Research on Spoke-Based Emergency Logistics Network in Urban Clusters in Jiangsu Province

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Abstract. In this paper, we collected data on twenty-three dimensions of epidemic emergency logistics from thirteen cities in Jiangsu, and used entropy weighting method for normalization to obtain the comprehensive emergency logistics capability score. The primary and secondary node cities and other cities are identified for all the city scores and rankings. The gravitational formula is used to calculate the radiation range of the core node cities and the layout operation of the spoke cities. Strategies and methods for improving emergency logistics in the post-epidemic era are proposed for the results of this radial Jiangsu epidemic emergency logistics study.

Keywords: Emergency logistics · Comprehensive ability score · Radiant layout · Gravitational formula

1 Introduction

As we enter the post-pandemic era, the importance of emergency logistics has been further understood. Many scholars continue to reflect on and improve emergency logistics.From the perspective of emergency logistics organization, emergency logistics materials and emergency logistics information, Liu et al. [1] defined the concept of emergency logistics management and established the structure of emergency logistics management system.On the research methods of emergency logistics, Liu et al. [2] established the second-level programming model of emergency logistics system, which adopted the cooperative mode of vertical supply and horizontal transfer.This gives us a lot of new thinking on the mathematical model of emergency logistics.In view of the problems existing in the emergency distribution and circulation management of grain in China, Han [3] suggested that the emergency logistics structure should be designed reasonably and the construction of emergency distribution system should be promoted. Lei [4] discusses the reasons for the use of agents in emergency logistics, formulates a multi-agent system in emergency logistics, and focuses on the main features of management system design to achieve the ability to master the system in a dynamic environment.Hu [5] studied the management mechanism of public health emergencies in the United States to provide reference for the establishment and improvement of the management mechanism of public health emergencies in China, and stressed the importance of emergency logistics.

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2 Study Area and Data Source

In order to determine the hierarchy of urban clusters and axis cities in Jiangsu Province, the following characteristics were selected based on the full consideration of all influencing factors: population density, fixed asset investment in logistics industry, gross regional product, gross per capita product, gross logistics industry output, number of logistics parks in epidemic areas, freight volume during epidemic period, passenger volume during epidemic period, total logistics mileage in epidemic areas, civilian vehicle traffic during epidemic period, epidemic-proof food and material reserve centers, the amount of emergency material reserves for epidemic prevention, new crown epidemic monitoring stations, the gross value of the accommodation and catering industry, the number of epidemic prevention and health institutions, the number of new epidemic prevention and rescue sites, the number of beds in epidemic prevention and health institutions, the number of epidemic prevention and health technicians, local defense and public security epidemic budget expenditures, local medical and health epidemic public budget expenditures, the total amount of post and telecommunications services during the epidemic, the number of Internet broadband access users, the Number of mobile fixed telephone users. All data were obtained from the China Statistical Yearbook.There are 23 dimensions.

3 Methods

Firstly, the entropy weight method was used to obtain the scores of the comprehensive emergency logistics capability of Jiangsu cities.

This experiment adopts the processing method of extreme value standardization to respectively deal with the positive and negative indicators, as follows:

When x is a positive indicator,

$$Y_{ij} = \frac{x_{ij}}{\max\{x_{ij}\}} \tag{1}$$

When x is a negative indicator,

$$Y_{ij} = \frac{\min\{x_{ij}\}}{x_{ij}} \tag{2}$$

where, i (i = 1,…,13) represents the region, j (j = 1,…,23) represents different indicators.

In this paper, entropy weight method is used to calculate the weight of each index, which is less computational and more objective. The specific steps are as follows:

Calculate the proportion of the ith sample in the jth index:

$$p_{ij} = Y_{ij}(\sum_{i=1}^{n} Y_{ij})^{-1} \tag{3}$$

Calculate the information utility value.

For the jth index, the formula for calculating information entropy is:

$$E_j = -\frac{\sum_{i=1}^{n} p_{ij} \ln p_{ij}}{\ln(n)} \tag{4}$$

Ej The larger the value is, the larger the information entropy of the jth index is, and the smaller the corresponding amount of information is.

Normalize the information utility value to obtain the weight of each index:

$$W_{\mathrm{j}} = (1 - E_j)(23 - \sum E_j)^{-1} \tag{5}$$

Calculate the comprehensive level of emergency logistics in each city:

$$S = \sum_i \sum_j W_j \cdot Y_{ij} \tag{6}$$

In the hub-and-spoke emergency logistics network, the stronger the integrated emergency logistics capability of the hub city, the wider its radiation range and the greater its radiation influence, and the layout of its surrounding spoke cities will also change. At present, most scholars at home and abroad use gravitational model and rupture point theory to study the influence degree and radiation range of regional cities. Therefore, combining with the literature and the characteristics of hub-and-spoke emergency logistics network, this section selects the modified gravitational model to determine the radiation range of the hub city and the layout of the spoke cities.

