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Research on Capability Evaluation of the Emergency Logistics Center with Fuzzy Clustering and Extension of TOPSIS Method in the Context of Network

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Abstract: Emergency logistics center is the key node of emergency logistics network to achieve a effective dispatching and distribution of emergency supplies under unconventional emergency. The selection of capability index in the context of network has a very important role for the construction of emergency logistics center. In this study, the pre-selected indexes for emergency logistics capacity assessment was classified based on the fuzzy clustering analysis method, to get rid of unreasonable indexes and identified emergency logistics center key elements of evaluation capacity, constructed a reasonable evaluation index system. On the basis of the index system, the evaluation value of the expert linguistic variables is transformed into interval number , the maximum deviation method is used to determine the attribute index weight and finally extendable TOPSIS method is used to calculate the distance between the ideal solutions and negative ideal solutions in each scheme and calculate the relative close degree, according to which the arranging order of each scheme is determined and thus provides an important basis for the construction of emergency logistics center and its performance evaluation in the unconventional emergencies.

Key words: Emergency logistics center, emergency logistics networks, capability evaluation, linguistics variables, fuzzy clustering analysis, interval number

INTRODUCTION

With the acceleration of China's modernization, the frequency and scale of occurrences of various natural disasters, public safety incidents were significantly larger than before. The SARS crisis in 2003, the Wenchuan earthquake on May 12th, 2008 and Yushu earthquake on April 14th, 2010 has brought great impact on social and economic activities of our country.

These unexpected events, in a short period of time, require a lot of emergency relief supplies, such as drugs, medical equipment, food, clothing, tents, etc. Emergency logistics refers to special logistics activities which intend to provide the required emergency supplies for sudden natural disasters and public safety incidents with the least losses in the minimized time. It should be said that emergency response is an extreme important stage during the process of dealing with emergencies (Xin *et al*., 2012; Yin *et al*., 2012). The operational efficiency of emergency logistics will directly affect the effectiveness of the emergency disposal (Qin and Zhang, 2011; Gu, 2011).

According to the theory of enterprise capability, an enterprise is a coalition of resources and capability. The capability refers to the unique ability which is formed through the integration of various internal resources inside the enterprise, so as to improve the operational performance of enterprises to realize the final profit target. On the other hand, network has become a trend in the development of various industries. Similarly the modern logistics industry has gradually formed a comprehensive service system of network and logistics network is the inevitable trend of modern logistics development. Without a doubt, the emergency logistics network will also be the inevitable trend of the development of emergency logistics. In the case of unconventional emergency, the emergency Logistics center in the network environment will also be confronted with many emergency resources within the emergency logistics network in carrying out the emergency tasks.

The emergency Logistics centers using its emergency logistics capability rationally integrated the emergency resources generally scattered in emergency logistics networks; The emergency resources should be delivered to the destinations in great need timely and immediately through these centers.

There are a lot of relevant research literatures in the concept and constituent elements of logistics capability (Fawcett *et al*., 1996; Daughert *et al*., 1997). But emergency logistics capability is a crossed research realm which integrates such theories as emergency logistics,

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logistics capability, etc. and the earliest research on emergency logistics capability is carried by Xiaoqun Liu. He puts forward the Concept of emergency logistics capability and analyzes its characteristic in the five aspects of time effectiveness, flexibility, peculiarity, extendibility and integrity (Liu *et al*, 2007). Yuanming Lin sets up the natural disaster emergency logistics capability evaluation indexes and evaluates these index by ANP; evaluates the ability of emergency logistics by the method of multilevel gray evaluation and proposes evaluation gray class hierarchy, obtains emergency logistics capability evaluation results at last (Lin and Zhuo, 2010). Aimin Deng uses the fuzzy gray comprehensive evaluation method to evaluate the emergency logistics capability and realized the quantization of the index system (Deng and Zhang, 2010). Tongtong Nie, making use of the relevant application of maturity model, constructs the model of emergency logistics capability maturity and classifies the emergency logistics capability; with the help of powerful reasoning of Bayesian network realizes the ascension of emergency logistics capability level (Nie *et al*., 2011).

