Assessment of Meteorological Disaster Emergency Management Capability Used Information Entropy Theory

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***Abstract*—In recent years, Meteorological disasters are frequently occurred, which bring tremendous suffering to people's lives and property. Meteorological emergence management capability appraisal is a system engineering which involved many factors, This paper design a multi-index appraisal system, built an emergency response capability assessment index system, gave a method to quantitatively describe Assessment on Meteorological disaster emergency management capability. Established an appraisal model based on unascertained theory, and sets up the weight of classification index by information entropy, more valuable to application.**

Keywords- meteorological disaster; emergency management capability; information entrop

I. INTRODUCTION

In the past years, some serious meteorological disasters are frequently occurred in the world, these disasters such as rainstorms and floods have brought serious damage to human beings, along with the rapid urbanization in China, the damages of meteorological disasters are growing, the annual economical damage of such disasters equals 4%~8% of the GDP in China since 1990 according to the statistic data. The issue is not whether governments will be required to respond to emergencies but rather when and how frequently. The time to think about emergencies is before they happen[1].To reduce the unexpected losses resulting from the incident to the great extent, It is indispensable for emergency management department to devise effective emergency response capability evaluation criteria and choose advanced evaluation method[2].

Many multiple attribute decision making methods, such us the analytic hierarchy process (AHP), the technique of order preference by similarity to ideal solution (TOPSIS) and gray relation analysis (GRA), were utilized to evaluate the emergency response capability. Presently, many scholar have studied the emergency response capability evaluation problem. Yuan Fei[3]showed us the method of evaluating the emergency response capability of chemical industrial park based on improved AHP. Wang xia[4]discussed the evaluation method of urban emergency response capability. Zhang Hao[5]presents an index system of the maritime emergency capability assessment and the fuzzy synthetic assessment model. This paper gives appraisal method based on unascertained measurement theory and redesign the appraisal indexes system, determined the weight of each index by information entropy, it can make the appraisal comprehensive, facilitates management and decision-making,.

II. ASSESSMENT INDEXES SYSTEM OF METEOROLOGICAL DESASTER EMERNGENCY MANAGEMENT CAPABILITY

A. Appraisal index system establish principle

Building the meteorological disasters emergence management capability index system is the basis of emergency management capability assessment. Selecting the indexes appropriately is the key factor of establishing the assessment indexes system. So we establish the assessment indexes system according to flowing principal:

(1) Integrated system principal. We not only set emphasis on government response capability after the disasters happen but also the monitor and early warning capability and guarantee capability, etc.

(2) Precision and fuzziness combination principal. Some indexes can be measured exactly, other indexed can only be directed and give the tendency to some extent.

(3)Operational principle. Appraisal index system should be build simply, can be applied efficiently, the indexes should be quantitative.

B. Establishing the indexes system

According to the analysis on the main factors that influences meteorological disasters emergency management capability, we refined the valuable and representative assessment element. These elements can be described as 4 classes, which are

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meteorological monitor and early warning capability; Government and social rescue capability; Rescue guarantee capability of meteorological disasters; Resume work after disaster. The detailed appraisal system can be described by table1.

TABLE I. M-DISASTERS EMERGENCY MANAGEMENT ASSESSMENT INDEXES SYSTEM

Main purpose	The first grade index	The second grade index
Main character of appraisal	Meteorological monitor and early warning capability F_1	Monitor network of M-disasters f_{11}
		Weather forecasting capabilty f_{12}
		Meteorological equimpents of early warning f_{13}
		Defensive equipment of M-disasters f_{14}
		Defensive capability of buildings f_{15}
	Rescue capability F_2	Government organizational capability f_{21}
		Emergengcy information issue capabilty of M-disasters f_{22}
		Medical salvation capability f_{23}
		Transportation capabilty f_{24}
		Capability of command f_{25}
	Rescue guarantee capability of M-disasters F_3	Emergency preplan of M-disasters f_{31}
		Emergency self-halp capabilty of residants f_{32}
		Emergency material and capital f_{33}
		Communication capability f_{34}
		Common rescue kowledge popularize degree f_{35}
	Resume work after disaster F_4	Disaster analysis and evvaluation f_{41}
		Deal with aftermath f_{42}
		Social salvation f_{43}
		Insurance capability f_{44}
		Improvement capability f_{45}

III. MEASUREMENT MODEL BASED ON UNASCERTAINED THEORY [6][7][8]

Suppose $x_1, x_2, \cdots, x_n$ denote n projects would be evaluated, marked $X = \{x_1, x_2, \cdots, x_n\}$, named it discussion field; appraise object x_i ($x_i \in X$) have m appraisal indexes $I_1, I_2, \cdots, I_m$, marked $I = \{I_1, I_2, \cdots, I_m\}$.Suppose x_{ij} denotes the observation of index x_i at I_j . Suppose $C = \{c_1, c_2, \cdots, c_K\}$ means the space of appraisal, where $c_k (1 \le k \le K)$ is the k class of appraisal.

