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Considering the Research on The Distribution Priority of Materials at The Disaster-Stricken Points After the Earthquake

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Abstract: After the earthquake, it is necessary to effectively and quickly carry out the distribution of emergency materials. This paper considers the different disaster situations of different disaster areas, selects the attributes that affect the material demand in the disaster area, and uses fuzzy clustering technology to classify the demand points; then, uses the entropy The right method sorts different classifications to obtain the priority of material distribution at disaster-stricken points; determines the material satisfaction requirements of each demand point in the distribution system, and finally takes the Yushu earthquake in Sichuan as an example to verify.

Keywords: Demand allocation priority, Fuzzy clustering, Entropy weight method.

1. Introduction

Since the 21st century, earthquakes have occurred frequently around the world, bringing great threats to the economic development and safety of people's lives in various countries. China is also in the active plate of earthquakes all year round, and the frequent earthquake disasters have brought huge losses to our country. In recent years, with the rapid development of the economy, resulting in ecological imbalance, earthquakes, floods, typhoons and other natural disasters have posed a great threat to the country and its people. Earthquakes are the most destructive and unpredictable of these disasters, with the highest number of casualties. Unlike other natural disasters, earthquakes are not predictable, so it is difficult to accurately predict and notify the affected people to evacuate in advance, which also leads to serious consequences of earthquakes. China is also located in two of the world's most active seismic zones, and is one of the most frequently quake-prone and disaster-stricken countries. In recent years, the frequent occurrence of earthquake disasters, the Jiuzhaigou earthquake in 2017 caused 25 deaths, and in September 2022, a major earthquake of 6.8 magnitude occurred in Luding County, Ganzi Prefecture, Sichuan causing 93 people to be killed and 25 people lost. In the same month Taiwan's Taitung County, Hualien County was hit by seven major earthquakes of 5.0 magnitude or higher in two days. This resulted in 1 death and 171 casualties. In terms of direct economic losses caused by earthquakes, more than half of China's population and land is in the earthquake prone zone, and the average direct economic losses caused by earthquakes accounted for 16.5% of the direct economic losses of various natural disasters. 2020 earthquake disasters in China occurred three times, respectively, in Xinjiang 3 times, Sichuan and Yunnan 1 time each, causing economic losses of 1.71 billion yuan, 200 million yuan and 100 million yuan, respectively. The main reason for the large losses in Xinjiang is that there were two earthquakes of magnitude 6 or higher, with total economic losses of 2.054 billion yuan. Overall, it is clear that the earthquake disaster poses a serious threat to us, and also triggers us to contemplate on the issue of emergency logistics and rescue, earthquake relief work can not be delayed.

After the earthquake, the affected areas were in urgent need of various materials to sustain life, but due to the early post-earthquake, many allocations were slow to follow up, such as manpower, financial resources, transportation tools, etc. Moreover, the disaster situation of each disaster-stricken point is different, and the demand for materials is also different. If all conditions are scarce and materials are scarce, incorrect material distribution will lead to a backlog of materials in a certain place or waste in a certain place. There is a serious shortage of materials in the local area, and even the lives of the people are threatened because of improper distribution of materials. Therefore, it is necessary to prioritize the distribution of materials at each disaster-stricken demand point, which can ensure the fairness and rationality of material distribution, and can also provide basis and help for future emergency rescue.

2. Research on the Priority of Emergency Material Distribution

2.1. Attributes of material demand points

After the earthquake, the different attributes of each demand point will lead to different relief levels of the demand point, such as the number of casualties, population size, geographical location, age structure, secondary disasters, house collapse rate, etc, will all affect the urgency of the disaster-stricken point. Therefore, it is necessary to select appropriate attributes to analyze the disaster-affected points. According to historical experience, this paper selects the following four attributes to analyze the disaster-affected points [1] .

(1) Proportion of Vulnerable Population: Indicates the proportion of vulnerable population (such as children and the elderly) relative to the total trapped population in a specific affected area i within a given time interval t . Children and the elderly can be considered as vulnerable communities most in need of relief and rescue. Therefore, when determining the priority of relief needs, the corresponding proportion should be considered.

(2) complete damage is observed in a given affected area i

within a given time interval t . In general, the damage to buildings may reflect the severe impact of the disaster on the probability of survival of those trapped. Therefore, relatively large levels of building damage may indicate more urgent relief needs in correspondingly affected areas .

