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Research Article

Investment Risk Assessment of Dispersed Wind Power in Low Wind Speed Area Using a Hybrid Multi-Criteria Decision-Making Approach Based on Hesitant Fuzzy Linguistic Environment

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Reducing the phenomenon of wind curtailment is essential to improve the level of wind power consumption. Wind power development in China has shifted to southeast region and dispersed wind power has developed rapidly and gradually become the new main force. However, various obstacles limit the smooth progress of dispersed wind power in low wind speed area. An important point is the absence of targeted risk analysis and evaluation methods. Therefore, the principal contribution of this paper is to find out the critical risk factors of such projects and propose the risk assessment model. First, 18 critical risk factors are identified using the constructed five-dimensional risk analysis model. Second, the hesitant fuzzy linguistic term set with credibility is utilized to collect evaluation information on one hand and to improve the multicriteria decision-making methods involved on the other hand. Third, the risk evaluation and ranking for 10 provinces that mainly develop dispersed wind power is carried out. The evaluation results indicate that the risk level of dispersed wind power projects is "Relatively Low" in most study provinces and the risk levels of Guangdong and Fujian are higher. It is worth noting that the consistency between the evaluation results and the distribution of wind resources can be used to guide the formulation of stimulus policies. Besides, the ranking results show some preference for investment choice. Finally, dual sensitivity analysis tests the stability of the model and shows the ranking results under different decision preferences. Scenario analysis gives the possible risk scenarios and evaluation results in the future. This study can provide insightful inspiration to wind power investors, risk management practitioners, and policymakers.

1. Introduction

Under the double crisis of energy and environment, renewable energy is valued and exploited by countries all over the world. At present, China's energy consumption structure is still dominated by fossil energy such as coal and oil, while the reserves of coal and oil are facing a severe shortage situation. The country urgently needs to adjust the energy structure to reduce its dependence on fossil energy. The development of wind power has become a strategic path for China to promote energy structure adjustment and an important means to promote air pollution control. In the "13th five-year plan of wind power," China has clearly stated that the total installed capacity of wind power grid-connected will reach more than 210 million kilowatts by the end of 2020, so as to achieve the goal of nonfossil energy accounting for 15% of primary energy consumption in 2020 [1]. According to the "China 2050 high renewable energy penetration scenario and roadmap study," 60% of China's power structure will be generated from renewable energy, of which 35.2% will be generated from wind energy [2].

Although the installed scale of wind power in China is expanding, the development of wind power still faces many challenges. At present, the development of wind power in China is mostly concentrated in the high wind energy resource areas represented by the "Three North" region, but these areas are far away from the power load center [3]. The current operation mechanism and transmission network cannot meet the large-scale wind power grid connection demand, resulting in serious wind power curtailment in these areas.

Therefore, the development of wind power in China has gradually shifted to the central and eastern regions, where wind resources are scarce. Distinct from the centralized wind power, dispersed wind power is close to the power load center and connected to the local power grid nearby, thereby avoiding long-distance transmission. Dispersed wind power has become a new driving force for the secondary growth of wind power. In order to achieve the goal of adding more than 42 million kilowatts of installed capacity of land wind power in the Middle East and south of China by the end of the "13$^{\text{th}}$ five-year plan" [1], the dispersed wind power in low wind speed areas will become the focus of the future development of wind power industry.

However, although the capacity of dispersed wind is small, various risks involved in the development and construction are no less than centralized wind power and even more complicated in terms of construction and coordination. Wind power projects would be affected by uncertainties in meteorology and technology [4, 5]. Low wind speed itself could bring risks and uncertainties to dispersed wind power [6, 7]. In addition, dispersed wind power from the initial investment and construction to the later operation and maintenance is vulnerable to policy and face many risks [8]. Dispersed wind power is still a new development mode in China, and there are numerous differences with centralized wind power. In order to fully release the development potential, some problems and risks must be solved. These are the main reasons for the embarrassing situation of "big thunder, small rain" in the development of dispersed wind power in China. The adequacy and rationality of risk analysis and evaluation (risk management) of renewable energy power generation are the key to the success of the project [9]. The same is true for dispersed wind power projects. The preliminary assessment and management of risks will affect the entire life cycle of the project [10]. Therefore, it is very necessary and urgent to carry out risk assessment for dispersed wind power.

The gap between the existing research and this study can be summarized as follows. First, most of the existing research objects are conventional wind power, lack of risk research on dispersed wind power in low speed area. Second, this paper selects the critical risk factors through five-dimensional risk analysis. Risk transmission is a vital feature of risk factors, in which risk infectiousness is considered for the first time. The novelty of this study can be described in the following aspects. (1) The critical risk factors (CRFs) of dispersed wind power in low wind speed area are identified. (2) Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach, fuzzy synthetic evaluation (FSE), and Vlsekriterijumska Optimizacija IKompromisno Resenje (VIKOR) method are improved through the Hesitant fuzzy linguistic term sets (HFTLS) to conduct risk assessment. (3) A practical risk assessment framework is proposed to carry out risk management for dispersed wind power. (4) The case study conducted risk evaluation and ranking around ten provinces that mainly developed dispersed wind power.

To this end, the rest of the paper is structured as follows: The second chapter provides a comprehensive literature review. The third chapter gives details of the selected CRFs from the five dimensional of possibility, severity, infectiousness, uncontrollability, and urgency. The fourth chapter combs the important theoretical methods involved in this paper. Chapter 5 is the specific application of the constructed risk assessment framework. In Chapter 6, dual sensitivity analysis and scenario analysis are performed. Sensitivity is used to test the stability of the evaluation results and the influence of different decision preferences on the results. Scenario analysis gives the possible risk scenarios and the corresponding evaluation results in the future. Chapter 7 provides conclusions and outlooks.

2. Literature Review

This part provides an updated literature review from the following aspects: (1) risks faced by dispersed wind power in low wind speed area; (2) risk analysis angle and screening method of CRFs; (3) collection tools of evaluation information; and (4) risk evaluation and ranking methods.

