Location of Emergency Logistics Center in Central China Based on D-CRITIC and Grey Relational Analysis Method

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Abstract. In order to explore the location problem of emergency logistics center in Central China under public health emergencies, this study selected 30 cities in Central China as the research object and realized the location of emergency logistics center in Central China by constructing the location model of emergency logistics center. Firstly, the model uses a two-stage iterative method to extract the structure of large network communities, and divides the Central China into 5 communities with close internal road networks. Then, the Floyd algorithm was used to select 5 potential emergency logistics center cities from these communities. Further, starting from four key dimensions such as social economy and infrastructure development level, this study constructs an evaluation system including 14 comprehensive evaluation indicators. By applying D-CRITIC (Distance Correlation-based CRITIC)-GRA (Grey Relational Analysis), the paper conducts an in-depth analysis of 5 candidate cities within each community, and obtains the grey weighted Correlation degree of 5 candidate cities within each community. Finally, the study identified the city with the highest gray weighted correlation degree in each community as the first-level emergency logistics center, and selected the candidate city of second-level emergency logistics center. Through the model constructed in this paper, the hub-and-spoke network structure of emergency logistics in Central China under public health emergencies is constructed.

Keywords: Central China, Community division, Site selection research, D-CRITIC method, GRA

1 INTRODUCTION

In recent years, various public health emergencies have occurred frequently around the world. Under public health emergencies, the emergency logistics system can build a bridge between the supply side and the demand side, and the emergency logistics center, as the most important node facility of the emergency logistics system, exposed

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problems such as unbalanced spatial layout and lack of scientific planning in the early stage of the epidemic. In view of the suddenness and unpredictability of public health emergencies, it is required that the emergency logistics system must be able to pre-select the regional emergency logistics center, which can undertake the logistics function of regional warehousing and distribution in case of emergencies, and require the pre-selected emergency logistics center to have rich medical materials, medical facilities, and mature medical and health conditions, so as to be able to timely distribute medical materials and accommodate some affected people.

In public health emergencies, the unique geographical advantages of the Central China and the perfect transportation network layout are crucial to the material transfer in China 's emergency logistics network. At the same time, while the population size and economic scale of the Central China may provide a foundation for the response of emergency logistics systems within this area, further in-depth research is needed to determine whether effective management of storage and distribution needs for medical supplies in various cities within the region can be achieved in the event of large-scale emergencies. Therefore, according to the characteristics of public health emergencies, regional division of Central China and the location of emergency logistics centers in each region can be one of the ways to improve the efficiency of emergency logistics system.

Based on the special requirements for the comprehensive strength of emergency logistics centers under public health emergencies, this paper takes public health emergencies as the research background, aiming at 30 cities in the Central China, from the four levels of social and economic development status, transportation infrastructure status, passenger and freight transport capacity level and medical and health facilities level of each city. A comprehensive evaluation of the alternative cities of each community is carried out in order to optimize the emergency logistics centers of each community in the Central China urban agglomeration, so as to give full play to the functions of regional emergency logistics centers in public health emergencies and improve the efficiency of dealing with public health and health emergencies.

2 LITERATURE REVIEW

Through combing the research methods in the research of emergency logistics center location, it is found that the current domestic and foreign research is mainly divided into two aspects: regional clustering and emergency logistics node location. In the aspect of regional clustering of emergency logistics network, the existing research methods are mainly based on clustering algorithm and heuristic algorithm.An Congzhuo et al. [1] proposed the model of horizontal distribution between epidemic areas and epidemic areas, and carried out cluster analysis on the affected points in each epidemic area. The clustering basis is the distance between the affected points and the material distribution center. Similarly, Ni Weihong et al. [2] analyzed the disaster degree, geographical location and emergency material demand of the affected areas by cluster analysis, and the clustering results were intersected by the principle of priority of disaster degree. On the basis of the traditional k-means algorithm, Wang et al. [3] added the time dimension and proposed the 3D k-means algorithm, which combined time, space and customer demand to effectively improve the logistics efficiency in emergency situations, and realized the clustering of the emergency logistics network in Chongqing, China through this algorithm.

In terms of emergency logistics node location, domestic and foreign research mainly involves the algorithm of emergency facility location model. Algorithms can be roughly divided into two categories : exact algorithms and inexact algorithms [4]. In terms of accurate algorithms, most scholars use analytic hierarchy process, ideal solution, fuzzy mathematics and other methods to study site selection. Liu et al. [5] proposed an ideal solution-entropy weight (TOPSIS-EW) fuzzy symmetry technique based on multi-granularity linguistic assessment (MGLA) information to comprehensively evaluate and rank the five regions most affected by the Wenchuan earthquake. Yang et al. [6] established a multi-objective location model for temporary distribution stations of emergency supplies, and used a comprehensive evaluation method to solve the priority of candidate points. Based on a grey decision support framework, Zolfani et al. [7] used standard part correlation (CRITIC) and joint compromise solution (CoCoSo) for the location of temporary hospitals during the COVID-19 epidemic. In the inexact solution of the location model, it mainly includes classical heuristic algorithms such as genetic algorithm, simulated annealing algorithm, and ant colony algorithm. Lu Lingling et al. [8] combined K-means clustering algorithm with improved simulated annealing algorithm to establish a location-routing planning model for UAV distribution relay station in Putuoshan Island, Zhoushan City, Zhejiang Province. He Shanshan et al. [9] took emergency logistics in Hubei Province as an example, and used genetic algorithm to solve the bi-objective optimization problem, which solved the problems of emergency logistics center location and road-rail inter-modal transportation path.

