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An Improved Multilevel Fuzzy Comprehensive Evaluation to Analyse on Engineering Project Risk

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Abstract

Purpose: To overcome the question that depends too much on expert's subjective judgment in traditional risk identification, this paper structure the multilevel generalized fuzzy comprehensive evaluation mathematics model of the risk identification of project, to research the risk identification of the project. **Research design, data and methodology:** This paper constructs the multilevel generalized fuzzy comprehensive evaluation mathematics model. Through iterative algorithm of AHP analysis, make sure the important degree of the sub project in risk analysis, then combine expert's subjective judgment with objective quantitative analysis, and distinguish the risk through identification models. Meanwhile, the concrete method of multilevel generalized fuzzy comprehensive evaluation is probed. Using the index weights to analyse project risks is discussed in detail. **Results:** The improved fuzzy comprehensive evaluation algorithm is proposed in the paper, at first the method of fuzzy sets core is used to optimize the fuzzy relation matrix. It improves the capability of the algorithm. Then, the method of entropy weight is used to establish weight vectors. This makes the computation process fair and open. And thereby, the uncertainty of the evaluation result brought by the subjectivity can be avoided effectively and the evaluation result becomes more objective and more reasonable. **Conclusions:** In this paper, we use an improved fuzzy comprehensive evaluation method to evaluate a railroad engineering project risk. It can give a more reliable result for a reference of decision making.

Keywords: Fuzzy mathematics, Project risk, Fuzzy assessment, Improved multilevel fuzzy comprehensive

JEL Classification Code: B17, C11, B26

1. Introduction

The construction industry, perhaps more than others, has been plagued by various risks often resulting in poor performance with increasing costs and time delay, even project failure (Krechowicz, 2020; Burkov et al., 2018).The nature of construction has made it a challenging regime to handle risks, e.g. constant change on building environment, direct exposure to hazardous sources, high pressure on demanding schedules and costs, and increasing complexity on construction techniques (Healy & Judith, 2016; Song et al., 2022).Construction risk analysis, especially at the early stages of the project, is intricate because the nature of risk is usually affected by numerous factors including human error and the data and information available. In many circumstances, it may be extremely difficult to assess the risks associated with a project due to the great uncertainty involved. Many risk assessment techniques currently used

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in the UK construction industry are comparatively mature, such as Fault Tree Analysis, Event Tree Analysis, Monte Carlo Analysis, Scenario Planning, Sensitivity Analysis, Failure Mode and Effects Analysis, Program Evaluation and Review Technique (Shibani et al., 2021). Nevertheless, for effective applications of these sophisticated quantitative techniques, high quality data are a prerequisite (Lin et al., 2021). Regrettably, such data are hard to obtain or even have not existed in the construction industry. Moreover, they are difficult to address the uncertainties and subjectivities associated with construction activities. It is therefore essential to develop new risk analysis methods to identify and assess construction risks in an acceptable way where any risk information produced is processed and reliably applied to decision making in the project management.

2. Literature Review

Risk management is a critical part of project management as 'unmanaged or unmitigated risks are one of the primary causes of project failure edition (Ullah et al., 2021). While numerous papers have been written on the subject of risk management (Munawar et al., 2022). Many approaches have been suggested in the literature for classifying risks. Perry and Hayes (1985) give an extensive list of factors assembled from several sources, and classified in terms of risks retainable by contractors, consultants, and clients. Parsaei Motamed et al. (2022) classify risks into the two major groupings of primary and secondary risks according to their nature and magnitude. Grouping risks into the two major groupings of primary and secondary risks. Tah et al. (1993) use a risk-breakdown structure to classify risks according to their origin and to the location of their impact in the project. This study takes the railroad engineering project for the application of the proposed method.

