Research Article

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Multi-attribute perceptual fuzzy information decision-making technology in investment risk assessment of green finance Projects

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Abstract: In the investment risk assessment of green finance (GF) projects, the application of multi-attribute perceptual fuzzy information decision technology is taken as the main research object. With the promotion of the concept of environmental protection and the development of green economy, the investment risk assessment of GF projects has become more and more important. However, this requires dealing with a large amount of fuzzy information and multi-attribute decision problems, which is a big challenge for traditional decision techniques. Based on this background, a new decision model, intuitionistic fuzzy preference theory-based tomada de decisão interativa multicritério (IF-PT-TODIM), is adopted, which can better deal with fuzzy information and multi-attribute decision problems by taking two different choices as reference. By knowing the weight distribution of experts, the model can better assess the influence of various factors on the decision. In the research results, the calculated results of expert weights are 0.2796, 0.2221, 0.1914, 0.1328, and 0.1745, respectively, showing that each expert has different degrees of influence on decision-making. In addition, the application of IF-PT-TODIM model can effectively reduce the investment risk. Compared with national bank of Kuwait, systematic review, evolutionary algorithm, the improved method can reduce the risk of venture capital by 28.14, 15.47, and 11.05%, respectively. This result further confirms the advantage of the IF-PT-TODIM model in dealing with fuzzy information and multi-attribute decision problems. This study has practical implications for understanding and improving the investment risk assessment of GF projects. It not only provides a new decision model for risk assessment, but also provides an effective method to deal with fuzzy information and multi-attribute decision problems. This provides new ideas and methods for the risk management of GF projects and also provides a new perspective and reference for research in related fields.

Keywords: Green Finance, risk assessment, multi attribute decision-making, perceptual ambiguity attribute, TODIM

1 Introduction

In the promotion of the concept of environmental protection and the development of green economy, the investment risk assessment of green finance (GF) projects has been paid more and more attention. However, due to the characteristics of GF projects, their investment risk assessment involves a lot of fuzzy information and multi-attribute decision-making problems, which is a big challenge for traditional decision-making techniques. Therefore, it is necessary to find a new decision-making technique to deal with these problems more effectively [1,2]. The purpose is to solve the fuzzy information and multi-attribute decision-making problems in the investment risk assessment of GF projects by introducing a new decision model intuitionistic fuzzy

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preference theory-based tomada de decisão interativa multicritério (IF-PT-TODIM). This model evaluates the impact of various factors on decision-making in a more scientific and objective way by comprehensively comparing different choices [3,4]. In terms of method, the weight of experts is calculated by quantitative method to further optimize the decision-making process. This kind of weight calculation also provides a new research path for dealing with fuzzy information and multi-attribute decision problems [5]. The innovation lies in that the IF-PT-TODIM model can not only effectively deal with fuzzy information, but also solve the multi-attribute decision-making problem. By introducing two different options as a reference, the model is expected to produce more comprehensive and accurate results when assessing investment risk. The contribution is that the research results can not only provide new perspectives and tools for theoretical research, but also provide practical decision-making support for the practical field. For investors in GF projects, being able to assess investment risks more accurately and reduce the possibility of investment mistakes helps them to obtain better investment returns in the GF market. For policy makers, it can also provide a more scientific basis for decision-making, so as to promote the healthy development of GF market. It is expected that this study can promote the theoretical and technological progress of risk assessment of GF projects, and inject new vitality into the future development of green economy. At the same time, it is also expected that this new decision model can be applied in more fields and provide new possibilities for solving other complex decision problems [6]. The research will be conducted in four. The first is an overview of GF project investment RA in view of multi-attribute perceptual fuzzy information decision-making technology; the second is the research on investment risk assessment (RA) of GF projects in view of multi-attribute perceptual fuzzy information decision-making technology; the third is the experimental verification of the second part; and the fourth is a summary of the research content and points out the shortcomings.

2 Related works

Wei et al. proposed an algorithm for intuitionistic fuzzy C-means clustering using local information weights. On this basis, a new weighting method in view of local information is proposed, which enables it to adaptively adjust the weighting of local information during fuzzy segmentation, thereby improving the algorithm's noise resistance. On this basis, a new swarm intelligence algorithm, namely, the "golden" method, was introduced; it optimized the initial cluster center and optimized some key parameters in the cluster. On this basis, the golden section method was adopted to further enhance the adaptive ability of the clustering method [7]. Wang and other scholars proposed this measure as an extension of traditional measures. The experimental results show that this method has high computational efficiency and accuracy [8]. Huang and his research team utilized the correlation between three different types of goals to obtain the correlation between different types of goals. On this basis, it synthesizes the overall relative similarity between the objectives, selects and arranges the set of alternatives, and forms a new solution method for the related similarity problem of multiple indicators and multiple objectives. Then, a specific example is given, and the results show that the method is feasible [9]. Haibo et al. proposed a semantic analysis that not only takes into account decision-making risks, but also enables effective behavior selection and corresponding semantic analysis for different strategies. Taking the securities market as an example, it is demonstrated that the algorithm proposed in this article is effective. Then, the study utilized sensitivity analysis and comparative analysis to demonstrate the performance and characteristics of the proposed model in practical applications [10]. Li et al. used crawling technology to collect e-commerce sites and fused linear discriminant analysis with apriori to extract typical conditioned reflexes. This experiment proves that compressed sensing is improved by text mining technology and intuitionistic fuzzy set technology, and has strong practicability and scientificity [11].