Investment and development of dispersed wind power are affected by many risk factors. Collecting and identifying the key risk factors is the prerequisite for risk management and risk assessment. Dispersed wind power would face various risks of conventional wind power projects. In addition, it has special risks that need to be excavated and identified. Wu et al. [11] set up the evaluation criteria of wind power projects from the aspects of construction environment, total investment, policy risk, pollution reduction, and impact on local economy. Kang et al. [12] evaluated the performance of wind power from the perspectives of policies, wind energy resources, and environment. Onar et al. [13] regarded reliability, technical characteristics, performance, cost factors, availability, maintenance, co-operation, and family life as the selection criteria of wind energy technology. Tian et al. [14] pointed out that wind power has the characteristics of intermittence, randomness, volatility, and uncontrollability. It is suggested to consider the reliability, economy, and stability of large cluster wind power when it is connected to the transmission system. Similarly, dispersed wind power also has such problems, and these technical factors need to be considered for risk analysis. Jiang et al. [15] introduced that the wind has obvious diurnal and seasonal variation, and the fluctuation of wind speed could affect the construction of wind farm. There are many studies [16, 17] using a geographical information system and multicriteria decision-making methods to locate wind farms, the main factors considered are average wind speed, land use restrictions, traffic conditions, protected areas, population density, and so on. It can be concluded that the risk factors affecting the development of wind power mainly come from policy, economy, natural environment, and technology. However, there are few studies considering the impact of wind power on the ecological environment. Al Zohbi et al. [18] analyzed the impact of wind farms on birds and suggested avoiding building wind turbines in areas where birds are highly concentrated. In addition, the deployment of wind power would also affect other animals and plants in the project site.

However, compared with general wind power, dispersed wind power has its own unique characteristics and deployment points. Wu et al. [19] constructed four evaluation indexes of economy, environment, infrastructure, and society for the location of low wind speed wind farm. But the influencing factors corresponding to the distributed wind power in low wind speed regions have not been excavated. Couture and Gagnon [20] introduced the impact of feed in tariff policy on the development of renewable energy. At present, the profitability of dispersed wind power also depends on the electricity price policy. The research of Yang et al. [21] shows that although the dispersed wind power connection mode can solve the problem of centralized grid connection, it will also bring challenges to the operation mode of the traditional distribution network. In addition, since the existing technology research is concentrated on the conventional wind turbine, the technical status of the wind turbine corresponding to the dispersed wind power in the low wind speed region is still not mature [22, 23]. Therefore, the technology risk should obtain enough attention. It is worth noting that "local balance, nearby consumption" is the most important feature of decentralized wind power, and its pilot, growth and expansion path is the opposite of that of large wind power bases. Therefore, the market risk of the location of the dispersed wind power project needs to be considered.

To sum up, this study will explore the risk factors of dispersed wind power in low wind speed areas from five aspects: policy, natural environment, technology, economy, and market and focus on its unique risks in policy, market, and technology.

The effectiveness of risk assessment mainly depends on the perspective of risk analysis and the applicability of risk evaluation method. After collecting all kinds of risk factors that dispersed wind power may face in low wind speed areas, the fundamental work is to use a risk analysis mechanism to select the critical risk factors (CRFs). Most scholars rate risk factors from several representative perspectives. Yazdani-Chamzini et al. [24] described risks factor from four dimensions: uncertainty impact, likelihood or probability, and ability to respond. Sarkar and Panchal [25] proposed the exposure of risk. Wang et al. [26] added two new analysis angles, namely, urgency and unpredictability. Wu and Zhou [10] believed that the uncontrollability of risk is also essential and should be considered. More and more researchers pay attention to the infectivity of risk factors, which will lead to a domino effect. Therefore, it is necessary to focus on these risk factors with significant infectiousness. Besides, the characteristics and impact of risk factors should be reflected from multiple aspects, and a single dimension is not representative [10]. After carefully studying the above risk analysis perspective, this study considers the infectivity of risk. To sum up, this study will analyze the identified risk factors from the opinions of probability, severity, uncontrollability, urgency, and infectiousness.

The important link after determining the key risk factors is to collect evaluation information. The evaluation of the risk level is qualitative, which is largely ambiguous and uncertain. Therefore, a great information collection tool is particularly important. There are numerous tools for collecting and describing evaluation information. The fuzzy set (FS) [27] can describe the fuzziness of evaluation information, but it cannot adapt to complex evaluation problems based on a single evaluation linguistic variable. Intuitionistic fuzzy set (IFS) [28] and 2-tuple linguistic (2TL) [29] introduced multiple evaluation language variables to ensure the accurate expression of expert opinions, but ignored the reliability of evaluation information. 2-dimensional linguistic (2DL) [30] represents the reliability of evaluation information by introducing new dimensions. However, experts are often unable to give the exact linguistic variables for risk evaluation. Specifically, it will appear between two evaluation linguistic variables, above or below a certain evaluation linguistic variable. Therefore, hesitant fuzzy linguistic term set (HFLTS) [31] came into being. HFLTS can contain multiple linguistic variables and flexibly obtain the qualitative evaluation information provided by the interviewees. This qualitative information collection tool is more in line with the actual interview situation, so it is very suitable for the collection of risk assessment information in this study. Through the above analysis, this study uses the HFLTS with credibility to obtain evaluation information of each CRFs.

After the completion of information collection, the risk evaluation stage is officially entered. This stage involves the selection of evaluation methods. According to the above analysis, it can be observed that the risk factors that affect the dispersed wind power in low-speed areas come from many aspects and its risk assessment should be a multicriteria decision-making (MCDM) problem [32, 33]. Fuzzy synthetic evaluation (FSE) is a MCDM method commonly used in the field of risk assessment. The risk assessment of dispersed wind power is based on multiple CRFs and belongs to the MCDM problem. The FSE method can well deal with such risk assessment problems [34]. Many scholars use the FSE method to conduct risk studies. Table 1 summarizes representative cases to prove the applicability of the method. It is easy to see that FSE method is widely used in the field of risk assessment. This study will use FSE method to conduct the risk evaluation and obtain the risk level of the assessment objects.

The evaluation value given by the FSE method can be employed to sorting. In addition, this paper also uses the fuzzy VIKOR method to rank the evaluation objects. VIKOR is one of the classical MCDM methods, which can fully reflect the decision-maker's subjective preferences. This method has been widely used in the ranking of MCDM problems. Numerous studies [40–42] show that the effectiveness of fuzzy VIKOR method for solving MCDM problems. Sorting results given by the two methods can be compared and verified on one hand and complement each other on the other hand. The sensitivity analysis section will study the influence of different decision preferences on the

Table 1: Typical risk assessment research and methods used.

Authors	Objects of risk assessment	Evaluation method
Liu et al. [35]	Ultradeep drilling project	
Rai et al. [36]	International transboundary rivers	
Zhao et al. [37]	Green projects	FSE method
Ruparathna et al. [38]	Service of buildings	
Wu et al. [39]	Straw power generation project, offshore wind power project	

final ranking results by adjusting the decision mechanism coefficient in the VIKOR method.

3. Risk Evaluation Index System for Dispersed Wind Power Project

A scientific and reasonable risk criteria system is a prerequisite for conducting risk analysis and evaluation. In this study, risk identification and screening of critical risk factor are two key steps to build a dispersed wind power risk assessment index system in low wind speed area.

