Scientific and Social Research, 2024, Volume 6, Issue 1
https://ojs.bbwpublisher.com/index.php/SSR

Creating a Decision-Making Program for the Decline Period of Emergency Events

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Abstract: Based on the analysis of the life cycle theory of emergencies, an emergency decision-making method based on linguistic information and ordering organization is proposed to solve the problem of emergency plan selection during the decline period of emergencies. Firstly, language decision theory is introduced to determine the relative importance of decision members and the weight of key indicators. Secondly, the extended weighted average operator is used to aggregate the preference information of alternative solutions and the relative importance of decision members. On this basis, the ranking organization method is introduced to deal with the complex relationship between different key indicators and alternative solutions. Finally, the net flow of each alternative is ranked to determine the optimal one. The feasibility and effectiveness of this method are verified by taking the operation recovery after a fire in a logistics park as an example.

Keywords: Emergency; Decline period; Linguistic terms; Decision-making

Online publication: January 20, 2024

1. Introduction

When emergencies occur, decision-makers must make effective emergency decisions quickly and accurately to minimize the negative impact of emergencies. However, the occurrence of emergencies is extremely unpredictable, and with the passage of time and the adoption of emergency measures, the situation of emergencies is highly dynamic and uncertain. Therefore, the core issue of emergency management is to select an appropriate emergency plan according to the evolution trend of events [1].

Emergency decision-making involves the full use of relevant information and limited social resources to reduce the loss and negative impact of emergencies. During an emergency, the information obtained is usually incomplete and inaccurate, so the decision-making members often select corresponding emergency decision-making methods based on the existing data and experience [2]. In the process of emergency handling, decision-makers can also timely adjust the emergency plan according to the constantly enriched information to improve the effectiveness of emergency decision-making.

The focus of emergency decision-making research is usually on the disposal process before and after the occurrence of an emergency [3], while ignoring the problem of decision-making during the recovery stage after the event is effectively controlled. In fact, there is a certain pattern in the occurrence of emergencies, and the ultimate goal of emergency management is to restore production and life as soon as possible. With the continuous evolution of emergencies, the trend is gradually clear and clear, and the fuzziness of information is also significantly reduced, which makes the information form preferred by decision members different from that in the early stage. To avoid the loss of information during multiple transformations, it is recommended to use terms of the same language set to represent preference information. In addition, the existing methods do not consider the complex relationship between different key indicators and emergency plans [4]. Research shows that even if the same key indicators are of benefit type, different key indicators have corresponding evaluation criteria and preference functions. In the process of information processing, the relationship between the pros and cons of alternative schemes must be determined according to the preference function values of alternative schemes on corresponding indicators [5]. This paper proposes an emergency decision-making method for emergency decline periods based on the preference ranking organization method for enrichment evaluations.

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

Step 1: After the occurrence of an emergency, the relevant departments take effective measures to deal with it, and then they should begin to resume production and operation to reduce the loss of social property. The person in charge of handling the emergency selects members to form the recovery decision group. In reality, decision-makers with different experiences have different judgment abilities. Decision-makers can use language terms to judge the importance of other decision-makers, and then process decision information according to the aggregation method. The relative importance of decision members can be calculated using Equation (1).

$$\theta_h = \frac{\sum_{h_1=1}^{6} f_{h_1 h}}{\sum_{h_1=1}^{6}\sum_{h_2=1}^{6} f_{h_1 h_2}} \qquad (1)$$

Step 2: The recovery decision group makes a comprehensive analysis of the characteristics of emergencies and the latest progress data, and obtains the key influencing factors of emergency decision-making during the decline of emergencies. To reflect the fuzziness in the judgment process of key indicators, decision-makers use preferred language terms to represent the importance of each indicator and then obtain the importance evaluation matrix of key indicators.

Step 3: An extended weighted arithmetic averaging EWAA operator is used to aggregate the relative importance of decision-making members and the importance evaluation information of key indicators, and the weight coefficient of each key indicator is obtained through Equation (2).

$$\rho_i = \sum_{h=1}^{l} \theta_h r_{hi} \qquad (2)$$

The normalized weight vector of each key indicator is obtained through Equation (3).

$$\omega_i = \frac{\rho_i}{\sum_{i=1}^{m} \rho_i} \qquad (3)$$

Step 4: After the emergency has been brought under control through the efforts of all sectors of the community, the recovery decision team must draw up operational recovery options based on the actual situation of the emergency and the place where it occurred. To better reflect the objective environment and the fuzziness of human thinking, decision-makers use appropriate language terms to represent the evaluation information of different alternatives and then construct the evaluation matrix of alternative alternatives.

