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Research on Determining the Weights of Key Influencing Factors Based on Multi-Grained Binary Semantics

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Abstract: To effectively address the complexity of the environment, information uncertainty, and variability among decision-makers in the event of an enterprise emergency, a multi-granularity binary semantic-based emergency decision-making method is proposed. Decision-makers use preferred multi-granularity non-uniform linguistic scales combined with binary semantics to represent the evaluation information of key influencing factors. Secondly, the weights were determined based on the proposed method. Finally, the proposed method's effectiveness is validated using a case study of a fire incident in a chemical company.

Keywords: Multi-grained binary semantics; Emergency; Key influencing factor

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1. Introduction

As the frequency of various emergencies in enterprises continues to rise, there is an increasing demand to enhance emergency management capabilities, particularly in emergency decision-making, to mitigate disaster occurrences and control the impact scope of accidents. Generally, the analysis of emergency decision-making methods consists of three stages: identifying the key influencing factors of emergency decision-making methods, obtaining the weight values of each key influencing factor, and determining the feasibility of various emergency decision-making schemes to select the optimal one. Currently, the research outcomes of the first stage have gained widespread recognition within the academic community, and therefore, the focus of research on emergency decision-making methods typically concentrates on the latter two stages. However, emergencies in enterprises often exhibit high levels of unpredictability and urgency. Traditional enterprise emergency management usually relies on pre-established plans for decision-making, making it difficult to achieve scientifically effective emergency preparedness during crises [1]. Consequently, decision-making teams need to rapidly develop response plans and select the optimal one. This paper will also emphasize determining the weight values of key influencing factors and selecting the optimal plan.

In addressing practical problems, due to the complexity and fuzziness of decision environments, evaluations are often difficult to express precisely with numerical values. Therefore, Herrera and Martinez first proposed using binary semantic representation for evaluation information and defining operational rules and integration operators for binary semantics [2]. This model consists of a linguistic term and a real number within the range of [-0.5, 0.5), effectively reducing information loss during computation. The binary semantic representation model allows decision-makers to express preference information more accurately in complex decision scenarios, thus holding significant theoretical and practical value.

To enhance the rationality of emergency decision-making methods, the process by which decision-making teams and experts express their preference information is crucial. The use of linguistic variable scales to convey preference information is widely regarded as an effective way to gather information, as it converts the linguistic forms used by decision-makers into concrete linguistic evaluation scales, thereby ensuring that the final decision outcomes are more aligned with the actual circumstances.

To address the issues inherent in traditional cybersecurity, Wang proposed a cybersecurity situational assessment model based on binary semantic analysis [3]. By incorporating binary semantic analysis and sequential relationship analysis, this model significantly enhances the accuracy of cybersecurity situational assessments. Chen *et al.* developed an enhanced quality function deployment model that integrates hesitant fuzzy binary semantic variables, the best-worst method, and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [4]. This model aims to address the shortcomings of traditional methods in expert evaluations, customer needs, and the prioritization of engineering characteristics. Additionally, Zhao constructed a group decision-making model based on intuitionistic binary semantics, combining the rapid qualitative assessment features of binary semantic evaluations with the ability of intuitionistic fuzzy sets to reflect both positive and negative attitudes of experts [5].

Based on the above considerations, given the uncertainty and fuzziness of emergencies in enterprises, and the frequent difficulty in achieving consensus among decision-making departments and stakeholders, a multi-granularity language allows each decision-making entity to fully express their preferences [6]. Binary semantics, on the other hand, can reduce information loss in complex environments, enabling decision-makers and departments to promptly grasp critical information and select emergency solutions that satisfy all stakeholders with Prospect Theory. Therefore, proposing a multi-granularity binary semantic-based decision-making method is crucial for addressing sudden corporate emergencies.

2. Emergency influencing factors determination methods

In the process of emergency decision-making, formulating appropriate contingency plans requires assessing the impact levels of key influencing indicators and subsequently allocating limited resources accordingly. However, in complex environments, decision-makers often face severe constraints on the availability of information. To fully leverage the subjectivity of decision-makers and minimize information loss during computation, this paper proposes a method for determining weights based on multi-granularity binary semantic deviation.

