Journal of Architectural Research and Development, 2024, Volume 8, Issue 1
http://ojs.bbwpublisher.com/index.php/JARD
Online ISSN: 2208-3537
Print ISSN: 2208-3529

Research on Public Engineering Emergency Decision-Making Based on Multi-Granularity Language Information

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Abstract: To effectively deal with fuzzy and uncertain information in public engineering emergencies, an emergency decision-making method based on multi-granularity language information is proposed. Firstly, decision makers select the appropriate language phrase set according to their own situation, give the preference information of the weight of each key indicator, and then transform the multi-granularity language information through consistency. On this basis, the sequential optimization technology of the approximately ideal scheme is introduced to obtain the weight coefficient of each key indicator. Subsequently, the weighted average operator is used to aggregate the preference information of each alternative scheme with the relative importance of decision-makers and the weight of key indicators in sequence, and the comprehensive evaluation value of each scheme is obtained to determine the optimal scheme. Lastly, the effectiveness and practicability of the method are verified by taking the earthwork collapse accident in the construction of a reservoir as an example.

Keywords: Public engineering; Emergency; Multi-granularity language; Decision-making

Online publication: January 23, 2024

1. Introduction

The implementation of public projects is affected by various factors such as local social environment, geographical environment, and climatic conditions, which determine the high risk of public project construction [1]. To reduce the loss and negative impact of emergencies, it is necessary to integrate emergency information and limited social resources to quickly achieve the purpose of optimal decision-making. However, the current emergency measures for public engineering emergencies often do not consider the characteristics of public engineering, so it is highly necessary to propose targeted emergency decision-making methods.

After the occurrence of public engineering emergencies, the urgency of time and the massive diffusion of information make it difficult to quickly grasp complete and accurate information, and the highly subjective thinking of decision-makers increases the uncertainty of emergencies [2]. However, traditional decision-making methods cannot effectively solve the uncertainty and fuzziness in decision-making problems. Some literatures introduce fuzzy theory into the decision-making of emergency schemes [3,4], which improves the consistency of decision-making conclusions. However, the use of fuzzy theory must determine the membership function of members, but its rationality is affected. In recent years, with the rapid development of computer technology, relevant theories and methods of multi-objective decision-making have been widely used in the decision-making of emergencies [5]. However, the realization of these methods requires a large amount of data and information as support, which cannot guarantee the timeliness of accident handling.

The existing emergency decision-making methods attempt to get rid of the qualitative analysis of decision-makers and quantify all indicators in emergencies. In fact, due to the characteristics of large scale and long investment cycle of public projects, decision-makers have different understandings of emergencies, and it is challenging to quantify many indicators. In the decision-making process of key indicators and emergency plans, people usually use language phrases such as "unimportant" or "important" to represent their own preferences, which can not only reflect the uncertainty of the judgment object but also avoid the loss of decision information [6]. In addition, due to the influence of decision-makers' experience and understanding ability, decision-makers prefer different language sets. To maximize the use of decision information in uncertain environments, it is necessary for decision-makers to freely choose appropriate language phrase sets. Therefore, the author proposes an emergency decision-making method based on multi-granularity language phrases.

2. Analysis method of construction enterprise emergency plan development

Limited by subjective and objective factors such as complex environment, technical strength, and management support, emergencies occur frequently in the construction of public works, and the factors affecting emergency decision-making are complicated. Decision-makers involved in the evaluation also have different abilities. In actual decision-making, they are more inclined to use language phrases to represent the preference information of key indicators and alternative solutions. Decision-makers may adopt different sets of language phrases. This paper combines multi-granularity language information with TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). According to the relative proximity of each key indicator, the weight is determined. Then, the weighted average operator is used twice to aggregate the importance of decision-makers and the weight of key indicators with the preference information of alternative schemes, and the comprehensive evaluation value of each alternative scheme is obtained.

