Research on Emergency Logistics Support Capacity: Evaluation Model and Grey-AHP Method

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Abstract - Based on the grey analysis hierarchy process, this paper introduces an evaluation method of emergency logistic support capacity. The comprehensive evaluation model is established according to the analytical hierarchy process which gives each key index a weight. To illustrate the effectiveness of the above method and the application of the proposed model, a case is studied that verifies the importance of the research in the engineering theory and practice. The computational results indicate that the emergency logistic support capacity of selected case is in decent rank.

Index Terms - Emergency logistics, Analysis hierarchy process, Grey theory, Evaluation model

1. Introduction

In recent years, the natural disasters, e.g., the earthquake, the tsunamis, the typhoon and many other disasters, have occurred frequently. With the increasing of disaster-frequency, disaster-scale and disaster-influence, it is harder and harder to organize the emergency logistics effectively and promptly. Thus, it has significant meaning to research the evaluation of emergency logistics as well as develop appropriate plans for the engineering theory and practice.

To set the context, this paper begins by analyzing the characteristics of emergency logistics. The emergency logistics support ability should be with extreme timeliness, powerful adaptability, open, holistic and so on. That is to say, the aim of emergency logistics is to maximize the efficiency in the shortest possible time. Therefore, how to evaluate the emergency logistics support ability quickly and efficiently is the key factor to develop appropriate program.

In conclusion, this paper based on the characteristics of emergency logistics, adopts the analysis hierarchy process (AHP) together with grey theory to further improve the evaluation method of emergency logistics support ability. By systematically considering all the key factors of emergency logistics and correctly analyzing the importance of these factors on overall support capacity, it is better to solve practical problems.

2. Grey Analysis Hierarchy Process

The analysis hierarchy process (AHP) was firstly proposed by Pittsburgh University professor Satie which was a level-weight of decision analysis method [1]. It treats a multiple decision problem as a system and decomposes the target into sub-goals. Thus, the problem is decomposed into several multi-index hierarchy processes. What's more, these hierarchy processes are fuzzy quantified to compute their single ranking as well as aggregate ranking [2]. Besides, the grey theory was first introduced by professor Deng to solve the uncertainty problems that are provided with part clear and unclear information.

With the combination of AHP and grey theory, a systematic optimization Grey-AHP method is developed. In other words, the weight value of different hierarchy process is calculated according to grey theory. By adopting the AHP to fix the weight values of factors and the grey theory to analyze uncertainty problem, this comprehensive Grey-AHP improves the reliability and accuracy of the evaluation results. The detailed Grey-AHP method is described as follows.

A. *The indicator ranking standards*

Here, we divide the indicators into four ranks, excellent, good, medium and poor. And the corresponding values are 1, 2, 3, and 4. If the indicator rank is between two continuous standards, the average value is selected. Table 1 gives the indicator ranking standards in detail [3].

TABLE Ⅰ Indicator ranking standards

Indicator ranking	Standard
excellent	1
good	2
medium	3
poor	4

B. *Evaluation sample matrix*

There are r experts to evaluate n indicators. d_{ki} represents the evaluation value given by the $k\text{-}th$ expert to the $i\text{-}th$ indicator. Thus, the evaluation sample matrix D is as follows:

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1i} & d_{1n} \\ d_{k1} & \cdots & d_{ki} & d_{kn} \\ \vdots & \vdots & \vdots & \vdots \\ d_{r1} & \cdots & d_{ri} & d_{rn} \end{bmatrix} \quad (1)$$

C. *Indicator ranking function*

Followed by the indicator ranking standards section, there are also 4 ranks of indicating ranking functions. Set d as the serial number of grey-class. And the indicating ranking functions can be tracked as follows.