3 . An I mproved M ultilevel F uzzy C omprehensive Evaluation Algorithm

During the computation process of fuzzy comprehensive evaluation, the rational establishment of fuzzy relation of matrix R and the weight vector A, has a great influence on the final evaluation result. The fuzzy relation attained from the method of expert evaluation and fuzzy statistics has the characteristics of subjectivity and deficiency. Similarly, weight admeasurements with the method of expert consultation and evaluation (Delphi) cannot satisfy the accuracy requirement (He Xin-gui, 1998). At present, the method of AHP is often used in weight computation, which is just a more mathematical disposal of the expert's subjective estimation. Although it makes the evaluation more scientific, the deficiency of the expert's experience and knowledge still exists. Thereby this article uses an improved fuzzy comprehensive evaluation to gain the rational optimization of fuzzy relation matrix and the accurate admeasurements of weights. The method of fuzzy sets core has been used here, to optimize the fuzzy relation matrix and that of entropy weight to establish weight vectors (Zadeh & Lotfi, 1999).

3.1. Evaluation Matrix

Let the set of m factors considered in evaluation be U = (u1,u2 , ...,um). Let the set of n comments be V = [v1 ,v2, ... ,vn]. With rij presenting the grade of membership of factor ui aiming at comment vj, the fuzzy relation between factor full sets and comment full sets can be described by the evaluation matrix R:

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{3n} \\ \vdots & \vdots & & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{1}$$

Where $0 \le r_{ij} = \mu_R(u_i, v_j) \le 1,\ i=1,2,...m; j=1,2,...,n$

3.2. Optimization of Fuzzy Relation Matrix

Let U be the limitary and measurable set of real number region S. The core of membership function, which belongs to the fuzzy set D of U can be defined as: Optimization of fuzzy relation matrix.

$$G_D = \frac{\int_D \mu_D(x) x \mathrm{d}x}{\int_D \mu_D(x) \mathrm{d}x} \tag{2}$$

Where $\int_D \mu_D(x) \mathrm{d}x \neq 0$

Especially when the full set $U = \{x_1, x_2, ..., x_n\} \subset S$

$$G_D = \frac{\sum_{i=1}^{n} \mu_D(x) x}{\sum_{i=1}^{n} \mu_D(x)} \tag{3}$$

Where $\sum_{i=1}^{n} \mu_D(x) \neq 0$

The core, as an inherent attribute of fuzzy set, depicts the place where the membership function of the fuzzy set concentrates together in the full set U. Therefore, the core of the fuzzy set can be used to describe the admeasurements of the membership function. The method of comprehensive evaluation based on fuzzy set core can be used to optimize the fuzzy relation matrix, which can reflect the advantages and disadvantages of various factors objectively. This is because the larger the core the more praise comments its factor will gain. and the more praise comments it gains, the better the factor will be and vice versa.

3.3. The Method of' Entropy Weight

The idea of entropy comes from thermodynamics (Qiu Pei-liang, 1999). Introduced into informatics by Shannon, it is used as a measurement for uncertainty: the more the information, the less the uncertainty. Then the entropy will also be less and vice versa. Here entropy represents the uncertainty of factors that satisfy the comments. The adjustment of weights will be based on the membership function in this article.

In the evaluation issue including m evaluation factors and n comments (it is called the (m,n) evaluation issue), the entropy of an evaluation factor i can be defined as:

$$H_i = -k\sum_{j=1}^{n} r_{ij} \ln r_{ij}, \quad i = 1,2,...,m \tag{4}$$

where $k = (\ln n)^{-1}$.

It is assumed that when $r_{ij} = 0, r_{ij} \ln r_{ij} = 0$.

