internal social economy and the boundary of the economic development of the circle.

1.2. Criteria of metropolitan area

The New York metropolitan area is a geographic unit defined by the US Bureau of Statistics (NY-NJ-PA Metropolitan Statistical Area). A core-based statistical area (CBSA) is a U.S. geographic area defined by the Office of Management and Budget (OMB) that consists of one or more counties (or equivalents) anchored by an urban center of at least 10,000 people plus adjacent counties that are socioeconomically tied to the urban center by commuting (Vicino, 2007; Luo, 2007). The standards of urban areas and non-urban areas are according to different national conditions. Japan refers to urban areas as “Shigaichi”, an area with a population density of not less than 4,000 people per square kilometre (Sorensen, 1999). People have a tolerance for the length of commuting time, so the long axis radius of the metropolitan area is stable around 50 kilometers, that is, the size of the commuting circle determines the size of the metropolitan area. In the 1950s, the Japanese Administrative Office defined the metropolitan area as: a one-day cycle that can accept the geographical scope of a functional service in a certain aspect of the city (the population must be more than 100,000). The metropolitan area is the spatial scope that is closely related to the various regions formed by the city when it exerts its functions. It is usually measured by logistics, people flow, economic flow, information flow, etc. And the city's own external control ability and economy radiation capacity is also an important measure of metropolitan area. The Japanese Administrative Office revised the concept of the metropolitan area in 1960, and defined the commuting population in the central city and the periphery, and the logistics traffic volume in the metropolitan area. It pointed out that the metropolitan area is centered on the designated city of the central government. An area consisting of one or two or three mega-central cities with a population of more than 2 million and a number of neighboring cities with more than 500,000. The commuting rate from the peripheral area to the central city is not less than 15% of the population, and the amount of material transportation between metropolitan areas cannot exceed 25% of the total transportation volume (Qiu, 2009). The commuting rate from central cities and peripheral cities largely reflects the economic, transportation and other links between metropolitan area.

2. Metropolitan area identification

2.1. Research objects

In this study, 32 major cities (excluding Hong Kong, Macao and Taiwan) were selected as research objects, 31 of which were located in the east of Heihe-Tengchong Line, including 4 municipalities (Beijing, Shanghai, Tianjin, Chongqing), 5 cities with separate plans (Shenzhen, Dalian, Qingdao, Ningbo, Xiamen) and 10 sub-provincial cities (Guangzhou, Nanjing, Hangzhou, Wuhan, Chengdu, Xi'an, Harbin, Changchun, Shenyang, Jinan), 12 provincial capital cities (Zhengzhou, Hefei, Changsha, Kunming, Nanchang, Nanning, Taiyuan, Guiyang, Fuzhou, Shijiazhuang, Haikou, Urumqi) and a prefecture-level city (Suzhou). We conduct in-depth research on the national metropolitan area, judge its development stage, and fully grasp the development of China's metropolitan area, and establish a methodology for the identification and scope of metropolitan areas.

2.2. Data source

Sources of this research data include national and local statistics (2013, 2015, 2017), China Unicom's “smart step” mobile phone signaling data (2018), AMAP point of interest (POI)

data(2018), DMSP/OLS remote sensing lighting data(2015), remote sensing image data(2018), and official website of local government.

2.3. Metropolitan area identification method

According to the factors such as population density, facility space density, and economic production activity intensity, the spatial unit with the highest development intensity in the region and taking the central function in the region is identified as the core circle. The determination process of the core area is as follows: (1)Assign multisource data to the kilometer grid. (2)Extract weighted scores greater than 15 points as the base layer after normalized processing of different kinds of data. (3)Screen the township street data to obtain the initial boundary of the core circle, and then use the light index data which can reflect the concentration level of economic activities to complete the boundary check. Extract the area where the light index value is greater than a certain threshold, and combine it with the initial boundary of the core area. And then get the boundary urban core circle of metropolitan area.

The urban circle is a spatial unit that is closely related to the core area in the region, and the commuting level that can directly reflect the degree of contact in different regions is selected as an indicator. Based on AMAP map commuting data, take the districts and counties around the core area as the basic unit. And the district or county units with the commuting rate to the core area greater than 10% are identified as the urban circle of the metropolitan area.

The metropolitan circle is a spatial unit that is closely related to the urban area within the region. It is also based on the commuting rate to realize the identification of the metropolitan area. Based on AMAP map commute data, calculate the commuting rate of districts and counties around the urban circle. Extract the district and county units with core circle and urban circle commuting rate greater than 1% as metropolitan circle. So far, the scope of the metropolitan area has been formed by the core circle layer, the urban circle layer, and the metropolitan circle layer.

