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Early Warning Index Weight Assignment and Decision Mechanism for Network Public Sentiment Emergency in Uncertain Environment

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Abstract: In the real-life uncertain environment, many attribute values of network public sentiment emergency are easily expressed by fuzzy linguistic terms. In this study, we aim to propose the weight assignment method for the selected warning indexes of network sentiment emergency by using extended fuzzy AHP and a new decision-making approach for uncertain network public sentiment emergency is then presented. By means of the information fusion technique of fuzzy warning index values, we can order the severity of each network public sentiment emergency according to the ranking value of the fuzzy aggregation value of each network public sentiment emergency and select the most severe one for emergency decision.

Key words: Network public sentiment emergency, warning index, fuzzy AHP, weight assignment

INTRODUCTION

Network public sentiment is the public opinions of some event with a lot of influence and strength. Recently, Network sentiment analysis and early warning become very important research issues. As is well known, the uncontrolled network sentiments easily incur the emergency. Simultaneously, emergency will affect network public sentiment. So, in order to decrease the risk of emergency management decision (Ashley and Morrison, 1997; Morrison and Wilson, 1997), there is much need to analyze and control the network public sentiment effectively. In the above areas, Zeng and Xu (2009), Zeng (2010) and Zhang (2008) proposed the methods of selecting sentiment indexes and determining their weights for network sentiment emergency. Peng (2008) and Zhang and Qi (2010) discussed the close relationship between network public sentiment and emergency. Also some authors (Wu and Li, 2008; Zhang, 2010) have proposed many early warning decision or alarm severity priority ordering methods for network emergency. However, the most existing related emergency decision methods and alarm severity ranking mechanisms can only deal with the emergency under precise conditions. Although Lin *et al.* (2011) proposed a method for the network sentiment early warning, it excessively depended on the selected fuzzy reasoning rules and the weight of network sentiment index is not considered. Thus, this proposed approach is inconvenient in some cases and it can not deal with network sentiment emergency with interval values.

In fact, due to the increasing complexity of the socio-economic environment and the lack of knowledge about the problem domain, most of the real-world problems, such as network public sentiment analysis and uncertain decision-making, are involved variety of fuzziness, like fuzzy number (Deng *et al.*, 2004; Chen and Chen, 2007) and fuzzy linguistic term (Rodriguez *et al.*, 2012). In the process of network sentiment emergency decision-making, a decision maker may provide his/her and preferences over the alternate emergencies with fuzzy numbers or fuzzy linguistic values rather than exact real numbers. Especially, in the evaluation process of network public sentiment emergency it inevitably involves some uncertain indexes, like the great attention degree, the heavy diffusion extent, the strong emotional tendentiousness, the unauthentic network sentiment report and the low emergency response speed. Also, the warning index values are assessed by fuzzy linguistic terms.

Although some researchers studied the approaches of fuzzy index analysis in supplier selection and service quality evaluation (Kahraman *et al.*, 2003; Buyukozkan and Cifci, 2012), few works focus on investigating the fuzzy warning index analysis of network public sentiment emergency. By now, the fuzzy warning index selection and weight assignment methods were not solved effectively. In fact, most of the existing fuzzy index analysis methods have some drawbacks, which can not effectively determine the rational weights of fuzzy warning indexes for network sentiment emergency. And we notice that different weight assignment of early warning index greatly influences the emergency decision result. So, for the sake of network public sentiment emergency decision making, in this paper we try to propose an effective approach of early warning index selection and weight assignment for uncertain network public sentiment

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emergency and then help the related managements deal with the network sentiment emergency decision problem involved fuzzy evaluation value based on the severity ranking of all network sentiment emergencies.

WARNING INDEX SELECTION FOR UNCERTAIN ENVIRONMENT

Fuzzy set introduced by Zadeh is a useful generalization of the ordinary set, which has been proved to be more suitable way for dealing with vagueness and uncertainty.