And in the (m. n) evaluation issue, the entropy weight of the evaluation factor i can be defined as:

$$\omega_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{5}$$

Where $0 \le \omega_i \le 1, \sum_{i=1}^{m} \omega_i = 1$

4. Model of Project Risk

4.1 Index Selecting

It is expected that as the experience of a company gets higher, the manageability of risk factors increases, thus, impact of risk retained by the company may be lower when compared with that of another company having no experience. Similarly, favorable contract conditions may decrease the cost overrun risk. For example, although economic environment is poor and inflation is unpredictable in the future, an escalation formula that is used to adjust the current prices according to actual inflation rate may decrease the risk retained by the company. Similarly, level of project risk depends on construction risk, design risk, payment risk, client risk and subcontractor risk. The influencing factors are defined as experience of the company in similar projects and existing contract clauses about project risk. Committee members state that they did not have any problems in understanding the risk model as the influence diagram provides an effective visual representation of the risk model. However, we would like to note that, risk factors and influencing factors are by no means exhaustive, therefore, new factors may be added according to different company needs. Finally, experts rated the risk factors as well as the influencing factors given in the risk model considering the project and country conditions and company capabilities based on their personal judgment. In this paper thirteen evaluation factors from various aspects are colligated and the evaluation model in Figure.1 is constructed:

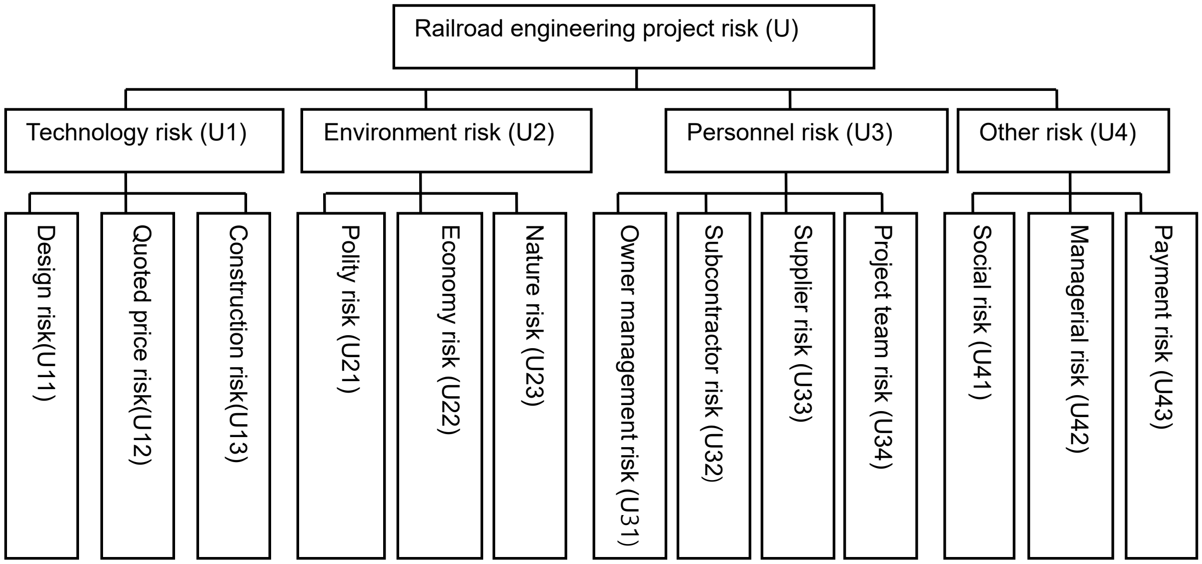

Figure 1: Railroad engineering project risk influence factors hierarchical structure

4.2. Realization of the Improved Algorithm

As Personnel risk is the most important in the railroad project, the method of fuzzy comprehensive evaluation is used (k= 2 is chosen) to make an instant analysis of the communication security U3, in the evaluation model. In this article, comment set V = (foolproof, more secure, unsecured, more dangerous, very dangerous) is chosen. According to the comment set V and some data, the method of fuzzy statistics and expert consultation is adopted to get the grade of membership of all factors aiming at comment set V.

