Journal of World Architecture, 2023, Volume 7, Issue 6
https://ojs.bbwpublisher.com/index.php/JWA
Online ISSN: 2208-3499
Print ISSN: 2208-3480

The Evaluation of Risk-Based Resource Allocation Alternatives Based on Fuzzy Information Axiom

Jie Yu[1]*, Yuliang Wang[2]

[1]Chongqing Construction Residential Engineering CO., LTD., Chongqing 400000, China
[2]School of Public Administration, Southwest Jiaotong University, Chengdu 610000, Sichuan Province, China

***Corresponding author:** Jie Yu, wzqlinger@163.com

Abstract: This paper presents an analysis of the challenges in risk-based resource allocation in engineering projects. Subsequently, an alternative resource allocation evaluation method based on language information and information axioms is proposed. Firstly, the evaluation team uses language information to give the evaluation information of the alternatives of risk resource allocation and provides the corresponding expected information for each resource. Secondly, according to the transformation formula of language information and fuzzy numbers, the above information is transformed into the evaluation information and expected information of the alternatives of risk-based resource allocation. Thirdly, according to the transformation formula of language information and fuzzy numbers, the above information is transformed into evaluation information and expectation information of alternative risk resource allocation. Finally, according to the information amount of each risk resource and the corresponding weight, the comprehensive information amount of the expected risk-based resource allocation alternatives is determined.

Keywords: Engineering project; Risk assessment; Language information; Fuzzy information axiom

Online publication: December 26, 2023

1. Introduction

China's government has launched several projects in order to further promote economic development and technological innovation. However, large-scale engineering projects will not only drive economic and social development but also lead to various risks [1]. If resources cannot be allocated reasonably, it will greatly affect the efficiency of the risk investigation and management of a project and may also lead to the waste of resources [2]. Therefore, it is important to improve resource assurance to realize effective risk-based resource allocation.

Many scholars have put forward many different methods of risk-based resource allocation of engineering projects, and have obtained good results. The commonly used methods include data envelopment analysis, fuzzy analytic hierarchy process, fuzzy network analysis, case-based reasoning, stochastic programming model, and assessment method based on Vague set similarity [3-5].

Further consideration should be focused on evaluating risk-based resource allocation alternatives for major engineering projects, considering linguistic index expectations. This involves members providing strategic expectations for various resource risks based on the actual resource proficiency of production enterprises. These expectations play a crucial role in selecting risk-based resource allocation alternatives for key engineering projects [6]. Representing the resource-based allocation expectation in the evaluation and decision-making process for risk resource allocation alternatives in major engineering projects is typically challenging to depict using precise mathematical information. Evaluation members often rely on subjective assessments in such cases [7]. In view of the above characteristics, the evaluation members are more inclined to use language information to represent the preference information of a certain resource allocation. This paper proposes a risk-based resource allocation evaluation method for major engineering projects based on fuzzy information axioms, aiming at evaluating risk-based resource allocation alternatives for major engineering projects considering language expectations.

2. Proposed approach

2.1. The conversion of language information

Fuzzy mathematics is used to convert qualitative language information description and quantitative value, that is, the membership function is used to calculate the information content of the qualitative index. The formula for converting language information into triangular fuzzy numbers is shown in Equation (1).

$$\tilde{l}_q = (l_p^1, l_p^2, l_p^3) = \left[max\left\{\frac{q-1}{t}, 0\right\}, \frac{q}{t}, min\left\{\frac{q+1}{t}, 0\right\}\right], q \in \{0, 1, \ldots, t\} \tag{1}$$

In order to highlight the research priority of this paper and facilitate a smooth follow-up evaluation, it is assumed that the decision-makers involved in the allocation of risk resources for major engineering projects have the same importance. According to Equation (1), the expected information of an indicator given by an expert group in language form is converted into a triangular fuzzy number. The membership function of a triangular fuzzy number is defined as Equation (2).

$$u_j^E(x) = \begin{cases} \frac{x-e_j^1}{e_j^2-e_j^1}, & e_j^1 \le x \le e_j^2 \\ \frac{e_j^3-x}{e_j^3-e_j^2}, & e_j^2 \le x \le e_j^3, \quad j \in N \\ 0, & Others \end{cases} \tag{2}$$

Similarly, according to Equation (1), the linguistic word evaluation information given by the expert group for the alternative of indicators is converted into triangular fuzzy numbers. The membership function of triangular fuzzy number is defined as Equation (3).

$$u_{ij}^p(x) = \begin{cases} \frac{x-p_{ij}^1}{p_{ij}^2-p_{ij}^1}, & p_{ij}^1 \le x \le p_{ij}^2 \\ \frac{p_{ij}^3-x}{p_{ij}^3-p_{ij}^2}, & p_{ij}^2 \le x \le p_{ij}^3, \quad i \in M, j \in N \\ 0, & Others \end{cases} \tag{3}$$