Definition 1: A fuzzy set $\tilde{a} = (l_a, m_a, u_a)$ in a universe of discourse X in R is called a triangular fuzzy number if its membership function $f_{\tilde{a}}$ can be expressed as:

$$f_{\tilde{a}}(x) = \begin{cases} 0, & x \le l_a, \text{or } x > u_a; \\ f_{\tilde{a}}^L(x) = \dfrac{x - l_a}{m_a - l_a}, & l_a < x \le m_a; \\ f_{\tilde{a}}^U(x) = \dfrac{u_a - x}{u_a - m_a}, & m_a < x \le u_a. \end{cases}$$

Notably, the inverse functions of $f_{\tilde{a}}^L(x)$ and $f_{\tilde{a}}^U(x)$, respectively, are easily expressed as:

$$g_{\tilde{a}}^L(y) = l_a + (m_a - l_a)y$$

$$g_{\tilde{a}}^U(y) = u_a - (u_a - m_a)y, \quad \forall y \in [0,1]$$

Definition 2: Let $\tilde{a} = (l_a, m_a, u_a)$ and $\tilde{b} = (l_b, m_b, u_b)$ be two triangular fuzzy numbers, some basic operations are given as follows:

$$\begin{aligned} &\tilde{a} + \tilde{b} = (l_a + l_b, m_a + m_b, u_a + u_b) \\ &\tilde{a} \otimes \tilde{b} = (l_a, m_a, u_a) \otimes (l_b, m_b, u_b) = (l, m, u) \end{aligned} \tag{1}$$

where $l = \min(l_a l_b, l_a u_b, u_a l_b, u_a u_b)$, $m = m_a m_b$, $u = \max(l_a l_b, l_a u_b, u_a l_b, u_a u_b)$.

Remark 1: If l_a, m_a, u_a, l_b, m_b, $u_b>0$, $w>0$ then:

$$\tilde{a} \otimes \tilde{b} = (l_a, m_a, u_a) \otimes (l_b, m_b, u_b) = (l_a l_b, m_a m_b, u_a u_b)$$
$$\tilde{a} / \tilde{b} = (l_a, m_a, u_a) / (l_b, m_b, u_b) = (l_a / u_b, m_a / m_b, u_a / l_b)$$

and

$$w\tilde{a} = (wl_a, wm_a, wu_a)$$

Definition 3: The centroid method is very useful to deal with defuzzification problems and fuzzy ranking problem. A formula for calculating the centroid $(x_{\tilde{a}}, y_{\tilde{a}})$ of the fuzzy number $\tilde{a} = (l_a, m_a, u_a)$ is defined as below.

$$x_{\tilde{a}} = \frac{\int_{l_{\tilde{a}}}^{m_{\tilde{a}}} x f_{\tilde{a}}^L(x)dx + \int_{m_{\tilde{a}}}^{u_{\tilde{a}}} x f_{\tilde{a}}^U(x)dx}{\int_{l_{\tilde{a}}}^{m_{\tilde{a}}} f_{\tilde{a}}^L(x)dx + \int_{m_{\tilde{a}}}^{u_{\tilde{a}}} f_{\tilde{a}}^U(x)dx} \tag{2}$$

$$y_{\tilde{a}} = \frac{\int_0^1 y g_{\tilde{a}}^L(y)dy + \int_0^1 y g_{\tilde{a}}^U(y)dy}{\int_0^1 g_{\tilde{a}}^L(y)dy + \int_0^1 g_{\tilde{a}}^U(y)dy}$$

Definition 4: The ranking value of fuzzy number $\tilde{a} = (l_a, m_a, u_a)$ is defined as follows:

$$\text{Rank}(\tilde{a}) = x_{\tilde{a}} \times y_{\tilde{a}} \tag{3}$$

The larger the value of Rank($\tilde{a}$), the better the ranking of fuzzy number $\tilde{a} = (l_a, m_a, u_a)$.

Definition 5: Let $C = \{c_1, c_2, ..., c_n\}$ be the warning index set of network sentiment emergency, suppose $(g_{if})_{n \times n}$ is the pair-wise comparison fuzzy preference relation matrix constructed by the knowledge of experts, where fuzzy number $g_{ij} = (l_{gij}, m_{gij}, u_{gij})$ represents the fuzzy preference degree of index c_i over index c_j. The fuzzy synthetic extent with respect to the ith index is defined as:

$$S_i = \sum_{j=1}^{n} g_{ij} / \sum_{i=1}^{n} \sum_{j=1}^{n} g_{ij}$$

and the possibility degree for a fuzzy number S_i to be greater than the other fuzzy number S_k is defined as:

$$V(S_i \ge S_k) = \begin{cases} 1, & \text{if } m_i \ge m_k \\ 0 & \text{if } u_i < l_k \\ \dfrac{(l_k - u_i)}{(m_i - u_i) - (m_k - l_k)}, & \text{otherwise} \end{cases} \tag{4}$$

Definition 6: The weight vector of all the warning indexes of network sentiment emergency is given by normalizing the vector $W' = (d(S_1), d(S_2))$, where:

$$d(S_i) = \min v(S_i \ge S_k), \quad k = 1,2,...,n, k \ne i \tag{5}$$

represents the possibility degree that S_i is greater than all the other fuzzy numbers $S_k (k \ne j)$.