When d is equal to 1, 2, 3 and 4, the indicating ranking function f_d is:

$$f_1=\begin{cases} x_{ij}/3 & x_{ij}\in[0,4] \\ 1 & x_{ij}\in[4,\infty] \\ 0 & x_{ij}\notin[0,\infty] \end{cases} \quad (2)$$

$$f_2=\begin{cases} x_{ij}/3 & x_{ij}\in[0,3] \\ 2\text{-}x_{ij}/3 & x_{ij}\in[3,4] \\ 0 & x_{ij}\notin[0,4] \end{cases} \quad (3)$$

$$f_3=\begin{cases} x_{ij}/2 & x_{ij}\in[0,2] \\ 2\text{-}x_{ij}/2 & x_{ij}\in[2,4] \\ 0 & x_{ij}\notin[0,4] \end{cases} \quad (4)$$

$$f_4=\begin{cases} 2\text{-}x_{ij} & x_{ij}\in[1,2] \\ 1 & x_{ij}\in[0,1] \\ 0 & x_{ij}\notin[0,2] \end{cases} \quad (5)$$

D. *Grey statistics and evaluation matrix*

The grey statistics are some uncertainty values. And the indicator ranking function solves the satisfactory or probability of making these uncertainty values to become determined. Here, the weight matrix R_i is obtained, where r_{ij} is calculated by $r_{ij}=\frac{n_{ij}}{n_i}$; grey statistic n_{ij} can be tracked by $n_{ij}=\sum_{s=1}^{r} f_j(x_{si})$; the total grey statistics n_i will be computed by $n_i=\sum_{j=1}^{n} n_{ij}$.

$$R_i=\begin{bmatrix} r_{11} & \cdots & r_{1j} & r_{1k} \\ r_{i1} & \cdots & r_{ij} & r_{ik} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & \cdots & r_{nj} & r_{nk} \end{bmatrix} \quad (6)$$

E. *The evaluation function*

The first indicator weight vector W is calculated by adopting AHP method. Thus, the evaluation value B can be followed as $B=W^T R$. Besides, the evaluation ranking vector which is given by experts can be donated as $G=[g_1,g_2,\cdots g_n]^T$. In summary, the mathematical evaluation function is formed as formula (7).

$$U=BG \quad (7)$$

3. Case Study

To illustrate the application of our proposed model and efficiency of evaluation method, we carry out the following numerical experiments.

According to accident occurrence process, accident mechanism and property, the sudden public events can be divided as nature disasters, accidental disasters, public healthy events and social security incidents [4]. In one area, emergency logistics support capacity includes human resources support, district materials reserve, medical system of material reserve, transportation capacity reserve, communication security reserve, shared security of special equipments reserve and military material reserve. Thus, the hierarchical structure model is illustrated in Figure 1 [5].

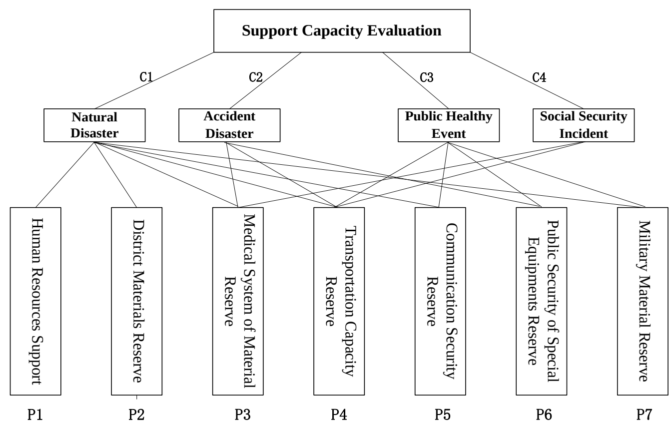

Fig. 1 Hierarchical structure of emergency logistics

F. *Judgment matrix*

There are two kinds of judgment matrixes, standard matrix (Z-C matrix) and program matrix (C-P matrix), respectively. The detailed matrixes can be seen from Table 2 to Table 6.