3.1. Identifying Risk Factors through Relevant Literature. Dispersed wind power project in low wind speed area involves many risks. The main point of this step is to study and sort out the various risks involved. Literature read covers wind power site selection, wind power project decisions, and wind power risk analysis. Research subjects include conventional wind power, centralized wind power, distributed wind power, and low wind speed wind power. There are similar risks in various types of wind power. Different types of wind power have similar risks. The key of this study is to find out the risk of dispersed wind power in low wind speed areas. Finally, a list containing 36 risk factors affecting dispersed wind power project in low wind speed area is obtained. Table 2 details the risk factors identified in this section in relation to distributed wind power.

3.2. Selecting CRFs Based on Five-Dimensional Risk Analysis. In this part, infectiousness is used to describe the characteristics that a certain risk will lead to other risks. Figure 1 shows five analysis angles and scoring mechanism of identified risk factors. The comprehensive influence degree of the scores of the five dimensions after standardization will be used as the basis for selecting CRFs.

This section collects the evaluation information about the importance of risk factors by sending questionnaires to experts. In this part, the questionnaire was submitted to experts in the field to score the identified risk factors from the above five dimensions. The scoring process uses a seven-point system [47, 48]. The background information of the experts involved in the process is detailed in Table 3. Referring to the calculation method of comprehensive impact index of risk factors obtained in research [49], equation (1) is used in this section to calculate the comprehensive impact. According to the comprehensive impact value after standardization, a value greater than 0.6 is selected as the CRF [50]. Table 4 shows the CRFs screened through the above process.

$$\text{Comprehensive impact} = \sqrt[5]{\text{Probability} \times \text{Severity} \times \text{Uncontrollability} \times \text{Urgency} \times \text{Infectiousness}}. \tag{1}$$

3.3. CRFs and Their Specific Meaning

3.3.1. Policy Risk G1. Since 2006, China wind power has entered the stage of bidding and approval of electricity prices. However, with the generation of wind curtailment phenomenon and power limitation, benchmarking tariff has been implemented in China in 2009. The wind power industry has changed from rapid expansion to contraction, and the problem of wind curtailment has been curbed to a certain extent. Policy plays an important role in the wind power industry, and for dispersed wind power project in low wind speed area, it depends more on the support of relevant policies.

(i) Policy subsidy risk C11: Current financial subsidy mainly includes the differential subsidy between wind power benchmark price and coal power price, as well as the project investment and OM costs of wind power project connected to power grid system. Appropriate subsidies shall be granted according to the amount of electricity connected to the power grid. Because of the different price of benchmark electricity in different regions, the corresponding subsidies are also different. With the development of wind power for decades, financial subsidies for centralized wind power in high wind speed areas have matured and stabilized. However, dispersed wind power in low wind speed areas needs to be developed, and related policies and government services need to be improved. There is a risk of uncertainty in financial subsidies.

The types of taxes involved in various wind power projects in different regions are different, and the risk of preferential tax treatment for wind power projects is also different. For example, some low wind speed wind power projects use imported wind

Table 2: Risk factors associated with wind power projects.

No.	Risk factors	References																	
		[18]	[14]	[17]	[16]	[17]	[13]	[23]	[43]	[11]	[19]	[44]	[21]	[12]	[22]	[20]	[45]	[46]	[46]
1	Policy subsidy risk				√			√		√	√			√		√		√	√
2	Green power certificate risk													√					
3	Wind resource condition risk	√	√	√	√	√		√	√	√	√	√	√	√			√	√	√
4	Regional capacity		√	√	√								√		√				
5	Electricity demand risk		√	√	√	√			√			√	√		√				
6	Installed capacity matching risk		√	√	√		√	√	√						√				
7	Output characteristic risk		√	√	√		√		√										
8	Annual utilization hour risk			√						√									
9	Terrain conditions													√			√		
10	Construction difficulty risk				√	√		√		√	√	√							
11	Project design management risk									√									
12	Climatic conditions																		
13	Construction work coordination				√					√									
14	Wind turbine technical condition						√	√		√				√			√		
15	Site selection risk	√			√	√						√							
16	Noise control risk	√				√				√	√								
17	Grid connection risk		√			√			√		√		√						
18	Scheduling risk		√						√				√		√				
19	On-grid price risk							√	√	√	√			√		√			
20	Communication delay risk												√						
21	Land acquisition cost risk							√		√	√								
22	Construction cost risk													√			√	√	√
23	Operation and maintenance cost													√					
24	Profitability risk										√			√			√	√	√
25	Construction cycle risk							√											
26	Operational maintenance risk																		
27	Ecological damage risk	√				√				√	√			√			√	√	√
28	Construction risk																		
29	Loan interest rate fluctuation risk							√			√								
30	Wind direction error risk		√	√			√	√		√									
31	Public acceptance																	√	√
32	Impact on agriculture and tourism									√								√	√
33	Life cycle risk						√	√											
34	Installed cost risk						√	√	√	√	√								
35	Energy supply reliability						√			√									
36	Turbulence risk						√					√							

turbine equipment, and tariff preferential policies will have an impact on them.

(iii) On-grid price risk C12: Feed in tariff policy is the key factor to affect the return on investment. Because of the characteristics of low wind speed wind turbines, such as long blades, high hub, and low cut-in wind speed, the unit cost of wind power in low wind speed environment is higher. If the power tariff policy is not supported, the development of low wind speed wind power projects and related industries will face difficulties. The price summary of wind power benchmark in each resource area is shown in Table 5. However, the power tariff policy for dispersed wind power project in low-speed areas is not yet mature, which has caused certain risks and uncertainties to the project.

(iv) Green power certificate risk C13: The key content of green power certificate mainly includes quota system, consumption, and green certificate trading mechanism. Quota system can ensure the strategic position of wind power development, and the absorption policy can ensure the absorption of wind power, thereby reducing the phenomenon of wind curtailment.