The Gravity Model was originally derived from Newton's "gravity" model in physics, which effectively links geography and physics. The basic model form is:

$$G_{ij} = \frac{K_{ij} M_i M_j}{D_{ij}}$$

where, denotes the gravitational strength between nodes i and j, and denotes the "mass" of the research object, denotes the generalized distance between i and j, and denotes the adjustment coefficient. According to the modified gravitational model to measure the spatial gravitational linkage strength of 13 cities in Jiangsu urban agglomeration, the final form of gravitational model is adopted according to the literature and the actual research object of this paper as follows:

$$G_{ij} = \frac{K\, M_i M_j}{D_{ij}}$$

where, is the logistics gravitational force of city i to city j: and represents the quality, replaced by the comprehensive emergency logistics capacity score found above; is the "comprehensive distance" between city i and city j; K is the gravitational force constant, does not affect the measurement results, usually taken as 2. The gravitational linkage strength of logistics during the epidemic.

4 Results

According to the results of the entropy weight method after normalizing all the data, the emergency logistics comprehensive capacity scores of 13 cities in Jiangsu Province were calculated and ranked, as shown in Table 1. Among them, the score of the comprehensive capacity of emergency logistics of cities under the new crown epidemic.

From the above comprehensive scores of each city in Jiangsu Province, it can be seen that the level of emergency logistics for epidemic prevention and epidemic fighting is unevenly distributed among cities in Jiangsu Province, with large differences in capacity and uneven development. The investment and establishment of emergency logistics system are concentrated in one or a few cities, but cannot effectively drive the further development and improvement of the rest of cities or the whole region.

In order to make the city hierarchy clearer, cluster analysis was conducted on 13 prefecture-level cities using SPSS, and the results are shown in Fig. 1:

Based on the score and cluster analysis of the above cities, this section divides the 13 cities in Jiangsu city cluster as follows: The first level node city is Taizhou, which ranks first with a score of 15.61 in the comprehensive capacity of emergency logistics, with Beijing-Shanghai, Shanghai-Shaanxi, Qi-Yang, Yan-Jing and Fuli highways running across the whole territory of Taizhou. In addition, the Jiangyin Yangtze River Bridge and Taizhou Yangtze River Bridge are connected to the north and south of the river. Taizhou is located in the middle of the Yangtze River Economic Belt, and has obvious advantages in the volume of civilian car freight and passenger transportation.

Secondary node city: Nanjing, with a score of 12.42 in the comprehensive capacity of emergency logistics, ranks fourth and is therefore naturally classified as a secondary node city in anticipation of its radiation and driving role. Nanjing is strategically located at the “neck of the dragon” of the Yangtze River Economic Belt and is a comprehensive transportation hub integrating highways, railroads, waterways, airlines and pipelines. Nanjing is connected to Shanghai-Nanjing Expressway, Ning-Hang Expressway, Ning-Tong Expressway and other highways, which can play an important role as a hub for logistics transportation in Jiangsu Province.

Table 1. The Emergency Logistics Comprehensive Capacity Scores of 13 Cities in Jiangsu Province

city	score	rank	city	score	rank
Yangzhou	5.62	11	Nanjing	12.42	4
Zhenjiang	15.50	2	Wuxi	5.99	9
Taizhou	15.61	1	Xuzhou	6.58	7
Suqian	5.52	12	Changzhou	12.00	5
Lianyungang	5.63	10	Suzhou	14.63	3
Huaian	5.49	13	Nantong	10.21	6
Yancheng	6.48	8			

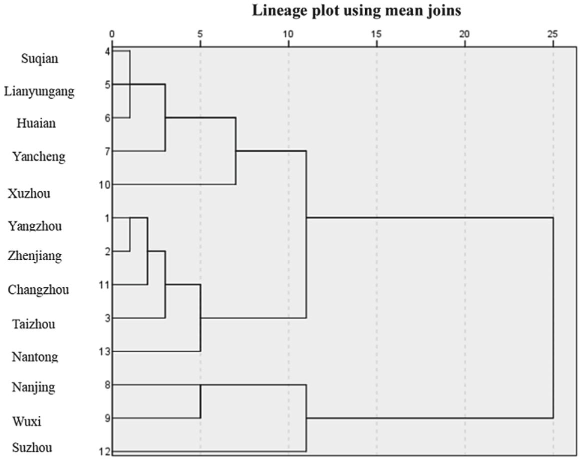

Fig. 1. Picture1 cluster result according to comprehensive scores

Secondary node cities are also: Taizhou, Wuxi and Zhenjiang. Taizhou is located in the middle of Jiangsu Province, connecting the south and north of Jiangsu. It is the transportation hub of Wuxi in southern Jiangsu. Zhenjiang is located in the southwest of Jiangsu Province. These three cities are in the top of the city's overall emergency response capability score.

Apart from these, the remaining node cities include: Yangzhou, Suqian, Lianyungang, Huaian, Yancheng, Xuzhou, Changzhou, Suzhou and Nantong.

