Research on Urban Network Characteristics of Shanghai Metropolitan Area

Based on Population Migration Data of AutoNavi Map

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Abstract

With the advancement of urban development, the relationship between cities has gradually evolved from a hierarchical structure to a network structure. "Shanghai 2035" emphasizes on strengthening collaboration with surrounding cities and develop a metropolitan area with global influence. This study selects 9 cities (Shanghai, Suzhou, Wuxi, Changzhou, Jiaxing, Nantong, Huzhou, Ningbo, Zhoushan) in the Shanghai metropolitan area mentioned in the "Shanghai 2035" as the preliminary research scope and use python to obtain population migration data from AutoNavi Map to promote research on urban network characteristics. This study refers to some mature urban network construction methods, and uses migration index to reflect the degree of connection between cities. Combine social network analysis and other methods to build a city relationship network based on migration index to analyse urban network characteristics of Shanghai metropolitan area. We can tell that the cities in Shanghai metropolitan area have formed stable and strong urban ties with each other; and the urban network structure of Shanghai metropolitan area has obvious hierarchy, with Shanghai and Suzhou as the core and Wuxi, Jiaxing, Changzhou and Nantong as important network nodes. Shanghai metropolitan area has the development trend of further expanding to other metropolitan areas and co-located development areas in the Yangtze River Delta. Compared with the Pearl River Delta City Cluster, this paper also provides some opinions for the development of Shanghai metropolitan area, such as establishing a new management system and accelerate the implementation of the new city strategy.

Keywords

population migration data of AutoNavi Map, Social network analysis method, Shanghai metropolitan area, Urban network structure, Comparative analysis with the Pearl River Delta city cluster

1. Research Background

1.1. Development of Regional Studies Theory

In the 21st century, the concepts of "mobility space" (M. Castells, 1996) and "urban networks" (P. J. Taylor, G. Catalano, 2002) have been developed in the discipline of regional studies and applied in China's regional studies. Scholars believe that there are various types of functional networks between cities, such as "economic flows", "transport flows" (Chen Wei, Liu Weidong, Ke Wenqian, 2017) (Liu Zhengbing, Liu Jingyu, He Xiaopei, 2014) and "information flows" (Li Jun, Dong Suocheng, Huang Yongbin, 2014). The study of urban networks from different perspectives has become the focus of the discipline, extending the traditional research perspective from the scale level and providing a theoretical basis for promoting the development of urban regional space (Fang Wei, Zhao Min, 2013) (Wang Lucang, Liu Haiyang, 2021).

1.2. Background of Urban Planning

In the approval of the 2016 version of the Shanghai Urban Master Plan, the State Council proposed "building the Shanghai metropolitan area", pointing out that it should give full play to the radiation role of the core city of Shanghai and strengthen the division of labor and collaboration between Shanghai and the surrounding small and medium-sized cities in order to cultivate a city cluster with world influence. The subsequent Shanghai Urban Master Plan (2017-2035), the Shanghai Metropolitan Area Spatial Synergy Plan and the Yangtze River Delta City Cluster Development Plan (2015-2030) also put forward relevant concepts and planning proposals, and the current trend of synergistic development of the Yangtze River Delta City Cluster, the development of cities in the Shanghai metropolitan area towards networking is an important development direction.

1.3. Development of Technical Methods

With the development of information technology, various kinds of big data such as migration data (Liu Wangbao, Shi Enming, 2016), POI data (Zhen Feng, Wang Bo, 2012), cell phone signaling data (Kang C G, Zhang Y, Ma XJ, et al, 2013) (Niu Xinyi, Wang Yao, 2017), provide technical support for the study of urban relations and regional development (CHEN Shuang, ZHOU Rui, GAO Jun, 2020) (Lai Jianbo, Pan Jinghu, 2019).

2. Research Subjects and Methods

2.1. Research subjects

This paper investigates nine cities in the Shanghai metropolitan area proposed in the Shanghai Urban Master Plan (2017-2035) and the Spatial Synergy Plan of Shanghai Metropolitan Area, including Shanghai, Suzhou, Wuxi, Changzhou, Jiaxing, Nantong, Huzhou, Ningbo, and Zhoushan. In addition, by picking up and processing the migration data, it is found that the radiation of Shanghai's metropolitan area is not limited to these nine cities, and other cities within the Yangtze River Delta with higher intensity of urban ties to Shanghai are included in the scope of exploration.