INDEX WEIGHT ASSIGNMENT AND DECISION FOR NETWORK SENTIMENT EMERGENCY

As we know, every network public sentiment emergency is greatly influenced by many types of early warning indexes. And, by emergency management questionnaire survey and statistical analysis from network public sentiment emergency management we can easily get some important indexes which possibly cause the network public sentiment significant emergency. Also, through emergency supervisors and search engines, we can obtain much information of network public sentiment emergency warning indexes including subjective and objective indexes. For the sake of dealing with early warning and emergency decision making, we firstly choose the finite comprehensive and hierarchical indexes from all the possible alternate indexes based on the well-established principle that each index should possess independency, sensitivity and representation, as well as guidance quality. Usually, each network public sentiment emergency comprises the following first-grade indexes: network public sentiment emergency power index, network sentiment intensity index and emergency coping capacity index.

Additionally, each first-grade early warning index also has many second-grade warning indexes. In general, network public sentiment emergency power index briefly consists of the following second-grade indexes, time duration, extent of diffusion, environment disruption degree, severity of economic loss. And network sentiment intensity index briefly consists of the following second-grade indexes, sentiment attention degree, spreading speed of network sentiment, emotion tendency like religious conflict and behavior tendentiousness such as network group attack and political assembly, as well as authenticity of network public sentiment. The government emergency coping capacity briefly consists of the following second-grade indexes, including response speed, information transparency, emergency evacuation capacity, emergency resource allocation capacity, government responsibility, etc.

Notably, in complex uncertain decision environment the above-mentioned early warning indexes of network public sentiment emergency are difficult to measure by precise real numbers, instead, they are easily assessed by emergency managers and related field experts in terms of fuzzy linguistic words. Moreover, the evaluation values of every alternate network public sentiment emergency with many warning indexes are easily expressed by the fuzzy linguistic terms like extremely strong, very strong, strong, medium, weak, very weak, extremely weak rather than by using accurate real numbers. In order to simplify evaluating the early warning index of network public sentiment emergency, a unified set of fuzzy linguistic variables is predetermined as in Table 1.

Based on the above analysis and the previous formulae, next we aim to extend the fuzzy AHP method to determine the rational weight of warning index and then to make network public sentiment emergency decision involved fuzzy linguistic values in uncertain environment:

Step 1: By statistical questionnaire and the scores assigned by emergency management experts, we first construct the fuzzy preference relation $\tilde{B} = (\tilde{b}_{ij})_{n\times n}$ over each warning index level, where $\tilde{b}_{ij}$ is the importance degree of i-th index compared to j-th index, which takes fuzzy linguistic number as listed in Table 2. Then, by the extended fuzzy AHP and formulae (4) (5) we can first compute the weight vector of each index level. Moreover, by using multiplication of the weights of all the early warning indexes of top-level and its sub-level, we can obtain the overall weight of each warning index regarding network sentiment emergency decision goal

Step 2: By using the above-assessed weight of each warning index, we compute the fuzzy weighted arithmetic aggregation value $\tilde{e}_i$ of each potential network public sentiment emergency e_i by applying formula (1)

Step 3: Compute the centroid (x_{ei}, y_{ei}) of each fuzzy number $\tilde{e}_i$ by using formula (2)

Step 4: By using formula (3) we calculate the ranking value $Rank(\tilde{e}_i)$ of each fuzzy number $\tilde{e}_i$, then we rank all the possible network public sentiment emergencies. If $Rank(\tilde{e}_i) > Rank(\tilde{e}_k)$, then the alternate network public sentiment emergency e_i is more severe than emergency e_k and we must deal with emergency e_i earlier than e_k

Table 1: Linguistic terms for evaluating network public sentiment emergency with fuzzy warning index

Linguistic term	Fuzzy No.
Extremely strong (ES)/Extremely high(EH)/Extremely big (EB)	1,1,1
Very very strong (VVS)/Very very high(VVH)/Very very big (VVB)	0.9,0.95,1
Very strong (VS)/Very high (VH)/Very big (VB)	0.8,0.9,0.95
Strong (S)/High (H)/Big (B)	0.58,0.7,0.8
Medium (M)	0.4,0.5,0.6
Weak (W)/Low (L)/Tiny(T)	0.2,0.3,0.42
Very weak (VW)/Very low (VL)/Very tiny (VT)	0.15,0.2,0.25
Very very weak (VVW)/Very very low (VVL)/Very very tiny (VVT)	0,0.05,0.1
Extremely weak (EW)/Extremely low (EL)/Extremely tiny (ET)	0,0,0