In addition, as a complete system, emergency logistics includes research on management, resource scheduling, material distribution and vehicle routing optimization. In the study of emergency logistics management, Kun et al. [10] combed the research content in the field of emergency logistics in the past 25 years, and put forward the theme of "self-organizing response system of emergency logistics management" and "integrated emergency transportation-logistics system" architecture. In terms of resource allocation scheduling, Wang et al. [11] adopted a deep reinforcement learning algorithm-deep deterministic policy gradient to solve the problem of large-scale problems and improve the efficiency of creating high-quality allocation strategies. In the aspect of emergency material allocation, Wang et al. [12] established a multi-rescue station, multi-disaster station and multi-period emergency material allocation model, which can ensure decision makers to make a trade-off between efficiency, fairness and effectiveness. Hao et al. [13] studied the optimal decision scheme for emergency distribution of fresh agricultural products based on improved genetic algorithm under the objectives of minimizing vehicle number, minimizing average response time and minimizing virus infection. In terms of vehicle route optimization of emergency logistics, Tan et al. [14] proposed improved particle swarm optimization algorithm to solve the problem of insufficient timeliness of emergency logistics distribution and optimized vehicle routes of emergency medical supplies logistics, and found that the improved particle swarm optimization algorithm could reduce the total cost by 20.09% compared with the basic particle swarm optimization algorithm. Through the above research and analysis, it is found that there are some research results on the location of emergency logistics centers, but few studies take into account the level of medical facilities in the city in the location model of emergency logistics centers. Secondly, as an important economic region in China, the Central China's geographical advantages and transportation network layout can not be ignored in the emergency logistics system, so it is very important to study the location of emergency logistics center in the Central Plains region.

3 DIVISION OF REGIONAL COMMUNITIES

3.1 The Community Modularity Index Function

Before the community division of regional cities, it is necessary to extract the weighted network of regional cities, and the adjacency matrix can be used to represent the weighted network. Considering the complexity of the roads between traffic nodes (there are many roads between urban nodes in the urban road network diagram), the value of the adjacency matrix is not only 0 and 1, but also the adjacency matrix with weights [15]. The weight represents the traffic accessibility of the two urban nodes. The greater the weight, that is, the traffic mode, traffic environment and traffic infrastructure conditions between the two nodes are more conducive to passenger traffic.

In this paper, we assume that any two city nodes v_i and v_j, and the weight between city i and city j is w_{ij}. The value of w_{ij} is shown in Formula (1), where the weight of the edge between nodes i and j is represented by b_{ij}, the weight matrix composed of all nodes v_i and v_j in the road network is represented by A_{ij} .Since the weighted adjacency matrix A_{ij} represents the accessibility between city nodes, the weight between each city node pair in this adjacency matrix can be expressed by the reciprocal of the adjacency distance of each city node pair.

$$w_{ij} = \begin{cases} b_{ij}.\text{When there is an edge between } i \text{ and } j \\ \infty.\text{When there is no edge between } i \text{ and } j \end{cases} \tag{1}$$
$$(v_i \neq v_j), w_{ij} = 0, i = 1,2,3,\cdots,n$$

The community in the network refers to the clustering of nodes in a large network. The connections between nodes within the community are relatively close, while the connections between communities are relatively sparse [16]. By dividing the urban communities closely linked to the internal road network, it is conducive to quickly finding the community emergency logistics center under sudden public health events, so as to be able to respond quickly in emergencies and ensure the deployment of emergency supplies. How to measure whether the divided urban communities have strong modularity can be quantitatively analyzed by the modularity index function.

Newman [17] used the modularity index Q function to quantitatively measure the rationality of the network community structure division:

$$Q = \frac{1}{2m}\sum_{i,j}\left[w_{ij} - \frac{k_i k_j}{2m}\right]\delta\left(c_i, c_j\right) \tag{2}$$

In formula (2) : $k_i = \sum_j w_{ij}$ is the sum of the weights of all edges of the node i, which can represent the degree of the node in the urban road network ; c_i and c_j are the communities divided by nodes i and j ; $\delta(c_i, c_j)$ is 0-1 variable, when c_i = c_j, the value is 1, and the rest is 0 ; m is the sum of all edge weights in the whole network, $m = \frac{1}{2}\sum_{ij} w_{ij}$.

In practical applications, the modularity index Q function can measure whether a large network partition is reasonable. When the modularity index Q function value of the divided community is higher than 0.3, it can be considered that the network community division effect is good, and the larger the Q value is, the more reasonable the network division is, and the maximum Q value is 1.