4.2.1. Computation of the Second Layer (the Base Layer)

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The fuzzy relation matrix of communication security U_3 aiming at comment set V in railroad project is:

$$R_3 = \begin{bmatrix} 0.1 & 0.2 & 0.4 & 0.2 & 0.1 \\ 0.2 & 0.3 & 0.2 & 0.2 & 0.1 \\ 0.2 & 0.3 & 0.2 & 0.2 & 0.1 \\ 0.1 & 0.3 & 0.4 & 0.1 & 0.1 \end{bmatrix} \tag{6}$$

Numbers 1, 2, 3, 4, 5 are used to represent the comment set V, that is:

1-foolproof
2-more secure
3-unsecured
4-more dangerous
5-very dangerous

1) Using the method of fuzzy sets core to optimize fuzzy relation matrix.

According to Eq. (6) and fuzzy relation matrix ***R2,*** arrived at is:

$$G_{U31} = \frac{0.1+0.2\times3+0.4\times5+0.2\times7+0.1\times9}{2\times(0.1+0.2+0.4+0.2+0.1)} \tag{7}$$

In the same way, what can be got is: $G_{U32} = 2.2$, $G_{U33} = 2.3$, $G_{U34} = 2.3$

Then the optimization matrix is derived

$$G_{U3} = (2.5\ \ 2.2\ \ 2.3\ \ 2.3)^T \tag{8}$$

2) Using the method of entropy weight to establish weight vectors

According to Eqs. (3) and (4), the method of entropy weight is used to compute the four factors of U_3:

$$\omega_1=0.320, \omega_2=0.119, \omega_3=0.119, \omega_4=0.442$$

Then there is the weight vector

$$A_3 = ((0.320\ \ 0.119\ \ 0.119\ \ 0.442)$$

According to $M(\bullet,\oplus)$ model, the evaluation result of the first layer can be known:

$$\begin{aligned} B_3 &= A_3 \circ G_{U_3} \\ &= (0.320\ \ 0.119\ \ 0.119\ \ 0.442) \circ \\ &\quad (2.5\ 2.2\ 2.3\ 2.3)^T = 2.35 \end{aligned} \tag{9}$$

Similarly, the evaluation results of the first layer can be calculated from U_1, U_2.

$$B_1 = 2.76, B_2 = 2.71$$

4.2.2. Computation of the First Layer (the Topmost Layer)

According to the expert's comments and the sample analysis, the fuzzy relation matrix of the four factors is obtained, aiming at comment set V in the P2P network security:

$$R_3 = \begin{bmatrix} 0.2 & 0.2 & 0.3 & 0.15 & 0.15 \\ 0.1 & 0.1 & 0.3 & 0.3 & 0.3 \\ 0.2 & 0.2 & 0.3 & 0.2 & 0.1 \\ 0.15 & 0.2 & 0.3 & 0.2 & 0.15 \end{bmatrix} \tag{10}$$

According to the fuzzy relation matrix R, the entropy weight is used to establish the weight vector:

A_1 = (0.156 0.461 0.227 0.156)

Then the fuzzy change is found for the second layer:

$$\begin{aligned} B &= A_1 \circ G \\ &= A_1 \circ (B_1\ B_2\ B_3\ B_4)^T \\ &= (0.156\ 0.461\ 0.227\ 0.156) \\ &\quad \circ (2.76\ 2.35\ 2.71\ 2.74)^T = 3.28 \end{aligned} \tag{11}$$

4.2.3. Disposal of the Evaluation Result

Because B = 3.28 is most close to 3, the comprehensive evaluation result is 3-unsecured. Using the method of ration disposal, it is calculated as:

$P_1 = (4 - 3.28) \times 100\% = 72.0\%$

$P_2 = (3.28 - 3) \times 100\% = 28.0\%$

That is to say, the proportion of the unsecured is 72.0%, and that of the more dangerous is 28.0%.

