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Cluster Analysis of Wuhan Metropolitan Area Based on Improved Gravity Model

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Abstract: This paper takes the Wuhan city circle as the research object, statistics the data of the city circle in recent years, and improves the urban gravity model by using the related theory and the analysis index of statistics, and obtains the competitiveness and mutual gravitation of each city in the city circle. Then, the cluster analysis is carried out by python programming to discuss the characteristics of the city in the Wuhan city circle.

Keywords: Wuhan City Circle; Urban Gravitational Model; Cluster Analysis

1. Wuhan urban circle and statistics

Wuhan urban circle refers to Wuhan as the core area, mainly including Wuhan and the eight cities, including Huangshi, Ezhou, Xiaogan, huanggang, Xianning, Xiantao, Qianjiang and Tianmen, which are close to Wuhan.

Since the 21st century, in April 2006, relevant documents have been issued to take "Wuhan Urban Circle" as the first of four urban agglomerations focusing on development. In 2007, Wuhan was established as a pilot zone for two types of social reform, which raised the status of "Wuhan Urban Circle" to the national strategic level; In 2008, the overall plan of comprehensive supporting reform and test of Wuhan urban circle was approved by the State Council and became the first approved urban circle; In 2014, Wuhan urban circle regional development plan was officially approved; In 2016, Wuhan was successfully selected as a national central city; In 2021, Wuhan city circle proposed that nine cities are the development goals of one city.

The specific aspects to be evaluated include: economic development, social development, quality of life of residents and the degree of opening up to the outside world. In terms of the statistics obtained, we have looked up the statistical yearbook of Hubei Province in 2019 and the statistical yearbook of all cities in Wuhan city circle in 2019.

2. Application of urban gravity model in Wuhan Metropolitan Area

With the development of human activities, different regions are connected and different cities interact with each other. Such activities include: product flow, financing, regional trade, commuting, tourism flow, student enrollment, labor migration, information flow, information dissemination, etc. We define the relationship established by these activities as the spatial interaction between regions. In order to study the economic relationship and spatial interaction

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between cities, we define the concept of urban gravity.

The concept of urban quality reflects the comprehensive competitiveness of a city. The factors that should be considered include economic development, social development, residents' quality of life and the degree of opening to the outside world. Therefore, urban quality is defined as:

$$Q = \sum_{h=0}^{n} W_h \times P_h$$

Where P_h is the value of each index and W_h is the corresponding weight. According to the change direction of indicators, it can be roughly divided into positive indicators and negative indicators.

Positive index has the property that the larger the index value, the better, such as income type and output type; Reverse indicators have the opposite characteristics, such as energy consumption and cost. First of all, it is necessary to adopt the normalization standard method to standardize each index, and then use the method of mean square error decision weight coefficient to allocate the weight of the standardized data. Based on the deviation and mean square error, the weight of different comprehensive evaluation indexes is calculated.

The gravitation between cities is asymmetric. Generally speaking, the gravitation of big cities is greater than that of small cities. Therefore, the direction of gravitation constant should be considered, and the definition of relative gravitation constant K: K in the existing model should be adjusted.

$$K = G(1 \pm a), \quad a = \frac{Q_i^2 + Q_j^2}{(Q_i + Q_j)^2}$$

G is usually 1. When calculating the gravity between cities, compare Q value, and take larger to smaller ones and smaller ones to larger ones.

Spatial distance is not enough to reflect the interaction distance between cities, so it is measured by economic distance. The economic distance is based on the mode of transportation, according to the level of economic development gap between cities to revise the distance.

After the above modification, we can get an improved urban gravity model.

$$F_{ij} = K \frac{Q_i Q_j}{d}$$

Q is the quality of comprehensive evaluation, K is the relative gravitational constant, d is the economic distance.

The improved urban gravity model is applied to Wuhan metropolitan area, and Tables 1 is obtained.