Renewable energy quota assessment and green power certificate compulsory constraint trading mechanism were launched in 2018. Green power certificate is a supplement to the existing wind power subsidy mechanism in China, which

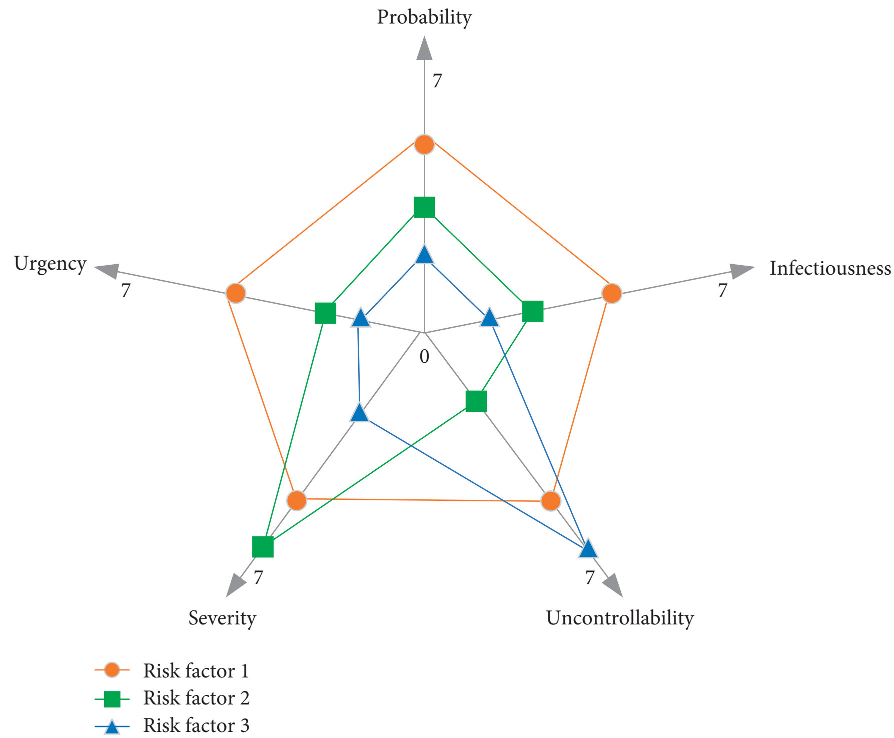

Figure 1: The mechanism of five-dimensional risk analysis.

Table 3: The background information of the experts involved in this study.

Institution	University				Energy development research institute		Electric power planning & engineering institute		TBEA Co., Ltd		Relevant government departments	
Rate	(4) 33.33%				(2) 16.67%		(2) 16.67%		(2) 16.67%		(2) 16.67%	
Number	1	1	1	1	1	1	1	1	1	1	1	1
Number of related SCI papers	5	4	4	4	2	2	2	2	1	2	2	2
Number of projects involved	2	2	2	2	3	3	4	3	3	3	2	2

can promote the efficient utilization of wind power and reduce the direct subsidy intensity of national financial funds. However, the layout of dispersed wind power project will affect the allocation of renewable energy quotas, so green power certificates have an important impact on the investment of dispersed wind power project in low wind speed areas.

3.3.2. Environmental Risk G2

(i) Wind resource conditions C21: The level of wind resources has a direct impact on the installed capacity and on-grid electricity of wind power projects in low wind speed area. At the same time, it has a direct impact on the safety and reliability of low wind speed wind turbines. The level of wind resources is mainly expressed by annual average wind speed, wind power density, and available hours of wind resources. Generally speaking, the greater the average annual wind speed, the greater the average annual wind power density, the more hours available for wind resources, and the higher the power generation capacity of wind farms.

(ii) Topographic conditions C22. Topographic conditions mainly include geology, topography and regional stability. Geological conditions directly affect the investment of low wind speed wind farm projects; terrain affects the layout of low wind speed wind turbines; and regional stability determines the safe operation of low wind speed wind farms. Terrain conditions not only affect the construction activities of low wind speed wind power projects, but also affect the later operation. Therefore, when considering the risk assessment index of dispersed wind power project, topographic conditions need to be included in the environmental risk.

(iii) Climatic conditions C23: Climate conditions have a direct impact on installation and maintenance of low wind speed wind turbine equipment. Strong winds, thunderstorms, and ice deposits are all environmental risk factors affecting the operation of low-speed wind turbines. At the same time, seasonal changes will also have an impact on wind power

Table 4: CRFs selected by five-dimensional risk analysis.

No.	CRFs	Probability	Severity	Urgency	Uncontrollability	Infectiousness	Normalized impact
1	Technical conditions for wind turbine	5	5	6	3	5	1.0000
2	Policy subsidy risk	4	4	6	4	5	0.9519
3	Grid connection risk	5	5	5	3	5	0.9448
4	Regional absorptive capacity	5	5	6	2	5	0.8800
5	Operation &maintenance risk	6	4	5	3	4	0.8684
6	Demand risk of electricity consumption	4	5	6	2	5	0.8179
7	Topographic conditions	4	6	4	3	4	0.8069
8	Project construction risk	6	4	5	3	3	0.7896
9	On-grid price risk	5	4	5	2	5	0.7693
10	Operation &maintenance cost	5	5	4	3	3	0.7420
11	Wind resource condition risk	4	5	4	2	5	0.7121
12	Ecological damage risk	4	5	5	2	4	0.7121
13	Impact on agriculture and tourism	4	5	5	2	4	0.7121
14	Green power certificate risk	3	4	5	3	4	0.6860
15	Climatic conditions	5	4	3	4	3	0.6860
16	Public acceptance	3	5	5	2	4	0.6420
17	Construction cost risk	3	4	4	3	4	0.6324
18	Profitability risk	3	4	4	3	4	0.6324

Table 5: The benchmark grid price of wind power in low wind speed areas in recent five years.

Resource area	Areas covered by each resource area	Benchmarking on-grid price (Yuan/kWh)					Guide price
		2015	2016	2017	2018	2019	2020
Class IV resource area	Areas other than class I, II, and III resource areas	0.61	0.6	—	0.57	0.52	0.47

equipment. For example, in winter Hilly areas, the surface of conductor lines and wind turbine blades is easy to freeze, resulting in excessive load of conductor lines and unit operation, affecting the life of units. When the ice is serious, it also needs to be stopped for maintenance, resulting in many power losses.

(iv) Ecological damage risk C24: Low wind speed wind farms usually arrange wind turbines along ridges. Most of these areas have not been developed. In the process of construction of low wind speed wind power projects, ecological damage and soil erosion may be caused by inadequate management measures. At the same time, wind farms will also affect migratory birds migration [51]. With the increasingly stringent requirements of local governments for environmental impact assessment, the ecological damage risk has a direct impact on whether dispersed wind power projects can start construction.

3.3.3. Market Risk G3

(i) Regional absorptive capacity C31: Matching the load points with the absorptive capacity and access conditions to meet the requirements is the key link in site selection and planning of dispersed wind power projects. The output characteristics of the wind turbines should be adapted to the load composition and load variation characteristics of the substation. For distributed projects, the load stability characteristics of the self-service part should also be considered.