This study will use the evaluation model based on linguistic variables, change the language evaluation information by the experts into interval number and then propose a multi-attribute comprehensive evaluation method based on interval numbers to assess the level of emergency logistics capability.

PRE-SELECTED INDICATORS OF CAPABILITY EVALUATION FOR EMERGENCY LOGISTICS CENTER THE CONTEXT OF NETWORK

The research on enterprise logistics capabilities have a good reference, but not directly make general logistics evaluation index of logistics enterprises apply to the selection and performance evaluation of the emergency logistics center for logistics enterprises. Because the general logistics capacity evaluation is designed to enhance the performance and core competitiveness of logistics enterprises. In the formulation of suitable assessment indicators for emergency logistics centre capabilities, we must first clear the purpose of the development of indicators.

The establishment of the indicators from national level, specifically is how to guide emergency response organizations and logistics enterprises to build emergency logistics capability and to evaluate the performance of the enterprise executing emergency logistics tasks. Therefore, at the time of construction, we want to change the existing logistics evaluation index: On the one hand, to preserve the indicators reflecting the level of logistics enterprises, which is the basic premise to complete the emergency task, on the other hand, to add the indicators reflecting the characteristics of emergency logistics, which is the premise for emergency logistics center enterprises to adapt to the unconventional emergency environment and complete successfully emergency task. In other words, the logistics capability index system of emergency logistics centre enterprises Has both personality also the generality, both are indispensable.

Logistics network put forward by Professor Ju Songdong in the Beijing Jiaotong University consists of three parts: The network of logistics organization, logistics information network and logistics infrastructure network. Emergency logistics network is the same. Emergency logistics center is the central of the emergency logistics network environment, which actually is supported and run by the three sub-networks organized by the organizational network of emergency logistics, emergency logistics information network and infrastructure network. In such a logistics network environment, the logistics capabilities evaluation of emergency logistics center must be considered from the organization's network environment , information network environment and infrastructure network environment. Therefore, this study will build pre-selected index system in the three sub-network environment.

Combined with the capability research in the organizational network environment for domestic and foreign scholars, this study have put forward the following organizational construction capability elements of emergency logistics: rationality of institutional framework, scientificity of institutional responsibilities, Personnel competence, personnel emergency sense of responsibility, the organization expansion ability, ability of organization change, coordination capacity of organizational institutions, Cooperation capacity of organizational institutions. Combined with achievements of the domestic and foreign scholars in information capability, the elements of emergency logistics information capability summed up are as follows: Perfect information network system, software and hardware level of information system, information system security, information personnel construction, the level of use and maintenance of emergency logistics information system, Integration of emergency logistics capability. Combined with achievements of the domestic and foreign scholars in basic capacity, the elements of the emergency logistics infrastructure comprehensive capability summed up are as follows: distribution capability of emergency logistics, storage capacity, emergency logistics loading and unloading capability, emergency logistics sorting capability, emergency logistics packaging capacity,

Table 1: Pre-selected indicators of capability evaluation for emergency logistics center

First-level indicators	Second-level indicators	Third-level indicators
Pre-selection indicators of capability evaluation for emergency logistics center (A)	Emergency logistics organizational construction capability (B_1)	Organization expansion ability(C_{11})
		personnel emergency sense of responsibility (C_{12})
		Scientificity of institutional responsibilities (C_{13})
		Coordination capacity of organizational institutions (C_{14})
		Personnel competence (C_{15})
		Rationality of institutional framework (C_{16})
		Ability of organization change (C_{17})
		Cooperation capacity of organizational institutions (C_{18})
	Emergency logistics information capability (B_2)	Perfect information network system(C_{21})
		Software and hardware level of information system (C_{22})
		Information system security (C_{23})
		Information personnel construction (C_{24})
		Level of use and maintenance of emergency logistics information system (C_{25})
		Integration of emergency logistics capability (C_{26})
	Emergency logistics infrastructure comprehensive capability (B_3)	Distribution capability of emergency logistics (C_{31})
		Storage capacity (C_{32})
		Emergency logistics loading and unloading capability (C_{33})
		Emergency logistics sorting capability (C_{34})
		Emergency logistics packaging capacity (C_{35})
		Emergency logistics distribution processing capability (C_{36})
		Emergencymaterialtracking ability (C_{37})
		Construction capability of emergency plan (C_{38})

emergency logistics distribution processing capability, emergency material tracking ability.

