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An Emergency Plan Selection Method for Emergency Latency

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Abstract: Drawing upon a characteristic analysis of the latency period in emergencies, this paper proposes an emergency plan selection method based on interval language variables and information entropy to address the challenge of acquiring critical information during this crucial stage. Initially, decision-makers employ interval language variables to express the preference information regarding emergency plans, while also introducing an enhanced information entropy theory to derive the weight coefficients of key indicators. Subsequently, the weighted arithmetic average operator of interval language is applied twice to aggregate the preference information alongside the relative importance of decision-makers and the weight coefficients of key indicators. Finally, the ranking coefficients of each emergency plan are sorted to determine the optimal scheme. The feasibility and effectiveness of this method are demonstrated through a case study involving the selection of an emergency plan for a flood disaster in a specific location.

Keywords: Emergency; Latency period; Linguistic terms; Information entropy

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1. Introduction

An emergency plan encompasses the action plans and guidelines devised by government-organized experts at all administrative levels to address impending emergencies [1]. However, the detection and anticipation of emergent situations pose significant challenges, compounded by the limited availability of pertinent information to organizations at various levels. Consequently, selecting a rational emergency plan has emerged as a pivotal issue during the incubation period.

This paper is focused on determining the weightage of key indicators and selecting the optimal emergency plan. Prior literature has employed the Delphi method to ascertain the significance of each influencing factor [2]. Here, evaluation experts were tasked with providing preference information for each influencing factor, followed by an arithmetic averaging process. However, it was observed that experts tended to assign higher scores to each influencing factor, thereby impacting the objectivity of conclusions. To address this, a data enveloping analysis method capable of handling multiple indicators effectively was studied and introduced [3]. Nonetheless, the implementation of this method necessitates extensive data support, posing challenges during the emergency plan selection process.

Given that much of the information prior to emergencies is inherently uncertain, traditional methods such as the Analytic Hierarchy Process (AHP) have limitations [4]. To more accurately capture the uncertainty inherent in emergency plan selection, this paper explores methods based on fuzzy language [5,6], which reflect both the subjective assessments of experts and the complexities of the objective environment. However, challenges persist in determining membership functions within fuzzy theory.

Information entropy theory offers a means to mitigate the subjectivity of decision-makers in practical applications. Yet, Shannon's information entropy method requires decision-makers to provide precise numerical values to evaluate the performance of emergency plans [7], thereby limiting its widespread adoption.

Given the scarcity of valuable information during emergency formation, decision-makers tend to prefer linguistic variables to represent preference information regarding emergency plans. Moreover, to ensure the scientific selection of emergency plans, the participation of multiple decision-makers is imperative. However, practical constraints such as environmental factors and decision-makers' cognitive abilities limit this participation. As such, decision-makers often provide preference information using interval language variables. Consequently, this paper proposes an integrated method leveraging interval language variables and information entropy to facilitate the selection of the optimal emergency plan.

2. The method of emergency plan selection in the latency period

Step 1: Before the occurrence of an emergency, all stakeholders should be invited to form a decision-making team for the emergency plan. Considering the differences in the cognitive ability and understanding level of decision-makers, the relative importance vector of each decision-maker should be obtained by using the pairing comparison method. The decision team identifies a set of key indicators based on the contingency to be analyzed.

Step 2: Based on the comprehensive research information and their experience knowledge, decision-makers select appropriate language variables to give the performance evaluation values of each emergency plan in various key indicators and then use the weighted average operator of interval linguistic information to aggregate the relative importance vector of decision-makers and the performance evaluation values given by decision makers to obtain the group performance evaluation values of emergency plans.

Step 3: To eliminate the dimensional influence of different key indicators, it is necessary to normalize the group performance evaluation value of the emergency plan to get the standardized group performance evaluation value of the emergency plan. The normalized conversion formulas of the benefit index are as follows:

$$sg\tilde{r}_{kj}^{\mu} = \frac{\varsigma_j + \phi - 1}{\sum_{j=1}^{n} \left(\tau_j + \phi - 1\right)} \qquad (1)$$

$$sg\tilde{r}_{kj}^{\nu} = \frac{\tau_j + \phi - 1}{\sum_{j=1}^{n} \left(\varsigma_j + \phi - 1\right)} \qquad (2)$$

The normalized conversion formulas of the cost index are as follows:

$$sg\tilde{r}_{kj}^{\mu} = \frac{1/(\tau_k + x - 1)}{\sum_{j=1}^{n} 1/(\varsigma_k + x - 1)} \qquad (3)$$

$$sg\tilde{r}_{kj}^{\nu} = \frac{1/(\varsigma_k + x - 1)}{\sum_{j=1}^{n} 1/(\tau_k + x - 1)} \qquad (4)$$

Step 4: In this paper, the calculation formula of information entropy of interval language is used as follows:

$$E_j = \theta\left(-1/ln\, l \sum_{k=1}^{l} sp\tilde{r}_{kj}^{\mu}\, ln\, s\, p\tilde{r}_{kj}^{\mu}\right) + (1-\theta)\left(-1/ln\, l \sum_{k=1}^{l} sp\tilde{r}_{kj}^{\nu}\, ln\, s\, p\tilde{r}_{kj}^{\nu}\right) \qquad (5)$$

where is the balance coefficient of interval language variables determined by the decision-making team. In the application example of this paper, the balance coefficient given by the decision-making team is 0.8.

