Assessment of Meteorological Disaster Emergency Management Capability Used Information Entropy Theory

Li Weiying
Science & Technology Service Center
Handan Meteorological Bureau
Hanhan City, Hebei, P.R China
hd_lwy@163.com

Jiang Shuxia
Bureau of Finance, County She
Hanhan City, Hebei, P.R China
tjwaf@sina.com

Abstract—In recent years, Meteorological disasters are frequently occurred, which bring tremendous suffering to people’s lives and property. Meteorological emergency 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 entropy

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 as 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 EMERGENCY MANAGEMENT CAPABILITY

A. Appraisal index system establish principle

Building the meteorological disasters emergency 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
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

<table>
<thead>
<tr>
<th>Main purpose</th>
<th>The first grade index</th>
<th>The second grade index</th>
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</thead>
<tbody>
<tr>
<td><strong>F_1</strong> Meteorological monitor and early warning capability</td>
<td>Monitor network of M-disasters $f_{11}$</td>
<td>Weather forecasting capability $f_{12}$</td>
</tr>
<tr>
<td></td>
<td>Meteorological equipments of early warning $f_{13}$</td>
<td>Defensive equipment of M-disasters $f_{14}$</td>
</tr>
<tr>
<td></td>
<td>Defensive capability of buildings $f_{15}$</td>
<td>Government organizational capability $f_{21}$</td>
</tr>
<tr>
<td>Rescue capability</td>
<td>Emergency information issue capability of M-disasters $f_{22}$</td>
<td>Medical salvation capability $f_{23}$</td>
</tr>
<tr>
<td></td>
<td>Transportation capability $f_{24}$</td>
<td>Transportation capability $f_{24}$</td>
</tr>
<tr>
<td></td>
<td>Capability of command $f_{25}$</td>
<td>Emergency preplan of M-disasters $f_{31}$</td>
</tr>
<tr>
<td>Resume work after disaster</td>
<td>Emergency self-help capability of residents $f_{32}$</td>
<td>Emergency material and capital $f_{33}$</td>
</tr>
<tr>
<td></td>
<td>Emergency analysis and evaluation $f_{41}$</td>
<td>Communication capability $f_{34}$</td>
</tr>
<tr>
<td></td>
<td>Deal with aftermath $f_{42}$</td>
<td>Common rescue knowledge popularize degree $f_{45}$</td>
</tr>
<tr>
<td></td>
<td>Social salvation $f_{43}$</td>
<td>Improvement capability $f_{45}$</td>
</tr>
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<td></td>
<td>Insurance capability $f_{44}$</td>
<td></td>
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</tbody>
</table>

### III. MEASUREMENT MODEL BASED ON UNASCERTAINED THEORY

Suppose $x_i, x_2, \ldots, x_n$ denote $n$ projects would be evaluated, marked $X = \{x_1, x_2, \ldots, x_n\}$, named it discussion field; appraise object $x_i \ (x_i \in X)$ have $m$ appraisal indexes $I_1, I_2, \ldots, I_m$, marked $I = \{I_1, I_2, \ldots, I_m\}$. Suppose $x_{ij}$ denotes the observation of index $x_i$ at $I_j$. Suppose $C = \{c_1, c_2, \ldots, c_K\}$ means the space of appraisal, where $c_k (1 \leq k \leq K)$ 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 $\mu_{ijk}$ is the measurement result. As a kind of measurement, it must accord with the common principles such as “Nonnegative boundedness, Additivity, Normalizing”. So $\mu_{ijk}$ accord with

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

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

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

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

$$\mu_{ijk} = \begin{pmatrix} \mu_{i11}, \mu_{i12}, \ldots, \mu_{i1K} \\ \mu_{i21}, \mu_{i22}, \ldots, \mu_{i2K} \\ \vdots \\ \mu_{im1}, \mu_{im2}, \ldots, \mu_{imK} \end{pmatrix}$$

$$i = 1, 2, \ldots, n$$

It is a single index measurement appraisal matrix of the object $x_i$. Where $\mu_{ij} (1 \leq j \leq m)$ 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 $c_1, c_2, \ldots, c_K$ so called unascertained measurement is
\[
\mu_j = (\mu_{j1}, \mu_{j2}, \ldots, \mu_{jk})
\]  
(2)

So we know how much the index \( I_j \) contribute to sort the object \( x_i \).

1) If \( \mu_{k1} = \mu_{k2} = \ldots = \mu_{kj} = \frac{1}{K} \), means the same extent to which the index \( I_j \) make \( x_i \) locate at each appraisal grade, so we can’t distinguish which appraisal grade \( x_i \) locate.