(ii) Demand risk of electricity consumption C32. Electricity demand refers to the amount of electricity needed by local economic development and residents' daily life, which has the characteristics of fluctuation. The project construction is mainly to solve the local demand for electricity. Great load forecasting of electricity demand can better guide the development, so that the generated electricity can be absorbed locally. However, the demand for social electricity will change with time and current economic level. When the demand for electricity is high, the absorption capacity of low wind speed wind power will be stronger, and the investment income of the project will be greater. When the demand for electricity is low, the investment benefit of the project will be affected.

3.3.4. Technical Risk G4

(i) Technical conditions for wind turbine C41: The existing market mainly produces and develops wind turbine suitable for better wind resource conditions. Mainstream wind turbine manufacturers have not yet put their energies into the immature low wind speed wind turbine field. The matching degree between the technical conditions of wind turbines that have not entered the era of low wind speed and dispersed wind power projects is relatively low. This factor will become an important risk in the layout of dispersed wind power in low wind speed area.

(ii) Project construction risk C42: The sites of dispersed wind power projects are often located in hilly areas, where the terrain is complex and access road conditions are poor. At the same time, low wind speed wind turbine blades and tower barrels generally have transportation problems. The main equipment of low wind speed wind turbines has a long transportation distance, and it is difficult to meet the requirements of equipment transportation on access roads, which will undoubtedly bring risks to construction. In the construction process, due to the lack of ecological protection awareness, inadequate management measures are easy to cause soil erosion, ecological damage, and then cause changes in construction conditions, which in turn will cause construction risks for the project. Therefore, in the risk analysis of dispersed wind power projects in low wind speed areas, construction risks should be considered.

(iii) Grid connection risk C43: Because of the inherent intermittence and fluctuation of wind power, the prediction accuracy of power grid is reduced, which has an adverse impact on power grid. At present, power grid is inclined to avoid wind power integration, which brings uncertainty and risk to the grid connection. The construction cost of the low wind speed wind power project is relatively high, which makes the project investment benefit more dependent on the power generation revenue. This puts higher requirements on the wind power grid connection, to ensure the maximum output of the project.

(iv) Operation and maintenance (O&M) risk C44: Due to the existence of environmental risk factors, there are certain risks in the operation and maintenance of dispersed wind power in this area. Topographic conditions would make it difficult to replace and repair equipment components, while climate conditions would affect the normal operation of low wind speed wind power equipment. Once problems occur in the operation process, it is possible to cause wind turbine outage due to maintenance, which could lead to a large number of power losses, affecting the investment benefits of project. So, it is necessary to take operational maintenance risk into account when analyzing risk factors.

3.3.5. Economic and Social Risks G5

(i) Construction cost risk C51: The infrastructure such as roads is relatively backward, which results in high investment in civil engineering and transportation costs of dispersed wind power projects. At present, the cost of wind turbine equipment in China has decreased, but the price is still high, and there would be a corresponding large cost expenditure when purchasing wind turbines, which would bring risks to the construction cost of project.

(ii) Operation and maintenance cost risk C52: After the completion of wind power project construction, it will enter the stage of power generation operation. O&M cost refer to the cost incurred in the maintenance of wind power equipment during the power generation stage, and the risk mainly manifests in the risk of cost increase. The O&M experience of dispersed wind power in low wind speed areas is still insufficient, and the cost of daily O&M management is uncertain and would gradually increase with the running time of the project.

(iii) Profitability risk C53: For investors, the goal of investing in dispersed wind power projects in low wind speed areas is to achieve profitability. However, there are various problems in the construction and operation of the project, which lead to the risk of project profit. The analysis of profitability is based on the financial indicators of typical projects in the area to judge the profitability risk. For profitability risk, project investment payback period and internal rate of return are good judgment basis.

(iv) Public acceptance risk C54: It refers to whether the attitude of residents towards the project contributes to the construction investment of the project. If the public can accept the implementation of dispersed wind power projects in the local area, it will speed up the development of the project. On the contrary, it may delay the development of the project. The operation of the project can provide local electric power resources needed for production and living, and can promote employment and local economic development. However, there are also disadvantages. The construction of wind power projects may cause damage to the local ecological environment to a certain extent, resulting in the inconsistency of the landscape, and may also have an impact on migratory bird migration. There will be noise in the operation of wind turbines, and there may be noise disturbing problems, which will affect public acceptance, and then cause public acceptance risk.

(v) Impact on agriculture and tourism C55: This factor refers to the impact of the construction and operation of dispersed wind power on local agricultural production and tourism development, thus bringing risks to the project. The layout of the project may involve agricultural land, affecting the distribution of roads and waterways. Dispersed wind power is limited in scale, which cannot bring the landscape effect created by centralized wind power.

The matching degree between the technical conditions of wind turbines that have not entered the era of low wind speed and dispersed wind power projects is relatively low. This factor will become an important risk in the distribution of dispersed wind power in low wind speed area. Therefore, these adverse effects would bring risk to the project.

The above 18 risk factors are the critical criteria affecting the development of dispersed wind power in low wind speed areas. In summary, it can be divided into five categories: policy, environment, market, technology, economy, and society. These CRFs constitute the evaluation index system of this study as shown in Figure 2.

4. Methods and Tools

4.1. Collection Tool for Qualitative Evaluation information—HFLTS with Credibility. Collecting evaluation information is the critical part for risk assessment of dispersed wind power in low wind speed area. The expert committee is responsible for giving the evaluation information of each CRF. This paper uses HFLTS with credibility to gather evaluation information.

Definition 1 ([See 52, 53]). Linguistic term set $S = \{s_i, s_{i+1}, s_{i+2}, \ldots, s_n\}$ is a finite ordered set, and there are odd types evaluation terminologies in set S. Besides, there are some conditions to satisfy for linguistic term set S:

(1) Order: $s_i \geq s_j \Longleftrightarrow i \geq j$

(2) Maximum operator: if $s_i \geq s_j$, then $\max(s_i, s_j) = s_i$

(3) Minimum operator: if $s_i \geq s_j$, then $\min(s_i, s_j) = s_j$

Definition 2. HFLTS is utilized in three aspects: the collection of evaluation information of each CRF, the linguistic measurement scale of influence degree, and the risk level. There are seven linguistic elements in the HFLTS used in this part, and the details are as follows:

$$S = \left\{ \begin{array}{c} s_{-3}\text{: Very low (VL)}, s_{-2}\text{: Low } (L), s_{-1}\text{: Relatively } low\text{ (RL)}, s_0\text{: Medium } (M), \\ s_1\text{: Relatively high (RH)}, s_2\text{: High } (H), s_3\text{: Very high (VH)} \end{array} \right\}. \tag{2}$$

It is generally discrete that the evaluation value is obtained by the traditional linguistic model, which makes a difficulty for further calculation and analysis. In the calculation process of HFLTS, the discrete linguistic terminology set will be transformed to be continuous. It is needed to notice that the continuous linguistic terminology will appear not only in calculation process, but expert evaluation questionnaire. Each linguistic variable in a linguistic terminology set can be paired with a triangular fuzzy number (TFN). It is relatively common functions that triangular membership functions are commonly used to construct transformation correspondences (as shown in Figure 3) [54].