3.2 Community Partition

BLONDEL et al. [18] proposed a two-stage repeated iteration method to extract the community structure of large-scale networks. Assuming a network with weights and N nodes, the steps of extracting the community structure of this network through two-stage repeated iteration are as follows :

(1) Each node of the weighted network is assigned to a community. In the initial partition, the number of communities is as large as the number of nodes.

(2) For each node i in the network, it is removed from the initial partition and placed in the community where the node j is located, and then the modular income ΔQ after the mobile node is calculated. The operation for the size of the modular income has the following three cases : when $\Delta Q > 0$, the node i is incorporated into the community where the node j is located ; when $\Delta Q < 0$, the node i remains in the original community ; when $\Delta Q = 0$, the node i is merged into the community where the node j is located according to the destruction principle.

(3) Repeat steps (1) and (2) on all nodes in the network, until any node in the network is moved, the modular gain ΔQ is not increased, and the first stage of network community division is completed.

(4) In the second stage, a new network is first established, and the nodes of the new network are composed of the communities extracted iteratively in the first stage. In the new network, the weights of the edges between the nodes of each community are the

sum of the weights of the edges between all the nodes in the corresponding two communities. At this time, the steps (1) and (2) are applied again until any node in the new network is moved, and the modular benefit ΔQ is not increased. At this time, the second stage of network community division is completed.

$$\Delta Q=\left[\frac{\sum_{in}+k_{i,in}}{2m}-\left(\frac{\sum_{tot}+k_i}{2m}\right)^2\right]-\left[\frac{\sum_{in}}{2m}-\left(\frac{\sum_{tot}}{2m}\right)^2-\left(\frac{k_i}{2m}\right)^2\right] \tag{3}$$

In formula (3) : $\sum_{tot}$ is the sum of the weights of the edges associated with all nodes in C, $\sum_{in}$ is the sum of the weights of all edges within the community ; $k_{i,in}$ is the weight sum of node i and the edge of the node inside the community.

4 COMPREHENSIVE EVALUATION

4.1 Evaluation Index System

The evaluation index system established in this paper starts from the four aspects of social and economic development level, infrastructure development level, passenger and freight capacity development level, and medical and health development level, and comprehensively analyzes and determines the indicators for evaluating the emergency logistics capacity of each community city. Under the level of social and economic development of the first-level indicators, two second-level indicators of the overall economic development level of the city and the degree of urbanization are selected, so that the economic level of the alternative cities can be analyzed from the perspective of economic development level. Under the level of infrastructure development, five secondary indicators of natural conditions, logistics, aviation, railways and highways were selected to evaluate the transportation infrastructure construction of alternative cities. Passenger and freight capacity is also one of the important evaluation indexes for emergency logistics center cities under public health emergencies. The transportation capacity of alternative cities of emergency logistics center can be evaluated from three aspects : passenger volume, freight volume and cargo turnover. Under public health emergencies, the selection of emergency logistics center cities should also consider the important evaluation indicators of emergency logistics center location, such as “medical and health facilities conditions”, “number of medical and health personnel” and “infrastructure level”. Finally, through the 2022 statistical yearbook of various provinces and cities, 14 index data of all alternative cities of the five associations after division are obtained.

There are many attributes of data, including benefit data, cost data and interval data. The values of the three attributes represent different meanings. In this paper, the benefit data represent the evaluation indicators of positive indicators, such as gross product, foreign investment amount and urbanization rate. The larger the value of such data, the better the evaluation. When evaluating the emergency logistics center city, the higher the gross urban product and the more funds used outside the province, the higher the evaluation value. Correspondingly, the smaller the value of the cost data, the better the evaluation. In this paper, the sum of the transportation distance from the candidate cities within the community to other spoke cities within the community is a kind of cost data. By minimizing the sum of transport distances, transport efficiency can be improved and the time required for transport can be reduced.

4.2 D-CRITIC Method

Advantages of the D-CRITIC Method. D-CRITIC is developed by adding the idea of distance correlation to the original CRITIC method. The proposed D-CRITIC method can more reliably simulate the conflict relationship between criteria by means of distance correlation. More importantly, the D-CRITIC method can produce a set of standard weights and rankings that are more effective than the original CRITIC method.

The distance correlation test is used as an alternative method to compare the degree of consistency between different standard weight sets. The distance correlation test is provided for the first time to measure the performance of different weighting methods.

Steps for Using the D-CRITIC Method. Step 1 : Normalization of decision matrix

In this paper, the data of two attributes in the evaluation index system are preprocessed by “standardization” and “standard 0-1 transformation” [15]. The dimension of 14 evaluation indexes can be eliminated by standardization, so that each index variable is under the same dimension. Standardized treatment of indicators :

$$b_{ij} = \frac{a_{ij} - \mu_j}{s_j}, i = 1,2,\cdots,5, j = 1,2,\cdots,14 \tag{4}$$

Where μ_j and s_j are computed as follows :

$$\mu_j = \frac{1}{m}\sum_{i=1}^{m} a_{ij} \tag{5}$$

$$s_j = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(a_{ij} - \mu_j\right)^2}, j = 1,2,\cdots,14 \tag{6}$$

Where a_{ij} are the index data of the i th city about the j th index, μ_j is the average value of the index j , and m is the total number of alternatives.

