Research on the application of TOPSIS method in EPC risk assessment

Abstract:TOPSIS method, as a relatively new comprehensive evaluation method formulti-objective decision making, makes use of the proximity between the evaluationobject and its ideal target to rank the relative advantages and disadvantages, and is a comprehensive evaluation method for intra-group distance. This method is often combined with risk identification technology in the field of risk assessment, which can accurately reflect the gap between evaluation schemes, correctly identify risks, assess risks and scientifically control risks, reduce adverse effects and improve management level, so it is widely used in the engineering field.As the infrastructure construction tends to be saturated and the industry competition becomes increasingly fierce, the project construction mode is gradually changing from the traditional mode to the EPC mode. EPC projects have the characteristics of large construction scale, many personnel and mixed technologies, and are faced with complex risk factors in the construction process.Therefore, it will become a trend to explore the better integration of EPC projects and TOPSIS method.This paper mainly discusses the advantages and disadvantages of TOPSIS method, research status and applicability with EPC，proposes my own views on the improvement of TOPSIS method in EPC projects, and looks forward to its future research direction in the field of risk assessment, so as to provide references for the integration and improvement of EPC projects and TOPSIS method.
Key words: Risk assessment; EPC; Combinatorial empowerment; MCDM

1Introduction

Risk management is an indispensable part of the engineering field, which aims to provide a systematic, standardized and scientific risk management process, so that enterprises or organizations can effectively identify risks, assess risks, formulate countermeasures and continuously improve the level of risk management.With the development of society, due to the saturation of infrastructure construction and maintenance market. The industry competition is becoming more and more fierce, the demand for large-scale construction projects is increasing, and the technical requirements are getting higher and higher. The number of owners and contractors who can provide comprehensive services for project construction is also increasing, and the technical level and project management ability of enterprises are facing new challenges. Therefore, the project construction mode has gradually changed from the traditional mode to the EPC mode integrating design, procurement and construction. The EPC project general contracting mode is that the general contractor signs a contract with the owner, completes the entire planning and design, material procurement and construction management of the construction project according to the contract, and finally delivers the complete product to the owner. It shortens the delivery time and reduces the overall procurement cost, thus winning more profit margins for enterprises. In addition, a series of overall planning and coordinated management modes that are fully responsible for the owner in the implementation process. This complicates the risk factors faced by EPC project contractors. Therefore, it is important not only to identify risks, but also to assess and manage them.[1][2][3]

It can be seen from the relevant literature that in order to evaluate risks more scientifically, many scholars have put forward a variety of risk assessment methods. Among them, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is a very popular technique in the field of risk assessment and is often combined with risk identification technology. Therefore, it will become a trend to explore the better integration of EPC projects and TOPSIS method. The rest of this paper will discuss the advantages and disadvantages of TOPSIS method, research status and its applicability to EPC, and then put forward my own views on the improvement of TOPSIS method in EPC projects, and forecast its future research direction in the field of risk assessment.[4]

2Study of the TOPSIS method

TOPSIS method is one of the Multi-criteria decision-making (MCDM) methods. It makes full use of the information in the raw data and accurately reflects the gaps between evaluation schemes. The basic idea is to assume a positive ideal solution (PIS) and a negative ideal solution (NIS). Then the distance between each sample data and the positive and negative ideal solution after standardization and normalization is measured. The relative nearness degree to the ideal scheme is calculated, and then the advantages and disadvantages of each evaluation object are sorted.The following chapter is divided into two sections to discuss the advantages and disadvantages of TOPSIS method and its research progress.[5][6]

2.1Advantages and disadvantages of TOPSIS method

TOPSIS method is a very popular technique in the field of risk assessment, and its advantages are as follows:

First, subjective and objective indicators can be used simultaneously, and the decision of subjective and objective indicators can be considered simultaneously. Secondly, it is easy to understand and use, that is, the method does not require a complex grasp of multivariate statistics or mathematics. Therefore, even without a professional mathematical background, decision makers can quickly grasp and apply. Third, it is robust enough to handle complex problems with multiple imperfect indicators. And it can effectively deal with problems such as potential outliers and errors or even missing data. Finally, use flexibility. It can deal with all kinds of complex and multi-dimensional decision-making problems at any time. And provide accurate and reasonable decision support for decision makers.[7]

With the rapid increase in the application of TOPSIS method in different fields and industries, some of its shortcomings have also been exposed, as follows:

First, the determination of index weights is highly sensitive. The determination of indicator weights may have an impact on the final result. Second, more than two study subjects must be used and data for each indicator is required. Third, there is a failure of Euclidean distance. Finally, the reduction or increase of new decision options may lead to changes in the positive and negative ideal solutions. Then the order of the good and bad of the scheme changes, resulting in the reverse order problem.[7]

At present, the introduction of TOPSIS method in different fields will not stop,

so the improvement of TOPSIS method is imperative.