A. Single index unascertained measurement

If the observed value x_{ij} of object x_i about I_j are indifferent, the extent to which make the index x_i be posit in every grade indifferent too. Suppose the extent to which x_{ij} make x_i at the k grade is $\mu_{ijk} = \mu(x_{ij} \in c_k)$. Then μ_{ijl} is the measurement result. As a kind of measurement, it must accord with the common principles such as “Nonnegative boundedness, Additivity, Normalizing”. So μ_{ijl} accord with

$$0 \le \mu_{ijk} \le 1 \quad ; \quad \mu(x_{ij} \in \bigcup_{k=1}^{K} c_k) = \sum_{k=1}^{K} \mu(x_{ij} \in c_k) \quad ;$$

$$\mu(x_{ij} \in C) = 1 \; x_{ij}$$

Where $i = 1,2,\cdots,n \quad j = 1,2,\cdots,m \quad k = 1,2,\cdots,K$

We call μ_{ijk} which accord with above three principles as unascertained measurement, simply measurement. so

$$(\mu_{ijk})_{m \times K} = \begin{pmatrix} \mu_{i11}, \mu_{i12}, \cdots, \mu_{i1K} \\ \mu_{i21}, \mu_{i22}, \cdots, \mu_{i2K} \\ \vdots \quad \vdots \quad \cdots \quad \vdots \\ \mu_{im1}, \mu_{im2}, \cdots, \mu_{imK} \end{pmatrix}$$

$$(i = 1,2,\cdots,n) \qquad (1)$$

It is a single index measurement appraisal matrix of the object x_i . Where $\mu_j^i (1 \le j \le m)$ indicate the unascertained measurement which observed value x_{ij} make x_i at each appraisal grade.

B. Ascertain of index weight

The observed value x_{ij} of object x_i about index I_j make the object locate at each grade such as $c_1, c_2, \cdots, c_K$ so called unascertained measurement is

$$\mu_j^i = (\mu_{ij1}, \mu_{ij2}, \cdots \mu_{ijK}) \quad (2)$$

So we know how much the index I_j contribute to assort the object x_i.

1) If $\mu_{ij1} = \mu_{ij2} = \cdots, \mu_{ijK} = \frac{1}{K}$, means the same extent to which the index I_j make x_i at each appraisal grade, so we can't distinguish which appraisal grade x_i locate.

2) If one of K μ_{ijk} is 1, marks $\mu_{ijk_0} = 1$, all of other $K-1$ μ_{ijk} are 0, so index I_j make x_i locate at appraisal grade c_{k_0}. In this case, we call index I_j give the absolute contribution to sort x_i. If w_j^i indicates the grade weight of index I_j about x_i, then w_j^i gets the biggest value.

3) Likewise may explain, the more separate value of K μ_j^i, the smaller value of w_j^i be, the more centralized value of K μ_j^i, the bigger value of w_j^i be.

Suppose the entropy ascertained by measurement μ_{ijk}

$$H(j) = -\sum_{k=1}^{K} \mu_{ijk} \cdot \log \mu_{ijk} \quad (3)$$

then

$$V_j^i = 1 - \frac{1}{\log K} H(j) = 1 + \frac{1}{\log K} \sum_{k=1}^{K} \mu_{ijk} \cdot \log \mu_{ijk} \quad (4)$$

then

$$W_j^i = \frac{V_j^i}{\sum_{j=1}^{m} V_j^i}$$

obviously

$$0 \le W_j^i \le 1, \text{且} \sum_{j=1}^{m} W_j^i = 1 \quad (5)$$

By the character of information entropy [9] :

① Only when $\mu_{ij1} = \mu_{ij2} = \cdots \mu_{ijK} = \frac{1}{K}$, V_j get the smallest value 0 ;

②Only when exit a $\mu_{ijk_0} = 1$ and other $K-1$ $\mu_{ijk_0} = 0$, V_j get the biggest value 1.

③The more centralized value of μ_{ijk}, the more closed V_j to 1, the more separate value of μ_{ijk}, the value of V_j more closed to 0.

By the over principles of V_j, the formula（5）defines w_j^i the grade weight of index I_j about x_i.

So $$W^i = (w_1^i, w_2^i, \cdots, w_m^i) \quad (6)$$

is weight vector of index $I_1, I_2, \cdots, I_m$ about x_i.

C. the purpose of index grade weight

If we get the appraisal matrix（1）of single index measurement about x_i, the grade weight of each index about x_i.Then

$$\mu^i = W^i \cdot (\mu_{ijk})_{m \times K} = (w_1^i, w_2^i, \cdots, w_m^i) \begin{pmatrix} \mu_{i11}, \mu_{i12}, \cdots, \mu_{i1K} \\ \mu_{i21}, \mu_{i22}, \cdots, \mu_{i2K} \\ \vdots \quad \vdots \quad \cdots \quad \vdots \\ \mu_{im1}, \mu_{im2}, \cdots, \mu_{imK} \end{pmatrix}$$

, $$\mu^i = (\mu_{i1}, \mu_{i2}, \cdots, \mu_{ik}) \quad (7)$$

so μ^i is the appraisal vector of x_i.