(1) Step 1: After a business emergency occurs, relevant departments and responsible individuals select

suitable personnel to form an emergency decision-making group. Considering that the influence of each participating member on the decision outcome varies, each decision member selects from a preferred linguistic scale set the granularity that best represents the relative importance of other decision members. Then, the language information of different granularities is transformed into equivalent language assessment information. This yields the assessment matrix corresponding to the relative importance among decision members. Therefore, the calculation formula for the relative importance coefficient of the decision member is:

$$\rho M_1 = \frac{\sum_{M1=1}^{m} g_{M_1 M_2}}{\sum_{M_1=1}^{m} \sum_{M_2=1}^{m} g_{M_1 M_2}} \quad (1)$$

(2) Step 2: The emergency decision-making group, through discussion and considering practical circumstances and the members' experiences, identifies several key impact indicators with significant influence levels. Similarly, the unpredictability of environmental information during a business emergency event leads to varying interpretations among decision-makers. Each member selects a suitable linguistic assessment granularity to express their preferences. Subsequently, these consistent granularity assessments of key indicators were converted into a binary semantic information matrix.

(3) Step 3: Based on the binary semantic information matrix of consistent granularity key indicators, we can formulate the binary semantic evaluation vector σ_i for each key indicator. Using **Equation (2)** and **Equation (3)**, the positive expectation point and the negative expectation point of the key indicators can be determined.

$$D_n^+ = \rho M_1 D\{\sigma_{1n}, u_1^+\} + D\{\sigma_{2n}, u_2^+\} + \ldots + D\{\sigma_{mn}, u_m^+\} \quad (2)$$

$$D_n^- = \rho M_1 D\{\sigma_{1n}, u_1^-\} + D\{\sigma_{2n}, u_2^-\} + \ldots + D\{\sigma_{mn}, u_m^-\} \quad (3)$$

(4) Step 4: The relative closeness of each key indicator can be computed by using **Equation (4)**. If the relative closeness is higher, then the weight coefficient of the key indicator will be higher. Finally, the weight of each key indicator can be determined by using **Equation (5)**.

$$Z_i = \frac{D_n^-}{D_n^+ + D_n^-}, \quad (4)$$

$$W_i = \frac{z_i}{\sum_{i=1}^{n} z_i}, \quad (5)$$

3. Examples and analysis of results

This section uses the emergency response decision-making of a chemical enterprise following a fire accident as an example to illustrate the feasibility of the methods proposed in this paper. The chemical enterprise primarily engages in research, development, production, sales, and service related to chemical raw materials, chemical products, and chemical equipment. The fire in question covered an area of approximately 240 m^2, threatening the safety of 132 individuals and substantial property. Following the fire incident, to maximize employee safety and protect property effectively during fire emergencies, decision-makers must promptly make rational decisions to select the most influencing factors.

(1) Step 1: Immediately following the occurrence of the fire emergency at the enterprise, a response team was formed, comprising personnel selected from relevant government departments and chemical companies. Considering that the influence of each member on the decision outcome varies, as does

their perception of local conditions and subsequent impacts, each decision-maker selected a linguistic granularity suitable for expressing the relative importance of other decision-makers. Specifically, members A_1, A_4, and A_5 select a seven-granularity linguistic set, A_2 choose a nine-granularity set, and A_3 select a five-granularity set. Then the preference information was utilized to convert preference linguistic assessments from different granularities into uniform linguistic assessment information. The relative importance weights of each decision-making member were calculated by using **Equation (1)** as ρ = (0.173, 0.235, 0.200, 0.124, 0.268).

(2) Step 2: To make reasonable and effective decisions, decision-makers need to identify key indicators and their weights. The emergency decision-making group, based on the actual situation and relevant information of the chemical plant fire, identified the critical factors affecting this incident: maximum protection of personal safety, minimizing property losses to the greatest extent, faster and more rational allocation of emergency supplies, minimizing public opinion impact to the maximum extent, faster response time to the event, and better prevention of secondary explosions or fires of chemical products. Similarly, each decision-maker provided preference information on key indicators based on their familiarity with the accident, using suitable language granularity. Subsequently, the preference information was used to transform the assessment information matrix of key indicators into an information assessment matrix with seven granularities of linguistic sets, the obtained assessment matrix of key indicator information with the same granularity was transformed into a binary semantic matrix, as shown in **Table 1**.

Table 1. Binary semantic information matrix of key indicators with the same granularity

	t_1	t_2	t_3	t_4	t_5	t_6
A_1	$(s_3^4,0)$	$(s_0^4,1/3)$	$(s_0^4,1/3)$	$(s_0^4,1/3)$	$(s_3^4,0)$	$(s_1^4,1/3)$
A_2	$(s_3^4,0)$	$(s_1^4,-1/4)$	$(s_1^4,-1/4)$	$(s_0^4,0)$	$(s_1^4,-1/4)$	$(s_1^4,1/2)$
A_3	$(s_3^4,0)$	$(s_1^4,0)$	$(s_1^4,0)$	$(s_1^4,0)$	$(s_0^4,1/2)$	$(s_0^4,1/2)$
A_4	$(s_3^4,0)$	$(s_1^4,1/3)$	$(s_0^4,1/3)$	$(s_0^4,1/3)$	$(s_1^4,1/3)$	$(s_0^4,1/3)$
A_5	$(s_3^4,0)$	$(s_0^4,1/3)$	$(s_1^4,1/3)$	$(s_0^4,1/3)$	$(s_1^4,1/3)$	$(s_1^4,1/3)$

(3) Step 3: Based on the binary semantic information matrix of key indicators with the same granularity, the binary semantic evaluation values λ_j for each key indicator can be listed as provided by different decision-makers.