Step 5: The relative importance of decision members is aggregated with the evaluation information of alternative solutions, and the group evaluation matrix of alternative solutions is obtained through Equation (4).

$$g_{ji} = \sum_{h=1}^{l} \theta_h e_{ji}^h \qquad (4)$$

Step 6: The comprehensive value of the preference function corresponding to alternative pairs of all key indicators is calculated using Equation (5).

$$v_{j_1 j_2} = \frac{\sum_{i=1}^{m} \omega_i P(b)}{\sum_{i=1}^{m} \omega_i} \qquad (5)$$

According to the comprehensive value of the preference function, the outflow, the inflow, and the net flow of each alternative are calculated using Equations (6) to (8).

$$\phi^+(c_j) = \sum_{c_j \in C} v_{(j,C)} \qquad (6)$$

$$\phi^-(c_j) = \sum_{c_j \in C} v_{(C,j)} \qquad (7)$$

$$\phi(c_j) = \phi^+(c_j) - \phi^-(c_j) \qquad (8)$$

Step 7: According to the order of the net flow of each alternative, the order of the advantages and disadvantages of alternatives is determined.

3. Application examples

To illustrate the effectiveness and operability of the proposed method, this study uses the emergency decision-making of a fire in a logistics park as an example. The logistics park relies on the manufacturing industry base of the economic development zone and is planned to provide logistics integration services for production enterprises, including warehousing and transportation services for raw materials and semi-finished products, as well as distribution, transportation, distribution, warehousing, information processing and circulation processing services for finished products. The fire accident damaged an area of 98 mu, resulting in 18 deaths and 39 serious injuries. The economic loss is more than 80 million yuan.

Step 1: After the disaster situation of the logistics park has been effectively controlled, relevant personnel shall be selected from the competent government departments and the management committee of the logistics park to form the operation recovery decision-making team. Considering that these decision-makers do not have the same understanding of the operation and disaster situation of the park, to ensure the rationality of the research results, the relative importance of the members must be gathered in the process of information processing. According to the actual situation, the evaluation matrix of relative importance is obtained accordingly (**Table 1**). The importance vector of each member is determined to be θ = (0.209, 0.267, 0.105, 0.328, 0.091).

Table 1. The weight evaluation matrix of decision-makers

	d_1	d_2	d_3	d_4	d_5
d_1	-	$S_{4/3}$	$S_{4/3}$	S_3	$S_{1/3}$
d_2	$S_{4/3}$	-	S_0	S_0	$S_{4/3}$
d_3	S_3	$S_{4/3}$	-	$S_{4/3}$	$S_{1/3}$
d_4	$S_{1/3}$	S_3	$S_{-1/3}$	-	S_0
d_5	S_0	$S_{1/3}$	$S_{4/3}$	S_3	--

Step 2: At this stage, the operation recovery decision team carries out the following work: (1) The cause and severity of the incident are sorted out and analyzed, (2) all factors for the resumption of operation of the logistics park are comprehensively analyzed, and the key indicators are determined, (3) the importance of key indicators are assessed. Through relevant analysis, the key indicators determined by the decision-making group are as follows: the control degree of negative public opinion, the control intensity of operation recovery costs, the matching degree of resources, the timeliness of operation recovery, and the reduction degree of property losses.

Since the importance analysis of key indicators is based on the information of the decision-making group's collation and analysis of data in the recession period, there is some ambiguity. Therefore, this study requires decision-makers to use language terms to judge the importance of each key indicator, as shown in **Table 2**.

Table 2. The weight evaluation matrix of key attributes

	k_1	k_2	k_3	k_4	k_5
d_1	S_3	$S_{1/3}$	$S_{4/3}$	S_3	S_0
d_2	$S_{4/3}$	$S_{4/3}$	S_3	$S_{1/3}$	$S_{1/3}$
d_3	$S_{1/3}$	S_0	$S_{4/3}$	S_3	$S_{4/3}$
d_4	S_3	$S_{1/3}$	S_3	$S_{4/3}$	$S_{1/3}$
d_5	$S_{4/3}$	S_3	$S_{4/3}$	$S_{1/3}$	S_0

Step 3: Equation (2) is used to aggregate the importance vector of decision-making members and the importance evaluation matrix of key indicators. Equation (3) is used for normalization processing, and the normalized weight vector of key indicators is obtained as $\omega = (0.275, 0.152, 0.287, 0.231, 0.055)$.

Step 4: In order to restore the normal operation of the logistics park as soon as possible and reduce the subsequent impact of the emergency, the operation recovery decision-making team has made full use of the existing information and knowledge and experience, and formulated the alternatives as c_1, c_2 and c_3. Decision-makers use preferred language terms to represent preference information for alternatives, as shown in **Table 3**.