Figure 1. Shanghai Metropolitan Area Planning Scope. Source: Shanghai Urban Master Plan 2017-2035 .

2.2. Data sources and processing

In recent years, due to the development of geographic big data information technology, there are more studies on geolocation big data based on Tencent, Baidu and other platforms, and the research results prove that this kind of big data has a strong auxiliary confirming role for metropolitan area and urban agglomeration analysis. This paper starts the research based on Migration Big Data of AutoNavi Map

(website: <https://trp.autonavi.com/migrate/page.do>), which is the data provided by AutoNavi Map platform using geolocation location service technology to reveal urban population flow. Due to the processing of the platform, the data is a relative value, which is proportional to the actual migrating population.

In this study, we crawled the data of the top 30 actual migration indices of each city in the Shanghai metropolitan area from May 1, 2020 to May 1, 2021 for each city moving in and out of the city on a daily using python, and processed the data by connecting the PostgreSQL database with Navicat software. Aggregated the data by date to analyse whether there are different migration characteristics of weekdays, rest days, and holidays, and to reflect the strength of connections between cities by the intensity of population migration.

Considering the impact of Covid-19 on inter-city commuting in the first half of 2020, the migration data selected in this study started on 1 May 2020 to reduce the impact of epidemic factors and to keep the migration characteristics and intensity of city links reasonable.

2.3. Research Methods

Based on the data crawled above (98,600 data of Shanghai metropolitan area and 14,600 data of Yangtze River Delta), and with reference to some more mature methods of city network construction (A.S. Alderson, J. Beckfield, 2004; P. J. Taylor, 2010), the main indicators are defined in this study: the migration index for city "i" with origin and city "j" with destination is "Qij", and the migration index between two cities is "Vij". "Qij" and "Qji" are directional. The total outward linkage (outward degree) "Oi" and the total inward linkage (inward degree) "Ii" of city "i" represent the ability of city "i" to transport population outward and absorb population in an urban network of all cities within the study area. "Ci" means the sum of connection index of city "i", and expresses the position of this city in the network. Here is the calculation formula:

$$V_{ij}=Q_{ij}+Q_{ji}$$

$$O_i=\sum_j Q_{ij}$$

$$I_i=\sum_j Q_{ji}$$

$$C_i=O_i+I_i$$

On this basis, the social network analysis (SNA) methods are used to explore the strength of each city in the Shanghai metropolitan area in terms of its ability to export and attract population in the region, and the index is defined as the "in and out ratio", which is the ratio of "outward degree" and "inward degree" of a city in the urban network of the metropolitan area.

Based on the above research methods, the city network based on migration index is constructed, and the data is processed and analysed and by database. Then use ArcGis platform to finish the visual expression.

3. Analysis of Urban Network Characteristics in Shanghai Metropolitan Area

3.1. Analysis of urban linkages in Shanghai metropolitan area

By visualizing the data analysis results through ArcGis (Figure 2), it can be seen that a more obvious network structure has been formed among the cities within the Shanghai metropolitan area. The overall spatial network structure is formed with Shanghai and Suzhou as the core, and Wuxi, Changzhou, Jiaxing and Nantong as the important nodes, showing flat and networked development characteristics. Locally, a close urban linkage of "Shanghai-Suzhou-Wuxi-Changzhou" is formed, which to a certain extent reflects the influence of Shanghai and Suzhou as the core of the metropolitan area and is also closely related to

the development of the "Suzhou-Wuxi-Changzhou" metropolitan area. Nantong and Jiaxing are also important nodes in the metropolitan area due to their borders with Shanghai and Suzhou. Ningbo and Zhoushan in the southern part are the weakest cities in the metropolitan area network, while the links between the two cities are stronger than those between them and other cities.

Figure 2. Strength of urban linkages in Shanghai metropolitan area. Source: Self-drawn.

The analysis of the data by time period (Figure 3-5) shows that there is almost no difference in the degree of connectivity between the cities in the Shanghai metropolitan area on weekdays and rest days, which can prove that the cities in the metropolitan area have formed a relatively stable network structure. Shanghai and its adjacent cities, Suzhou and Jiaxing, have formed close "live-work" functional links, Suzhou and Shanghai have formed "centre to centre" links. The network relationship between the three cities of "Suzhou, Wuxi and Chang" is also relatively stable.