On the other hand, the construction of the plan conform to the characteristics and requirements of the emergency. In the field of economic emergency, emergency contingency plans were made to complete scenario background task. Emergency logistics plans can not only promote the usual preparations for emergency logistics and achieve rapid emergency response. but also is one of the means for emergency aid decision making. So, the construction capability of emergency plan should be put in the emergency logistics infrastructure comprehensive ability

According to the above two paragraphs of exposition, construct the pre-selected index system of capacity assessment for emergency logistics center as shown in the Table 1.

IDENTIFICATION METHOD OF KEY ELEMENTS FOR LOGISTICS CAPABILITY EVALUATION IN THE CONTEXT OF NETWORK

For the Pre-selection of secondary indicators with a great deal of subjectivity, some indicators are not reasonable, weeded out necessarily through a certain method and identifying the key factors, thus constructing a more reasonable capability evaluation index system of emergency logistics center. During the Identification of the key elements of capability evaluation in emergency logistics, the evaluation elements reflecting the degree of emergency logistics is not the same as each other and the boundary is not clear, has a certain ambiguity, So this study use the method of fuzzy clustering analysis to process these indicators.

Selection of fuzzy clustering method: Clustering analysis is also called group analysis, which is a method of statistical analysis for the study of classification (sample or index) problem. Clustering analysis is very rich in content, including systematic clustering method, the ordered sample clustering method, dynamic clustering method, the fuzzy clustering method, the graph clustering method, clustering forecast method, etc. Fuzzy clustering method is a kind of method to explore the quantitative classification of things from the point of view of fuzzy sets. In recent years, it has been widely used for fuzzy clustering analysis method in the study of the classification of the various fields. At present the commonly used method of fuzzy clustering mainly have a graph clustering method, the direct clustering method, the c-means clustering method and the transitive closure method and so on.

In the above four methods, the premise of using graph clustering method is to establish a fuzzy graph, but its disadvantage is that with the increase of vertex number in the figure, the establishment of the fuzzy figure will be more and more complex. As for direct clustering method, the computation quantity is small, but its fuzzy similar matrix only meet symmetry and reflexivity, in the clustering process also need to merge classes to realize transitivity. C-means clustering method should not be used when you can not know the categories of clustering class in advance. And because transitive closure method can realize multidimensional data analysis, better realize the clustering of symmetry, reflexivity and transitivity and do not need to manually clustering categories. Therefore,

according to the characteristics and properties of the emergency logistics capability evaluation index we use the transitive closure method to deal with the evaluation.

Steps of fuzzy clustering analysis method

Characterization of the domain and construct the scoring matrix theory: The object to be classified as a domain $U = \{u_1, u_2, \ldots, u_m\}$, each element has n statistical indicators as a basis for classification, vectors are represented as $u_1 = (x_{i1}, x_{i2}, \ldots, x_{im})$ i =1, 2, …, n, According to the criteria of important degree of each evaluation index conduct the fuzzy rating, form factor scoring matrix $X = (x_{ij})_{m\times n}$.

Construct the fuzzy similar matrix: Establishment of fuzzy similar matrix is also called calibration. How to establish similar relationships $R(u_i, u) = r_{ij}$ between different objects u_i and u_j, there are many methods to choose from, which can be selected according to the actual situation in practical application.

