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Assessment of Emergency Dynamic Classification in Supply Chain

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Abstract: Emergency management is a new topic in supply chain management theory and has great significance in theoretical study. As emergency accidents always have a life span of different scales, dynamic assessment and targeted preventive measures which are basic ways to check consequences as well as the premise of building emergency management mechanism are eagerly desired. The study first reviewed the emergency classification and grading situation, then discussed the disadvantages of existing technology and method, eventually calculated and sorted the value of emergency expectations by mathematical method of Fuzzy Comprehensive Evaluation Method (FCEM) and Analytic Hierarchy Process (AHP) synthetically which help incorporate the inherent uncertainties, imprecision and subjectivity of available data throughout the whole model to consistent with the actual situation. In the last part, the final evaluation level in the future is predicted.

Key words: Emergency, scale, classification

INTRODUCTION

In recent years, various emergencies have a significant impact upon supply chains of all industries with the rapid development of economic and society. For example, the haze weather phenomenon that existed in most parts of China such as He bei, Beijing, Hunan, Zhengzhou, became a powerful promotion for products like anti-PM2.5 respirator, indoor air purifier and so on. Manufacturing enterprises are shocked from the direct impact. The downstream enterprises are also vulnerable to the supply volatility because supply capacity makes up a greater percentage of their total profit. Another example is the reverse tend in Spring Festival, a large number of urban migrant workers drift back to their villages for the holiday which disturbed the normal operation of labor intensive manufacturing enterprises like electronics assembly plants. Some have been forced to halt part production which leads to the inventory shortage, so the supply capacity bottleneck gradually highlighted. We still remember the Lian-Huo expressway was cut off for the explosion of firecrackers transporter, the adjacent Hu-Shan expressway, Zheng-Lu expressway and 301 national road were faced the sustaining growth of traffic pressure and the transportation costs, storage costs of cold fresh food transportation enterprises that have to go into Shangxi area increased. As a result, the sales cost got a high level, the product demand cost was influenced as well. All kinds of emergency events and emergency measures change with time, so as the influence on supply chain performance. How to carry on dynamic evaluation, dynamic hierarchical, dynamic response in the development process according to the harm degree are urgent problems need to be solved.

PROBLEMS RELATED TO EMERGENCY EVENTS

Improved algorithm: Due to the shortcomings of any single method listed above, the application of evaluation method is a combination of two or more methods. This study improved the existing emergency dynamic classification algorithm based on AHP (Zhan *et al*., 2013) and Fuzzy Comprehensive Evaluation Method (FCEM). The rank of expectation values and incentive causes were given with the proprieties after the indexes weights were provided by experts, then the fuzzy results were tested to avoid the inconsistency on fuzzy results by accurate evaluation method. For example, the weights in common AHP algorithms are assumed that each expert can provide the relative importance of each factor obviously in traditional decision. In fact, the judgment of "important", "relative importance" or "less important" level is hard to ensure, even the experts can't determine how important the factor is which value is more suitable among a numerical representation of the 0.6 or 0.8. As a result, the importance degree of each attribute value, should not be expressed with a certain number but should be a complete fuzzy number or fuzzy sets, namely some or all of the

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evaluation matrix elements are fuzzy sets; the second innovation of this article simplified the complex fuzzy quantity to simple fuzzy quantity by the use of L-R type fuzzy numbers (Wang *et al*., 2010), ensured the left and right number of the fuzzy weighted values are constant which is reasonable and effective.

Establish the simplified indexes system: It is difficult to sum up the unified pattern and fixed laws for emergency events as the causes are complex. The derivative conditions, accident environment and implied demand uncertainty of emergency events are different but the statistical result shows that the influence factors of emergency have something in common. Choosing reasonable index is the first step in the emergency dynamic classification, however, this is not the key point of this study, therefore, we selected some indexes from existing works. The uncertainty of emergency classification mainly concentrated at the early stages of the event, the main factors influenced the emergency classification include: Influence scope, degree, extant of damage, diffusion factor, time factor, cognitive, social influence, public psychological tolerance and resource security. The study dealt with emergency cases happened in the past decade (Chai, 2011), selected four indexes: the emergency intensity a_1, the enterprise loss rate a_2, the degree of impact on the whole supply chain a_3, recovery capability a_4. The intensity can be measured from three aspects: Propagation velocity, diffusion range and the number of influenced node enterprises; the loss rate can be evaluated from the capability of production, order processing, revenues, reputation before the emergency and compare with themselves after emergency; the influence degree depend on whether the enterprise is core enterprise in the supply chain, the influence degree of core enterprise, whether there are emergency measures or not; recovery capability of supply chain is mainly measured from two aspects: recovery time and recovery degree. The above indexes could be quantitatively measured and obtained easily.