Figure 3. Weekdays. Source: J.L.

Figure 4. Rest days. Source: J.L.

Figure 5. Holidays. Source: J.L.

The intensity of inter-city connections during the holiday season has increased significantly, mainly in the three cities of Nantong, Ningbo and Zhoushan with other cities. This is related to basic behaviors such as holiday travel, and reflects the clear potential for these cities to improve in the network of city connections beyond their current status as tourist-oriented commuting destinations.

3.2. Analysis of urban centrality in Shanghai metropolitan area

The first result of the analysis of the urban centrality of the Shanghai metropolitan area is that the highest urban centrality is not Shanghai, but Suzhou. The reason for this phenomenon is partly related to the geographical location, as the actual location of the geographic center of the Shanghai metropolitan area is Suzhou, and partly due to the better development of the Suzhou-Xi-Chang metropolitan area, which has formed an obvious regional integration in recent years, so Suzhou has formed close ties with Wuxi and Changzhou, in addition to Shanghai. The decrease of Shanghai's city centrality is to some extent the inevitable result of the transformation of city relations from a hierarchical structure to a network structure, reflecting the higher degree of urban network development in the Shanghai metropolitan area.

Figure 6. Urban centrality in Shanghai metropolitan area. Source: Self-drawn.

The centrality of each city in the Shanghai metropolitan area reflects the characteristics of the urban network structure of the metropolitan area (Figure 6), both Shanghai and Suzhou at the first level; Wuxi, Jiaxing, Changzhou and Nantong at the second level; Huzhou and Ningbo at the next level; and Zhoushan

at the last level. This network structure reflects that the city network within the region breaks through the limitation of administrative hierarchy and is the spatial order presented by the regional development.

According to the analysis results, it can be seen that the current Shanghai metropolitan area has initially formed a well-connected and clearly structured network system, but it can still pay attention to the integrated development with Ningbo and Zhoushan in the future development.

3.3. Analysis of urban “out/in ratio” in Shanghai metropolitan area

An analysis of the “out/in ratio” of cities in the Shanghai metropolitan area (Figure 7) shows that Shanghai assumes a significant role in attracting population in the metropolitan area. Combined with the analysis of the metropolitan area's city centrality, it is clear that only Shanghai assumes the city function of attracting population among the cities at the higher network level; Suzhou and Jiaxing are the two most significant cities in terms of population migration out of the metropolitan area, due to the fact that both cities are directly connected to Shanghai, which highlights that Shanghai is the core city in the metropolitan area. The rest of the important network node cities have an out/in ratio slightly higher than 1, showing a tendency to gather in the central cities.

Figure 7. Migration direction in Shanghai metropolitan area. Source: Self-drawn.

As Nantong is adjacent to Shanghai, the access ratio is less than 1. On the one hand, it is because Shanghai and Nantong do not directly border each other, and on the other hand, it is because the Shanghai-Nantong railroad was just opened in July 2020, and the traffic connection is still weak. The access ratio of Ningbo and Zhoushan is much less than 1, which also reflects that the two cities are not yet fully integrated into the Shanghai metropolitan area, and the attraction of Shanghai's radiation has not yet reached the level of synergy and integrated development.

3.4. Analysis of the radiation range of Shanghai metropolitan area

This part of the analysis takes into account the top 20 cities in Shanghai in terms of daily in-migration and out-migration data, and analyses the radiation range of the Shanghai metropolitan area by comparing the strength of the connection between cities within the metropolitan area and outside the metropolitan area.

The ArcGIS visualization results show that the eight cities within the current metropolitan area, with the exception of Zhoushan, are generally more connected to Shanghai than cities outside the metropolitan area. In addition, Shanghai has formed high intensity urban links with other central cities within the

Yangtze River Delta, such as Hangzhou and Nanjing, and is second only to Suzhou, Jiaxing, Wuxi and Nantong in terms of intensity of links with Hangzhou. This indicates that the radiation range of Shanghai metropolitan area has the development trend of expanding beyond the current planning scope to the Yangtze River Delta.