The information deviation degree of the key indicators is determined by Equation (6). Therefore, the normalized weight coefficient of each key indicator is determined by Equation (7).

$$\varepsilon_j = 1 - E_j \qquad (6)$$

$$\omega_j = \frac{\varepsilon_j}{\sum_{j=1}^{n} \varepsilon_j} \qquad (7)$$

Step 5: Again, the weighted average operator of interval language was used to aggregate the normalized weight coefficient of each key indicator and the performance evaluation value of the emergency plan, and the comprehensive attribute evaluation value of each emergency plan was obtained. Then, the comprehensive attribute evaluation value of each emergency plan was compared pairwise, and the possibility matrix of the comprehensive attribute evaluation value of each emergency plan was established.

Step 6: The ordering coefficient of each emergency plan is obtained based on the row and normalization method of the possibility matrix by using Equation (8) to determine the best plan.

$$\psi_{k_1} = \frac{\sum_{k_2=1}^{l} p_{l_1 l_2} + \frac{l}{2} - 1}{l(l-1)} \qquad (8)$$

3. Application examples

To verify the effectiveness and operability of the proposed method, this study takes the selection of emergency plans for flood disasters in a county-level city with frequent natural disasters as an example. To prevent floods and ensure the personal and property safety of residents, organizations at all levels have initially drawn up three plans to choose from.

Step 1: Before an emergency occurs, all stakeholders are invited to form a decision-making team for the emergency plan, and the relative importance vector of each decision-maker is obtained by using the pairwise comparison method as ρ = (0.219, 0.207, 0.185, 0.228, 0.161). Through the analysis of all the collected information, the key indicators selected by the decision-making team included the completeness of the plan, the operability of the plan, the rationality of the resource allocation, the pertinence of the event assumption, and the effectiveness of the drill and training.

Step 2: The specific decision information given by decision makers is shown in Table 1.

Table 1. Information on preferences for contingency plans from decision-makers

		t_1	t_2	t_3	t_4	t_5
d_1	c_1	$[S_0, S_{1/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_0, S_{4/3}]$	$[S_{4/3}, S_3]$	$[S_{-1/3}, S_{1/3}]$
	c_2	$[S_0, S_{4/3}]$	$[S_{1/3}, S_3]$	$[S_{4/3}, S_3]$	$[S_{1/3}, S_3]$	$[S_{1/3}, S_{4/3}]$
	c_3	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{4/3}, S_3]$	$[S_0, S_{1/3}]$
d_2	c_1	$[S_{-1/3}, S_{1/3}]$	$[S_{1/3}, S_3]$	$[S_0, S_{1/3}]$	$[S_{1/3}, S_3]$	$[S_{-1/3}, S_0]$
	c_2	$[S_{1/3}, S_3]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_3]$	$[S_{4/3}, S_{-3}]$	$[S_0, S_{4/3}]$
	c_3	$[S_{1/3}, S_3]$	$[S_0, S_{1/3}]$	$[S_0, S_{1/3}]$	$[S_{1/3}, S_3]$	$[S_{-1/3}, S_{1/3}]$
d_3	c_1	$[S_0, S_{1/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{4/3}, S_3]$	$[S_0, S_{1/3}]$
	c_2	$[S_0, S_{4/3}]$	$[S_{1/3}, S_3]$	$[S_{4/3}, S_3]$	$[S_{1/3}, S_3]$	$[S_{1/3}, S_{4/3}]$
	c_3	$[S_0, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{4/3}, S_3]$	$[S_{-1/3}, S_0]$
d_4	c_1	$[S_{-1/3}, S_{1/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_0, S_{1/3}]$	$[S_{4/3}, S_3]$	$[S_{-1/3}, S_0]$
	c_2	$[S_0, S_{1/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_0, S_{4/3}]$
	c_3	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_3]$	$[S_0, S_{1/3}]$	$[S_{1/3}, S_3]$	$[S_{-1/3}, S_{1/3}]$
d_5	c_1	$[S_{-1/3}, S_0]$	$[S_{1/3}, S_3]$	$[S_0, S_{4/3}]$	$[S_{1/3}, S_3]$	$[S_0, S_{1/3}]$
	c_2	$[S_{1/3}, S_{4/3}]$	$[S_{4/3}, S_3]$	$[S_{1/3}, S_3]$	$[S_{4/3}, S_3]$	$[S_{1/3}, S_{4/3}]$
	c_3	$[S_0, S_{4/3}]$	$[S_0, S_{1/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{1/3}, S_{4/3}]$	$[S_{-1/3}, S_{1/3}]$

Step 3: The weighted average operator of interval language was used to obtain the group preference information of the emergency plan, as shown in Table 2.