FUZZY COMPREHENSIVE EVALUATION

Fuzzy comprehensive evaluation mainly includes three parts: Determining the fuzzy weighting and sorting, choosing the optimal scheme, calculating the state transition probability.

Definition and arithmetic of fuzzy numbers: Let A be normal fuzzy set in field of real numbers, $\lambda \in [0, 1]$, A_λ be closed interval, A is said to be a fuzzy number, or F number for short. A fuzzy number N is normal convex fuzzy sets, defined in field of real numbers R and meet the following conditions:

- There existed a unique point $a_0 \in R$, with membership u (a_0) =1 (a_0 is called the mean value of N)
- The membership is continuous, a general expression of the fuzzy number N is:

$$\text{UN}(a) = \begin{cases} L(a) & l \le x \le m \\ R(a) & m \le x \le r \end{cases}$$

L (a) is increasing function, continuity from the right and $0 \le L\ (a) \le 1$, R (a) is decreasing function, continuity from the left and $0 \le R\ (a) \le 1$. If L (a) and R (a) are both liner functions, then N is called the triangle fuzzy number, that is shorthand for N = (l, m, r). Let M and N are arbitrary fuzzy numbers, its algorithms could be represented as:

Fuzzy number addition:

$$[M(+)N]a = [m_X^L + n_X^L,\ m_X^R + n_X^R]$$

Fuzzy number subduction:

$$[M(-)N]a = [m_X^L - n_X^L,\ m_X^R - n_X^R]$$

Fuzzy number multiplication:

$$[M(\times)N]a = [m_X^L \times n_X^L,\ m_X^R \times n_X^R]$$

Fuzzy number division:

$$[M(\div)N]a = [m_X^L / n_X^L,\ m_X^R / n_X^R],\ n_X^L > 0,\ n_X^R > 0$$

Triangle fuzzy number definitions and algorithms: Let $\tilde{p} = (l, m, u)$ be triangle fuzzy number, its membership function can be represented as (Jiang and Fan, 2000):

$$f(x) = \begin{cases} 0 & x \le l \\ x\text{-}l/m\text{-}l & l<x \le m \\ x\text{-}u/m\text{-}u & m<x \le u \\ 0 & x>u \end{cases}$$

$x \in R$, $l<m<u$, l and u are upper critical value and lower critical value which represents representing the grade of fuzzy, the more u-l, the greater the degree of fuzzy. Triangle fuzzy number operation rule can be represented as:

$$\tilde{p}_1 \oplus \tilde{p}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$\tilde{p}_1 \oplus \tilde{p}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$\lambda \otimes \tilde{p}_1 \approx (\lambda l_1, \lambda m_1, \lambda u_1)$$

$$(\tilde{p}_1) \approx (1/u_1, 1/m_1, 1/l_1)$$

Implementation of algorithm: The importance of indexes ware judged by a panel of experts in the form of triangle fuzzy number, setting up the assembly of experts $C = \{C^1, C^2, \Lambda, C^q\}$ and evaluation criteria, determine the evaluation index set $a = \{a_1, a_2, \Lambda, a_n\}$, the scale 0.1-0.9 was applied to it, judgment matrix was obtained by comparing arbitrary two factors, the meaning of scales are shown in Table 1.

The judgment matrixes were given by four experts C_i (I = 1, 2, 3, 4) independently and experts weights were achieved based on each expert's research field, results relevance and practical experiences. Each expert has a corresponding weighting coefficient r_i (i = 1, 2, 3, 4).