The optimal value of the data processing of the cost-type and benefit-type attributes is 1, and the worst value is 0. The standard 0-1 transformation can be performed, and the comprehensive evaluation value of each alternative city is also placed within the range of [0, 1]. For the cost-type attribute data a_j, the processing is as follows :

$$b_{ij} = \frac{a_j^{\max} - a_{ij}}{a_j^{\max} - a_j^{\min}} \tag{7}$$

For the benefit attribute data a_j, the processing is as follows :

$$b_{ij} = \frac{a_{ij} - a_j^{\max}}{a_j^{\max} - a_j^{\min}} \tag{8}$$

Through the above "standardized processing-standard method 0-1 transformation", all the data in the table can be transformed into the range of [0,1]. The larger the value, the better the overall evaluation result, thus better eliminating the dimension of the data, and laying the foundation for the subsequent evaluation index weight calculation and evaluation.

Step 2 : Use formula (6) to calculate the standard deviation s_j of each standard.

Step 3 : Calculate the distance correlation of each pair of indicators.

In the initial CRITIC method, the conflict relationship between indicators was captured with the help of Pearson correlation. However, Pearson correlation has the risk of inaccurate capture of the actual relationship between standards. More precisely, the two criteria of Pearson correlation coefficient of zero may not be completely independent. Therefore, reference [19] introduced a new correlation measure, called distance correlation, which is zero if and only if the index is independent. Therefore, in the improved D-CRITIC method, distance correlation is used as an alternative method to model the relationship in order to minimize the possible error of the final weight. Formula (9) defines the distance correlation between c_j and $c_{j'}$.

$$dCor\left(c_j, c_{j'}\right) = \frac{dCov\left(c_j, c_{j'}\right)}{sqrt\left(dVar\left(c_j\right) dVar\left(c_{j'}\right)\right)} \tag{9}$$

$dCov\left(c_j, c_{j'}\right)$ is the distance covariance between c_j and $c_{j'}$, $dVar\left(c_j\right) = dCov\left(c_j, c_j\right)$ is the distance variance of c_j, $dVar\left(c_{j'}\right) = dCov\left(c_{j'}, c_{j'}\right)$ is the distance variance of $c_{j'}$. The specific steps to determine the distance correlation between each two indicators c_j and $c_{j'}$ are as follows :

Step 3.1 : For each indicator c_j, an Euclidean matrix is constructed based on its score associated with all alternatives. For $c_{j'}$, a similar matrix is also constructed.

Step 3.2 : For the Euclidean matrices obtained by c_j and $c_{j'}$, the bi-centralization step is performed so that the row mean, column mean and total mean of the elements in each matrix are zero : each element in the matrix subtracts the row mean, then each element in the matrix subtracts the column mean, and finally adds the mean of the entire matrix to achieve the bi-centralization of the two Euclidean matrices.

Step 3.3 : The double center matrix is multiplied by the elements, and the average value of the elements in the matrix is calculated, that is, the sum of the elements divided by the total number of elements. The square root of this mean is the distance covariance of c_j and $c_{j'}$, namely $dCov(c_j, c_{j'})$.

Step 3.4 : The distance variance $dVar(c_j)$ of c_j and the distance variance $dVar(c_{j'})$ of $c_{j'}$ are calculated. Since $dVar(c_j) = dCov(c_j, c_j)$ and $dVar(c_{j'}) = dCov(c_{j'}, c_{j'})$, these two values can be calculated by repeating steps 3.1-3.4.

Step 4 : Calculate the amount of information. Calculate the amount of information contained in c_j according to formula (10).

$$I_j = s_j \sum_{j'=1}^{n} \left(1 - dCor(c_j, c_{j'})\right) \tag{10}$$

In this formula, I_j denotes the information content of c_j.

Step 5 : Determine the target weight, according to the formula (11) to determine the target weight of c_j.

$$\omega_j = \frac{I_j}{\sum_{j=1}^{n} I_j} \tag{11}$$

Where w_j is the objective weight of c_j.

4.3 Grey Relational Analysis

After calculating the weight of 14 evaluation indexes within each community by D-CRITIC method, the final evaluation scheme can be determined by grey correlation analysis [20]. In each divided community, this paper will select five alternative cities for emergency logistics centers within each community through the Floyd algorithm. At this time, it is known that there are 5 cities to be evaluated, and there are 14 evaluation index variables. Let the comparison number be $b_i = \{b_{ij} | j = 1,2,\cdots,14\}, i = 1,2,\cdots,5$.