Zeng et al. analyzed theoretically the problems in haze control in China in view of the existing problems. When other factors are the same, each standard deviation of "GF" can reduce PM2.5 by 8.8 mg per cubic meter. Meanwhile, driven by technological progress, GF can also improve the overall level of the ecosystem. Due to the particularity of the company's property rights system, this regulatory effect may occur in non-state-owned enterprises, but it will not occur in state-owned enterprises [12]. Yu et al. found that private enterprises exhibit relatively strong innovation capabilities under severe financing constraints. Meanwhile, financial institutions and private companies should also be allowed to publicly disclose more information about green loans and green projects [13]. Zhang and others found that industrial structure, economic development level, environmental regulation, and other factors have a positive impact on the relationship between GF and environmental performance, but meanwhile, it will also be constrained by population density [14]. Ozili PK trained and tested the method using field AGB data and multi-temporal phased array type l-band synthetic aperture radar (PALSAR) backscatter values from the Hyrcanian forest in Iran. The results of the multivariate relevance vector regression (MVRVR) method are compared with other methods: multiple linear regression (MLR), multilayer perceptron neural network (MLPNN), and support vector regression (SVR). The results show that the R^2 value of MLR model is lower than that of the other three methods. Although the SVR model is more accurate than MLPNN, the lowest saturation point is 224.75 Mg/ha. Using the MVRVR model can significantly improve the estimation of AGB (R^2 = 0.90; RMSE = 32.05 Mg/ha); the model has excellent performance in estimating AGB, with the highest saturation point (297.81 Mg/ha) [15]. Kosari et al. proposed a fast fining method based on performance design strategy for determining the design parameters of the attitude determination and control subsystem of Earth observation satellites. The results show that compared with the traditional method, the proposed method can minimize the design cycle caused by the interdependency between parameters, thus shortening the design time and reducing the cost. This method comprehensively considers parameters such as task, system, and performance requirements; realizes rapid finalization and optimization; and makes the design of attitude decision and control subsystem more efficient [16]. Meo MS and Abd Karim MZ proposed an algorithm to extract optimized features from polarimetric synthetic aperture radar (POLSAR) images for biomass estimation. The algorithm mainly consists of three steps: 1) feature extraction, including radar reflection intensity and some POLSAR parameters; 2) use particle swarm optimization method for feature selection; and 3) biomass estimation using multiple correlation vector regression and SVR. The results showed that MVRVR model based on the feature selection of particle swarm optimization had the most accurate biomass estimation results, with the determination coefficient R^2 of 0.86, root mean square error of 39.17, mean absolute error of 36.50, and mean error of 11.59. Studies have proved that the optimized feature extraction and selection algorithm can effectively improve the biomass estimation accuracy of POLSAR images [17]. Sadiq M et al. proposed a speckle removal method for PoLSAR images based on Fast independent component analysis (ICA) algorithm to process the information of different polarization channels simultaneously. The experimental results show that the more image channels the fast ICA algorithm inputs, the better the separation effect of signal components from speckle noise. Compared with only using HH, HV, VV and other single polarization channels, the combination of multi-polarization channels can improve the equivalent number value of ALOSPALSAR image by 37%. This method can effectively improve the speckle removal performance of PoLSAR images [18]. Zhu Q et al. proposed a spectral image classification model based on fast patchless global learning. This model mainly combined attention mechanism and classifies hyperspectral images through global spatial context information. The experimental results on three publicly available HSI datasets showed that the proposed method had strong performance in dealing with sample shortage and imbalance issues, outperforming other methods [19]. Zhan J et al. proposed a method that combines threshold segmentation, machine learning algorithms, and object-based classification methods to process SAR data for flood monitoring. The results show that the machine learning algorithm achieves significant classification results. The study concluded that Sentinel-1 images could be used as a baseline data source for improved methodological guidelines and should be used for flood risk monitoring. This shows that Sentinel-1 images are very suitable for flood monitoring and risk assessment [20]. Tariq et al. proposed a method to generate rapid flood risk area maps for river flood plains using analytic hierarchy process and frequency ratio models. The study considers that the area within 2,500 m from the river has a high risk value and is classified as an extremely high risk area, with an area of 1,343 square kilometers, accounting for 6.68% of the total area. The high-risk areas identified in this study, Mangera, Malala, and Trimo Valley, have suffered severe damage from rapid floods for many times, which provides policy guidance for risk management, emergency rescue, urban planning, hydrologists, and climate scientists of relevant departments [21]. Mohammadi et al. proposed the use of Sentinel-1 SAR data and Sentinel-2 images and object-based image analysis methods for timely oil spill detection in the Persian Gulf region. The results show that the oil pollution areas extracted from Sentinel-2 optical data, Sentinel-1 SAR data, and field data are 114.7, 98.5, and 124.7 square kilometers, respectively [22].

Zamani et al. used Landsat-8 images and a weighted linear combination method to determine suitable areas for croc cultivation in Miane. The results show that southeast and northwest of Miane, especially the riparian and catchment areas, were identified as suitable for saffron cultivation, with 28% of the area classified as suitable, 36% as moderately suitable, 20% as critical suitable, and the remaining approximately 16% as unsuitable. If the suitable cultivation area of crocus can be determined according to the climate requirements and the increase in yield per unit area can be achieved, it will help improve the economic conditions and income level of farmers. Due to the special nature of saffron, its replacement with onions, potatoes, tomatoes, and other water-intensive crops will help reduce water consumption [23].

In summary, scholars and scientists have made outstanding contributions in GF investment and multi-attribute perceptual fuzzy information planning. Many improved algorithms have been designed to meet more efficient dataset processing and collection algorithms. Meanwhile, the multi-attribute perceptual information fuzzy set model has good data processing performance, and the current GF venture capital algorithm is insufficient; therefore, it utilizes this method to make information decisions on the efficiency of GF investment; it has a significant application value in the operational decision-making of venture capital in the financial industry.

3 A method for investment RA of GF projects in view of multi-attribute perceptual fuzzy information decision technology

This study uses a decision technology model in view of multi-attribute perceptual fuzzy information to conduct high-precision RA of GF projects; then, it combines the actual situation and the decision model of the evaluation to optimize and improve the model. It optimizes existing algorithms, enhances existing modules, improves existing RA strategies, and utilizes cutting-edge theoretical support to construct the RA model. Finally, it obtains the GF project investment RA model in view of multi-attribute perception fuzzy information technology; this model is suitable for real situations and can provide valuable references for decision-makers, as well as forward-looking strategic value for the development of the industry.

3.1 A method for multi-attribute decision-making in view of perceptual fuzzy attributes

There are some differences between perceptual fuzzy set and fuzzy set proposed by Professor Zadeh. Fuzzy set can only express the degree of an object belonging to a non-empty set from the two aspects of membership and opposites; perceived fuzzy sets enhance decision hesitancy, which is reflected in capturing human fuzzy perception, quantifying hesitancy, and providing complex expressions for fuzzy information in decision-making [24,25]. It is showcased in equation (1):

$$\begin{cases} T(y) = \{\langle y,\ \alpha_{\mathrm{T}}(y),\ \beta_{\mathrm{T}}(y)\rangle | y \in Y\}, \\ \pi_{\mathrm{T}}(y) = 1 - \alpha_{\mathrm{T}}(y) - \beta_{\mathrm{T}}(y), \end{cases} \tag{1}$$

where $\alpha_{\mathrm{T}}(y)$, $\beta_{\mathrm{T}}(y)$, and $\pi_{\mathrm{T}}(y)$ jointly express the element y of non-empty set Y, which belongs to the degree of perceptual fuzzy set T. The scoring function and accurate function for measuring the perceptual fuzzy set function are shown in equation (2):