$r_1 = 0.35$, judgment matrix by C_1:

$$\tilde{p}_1 = \begin{pmatrix} (0.50,0.50,0.50)(0.80,0.90,0.95)(0.60,0.85,0.95)(0.40,0.60,0.80) \\ (0.05,0.10,0.20)(0.50,0.50,0.50)(0.20,0.35,0.60)(0.10,0.20,0.30) \\ (0.05,0.15,0.40)(0.40,0.65,0.80)(0.50,0.50,0.50)(0.10,0.25,0.40) \\ (0.20,0.40,0.60)(0.70,0.80,0.90)(0.60,0.75,0.90)(0.50,0.50,0.50) \end{pmatrix}$$

$r_2 = 0.25$, judgment matrix by C_2:

$$\tilde{p}_2 = \begin{pmatrix} (0.50,0.50,0.50)(0.30,0.45,0.60)(0.55,0.65,0.80)(0.10,0.35,0.60) \\ (0.40,0.55,0.70)(0.50,0.50,0.50)(0.50,0.60,0.80)(0.20,0.30,0.40) \\ (0.20,0.35,0.45)(0.20,0.40,0.50)(0.50,0.50,0.50)(0.10,0.35,0.70) \\ (0.40,0.65,0.90)(0.60,0.70,0.80)(0.30,0.65,0.90)(0.50,0.50,0.50) \end{pmatrix}$$

$r_3 = 0.2$, judgment matrix by C_3:

$$\tilde{p}_3 = \begin{pmatrix} (0.50,0.50,0.50)(0.60,0.75,0.90)(0.50,0.75,0.90)(0.40,0.65,0.80) \\ (0.10,0.25,0.40)(0.50,0.50,0.50)(0.30,0.45,0.60)(0.60,0.75,0.90) \\ (0.10,0.25,0.50)(0.40,0.55,0.70)(0.50,0.50,0.50)(0.20,0.35,0.60) \\ (0.20,0.35,0.60)(0.10,0.25,0.40)(0.40,0.65,0.80)(0.50,0.50,0.50) \end{pmatrix}$$

$r_4 = 0.2$, judgment matrix by C_4:

$$\tilde{p}_4 = \begin{pmatrix} (0.50,0.50,0.50)(0.40,0.65,0.80)(0.50,0.70,0.90)(0.40,0.50,0.60) \\ (0.20,0.35,0.60)(0.50,0.50,0.50)(0.35,0.50,0.70)(0.30,0.50,0.70) \\ (0.10,0.30,0.50)(0.30,0.50,0.65)(0.50,0.50,0.50)(0.30,0.40,0.50) \\ (0.40,0.50,0.60)(0.30,0.50,0.70)(0.50,0.60,0.70)(0.50,0.50,0.50) \end{pmatrix}$$

The weights of fuzzy factors a_{ij} by experts are calculated according to the formular:

Table 1: Evaluation scale and meaning of effect factors

Intensity m_{ij}	Significance comparison	fuzzy degree u_{ij}-l_{ij}
0.1	Absolute importance compared A_j with A_i	fuzzy degree is the range of scale given by experts, the more the egree, the more blurred the scales
0.2	Very importance compared A_j with A_i	
0.3	Essential importance compared A_j with A_i	
0.4	weak importance compared A_j with A_i	
0.5	Equal importance compared A_j with A_i	
0.6	weak importance compared A_i with A_j	
0.7	Essential importance compared A_i with A_j	
0.8	Very importance compared A_i with A_j	
0.9	Absolute importance compared A_i with A_j	

$$\tilde{u}i = (\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}) \otimes (\sum_{i=1}^{n} \sum_{j=1}^{n} l_{ij}, \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij}, \sum_{i=1}^{n} \sum_{j=1}^{n} u_{ij})^{-1}$$
$$\approx (\sum_{j=1}^{n} l_{ij} / \sum_{j=1}^{n} \sum_{j=1}^{n} u_{ij}, \sum_{j=1}^{n} m_{ij} / \sum_{j=1}^{n} \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} / \sum_{j=1}^{n} \sum_{j=1}^{n} l_{ij}) i \in I$$

The results are as follows in Table 2.