Example 1. Taking $s_{1.3}$ as an example,

$$\begin{aligned} s_{1.3}\text{: } (0.5501, 0.7171, 0.8831) = (0.5 &+ (1.3 - 1) \times 0.167, 0.667 \\ &+ (1.3 - 1) \times 0.167, 0.833 \\ &+ (1.3 - 1) \times 0.167). \end{aligned} \tag{3}$$

Definition 3. [31]). E_{G_H} is a transformation relationship, which can transform the linguistic description LD into a HFLTS H_S on the linguistic term set S. The specific rules are as follows:

(1) $E_{G_H}(s_i) = \{s_i \mid s_i \in S\} = \{s_i\}$

(2) $E_{G_H}(\text{between } s_i \text{ and } s_j) = \{s_k \mid s_k \in S, s_i \leq s_k \leq s_j\} = \{s_i, s_{i+1}, \ldots, s_j\}$

(3) $E_{G_H}(\text{below } s_i) = \{s_k \mid s_k \in S, s_k \leq s_i\} = \{s_0, s_1, \ldots, s_i\}$

(4) $E_{G_H}(\text{above } s_i) = \{s_k \mid s_k \in S, s_k \geq s_i\} = \{s_i, s_{i+1}, \ldots, s_g\}$

Respondents prefer a linguistic rather digital value diametrically and generally tend to give the evaluation results with a certain level rather than a total assurance. Therefore, the HFLTS based on credibility [10, 55] will be collected in this paper to fully grasp the evaluation information of qualitative indicators.

Definition 4. A HFLTS with credibility can be expressed as follows:

$$H_S = \{(s_i, C(s_i)) \mid s_i \in S\}. \tag{4}$$

Example 2. Respondents considered that the grid connection risk C43 of object A3 is between s_0 and s_1. Then, the credibility-based HFLTS for this qualitative index can be obtained as follows:

$$H_S(C_{s_i}) = \{(s_0, 0.2), (s_1, 0.3), (s_2, 0.5)\}. \tag{5}$$

The credibility of the linguistic value for a certain evaluating criterion are 0.2, 0.3, and 0.5, which correspond to the medium, relatively high, and high, respectively.

Example 3. Taking the result of HFLTS with credibility as an example to illustrate the aggregation operation. The evaluation information of C_{ij} we have got is that experts think this indicator can be descripted as term s_{-2} with twenty percent, term s_{-1} with fifty percent, and term s_0 with thirty percent.

$$\begin{aligned} H_S(C_{ij}) &= \{(s_{-2}, 0.2), (s_{-1}, 0.5), (s_0, 0.3)\} \\ &= (0.2s_{-2}, 0.5s_{-1}, 0.3s_0) \\ &= (0.2 * (0, 0.167, 0.333), 0.5 * (0.167, 0.333, 0.5), 0.3 \\ &\quad * (0.333, 0.5, 0.667)) \\ &= (0.183, 0.35, 0.517). \end{aligned} \tag{6}$$

4.2. HFLTS-DEMATEL Method. DEMATEL is a factor analysis method used to study the correlation and degree

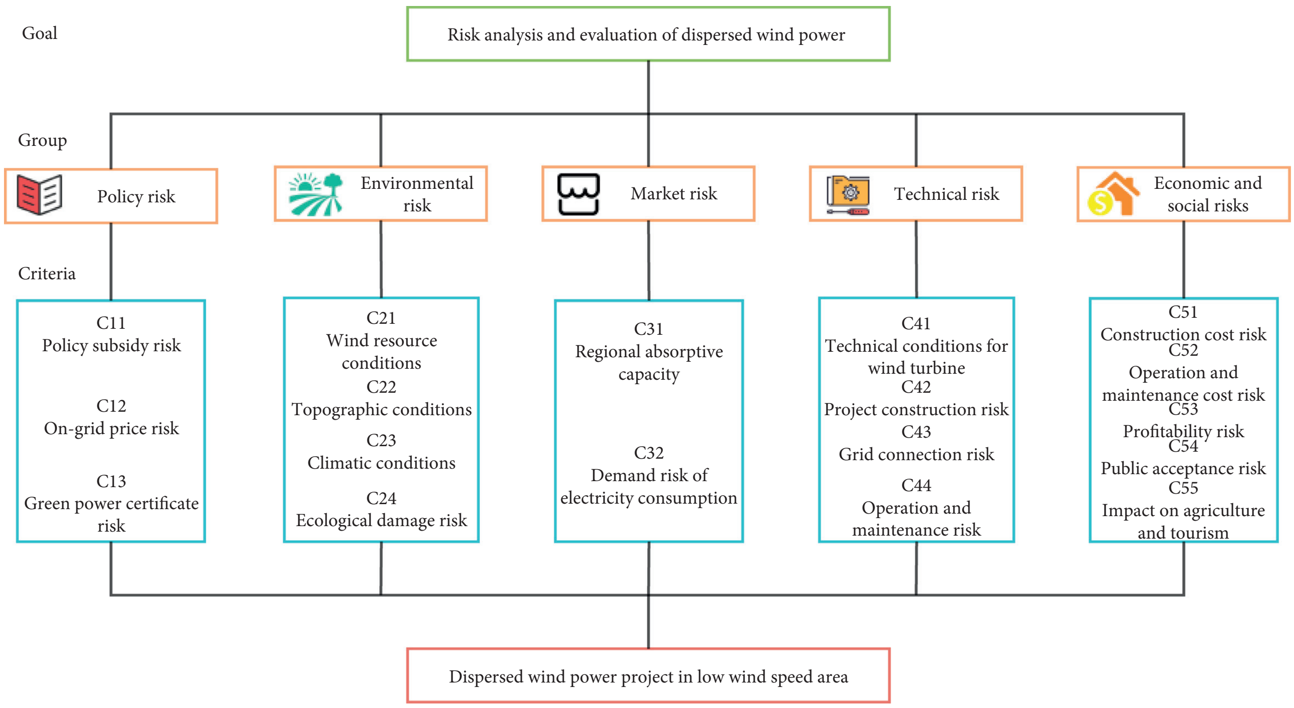

FIGURE 2: Risk evaluation criteria system composed of CRFs.