$$\begin{cases} \mathfrak{R}(t) = \alpha_t - \beta_t, \quad \mathfrak{R}(t) \in [-1, 1], \\ \mathfrak{I}(t) = \alpha_t + \beta_t, \quad \mathfrak{R}(t) \in [0, 1], \end{cases} \tag{2}$$

where $\mathfrak{R}(t)$ and $\mathfrak{I}(t)$ are the scoring functions and exact functions, respectively; then, the definition of the intuitionistic fuzzy weighted arithmetic mean (IFWA) operator is shown in equation (3):

$$\mathrm{IFWA}_{\varepsilon}(t_1,\ t_2 \ldots,\ t_n) = \varepsilon_1 t_1 \oplus \varepsilon_2 t_2 \oplus \cdots \oplus \varepsilon_n t_n = \left(1 - \prod_{r=1}^{n}(1 - \alpha_{t_r})^{\varepsilon_r},\ \prod_{r=1}^{n}(\beta_{t_r})^{\varepsilon_r}\right), \tag{3}$$

where ε is the weight vector and t_r is a set of perceptual blur vectors; the prospect theory is a new decision-making theory in view of the "bounded rationality hypothesis" proposed by Tversky and Kahneman in 1979. The prospect function is shown in equation (4):

$$P(i) = \sum_{u=1}^{s} N(i_u) W(\varpi_u), \tag{4}$$

where $P(i)$, $N(i_u)$, and $W(\varpi_u)$ are the prospect function, value function, and weight function, respectively. The value function expression is shown in equation (5):

$$N(i_u) = \begin{cases} (i_u - i_o)^{\varsigma}, & i_u - i_o \geq 0, \\ -\sigma \cdot (i_o - i_u)^{\xi}, & i_o - i_u < 0, \end{cases} \tag{5}$$

where i_o and i_u are the reference points and actual points, respectively; $N(i_u)$ represents the loss; and ς and ξ are the parameters that reflect the curvature of the value function, respectively; σ is the attenuation coefficient of loss. Therefore, the weight function is shown in equation (6):

$$W(\varpi_u) = \begin{cases} W^{+}(\varpi_u) = \varpi_u^{\delta} / (\varpi_u^{\delta} + (1 - \varpi_u)^{\delta})^{\frac{1}{\delta}}, \varpi_u - \varpi_o \geq 0, \\ W^{-}(\varpi_u) = \varpi_u^{\tau} / (\varpi_u^{\tau} + (1 - \varpi_u)^{\tau})^{\frac{1}{\tau}}, \varpi_u - \varpi_o < 0, \end{cases} \tag{6}$$

where ϖ_o and ϖ_u are the weights of reference point i_o and actual value i_u, respectively; the parameters δ and τ reflect the curvature of the weight function, respectively. For a certain multi-attribute decision-making problem, the evaluation matrix for multi-attribute decision-making can be obtained, as shown in equation (7):

$$F = [f_{rg}]_{\max} = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1g} & \cdots & f_{1m} \\ f_{21} & f_{22} & \cdots & f_{2g} & \cdots & f_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ f_{r1} & f_{r2} & \cdots & f_{rg} & \cdots & f_{rm} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ f_{n1} & f_{n2} & \cdots & f_{ng} & \cdots & f_{nm} \end{bmatrix}, \tag{7}$$

where the evaluation matrix is composed of $n \times m$ evaluation values f_{rg}. The tomada de decisão interativa multicritério (TODIM) algorithm was first proposed by Gomes et al. in 1992. The unique feature of this method is to compare multiple choices in pairs and finally select the best choice from multiple choices in view of the comprehensive comparison results. First, it calculates the weight vector, as shown in equation (8):

$$v_g^{\#} = \frac{v_g}{\max_g \{v_g\}}, \quad g = 1, 2, \ldots, m, \tag{8}$$

where v_g is the weight vector, and in view of the evaluation matrix of multi-attribute decision-making, the standard overall dominance of the TODIM method is shown in equation (9):

$$\Phi(Al_r) = \frac{\sum_{k=1}^{n} \Lambda(Al_r, Al_k) - \min_r \left\{\sum_{k=1}^{n} \Lambda(Al_r, Al_k)\right\}}{\max_r \left\{\sum_{k=1}^{n} \Lambda(Al_r, Al_k)\right\} - \min_r \left\{\sum_{k=1}^{n} \Lambda(Al_r, Al_k)\right\}}, \quad r = 1, 2, \ldots, n, \tag{9}$$

where Λ represents the different attitudes of decision-makers toward losses; $\Phi(\mathrm{Al_r})$ represents the overall dominance of the standard; and Al_r is an attribute of the attribute set. If the overall advantage of the criterion is relatively high, the corresponding alternative solutions are more suitable, which is beneficial for decision-makers to make appropriate choices. Multi-attributive border approximation area comparison (MABAC) is a comprehensive evaluation method with multiple indicators, and its evaluation indicators are approximation domains with edges. When it has a higher approach edge, it is placed at a lower approach edge; on the contrary, it happens to be placed on the edge close to the edge [26]. This method mainly focuses on the overall distance between attribute Al_r and the approximate boundary region, as shown in equation (10):

$$S_r = \sum_{g=1}^{m} v_g \left(1 + \frac{f_{rg} - \max_r\{f_{rg}\}}{\min_r\{f_{rg}\}} \right) - \mathrm{BAA}_g, \tag{10}$$

where S_r is the overall distance and BAA is the approximate boundary region. In 2015, Keshavarz Ghorabaee et al. first proposed and demonstrated the effectiveness of evaluation based on distance from average solution (EDAS). Compared with other algorithms, it has been proven that the EDAS algorithm has good adaptability to data with conflicting attributes. The overall evaluation value of this method is shown in equation (11):

$$\mathrm{AS}_r = \frac{1}{2}(\mathrm{NSP}_r + \mathrm{NSN}_r),\ r = 1,\ 2, \ldots,\ n, \tag{11}$$

where AS_r is the overall evaluation value; and NSP_r and NSN_r are the weighted standard positive and negative distances, respectively. The larger the AS_r, the more suitable the corresponding solution is. GF is a new development concept proposed in recent years; this concept is led by the government to promote green transformation in all aspects of the financial system, and to provide a green light for green projects related to environmental protection, resource conservation, etc. This is to address the financial constraints of these projects and enterprises and to contribute to the development of a green and environmentally friendly economy. From its inception to today, venture capital has undergone a series of development, decline, restructuring, and transformation, and has gradually become an important and stable financial force in the financial investment system after recovery. The GF investment process diagram is shown in Figure 1.