Table 2: Linguistic terms for comparing importance degree of indexes

Intensity of importance	Definition of grade	Fuzzy No.
9	Extremely strong importance	8,9,10
7	Very strong importance	6,7,8
5	Strong importance	4,5,6
3	Moderate importance	2,3,4
2	Fair importance	1,2,3
1.5	Just Equal importance	1,1,2
1	Equal importance	1,1,1

By the above emergency decision approach, the emergency management can design the corresponding decision mechanism to cope with the emergency more efficiently and decrease the risk loses according to the severity ranking of all the network public sentiment emergencies with the many fuzzy early warning indexes.

Illustrative example: In uncertain setting, the field decision makers and network public sentiment emergency management experts usually use fuzzy linguistic value to evaluate the importance of warning index and to rate the alternatives with various fuzzy warning indexes. Most of the existing emergency decision problems have only precise values for the performance ratings and for the index weighting. Therefore, in order to select the most severe one from a number of alternate network public sentiment emergences with different fuzzy warning indexes, we will extend the fuzzy AHP to determine the priority of different early warning indexes and then choose the most severe network public sentiment emergency to facilitate emergency decision. The detailed network public sentiment emergency early warning index weight assignment and decision process are illustrated in the following example.

Example 1: Suppose the network public sentiment emergency managements acquire much information of uncertain early warning indexes of some possible urban emergencies by employing supervisor control platforms or search engines. And it is urgent for them to evaluate the severity of all the potential network public sentiment emergencies, then to make final emergency decision-making. Now assume there exist multiple potential network sentiment emergencies $E = (e_1, e_2, e_3, e_4)$ which may be influenced by many fuzzy warning indexes. By the aid of statistical questionnaire from emergency decision experts and through our presented principle of early warning index selection, here we choose three first-grade warning indexes including network public sentiment emergency power index (C_1), government emergency coping capacity (C_2) and network sentiment intensity index (C_3). Moreover, in first-grade warning index level C_1 we select the following second-grade indexes: Severity of economic loss (C_{11}), extent of diffusion (C_{12}). And in first-grade warning index level (C_2) we also select the following second-grade indexes including response speed (C_{21}), network sentiment information transparency (C_{22}). Also, in the network sentiment intensity index C_3 we choose the following sub-indexes: Sentiment attention degree (C_{31}), spreading speed of network sentiment (C_{32}) and behavior tendency (C_{33}). Moreover, by emergency experts assigning scores to each pair of warning indexes, we can easily get the fuzzy preference relation matrix over each warning index level as shown in Table 3. Also, the evaluated values of all the alternate network public sentiment emergencies with many uncertain warning indexes are given by related expertise as shown in the following Table 4. Our main task is to determine the severity ranking of all the possible network sentiment emergencies involved fuzzy linguistic terms. And then we make final urgent decision to select the most severe one we must deal with first out of all the alternate emergencies.

Table 3: Fuzzy preference relations over all warning index levels

	C1	C2	C3	C11	C12
C1	1,1,1	4,5,6	1/8,1/7,1/6		
C2	1/6,1/5,1/4	1,1,1	2,3,4		
C3	6,7,8	1/4,1/3,1/2	1,1,1		
C11				1,1,1	1,1,2
C12				1/2,1,11,1,1	

	C21	C22	C31	C32	C33
C21	1,1,1	1,2,3			
C22	1/3,1/2,1	1,1,1			
C31			1,1,1	2,3,4	1/3,1/2,1
C32			1/4,1/3,1/2	1,1,1	4, 5,6
C33			1,2,3	1/6,1/5,1/4	1,1,1

In what follows we extend fuzzy AHP method to assign the rational weight of each early warning index of network sentiment emergency and then facilitate the related emergency management adopting the corresponding decision strategy to decrease the risk loss of network public sentiment emergency.

First, from the pair-wise comparison fuzzy preference relations of the first-grade indexes and the second-grade indexes in Table 3, by taking Step 1 and employing formulae (4), (5) we compute the priority weight of each early warning index level as in Table 5.