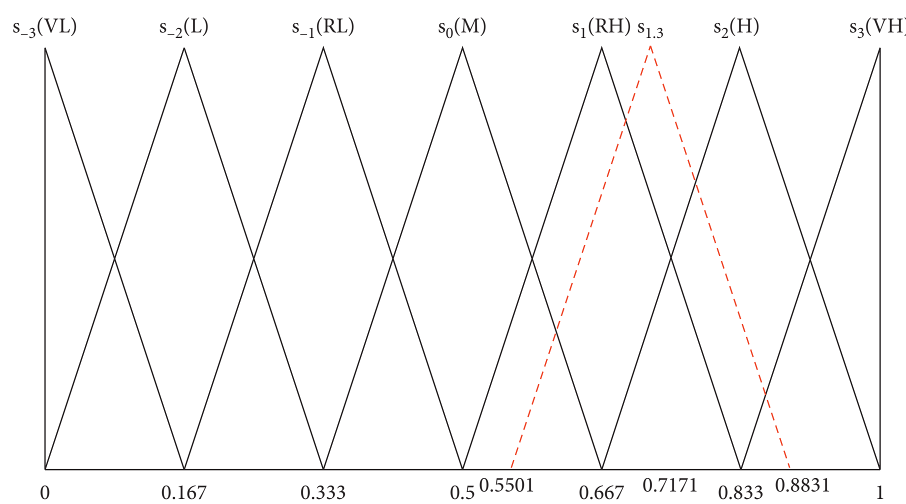

FIGURE 3: Correspondence between FLTS and TFNs.

of influence between factors. At the same time, this method is also widely used to calculate the weight of criteria [10, 56]. DEMATEL method could consider the problem form the perspective of causality and divide involved factors into cause group and effect group [57]. The logical relationship and influence matrix will be used in this method to calculate the influence degree of each CRF. The subjective weight can be determined according to the degree of influence. It is need to be pointed out the thoughts of HFLTS-DEMATEL are based on these related works [58]. Its staple steps are synoptically introduced as follows.

Step 1: set up evaluation linguistic variable (LV).

This study constructs a unified, seven-level linguistic scale. HFLTS, risk level, and the linguistic measurement scale of influence degree here are consistent. The expert committee will choose a linguistic term in this linguistic scale when evaluating indicators. Table 6 has shown these linguistic terms and corresponding TFNs.

Step 2: obtain the direct influence matrix.

Evaluation information will be gathered by experts using linguistic terminologies. According to the transformation relationship introduced in Table 6, the

Table 6: The linguistic measurement scale of influence degree and corresponding TFNs.

Common scale	LV	Corresponding TFNs
7	Very high influence (VH)	(0.833, 1.000, 1.000)
6	High influence (H)	(0.667, 0.833, 1.000)
5	Relatively high influence (RH)	(0.500, 0.667, 0.833)
4	Medium influence (M)	(0.333, 0.500, 0.667)
3	Relatively low influence (RL)	(0.167, 0.333, 0.500)
2	Low influence (L)	(0.000, 0.167, 0.333)
1	Very low influence (VL)	(0.000, 0.000, 0.167)
0	No influence	(0.000, 0.000, 0.000)

linguistic variables can be transformed into corresponding TFNs. Then, the direct influence matrix $\widetilde{X}$ is obtained.

$$\widetilde{X} = \begin{bmatrix} 0 & \widetilde{x}_{12} & \cdots & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & 0 & \cdots & \widetilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{x}_{n1} & \widetilde{x}_{n2} & \cdots & 0 \end{bmatrix}. \quad (7)$$

Step 3: obtain the standardized direct influence matrix.

Element $\widetilde{x}_{ij}$ in $\widetilde{X}$ needs to be de-fuzzified to get direct influence matrix X (element x_{ij}) of real number type. Let $\widetilde{x}_{ij} = (a^L, a^M, a^U)$ be a TFN, the value of defuzzification x_{ij} is given as follows [59]:

$$x_{ij} = \frac{a^L + 4a^M + a^U}{6}. \quad (8)$$

Then, it is the standardization of elements in matrix X that needs to conduct.

$$Y = \left[y_{ij}\right]_{n\times n} = \frac{1}{s}\cdot X,$$
$$s = \mathrm{Max}_{i=1}^{n}\left\{\sum_{j=1}^{n} x_{ij}\right\}. \quad (9)$$

Step 4: obtain the synthetic impact matrix.

Based on the standardized direct impact matrix Y, the calculation formula of the comprehensive influence matrix T is shown as follows:

$$T = \left[t_{ij}\right]_{n\times n} = Y(I - Y)^{-1}, \quad (10)$$

where t_{ij} is the comprehensive influence of CRF i on CRF j, and I represents the identity matrix.

Step 5: get the global impact of each index.

The sum of rows R_i reflects the extent to which this factor affects others, and the sum of columns C_j reflects the extent to which this factor is affected by other factors.

$$R_i = \sum_{j=1}^{n} t_{ij}, \quad (11)$$

$$C_j = \sum_{i=1}^{n} t_{ij}. \quad (12)$$

Then, $(R_i + C_j)$ is defined as "Prominence," which represents the importance of the CRF. Similarly, the $(R_i - C_j)$ is defined as "Net effect," which makes it come true that CRF is divided into a cause group and an effect group. Generally, when the net effect of the CRF is bigger than zero, it will belong to the cause group. Otherwise, the effect group will admit it.

Step 6: Obtain the subjective weight.

The following formulas obtain the subjective weight of the index based on centrality $(r_j + c_j)$ and causality $(r_j - c_j)$:

$$w'_{sj} = \left[\left(r_j + c_j\right)^2 + \left(r_j - c_j\right)^2\right]^{(1/2)},$$
$$w_{sj} = \frac{w'_{sj}}{\sum_{j=1}^{n} w'_{sj}}. \quad (13)$$

4.3. HFLTS-FSE Method. FSE is a method of comprehensive evaluation from multiple attributes by applying the principle of fuzzy relation synthesis. It uses the concept of membership degree to divide the change range of the evaluated object. On one hand, it can consider the hierarchy of object division and embody the ambiguity of evaluation criteria and influencing factors; on the other hand, it can also give full play to the knowledge and experience of decision makers, so that the evaluation results are more in line with the actual situation.

The basic steps of the HFLTS-FSE method can be summarized as follows:

Step 1: establish evaluation factors set for dispersed wind power project in low wind speed area.

The risk evaluation index system has been established in chapter 3. A total of eighteen CRFs in the five CRGs are summarized in Figure 3.