D. Appraisal principle

The appraisal grade is orderly, the k-section appraisal grade c_k is better than $k+1$-section appraisal grade c_{k+1},so the most measurement principle is not suitable, we take the confidence principle.

Suppose confidence is $\lambda, (\lambda > 0.5)$, usually 0.6 or 0.7,then

$$k_0 = \min_k \left[(\sum_{l=1}^{k} \mu_{il}) \ge \lambda, k = 1,2,\cdots K \right] \quad (8)$$

So x_i is the k_0-section appraisal grade c_{k_0}.

IV. REAL CASE EXAMINATION

We selected HD city which located in Huabei district as our research object,. according to the indicate appraisal model based on unascertained theory , we select 100 experts give 20 appraisal indexes evaluation results , each index marks 100, distributed at 5 appraisal grades. So each index total sum is 100 point, each appraisal object at the different grade. We divide the appraisal result at five grade, they are {A,B,C,D,E},A means very good, E means very bad. The appraisal object score statistics are denotes by table2:

Table2 appraisal object score statistics

Index	A	B	C	D	E
f_{11}	16	22	43	18	1
f_{12}	20	20	45	14	1
f_{13}	20	50	20	5	5
f_{14}	27	50	10	10	3
f_{15}	40	46	11	2	1
f_{21}	25	50	14	10	1
f_{22}	30	48	20	1	1
f_{23}	21	54	20	4	1
f_{24}	25	40	15	15	5
f_{25}	14	36	37	10	3
f_{31}	15	40	25	10	10
f_{32}	25	55	10	9	1
f_{33}	20	55	15	9	1
f_{34}	18	45	22	10	5
f_{35}	14	46	30	8	2
f_{41}	20	50	18	8	4
f_{42}	22	50	18	6	4
f_{43}	25	45	15	9	6
f_{44}	24	47	18	8	3
f_{45}	18	36	24	12	10

According to the statistics data of bable2,we get the following single index measurement matrix

$$\mu_{1jk} = \begin{bmatrix} \mu_{1jk}^1 \\ \mu_{1jk}^2 \end{bmatrix}$$

By which

$$\mu_{1jk}^1 = \begin{bmatrix} 0.16 & 0.22 & 0.43 & 0.18 & 0.01 \\ 0.20 & 0.20 & 0.45 & 0.14 & 0.01 \\ 0.20 & 0.50 & 0.20 & 0.05 & 0.05 \\ 0.27 & 0.50 & 0.10 & 0.10 & 0.03 \\ 0.40 & 0.46 & 0.11 & 0.02 & 0.01 \\ 0.25 & 0.50 & 0.14 & 0.10 & 0.01 \\ 0.30 & 0.48 & 0.20 & 0.01 & 0.01 \\ 0.21 & 0.54 & 0.20 & 0.04 & 0.01 \\ 0.25 & 0.40 & 0.15 & 0.15 & 0.05 \\ 0.14 & 0.36 & 0.37 & 0.10 & 0.03 \\ 0.15 & 0.40 & 0.25 & 0.10 & 0.10 \end{bmatrix}$$

$$\mu_{1jk}^2 = \begin{bmatrix} 0.25 & 0.55 & 0.10 & 0.09 & 0.01 \\ 0.20 & 0.55 & 0.15 & 0.09 & 0.01 \\ 0.18 & 0.45 & 0.22 & 0.10 & 0.05 \\ 0.14 & 0.46 & 0.30 & 0.08 & 0.02 \\ 0.20 & 0.50 & 0.18 & 0.08 & 0.04 \\ 0.22 & 0.50 & 0.18 & 0.06 & 0.04 \\ 0.25 & 0.45 & 0.15 & 0.09 & 0.06 \\ 0.24 & 0.47 & 0.18 & 0.08 & 0.03 \\ 0.18 & 0.36 & 0.24 & 0.12 & 0.10 \end{bmatrix}$$

According formula（3）—（6）the weight of index are following:

$$W^1 = (0.0422, 00452, 0.0507, 0.0545, 0.0823, 0.0579, 0.0765, 0.0718, 0.0282, 0.0418, 0.0240, 0.0700, 0.0653, 0.0362, 0.0533, 0.0479, 0.0514, 0.0371, 0.0470, 0.0168)$$

The object appraisal vector is:

Select $\lambda = 0.6$, according to formula (8)

When $k_0 = 2$,

$$0.2316 + 0.4588 = 0.6904 > 0.6 = \lambda$$

The result is B, the management capability on meteorological disasters get a good mark, consistent with the actual situation of the object.

V. CONCLUSION

The comprehensive assessment of meteorological emergency management capability is a very complicated system engineering. It is indispensable for emergency management department to devise effective evaluation criteria and choose advanced evaluation method to evaluate meteorological disasters emergency respond capability. This paper use unascertained measurement model, and determined the index weight by information entropy, Obviously superior then AHP method, has higher scientific and practical value. We must amendments and improve the appraisal index system according to the development of meteorological emergency management technology, make it more suitable to the real circumstance.

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