(3) Population density, population density is the ratio of the total population of the region to the total area of the region. The greater the population density of an area, the higher the concentration of its personnel, resulting in the more serious impact of earthquake disasters on the area, so after the earthquake, the higher the urgency of its material needs

(4) The number of secondary disaster points:[2] Due to the large-area geological secondary disasters caused by the earthquake and aftershocks, continuous rupture zones appear on the surface and induce a large number of landslides and landslide groups. The complex disasters of major earthquakes [3]are relatively serious, and various facilities in the disaster area are destroyed, and the demand for materials is large and time is tight.

2.2. Fuzzy clustering

Fuzzy clustering analysis is a mathematical method that uses fuzzy mathematical language to describe and classify things according to certain requirements. With the formation and development of fuzzy set theory, the more typical fuzzy clustering methods are: fuzzy clustering method of equivalence relations, clustering method based on fuzzy graph theory, fuzzy clustering method based on objective function and spectral clustering method, etc.; dynamic clustering method of fuzzy equivalence relations is a more widely used method, which is applied to fuzzy clustering of the demanded material points, and the specific steps are as follows:

2.2.1. Steps of fuzzy clustering

(1) Creation of original data

Divide the analyzed objects into n categories, that is, divide the disaster-affected points to be analyzed into n categories, obtain the set $X=\{X_1, X_2 \cdots X_n\}$, and determine the analysis objects. In order to obtain the clustering results For more scientific management, it is necessary to select m meaningful characteristic indicators for each research object, that is, each sample of a disaster point has m attributes. That is, x_{ij} represents the j (j=1,2 ⋯m ,) attribute of the i demand point . That is, $X_i=\{x_{i1}, x_{i2}, x_{i3}, \cdots, x_{im}\}$, i=1,2, ⋯n .

The original data matrix is thus obtained, as follows:

$$X=\begin{bmatrix} x_{11} & B & x_{1m} \\ C & E & C \\ x_{n1} & B & x_{nn} \end{bmatrix} \tag{1}$$

(2) Data standardization

Usually, after the original data is obtained, the data has a different dimension, so the original data needs to be processed so that the data is within the interval [0,1], and the common methods of data normalization are "translation-standard deviation transformation" and "translation-polar deviation transformation".

In this paper, the calculation formula of translation - range transformation is as follows:

$$x_{ij}'=\frac{x_{ij}-\min\limits_{1\le i\le n}\{x_{ij}\}}{\max\limits_{1\le i\le n}\{x_{ij}\}-\max\limits_{1\le i\le n}\{x_{ij}\}} \tag{2}$$

(3) Establish fuzzy similarity matrix

According to the standardized matrix calculated by the above formula, each demand point is calculated, and the fuzzy similarity matrix R is established . This process is called calibration.

$$R=\begin{bmatrix} r_{11} & B & r_{1m} \\ C & E & C \\ r_{n1} & B & r_{nm} \end{bmatrix} \tag{3}$$

In this paper, the arithmetic mean minimum method is used for calibration, and its calculation formula is shown below:

$$r_{ij}=\frac{\sum_{k=1}^{s}\min(x_{ik},x_{jk})}{\frac{1}{2}\sum_{k=1}^{s}(x_{ik}+x_{jk})} \tag{4}$$

(4) Determine the clustering method

The fuzzy equivalence matrix is obtained by using the method of passing the closure. Starting from the similarity matrix R, $R^2, R^4 \cdots R^n$ in turn, when $R^{2K}=R^K$ is satisfied, then RK is a fuzzy equivalence matrix, i.e., $t(R)=R^K$.

(5) Cluster analysis

Set different confidence levels $\lambda \in [0,1]$ for λ , and cluster the fuzzy equivalent matrix. When λ takes different values, different clustering results will be obtained. When λ decreases from 1 to 0 , the classified classes change from thin to thick, and gradually merge to form a dynamic clustering diagram.