Construct the fuzzy equivalent matrix: The above fuzzy similar matrix R obtained usually only satisfy reflexivity and symmetry, it must be converted into equivalent matrix. Therefore, the transitive closure R (the equivalent matrix) of R is gotten by the use of quadratic method. $U = \{u_1, u_2, \ldots, u_n\}$ can be classified by R Assume that R, S are fuzzy similar matrix, $R = (r_{ij})_{n\times m}$, $S = (S_{ij})_{n\times n}$,so $R\bullet S = (t_{ij})$, where:

$$t_{ij} = \bigvee_{k=1}^{n}(r_{ik} \wedge s_{ik})$$

Based on the theorem, After a composite calculation up to $[\log_2 n]+1$ times the transitive closure can be obtained.

Construct the clustering hierarchical diagram: Suppose that transitive closure obtained $t(R) = (\overline{r}_{ij})_{n\times n}$,so $\forall\lambda\in[0, 1]$, we can get X relationships $t(R)_\lambda \subset X\times X$, namely existing Boolean matrix $t(R)_\lambda \triangleq (\overline{r}_{ij}(\lambda))_{n\times n}$:

$$\overline{r}_{ij}(\lambda) = \begin{cases} 1, \overline{r}_{ij} > \lambda \\ 0, \overline{r}_{ij} \le \lambda \end{cases} \quad (1)$$

As for u_i and u_j, if $\overline{r}_{ij}(\lambda) = 1$, so are grouped together Under level λ, so as to achieve the purpose of classification for a set of objects to be clustered. As the level of λ in the [0,1] is changed, the corresponding cluster will also change, so as to form Clustering hierarchical diagram.

EVALUATION INDEX SYSTEM OF EMERGENCY LOGISTICS CAPABILITY IN THE CONTEXT OF NETWORK

Characterization of the domain and construct the scoring matrix: Through a questionnaire survey of 20 emergency logistics experts, the earlier pre-selected indicators are selected as evaluation factors, the formation of the domain for fuzzy clustering analysis. On the basis of the scientificity, objectivity, feasibility and dynamics four dimensions, "Very reasonable (V), Reasonable (R) and Unreasonable (N)" three levels is designed to reflect the degree of each evaluation factor and each level corresponding weights respectively is: 3, 2, 1, invite experts according to their experience and judgment to select one of them.

To select the evaluation factors of emergency logistics constructional capability as an example, this study studies the fuzzy clustering analysis model. The analysis of other component elements for emergency logistics capability can be made according to this method. Selection of emergency logistics organizational construction capability index as the domain $U = \{u_1, u_2, \ldots, u_8\}$, based on the questionnaire results, each factor according to scientificity, objectivity, feasibility and dynamics of the four dimensions, grades the "Very reasonable (V), Reasonable (R) and Unreasonable (N)" three degree of statistical distribution, Statistical score distribution of each expert are listed in the following Table 2.

According to the different weights of accumulation and statistical average in the above table, the score of each index is calculated. Namely to obtain the original scoring matrix of reasonable degree of each evaluation factor and then use the method of maximum to be standardized , finally get the standard scoring matrix for the emergency logistics organizational construction capability. The result is shown in Table 3.

We can also calculate the score of each indicator according to the standard scoring matrix. Obviously, the four latitudes have different weights in the classification of indicators that firstly have the scientificity and feasibility, on this basis, we can consider its dynamism and objectivity. So, we rated them according to the following equation:

$$S = 0.4\times S_{sciectificity} + 0.1\times S_{objectivity} + 0.4\times S_{feasibility} + 0.1\times S_{dinamics} \quad (2)$$

Score Table is shown in Table 4.