Set the reference number as $b_0 = \left\{ b_{0j} \middle| b_{0j} = \max_{1\le i\le 5}\{b_{ij}\}, j = 1,2,\cdots,14 \right\}$, that is, the reference number is listed as the 14 index values of a virtual best evaluation object.

Then, the grey correlation coefficient of the sequence b_i to the reference sequence b_0 on the j th index is calculated and compared :

$$\xi_i(j) = \frac{\min_{1\le s\le m}\min_{1\le t\le n}|b_{0t} - b_{st}| + \rho \max_{1\le s\le m}\max_{1\le t\le n}|b_{0t} - b_{st}|}{|b_{0j} - b_{ij}| + \rho \max_{1\le s\le m}\max_{1\le t\le n}|b_{0t} - b_{st}|} \tag{12}$$

In the formula : $\min_{1\le s\le m}\min_{1\le t\le n}|b_{0t} - b_{st}|$ is the minimum difference between the two levels, $\max_{1\le s\le m}\max_{1\le t\le n}|b_{0t} - b_{st}|$ is the maximum difference between the two levels. Resolution coefficient ρ, the greater the value, the greater the resolution ; the smaller the value, the smaller the resolution, let $\rho = 0.9$.

Finally, the grey weighted correlation degree is calculated. The grey weighted correlation degree represents the correlation value between each object to be evaluated and the virtual best evaluation object. Therefore, the five alternative cities within each community can be sorted by this value. The calculation formula is :

$$r_i = \sum_{k=1}^{n} \omega_k \xi_i(k) \tag{13}$$

In the formula : ω_k is the weight of each index ; r_i is the grey weighted correlation degree of the i th evaluation object to the ideal object.

The grey weighted correlation degree of the five alternative cities within each community is calculated, such as the grey correlation degree of the five alternative cities of the five emergency logistics centers of community A, which can be sorted into $r_4 > r_3 > r_1 > r_5 > r_2$, that is, the grey weighted correlation degree of the city represented by community r_4 is the largest with the virtual optimal emergency logistics center city, and the city is superior to other cities. The city can be given priority as the emergency logistics center city of community A.

5 COMMUNITY DIVISION OF EMERGENCY LOGISTICS CENTER IN CENTRAL PLAINS REGION

5.1 Central Plains Regional Urban Agglomeration

According to the "Central Plains Urban Agglomeration Development Plan" issued by the National Development and Reform Commission in 2016, the Central Plains Urban Agglomeration takes 14 cities such as Zhengzhou City, Kaifeng City, and Jincheng City as the core development areas, and radiates 16 Central Plains Economic Zone cities such as Anyang City and Handan City. The distribution of 30 cities in the Central Plains region is shown in Fig. 1.

Fig. 1. Central Plains regional urban agglomeration

5.2 Division of Community in Central Plains Region

Through a two-stage iterative method to extract the community structure of large-scale networks, according to the adjacent distance of some node cities in the Central Plains region, using the method in Section 3, 30 cities in the Central Plains region are divided into five community networks as shown in Fig. 2

(a) A Community City Network Diagram (b) B Community City Network Diagram (c) C Community City Network Diagram

(d) D Community City Network Diagram (e) E Community City Network Diagram

Fig. 2. The network diagram of each community city

6 SELECTION AND COMPREHENSIVE EVALUATION OF ALTERNATIVE CITIES FOR EMERGENCY LOGISTICS CENTER IN CENTRAL PLAINS REGION

6.1 Selection of Alternative Cities for Emergency Logistics Center

In this paper, the Floyd algorithm [15] is used to select the candidate cities of the internal emergency logistics center of each community. Through the Floyd shortest path algorithm, the shortest distance from any city in all cities within the four communities to other cities within the community can be calculated, and finally the total transportation distance from any city to other cities within the community can be obtained. In this paper, aiming at the shortest transportation time, five cities with the smallest total transportation distance and the smallest total transportation distance are selected within the four associations, and these five cities are used as alternative cities for the emergency logistics center of the association.

The distance adjacency matrix of A community is calculated as follows :

$$
\begin{array}{ccccccc}
Chang & An & He & Xing & Han & Liao & Pu \\
zhi & yang & bi & tai & dan & cheng & yang
\end{array}
$$

$$
A_0 = \begin{bmatrix}
0 & 153.8 & 0 & 0 & 203.4 & 0 & 0 \\
153.8 & 0 & 44.8 & 0 & 67.4 & 0 & 114.9 \\
0 & 44.8 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 56.5 & 190 & 0 \\
203.4 & 67.4 & 0 & 56.5 & 0 & 150.7 & 162.3 \\
0 & 0 & 0 & 190 & 150.7 & 0 & 150.6 \\
0 & 114.9 & 0 & 0 & 162.3 & 150.6 & 0
\end{bmatrix}
\begin{array}{c}
Changzhi \\ Anyang \\ Hebi \\ Xingtai \\ Handan \\ Liaocheng \\ Puyang
\end{array}
$$