Step 1: In the process of determining the emergency plan for public engineering emergencies, multi-stakeholders must be invited to form the decision-making team of the emergency plan. These decision-makers have different tasks and relative importance in the decision-making process of the emergency plan. The relative importance vector of decision-makers is obtained by using the analytic hierarchy process. The formulation of an emergency plan involves many factors such as time, cost, and manpower, and the decision-making team determines various key indicators according to the actual situation of the emergency.

Step 2: Decision-makers use appropriate language phrases to give the preference information of each key indicator weight, according to which the evaluation matrix of key indicator weight can be obtained, and the transformation function is used to uniformly transform language phrases of different granularity to obtain the evaluation matrix of the same granularity. For the convenience of evaluation, the set of language phrases used in the evaluation of key indicators is given, as shown in **Table 1**, **Table 2**, and **Table 3**.

Table 1. Linguistic labels with five phrases

Very unimportant	Unimportant	Normal	Important	Very unimportant
S_{-2}^{3}	$S_{-2/3}^{3}$	S_{0}^{3}	$S_{2/3}^{3}$	S_{2}^{3}

Table 2. Linguistic labels with seven phrases

Very unimportant	Unimportant	Less important	Normal	More important	Important	Very unimportant
S_{-3}^{4}	$S_{-4/3}^{4}$	$S_{-1/3}^{4}$	S_{0}^{4}	$S_{1/3}^{4}$	$S_{4/3}^{4}$	S_{3}^{4}

Table 3. Linguistic labels with nine phrases

Extremely unimportant	Very unimportant	Unimportant	Less important	Normal	More important	Important	Very important	Extremely unimportant
S_{-4}^{5}	S_{-2}^{5}	S_{-1}^{5}	$S_{-0.4}^{5}$	S_{0}^{5}	$S_{0.4}^{5}$	S_{1}^{5}	S_{2}^{5}	S_{4}^{5}

Step 3: According to the evaluation matrix with the same granularity, the weight evaluation vector of each key indicator can be listed, and the positive ideal point and negative ideal point of the weight evaluation vector of each key indicator can be determined. Then, the deviation between the weight evaluation vector of each key indicator and the positive and negative ideal points can be calculated by using equations (1) and (2).

$$D_n^+ = \rho_1 D(\lambda_{1n}, u_1^+) \oplus \rho_2 D(\lambda_{2n}, u_2^+) \oplus \dots \oplus \rho_m D(\lambda_{mn}, u_m^+) \quad (1)$$

$$D_n^- = \rho_1 D(\lambda_{1n}, v_1^-) \oplus \rho_2 D(\lambda_{2n}, v_2^-) \oplus \dots \oplus \rho_m D(\lambda_{mn}, v_m^-) \quad (2)$$

Step 4: The relative proximity between the weight evaluation vector of each key indicator and the positive and negative ideal points can be obtained by equation (3).

$$z_j^* = \frac{D_j^-}{D_j^+ + D_j^-} \quad (3)$$

The greater the relative proximity of the key indicator, the higher the weight coefficient of the key indicator. According to equation (4), the weight of each key indicator is determined.

$$\omega_j = \frac{z_j^*}{\sum_{j=1}^{n} z_j^*} \quad (4)$$

Step 5: Decision-makers develop alternatives immediately after an accident and evaluate them accordingly. Decision-makers can obtain the preference matrix of emergency plans by using appropriate language phrases to give the preference information of different emergency plans. The preference matrix with the same granularity is obtained by converting the phrases with different granularity.

Step 6: The weighted average operator is used to aggregate the preference matrix with the same relative importance and granularity of each decision-maker, and the group evaluation matrix of each key index is obtained.

Step 7: The weighted average operator was used to aggregate the weights of key indicators and group evaluation values to obtain the comprehensive evaluation values of each emergency plan, and then sorted according to the comprehensive evaluation values of each emergency plan to determine the optimal plan.

