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An Multi-criteria Decision Making Approarch for Evaluating Efficiency of Emergency Plan Based on Intuitionistic Fuzzy Information

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Abstract: Efficiency evaluation of emergency plan system play an important role in emergency management but how to evaluate emergency plan is currently no systematic approach. This study is aimed to present a intuitionistic fuzzy decision-making approach to deal with the efficiency evaluation of emergency plan system. On the basis of establishing the efficiency evaluation index system, a new approach based on intuitionistic fuzzy sets and TOPSIS is presented. Finally, a numerical example was used to illustrate that the approach is valid.

Key words: Efficiency evaluation, emergency plan system, intuitionistic fuzzy sets, TOPSIS

INTRODUCTION

In recent years, some natural disasters and man-made catastrophic events, such as China Wenchuan earthquake (2008),U.S. southern storm and tornado (2011), Japan earthquake and tsunami (2011), are frequently occurred. These catastrophic events brought enormous damage to the local development of economy and society. To reduce the unexpected losses resulting from emergency to the great extent it is indispensable for emergency management department to devise effective emergency plan evaluation criteria and choose advanced evaluation method.

Emergency plan are a plan or program that established in advance against possible major accidents or disasters, to insure rapid, orderly and effective implementation of emergency activities and rescue operations and reduce accidents loss. Presently, many scholars have studied the emergency response capability evaluation problem. Perry and Lindell, (2003) described emergency plan as an ongoing activity in which a multidisciplinary team of experts collaborates to be prepared for emergencies and disasters. Cheng and Qian (2010) proposed the fuzzy comprehensive assessment to evaluate of emergency plan based on its completeness, operability, effectiveness, flexibility, rapidity and rationality and gives an example of “good emergency plan” at last. To minimize the energy restoration time for the entire energy network (Cai *et al*., 2012) developed a new methodology for energy network dispatch optimization under emergency of local energy shortage. Cheng *et al*. (2008) put forward a quantitative method to assess the effectiveness of the emergency plan by simulating the best evaluation routes and time of the flooded residential point in the research area using GIS. Zhang and Chen (2008) presented a complexity evaluation method by taking the national emergency response plan for earthquake as an example. Zhang *et al*. (2009) put forward a fuzzy evaluation method for emergency plan. The whole emergency evaluation process includes the first order model evaluation and the second order model evaluation. The article established the first order model and the second order model and given their corresponding evaluation function. Han *et al*. (2009) presented a fuzzy evaluation model. This model links the time of the emergency disposal in the form of membership with the quichness of emergency response time to present a evaluation model of high standard and give a selection-based evaluation function. Guo and Zhang (2008) presented a new method for assessing the emergency plan operability which represent fuzzy information by triangle fuzzy number and give a formula for measuring the distance between two triangle fuzzy numbers. In this study, we proposed a new intuitionistic fuzzy sets-based approach for efficiency evaluation of emergency plan system.The remainder of this study is organized as follows: Section 2 introduced the elements of intuitionistic fuzzy sets theory; in the section 3, we constructed the evaluation indexes for evaluating the efficiency of emergency plan. In the section 4, we present a fuzzy decision-making method based on intuitionistic fuzzy sets and TOPSIS to deal with the supplier selection problem. and in section 5 of this study, to highlight and clarify our proposed procedure, a numerical example is discussed. Finally, section 6 is conclusions.

PRELIMINARIES

In the following, we first recall basic notions and definitions of intuitionistic fuzzy sets (Zadeh, 1965; Atanassov, 1986; 1994; 1999; Atanassov and Georgiev, 1990; 1993; Szmidt and Kacprzyk, 2000).

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Concept of intuitionistic fuzzy sets:

Definition 1: A fuzzy set Ãdefined on a universe X may be give as:

$$\tilde{A} = \{< x, \mu_{\tilde{A}}(x) > | x \in X\} \quad (1)$$

where, $\mu_{\tilde{A}} : X \to [0, 1]$ is the membership function of Ã. The membership value μÃ (x)describes the degree of belongigness of x∈X in Ã.