The Floyd algorithm is realized by Matlab programming to extract the candidate cities of the emergency logistics center of the A community. The shortest distance from each city node to another city, that is, the final distance matrix, can be calculated by the distance adjacency matrix. The calculation results of the distance matrix of A community are as follows :

$$
\begin{array}{ccccccc}
Chang & An & He & Xing & Han & Liao & Pu \\
zhi & yang & bi & tai & dan & cheng & yang
\end{array}
$$

$$
D_{ij} = \begin{bmatrix}
0 & 270.8 & 360.4 & 259.9 & 203.4 & 354.1 & 365.7 \\
270.8 & 0 & 89.6 & 123.9 & 67.4 & 218.1 & 114.9 \\
360.4 & 89.6 & 0 & 213.5 & 157 & 307.7 & 204.5 \\
259.9 & 123.9 & 213.5 & 0 & 56.5 & 190 & 218.8 \\
203.4 & 67.4 & 157 & 56.5 & 0 & 150.7 & 162.3 \\
354.1 & 218.1 & 307.7 & 190 & 150.7 & 0 & 150.6 \\
365.7 & 114.9 & 204.5 & 218.8 & 162.3 & 150.6 & 0
\end{bmatrix}
\begin{array}{c}
Changzhi \\ Anyang \\ Hebi \\ Xingtai \\ Handan \\ Liaocheng \\ Puyang
\end{array}
$$

The sum of the distances from the seven cities to the remaining six cities is calculated as [1814.3,884.7,1332.7,1062.6,797.3,1371.2,1216.8].It is easy to know that the sum of the distances from Handan City to the remaining six cities in the A community is 797.3 kilometers. The five alternative emergency logistics center cities of each community are shown in Table I :

Table 1. The total transportation distance of each community emergency logistics center alternative city (Unit : km)

Community A	Distance	Community B	Distance	Community C	Distance	Community D	Distance	Community	Distance
Anyang	884.7	Shangqiu	830.2	Jincheng	834.0	Pingdingshan	1342.9	Yuncheng	60.2
Hebi	1332.7	Bozhou	833.2	Jiyuan	751.7	Xuchang	1330.9	Sanmen-	60.2
Xingtai	1062.6	Huaibei	734.8	Jiaozuo	596.7	Luohe	1046.1	—	
Handan	797.3	Bengbu	1181.1	Zhengzhou	706.8	Zhoukou	1260.6	—	
Puyang	1216.8	Suzhou	823.5	Xinxiang	759.5	Zhumadian	1047.3	—	

In this paper, the Floyd algorithm can be used to calculate the shortest distance between any two city network nodes. Each iteration will record the path. When the final distance matrix is generated, the nodes in the center of the community can be determined. The establishment of an emergency logistics center at this node can meet the timeliness requirements of emergency transportation and provide a basis for the establishment of emergency logistics centers in other areas.

6.2 Calculation of Index Weight

Taking A community as an example, the specific values of 14 evaluation indexes in five alternative cities of emergency logistics center are shown in Table II :

Table 2. The evaluation index data of A community candidate cities

Cities / Evaluating Indicator	Anyang	Hebi	Xingtai	Handan	Puyang
Gross product（billion yuan）	2275.48	971.96	2427.1	4114.8	1620.51
Amount of foreign investment（million American dollar）	62037	102809	78654	148946	78122
Urbanization rate	53.04%	62.29%	54.41%	56.87%	49.97%
Urban area	7413	2182	12400	12066	4271
National and regional logistics hub	1.0	0.5	0.5	0.5	0.5
Military or civil airfield	1.0	0.5	1.0	1.0	0.5
Railway mileage（km）	274.4	158.0	327.0	243.0	238.0
Graded highway length	12576	4533	23140	23022	6949
Transport distance	884.7	1332.7	1062.6	797.3	1216.8
Passenger volume（million people）	1666	428	2998	3049	885
Volume of freight traffic（million tons）	17845.0	6071.0	32121.0	32667.6	6265.0
Turnover of goods（Billion tons of kilometers）	629.48	213.14	1133.00	1152.34	284.70
Beds in medical and health institutions	34537	10146	40577	59368	27368
Number of health personnel	47410	15372	62270	82903	35587

In order to evaluate the level of urban logistics transportation capacity, this paper measures whether the city is a national and regional emergency logistics center, that is, if it is a national logistics hub, the value is 1 ; if it is a regional logistics hub, the value is 0.5. In this paper, the value of the alternative cities of the emergency logistics center in the logistics hub comprehensively considers multiple factors. Due to the different emergency transportation capabilities that the national logistics hub and the regional logistics hub can bear, the corresponding value of the urban logistics hub also needs to be appropriately changed.