Table 2. Group preference information for contingency plans

	t_1	t_2	t_3	t_4	t_5
c_1	$[S_{-0.198}, S_{0.279}]$	$[S_{0.333}, S_{1.947}]$	$[S_{0.062}, S_{0.898}]$	$[S_{0.965}, S_3]$	$[S_{-0.217}, S_{0.188}]$
c_2	$[S_{0.122}, S_{1.105}]$	$[S_{0.494}, S_{2.274}]$	$[S_{0.737}, S_{2.619}]$	$[S_{0.701}, S_{2.619}]$	$[S_{0.188}, S_{1.333}]$
c_3	$[S_{0.218}, S_{1.678}]$	$[S_{0.210}, S_{1.345}]$	$[S_{0.188}, S_{0.898}]$	$[S_{0.737}, S_{2.732}]$	$[S_{-0.260}, S_{0.274}]$

Step 4: Next, it can be seen from these indicators that the preference value of each key indicator is a benefit-based attribute. Equations (1) and (2) are used to normalize the group preference information of the emergency plan and obtain the group standardized information of the emergency plan, as shown in Table 3.

Table 3. Group standardized information for contingency plans

	t_1	t_2	t_3	t_4	t_5
c_1	$[S_{0.132}, S_{0.206}]$	$[S_{0.156}, S_{0.310}]$	$[S_{0.144}, S_{0.245}]$	$[S_{0.186}, S_{0.376}]$	$[S_{0.131}, S_{0.200}]$
c_2	$[S_{0.125}, S_{0.238}]$	$[S_{0.140}, S_{0.306}]$	$[S_{0.150}, S_{0.326}]$	$[S_{0.148}, S_{0.326}]$	$[S_{0.128}, S_{0.251}]$
c_3	$[S_{0.147}, S_{0.291}]$	$[S_{0.146}, S_{0.270}]$	$[S_{0.145}, S_{0.242}]$	$[S_{0.170}, S_{0.356}]$	$[S_{0.125}, S_{0.203}]$

Step 5: Equations (5), (6), and (7) were used to process the group preference information of the emergency plan to obtain the entropy, deviation degree, and normalized weight coefficient of each key index, as shown in Table 4.

Table 4. The entropy, deviation degree, and normalized weight coefficient for contingency plans

	t_1	t_2	t_3	t_4	t_5
E_j	0.774	0.812	0.810	0.855	0.754
ε_j	0.226	0.188	0.190	0.145	0.246
ω_j	0.227	0.189	0.191	0.146	0.247

Step 5: The weighted average operator of interval language is used to aggregate the weight coefficient of each key index and the group preference information of the emergency plan, and the comprehensive attribute evaluation value of each emergency plan is obtained as $ce_{\widetilde{v}_1}$ = [0.147, 0.256], $ce_{\widetilde{v}_2}$ = [0.137, 0.284], $ce_{\widetilde{v}_3}$ = [0.144, 0.265].

Step 6: Equation (8) is used to calculate the possibility degree between the evaluation values of the comprehensive attributes of each emergency plan, and the possibility degree matrix is established accordingly as:

$$P = \begin{bmatrix} 0.500 & 0.463 & 0.485 \\ 0.537 & 0.500 & 0.522 \\ 0.515 & 0.478 & 0.500 \end{bmatrix}$$

The sorting coefficient of each emergency plan can be obtained as cv_1 = 0.325, cv_2 = 0.343, cv_3 = 0.332, and the emergency plan can be sorted accordingly as $cv_1 > cv_2 > cv_3$, and the optimal emergency plan should be c_2.

4. Conclusion

During the latency period of emergencies, the information available to humans is severely limited. To optimize decision-making and harness the subjective expertise of decision-makers, it is proposed to utilize interval language variables to express decision-makers' preference information. Additionally, in the analysis of key indicator weights for emergency plans, the introduction of information entropy theory is advocated. This theory posits that the weight of key indicators fluctuates based on variations in the performance values of emergency plans.

Disclosure statement

The author declares no conflict of interest.

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