Construct the fuzzy similar matrix: According to the equation:

Table 2: Evaluation score of emergency logistics organizational construction capability

	Scientificity			Objectivity			Feasibility			Dynamics		
	V	R	N	V	R	N	V	R	N	V	R	N
C_{11}	10	10	0	14	6	0	14	6	0	0	2	18
C_{12}	12	8	0	16	4	0	16	4	0	14	6	0
C_{13}	4	8	8	16	4	0	16	4	0	0	2	18
C_{14}	16	4	0	15	5	0	16	4	0	14	6	0
C_{15}	15	5	0	14	6	0	18	2	0	18	2	0
C_{16}	18	2	0	16	4	0	18	2	0	20	0	0
C_{17}	2	6	9	17	3	0	17	3	0	6	8	4
C_{18}	16	4	0	4	9	6	18	2	0	1	5	14

Table 3: Emergency logistics organizational construction capability standard score

Indicators	Scientificity	Objectivity	Feasibility	Dynamics
C_{11}	0.86	0.95	0.93	0.37
C_{12}	0.90	0.98	0.97	0.90
C_{13}	0.62	0.98	0.97	0.37
C_{14}	0.97	0.96	0.97	0.90
C_{15}	0.95	0.95	1.00	0.97
C_{16}	1.00	0.98	1.00	1.00
C_{17}	0.52	1.00	0.98	0.70
C_{18}	0.97	0.67	1.00	0.45

Table 4: Emergency logistics organizational construction capability standard score talbe based on (2)

Score value	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
S	0.96	0.76	0.97	0.93	0.77	0.84	0.99	0.90

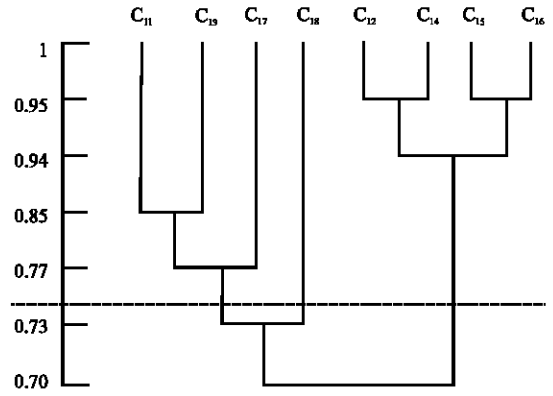

Fig. 1: Dynamic clustering figure of emergency logistics organizational construction capability

$$r_{ij} = 1 - c\sum_{k=1}^{m}\left|x_{ik} - x_{jk}\right|$$

take c = 0.5, to calculate the similarity among elements of the domain and get the fuzzy similar matrix $R = (r_{ij})_{8\times 8}$ after standardization, the result is shown as follows:

$$R=\begin{bmatrix} 1.00 & 0.68 & 0.85 & 0.66 & 0.62 & 0.56 & 0.62 & 0.73 \\ 0.68 & 1.00 & 0.60 & 0.96 & 0.91 & 0.89 & 0.70 & 0.57 \\ 0.85 & 0.60 & 1.00 & 0.55 & 0.51 & 0.48 & 0.77 & 0.62 \\ 0.66 & 0.96 & 0.55 & 1.00 & 0.94 & 0.91 & 0.65 & 0.62 \\ 0.62 & 0.91 & 0.51 & 0.94 & 1.00 & 0.95 & 0.62 & 0.59 \\ 0.56 & 0.89 & 0.48 & 0.91 & 0.95 & 1.00 & 0.59 & 0.55 \\ 0.62 & 0.70 & 0.77 & 0.65 & 0.62 & 0.59 & 1.00 & 0.48 \\ 0.73 & 0.57 & 0.62 & 0.62 & 0.59 & 0.55 & 0.48 & 1.00 \end{bmatrix}$$

Table 5: Analytic results of evaluation factors

		Cluster results	
Indicators	Score	Category	Evaluation degree
Ability of organization change (C_{17})	0.99	I	V
Scientificity of institutional responsibilities (C_{13})	0.97		
The organization expansion ability (C_{11})	0.96		
Coordination capacity of organizational institutions (C_{14})	0.93	II	R
Cooperation capacity of organizational institutions (C_{18})	0.90	III	N
Rationality of institutional framework (C_{16})	0.84		
Personnel competence (C_{15})	0.77		
Personnel emergency sense of responsibility (C_{12})	0.76		