Definition 2: An intuitionistic fuzzy set A defined on a universe X is given by:

$$A = \{< x, \mu_A(x), \nu_A(x) > | x \in X\} \quad (2)$$

Where:

$$\mu_A\text{: } X \to [0, 1] \text{and } vA\text{: } X \to [0, 1] \quad (3)$$

with the condition:

$$0 \le \mu_A(x) + \nu_A(x) \le 1 \quad (4)$$

and $\mu_A(x)+v_A(x) \in [0, 1]$ denote a degree of membership and a degree of non-membership of x∈X, respectively. For an intuitionistic fuzzy set A in X, we will call:

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \quad (5)$$

an intuitionistic fuzzy index of x∈X.

We can consider $\pi_A(x)$as the hesitancy degree of X to A. It is obvious that $0 \le \pi_A(x) \le 1$ for each x∈X. Obviously, each fuzzy set Ã defined on X may be represented by the following intuitionistic fuzzy set:

$$A = \{< x, \mu_{\tilde{A}}(x), 1 - \mu_{\tilde{A}}(x) > | x \in X\} \quad (6)$$

Definition 3: Suppose, A = {<x, $\mu_A(x)$, $v_A(x)$>|x∈X} and B = {<x, $\mu_B(x)$, $v_B(x)$>|x∈X} are two intuitionistic fuzzy sets of the discussion field X, then:

- A = B if and only ∀x∈X, $\mu_A(x) = \mu_B(x)$, $v_A(x)$ $v_B(x)$
- A⊆B if and only ∀x∈X,$\mu_A(x) \le \mu_B(x)$,$v_A(x) \ge v_B(x)$

Definition 4: Suppose, A and B are two intuitionistic fuzzy sets of the discussion field X. To two intuitionistic fuzzy sets, defined the following operations:

$$\{< x, \mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x), \nu_A(x)\nu_B(x) > | x \in X\} \quad (7)$$

$$A \otimes B = \{< x, \mu_A(x)\mu_B(x), \nu_A(x) + \nu_B(x) - \nu_A(x)\nu_B(x) > | x \in X\} \quad (8)$$

Distance measures: In many theoretical and practical problems we want to express numerically the difference between two objects by means of a distance between corresponding fuzzy sets. Szmidt and Kacprzyk introduced some popular distance measures between two intuitionistic fuzzy sets A and B that take into account the membership degree μ, the non-membership degree v and the hesitation degree π in X = $\{x_1, x_2, ..., x_n\}$. Some of the intuitionistic fuzzy distance measures are as follows.

Intuitionistic Haimming distance:

$$d_H(A,B) = \frac{1}{2n}\sum_{i=1}^{n}(|\mu_A(x_i) - \mu_B(x_i)| + |\nu_A(x_i) - \nu_B(x_i)| + |\pi_A(x_i) - \pi_B(x_i)|)$$

The normalized intuitionistic Haimming distance:

$$d_E(A,B) = \sqrt{\frac{1}{2}\sum_{i=1}^{n}[(\mu_A(x_i) - \mu_B(x_i))^2 + (\nu_A(x_i) - \nu_B(x_i))^2 + (\pi_A(x_i) - \pi_B(x_i))^2]}$$

Intuitionistic Euclidean distance:

$$d_{nE}(A,B) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}[(\mu_A(x_i) - \mu_B(x_i))^2 + (\nu_A(x_i) - \nu_B(x_i))^2 + (\pi_A(x_i) - \pi_B(x_i))^2]}$$

The normalized intuitionistic Euclidean distance.

It can easily be checked that these distance measures (A, B) of intuitionistic fuzzy sets A and B satisfy the following properties:

- d (A, B)≥0
- d (A, B) = d (B, A)
- d (A, A) = 0, d (A, B) = 0, if and if only A = B
- Assume that A, B and C are three intuitionistic fuzzy sets of the discussion field X, then d (A, C)≤d (A, B)+d (B, C)
- Assume that X is a nonempty classic set, A, B and C are three intuitionistic fuzzy sets of the discussion field X, then B is closer to A than C if and if only d (A, B)≤d (A, C)

EFFICIENCY EVALUATION INDEX OF EMERGENCY PLAN SYSTEM

Emergency plan play an important role in the response to the emergency process. It is dispensable for