2.2. Calculation of risk allocation alternative information

After transforming the expected information and evaluation information in the form of language information into triangular fuzzy numbers, let S_j^E be the expectation for this risk resource, whose calculation formula is defined as Equation (4). Let S_{ij}^P be the actual performance of the risk resource, whose calculation formula is defined as Equation (5). Let S_{ij} be the intersection of S_j^E and S_{ij}^P or the common range, in which the calculation formula is defined as Equation (6).

$$S_j^E = \int_{-\infty}^{+\infty} u_j^E(x)dx = \int_{e_j^1}^{e_j^2} \frac{x-e_j^1}{e_j^2-e_j^1}dx + \int_{e_j^2}^{e_j^3} \frac{e_j^3-x}{e_j^3-e_j^2}dx = \frac{e_j^3-e_j^1}{2} \tag{4}$$

$$S_{ij}^P = \int_{-\infty}^{+\infty} u_{ij}^P(x)dx = \int_{p_{ij}^1}^{p_{ij}^2} \frac{x-p_{ij}^1}{p_{ij}^2-p_{ij}^1}dx + \int_{p_{ij}^2}^{p_{ij}^3} \frac{p_{ij}^3-x}{p_{ij}^3-p_{ij}^2}dx = \frac{p_{ij}^3-p_{ij}^1}{2}\ (i \in M, j \in N) \tag{5}$$

$$S_{ij} = \begin{cases} 0, & p_{ij}^3 \le e_j^1 \\ \int_{e_j^1}^{\phi} \frac{x-e_j^1}{e_j^2-e_j^1}dx + \int_{\phi}^{p_{ij}^3} \frac{p_{ij}^3-x}{p_{ij}^3-p_{ij}^2}dx, & e_j^1 \le p_{ij}^3 \le e_j^3 \\ S_j^E, & p_{ij}^3 > e_j^3 \end{cases} \tag{6}$$

Let $\emptyset$ be the mapping on the X-axis of the intersection points on the boundary line of the expected range and the actual range, of which the calculation formula is defined as Equation (7).

$$\phi = \frac{e_j^2 p_{ij}^3 - e_j^1 p_{ij}^2}{e_j^2 - e_j^1 + p_{ij}^3 - p_{ij}^2}(i \in M, j \in N) \tag{7}$$

Finally, the amount of information for risk allocation alternatives is calculated using Equation (8).

$$I_{ij} = \begin{cases} \infty, & p_{ij}^3 \le e_{ij}^1 \\ log_2\left(\frac{S_{ij}^P}{S_{ij}}\right) & e_{ij}^1 \le p_{ij}^3 \le e_j^3 \\ 0, & e_j^3 > p_{ij}^3 \end{cases} \tag{8}$$

2.3. Prioritization of risk resource allocation alternatives

For the new set of alternative risk resource allocation alternatives, the comprehensive information of the new alternative is determined according to the information under resource risks and the weight of resource risks, which is calculated using Equation (9).

$$I_k = \sum_{j=1}^{n} w_j I_{kj}\ , k \in NN \tag{9}$$

Therefore, risk-based resource allocation alternatives can be sorted according to the size of the comprehensive information, in which the alternative with the smaller comprehensive information is the optimal alternative.

3. Application example

A hydroelectric station was built in a specific area in southwest China in order to make full use of the water resources. After extensive research and continuous communication with the decision-making authorities, the evaluation team identified seven resources crucial for risk management in production enterprises: communication and information, skilled human resources, material and equipment, financial support, technical expertise, healthcare provisions, and other resources. Seven alternatives of risk-based resource allocation plans are devised by the evaluation team concerning the project's risk management. The team's objective is to select the most optimal plan among the seven alternatives to enhance the efficiency of project risk management.

Step 1: The team member gives the expectation of seven resources and the evaluation value of each attribute in the form of language information. The language information scale adopted in this example is as follows: $L = (l_0, l_1, l_2, l_3, l_4)$ = {*very bad*(*VL*), *bad*(*L*), *medium*(*M*), *good*(*H*), *very good*(*VH*)}(10)

According to the actual situation, the evaluation team uses the specified language information scale to evaluate 7 alternative risk-based resource allocation alternatives and then builds the evaluation matrix of risk resource allocation alternatives, which are shown in **Table 1**.