Figure 8. Radiation range of Shanghai metropolitan area. Source: Self-drawn.

3.5. Spatial structure of Shanghai metropolitan area – Influence of policy factors

Combining the analysis of the radiation range of Shanghai metropolitan area and the analysis of the city network structure, it can be realized that the “1+8” metropolitan area of Shanghai is not a spatial structure developed only from Shanghai itself. The formation of the Shanghai metropolitan area is closely related to the policies of several “metropolitan areas” and “integrated development” in China, and there is a significant intersection between its own spatial structure and the related policy scope. The three cities of Suzhou, Wuxi and Changzhou in the northern part of the metropolitan area have a metropolitan area policy, and their development predates the development of the Shanghai metropolitan area, and they are now the most closely connected areas in the Shanghai metropolitan area; Ningbo and Zhoushan in the southern part of the metropolitan area are within the “Hangzhou-Ningbo” integrated development strategy; Jiaxing and Huzhou are also within the “Hangzhou-Jiaxing-Huzhou” integrated development

strategy. Nanjing and Hangzhou, which are more connected with Shanghai, are not included in the sphere of influence of Shanghai metropolitan area from the administrative point of view because they are the capitals of Jiangsu Province and Zhejiang Province.

Figure 9. Spatial structure of Shanghai metropolitan area. Source: Self-drawn.

The proposal and development of Shanghai metropolitan area is deeply influenced by policy factors, and it is easy to see from its planning scope and spatial structure that the development of Shanghai metropolitan area is the process of its own continuous integration with the surrounding metropolitan areas as a national central city. The development of the Shanghai metropolitan area should be coordinated with the surrounding metropolitan areas and integrated areas, strengthen the radiation effect on the whole Yangtze River Delta region, and lead the integrated development of the Yangtze River Delta region. Shanghai itself also needs a higher level of development of the region as a whole to enhance its international competitiveness.

4. Comparative Analysis with the Pearl River Delta City Cluster

4.1. Demonstrate the feasibility of comparative analysis

The Pearl River Delta (PRD) City Cluster and Shanghai metropolitan area urban network are selected for comparative analysis, firstly, because of the similarity of the two regions in terms of the number of cities

and regional area. The urban structure of Shanghai metropolitan area "1+8" includes 9 cities with a land area of about 5.4 square kilometers, while the PRD city cluster includes 9 cities with a land area of about 4.22 square kilometers. The two regions have sufficient comparative significance in terms of spatial scale.

Second, both regions are well-developed city cluster in China; the concept of the PRD city cluster was first proposed in the City Cluster Plan for the Pearl River Delta Economic Zone in 1994, and the diversified development strategy was proposed in the Outline of the Plan for the Reform and Development of the Pearl River Delta Region in 2008, and the Outline of the Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area in 2019 incorporated the PRD city cluster on the basis of the Hong Kong and Macao Special Administrative Regions, opening a new stage of integrated development. Although the concept of Shanghai metropolitan area was proposed later, in the Shanghai Urban Master Plan approved by the State Council in 2016, and the development strategy was clarified in the Shanghai Urban Master Plan (2017-2035), its development is based on the development of the Yangtze River Delta city cluster. Therefore, both regions are examples of regional integrated development with the longest development time and better development stage in China at present.

4.2. Comparative analysis

This section classifies the strength of urban linkages in the PRD city cluster according to the six classification criteria delineated by the natural breakpoint method in the Shanghai metropolitan area urban linkage strength above. After the visualization of the same classification criteria (Figure 10), it can be found that the linkage strength of cities in the Shanghai metropolitan area is weaker and less networked than that of the PRD region as a whole. In the Shanghai metropolitan area, the linkage strength between Shanghai and Su-Xi-Chang is higher, while the linkage strength of other node cities is lower. In contrast, all cities in the PRD city cluster form closer ties with at least one other city, especially among Guangzhou, Dongguan, Shenzhen and Huizhou.

Figure 10. Comparison of Urban Network Structure between Shanghai Metropolitan Area and Pearl River Delta City Cluster. Source: Self-drawn.