Construct the fuzzy equivalent matrix: Application of fuzzy transitive closure method to carry out operations on fuzzy similar matrix R of organizational construction capability evaluation factor for emergency logistics center and get the fuzzy equivalent matrix R^*, the result is shown below:

$$R^{*}=\begin{bmatrix} 1.00 & 0.70 & 0.85 & 0.70 & 0.70 & 0.70 & 0.77 & 0.73 \\ 0.70 & 1.00 & 0.70 & 0.96 & 0.94 & 0.94 & 0.70 & 0.70 \\ 0.85 & 0.70 & 1.00 & 0.70 & 0.70 & 0.70 & 0.77 & 0.73 \\ 0.70 & 0.96 & 0.70 & 1.00 & 0.94 & 0.95 & 0.70 & 0.70 \\ 0.70 & 0.94 & 0.70 & 0.94 & 1.00 & 0.95 & 0.70 & 0.70 \\ 0.70 & 0.94 & 0.70 & 0.94 & 0.95 & 1.00 & 0.70 & 0.70 \\ 0.77 & 0.70 & 0.77 & 0.70 & 0.70 & 070 & 1.00 & 0.73 \\ 0.73 & 0.70 & 0.73 & 0.70 & 0.70 & 0.70 & 0.73 & 1.00 \end{bmatrix}$$

Clustering from 0.70 to 1 to the λ, form a dynamic clustering figure, as shown in Fig. 1.

When $\lambda = 0.75$, 8 assessment indicators of emergency logistics organizational construction capacity gathered into three categories. The results of cluster analysis are shown in Table 5.

According to the principle and steps of identifying key elements mentioned above, the method of fuzzy clustering analysis applied to emergency logistics capability index is used to identify the effective factors and gives the important degree rank of each index and the clustering results belonging to the "very reasonable (V)" and "reasonable (R)" level of evaluation index elements selected as the final evaluation index, namely the emergency logistics capability evaluation index system, which is shown in Table 6.

The capability index system of emergency logistics center processed by the method of fuzzy clustering analysis not only has a certain completeness but also has a certain rationality. It both includes the capacity indicators of organizational construction, information technology and infrastructure of emergency logistics

Table 6: Final evalution index system

First-level indicators	Second-level indicators	Third-level indicators
Pre-selection indicators of capability evaluation for emergency logistics center (A)	Emergency logistics organizational construction capability (B_1)	rationality of institutional framework (C_{11})
		Personnel emergency sense of responsibility (C_{12})
		Coordination capacity of organizational institutions (C_{13})
		Cooperation capacity of organizational institutions (C_{14})
	Emergency logistics information capabilities (B_2)	Perfect information network system (C_{21})
		The level of use and maintenance of emergency logistics information system (C_{22})
	Emergency logistics infrastructure comprehensive capability (B_3)	Distribution capability of emergency logistics (C_{31})
		Storage capacity (C_{32})
		The construction capability of emergency plan (C_{33})

center, also considers emergency plans for the indicator of capability construction incorporated into the overall index , which is not in the index system of logistics before. In this way can we make this index is more practical, more close to the reality of emergency logistics, better handle emergency logistics problems, as well as unpredictable and uncertain issues.

VULNERABILITY ASSESSMENT BASED ON LINGUISTIC VARIABLES

In this study, because each indicator is unable to describe with the accurate, the data needed to normalize is only language variable which is a qualitative index.

Linguistic variable set: Qualitative attribute index value is generally expressed as fuzzy language, such as "good", "very good", "absolute good " and so on . As it can not operate directly with quantitative indicators, standardized method for this attribute indicators generally use certain transformation rules ,namely fuzzy language-fuzzy digital conversion rules.

Suppose linguistic value sets $S = (s_0, s_1, \ldots, s_{l-1})$ Should consist of an odd number of elements, namly l should be an odd. Generally take 3,5,7,9, etc. It is represented as: $S = (s_0, s_1, s_2)$ = (bad, medium, good); $S = (s_0, s_1, s_2, s_3, s_4)$ = (bad, less bad, medium, good, very good); $S = (s_0, s_1, s_2, s_3, s_4, s_5, s_6)$ = (very bad, bad, less bad, medium, less good, good, very good).