2.2Research progress of TOPSIS method

The TOPSIS method was first proposed in 1981 by Professor Hwang of Southeastern University in the United States. Later, in the multi-objective decision-making of the continuous scheme, Jin Qiong and Wu Qiuming proposed specific ways and methods to promote the application, and gradually introduced the TOPSIS method into the industrial economic benefits and engineering risk assessment for comprehensive ranking, creating new possibilities for investors in the multi-criteria evaluation of investment options.The following is divided into three sections, and the application of TOPSIS method combined with different methods is discussed respectively.

2.2.1 The combined application of TOPSIS method and EWMmethod

The Entropy Weight Method (EWM) is an objective weighting method. It determines the objective weight according to the variation of the index and is less affected by human interference. The calculation principle is to calculate the information entropy and entropy weight of the evaluation index by the dimensionless processing of the original data through homology and normalization. The combination of TOPSIS method and EWM is to introduce entropy weight to weight the normalized matrix in TOPSIS model. EWM-TOPSIS weights are based on the actual attributes of each indicator. It avoids the bias brought by the main evaluation method and can make the decision more comprehensive and accurate.Then I will give some examples to prove the conclusion.

Ting H X and Ming H L proposes a hybrid model to assess the vulnerability of subway stations to waterlogging by integrating the entropy weight method (EWM) with a technique for order preference based on similarity to the ideal solution (TOPSIS) (the EWM-TOPSIS method). The model is based on analysis of factors influencing the vulnerability of subway stations to waterlogging. The proposed method was applied to a field case (Jinshahu station in Hangzhou, found to be vulnerable to waterlogging at level IV). The results from EWM-TOPSIS, EWM, and TOPSIS were compared. The results using the EWM-TOPSIS method were more accurate and reliable than those using EWM and TOPSIS.[8]

Zhang Yifan presents an efficient and thorough ranking method, that is, entropy weight method (EWM)–technology for order preference by similarity to an ideal solution (TOPSIS), named EWM–TOPSIS. It evaluates the critical degree of nodes by considering various characteristics of nodes in the complex network of Hong Kong Mass Transit Railway (MTR). Four evaluation indicators, that is, the frequency of nodes with the same ranking (F), the global network efficiency (E), the size of the largest connected component (LCC), and the average path length (APL), are computed to compare the performance of the four methods and measure network robustness under different designed attack and recovery strategies.The results demonstrate that the EWM–TOPSIS method has more obvious advantages than the others, especially in the early stage. It is of great practical significance to identify and quantify the criticality of nodes in complex PTN and improve the robustness of network against damage.[9]

In order to solve the potential underground aquifer area area of sandstone aquifer, Wang Ying proposed a prediction method of potential groundwater production area of sandstone aquifer based on EWM-TOPSIS method based on the available geological exploration data. The relationship between each factor in sandstone aquifer and groundwater production is studied and determined. Field data were used to check the accuracy of the prediction model.[10]

2.2.2 The combined application of TOPSIS method and AHP method

AHP is a subjective weighting method, which compares the importance of multiple factors by constructing a decision matrix, and decomposes complex decision problems into a series of sub-problems with hierarchical structure, making the decision process more transparent and convenient for decision makers to analyze and judge. The combination of AHP and TOPSIS can improve the reliability of decision making, and the combination of subjective weighting can take into account the relationship between factors and make the decision more comprehensive.Then I will give some examples to prove the conclusion.

In order to determine the best acidification modification scheme, He Jimin proposed an improved AHP-TOPSIS method to determine the best conditions for wettability modification. This method constructs an evaluation index system, taking the wettability of coal as the target layer and the pro/hydrophobic functional groups in coal as the index layer. Meanwhile, it innovatively takes the adsorption energy of each functional group when absorbing a single water molecule as the basis for assigning weights to the evaluation indexes. Then, nine acidification modification schemes are evaluated and selected by the improved AHP-TOPSIS method based on the test results of different schemes to get the optimal one. The optimal scheme selected by the AHP-TOPSIS method is validated by water adsorption tests and isothermal adsorption tests. The results showed that the ranking of acidification modification schemes obtained by the AHP-TOPSIS method is in high agreement with the ranking of water adsorption tests. When compared with raw coal, the coal samples treated with the optimal scheme have lower adsorption capacity for gas, which indicates that the selected optimal scheme has the potential to increase the output of coalbed methane.[11]

Duzce Univ discovers the test sequence with the best surface quality by optimizing the multi-criterion decision method. Different cutting tool geometrics are preferred. The comparison of these cutting tools is discussed in detail. The output parameters of thrust, delamination coefficient and surface roughness were optimized by AHP-TOPSIS method. Finally, the aim is to optimize the bit geometry and cutting parameters and improve the surface quality of CFRP composites.[12]