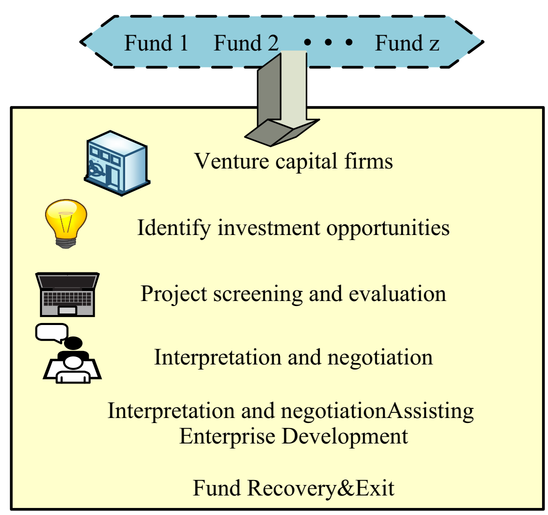

Figure 1: GF venture capital operation flow chart.

In Figure 1, by sorting out the operational process of GF, it is shown that the real starting point for investment is in the screening and evaluation stage of the project. The investment effectiveness of GF is closely related to its stage, and if it is effectively screened and evaluated, it is likely to declare its investment failure from the beginning. Venture capital has always been known for its high risk, and there are various unpredictable risks in its investment process; However, in the final analysis, it is still an investment activity, with the goal of obtaining returns. In all investment activities, it is most important to avoid risks as much as possible. Moreover, when selecting and evaluating projects, GF venture capital will also focus on the environmental effects of the project, which means that the selection and evaluation of the project is very important.

3.2 Construction of multi-attribute decision model in view of perceptual fuzzy information for GF projects

In the process of evaluation, there will be a lot of ambiguity and uncertainty; therefore, it maximizes the protection of the integrity of evaluation information and utilizes a more scientific and rational method to extract and process this information; this helps venture capitalists make the right decisions. To address the ambiguity in the project evaluation process of GF venture capital, this article uses the method of fuzzy multi-attribute decision-making to study this evaluation decision-making problem. The overall process of evaluating GF venture capital projects in an intuitively fuzzy environment is shown in Figure 2.

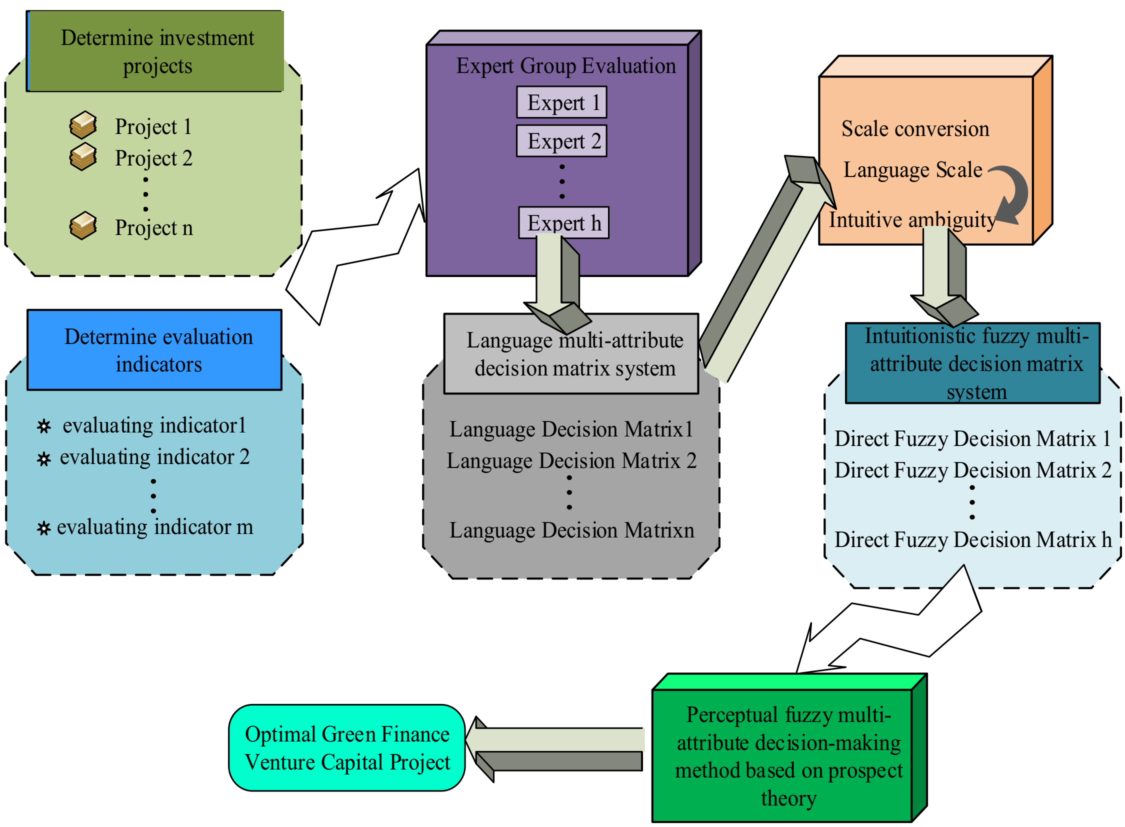

Figure 2: Schematic diagram of GF risk investment project evaluation.

In Figure 2, in GF venture capital, venture capitalists not only need to consider the investment risks faced by traditional venture capital, but also need to conduct a comprehensive assessment of the project's impact on the environment. The main content of the evaluation includes technical and team risks, market risks, enterprise and management risks, product greenness and transformation, and exit risks. With the increasing complexity of the decision-making environment, the traditional multi-attribute decision-making method can not meet the needs only by using the fuzzy set theory; therefore, combining new theories with fuzzy multi-attribute decision-making methods has become a significant development direction at present. Among these theories, intuitionistic fuzzy set theory and prospect theory are very representative theories. The viewpoint proposed by prospect theory that decision-makers' psychological state can have an impact on decision-making is also very consistent with actual decision-making scenarios. Therefore, it uses direct fuzzy information and prospect theory to improve the existing TODIM, MABAC, EDAS, and other methods, and applies them to the evaluation of GF venture capital projects. On this basis, a multi index decision-making method based on fuzzy clustering analysis is proposed. The overall process of intuitionistic fuzzy multi-attribute decision-making is shown in Figure 3.