$S = (s_0, s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8)$ = (super bad, very bad, bad, less bad, medium, less good, good, very good, super good).

Table 7: Converting 5 linguistic evaluation sets to interval numbers

Fuzzy linguistic level	Fuzzy linguistic express	Normalized interval number
S_0	Very bad	0,0.2
S_1	Bad	0.2,0.4
S_2	Medium	0.4,0.6
S_3	Good	0.6,0.8
S_4	Very good	0.8,1

Conversion between linguistic variable and interval number: For the linguistic variable, we may transform the variables to interval number as fellow:

Suppose interval number is $s_i = [a_i, b_i]$, then:

$$\begin{cases} a_i = \dfrac{i}{l} & (0 \le i \le l-1) \\ b_i = \dfrac{i+1}{l} & (0 \le i \le l-1) \end{cases} \tag{3}$$

Based on the above formula, we can get the correspondence for linguistic variables and interval numbers (normalized), which is shown in Table 7.

Calculate the objective weight: In order to use the variation coefficient method to calculate the objective weight of decision matrix, we need firstly to handle the interval data processing, get the precise number. Suppose attribute value is a normalized number, so:

- If it is interval number, we adopt mid-value to express:

$$r_{ij} = \frac{r_{ij}^- + r_{ij}^+}{2} \tag{4}$$

- Calculate the jth index mean-value:

$$\bar{r}_j = \frac{1}{m}\sum_{i=1}^{m} r_{ij}, j = 1,2,\cdots,n \tag{5}$$

- Calculate the jth index variance:

$$D_j = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2}, j = 1,2,\cdots,n \tag{6}$$

- Calculate the jth evaluation index variation coefficient:

$$E_j = \frac{D_j}{\bar{r}_j}, j = 1,2,\cdots,n \tag{7}$$

- Normalize variation coefficient of each index, get weights of each index:

$$\omega_j = \frac{E_j}{\sum_{j=1}^{n} E_j}, j = 1, 2, \cdots, n \tag{8}$$

An extend TOPSIS method

Calculate the distance of interval numbers: Suppose that a (a^l,a^r) and b (b^l, b^r) are two interval numbers. Define that:

$$d(a,b) = \frac{\sqrt{2}}{2}\sqrt{(a^l - b^l)^2 + (a^r - b^r)^2} \tag{9}$$

Determine the ideal and negative-ideal solution of interval number: Suppose ideal solution is $v^+ = (v_1^+, v_2^+, \ldots, v_n^+)$, negative-ideal solution is $v^- = (v_1^-, v_2^-, \ldots, v_n^-)$,after transform the linguistic variable into the interval number, the deal and negative-ideal solution can be determined as follows:

$$\begin{cases} v_j^+ = (v_j^{+l}, v_j^{+r}) = (\max\limits_i b_{ij}^l, \max\limits_i b_{ij}^r) \\ v_j^- = (v_j^{-l}, v_j^{-r}) = (\min\limits_i b_{ij}^l, \min\limits_i b_{ij}^r) \end{cases} \tag{10}$$

Calculate the generalized weighted distance of alternative a_i to the ideal and negative-ideal solution:

$$\begin{cases} d^+(a_i, v^+) = \sum\limits_{j=1}^{n} [w_j d(v_j^+, b_{ij})] \\ d^-(a_i, v^-) = \sum\limits_{j=1}^{n} [w_j d(v_j^-, b_{ij})] \end{cases} \tag{11}$$

Calculate the relative closeness of each alternative to the ideal solution:

$$C(a_i) = \frac{d^+(a_i, v^+)}{d^+(a_i, v^+) + d^-(a_i, v^-)} \tag{12}$$

Rank the order of the solutions: According to the size of the C (a_i), rank the order of the solutions. The C (a_i) is smaller, the solution is better; on the contrary, the C (a_i) is bigger, the solution is worse.