$\lambda 1 = [(S_3^4,0), (S_3^4,0),(S_3^4,0),(S_3^4,0), (S_3^4,0)]$;

$\lambda 2 = [(S_0^4,1/3),(S_1^4,-1/4),(S_1^4,0),(S_1^4,1/3),(S_0^4,1/3)]$;

$\lambda 3 = [(S_0^4,1/3),(S_1^4,-1/4),(S_1^4,0),(S_0^4,1/3),(S_1^4,1/3)]$;

$\lambda 4 = [(S_0^4,1/3),(S_0^4,0),(S_1^4,0);(S_0^4,1/3),(S_0^4,1/3)]$;

$\lambda 5 = [(S_3^4,0),(S_1^4,-1/4),(S_0^4,1/2),(S_1^4,1/3),(S_1^4,1/3)]$;

$\lambda 6 = [(S_1^4,1/3),(S_1^4,1/2),(S_0^4,1/2),(S_0^4,1/3),(S_1^4,1/3)]$.

Based on **Equation (2)** and **Equation (3)**, the positive expected value and negative expected value of the binary semantic evaluation for each key indicator can be determined as:

$u^+ = [(S^4_3,0), (S^4_3,0),(S^4_3,0),(S^4_3,0), (S^4_3,0)]$, $v^- = [(S^4_0,1/3),(S^4_0,0),(S^4_0,1/2),(S^4_0,1/3),(S^4_0,1/3)]$

(4) Step 4: The relative closeness of each key indicator can be computed by using **Equation (4)** as $Z_1 = 1$, $Z_2 = 0.211$, $Z_3 = 0.253$, $Z_4 = 0.091$, $Z_5 = 0.370$, $Z_6 = 0.225$. Finally, the weight of each key indicator can be determined by using **Equation (5)** as $w_1 = 0.465$, $w_2 = 0.098$, $w_3 = 0.118$, $w_4 = 0.042$, $w_5 = 0.172$, $w_6 = 0.105$.

4. Conclusion

To effectively respond to unexpected events in enterprises, it is essential to integrate the preference information of various decision-makers and to develop and select appropriate emergency decision-making solutions within a short timeframe. This paper proposes an enterprise emergency decision-making method based on multi-granularity binary semantics. The method employs multi-granularity binary semantics to derive the weights of various key influencing factors through the use of deviation values. Emergency decision-making in enterprises is often spontaneous, characterized by uncertainty in the decision-making environment and variability among decision-making members. The use of multi-granularity binary semantics for evaluation can effectively reduce information distortion and maximize the utilization of each decision-maker's experiential advantages. This approach ensures that the resulting decisions are more aligned with both the environmental context and the opinions of the decision-making members.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wang ZQ, Chen ZS, Garg H, et al., 2022, An Integrated Quality-Function-Deployment and Stochastic-Dominance-Based Decision-Making Approach for Prioritizing Product Concept Alternatives. Complex & Intelligent Systems, 8(3): 2541–2556.

[2] Herrera F, Martinez L, 2000, An Approach for Combining Linguistic and Numerical Information Based on the 2-Tuple Fuzzy Linguistic Representation Model in Decision-Making. International Journal of Uncertainty. Fuzziness and Knowledge-Based Systems, 8(05): 539–562.

[3] Wang H, Xin YJ, Deveci M, et al., 2024, Leveraging Online Reviews and Expert Opinions for Electric Vehicle Type Prioritization. Computers & Industrial Engineering, 197(11): 110579.

[4] Chen ZS, Zhu Z, Wang XJ, et al., 2023, Multiobjective Optimization-Based Collective Opinion Generation with Fairness Concern. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 53(9): 5729–5741.

[5] Zhao S, Dong Y, Wu S, et al., 2021, Linguistic Scale Consistency Issues in Multi-Granularity Decision Making Contexts. Applied Soft Computing, 101: 107035.

[6] Zheng Y, Xu Z, Tian Y, 2022, Granular Computing and Optimization Model-Based Method for Large-Scale Group Decision-Making and its Application. Economic Research-Ekonomska Istraživanja, 35(1): 5221–5252.