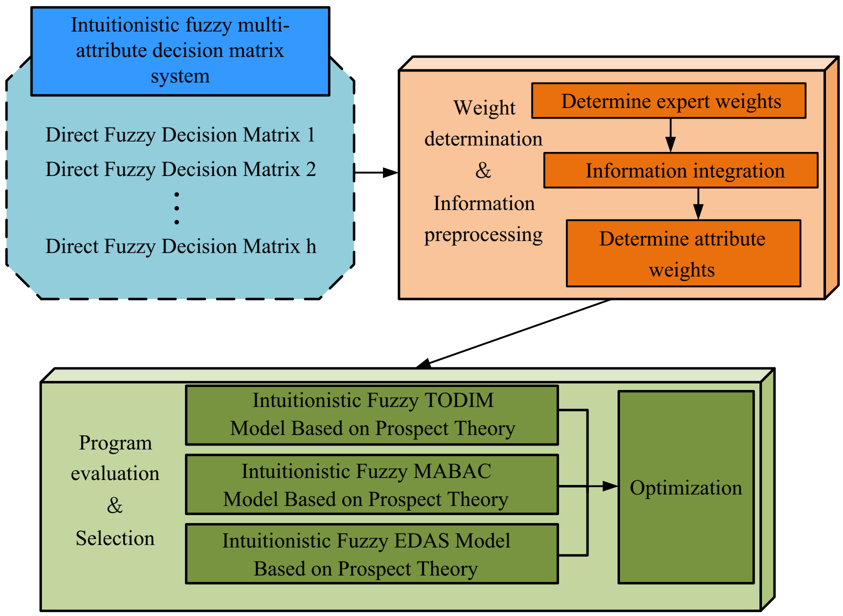

Figure 3: Intuitive fuzzy multi-attribute decision-making flow chart.

In Figure 3, the traditional TODIM method, MABAC method, and EDAS method are improved using intuitionistic fuzzy information and prospect theory, and the improved method is applied to the evaluation and decision-making of GF venture capital projects. The entropy weight method is used to determine the weight of objective evaluation of experts. Because the influence of expert weight in decision-making is objective, the multi-attribute decision model is an indicator that needs to balance the high degree of information confusion [27]. From this, it calculates the equilibrium evaluation matrix, as shown in equation (12):

$$\bar{b}_{rg} = (\bar{\alpha}_{rg}, \bar{\beta}_{rg}) = \left(1 - \sqrt[h]{\prod_{l=1}^{h}(1 - \alpha_{rg}^{(l)})}, \sqrt[h]{\prod_{r=1}^{h}(\beta_{rg}^{(l)})}\right), \tag{12}$$

where $\bar{b}_{rg}$ is the value of the equilibrium evaluation matrix and the entropy value is calculated using similarity information. From this, the similarity between the expert's evaluation value and the group equilibrium evaluation value can be used to calculate the corresponding entropy value, as shown in equation (13):

$$E_l = -\frac{1}{\ln(n \times m)} \sum_{r}^{n} \sum_{g=1}^{m} \left[\frac{\mathrm{Sim}(b_{rg}^{(l)}, \bar{b}_{rg})}{\sum_{r=1}^{n}\sum_{g=1}^{m}\mathrm{Sim}(b_{rg}^{(l)}, \bar{b}_{rg})} \cdot \ln\left(\frac{\mathrm{Sim}(b_{rg}^{(l)}, \bar{b}_{rg})}{\sum_{r=1}^{n}\sum_{g=1}^{m}\mathrm{Sim}(b_{rg}^{(l)}, \bar{b}_{rg})} \right) \right], \quad l = 1, 2, \ldots, h, \tag{13}$$

where h is the total number of experts collected, $b_{rg}^{(l)}$ is the expert evaluation value, and $\bar{b}_{rg}$ is the group equilibrium evaluation value. The entropy weight corresponding to expert evaluation information is shown in equation (14):

$$\varepsilon_l = \frac{1 - E_l}{\sum_{l=1}^{h}(1 - E_l)}, \quad l = 1, 2, \ldots, h, \tag{14}$$

where $\varepsilon_l = \frac{1 - E_l}{\sum_{l=1}^{h}(1 - E_l)}$, $l = 1, 2, \ldots, h$ is the entropy weight of the lth expert and E_l is the entropy value corresponding to the expert's evaluation information. In the construction of multi-attribute decision model in view of perceptual fuzziness, the numerical value of $\Phi(\mathrm{Al}_r)$ determines the pros and cons of the scheme and then constructs a suitable scheme model. Before processing the perceptual fuzzy matrix, it is usually necessary to first perform some preconditions and then synthesize the information in the perceptual fuzzy matrix through IFWA or intuitionistic fuzzy weighted geometric (IFWG). The criteria importance through intercriteria correlation (CRITIC) method is an objective weight determination method first proposed by Diakoulaki et al., which is in view of concepts such as correlation coefficient and standard deviation in statistics. A mixed method for determining attribute weights by combining CRITIC method and expert subjective weights is shown in equation (15):

$$\nu_g = \phi \cdot \nu_g^{(o)} + (1 - \phi)\cdot \nu_g^{(s)}, \tag{15}$$

where ϕ is a parameter and satisfies $0 \le \phi \le 1$, with a value of 0.5. The larger the standard deviation of a certain indicator, the greater the impact of its volatility on the overall evaluation value, and the greater the assigned weight value [28,29].

4 Analysis of investment RA for GF projects in view of multi-attribute perceptual fuzzy information decision-making technology

In this section, many simulation experiments were conducted to evaluate the effectiveness of GF project investment RA in view of multi-attribute perceptual fuzzy information decision-making technology. First, the relevant experiment utilizes information decision-making technology in view of multi-attribute perceptual fuzzy attributes to evaluate the investment risk of GF projects, and in view of this, analyzes and evaluates the changes in results from various parameter pairs. Finally, through experimental verification, the proposed method for RA of GF projects has shown greater practical value while ensuring accuracy and effectiveness.

4.1 Weighting and preprocessing of investment RA for GF projects incorporating multi-attribute perceptual fuzzy information decision-making technology

With the passage of time and changes in society, the issue of “greening” in society has become increasingly prominent; the emergence of GF further demonstrates the country’s support for the environmental protection industry, and the venture capital of GF is also a key link in this field. The expert evaluation content is shown in Table 1.