(6) Determination of the optimal threshold

After the clustering results are obtained, it is necessary to select the optimal threshold λ that meets the requirements . The methods for determining the optimal threshold include the F- statistic method or the selection and determination of the value by experts based on the relevant knowledge of the neighborhood. In this paper, the F- statistic method is used to calculate, and the formula is as follows:

$$F=\frac{\sum_{r=1}^{R} n_r\left\|\overline{x_r}-\overline{x}\right\|/(R-1)}{\sum_{r=1}^{R}\sum_{i=1}^{n_r}\left\|x_{rj}-\overline{x_r}\right\|^2/(n-R)} \tag{5}$$

Among them, R is the classification number of the corresponding λ , n_r is the number of samples of the rth class, and the sample is $x_{r1}, x_{r2} \dots x_{rm}$; $\overline{x}_r$ is the vector of the cluster center: $\overline{x}_r = \overline{x}_{r1}, \overline{x}_{r2}, \dots \overline{x}_{rm}$, $\overline{x}_{rj}$ is the average value of the jth attribute in the rth class , and the calculation formula is:

$$\overline{x}_{rj}=\frac{\sum_{r=1}^{n_r} x_{rj}}{n_r}, j=1,2 \cdots ,m \tag{6}$$

The central quantity of the overall sample is $\bar{x} = \bar{x}_1, \bar{x}_2, \ldots \bar{x}_m$, and the calculation formula is:

$$\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}\ , j=1,2\ \cdot\cdot\cdot\ ,m \tag{7}$$

The distance from the center of the rth class to the center of the population is:

$$\left\|\bar{x}_r - \bar{x}\right\| = \sqrt{\sum_{j=1}^{m}(\bar{x}_{rj} - \bar{x}_j)^2} \tag{8}$$

The distance from the i- th sample in the center of the rth class to the center of the sample is:

$$\left\|x_{rj} - \bar{x}_r\right\| = \sqrt{\sum_{j=1}^{m}(x_{rj} - \bar{x}_{rj})^2} \tag{9}$$

The numerator of the F statistic represents the distance from the center of each category to the center of the population, and the denominator represents the distance from the sample in the same class to the center of the sample. The larger the F value, the greater the distance between different classes, and the smaller the distance within the same class, that is, the closeness of the same class and the distance of the heterogeneous class indicate that the classification is more reasonable. The λ value corresponding to the largest F-statistic is the best value, and the corresponding classification is the best classification.

2.3. Entropy weight Topsis method

In the previous stage, fuzzy clustering technique was used to effectively group the affected areas, and the affected demand points classified in the same group have the same priority and material satisfaction requirements in the material distribution process, while different groups need to be prioritized. In this paper, based on the entropy power Topsis method to solve the multi-attribute decision, the basic step is to use the entropy power method to assign weights to each indicator after making standardization of each indicator, and then use TOPSIS method for quantitative analysis and comparison.

2.3.1. Steps of entropy weight method

The n disaster points are divided into R classes by the above clustering process. The clustering central value $\bar{x}_{rj}$ (r=1,2,⋯,R;j=1,2,⋯m)of each attribute in each category can be obtained from the above equation,The matrix X is formed by each cluster center value:

$$X = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & B & \bar{x}_{1m} \\ \bar{x}_{21} & \bar{x}_{22} & B & \bar{x}_{2m} \\ B & B & B & B \\ \bar{x}_{R1} & \bar{x}_{R2} & B & \bar{x}_{Rm} \end{bmatrix}$$

(1) Data standardization

Generally speaking, data indicators are divided into two categories: positive indicators and negative indicators. The positive indicator means that the larger the value, the better, and the negative indicator means that the smaller the value, the better. However, the attributes of the demand points affected by earthquakes are positive indicators. The larger the value, the more urgent the demand points for materials. Then its standardized formula is as follows:

$$y_{rj} = \frac{x_{rj} - \min\limits_{1\le r\le R}\bar{x}_{rj}}{\max\limits_{1\le r\le R}\bar{x}_{rj} - \min\limits_{1\le r\le R}\bar{x}_{rj}}\ ,\ j=1,2,\ \cdot\cdot\cdot\ ,m \tag{10}$$

Among them, $\bar{x}_{rj}$ is the average value of the jth attribute in the rth class.

The transformed matrix Y can be obtained through the above formula:

$$Y = \begin{bmatrix} y_{11} & y_{12} & B & y_{1m} \\ y_{21} & y_{22} & B & y_{2m} \\ B & B & B & B \\ y_{R1} & y_{R2} & B & y_{Rm} \end{bmatrix}$$

(2) Calculate the specific gravity p_{rj} of each sample

$$p_{rj} = \frac{y_{rj}}{\sum\limits_{r=1}^{R} y_{rj}} \qquad j=1,2,\ \cdot\cdot\cdot\ ,m \tag{11}$$