Biswas Brototi used AHP-TOPSIS and AHP-VIKOR models to develop basin maps of spring water suitability and vulnerability in Aizawl. In addition to the highest topography, average slope, average annual rainfall, average annual temperature, spring distribution, geomorphic units, geological formations, stream terraces, linear structures, and epicentral intensity, Landslide, forest fire, forest cover area, built-up area, stone mining area, proportion of agricultural land, proportion of degraded land, proportion of open land and proportion of water body were also selected to measure

the vulnerability of the basin. The correlation analysis results of AHP-TOPSIS method (0 ~ 0.60) and AHP-VIKOR method (0.04 ~ 1.00) show that the central part of the study area is suitable for spring water source. Finally,ROC curve shows that the prediction effect of AHP-TOPSIS method (0.816) is slightly better than that of AHP-VIKOR method (0.743).[13]

2.2.3 The combined application of TOPSIS method and G1 method

G1 method is a subjective weighting method obtained by optimizing AHP method, which has the characteristics of flexible calculation, extensibility, and no need to construct judgment matrix to test consistency. G1 method can solve the correlation problem between evaluation indicators, and form a complete decision-making process after combining with TOPSIS method, which can greatly reduce errors and uncertainties, and make the decision-making process more scientific and standardized.Then I will give some examples to prove the conclusion.

In order to avoid the inconvenience of AHP method in actual operation, Nai Ruo Xing proposed a G1-TOPSIS combination algorithm, using G1 method to calculate the weight of each index. It can be seen from the analysis of the example that the post ability evaluation of maintenance personnel has been effectively handled. The results are consistent with the actual situation and provide an important basis for the evaluation and promotion of maintenance personnel.[14]

Qingqi Zhao constructed a SIES technology-economic evaluation model based on G1-anti-entropy weight-TOPSIS method, analyzed the evaluation indicators qualitatively and quantitatively, and overcame the problems that the AHP method needs consistency testing and the high sensitivity of the entropy weight method can easily lead to index failure.The feasibility of the evaluation index system and evaluation method is verified by the results of the case study and analysis.[15]

To construct evaluation method and corresponding system,Ye Fang proposes and discusses the improved G1-Critical-TOPSIS method. Then, we design and implement a performance evaluation system for university collaborative innovation. Using data from 73 collaborative innovation centers in Jiangsu from 2015 to 2019, a basic data set is constructed to conduct an empirical analysis of performance evaluation. Furthermore, the evaluation results are compared with those of existing comprehensive evaluation methods. The experimental results show that the proposed evaluation method can objectively and effectively evaluate the performance of collaborative innovation centers.[16]

G1-TOPSIS method is mostly used in combination with other methods, and can be composed of multi-weight TOPSIS comprehensive evaluation method.The multi-weight TOPSIS comprehensive evaluation method can avoid the deviation brought by the single weight method, such as AHP-EWM-TOPSIS method and EWM-Fuzzy-TOPSIS method.When the multi-weight includes subjective weight and objective weight, the subjective and objective combination weighting method can be formed. Considering both the subjective knowledge of experts and the relationship between indicators in the actual situation, it can better reflect the actual situation. In addition, it can calculate the weight with high precision, which can be combined with the actual data and consider the evaluation index more fully.

3 Application of TOPSIS method in EPC projects

TOPSIS method is a multi-attribute decision making method. Its calculation speed is faster and the results are more intuitive, so it has become an important part of various decision support systems. At the same time, it is not limited by the sample size and the number of indicators, and can consider the influence of many factors at the same time, which is suitable for the risk assessment of multiple groups of evaluation objects. In addition, the calculation results are accurate and simple, and the applicability and practicability are high. It can deal with the risk assessment of various fields and industries, especially suitable for the risk assessment of EPC projects. TOPSIS method has a broad prospect in the applied research of EPC risk assessment, which is embodied in the following aspects:

First of all, scope, time, cost, and quality are the main factors that affect the efficiency of engineering projects, and one of the low-risk approaches to engineering construction is to pass on the lowest risk to the contractor under an EPC contract. At present, the EPC model has gradually become the mainstream in the field of engineering construction in China. As the complexity and scale of EPC projects continue to increase, the need for risk assessment is becoming more and more urgent. In view of this situation, the TOPSIS method provides an efficient and intuitive risk assessment method, which can provide more scientific support for the risk management of EPC projects, and is expected to become a commonly used risk assessment tool. Secondly, with the development of information technology, various data processing and decision support systems are emerging, and the TOPSIS method will also be widely used. Using technologies such as data mining and machine learning, the data of EPC projects can be obtained and processed more accurately, thus ensuring the accuracy of the TOPSIS method. Finally, the TOPSIS method can be combined with other methods in the risk assessment of EPC projects to form a more complete risk assessment system. For example, fuzzy mathematics, analytic hierarchy process and other methods can be combined to evaluate and rank various risk assessment indicators to achieve a more comprehensive evaluation effect.Then I will give some examples to prove the conclusion.