Table 1: Evaluation content and language-scale comparison table

Cost indicators	Benefit indicators	Language scale	Intuitionistic fuzzy number
At_2 Speed of emergence of alternative technologies	At_1 Technical feasibility	Very low (EL)	(0.1, 0.8)
At_5 Market access barriers	At_3 Technical team research and development capabilities	Lower (VL)	(0.2, 0.7)
At_{11} Resource consumption level	At_4 Market potential and demand	Low (L)	(0.3, 0.6)
At_{12} production of waste materials	At_6 Market access barriers	Moderately low (ML)	(0.4, 0.5)
At_{15} Difficulty of fund withdrawal	At_7 Quality of personnel	Medium (M)	(0.54, 0.4)
/	At_8 Progressiveness business philosophy	Moderate to high (MH)	(0.63, 0.28)
/	At_9 Enterprise centripetal force	High (H)	(0.78, 0.18)
/	At_{10} Renewable raw materials	Higher (VH)	(0.84, 0.03)
/	At_{13} Product recyclability	Extremely high (EH)	(1.2, 0.0)
/	At_{14} Return on investment	/	/

In Table 1, At_2, At_5, At_{11}, At_{12}, and At_{15} are the cost indicators, while the others are the benefit indicators. In view of the table information, expert weights can be calculated as 0.2796, 0.2221, 0.1914, 0.1328, and 0.1745, respectively. Because uncertain factors will inevitably have a certain impact on the results of venture capital, venture capitalists must conduct as comprehensive an investigation and analysis of the investment project as possible before making an investment; and in view of the evaluation recommendations of the expert group, make the final decision. First, by evaluating each indicator, the subjective and objective weights of each indicator are obtained; then, it analyzes the standardized direct fuzzy group evaluation matrix and extracts the target weights of each indicator from it. Finally, the weighting coefficients of the comprehensive evaluation indicators were obtained.

4.2 Model parameter changes and their effects in multi-attribute perceptual fuzzy information decision-making

The impact of parameter values in the model on decision results is explored by comparing them with empirical values to explore the reliability and robustness of the model. To more intuitively observe the degree of change in decision results caused by changes in the δ and τ parameters, 3D maps of IF-PT-TODIM and intuitionistic fuzzy preference theory-based evaluation based on distance from average solution (IF-PT-EDAS)

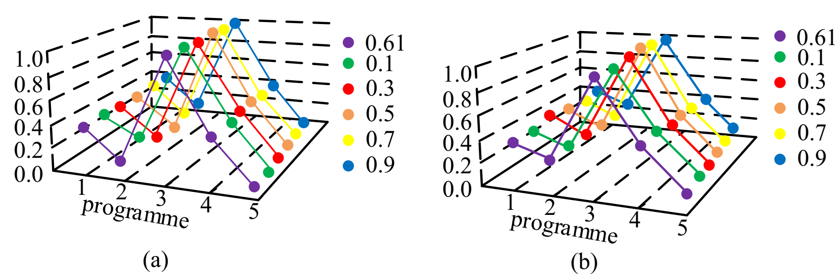

Figure 4: Effect diagram of individual changes in weight function parameter δ: (a) weight function parameter varies separately δ (IF-PT-TODIM model) and (b) weight function parameter varies separately δ (IF-PT-EDAS model).

with parameter changes were drawn, as shown in Figure 4.

As shown in Figure 4, the numerical changes of IF-PT-TODIM and IF-PT-EDAS are very small; however, these two values are consistent for the evaluation of each option, meaning that the ranking of these options has not changed, and the best option has not changed either. Therefore, changing the parameter δ alone will not have any impact on the correctness of the mode. The calculation results and their effect diagram when parameter τ changes separately are shown in Figure 5.

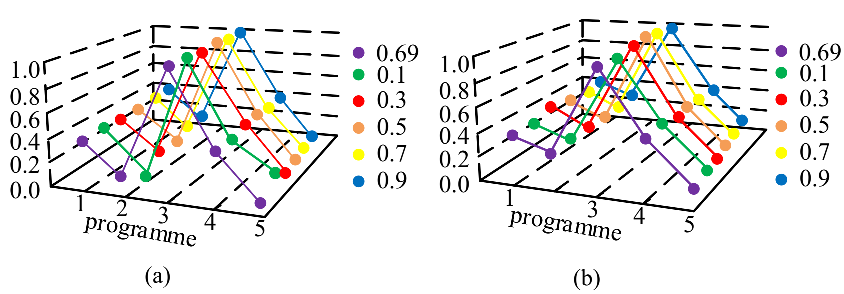

Figure 5: Effect diagram of individual changes in weight function parameter τ: (a) weight function parameter varies separately τ (IF-PT-TODIM model) and (b) weight function parameter varies separately τ (IF-PT-EDAS model).

In Figure 5, the individual change of parameter τ will also cause fluctuations in the ranking criteria in terms of numerical values, and the degree of fluctuation is similar to the effect when parameter δ is individually changed. In the IF-PT-EDAS model, the value function is used to improve the calculation of positive and negative distances between each scheme and the average scheme. That is to say, the changes in only a few variables will not have a significant impact on the changes in both variables. However, both models have the same overall rating for each project, which means they have no impact on the ranking of the project. Therefore, individual changes in parameter τ do not affect the effectiveness of the constructed model. The two parameters were put under the same parameter model for scientific control, as shown in Figure 6.

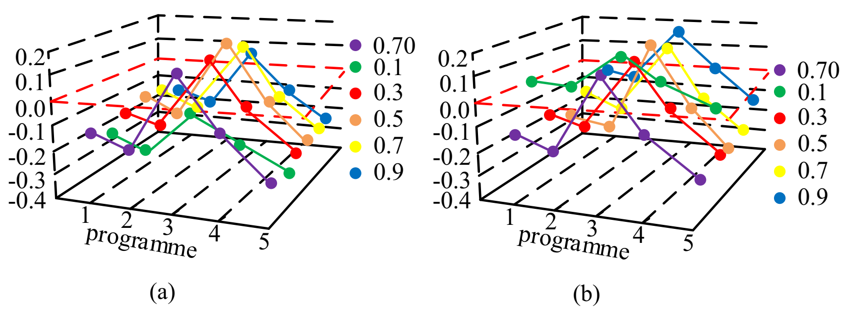

Figure 6: Weight function δ and τ changes only in intuitionistic fuzzy preference theory-based multi-attributive border approximation area (IF-PT-MABAC): (a) weight function parameter varies separately δ (IF-PT-MABAC model) and (b) weight function parameter varies separately τ (IF-PT-MABAC model).

In Figure 6, the sensitivity of each indicator was analyzed. The results indicate that the changes in each indicator will not affect the correctness and stability of the three models, while the overall stability of the IF-PT-MABAC model is poor. The IF-PT-MABAC model applies the concept of a value function to the calculation of the relative distance between each mode and the approximate boundary domain, and the parameter τ has poorer overall stability than the parameter δ in the model. The calculation results and their effect diagram when parameter σ is individually changed are shown in Figure 7.