In summary, the axis cities selected by entropy method are: Nanjing, Taizhou, Wuxi, and Zhenjiang.

The gravitational linkage of emergency logistics during the epidemic in 13 cities of the Jiangsu urban agglomeration was calculated by the gravitational formula as shown in Table 2:

Table 2. Gravity Connection of Emergency Logistics among 13 Cities of Jiangsu Urban Agglomeration

	Nanjing	Taizhou	Wuxi	Zhenjiang
Yangzhou	1.37809279368213	2.44709065550907	0.368514504652436	4.90760563380282
Suqian	0.550891120932101	0.59405170630817	0.164337972166998	0.642101313320825
Lianyungang	0.434314285714286	0.554650047333544	0.152699569843785	0.838683325324363
Huaian	0.715485834207765	0.836494875549048	0.207346153846154	0.817827967323402
Yancheng	0.595278106508876	1.62233841218925	0.313911847957946	0.987610619469027
Xuzhou	0.490390639063906	0.526332564693825	0.156841225626741	0.55656207366985
Changzhou	2.30533642691415	3.91064718162839	2.26393700787402	4.66750313676286
Suzhou	1.6871364902507	2.86183333333333	3.92097091722595	2.50569060773481
Nantong	1.02678704453441	2.44444938650307	1.05263166953528	1.60258227848101

Table 3. Urban Layout of Hub Point around Jiangsu Urban Agglomeration

Axis Cities	Radiation Range
Taizhou	Yangzhou, Yancheng, Changzhou, Suzhou, Nantong
Nanjing	Yangzhou, Changzhou, Suzhou, Nantong
Wuxi	Changzhou, Suzhou, Nantong
Zhenjiang	Yangzhou, Changzhou, Suzhou, Nantong

According to the above data, we analyze the layout of the axis and spoke cities of Jiangsu city cluster as follows: Taizhou, as the primary node city in the axis city of the region, has a more obvious radiation effect on the remaining 12 cities, so its radiation range includes all cities, and at the same time, its gravitational ties to Yangzhou, Changzhou, and Suzhou are high, so Taizhou focuses on radiation and drives the four cities on the basis of all the cities in the radiation region. The secondary node cities with Nanjing as the axis city have strong gravitational ties to Changzhou and Suzhou. The secondary node cities with Wuxi as the axis city are Suzhou, Changzhou and Nantong. These three spoke cities are ranked in the middle of the 13 cities in terms of comprehensive capacity of emergency logistics, their own logistics infrastructure is not perfect, and the government does not pay enough attention to it, resulting in less industrial input and output, and the emergency development is relatively lagging behind, so they need Wuxi and the neighboring axis cities to play the role of radiation to improve and help. Yangzhou and Changzhou. These two cities radiated by Zhenjiang have a large difference in emergency logistics capacity, indicating that despite the close distance between the cities, there are still polarization in logistics capacity and emergency level. In this regard, Zhenjiang should also pay attention to the tendency of people, materials and economic support when playing the role of radiation, and should strengthen the attention and influence on Xuzhou, Suqian and other cities in northern Jiangsu Province, so as to narrow the gap between cities in the small logistics circle in close proximity.Based on the results of the above analysis of the radiation capacity of the node cities, the following Table 3 is derived:

5 Countermeasures and Suggestions

5.1 Play the Role of Axial Cities and Promote the Coordinated Development of Each City

The overall logistics circle in Jiangsu is bifurcated, with the city in Suzhou as the axis, radiating to the south of Jiangsu, while the logistics system in the north of Jiangsu is relatively backward and less radiated by the axis city. Therefore, we should continue to consolidate the logistics emergency capacity of the axis city, optimize the allocation of infrastructure and public resources, increase the acceptance of supply and demand for cities in northern and southern Jiangsu, and gradually strengthen its radiation area to the north with its geographical advantage of access to the river and the sea and connection between the north and the south, so as to promote the interconnection between cities and cities and between regions and regions, common construction and sharing, and coordinated development.

5.2 Optimize the Allocation of Resources to Create an Axial City in Northern Jiangsu

Axis cities have relatively concentrated logistics resources, strong logistics capacity and high development level, but they cannot avoid the low utilization rate in some areas due to the over-concentrated distribution of resources. In addition, the radiation range of the axis cities is constrained by the real problems such as comprehensive distance, so it is urgent to realize the optimal allocation of resources on a larger scale and higher level to create the axis cities in northern Jiangsu and drive the development of the logistics system in the surrounding cities.

5.3 Establish Information Sharing Mechanism and Build an Emergency Logistics Supply Chain Information System

With the rapid development of information technology, in the special time context of the epidemic, full use should be made of artificial intelligence technology, automation control, logistics cloud, logistics big data and 5G technology to build a logistics information network platform, improve the efficiency of logistics information transmission between cities, make cities collaborate more closely and improve the execution capability of emergency management.

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