Synthesize the experts preferences value by the method of weighting, calculate the evaluation weight matrix on formula:

$$\tilde{p}_{ij} = r_1 \tilde{p}_{ij}^{(1)} \oplus \tilde{p}_{ij}^{(2)} \oplus \Lambda \oplus r_q \tilde{p}_{ij}^{(q)} \; r$$

is weighting coefficient:

$$\sum_{i=1}^{q} r_j = 1$$

the final fuzzy matrix is:

$$\tilde{p} = \begin{pmatrix} (0.5,0.5,0.5)(0.555,0.707,0.823)(0.548,0.75,0.893)(0.325,0.528,0.71) \\ (0.178,0.293,0.445)(0.5,0.5,0.5)(0.325,0.463,0.67)(0.265,0.395,0.525) \\ (0.108,0.25,0.453)(0.33,0.538,0.675)(0.5,0.5,0.5)(0.16,0.325,0.535) \\ (0.29,0.473,0.675)(0.475,0.605,0.735)(0.465,0.675,0.84)(0.5,0.5,0.5) \end{pmatrix}$$

Calculate the relative evaluation weight offered by experts and the value of fuzzy comprehensive evaluation $\tilde{u}_i$ (Han and Yang, 2003) about the solution xi:

$$\tilde{u}_i = (\sum_{j=1}^{n} l, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}) \otimes (\sum_{i=1}^{n} \sum_{j=1}^{n} l_{ij} \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} \sum_{i=1}^{n} \sum_{j=1}^{n} u_{ij})^{-1}$$
$$\approx (\sum_{j=1}^{n} l_{ij} / \sum_{i=1}^{n} \sum_{j=1}^{n} u_{ij}, \sum_{j=1}^{n} m_{ij} / \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} / \sum_{i=1}^{n} \sum_{j=1}^{n} l_{ij}) i \in I$$

The comprehensive fuzzy weight as shown in Table 3.

Calcaulate the expectancy value of fuzzy evaluation $\tilde{u}_i$.

Let $I_L \; \tilde{u}_i$ be the left expectation of $\tilde{u}_i$: $I_l \tilde{u}_i = l_i + m_i/2$,

Let $I_R \; \tilde{u}_i$ be the right expectation of $\tilde{u}_{i\,i}$: $I_R \; \tilde{u}_i = m_i + u_i/2$.

Table 2: Fuzzy weights of the four factors by C1

Expert	α1	α2	α3	α4
C1	(0.235, 0.356, 0.516)	(0.087, 0.143, 0.258)	(0.107, 0.193, 0.339)	(0.204, 0.306, 0.468)
C2	(0.143, 0.243, 0.427)	(0.157, 0.243, 0.41)	(0.098, 0.2, 0.368)	(0.177, 0.313, 0.529)
C3	(0.198, 0.331, 0.525)	(0.149, 0.243, 0.406)	(0.119, 0.206, 0.389)	(0.119, 0.218, 0.389)
C4	(0.181, 0.294, 0.463)	(0.136, 0.231, 0.413)	(0.121, 0.213, 0.355)	(0.171, 0.263, 0.413)

Table 3: Comprehensive fuzzy weight of the four factors graded by experts

C1, 2, 3, 4	a1	a2	a3	a4
	(0.193, 0.31, 0.486)	(0.127, 0.206, 0.355)	(0.11, 0.202, 0.359)	(0.173, 0.282, 0.456)

Table 4: Expectations of factors

Expert	a1	a2	a3	a4
C1	0.3754	0.1724	0.2229	0.3358
C2	0.2851	0.2839	0.2330	0.3536
C3	0.3617	0.5552	0.2543	0.2543
C4	0.3219	0.2744	0.2379	0.2920
C1, 2, 3, 4	0.3395	0.2410	0.2345	0.3145

Table 5: Factors of fuzzy matrix table

Expert	a1	a2	a3	a4
C1	(0.235, 0.356, 0.516)	(0.087, 0.143, 0.258)	(0.107, 0.193, 0.339)	(0.204, 0.306, 0.468)
C2	(0.143, 0.243, 0.427)	(0.157, 0.243, 0.41)	(0.098, 0.2, 0.368)	(0.177, 0.313, 0.529)
C3	(0.198, 0.331, 0.525)	(0.149, 0.243, 0.406)	(0.119, 0.206, 0.389)	(0.119, 0.218, 0.389)
C4	(0.181, 0.294, 0.463)	(0.136, 0.231, 0.413)	(0.121, 0.213, 0.355)	(0.171, 0.263, 0.413)

Let $I(\tilde{u}_i)$ be the expectation of $\tilde{u}_i$: $I(\tilde{u}_i) = \eta I_L(\tilde{u}_i) + (1-\eta)/I_R(\tilde{u}_i)\ 0 \le \eta \le 1$.