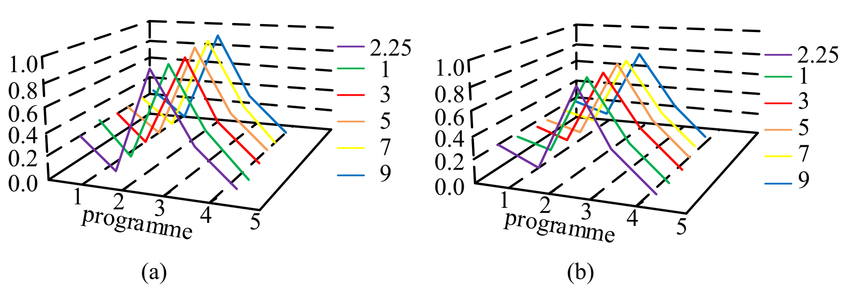

Figure 7: Effect diagram of individual changes in weight function parameter σ: (a) weight function parameter varies separately σ (IF-PT-TODIM model) and (b) weight function parameter varies separately σ (IF-PT-EDAS model).

In Figure 7, under different values of σ, the overall distance of the optimal solution is very close in numbers; as the value of σ gradually increases from 1, the overall distance between other schemes and the optimal scheme will also increase in number, i.e., the attenuation coefficient will increase. In the IF-PT-MABAC model, the gap between the superior scheme and the vulnerable scheme will be enlarged, so that the advantages of the optimal scheme will be more significant. Overall, only making changes to various factors did not affect the tendency of these two models to comprehensively evaluate each option; therefore, the two patterns constructed are stable. The calculation results and their effect diagram when parameter ς is individually changed are shown in Figure 8.

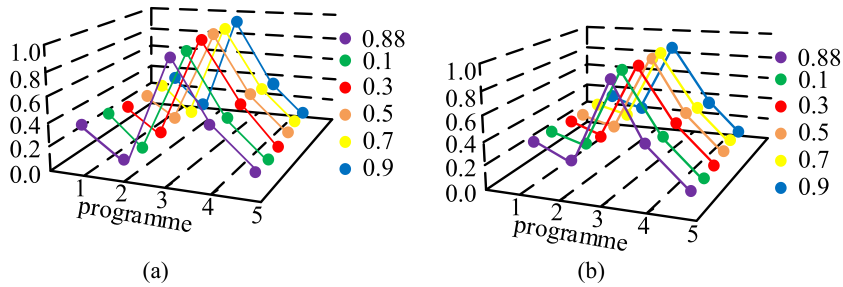

Figure 8: Effect diagram of individual changes in weight function parameter ς: (a) weight function parameter varies separately ς (IF-PT-EDAS model) and (b) weight function parameter varies separately ς (IF-PT-EDAS model).

Figure 8 shows the calculation results and its effect when the parameter ς is individually changed; this indicates that individual changes in parameter ς can also cause fluctuations in the numerical values of the calculation results. The effectiveness analysis of investment RA in view of parameter ς is shown in Figure 9.

In Figure 9, for the aforementioned RA analysis, the impact of different coping strategies under the same parameter on investment risk was compared. Compared with national bank of Kuwait (NBK), systematic review (SR), evolutionary algorithm (EA), the improved approach can reduce the risk of venture capital by 28.14, 15.47, and 11.05%, respectively. In the same model, IF-PT-MABAC, the influence of three different weight parameters is shown in Figure 10.

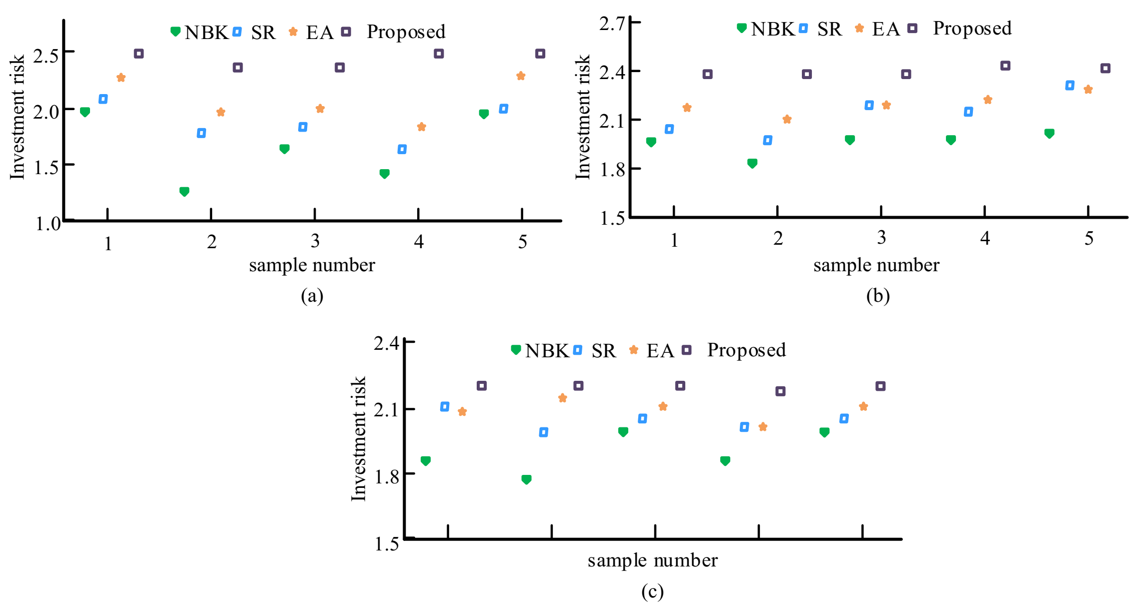

Figure 9: Analysis of the effectiveness of investment RA: (a) ς = 0.88, (b) ς = 0.5, and (c) ς = 0.9.

In Figure 10, according to the sensitivity analysis of the parameters related to the value function, the change of the three parameters of the value function will not affect the correctness and stability of the three models. Compared with methods such as IF-PT-TODIM and IF-PT-EDAS, the overall stability of the IF-PT-MABAC model is relatively poor. The results of sensitivity analysis indicate that whether it is the weight function or the value function; the changes in their parameters will not have an impact on the optimal and worst solutions; therefore, the IF-PT-TODIM model, IF-PT-MABAC model, and IF-PT-EDAS model are all effective and can provide assistance for decision-makers in evaluating and selecting optimal solutions in practice, with good stability. There is no clear connection between the advantages and disadvantages of each plan, which is in line with the actual situation. In addition, since changes in various parameters do not affect the