Table 3. The emergency evaluation matrix given by each decision-maker

		k_1	k_2	k_3	k_4	k_5
d_1	c_1	$S^4_{-1/3}$	$S^4_{1/3}$	S^4_{0}	$S^4_{4/3}$	S^4_{0}
	c_2	$S^4_{1/3}$	S^4_{0}	$S^4_{4/3}$	$S^4_{1/3}$	$S^4_{-1/3}$
	c_3	$S^4_{4/3}$	$S^4_{-1/3}$	$S^4_{1/3}$	S^4_{0}	$S^4_{-4/3}$
d_2	c_1	$S^4_{-4/3}$	$S^4_{4/3}$	$S^4_{-1/3}$	$S^4_{1/3}$	$S^4_{-1/3}$
	c_2	S^4_{0}	$S^4_{1/3}$	$S^4_{1/3}$	S^4_{0}	$S^4_{-4/3}$
	c_3	$S^4_{1/3}$	$S^4_{-1/3}$	S^4_{0}	S^4_{0}	$S^4_{-4/3}$
d_3	c_1	$S^4_{-4/3}$	$S^4_{4/3}$	$S^4_{-1/3}$	$S^4_{1/3}$	S^4_{0}
	c_2	$S^4_{-1/3}$	$S^4_{1/3}$	$S^4_{1/3}$	S^4_{0}	$S^4_{-1/3}$
	c_3	S^4_{0}	$S^4_{-1/3}$	$S^4_{1/3}$	$S^4_{-1/3}$	$S^4_{-4/3}$
d_4	c_1	$S^4_{-1/3}$	$S^4_{1/3}$	S^4_{0}	$S^4_{1/3}$	$S^4_{1/3}$
	c_2	$S^4_{1/3}$	S^4_{0}	$S^4_{4/3}$	S^4_{0}	S^4_{0}
	c_3	$S^4_{1/3}$	$S^4_{-4/3}$	S^4_{0}	$S^4_{-1/3}$	$S^4_{-1/3}$
d_5	c_1	$S^4_{-4/3}$	$S^4_{4/3}$	$S^4_{-1/3}$	$S^4_{4/3}$	S^4_{0}
	c_2	S^4_{0}	$S^4_{1/3}$	$S^4_{1/3}$	$S^4_{1/3}$	$S^4_{-1/3}$
	c_3	$S^4_{1/3}$	S^4_{0}	S^4_{0}	S^4_{0}	$S^4_{-4/3}$

Step 5: The relative importance vector of decision members is aggregated with the preference information of the alternatives by using EWAA operator, and the group preference matrix of the alternatives in various key indicators is obtained, as shown in **Table 4**.

Table 4. The group evaluation matrix of each alternative

	k_1	k_2	k_3	k_4	k_5
c_1	$S_{-0.796}$	$S_{0.796}$	$S_{-0.154}$	$S_{0.544}$	$S_{0.020}$
c_2	$S_{0.144}$	$S_{0.154}$	$S_{0.870}$	$S_{0.010}$	$S_{-0.491}$
c_3	$S_{0.507}$	$S_{-0.631}$	$S_{0.105}$	$S_{-0.144}$	$S_{-1.005}$

Step 6: According to the group evaluation matrix and preference function of the alternatives in Table 4, the preference function value of each pair of alternatives under the corresponding criteria is calculated, and the results are shown in **Table 5**.

Table 5. The preference function value derived by pairwise comparison on alternatives

	k_1	k_2	k_3	k_4	k_5
c_1-c_2	0.000	0.309	0.000	1.000	0.178
c_1-c_3	0.000	1.000	0.000	1.000	0.692
c_2-c_1	0.607	0.000	1.000	0.000	0.000
c_2-c_3	0.000	0.452	1.000	0.000	0.515
c_3-c_1	0.970	0.000	0.000	0.000	0.000
c_3-c_2	0.030	0.000	0.000	0.000	0.000

According to the Equations (6), (7), and (8), the outflow, the inflow and the net flow of each alternative are calculated to be as follows:

$\phi^{+}(c_1) = 0.709$, $\phi^{+}(c_2) = 0.838$, $\phi^{+}(c_3) = 0.275$;

$\phi^{-}(c_1) = 0.721$, $\phi^{-}(c_2) = 0.296$, $\phi^{-}(c_3) = 0.805$;

$\phi(c_1) = -0.012$, $\phi(c_2) = 0.542$, $\phi(c_3) = 0.530$.

Step 7: According to the net flow of each alternative scheme, the advantages and disadvantages are ranked, and the results are $c_1 > c_2 > c_3$.

4. Conclusion

Emergency decision-making in the decline period of emergencies is crucial for the recovery of production and life. In view of the continuous enrichment of information in the process of event processing, decision-makers use the same set of language phrases to represent their own preference information, reducing information loss caused by multiple transformations. The decision method considers the complex relationship between different key indicators and the pros and cons of alternative solutions and selects appropriate evaluation criteria and corresponding preference functions to make the conclusion more consistent with the real situation.

Disclosure statement

The authors declare no conflict of interest.

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