The comparison shows that cities in the PRD city cluster with lower network levels, such as Jiangmen, Zhuhai and Zhaoqing, are integrated into the urban network structure through their strong ties with secondary cities such as Foshan and Zhongshan. It can be concluded that some of the node cities in the

Shanghai metropolitan area are not fully integrated into the urban network structure, and the radiation from the central cities to some of the neighboring secondary-central cities and the influence of the secondary-central cities on the node cities are weak compared to the PRD city cluster.

The comparative analysis of urban centrality further confirmed the differences in the urban network structure of the two regions. Shanghai metropolitan area is represented by two centres (Shanghai and Suzhou); the PRD city cluster is represented by four centres (Guangzhou, Dongguan, Shenzhen and Foshan). The structure of the PRD city cluster can be summarized through the urban centrality analysis as follows: Guangzhou, Dongguan, Foshan and Shenzhen as the core cities, Huizhou and Zhongshan as the second circle, then Jiangmen, Zhuhai and Zhaoqing as the third circle.

The urban network structure of Shanghai metropolitan area reflects a "bicentre" structure - a flat structure with Shanghai and Suzhou as the core and other cities as the next level of development nodes; while the Pearl River Delta region has formed a "multi-centre" urban network structure. Compared with the PRD city cluster, Shanghai metropolitan area has formed a preliminary urban network, but it is still at the initial stage of network development.

4.3. Some advantages for reference

First, the intercity commuting time within the PRD city cluster is more reasonable and more acceptable compared to the Shanghai metropolitan area. The current cross-city commuting within the Shanghai metropolitan area is concentrated in the central city of Shanghai, only the commute time from Suzhou to the centre of Shanghai is within the generally acceptable range for residents. Therefore, commuting distance limits the further development of the Shanghai metropolitan area.

The "new city strategy" proposed in the Shanghai master plan (2017-2035) can improve this situation to a certain extent. The development strategy of positioning the five new cities (Jiading, Qingpu, Songjiang, Fengxian, Nanhui) as comprehensive node cities can strengthen the radiation of Shanghai as a central city to other cities within the metropolitan area. As independent node cities, the five new cities are closer to the centre of Shanghai than other node cities, forming a new development circle together with other near-Shanghai region. (Figure 11)

The development model of a comprehensive node city will enable the new city to have a degree of attraction and radiation capacity comparable to the central city of Shanghai. The policy can further promote the development of the Shanghai metropolitan area by increasing employment capacity, providing high-level public service facilities, and planning ecologically residential environments to strengthen ties with the near-Shanghai region.

Figure 11. “New city strategy” can enhance development of Shanghai metropolitan area. Source: Self-drawn.

Some other reasons for the high-level urban network structure in the PRD city cluster compared to the Shanghai metropolitan area is due to its early start of development and the presence of two national central cities within it, Guangzhou and Shenzhen. On the other hand, it benefits from the planning advantages of the administrative system. The PRD city cluster is under the governance of the same province, so it is more convenient and reasonable than the Shanghai metropolitan area in terms of resource allocation, factor flow and resource integration. This is also an important reference for the development of the Shanghai metropolitan area. The current “1+8” city structure has four cities each in Jiangsu Province and Zhejiang Province, and the establishment of a management mechanism and governance system beyond administrative divisions is of great help to the further development of the urban network in the Shanghai metropolitan area.

5. Conclusion and Reflection

5.1. Conclusion

Based on the big data of population migration and the research method of social network analysis, this study mainly draws the following conclusions. First, the cities in Shanghai metropolitan area have formed stable and strong urban ties with each other, and the integrated development among cities has broken through the hierarchical structure and formed a flatter network structure.

Second, the urban network structure of Shanghai metropolitan area has obvious hierarchy, with Shanghai and Suzhou as the core and Wuxi, Jiaxing, Changzhou and Nantong as important network nodes, but the role of Ningbo and Zhoushan in the urban network structure still needs to be strengthened.

Third, within the urban network of Shanghai metropolitan area, Shanghai, although slightly less central than Suzhou, is still the absolute central city through the out/in ratio analysis, carrying the important urban function of attracting population.

Fourthly, Shanghai has strong urban ties with other central cities and some cities in the Yangtze River Delta, and the development of Shanghai metropolitan area has been closely integrated with Su-Xi-Chang metropolitan area and has the development trend of further expanding to other metropolitan areas and co-located development areas in the Yangtze River Delta.

