The Evolution of Urban System in Shandong Province

Yanqiao Wang\textsuperscript{1,2,b}, Zhanqiang Chang\textsuperscript{1,2,a}, Lanting He\textsuperscript{3}, Xiaomeng Liu\textsuperscript{1} and Shujun Qian\textsuperscript{1,3}

\textsuperscript{1} College of Resource, Environment &Tourism, Capital Normal University, Beijing 100048, China
\textsuperscript{2} Key Lab of 3D Information Acquisition of Education Ministry of China, Beijing 100048, China
\textsuperscript{3}College of Geospatial Information Science and Technology, Capital Normal University, Beijing 100048

\textsuperscript{a}changkkll@tom.com; \textsuperscript{b}18810032012@163.com

Abstract. Shandong Province is one of the important provinces on the eastern coast. The total GDP is ranked third in the whole country. Since 2000, urbanization in Shandong Province has entered a period of rapid development, and the urban system has evolved into a focus. At present, there are relatively few research papers on urban system structure in China, and most of the focus is on urban agglomeration and urban circle research. Therefore, based on the socio-economic data of 17 cities from Shandong province, this paper aims to analyze the evolution of the urban system. From the aspect of economic spatial structure, we adopt principal component analysis (PCA) to obtain comprehensive score of economic scale and urban centrality of each city. It shows that Shandong province has developed from a dual-core urban system to a quad-core urban system. These four cores are Qingdao, Jinan, Weifang and Yantai. However, the gap of economical scale between Qingdao and Jinan is still relatively large. Based on the Economical Gravity Model, we obtain the strength of economic linkage between every two cities. It shows that the economic linkage of central Shandong and coastal areas is more concentrated, while economic linkage of southern Shandong is less concentrated. Overall, the urban system of Shandong Province has no obvious core cities and tends to be multi-core distribution. However, the four regional central cities described above are located in the central part of Shandong Province and the coastal peninsula, while the vast northern and southern parts of Shandong Province do not have a regional central city.

1. Introduction

In China, since the late 1980s, research on urban architecture has become a hot topic. Scholars use a variety of perspectives to analyze the spatial structure of urban systems.

Based on the hierarchical structure of population size, Sun scholars analyze the evolution of spatial structure of Chinese urban agglomerations based on the single-center-multi-center perspective of population distribution. [1] Sun Tieshan scholars have found that there is an inverted U relationship between economic spatial agglomeration and regional economic growth. There is also an inverted U relationship between the evolution of agglomerated spatial structure and regional economic development.[2] Based on the gravity model, Dong Qing have found that he spatial structure and spatial interaction of Chinese urban agglomeration system have obvious positive correlation.[3] and Zhang suggested that generally the spatial structure of these towns in Shanxi showed the tendency gradually...
optimized. The economic connection between them was enhanced year by year.[4] Sun Jinfang [5] analyzed the spatial structure of the Shandong Peninsula urban agglomeration. Yu Lanjun [6] and Guo Yuming [7] analyzed the urban spatial structure of Shandong Province and gave optimization suggestions.

Shandong is located in the eastern coast of China, downstream of Yellow River, north of Taihang Mountain. In terms of total population and GDP, there is no doubt that Shandong province is a province with strong comprehensive strength. In this paper, socio-economic data of each city which were acquired from Shandong Statistical Yearbook between 2009 and 2017.

2. Methodology

2.1 Principal component analysis (PCA)
Principal component analysis (PCA) [8] is a classic method in multivariate statistical analysis, which is the most suitable method for the analysis and calculation when there are some correlations between variables. The basic idea is that the linear transformation is used to gather indicators by abnegating a small part of the information and replacing the original index with several synthetic indexes. The comprehensive index is highly unrelated to each other, so that the high dimensional index data can be simplified in the best way.

2.1.1 Obtaining the spatial distribution of economic scale based on PCA. To obtain the spatial distribution of economic scale of 17 cities in Shandong province ,we get every city’s comprehensive score in 2009,2011,2013,2015 and 2017 respectively by PCA method and show these scores in the thematic map by ArcGIS, which can obviously and directly show the evolution of the spatial distribution of economic scale from 2009 to 2017.

5 indicators are used to present the economic scale of city and calculate comprehensive score of every city, including regional gross domestic product, total retail sales of consumer goods by region, total export value by region, total investment in fixed assets by region, general public budget revenue by region.

The process of data will be completed by Matlab, which is a powerful statistical software. First, these original indicators data should be normalized. Then, using PCA to deal with the data after normalization, we obtain every city’s comprehensive score of economic scale in 2009,2011,2013,2015 and 2017.

We classify the comprehensive score of every city in 2009,2011,2013,2015 and 2017, then we obtain the line chart(figure.1), from which we can see the evolution of every city’s economic scale during 2009-2017.

![Figure 1. the comprehensive score of economic scale in 2009, 2011, 2013, 2015 and 2017](image-url)
comprehensive score of less than 1.5 are low-grade economic scale cities. Then, 5 thematic maps of spatial distribution of economic scale are generated (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6)
2.1.2 Obtaining the spatial distribution of urban centrality based on PCA. As an important concept of urban geography, urban centrality [1] means the relative importance of a city as the provider of central goods and service in excess of the needs of its own residents. The concept of centrality is widely used in the study of cities system.

In this paper, we acquired the gross domestic product by region, non-agricultural population, tertiary industry gross output value, total investment in fixed assets by region, amount of contracted foreign capital in 2015 and 2017 from Shandong statistical yearbook to calculate the urban centrality index of each city.