Table 1: Index system of emergency plan system evaluation

Dimensions	Criteria
	Reasonable content of emergency plan(u11)
	Composing and collocation of various emergency (u12)
Perfection of emergency plan (U1)	Proper emergency plan of some district (u13)
	Emergency response and handling after disaster (u14)
	Capability of monitor and early waring (u15)
Emergency plan	Fast of handling disaster(u21)
operability	Reasonable cost (u22)
(U2)	Extensive suitability (u23)
Emergency	Propagate and education (u31)
preparation	Emergency practice (u32)
Capability (U3)	Emergency organization management (u33)
	Guarantee capability of emergency material (u41)
Guarantee capability of emergency resources (U4)	Guarantee capability of lows and regulations (u42)
	Guarantee capability of communication (u43)
	Guarantee capability of trasportation (u44)

Table 2: Evaluation values of emergency plan system of various city

	U_1	U_2	U_3	U_4
S_1	(0.6, 0.3,0.1)	(0.5, 0.3,0.2)	(0.5, 0.4,0.1)	(0.9, 0.0,0.1)
S_2	(0.6, 0.3,0.1)	(0.7, 0.1,0.2)	(0.5, 0.3,0.2)	(0.7, 0.2,0.1)
S_3	(0.4, 0.2,0.4)	(0.4, 0.3,0.3)	(0.6, 0.2,0.2)	(0.8, 0.1,0.1)
S_4	(0.6, 0.1,0.3)	(0.3, 0.1,0.6)	(0.7, 0.2,0.1)	(0.5, 0.2,0.3)

evaluating emergency plan system to establish the evaluation index system of emergency plan system, the accuracy of the evaluation result is affected directly by the selecting of evaluation index system. The indexes system of emergency plan assessment is established according to the objective and scientific principle; the general principle; the feasibility and operational principle and the combination of qualitative and quantitative principle. Based on the characteristic of emergency, we constructed a set of evaluation indexes to evaluate the efficiency of emergency plan which consists of four dimensions: perfection of emergency plan; emergency plan operability; emergency preparation; and guarantee capability of emergency resources. Moreover, each index can be further divided into other sub-indexes. The whole evaluation index system is shown in Table 1.

EFFICIENCY EVALUATION METHOD OF EMERGENCY PLAN SYSTEM

Intuitionistic fuzzy TOPSIS is the extension form of TOPSIS under fuzzy circumstance which is based on intuitionistic fuzzy positive ideal solution and intuitionistic fuzzy negative ideal solution. Intuitionistic fuzzy positive ideal solutions are defined as maximum of all attributes and intuitionistic fuzzy negative ideal solutions are defined as minimum of all attributes. The decision-making criteria is that, difference between alternatives and fuzzy positive ideal solutions is as small as possible and difference between alternatives and fuzzy negative ideal solutions is as larger as possible.

Assume that $S = \{S_1, S_2,...,S_m\}$ is a discrete set of m possible supplier alternatives. $U = \{U_1, U_2,..., U_m\}$ is a set of n attributes of suppliers. l experts, $D_1, D_2,\ldots, D_l$, form a committee to act as decision makers. The procedure for Intuitionistic fuzzy TOPSIS has been given as follows:

Step 1: Construct an IFS evaluation matrix

Concentrating assessment results of all experts, we can gain an IFS evaluation matrix as follows:

$$P = \begin{pmatrix} f_1(S_1) & f_2(S_1) & \cdots & f_n(S_1) \\ f_1(S_2) & f_2(S_2) & \cdots & f_n(S_2) \\ \vdots & \vdots & \cdots & \vdots \\ f_1(S_m) & f_2(S_m) & \cdots & f_n(S_m) \end{pmatrix}$$

where $f_j(S_i) = \{<S_i, \mu_j(S_i), v_j(S_i)>|i = 1, 2,..., m, j = 1,2...., n\}$, is the intuitionistic fuzzy evaluation to project S_i under criteria U_i.