TABLE Ⅱ The Z-C matrix

Z	C1	C2	C3	C4
C1	1	1	1/3	1/3
C2	1	1	1/3	1/3
C3	3	3	1	1
C4	3	3	1	1

TABLE Ⅲ The C1-P matrix

C1	P1	P2	P2	P4	P5	P7
P1	1	1/5	1/5	1/5	1/3	5
P2	5	1	3	7	4	2
P3	5	1/3	1	5	3	2
P4	5	1/7	1/5	1	1/2	1
P5	3	1/4	1/3	2	1	3
P7	1/5	1/2	1/2	1	1/3	1

TABLE Ⅳ The C2-P matrix

C2	P3	P4	P6
P3	1	2	3
P4	1/2	1	2
P6	1/3	1/2	1

TABLE Ⅴ The C3-P matrix

C3	P4	P5	P6	P7
P4	1	1/3	1/5	1/2
P5	3	1	1/2	5
P6	5	2	1	7
P7	2	1/5	1/7	1

TABLE Ⅵ The C4-P matrix

C4	P3	P4
P3	1	3
P4	1/3	1

The maximum matrix eigenvalue $\lambda_{\max}$ and eigenvector W are given as follows.

$$W_1 = (0.097, 0.380, 0.230, 0.092, 0.129, 0, 0.072)^T$$

$$W_2 = (0, 0, 0.456, 0.344, 0, 0.200, 0)^T$$

$$W_3 = (0, 0, 0, 0.083, 0.299, 0.520, 0.098)^T$$

$$W_4 = (0, 0, 0.750, 0.250, 0, 0, 0)^T$$

G. The weights of evaluation indicators

$W^{(3)}$ is the matrix developed by W_1, W_2, W_3 and W_4, and the weight vector of program W is known. According to $W = W^{(3)}W^{(2)}$, we get

$$W^{(2)} = (0.125, 0.125, 0.375, 0.375)^T.$$

Besides, the second weights indicators referring to above results are computed.

$$W_1 = (0.097, 0.380, 0.230, 0.092, 0.129, 0, 0.072)^T$$

$$W_2 = (0.456, 0.344, 0.200,)^T$$

$$W_3 = (0.083, 0.299, 0.520, 0.098)^T$$

$$W_4 = (0.750, 0.250)^T$$

H. The sample matrix

The four evaluation sample matrixes are listed here according to experts. They are nature disaster matrix (M_1), accident disaster matrix (M_2), public healthy event matrix (M_3) and social security incident matrix (M_4).

$$M_1 = \begin{bmatrix} 4 & 3 & 1 & 2 & 2 & 2 & 3 \\ 3 & 4 & 1 & 2 & 3 & 2 & 4 \\ 4 & 3 & 1 & 3 & 3 & 2 & 4 \end{bmatrix} \quad M_2 = \begin{bmatrix} 1 & 2 & 3 \\ 2 & 2 & 3 \\ 1 & 3 & 2 \end{bmatrix}$$

$$M_3 = \begin{bmatrix} 4 & 3 & 2 & 1 \\ 3 & 3 & 2 & 1 \\ 4 & 3 & 1 & 1 \end{bmatrix} \quad M_4 = \begin{bmatrix} 2 & 2 \\ 1 & 2 \\ 1 & 3 \end{bmatrix}$$

I. Weight matrix

Firstly, we calculate the weight matrixes R_1, R_2, R_3 and R_4 according to the above four indicators. Then the evaluation results can be gained by $B_d = W_d^T R_d$. Formula (8) gives the results in matrix.

$$B = W^{(2)^T} \times R = (0.244, 0.317, 0.285, 0.133) \quad (8)$$

In addition, $G = [1,2,3,4]^T$ is known, and the evaluation result is $U = BG = 2.265$. It reflects the emergency logistics support capacity is in good rank according to Table 1.

4. Conclusions

This paper introduces an evaluation method of emergency logistic support capacity based on the grey analysis hierarchy process. Then by giving each key index a weight, the comprehensive evaluation model is established. Furthermore, to illustrate the effectiveness of the above method and the application of the proposed model a case is studied. Our computational results indicate that the emergency logistic support capacity of selected case is in good rank. In summary, the Grey-AHP is practical, effective, and reliable that could be used to evaluate the emergency logistic support capacity.

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