PRACTICAL EXAMPLE

Consider to evaluate the capability level of emergency logistics center of the four logistics enterprises (a_1, a_2, a_3, a_4), the evaluation index system uses the index system shown in Table 6. linguistic evaluation set is S = (s_0, s_1, s_2, s_3, s_4). linguistic evaluation matrix is shown in Table 8:

- According to Table 8, get the Initial evaluation matrix R:

Table 8: Linguistic evaluation value of the four enterprises

	C1	C2	C3	C4	C5	C6	C7	C8	C9
a1	S_3	S_1	S_2	S_2	S_3	S_2	S_4	S_1	S_0
a2	S_1	S_3	S_0	S_3	S_2	S_2	S_3	S_3	S_4
a3	S_3	S_0	S_1	S_4	S_1	S_0	S_2	S_2	S_3
a4	S_4	S_1	S_2	S_2	S_3	S_1	S_3	S_2	S_0

$$R = \begin{bmatrix} (0.6,0.8) & (0.2,0.4) & (0.4,0.6) & (0.4,0.6) & (0.6,0.8) & (0.4,0.6) & (0.8,1.0) & (0.2,0.4) & (0.0,0.2) \\ (0.2,0.4) & (0.6,0.8) & (0.0,0.2) & (0.6,0.8) & (0.4,0.6) & (0.4,0.6) & (0.6,0.8) & (0.6,0.8) & (0.8,1.0) \\ (0.6,0.8) & (0.0,0.2) & (0.2,0.4) & (0.8,1.0) & (0.2,0.4) & (0.0,0.2) & (0.4,0.6) & (0.4,0.6) & (0.6,0.8) \\ (0.8,1.0) & (0.2,0.4) & (0.4,0.6) & (0.4,0.6) & (0.6,0.8) & (0.2,0.4) & (0.6,0.8) & (0.4,0.6) & (0.0,0.2) \end{bmatrix}$$

- According to matrix R calculate the objective weight W:

$$W = [0.1487 \quad 0.0896 \quad 0.1539 \quad 0.0784 \quad 0.1359 \quad 0.0890 \quad 0.1046 \quad 0.1047 \quad 0.0952]$$

- According to Eq. 10 calculate the ideal and negative-ideal solution:

$$V^+ = [(0.8,1.0) \quad (0.6,0.8) \quad (0.4,0.6) \quad (0.8,1.0) \quad (0.6,0.8) \quad (0.4,0.6) \quad (0.8,1.0) \quad (0.6,0.8) \quad (0.8,1.0)]$$
$$V^- = [(0.2,0.4) \quad (0.2,0.4) \quad (0.0,0.2) \quad (0.4,0.6) \quad (0.2,0.4) \quad (0.0,0.2) \quad (0.4,0.6) \quad (0.2,0.4) \quad (0.0,0.2)]$$

- According to Eq. 11 calculate the generalized weighted distance of alternative to the ideal and negative-ideal solution:

$$d^+ = [0.2150 \quad 0.2145 \quad 0.2820 \quad 0.2031]$$
$$d^- = [0.2528 \quad 0.2533 \quad 0.2176 \quad 0.2648]$$

- According to Eq. 12 calculate the relative closeness of each alternative:

$$C = [0.4596 \quad 0.4586 \quad 0.5680 \quad 0.4340]$$

Therefore we know the order of the emergency logistics capability level in the four logistics enterprise: $\alpha_4 \succ \alpha_2 \succ \alpha_1 \succ \alpha_3$.

CONCLUSION

Emergency logistics center is the key node to realize effective scheduling and delivery of goods under unconventional emergencies. Based on the emergency logistics system as the research object, through the fuzzy clustering analysis, this article establishes the evaluation index system and evaluates the emergency logistics capability level with the aid of language variables and extendable TOPSIS method. The application shows that this method is effective in the evaluation of the level of emergency logistics center capacity.

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