According to the concept of intuitionistic fuzzy sets, this IFS evaluation matrix is a normalized matrix:

Step 2: Construct weighted normalized matrix

Suppose the weighted vector is $W = (\omega_1, \omega_2,...\omega_n)$,we can get the following results:

$$w_j = \{< S_i, \omega_j, \xi_j > | i = 1, 2, \cdots, m\}$$

Where:

$$\omega_j \ge 0, \sum_{j=1}^{n} \omega_j = 10 \le \xi_j \le 1$$

According to Eq. 8, the weighted normalized matrix Q can be constructed using the weighted vector and the IFS evaluation matrix P:

$$Q = \begin{pmatrix} g_1(S_1) & g_2(S_1) & \cdots & g_n(S_1) \\ g_1(S_2) & g_2(S_2) & \cdots & g_n(S_2) \\ \vdots & \vdots & \cdots & \vdots \\ g_1(S_m) & g_2(S_m) & \cdots & g_n(S_m) \end{pmatrix}$$

Where:

$$gj\ (Sj) = \{<Sj,\ Uij,\ Vij>|i = 1,2,...,\ m\ j = 1,\ 2,...n\}$$
$$= \{< S_i, \omega_j\mu_j(S_i), \xi_j + \nu_j(S_i) - \xi_j\nu_j(S_i) > i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n\} \quad (9)$$

Step 3: Determine the positive ideal solution and the negative ideal solution

Suppose the positive ideal solution and the negative ideal solution are A^+ and A^-:

$$A^+ = (a_1^+, a_2^+, \cdots, a_n^+) A^- = (a_1^-, a_2^-, \cdots, a_n^-)$$

where $a_j^+ = (1, 0, 0) a_j^- = (0, 1, 0)\ (j = 1, 2, \cdots, n)$:

Step 4: Calculate the distance to ideal points

The distance measures of each alternative from the positive and negative ideal decisions, respectively, using the normalized Intuitionistic Euclidean distance, are as follows:
The distance of an alternative to the positive ideal solution d_i^+:

$$d_i^+ = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}[(\mu_{ij} - \mu_j^+)^2 + (\gamma_{ij} - \gamma_j^+)^2 + (\pi_{ij} - \pi_j^+)^2]} \quad (10)$$

and from the negative ideal solution d_i^-:

$$d_i^- = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}[(\mu_{ij} - \mu_j^-)^2 + (\gamma_{ij} - \gamma_j^-)^2 + (\pi_{ij} - \pi_j^-)^2]} \quad (11)$$

with the results being real numbers.

Step 5: Calculate the relative access degree

The relative access degree is calculated using Eq. 12:

$$K_i = \frac{S_i^-}{S_i^- + S_i^+} (i = 1, 2, \cdots, m) \quad (12)$$

According to the score of K_i, we can sequence all items to be assessed. The higher K_i is, the better the item is.

NUMERICAL EXAMPLE

Assuming that some district government desire to evaluate the effectiveness of emergency plan system of cities S_1, S_2, S_3, S_4. A committee of 20 experts D_1, D_2,…, D_{20}, has been formed to undertake the evaluation work . Four criteria are considered:

- Perfection of emergency plan (U_1)
- Emergency plan operability (U_2)
- Emergency preparation capability (U_3)
- Guarantee capability of emergency resources (U_4)

The proposed method is applied to solve this problem and the computational procedure is summarized as follow:

Step 1: Construct an IFS evaluation matrix

Concentrating assessment results of all experts, we can get an IFS evaluation matrix as follows:

Step 2: Construct weighted normalized matrix

According to the evaluation results of 20 experts, we can get the weight value of first layer index, as shown in Table 3.

According to 9, we can get the weighted normalized matrix, as shown in Table 4.

Step 3: Determine the positive ideal solution and the negative ideal solution

The intuitionistic fuzzy positive ideal solution A^+ and the intuitionistic fuzzy negative ideal solution A^- are shown in Table 5:

Step 4: Calculate the distance to the intuitionistic fuzzy ideal points and the relative access degree

According to Eps.(10)-(12), we can calculate the distance of each alternative from the intuitionistic fuzzy idea points and the relative access degree for each alternative. The results are shown in Table 6.