(3) Calculate information entropy e_j

$$e_j = -k\sum_{r=1}^{R} p_{rj}\cdot\ln p_{rj} \tag{12}$$

(4) Calculate the weight W j of each measurement index value Y ij in the measurement system;

$$w_j = \frac{1-e_j}{\sum\limits_{j=1}^{m}(1-e_j)} \tag{13}$$

(5) The entropy weight of each attribute is obtained from the above formula, and the matrix Y is processed to obtain the matrix Z. The processing method is as follows:

$$Z = \begin{bmatrix} z_{11} & z_{12} & B & z_{1m} \\ z_{21} & z_{22} & B & z_{2m} \\ B & B & B & B \\ z_{R1} & z_{R2} & B & z_{Rm} \end{bmatrix} = \begin{bmatrix} w_1y_{11} & w_2y_{22} & B & w_my_{1m} \\ w_1y_{21} & w_2y_{22} & B & w_my_{2m} \\ B & B & B & B \\ w_1y_{R1} & w_2y_{R2} & B & w_my_{Rm} \end{bmatrix} \tag{14}$$

(6) The maximum value of each column attribute in the matrix Z is used as the ideal point, and each ideal point forms a vector P:

$$P = (p_1, p_2, B\ \ p_m)^T \tag{15}$$

(7) Calculate the distance dr between each class in the

matrix Z and the ideal point:

$$d_r = \sqrt{\sum_{j=1}^{m} (z_{rj} - p_j)^2}\ , \qquad r=1,2, \dots R \qquad (16)$$

The distance calculated by the above formula is used as the evaluation standard. The smaller the distance is, the closer the ideal point is to the group, which means that the priority of the demand point in the emergency material distribution process is higher, and the material satisfaction requirements are higher.

3. Case Studies

On April 14,2010, six earthquakes occurred in Yushu City ,Yushu Tibetan Autonomous Prefecture, Qinghai Province . The highest magnitude was 7.1 , which occurred at 7:49 . The epicenter of the earthquake was located near the urban area of Yushu . The earthquake caused 2698 deaths and 270 missing , covering an area of about 30,000 square kilometers. It mainly caused 12 villages and towns in Yushu County and Chengduo County to be affected by the disaster, with a population of about 100,000 people , 875 kilometers of roads were almost paralyzed, and forestry economic losses exceeded 2.5 billion yuan, which brought destruction to the personal safety and economy of our people. blow. The Yushu Tibetan Autonomous Region has a total area of 265,000 km 2 and a total population of 283,100 . It currently governs Yushu, which is called Duo, Nangqian, Zaduo , and Zhiduo. There are 10 towns and 32 townships in 6 counties of Qumalai , of which Tibetans account for 97%. Jiegu Town, Yushu County was the hardest hit area by the earthquake, with a total population of 89,300 . The epicenter of this earthquake was near Jiegu Town, and it was extremely destructive. All houses were damaged, and 59.43% of them collapsed. [2][3]

3.1. Determination of the distribution priority of disaster-affected points

Through the report of " Yushu City People's Government Official Website " [4] and " Related Books about Yushu Earthquake " , we selected 12 areas with severe disasters and the attributes of each disaster site are shown in Table 1 below :

Table 1. Attribute values of affected points

Affected point number	Affected point	house collapse rate	Population density	vulnerable population	secondary disaster point
1	Jiegu Town	59%	78.3	28%	252
2	ChengWenzhen	15%	18.7	29.8%	3
3	Anchong	35%	2.06	37.48%	7
4	Batang	30%	2.47	43.29%	11
5	Long Bao	40%	5.36	39.71%	3
6	Shanglaxiu	15%	3.17	44.81%	0
7	Laxiu Town	10%	4.77	42.17%	1
8	Xiao su mang	8%	5.61	42.47%	3
9	Zhongda	35%	5.06	39.18%	9
10	La bu	10%	8.38	35.24%	11
11	Qingshuihe	5%	2.62	35.39%	0
12	Zhenqin	5%	5.01	36.23%	1

Use fuzzy clustering method formulas (2-1)-(2-9) to carry out cluster analysis on the above data, calculate the F- statistics of each clustering result , select the clustering result with the largest F- statistic, and determine the best The horizontal threshold is 0.831 , and the best clustering and the clustering center values of each attribute are obtained as shown in Table 2 :

Table 2. Optimal clustering and clustering center value of each attribute

Clustering result	Affected point	house collapse rate	Population density	vulnerable population	secondary disaster point
A	1	0.59	78.30	0.28	252
B	2	0.15	18.70	0.30	3
C	3 , 4 , 5 , 9	0.35	3.74	0.40	7.5
D.	6 , 7 , 8	0.11	4.52	0.43	1.3
E.	10 , 11 , 12	0.07	5.34	0.36	4