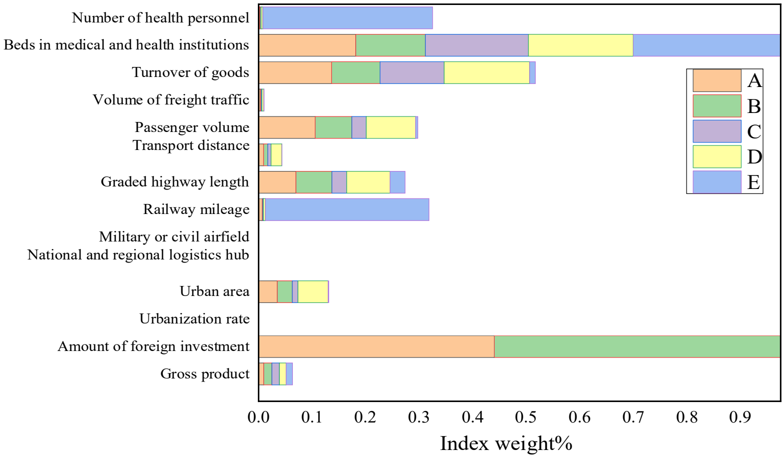

Fig. 3. The weight of each community evaluation index

Through the D-CRITIC method, the weight values of the 14 indicators of the candidate cities in each community are calculated, as shown in Fig. 3. From the diagram, it can be seen that the indexes with the highest weight of the five associations are different. Among them, the evaluation indexes with the highest weight of the two associations A and B are "the amount of foreign investment", while the weights of the two indexes of "the number of beds in medical and health institutions" and "the turnover of goods" in the two associations C and D are very close. Finally, the weight of "railway mileage" in the E community is the largest. It is worth noting that the weight of urban area, transportation distance, urbanization rate and national and regional logistics hub centers within each community is small. The degree of dispersion of each index can be reflected by the size of the weight. The index with a large weight value indicates a high degree of dispersion, and the index with a small weight value indicates a relatively low degree of dispersion.

6.3 The Comprehensive Evaluation Value of The Alternative Cities of Each Community

After obtaining the weight of each index by D-CRITIC method, the comprehensive evaluation value of the alternative cities of A, B, C and D four community emergency logistics centers calculated by grey correlation analysis method is shown in Fig. 4. The final comprehensive evaluation values of Yuncheng City and Sanmenxia City in E community are 0.8309 and 0.6428 respectively. Therefore, through the final comprehensive evaluation value, the optimal alternative cities of emergency logistics centers in the five associations can be finally obtained, which are Handan City, Shangqiu City, Zhengzhou City, Pingdingshan City and Yuncheng City.From the multi-index radar map of the five alternative cities of A community in Fig. 5, it can be intuitively concluded that Handan City is the strongest city in the comprehensive strength of A community, which is consistent with the comprehensive evaluation results obtained by the grey correlation analysis method, which further verifies the reliability of the comprehensive evaluation model in this paper.