As the result from Table 5, the result of ranking order is shown as follow:

$$S_4 \succ S_3 \succ S_2$$

Table 3: Weight value of first layer index

	U_1	U_2	U_3	U_4
w_j	(0.3,0.4,0.3)	(0.3,0.3,0.4)	(0.2,0.5,0.3)	(0.2,0.4,0.4)

Table 4: Evaluation values of the suppliers

	U_1	U_2	U_3	U_4
S_1	(0.18,0.58,0.24)	(0.15,0.51,0.34)	(0.1,0.7,0.2)	(0.18,0.4,0.42)
S_2	(0.18,0.58,0.24)	(0.21,0.37,0.42)	(0.1,0.65,0.25)	(0.14 0.52,0.34)
S_3	(0.12,0.52,0.36)	(0.12,0.37,0.51)	(0.12,0.6,0.28)	(0.16,0.46,0.38)
S_4	(0.18,0.46,0.36)	(0.09,0.37,0.54)	(0.14,0.6,0.26)	(0.1,0.52,0.38)

Table 5:Intuitionistic fuzzy ideal solutions

	U_1	U_2	U_3	U_4
A^+	(1,0,0)	(1,0,0)	(1,0,0)	(1,0,0)
A^-	(0,1,0)	(0,1,0)	(0,1,0)	(0,1,0)

Table 6: Relative Access Degree for Each supplier

	di+	di-	ki	Rank
S_1	0.7511	0.4113	0.3538	4
S_2	0.7437	0.4249	0.3636	3
S_3	0.7599	0.4619	0.378	2
S_4	0.7634	0.472	0.3821	1

Based on the result above, we can know that the emergency plan system of city S_4 is the best.

CONCLUSION

With the natural disasters and man-made catastrophic events increase, emergency plan play more important role in emergency management in china. It has become an urgent priority for improving emergency response capability to evaluate the efficiency of emergency plan system. In this study, we utilize the multiple attribute decision-making method to deal with the efficiency evaluation of emergency plan system and put forward a new approach based on intuitionistic fuzzy sets and TOPSIS which can make the result of evaluation more scientific and accurate. The study can provide effective decision-making reference for the emergency handling.

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REFERENCES

Atanassov, K. and C. Georgiev, 1990. Intuitionistic fuzzy logic. C. R. Acad. Bulg. Soc., 3: 9-12.

Atanassov, K. and C. Georgiev, 1993. Intuitionistic fuzzy prolog. Fuzzy Sets Syst., 53: 121-128.

Atanassov, K., 1994. New operations defined over the intuitionistic fuzzy sets. Fuzzy Sets Syst., 61: 137-142.

Atanassov, K., 1999. Intuitionistic Fuzzy Sets: Theory and Applications. Physica-Verlag, Heidelberg, New York.

Atanassov, K.T., 1986. Intuitionistic fuzzy sets. Fuzzy Sets Syst., 20: 87-96.

Cai, T.X., C.Y. Zhao and Q. Xu, 2012. Energy network dispatch optimization under emergency of local energy shortage. Energy, 42: 132-145.

Cheng, C.Y. and X. Qian, 2010. Evaluation of emergency planning for water pollution incidents in reservoir based on fuzzy comprehensive assessment. Procedia Environ. Sci., 2: 566-570.

Cheng, C.Y., X. Qian, J. Yang, L. Li, Y. Wan and M. Yang, 2008. Effectiveness evaluation of emergency plans for dam break. Chinese J. Geotech. Eng., 30: 1729-1733.

Guo, Z.X. and Q. Zhang, 2008. Research on the evaluation of emergency plans operability. Proceedings of the 3rd Annual Meeting of Risk Analysis Council of China Association for Disaster Prevention, November 8-9, 2008, Guangzhou, China, pp: 266-271.

Han, F.Y., H.L. Zhang and L.Y. Dong, 2009. Research on evaluation model of emergency response plans. Proceedings of the International Conference on Mechatronics and Automation, August 9-12, 2009, Changchun, China, pp: 5117-5122.

Perry, R.W. and M.K. Lindell, 2003. Preparedness for emergency response: Guidelines for the emergency planning process. Disasters, 4: 336-350.

Szmidt, E. and J. Kacprzyk, 2000. Distances between intuitionistic fuzzy sets. Fuzzy Sets Syst., 114: 505-518.

Zadeh, L.A., 1965. Fuzzy set. Inform. Control, 8: 338-353.

Zhang, H.L., X.F. Li and L.Y. Dong, 2009. Fuzzy evaluation model of emergency plans. China Safety Sci. J., 7: 142-148.

Zhang, P.J. and J. Chen, 2008. Study on evaluation of natural disaster emergency response plan in China: Flexibility evaluation. China Safety Sci. J., 10: 16-25.