The data in the table were normalized according to the formulas (2-10)-(2-12), and the clustering center standardized matrix was obtained:

$$\begin{bmatrix} 1.000 & 1.000 & 0.000 & 1.000 \\ 0.150 & 0.200 & 0.130 & 0.007 \\ 0.540 & 0.000 & 0.800 & 0.025 \\ 0.080 & 0.010 & 1.000 & 0.000 \\ 0.000 & 0.020 & 0.530 & 0.010 \end{bmatrix}$$

Calculate the entropy weight w of each attribute according to the formula (2-13) :

W=(0.1688,0.3049,0.115,0.4113)

According to the formula (2-14) , the matrix z is obtained as follows:

$$
z = \begin{bmatrix} 0.1688 & 0.3049 & 0.000 & 0.4113 \\ 0.026 & 0.0609 & 0.015 & 0.0028 \\ 0.0911 & 0.000 & 0.092 & 0.010 \\ 0.0135 & 0.003 & 0.115 & 0.000 \\ 0.000 & 0.006 & 0.060 & 0.040 \end{bmatrix}
$$

Calculate the ideal point p=(0.1688, 0.3049, 0.115, 0.4113) from the matrix Z , and calculate the distance between each group and the ideal point from P. The sorting results are shown in Table 3:

Table 3. The distance and priority ranking of demand points and ideal points

classification result	distance	to sort	priority
A	0.115	1	1
B	0.5099	3	3
C	0.5068	2	2
D	0.53	4	4
E	0.54	5	5

The sorting results are shown in the table. Group A has the smallest distance, indicating that its demand priority is the highest, and group E has the largest distance, indicating that its demand priority is the lowest.

4. Conclusion

From the above research results, it can be seen that Jiegu Town has the highest priority for supplies, followed by other towns and towns in Yushu County that were more severely affected; although Chengwen Town is far from the disaster area, its population density is extremely high. Disaster relief supplies are more urgent, so they are ranked third; comparing the obtained results with Figure 1 , it can be found that the demand points with high priority for material distribution are located in areas with high seismic intensity, while the areas with low priority are mostly in low-intensity areas . Therefore, the method proposed in this paper can timely and quantitatively calculate the distribution priority of material demand points when the intensity is not determined, and provide an effective reference for quickly and reasonably formulating a material distribution plan in the initial stage of post-earthquake rescue.

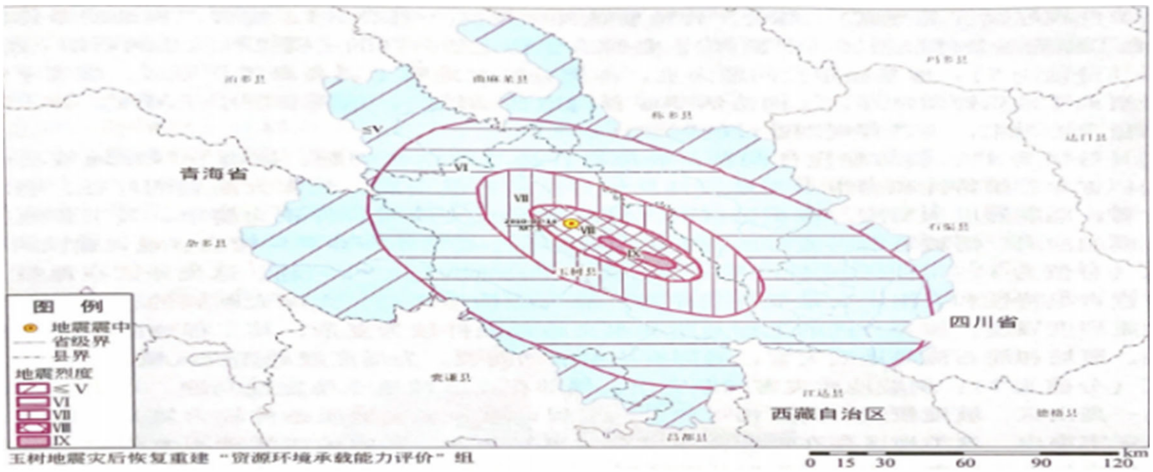

Figure 1. Seismic Intensity Map [2]

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