Table 1. Preference information of risk resource allocation alternatives

	O_1	O_2	O_3	O_4	O_5	O_6	O_7
A_1	*M*	*H*	*H*	*H*	*H*	*VH*	*L*
A_2	*H*	*VH*	*H*	*L*	*M*	*H*	*L*
A_3	*H*	*M*	*VH*	*H*	*H*	*VH*	*H*
A_4	*M*	*H*	*H*	*H*	*M*	*VH*	*H*
A_5	*M*	*L*	*M*	*L*	*L*	*M*	*H*
A_6	*H*	*H*	*M*	*M*	*VH*	*M*	*L*
A_7	*M*	*L*	*VH*	*H*	*VH*	*H*	*M*

The weights of each risk resource can be determined by the analytic hierarchy process, which is W = (0.11, 0.21, 0.16, 0.15, 0.14, 0.10, 0.13).

The preference information given by decision members is transformed into triangular fuzzy numbers by Equation (1), which are shown in **Table 2**.

Table 2. The language information and corresponding triangular fuzzy number

Language information	Triangular fuzzy number
VL	(0.00,0.00,0.25)
L	(0.00,0.25,0.50)
M	(0.25,0.50,0.75)
H	(0.50,0.75,1.00)
VH	(0.75,1.00,1.00)

The expected information in the form of language information given by the evaluation members is converted into the form of triangular fuzzy numbers.

Step 2: The expectation, the actual performance, and the common range of each resource risk can be determined by Equations (4), (5), and (6). The mapping on the *x*-axis of the intersection points on the boundary line of the expected range and the actual range can be determined by Equation (7). The information amount of risk allocation alternatives can be obtained by Equation (8), as shown in **Table 3.**

Table 3. The information amount of each alternative corresponding to risk resources

	O_1	O_2	O_3	O_4	O_5	O_6	O_7
A_1	2	0	0	0	0	0	2
A_2	0	0	0	2	2	0	2
A_3	0	2	0	0	0	0	0
A_4	2	0	0	0	2	0	0
A_5	2	∞	2	2	∞	2	0
A_6	0	0	2	0	0	2	2
A_7	2	∞	0	0	0	0	0

According to **Table 3**, the information amount of the alternative fails to meet the expectations of evaluation members completely. Similarly, it can be seen that the alternative cannot meet expectations. Therefore, the alternative and should be removed from the set to build a new set of risk resource allocation alternatives.

Step 3: According to the information amount of each risk resource and its corresponding weight, the comprehensive information amount of the risk resource allocation alternatives is determined by Equation (9), as shown in **Table 4**.

Table 4. The comprehensive information amount of each alternative

	A_1	A_2	A_3	A_4	A_6
I_j	0.48	0.84	0.42	0.50	0.78

The priority of the risk resource allocation alternatives could be defined by the comprehensive information amount as . Therefore, the risk-based resource allocation alternative is determined as the optimal alternative.

4. Conclusion

Aiming at the problem of resource allocation evaluation alternatives of engineering projects considering various resource risk expectations, this paper proposes a method of risk-based resource allocation alternative evaluation of major engineering projects based on language information and information axioms. The method first takes the expectation information and evaluation information of risk resources in the form of language information as the initial information. Secondly, the language information are converted into triangular fuzzy numbers, and the area of triangular fuzzy numbers is calculated. Thirdly, the information of each program in each resource risk is calculated and the program that does not meet the expectation is eliminated. Lastly, the comprehensive information on the remaining alternatives is calculated and prioritized. Considering the limited resources of production enterprises, the evaluation team usually has an expectation for the allocation of resource risks. Therefore, the risk-based resource allocation alternative evaluation method based on language information and information axioms proposed in this study has practical application value.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Hienuki S, Noguchi K, Shibutani T, et al., 2020, Risk Identification for the Introduction of Advanced Science and Technology: A Case Study of a Hydrogen Energy System for Smooth Social Implementation. International Journal of Hydrogen Energy, 45(30): 15027–15040.

[2] Nguyen S, Chen SL, Du Y, et al., 2019, A Quantitative Risk Analysis Model with Integrated Deliberative Delphi Platform for Container Shipping Operational Risks. Transportation Research Part E: Logs and Transportation Review, 129(9): 203–227.

[3] Dong Y, Zhao S, Zhang H, et al., 2018, A Self-Management Mechanism for Noncooperative Behaviors in Large-Scale Group Consensus Reaching Processes. IEEE Transactions on Fuzzy Systems, 26(6): 3276–3288.

[4] Cheng D, Cheng F, Zhou Z, et al., 2020, Reaching A Minimum Adjustment Consensus In Social Network Group Decision-Making. Information Fusion, 59(7): 30–43.

[5] 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.

[6] Ma Z, Zhu J, Kumaraswamy P, et al., 2019, A Clustering Method for Large-Scale Group Decision-Making with Multi-Stage Hesitant Fuzzy Linguistic Terms. Information Fusion, 50(10): 231–250.

[7] Huang H, Liu L, Parker G, et al., 2019, Multi-Attribute Procurement Auctions in the Presence of Satisfaction Risk. Production and Operations Management, 28(5): 1206–1221.