Kabirifar analyzes and prioritizes EPC key activities in large-scale residential construction projects in Iran by using the TOPSIS method as a multi-attribute group decision-making technique. The results show that engineering design, project planning and control are important factors affecting project performance and play a pivotal role in project performance, which proves that the construction stage is more important than procurement, and emphasizes the risk control in the construction process.[17]

In order to mitigate financial risks such as inflation, liquidity, and credit, financial risks are assessed and prioritized based on the well-known fuzzy TOPSIS model. Jahantigh took an EPC project for the procurement and construction of an oil refinery as an example, and interviewed EPC project experts at all levels to classify and extract risks, and then prioritized risks according to the fuzzy TOPSIS model. Finally, the proposed model is compared with other models and expertise methods to

determine its progress.[18]

In order to find the best administrative and contractual methods, and carefully plan the production, extraction and development projects in this field in the oil and energy industry. Niayeshnia Peyman uses TOPSIS method as a multi-criterion group decision method to analyze, prioritize, and manage the efficiency of EPC execution projects in Iran's energy and petroleum industry. The results show that engineering is the most important factor affecting the project.[19]

Xiaoting Yang constructed the fuzzy entropy TOPSIS selection model and specific decision steps from the perspective of general contracting, combining EPC resource integration characteristics and supply chain management theories. Finally, the application of this method in bidding is analyzed based on practical cases, in order to provide reference for supplier selection decision of EPC general contract project.[20]

Although TOPSIS comprehensive evaluation method has broad application prospects in EPC risk assessment, there are not many case empirical studies in the past decade. This direction deserves more case studies, and interested scholars can join the research team in this direction.

4 Own ideas for improvement of TOPSIS

For TOPSIS method under EPC project, I think TOPSIS method based on G1-EWM-CV combination empowerment is a good improvement scheme.

First of all, G1-TOPSIS and EWM-TOPSIS methods have been proposed and have good evaluation effect. Secondly, the existing research shows that the traditional entropy weight method has the disadvantage of equalizing the index weights. Coefficient of Variation method (CV method) is an objective weighting method, and its weight is measured according to the volatility of the data, that is, the greater the value difference of the evaluated object on a certain index, the greater the information it carries and the greater the weight. The coefficient of variation is a parameter that characterizes the variation among the eigenvalues of the evaluation index and is used to determine the weight of the index. It can overcome the defects of traditional entropy weight method. Thirdly, combined with G1 method of subjective weighting, the subjective and objective weighting method can better reflect the actual situation of indicators. Finally, the three weights are combined by linear weighted combination weighting method.Assuming there are l kinds of weighting methods, the calculation expression is shown as formula 1:

$$w_{\beta}=\sum_{s=1}^{l}\theta_{s}w_{s}\ (s=1,2,\ldots,l) \quad (1)$$

In the formula:w_s－Represents the weight of the s-th empowerment method; θ_S－Preference coefficient.

The mathematical evaluation model established on this basis can give full play to the advantages of both subjective and objective methods, and can make the evaluation results more objective and reasonable.

5 Result and discussion

At present, with the proposal of a large number of improved TOPSIS methods, it provides more scientific support for the risk management of EPC projects, provides useful solutions for the decision-making problems of contractors, and makes the scope of application of TOPSIS methods broader. This paper mainly studies the advantages and disadvantages of traditional TOPSIS method and research status, discusses the improvement of TOPSIS comprehensive evaluation method, in addition, the applicability of TOPSIS method to EPC projects and puts forward my own views on the improvement of TOPSIS method in EPC projects.

In future studies, the application of TOPSIS method in different engineering fields and scenarios in EPC project risk assessment and analysis should be further explored, the theoretical framework and technical details of TOPSIS method should be improved to better adapt to the actual situation and data, and the mathematical model and calculation algorithm should be improved and optimized. In addition, it is a forward-looking research idea to creatively combine TOPSIS method with technical theories in other related fields. For example, with the development and application of artificial intelligence technology, it has high efficiency and accuracy in data processing, data analysis and automatic decision-making. Combining it with artificial intelligence technology, we can get very beneficial research results.

Conclusion

In conclusion, with the development of EPC projects and the continuous strengthening of risk management, the application of TOPSIS method in EPC risk assessment has broad prospects, which can provide more scientific and effective risk management support for project managers, and is worthy of further research.

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