The expectations of factors are presented in Table 4.

Finally, the sequence order of the expectation is: $\tilde{u}_3 < \tilde{u}_2 < \tilde{u}_4 < \tilde{u}_1$ which means the intensity is the most affected factor, the recovery capability is closed behind, then is the loss of enterprise and the whole impact on supply chain is the least affected factor.

Dynamic fuzzy values of the current factors can be shown in Table 5.

Confirm the right fuzzy maximum sets and hamming distances of factors in each expert' solution. The right fuzzy maximum sets $\widetilde{M}_{iR} = \max(\bar{r}_{i1R}, \bar{r}_{i2R}, \dots \bar{r}_{inR})$ let $\bar{r}_{inR}$ be right fuzzy value of expert i for the factor n, with a membership function:

$$\widetilde{M}_{ir}(r_i) = \sup\min\}\mu\,\bar{r}_{i1r}(r_{i1}),\dots,\mu\,\bar{r}_{inr}(r_{in})\}ri = r_{il}\ Vr_{i2}V\dots Vr_{in}$$

The computational formula of the hamming distance between right fuzzy sets $\bar{r}_{ijR}, j = 1,\dots,n$ and right fuzzy maximum sets $\widetilde{M}_{iR}$ is:

$$dR = (\bar{r}_{ijR}, \widetilde{M}_{iR}) = \int_S \left|\mu rijR(x) - \mu\widetilde{M}_{ir}(x)\right| dx$$

the hamming distance can be showed as s1, s2 in the Fig. 1:

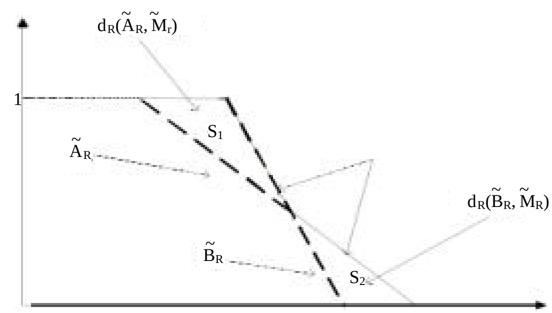

Fig. 1: Hamming distance diagram of two triangular fuzzy number and fuzzy right maximum

$$C1:\ dR = dR\,(\bar{r}_{11R}, \widetilde{M}_{1R}) = 0.484$$
$$dR = dR\,(\bar{r}_{12R}, \widetilde{M}_{1R}) = 0.742$$
$$dR = dR\,(\bar{r}_{13R}, \widetilde{M}_{1R}) = 0.661$$
$$dR = dR\,(\bar{r}_{14R}, \widetilde{M}_{1R}) = 0.532$$

then we get $\bar{r}_{1max} = 0.484$:

$$C2:\ dR = dR\,(\bar{r}_{21R}, \widetilde{M}_{2R}) = 0.573$$
$$dR = dR\,(\bar{r}_{21R}, \widetilde{M}_{1R}) = 0.59$$
$$dR = dR\,(\bar{r}_{21R}, \widetilde{M}_{2R}) = 0.632$$
$$dR = dR\,(\bar{r}_{21R}, \widetilde{M}_{2R}) = 0.471$$

then we get $\bar{r}_{2max} = 0.471$:

$$\begin{aligned} C3:\ dR &= dR\,(\bar{r}_{31R}, \widetilde{M}_{3R}) = 0.475 \\ dR &= dR\,(\bar{r}_{31R}, \widetilde{M}_{3R}) = 0.594 \\ dR &= dR\,(\bar{r}_{31R}, \widetilde{M}_{3R}) = 0.611 \\ dR &= dR\,(\bar{r}_{31R}, \widetilde{M}_{3R}) = 0.611 \end{aligned}$$

then we get $\bar{r}_{3max} = 0.475$:

$$\begin{aligned} C4:\ dR &= dR\,(\bar{r}_{41R}, \widetilde{M}_{4R}) = 0.537 \\ dR &= dR\,(\bar{r}_{41R}, \widetilde{M}_{4R}) = 0.587 \\ dR &= dR\,(\bar{r}_{41R}, \widetilde{M}_{4R}) = 0.645 \\ dR &= dR\,(\bar{r}_{41R}, \widetilde{M}_{4R}) = 0.58 \end{aligned}$$

then we get $\bar{r}_{4max} = 0.537$.