Figure 1 Diagram of 32 metropolitan areas in China and statistical results of basic data

3. Spatial Logic of China's Metropolitan Area Evolution

"Core-Near-Area-Node" : The evolution Process of the spatial structure of the metropolitan area

Based on the development cases of large cities and their surrounding areas at home and abroad, and combined with the researches in fields like urban and geographic science, it can be found that the spatial development of metropolitan area will focus on the core part of metropolitan area, the node cities near the core part, and the important node cities in the wide area. Experiences from the development process of foreign metropolitan areas reveal that the formation of metropolitan areas has obvious characteristics of stages, often going through the process of "single-center agglomeration- diffusion near the center- diffusion in the wide area- diffusion in a network way" (Fang,2009). At first, the spatial development of metropolitan area will go through the absolute concentration stage, that is, the rapid development of the core area, the rapid growth of population in the urban center, and the aggregation of peripheral resources and population to the core, which could be concluded as "single-center aggregation" in spatial. As core cities' economic development, metropolitan areas will enter the stage of "diffusion near the center", characterized as the stable development of core circles and industrial transformation and separation of employment and residence. Industry and population will also spread to the suburbs of cities in spatial, thus foster the rapid development of the areas near the metropolitan areas (Dong,2005). After that, "diffusion in the wide area" as the residential functions and economic activities spreading to more peripheral areas along transport trunks and rivers, will appear in the metropolitan area. With the gradual integration of industry and city along the main corridors of some node cities, the city develops from a single-function city to a comprehensive-

function city. The functions of the region are more sound through the form of new industrial new towns, thus the region evolves into a more advanced "multi-center network" structure.

Figure 2 Metropolitan space development stage model

Metropolitan areas of Beijing, Chengdu and Guiyang are chosen comparing cases by observing night-light maps. It could be found that, the core part of Beijing and the adjacent metropolitan areas have a higher development level, and the important node cities along Jing-Ha, Jing-Jin, Jing-Bao, Da-Guang and other high-speed corridors also have higher development levels, such as Guan. For Chengdu metropolitan area, the development center is the adjacent area near the core city circle, such as the new area of Tianfu. A few node cities along the development corridor have begun to develop rapidly in the meantime. Guiyang metropolitan area is in the initial stage of core circle development without significant expansion, which has an impact on the peripheral areas.

Table 2 Characteristics of different types of metropolitan areas in China

Type	Core area scale	Radius	Area	Typical metropolitan area
Developed metropolitan area	>1000km ²	120-150km	40-50thound km ²	Beijing metropolitan area
Mature metropolitan area	500-800km ²	80-100km	2-3.5thound km ²	Chengdu metropolitan area
Developing metropolitan area	200-300km ²	50-80km	1.5-2.5thound km ²	Guiyang metropolitan area

Figure 3 Diagram of Beijing, Chengdu and Guiyang metropolitan areas

Figure 4 Night lighting index map of Beijing, Chengdu and Guiyang metropolitan areas

4. Spatial components of the metropolitan area structure

Metropolitan areas in China are mainly in the stage of the single-center formation, and influences on the peripheral regions are gradually increasing. Based on the relevant researches at home and abroad, the basic components of metropolitan area can be summarized as the following five items:

- 1 Strong nucleus: The central area of a large city with a large population and developed economy is the core support of the metropolitan area. Normally, the nucleus radius ranges from 15 km to 20 km. The population is highly concentrated, and the population density is more than 10,000 people/km². The leading industry is high-end service industry, which has a strong comprehensive service function.
- 2 Radiation circle: The circle area composed of several surrounding towns located in the radiation region of the central area is the vast hinterland of supporting the development of core cities. The area is determined by the 1-hour commuting circle, with a radius of 50-80

km and an area about 120,000 km². The minimum population density in the region is about 1,000 people/km².

3 Expansion axis: The expansion of metropolitan area is not uniform, but forming the development axis connecting the central area and surrounding towns along the traffic corridors, which constitutes the development artery of the metropolitan area.

4 Key points: The node towns which play key roles in the hinterland of metropolitan area are the new growth poles supporting the high-quality development of metropolitan area.

5 Close network: Elements such as human flow, material flow and information flow between different cities form the close network in the metropolitan area. And the network guarantees integration development of metropolitan area essentially.

Figure 5 Metropolitan area structure model

5. Spatial development characteristics of metropolitan areas in China

Based on above components, the spatial development characteristics of metropolitan area can be summarized as the following four aspects:

1 The strong and sustained center city is the basis and guarantee for metropolitan area development and gradual maturation. In China's urban system, the basic condition for the formation of metropolitan area is the density of population in core city more than 10,000/km². However, the "big city disease" will become prominent when the population density is more than 20,000/km². It is necessary to promote the healthy development of the metropolitan area by means of regional coordination.

2 Limit commuting time exists, and "one-hour commuting circle" is the boundary of the hinterland of metropolitan circle. Under the current residence-employment conditions, the maximum commuting time that residents can accept is 45 minutes to 1 hour. That is to say, the scope of "one-hour commuter circle" often determines the maximum radial distance from the center to the edge of a metropolitan area. Most of the new towns in the London metropolitan area are located within the 50 km circle, The towns in the Paris metropolitan area are also mainly within the 50 km circle, while the radius of the whole metropolitan area is about 80 km.

3 Relying on the main corridors, the core circle and the outer circle are closely related by population, transportation and economy. Within the metropolitan area, most of the traffic links through expressways and rail transits, supporting the higher commuting rate from the outer circle to the core circle. Based on the good-condition corridors, direct investment activities are happened closely among the cities, and division of labor and cooperation among the cities in the metropolitan area are also promoted efficiently and orderly.

4 The coordination of the ecological pattern and the protection of resources in the metropolitan area should be emphasized. And high-quality development of the metropolitan area could not be separated from the sustained advancement of the construction of ecological civilization. In recent years, regional and watershed-scale environmental problems have replaced single and individual environmental events, and become the main factors constraining the conversions to a high-quality stage of China's developed areas. Establishing a reasonable and organized regional eco-spatial system through regional coordination, integrating economic and social developments, are necessary conditions for the healthy and sustainable development of metropolitan area.

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