The process of PCA was performed with Matlab software to obtain the comprehensive score of each city, which can represent the urban center functional degree of city. Results of the data process are as follows (table 1, table 2).

### Table 1. The comprehensive score of urban center functional degree in 2017

| City     | Comprehensive score | Ranking |
|----------|---------------------|---------|
| Qingdao  | 5.1098              | 1       |
| Jinan    | 1.8287              | 2       |
| Yantai   | 1.8003              | 3       |
| Weifang  | 1.6741              | 4       |
| Linyi    | 0.6314              | 5       |
| Jining   | 0.2785              | 6       |
| Zibo     | -0.0974             | 7       |
| Taian    | -0.1415             | 8       |
| Weihai   | -0.7699             | 9       |
| Dezhou   | -0.7953             | 10      |
| Heze     | -0.9392             | 11      |
| Liaocheng| -0.9440             | 12      |
| Zaozhuang| -1.0426             | 13      |
| Dongying | -1.1514             | 14      |
| Binzhou  | -1.2646             | 15      |
| Rizhao   | -1.6942             | 16      |
| Laiwu    | -2.4829             | 17      |

### Table 2. The comprehensive score of urban center functional degree in 2015

| City     | Comprehensive score | Ranking |
|----------|---------------------|---------|
| Qingdao  | 5.292143224         | 1       |
| Yantai   | 1.898855244         | 2       |
| Jinan    | 1.837395563         | 3       |
| Weifang  | 1.595364422         | 4       |
| Linyi    | 0.611962723         | 5       |
| Jining   | 0.250080816         | 6       |
| Zibo     | -0.057191954        | 7       |
| Taian    | -0.285849611        | 8       |
| Weihai   | -0.705589129        | 9       |
| Dezhou   | -0.76658696         | 10      |
| Liaocheng| -0.919113076        | 11      |
| Dongying | -0.992234279        | 12      |
| Heze     | -1.037608791        | 13      |
| Binzhou  | -1.158821405        | 14      |
Zaozhuang  -1.402327332  15
Rizhao     -1.694778341  16
Laiwu      -2.465701112  17

2.2 Economical Gravity Model
Based on the economical gravity model, this paper measures the strength of urban economical linkage and disparity characteristics between every two cities in Shandong Province in 2015. The economic gravity model is expressed as follows:

\[ I_{ij} = \sqrt{\frac{Q_i \times GDP_i \times Q_j \times GDP_j}{E_{ij}}} \]  \hspace{1cm} (1)

\( Q_i, Q_j \) are population of city i and city j, respectively. \( GDP_i, GDP_j \) are gross domestic product of every city. \( E_{ij} \) is the spatial distance between city i and city j.

Based on the above economical gravity model, we obtain the strength of economical linkage between every two cities. Then, we link the strength of economical linkage with thematic map to show the spatial characteristics of the strength of economic ties between every two cities between every two cities. We use the width of the line to indicate the size of gravity. The result is showed in figure 7 below:

![Figure 7: The strength of economical linkage between every two cities](image)

3. Result
From the aspects of time series, Qidao, Yantai, Jinan and Weifang always occupy the top 4. It is obvious that Qingdao has been promoting its economic, because of the increase of comprehensive score during 5 years.

We can see that spatial distribution of economic scale is imbalance. High-grade economic scale cities are located in the eastern coastal areas of Shandong and the middle of Shandong (Qingdao, Yantai, Jinan and Weifang), which driven the economic development of these region. Low-grade economic scale cities are located in the north and south of Shandong, which cause the low-speed economic development of these area because of lacking of leading cities.

We can also find cities with close spatial distances. The stronger the economic connection between them, and the weaker the economic connection as the spatial distance increases. Jinan has strong economic ties with the surrounding cities. Qingdao has the closest connection with Weifang.

4 Conclusion
The economic spatial structure of the urban system in Shandong Province tends to multi-level nuclear development, from the Jinan-Qingdao dual-core model to four distinct cores - Jinan, Qingdao, Yantai, Weifang. On the whole, the urban system of Shandong Province has formed a peninsula city group with
Qingdao and Yantai as the central cities, and a Jinan metropolitan area with Jinan and Zibo as the central cities. Besides, spatial distribution of economic scale is imbalance.

Acknowledgements
This research work was supported by National Natural Science Foundation of China (number 41771455/D010702) and the Beijing Outstanding Young Scientist Program (BJJWZYJH0120910028032)

References
[1] Bindong S, Jieyuan H, Wan L and Tin Z 2017 Spatial structure change and influencing factors of city clusters in China: From monocentric to polycentric based on population distribution Progress in Geography 36(10)
[2] Tie-shan S 2016 Evolution of agglomeration and its spatial structure with economic growth in three major metropolitan regions of China Economic Geography 36(05)
[3] Qing D, and Haizhen L 2010 The spatial structure and spatial interaction of Chinese urban agglomeration system have obvious positive correlation Economic Geography 30(6)
[4] Wen-li Z and Yu-xuan G, 2016 Gravity-model-based dynamic study of spatial structure of towns in shanxi province On Economic Problems
[5] Jianfang S Spatial Structure Analysis and Optimization of Shandong Peninsula Urban Agglomeration City and Community
[6] Lanjun Y 2015 Analysis of relationship between regional development strategy and urban spatial structure planning: a study on the urban spatial structure of shandong province areal research and development
[7] Yuming G Study on the Evolution and optimization of urban system in shandong province
[8] J.H.Xu 2002 Mathematical Methods in Contemporary Geography (Higher Education Press, Beijing )