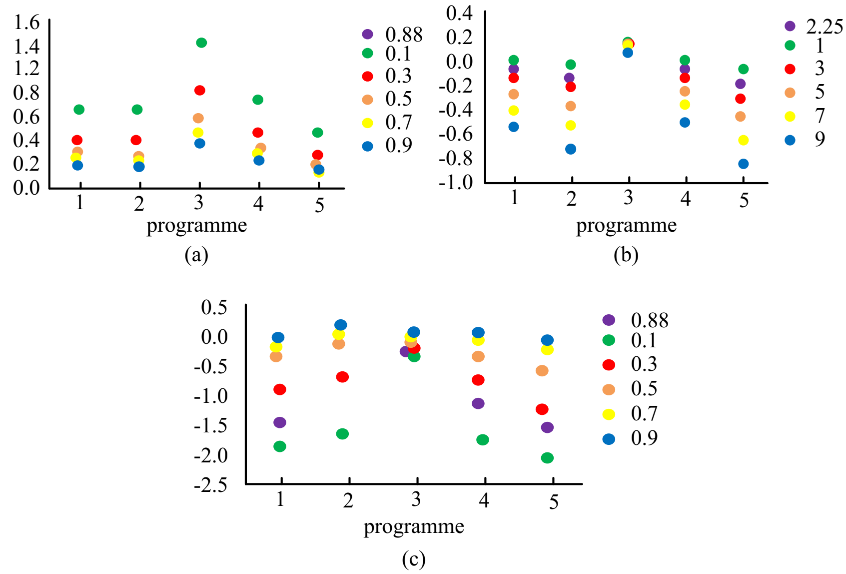

Figure 10: Variation of different parameters in the same model: (a) weight function parameter varies separately ς (IF-PT-MABAC model), (b) weight function parameter varies separately σ (IF-PT-MABAC model), and (c) weight function parameter varies separately ξ (IF-PT-MABAC model).

overall evaluation of each scheme by the three modes, all three modes are stable. Another method is to compare the proposed model with previous research results to verify the correctness of the proposed model.

4.3 Decision comparison of investment risk assessment for GF projects based on multi-attribute perceptual fuzzy information decision-making technology

In an intuitionistic fuzzy environment, several representative multi-attribute decision-making methods were selected, including the IFWA operator, IFWG operator, intuitionistic fuzzy multi-objective optimization by ratio analysis plus the full multiplicative form (MULTIMOORA) method, and intuitionistic fuzzy vlsekriterijumska optimizacija i kompromisno resenje method. In view of the same initial decision matrix, the ranking results are calculated and analyzed, as shown in Table 2.

Table 2: Different operators calculate and analyze the ranking results in view of the same initial decision matrix

Decision models	Sort results	Optimization	Worst-case scenario
IFWA operator	$Al_3 > Al_1 > Al_4 > Al_2 > Al_5$	Al_3	Al_5
IFWG operator	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5
IF-MULTIMOORA	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5
IF-VIKOL	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5
IF-PT-TODIM	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5
IF-PT-MABAC	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5
IF-PT-EDAS	$Al_3 > Al_4 > Al_1 > Al_2 > Al_5$	Al_3	Al_5

In Table 2, although there are certain differences between the IFWA operator's solution results and the proposed model, the difference only manifests as suboptimal and moderate, rather than optimal and worst; therefore, it does not affect the correctness and effectiveness of the proposed model. In addition, although the decision-making results under the three modes have high similarity, there are still certain differences in the decision-making process under each mode, such as the selection of reference points being different. The IF-PT-TODIM model uses two different choices as references, so the final evaluation value of each choice has better comprehensiveness compared to other choices; due to the fact that the IF-PT-MABAC model sets reference points near the edge and their values are easily influenced by extreme points, the model places more emphasis on locality; the IF-PT-EDAS mode, due to the use of the median method, can effectively eliminate the adverse factors brought about by the extreme value method; therefore, the options selected using this mode have good performance in all aspects. Compared with IF-PT-TODIM using only Hamming distance, IF-PT-TODIM using only Euclidean Reed distance, and IF-PT-MABAC using only Euclidean Reed distance, IF-PT-EDAS uses the weights of Hamming distance and Euclidean Reed distance to measure distance, resulting in a more accurate distance measurement; however, the Hamming distance used in both IF-PT-TODIM and IF-PT-MABAC modes is an Euclidean distance that takes into account hesitation, which can reduce data loss during processing.

5 Conclusion

As global climate change and environmental issues become increasingly serious, governments and financial institutions are stepping up efforts to promote GF in order to channel more funds to green and low-carbon projects, thus driving sustainable economic development. However, the long investment cycle of green projects, the uncertain change of returns, the fast speed of technological innovation, and the large change of policy environment make the risk assessment of GF projects more challenging. It is necessary to combine qualitative analysis methods, comprehensively consider the uncertainties in various aspects such as technical feasibility and policy impact, and carry out multi-scheme comparison and decision optimization. The results show that the initial step of the method is to define and calculate the expert weights, which are derived from the table information as 0.2796, 0.2221, 0.1914, 0.1328, and 0.1745. Next, by introducing the concept of attenuation coefficient, it is found that its increase leads to a quantitative expansion of the overall distance between the other alternatives and the optimal alternative. The evaluation techniques include IF-PT-TODIM and IF-PT-EDAS, which show consistency in evaluating the various options and are not affected by changes in their values. The order of these options and the optimal choice did not change. Through the sensitivity analysis of the weight function and value function, it is confirmed that the change of its parameters does not affect the optimal solution and the worst solution. This decision-making technology has a significant contribution to the investment risk assessment of GF projects. Compared with NBK, SR, and EA, the improved method reduces the risk by 28.14, 15.47, and 11.05%, respectively, showing significant advantages. However, there are still some shortcomings, such as aiming at a more complex investment risk environment; the scheme may need to be further optimized and adjusted. Looking to the future, this decision-making technology will continue to be optimized and extended to make it applicable to a wider range of GF project investment risk assessment scenarios. This may require empirical research in more fields to obtain more practical experience and theoretical support, so as to achieve better results in practical application.

6 Discussion

In the discussion section, the comparison of the results with the existing literature highlights the superiority of our study. First of all, compared with the work of Zhang J et al., the application of multi-attribute perceptual fuzzy information decision-making technology in the investment risk assessment of GF projects in this study has higher accuracy and real-time performance, and can more effectively define and warn high-risk projects [20]. Second, although Mohammadi et al. also proposed a method to evaluate the investment risk of GF projects, this study innovated in the method of analyzing fuzzy information and improved the accuracy of risk assessment [22]. In addition, compared with the study of Zamani A et al., the study not only evaluates the risk of the project, but also considers the improvement of the economic and social benefits of the project, thus providing investors with more comprehensive and scientific investment suggestions, which helps to improve the investment benefits and social benefits of GF [23].

In general, this study shows obvious superiority in both methodology and practicality, and is expected to play a greater role in multi-attribute perceptual fuzzy information decision technology in the investment risk assessment of GF projects in the future.

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