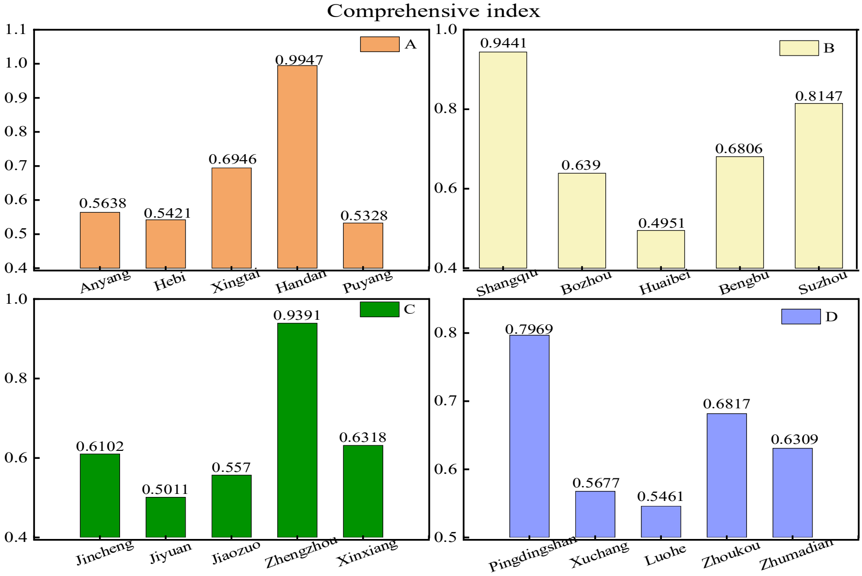

Fig. 4. Comprehensive evaluation value of community

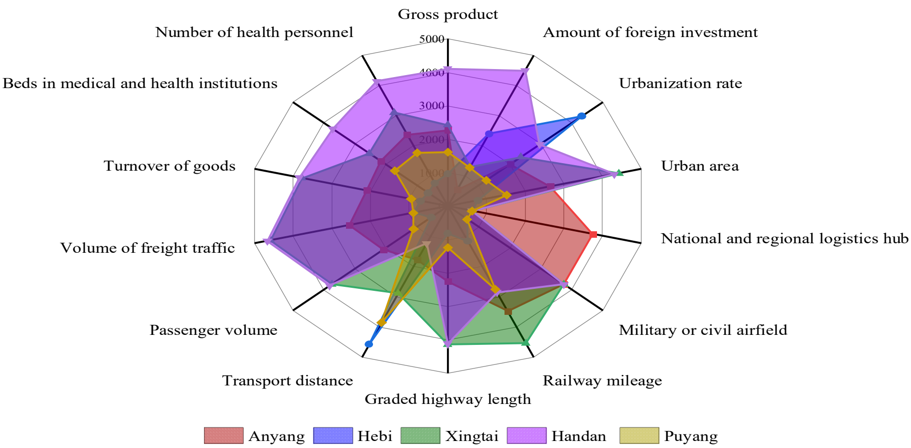

Fig. 5. A multi-index radar chart of alternative cities of community A

Among all the alternative cities within each community, through the comprehensive evaluation of D-CRITIC method and grey correlation analysis method, it can be found that there are alternative cities of emergency logistics center within each community, and there are also cities with certain comprehensive strength as the second level. For example, among all the alternative cities of the emergency logistics center of the B community, Shangqiu City has become an alternative city for the first-level emergency logistics center of the B community with a comprehensive evaluation value of 0.9941.However, it is worth noting that the evaluation value of Suzhou City in the B community is also as high as 0.8147, which is enough to make Suzhou City an alternative city for the second-level emergency logistics center of the B community. Based on the above analysis, the alternative cities and their distribution of emergency logistics centers at all levels of each community are shown in Fig. 6.

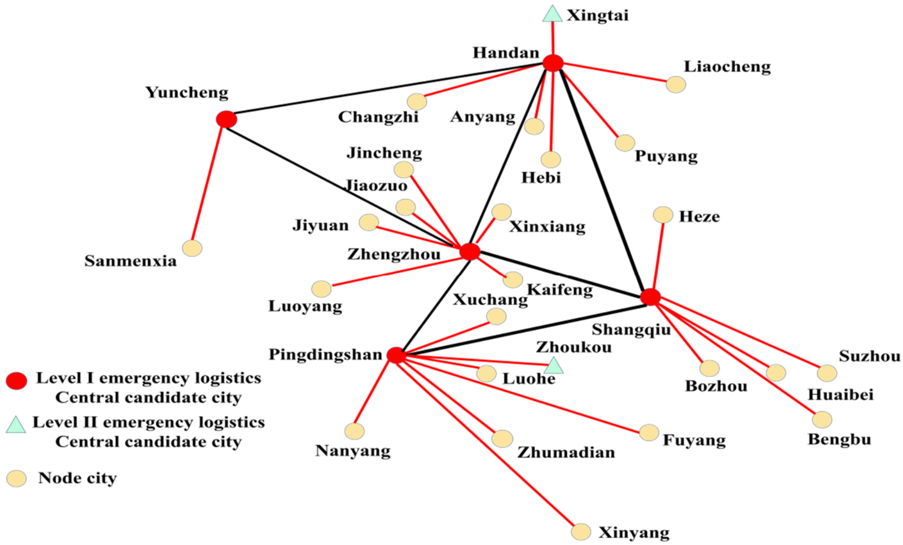

Fig. 6. Central Plains regional hub-and-spoke emergency logistics network diagram

7 CONCLUSION

Based on the research background of public health emergencies, this paper establishes a model for community division and emergency logistics center location in the Central Plains region, which provides a method for selecting emergency logistics center cities in the Central Plains regional urban agglomeration under public health emergencies. The following research results are obtained :

(1) Firstly, a two-stage iterative method is used to extract the large-scale network community structure. Based on the adjacency distance of 30 cities in the Central Plains region, it is finally divided into five communities with close internal road network connections. Secondly, for the five large-scale network communities, the minimum total transportation distance from each city to other cities in the community is calculated by the Floyd shortest path algorithm. The five cities with the smallest total transportation distance within the five communities are used as alternative cities for the emergency logistics center of each community.

(2) From the four levels of social economy, infrastructure, passenger and freight transport capacity and medical and health development level, the comprehensive evaluation indexes of 14 emergency logistics centers in the central plains region, such as “gross domestic product” and “urbanization rate”, are determined, and the weights of 14 indexes of alternative cities of emergency logistics centers of each community are calculated by D-CRITIC, and the dispersion degree of different communities under each index is obtained.

(3) Through the grey weighted correlation degree value in the grey correlation analysis method, five emergency logistics center cities were selected, namely Handan City, Shangqiu City, Zhengzhou City, Zhumadian City and Yuncheng City.Secondly, Xingtai City of Association A was used as an alternative city for secondary emergency logistics centers, and Zhoukou City of Association D was used as an alternative city for secondary emergency logistics centers.

The data studied in this paper come from the relevant statistical data of various provinces and cities in China at the end of 2022, which are the latest data. However, with the passage of time, the economic development level and infrastructure construction of various provinces and cities will change, and then the site selection of emergency logistics center in the Central China can be conducted again through the model constructed in this paper. In the future research, how to optimize material allocation and vehicle route optimization can be further discussed within the communities divided by this research, so as to give full play to the value of community division and location strategy, so as to enhance the efficiency of the entire emergency logistics network.

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