Table 1 Urban competitiveness of Wuhan metropolitan area in 2019

City	Wuhan	Ezhou	Xiaogan	Huanggang	Xianning	Xiantao	Qianjiang	Tianmen	Huangshi
Competitiveness	67.38	2.31	6.18	7.63	3.82	2.15	1.91	1.96	6.65

3. Cluster analysis of Wuhan Urban Circle

Now calculate the sum of the gravitation of the city to other cities in the city circle, and the sum of the gravitation of other cities in the city circle to the city. In this way, we can calculate the external economic radiation value and external economic dependence value of the cities in the city circle. See Table 2.

Table 2. External economic radiation and external economic dependence (2019)

	Wuhan	Xiaogan	Huanggang	Huangshi	Xianning	Ezhou	Xiantao	Qianjiang	Tianmen
radiation	83.63	3.89	8.93	6.10	1.44	1.69	0.78	0.37	0.59
dependence	6.18	22.87	21.56	19.55	9.79	13.51	5.75	3.72	4.48

Based on the above data, we can do K-means clustering analysis on Wuhan metropolitan area, and the results are shown in Figure 1.

According to the characteristics of the image, Wuhan metropolitan area can be divided into four types: ① Foreign

economic radiation city: Wuhan is the only foreign economic radiation city in Wuhan metropolitan area. ② Foreign economy dependence city, and its own economy is large: Xiaogan, Huanggang and Huangshi. ③ The external economy dependence city, and its own economic volume is small: Xianning and Ezhou. ④ The radiation depends on quite a few cities: Tianmen, Qianjiang and Xiantao.

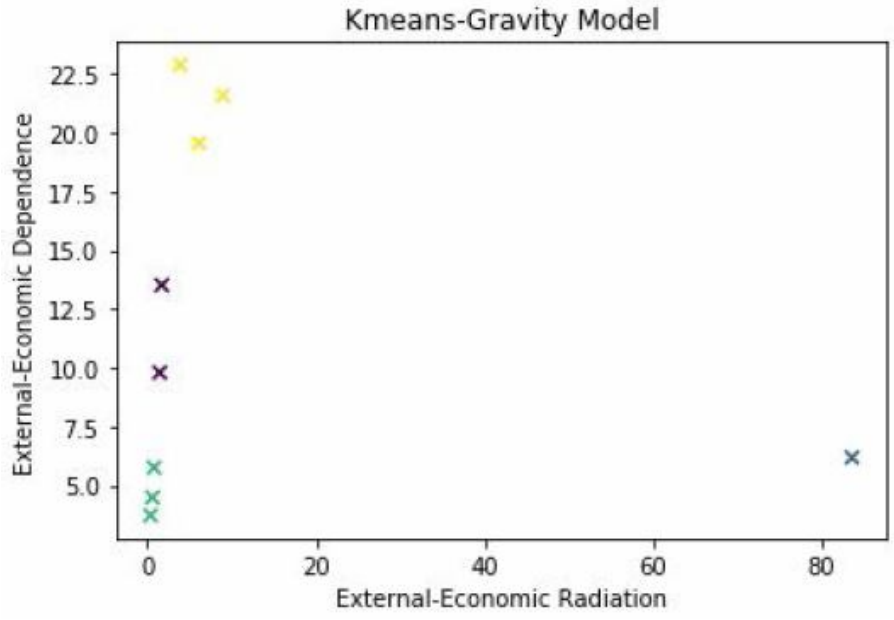

Figure 1 Results of cluster analysis.

4. Conclusion

In this paper, the mutual gravitation between cities in Wuhan metropolitan area is calculated by using the improved inter city gravitation model, and the cluster analysis is carried out. The conclusions are as follows: ① Wuhan is the core of Wuhan metropolitan area. ② Xiantao, Qianjiang and Tianmen are suitable for group development. ③ Ezhou's economy is small and depends on Wuhan. If it is merged into Wuhan, it will help to enhance the strength of Wuhan as a national central city and promote faster and better development.

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