2) If one of \( \mu_{ijk} = 1 \), marks \( \mu_{ijk} = 1 \), all of other \( K-1 \) \( \mu_{ijk} \) are 0, so index \( I_j \) make \( x_i \) locate at appraisal grade \( c_k \). 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 \( \mu_{ijk} \), the smaller value of \( W_j^i \) be, the more centralized value of \( \mu_{ijk} \), the bigger value of \( W_j^i \) be.

Suppose the entropy ascertained by measurement
\[
\mu_{jk}H(j) = -\sum_{k=1}^{K} \mu_{jk} \cdot \log \mu_{jk}
\]
then
\[
V_j^i = 1 - \frac{1}{\log K} H(j) = 1 + \frac{1}{\log K} \sum_{k=1}^{K} \mu_{jk} \cdot \log \mu_{jk}
\]
(3)

\[
W_j^i = \frac{V_j^i}{\sum_{j=1}^{m} V_j^i}
\]
then
\[
0 \leq W_j^i \leq 1, \quad \sum_{j=1}^{m} W_j^i = 1
\]
(4)

Obviously
\[
0 \leq W_j^i \leq 1, \quad \sum_{j=1}^{m} W_j^i = 1
\]
(5)

By the character of information entropy \([9]\) :
\[
\mu_{j1} = \mu_{j2} = \ldots = \mu_{kj} = \frac{1}{K}, \quad V_j \text{ get the smallest value 0,}
\]
(6)

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

③The more centralized value of \( \mu_{ijk} \), the more closed \( V_j \) to 1, the more separate value of \( \mu_{ijk} \), 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 \( W_j^i = (w_1^i, w_2^i, \ldots, w_m^i) \)
(6)

is weight vector of index \( I_1, I_2, \ldots, I_m \) 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

\[
\mu^i = W^i \cdot (\mu_{jk})_{m \times k} = (w_1^i, w_2^i, \ldots, w_m^i)
\]
(7)

\[
\mu^i = (\mu_{i1}, \mu_{i2}, \ldots, \mu_{ik})
\]
so \( \mu^i \) 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

\[
k_0 = \min_k \left[ \sum_{j=1}^{k} \mu_{jk} \geq \lambda, k = 1, 2, \ldots, K \right]
\]
(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 table 2:

<table>
<thead>
<tr>
<th>Index</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
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<td>22</td>
<td>43</td>
<td>18</td>
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According to the statistics data of table 2, we get the following single index measurement matrix

\[
\mu_{1,ik} = \begin{bmatrix}
\mu_{1,1k}^1 \\
\mu_{1,1k}^2
\end{bmatrix}
\]

By which

\[
W' = \begin{bmatrix}
0.16 & 0.22 & 0.43 & 0.18 & 0.01 \\
0.20 & 0.20 & 0.45 & 0.14 & 0.01 \\
0.20 & 0.50 & 0.20 & 0.05 & 0.05 \\
0.27 & 0.50 & 0.10 & 0.10 & 0.03 \\
0.40 & 0.46 & 0.11 & 0.02 & 0.01 \\
\end{bmatrix}
\]

\[
\mu_{1,1k}^1 = \begin{bmatrix}
0.25 & 0.50 & 0.14 & 0.10 & 0.01 \\
0.30 & 0.48 & 0.20 & 0.01 & 0.01 \\
0.21 & 0.54 & 0.20 & 0.04 & 0.01 \\
0.25 & 0.40 & 0.15 & 0.15 & 0.05 \\
0.14 & 0.36 & 0.37 & 0.10 & 0.03 \\
\end{bmatrix}
\]

\[
\mu_{1,1k}^2 = \begin{bmatrix}
0.15 & 0.40 & 0.25 & 0.10 & 0.10 \\
0.25 & 0.55 & 0.10 & 0.09 & 0.01 \\
0.20 & 0.55 & 0.15 & 0.09 & 0.01 \\
0.18 & 0.45 & 0.22 & 0.10 & 0.05 \\
0.14 & 0.46 & 0.30 & 0.08 & 0.02 \\
\end{bmatrix}
\]

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

\[
W = (0.0422, 0.0045, 0.0507, 0.0545, 0.0823, 0.0579, 0.0765, 0.0718, 0.0282, 0.0418, 0.0240, 0.0700, 0.0653, 0.0362, 0.0533, 0.0479, 0.0514, 0.0371, 0.0470, 0.0168)
\]

The object appraisal vector is:

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

\[ W' \begin{bmatrix} 0.2316 + 0.4588 = 0.6904 > 0.6 = \lambda \]

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 than 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.

REFERENCES