5.2. Development suggestions

First, accelerate the implementation of the new city strategy. Shorten the commuting distance between other node cities and Shanghai by developing comprehensive new cities to strengthen the connection with other cities such as Jiaxing, Ningbo and Nantong.

Then, establish a new management system beyond administrative divisions. This can better coordinate the integrated development of Shanghai metropolitan area with adjacent metropolitan areas and synergistic development areas.

Also, Strengthen infrastructure such as railroads and highways. Construction of transportation stations in suburban areas of Shanghai can accelerate the development of new cities and strengthen the connection with other cities in the metropolitan area.

6. References

- CASTELLS M. (1996) *The rise of the network society*. Wiley-Blackwell.
- TAYLOR P J, CATALANO G. (2002) 'Measurement of the world city network'. *Urban Studies*, 2002, 39(13): 2367-2376.
- ALDERSON A S, BECKFIELD J. (2004) 'Power and position in the world city system'. *American Journal of Sociology*, 2004, 109(4), 811-851.
- TAYLOR P J, HOYLER M, VERBRUGGENR. (2010) 'External urban relational process: introducing central flow theory to complement central place theory'. *Urban Studies*, 2010, 47(13), 2803-2818.
- Fang Wei, Zhao Min.(2013) 'Planning and Coordination of Urban Spatial Development under Paradigm of New Regionalism—— The Cases of City Cluster along the Yangtze River in Anhui and Jinan Metropolitan Area'. *Urban Planning Forum*, 2013(01), 51-60.
- Chen Wei, Liu Weidong, Ke Wenqian, et al. (2017) 'The spatial structures and organization patterns of China's city networks based on the highway passenger flows', *Acta Geographica Sinica*, 2017, 72(2), 224-241.
- Liu Zhengbing, Liu Jingyu, He Xiaopei, et al. (2014) 'The spatial connection and network feature of Zhongyuan Economic District base on intercity traffic flow', *Economic Geography*, 2014, 34(7), 58-66
- Li Jun, Dong Suocheng, Huang Yongbin, et al. (2014) 'Multi-scale spatial structure analysis of urban network based on Local IT Enterprise Network in China', *Geography and Geo-Information Science*, 2014, 30(1), 110-115.
- Wang Lucang, Liu Haiyang. (2021) 'A Study of China's Urban Networks Based on Tencent Migration Big Data', *Acta Geographica Sinica*, 2021,76(04), 853-869.
- Liu Wangbao, Shi Enming. (2016) 'Spatial pattern of population daily flow among cities based on ICT: A case study of "Baidu Migration"', *Acta Geographica Sinica*, 2016, 71(10), 1667-1679
- Zhen Feng, Wang Bo, Chen Yingxue. (2012) 'China's city network characteristics based on social network space: An empirical analysis of Sina Micro-blog', *Acta Geographica Sinica*, 2012, 67(8), 1031-1043.
- Xu Liuji, Long Ying. (2016) 'Analysis of Chinese urban network based on location and name of point of interest', *Beijing Planning Review*, 2016(6), 49-56.
- Kang C G, Zhang Y, Ma X J, et al. (2013) 'Inferring properties and revealing geographical impacts of intercity mobile communication network of China using a subnet data set', *International Journal of Geographical Information Science*, 2013, 27(3), 431-448.
- Niu Xinyi, Wang Yao, Ding Liang. (2017) 'Measuring urban system hierarchy with cellphone signaling', *Planners*, 2017,33(1), 50-56.
- CHEN Shuang, ZHOU Rui, GAO Jun. (2020) 'Spatial-Temporal CHARACTERISTICS of Population Flow during Spring Festival Travel Rush in Yangtze River Delta Urban Agglomeration Based on TENCENT Migration Data', *Human Geography*,2020,35(04),130-138
- Lai Jianbo, Pan Jinghu. (2019) 'Spatial pattern of population flow among cities in China during the Spring Festival travel rush based on "tencent migration" data', *Human Geography*, 2019,34(3), 108-117.

Deng Chuxiong, Song Xiongwei, Xie Binggeng, et al. (2018) 'City network link analysis of urban agglomeration in the middle Yangtze River basin based on the Baidu Post Bar data', *Geographical Research*, 2018, 37(6), 1181-1192.