3. Application examples

This section takes the emergency decision of the earthwork collapse accident in the construction of a city reservoir as an example. The main function of this reservoir is flood control, and it integrates various functions such as power generation, irrigation, and shipping. The total amount of earthwork collapse in this accident is 1.68 trillion cubic meters. To ensure personal safety and public property to the maximum extent, the decision-maker should make the right decision quickly and choose the appropriate emergency plan.

Step 1: After the earthwork collapse accident, personnel from relevant government departments (d_1, d_2, d_3) and construction companies (d_4, d_5) should be quickly selected to form a decision-making team, and then the analytic hierarchy process is used to determine the relative importance of each decision-maker as ρ =(0.231, 0.169, 0.189, 0.216, 0.195). The decision-makers identified a key indicator set consisting of the following six factors: the degree of reduction in property losses, the degree of reduction in casualties, the degree of reduction in cost consumption, the degree of matching of available resources, the degree of reduction in the influence of public opinion on evil, and the timeliness of treatment.

Step 2: The key indicators preference information of earthwork collapse accident is given by selecting language phrases according to one's own familiarity with the accident, the language phrase set used by d_1 and d_4 is S^3, the language phrase set used by d_2 and d_5 is S^4, the language phrase set used by d_3 and S^5, and the evaluation matrix of the weight of key indicators is constructed according to the preference information given by decision-makers. The evaluation matrix of key indicator weights was converted to obtain an evaluation matrix with the same granularity. The results are shown in **Table 4**.

Table 4. The evaluation matrix with the same granularity

	t_1	t_2	t_3	t_4	t_5	t_6
d_1	S^4_1	S^4_3	S^4_{-1}	S^4_0	S^4_3	S^4_1
d_2	$S^4_{1/3}$	S^4_3	$S^4_{-1/3}$	S^4_0	$S^4_{4/3}$	S^4_3
d_3	$S^4_{3/4}$	S^4_3	S^4_0	$S^4_{0.3}$	$S^4_{3/2}$	$S^4_{3/2}$
d_4	S^4_1	S^4_3	S^4_{-1}	S^4_0	S^4_1	S^4_1
d_5	$S^4_{4/3}$	S^4_3	$S^4_{1/3}$	S^4_0	$S^4_{1/3}$	$S^4_{4/3}$

Step 3: The positive and negative ideal points of each key index weight evaluation vector can be obtained as $\boldsymbol{u}^+ = (S^4_3, S^4_3, S^4_3, S^4_3, S^4_3)$, $\boldsymbol{v}^- = (S^4_{-1}, S^4_{-1/3}, S^4_0, S^4_{-1}, S^4_0)$. The deviation between the weight evaluation vector of each key indicator and the positive and negative ideal points can be calculated as follows:

$D^+_1 = 0.299$, $D^+_2 = 0$, $D^+_3 = 0.491$, $D^+_4 = 0.421$, $D^+_5 = 0.217$, $D^+_6 = 0.225$.

$D^-_1 = 0.202$, $D^-_2 = 0.578$, $D^-_3 = 0.009$, $D^-_4 = 0.080$, $D^-_5 = 0.285$, $D^-_6 = 0.363$.

Step 4: The relative closeness of each key indicator can be calculated by equation (3), and then its weight coefficient is determined by equation (4).

$\omega_1 = 0.145$, $\omega_2 = 0.360$, $\omega_3 = 0.006$, $\omega_4 = 0.058$, $\omega_5 = 0.205$, $\omega_6 = 0.226$.

Step 5: The decision-makers have made a preliminary analysis of the severity of the incident, and there are several possible emergency plans as follows:

p_1 indicates rescue, and part of the project continues; p_2 means quick rescue, the project temporarily stopped; p_3 indicates that the project will be stopped for a long time.

The preference information of each plan was converted to obtain the emergency alternatives matrix with the same granularity. The results are shown in **Table 5**.