It is concluded that the factor with the minimum Hamming distance is Cmax=C1, the final score of this solution depended on the Bonissone approximation formula (Chen and Larbani, 2006) was achieved.

The weighted sum of:

$$\begin{aligned} C2 &= \overline{w}_j \times \overline{x}_{ij} = (x,\ y,\ z)\times(a,\ b,\ c) \\ &= (0.193,0.31,0.486)\times(0.143,0.243,0.427) \\ &+ (0.127,0.206,0.355)\times(0.157,0.243,0.41) \\ &+ (0.11,0.202,0.359)\times(0.098,0.2,0.368) \\ &+ (0.173,0.282,0.456)\times(0.177,0.313,0.529) \\ &= (0.173,0.282,0.427) \end{aligned}$$

The right fuzzy value of triangular fuzzy number 0.427 is chosen as the final assessment level value. Previous expert experiences and cases are used to determine the state transition matrix. Let [0, 0.2) be level I, [0.2, 0.48) be level II, [0.48, 0.7) be level III, [0.7, 1] be IV level. The current state is level II. Emergency measures of level II should be carry out.

For this kind of emergency, the initial state transition probability matrix based on experiences is given in Table 6.

A state transition from the initial stage to the next, are shown in Table 7.

It can be seen that the probability that transfered from level 2 to level 1 in the second stage is the highest 0.29 which is greater than other state transition probabilities in the secondary phase, the resources demand of second stage should be determined to guide the next phase of work, according to the expectations of various influence factors and the corresponding contingency plans.

Advantage of improved algorithm: Index weights of factors occupy an important position in integrated decision-making which reflect the role of various index factors in decision making and affect the decision result directly. It is more reasonable to make decisions by the triangular fuzzy number and sorting method than a accurate numerical for the limitation of expert experiences, subjectivity, ambiguity and uncertainty in brain and the complexity of the events.

Table 6: Initial state transition probability matrix

Level	I	II	III	IV
I	0.3	0.3	0.2	0.2
II	0.2	0.3	0.3	0.2
II	0.1	0.2	0.4	0.3
IV	0.1	0.3	0.3	0.3

Table 7: Next state transition probability matrix

Level	I	II	III	IV
I	0.19	0.29	0.28	0.24
II	0.17	0.27	0.31	0.25
III	0.14	0.26	0.33	0.27
IV	0.15	0.27	0.32	0.26

The development of the emergency has certain randomness, the timing control of level calculating is discrete, the level transformations of emergency events obey the stability ineffectiveness theory of Markov. It is good to calculate the state transformation probability in the future, after time level is determined. Then compare the probability in future timing point with the probability of any discrete time point that have been calculated already to test its accuracy. This kind of validation strategy adjustment cycle makes the model more scientific.

CONCLUSSION

A new algorithm based on FCEM and AHP is put forward in view of existing algorithm insufficiency. Triangular fuzzy number is used to index weighing of judge matrix, the weight of which was also assessed by fuzzy weighing method. Then a comprehensive fuzzy matrix was achieved, given the relative preference of each expert and the expected value of each factor was calculated and sorted in the next step. Getting current state value dynamically and comparing them with expectations, so as to figure out the state transition probability and determine the level of emergency in the future. Dynamic classification assessment of the emergency response measures considers from a strategic perspective, suitable classification and grade play a decisive role in accuracy and efficiency of response measures, the mismatching risk of response to emergency could be avoid by adjusting the response measures relatively which plays an important role in promoting the reasonable and effective utilization of resources. The future direction of research is to build a simulating model by BP network for the output data of improved algorithm and make it more close to the actual value.

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