From Table 5, we notice that the weights, $w_{21} = 0.0136$, $w_{22} = 0.006<0.1$, are very small, so the two early warning sub-indexes c_{21}, c_{22} can be neglected. Here we only select the five warning index (C_{11}, C_{12}, C_{31}, C_{32}, C_{33}), which can be viewed as five fuzzy criteria ($r_1, r_2,..., r_n$) of the network public sentiment emergency. And we normalize the weight vector of the selected five criteria as $\overline{W} = (0.1793, 0.1655, 0.2214, 0.3316, 0.1022)$.

From linguistic term Table 1, we translate Table 4 into the following fuzzy decision matrix $D = (\tilde{r}_{ij})_{4\times5}$.

Table 4: Uncertain Network sentiment emergency decision system

Emergency	C_{11}	C_{12}	C_{21}	C_{22}	C_{31}	C_{32}	C_{33}
e_1	VT	B	V VH	H	M	L	S
e_2	EB	VB	H	V VL	S	L	W
e_3	VB	T	VH	V VH	W	VL	VW
e_4	T	B	V VH	H	V VW	VH	W

Table 5: Priority weights in all the warning index levels

Index 1	0.338				
Sub-index 11		0.52	1	0.1758	3
Sub-index 12		0.48	2	0.1622	4
Index 2	0.0197				
Sub-index 21		0.6923	1	0.0136	6
Sub-index 22		0.3077	2	0.0061	7
Index 3	0.6423				
Sub-index 31		0.3379	2	0.217	2
Sub-index 32		0.5061	1	0.3251	1
Sub-index 33		0.156	3	0.1002	5

where, $\tilde{r}_{ij}$ is a fuzzy number which denotes the fuzzy membership degree of network public sentiment emergency e_i with respect to j-th considered early warning index. For instance, $\tilde{r}_{34}$ = (0.15, 0.2, 0.25) = VL represents the fuzzy membership degree of emergency e_3 with respect to fourth chosen early warning index c_{32}.

From Table 5 and with Eq. 1 we calculate the fuzzy weighted arithmetic aggregation value $\tilde{e}_i$ of each network sentiment emergency e_i with all fuzzy warning indexes below.

$$\tilde{e}_1 = \sum_{j=1}^{5} w_j \tilde{r}_{1j} = (0.337, 0.4334, 0.5311)$$

$$\tilde{e}_2 = \sum_{j=1}^{5} w_j \tilde{r}_{2j} = (0.5269, 0.6134, 0.6958)$$

$$\tilde{e}_3 = \sum_{j=1}^{5} w_j \tilde{r}_{3j} = (0.2859, 0.3642, 0.4413)$$

$$\tilde{e}_4 = \sum_{j=1}^{5} w_j \tilde{r}_{4j} = (0.4176, 0.5098, 0.5878$$

Also, according to Eq. 2 we compute the corresponding centroid of each fuzzy number $\tilde{e}_i$ corresponding to the network sentiment emergency e_i.

$$(x_{\tilde{e}_1}, y_{\tilde{e}_1}) = (0.4338, 0.4999)$$

$$(x_{\tilde{e}_2}, y_{\tilde{e}_2}) = (0.612, 0.5003)$$

$$(x_{\tilde{e}_3}, y_{\tilde{e}_3}) = (0.3638, 0.5001)$$

$$(x_{\tilde{e}_4}, y_{\tilde{e}_4}) = (0.5051, 0.6666)$$

By using Eq. 3 we calculate the ranking value $Rank(\tilde{e}_i)$ of each fuzzy number $\tilde{e}_i$ below:

$$Rank(\tilde{e}_1) = 0.2169$$

$$Rank(\tilde{e}_2) = 0.3062$$

$$Rank(\tilde{e}_3) = 0.1819$$

$$Rank(\tilde{e}_4) = 0.3367$$

Since $Rank(\tilde{e}_4) > Rank(\tilde{e}_2) > Rank(\tilde{e}_1) > Rank(\tilde{e}_3)$, we obtain that the severity ranking of all the alternate network sentiment emergencies is as $e_3 \propto e_1 \propto e_2 \propto e_4$.

Thus, the network public sentiment emergency e_4 is the optimal decision alternative. That is to say, e_4 is the most severe network public sentiment emergency in all the potential network public sentiment emergencies, the related emergency management decision-maker must first deal with this network public sentiment emergency, next to cope with the secondary severe emergency e_2, then e_1 and e_3. The related network public sentiment emergency management will raise the corresponding early warning and take urgent decision mechanism to coordinate all kinds of emergency facilities among different municipal zones and districts to avoid or decrease the risk loss of the unexpected network public sentiment emergency before implementing some emergency responses.

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