Table 5. The emergency alternatives matrix with the same granularity linguistic scale

		t_1	t_2	t_3	t_4	t_5	t_6
	p_1	S_0^4	S_0^4	S_3^4	S_{-1}^4	S_0^4	S_1^4
d_1	p_2	S_1^4	S_1^4	S_1^4	S_1^4	S_3^4	S_3^4
	p_3	S_1^4	S_1^4	S_{-1}^4	S_1^4	S_1^4	S_3^4
	p_1	S_0^4	$S_{1/3}^4$	S_0^4	$S_{-1/3}^4$	S_0^4	$S_{4/3}^4$
d_2	p_2	$S_{1/3}^4$	$S_{4/3}^4$	$S_{-1/3}^4$	$S_{1/3}^4$	$S_{4/3}^4$	$S_{4/3}^4$
	p_3	$S_{1/3}^4$	$S_{4/3}^4$	$S_{-4/3}^4$	$S_{1/3}^4$	$S_{1/3}^4$	$S_{4/3}^4$
	p_1	S_0^4	S_0^4	$S_{0.3}^4$	S_0^4	$S_{-0.3}^4$	$S_{3/2}^4$
d_3	p_2	$S_{0.3}^4$	$S_{0.3}^4$	$S_{-0.3}^4$	$S_{0.3}^4$	$S_{3/2}^4$	$S_{3/2}^4$
	p_3	$S_{0.3}^4$	$S_{0.3}^4$	$S_{-3/2}^4$	$S_{0.3}^4$	$S_{0.3}^4$	$S_{3/2}^4$
	p_1	S_1^4	S_{-1}^4	S_3^4	S_{-1}^4	S_0^4	S_1^4
d_4	p_2	S_3^4	S_0^4	S_1^4	S_1^4	S_3^4	S_3^4
	p_3	S_3^4	S_0^4	S_{-3}^4	S_1^4	S_0^4	S_3^4
	p_1	S_0^4	S_0^4	$S_{1/3}^4$	$S_{-4/3}^4$	S_0^4	$S_{1/3}^4$
d_5	p_2	$S_{4/3}^4$	$S_{1/3}^4$	$S_{-1/3}^4$	S_0^4	$S_{4/3}^4$	$S_{4/3}^4$
	p_3	$S_{4/3}^4$	$S_{1/3}^4$	$S_{-4/3}^4$	S_0^4	$S_{1/3}^4$	$S_{4/3}^4$

Step 6: The weighted average operator is used to aggregate the preference matrix with the same relative importance and granularity of each decision-maker, and the group evaluation matrix of each key indicator is obtained. The results are shown in **Table 6**.

Table 6. The group evaluation matrix of each key indicator

	t_1	t_2	t_3	t_4	t_5	t_6
p_1	$S_{0.216}^4$	$S_{-0.16}^4$	$S_{1.463}^4$	$S_{-0.763}^4$	$S_{-0.057}^4$	$S_{1.021}^4$
p_2	$S_{1.252}^4$	$S_{0.578}^4$	$S_{0.269}^4$	$S_{0.56}^4$	$S_{2.11}^4$	$S_{2.11}^4$
p_3	$S_{1.252}^4$	$S_{0.578}^4$	$S_{-1.648}^4$	$S_{0.56}^4$	$S_{0.409}^4$	$S_{2.11}^4$

Step 7: The weighted average operator is used to aggregate the weights of each key indicator and the group evaluation matrix of each emergency plan to obtain the comprehensive evaluation value of each emergency plan as $v_1 = 0.157$, $v_2 = 1.333$, $v_3 = 0.923$, and the optimal emergency plan of the accident is p_1.

4. Conclusion

Public engineering has the characteristics of wide construction area, long duration, large investment, and complex technology, which increases unexpected risks. Coupled with the management concept and other reasons, emergencies occur frequently, and the situation is severe. Scientific and effective emergency decision-making method is proposed as an effective way to deal with public engineering emergencies. The language decision-making method is introduced into the decision-making process of public engineering emergencies. The use of language variables to represent the preference information of key indicators and emergency plans fully reflects the complexity of public projects and considers the differences among decision-makers to avoid the loss of decision information.

Disclosure statement

The authors declare no conflict of interest.

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