4.2.4. Comparison to the Traditional Fuzzy Comprehensive Evaluation

We just list the rational disposal of the final evaluation of the traditional fuzzy comprehensive evaluation:

$S_{high} = 79.22$, $S_{midle} = 75.05$, $S_{low} = 70.3$

After making adjustments on the comments with the rational disposal, the highest score 79.22 < 80 and the lowest score 70.3 > 70 are obtained. Therewith, the evaluation result is three, which means the security standard is just "unsecured". This project subsist risk.

We can see the results of the improved evaluation are in accord with the results of the traditional evaluation on the whole. But in the improved fuzzy comprehensive evaluation algorithm, at first the method of fuzzy sets core is used to optimize the fuzzy relation matrix. It improves the capability of the algorithm. Then, the method of entropy weight is used to establish weight vectors. This makes the computation process fair and open. And thereby, the uncertainty of the evaluation result brought by the subjectivity can be avoided effectively and the evaluation result becomes more objective and more reasonable.

5. Conclusion

The construction industry has been plagued by risk and this has not always been dealt with adequately, often resulting in poor performance with increasing costs and time delays. Additionally, construction projects are becoming increasingly complex and dynamic in their nature. Therefore, risk assessment is a complex subject which is determined by numerous factors. Many construction project risk assessment techniques currently used are comparatively mature tools. In this paper, we use an improved fuzzy comprehensive evaluation method to evaluate a railroad engineering project risk. It can give a more reliable result for a reference of decision making.

References

Burkov, V., Burkova, I., Barkhi, R., & Berlinov, M. (2018). Qualitative Risk Assessments in Project Management in Construction Industry. In MATEC Web of Conferences (Vol. 251, p. 06027). EDP Sciences.

Healy, Judith (2016). Improving health care safety and qualit y: reluctant regulators. Routledge.

He Xin-gui, (1998). Theories and Techniques of Fuzzy Kno wledge Disposal. Beijing: of National Defence Industry P ress, (6): 1-56.

Krechowicz, M. (2020). Qualitative risk assessment of passiv e house design and construction processes. In IOP Confer ence Series: Materials Science and Engineering (Vol. 960, No. 4, p. 042068). IOP Publishing

Lin, Song-Shun, et al. (2021). Risk assessment and manage ment of excavation system based on fuzzy set theory an d machine learning methods. Automation in Construction, 122: 103490.

Munawar, H. S., Mojtahedi, M., Hammad, A. W., Kouzani, A., & Mahmud, M. P.. (2022). Disruptive technologies a s a solution for disaster risk management: A review. Sci ence of the total environment, 806: 151351.

Parsaei Motamed, Mahsa, & Shahrooz Bamdad (2022). A m ulti-objective optimization approach for selecting risk res ponse actions: Considering environmental and secondary risks. Opsearch, *59*(1): 266-303.

Perry JG & Hayes RW (1985).Risk and its management in construction projects. Proc Inst Civil Engrs, *78*(1):499-521.

Qiu Pei-liang, (1999). Informatics and its application. Hangzhou China: Zhejiang University of Industry Press, 1-235.

Shibani, A., Hasan, D., Saaifan, J., Sabboubeh, H., Eltaip, M., Saidani, M., & Gherbal, N. (2022). Financial risks management within the construction projects. Journal of King Saud University-Engineering Sciences, (5):1-10.

Song, Y., Wang, J., Liu, D., & Guo, F. (2022). Study of occupational safety risks in prefabricated building hoisting construction based on HFACS-PH and SEM. International journal of environmental research and public health, *19*(3): 1550.

Tah, J. H., Thorpe, A., & McCaffer, R. (1993). Contractor projects risks contingency allocation using linguistic approximation. Comput Syst Engng, *4*(2-3): 281-93.

Ullah, F., Qayyum, S., Thaheem, M. J., Al-Turjman, F., & Sepasgozar, S. M. (2021). Risk management in sustainable smart cities governance: A TOE framework. Technological Forecasting and Social Change, 167: 120743.

Zadeh, L. A. (1996). Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by lotfi. a. zadeh. archive for mathematical logic, 394-432.