Step 2: determine the judgment set.

The unity of judgment set and risk level can better carry out the evaluation work.

$$S \ll \{s_{-3}: \text{very } l\text{ow (VL)}, s_{-2}: \text{Low } (L), s_{-1}: \text{Relatively low (RL)}, s_0: \text{Medium } (M), s_1: \text{Relatively high (RH)}, s_2: \text{High } (H), s_3: \text{Very high (VH)}\}. \tag{14}$$

Step 3: calculate the weights of CRFs.

This paper uses the HFLTS-DEMATEL method described in Section 4.2 to calculate the weights of CRFs.

Step 4: implement risk evaluation.

Definition 5. Let H_S be the expert comment based on HFLTS, corresponding to the performance of the corresponding evaluation object under CRFs. W represents the weight set calculated by HFLTS-DEMATEL method.

$$E = \left(e^L, e^M, e^U\right) = W \cdot H_S = (w_1, w_2, \ldots, w_n) \cdot \begin{pmatrix} (h_1^L, h_1^M, h_1^U) \\ (h_2^L, h_2^M, h_2^U) \\ \cdots \\ (h_n^L, h_n^M, h_n^U) \end{pmatrix}, \tag{15}$$

where E represents the evaluation results of dispersed wind power in low wind speed area. The results display form is TFNs. w_1 represents the weight of CRF C11, and (h_n^L, h_n^M, h_n^U) refers to the HFLTS aggregation value of a certain CRF.

Step 5: the final determination of the risk level based on the principle of maximum membership.

The evaluation results in Step 4 cannot show the risk level intuitively, because TFNs cannot compare sizes directly. Therefore, it is necessary to determine the specific risk level according to the principle of proximity.

Definition 6. The method for calculating the closeness of the two TFNs is as follows:

$$Sd(\alpha, \beta) = 1 - \frac{\left|\alpha^L - \beta^L\right| + \left|\alpha^M - \beta^M\right| + \left|\alpha^U - \beta^U\right|}{3}. \tag{16}$$

$\alpha = (\alpha^L, \alpha^M, \alpha^U)$ and $\beta = (\beta^L, \beta^M, \beta^U)$ are two TFNs, and $S \quad d(\alpha, \beta)$ represents the closeness of α and β. The final risk level is determined by calculating the closeness between the evaluation result E and the adjacent risk level (Risk level of left and right sides of calculation results).

4.4. HFLTS-VIKOR Method. VIKOR is a MCDM method proposed by Opricovic in 1998 [60]. It belongs to an optimal compromise solution method and a decision-making method based on ideal point method. This method mainly determines the positive and negative ideal solutions under each criterion, and then analyzes the closeness between the evaluation value of each scheme and the positive and negative ideal solutions. Under the condition of acceptability advantage and stable evaluation process, the schemes are sorted [61, 62]. The basic steps of VIKOR algorithm are summarized as follows:

Step 1: calculate the positive and negative ideal solutions for each CRF.

$$\begin{aligned} f_i^* &= \left[\left(\max_j f_{ij} \mid i \in I_1\right), \left(\max_j f_{ij} \mid i \in I_2\right)\right], \\ f_i^- &= \left[\left(\max_j f_{ij} \mid i \in I_1\right), \left(\max_j f_{ij} \mid i \in I_2\right)\right], \end{aligned} \tag{17}$$

where j is the evaluation object and i is the CRF; f_{ij} represents the evaluation value of the i^{th} CRF of the j^{th} evaluation object, where I_1 represents the benefit type criteria set and I_2 represents the cost type criteria set; f_i^* and f_i^- represent the positive ideal solution and the negative ideal solution, respectively. It is worth pointing out that the CRFs involved in this paper are all type criteria.

Step 2: calculate group utility S_j and individual regret R_j for each alternative j.

$$\begin{aligned} S_j &= \sum_i^n \frac{w_i\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)}, \\ R_j &= \max_i \left[\frac{w_i\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)}\right], \end{aligned} \tag{18}$$

where w_i represents the weight of the i^{th} CRF.

Step 3: calculate aggregating index Q_j for evaluation object j.

$$Q_j = v \frac{S_j - S^*}{S^- - S^*} + (1 - v) \frac{R_j - R^*}{R^- - R^*}, \tag{19}$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, $R^- = \max_j R_j$, and v is the coefficient of decision mechanism. v can range from 0 to 1. When VIKOR is used for ranking, we set v to 0.5 in order to maximize group utility and minimize individual regret.

Step 4: rank the evaluation objects, sorting by the values Q_j, S_j and R_j in increasing order.

Step 5: when the following two conditions are satisfied, the compromise solution arranged according to Q_j is the best evaluation object. The smaller the value of Q_j, the better the performance of evaluation object j.

Condition 1. Acceptable advantage: $Q(A_2) - Q(A_1) \geq D(Q)$, where A_2 is the evaluation object with second position in the ranking list by Q; $D(Q) = (1/(J-1))$, J is the number of evaluation objects.

Condition 2. Acceptable decision reliability:

After sorting by the value of Q_j, S_j of the first scheme must be better than that of the second scheme. Or after sorting by Q_j, R_j of the first scheme must be better than that of the second scheme. When there are several schemes, it is compared in order to compare whether the first, second, third, etc. schemes meet Condition 2.

4.4.1. Judging Criteria. If the relationship between the first scheme and the second scheme satisfies both Condition 1 and Condition 2, the first scheme is the optimal one; if the relationship between the first and the second schemes only satisfies Condition 2, the best scheme is to accept both the first and the second schemes; if the first-ranked scheme does not meet Condition 1 and only meets Condition 2 with other schemes, then we accept these schemes that meet Condition 1 as the optimal scheme at the same time.

4.5. Overall Risk Assessment Framework

Stage 1. Evaluation preparations:At this stage, it is necessary to collect various risk factors related to dispersed wind power, and then select CRFs through five-dimensional risk analysis to form an evaluation index system.

Stage 2. Data collection and processing: The evaluation information of each CRFs is collected by HFLTS with credibility, and then it is further transformed into TFN for quantitative evaluation by the method described in Section 4.1.

Stage 3. Implement risk assessment: Before the risk assessment, HFLTS-DEMATEL method is used to calculate the weight of each CRF in this stage. Then, the extended FSE method is used to classify the risk level of the evaluation objects. The results of FSE method reflect the ranking results to some extent. In addition, this study also used the VIKOR method to rank the evaluation objects again. After the two conditional tests, the ranking results are divided into corresponding echelons for decision makers.

Stage 4. Further analysis and discussion: In order to prove the reliability and stability of the proposed model, sensitivity analysis is needed. In this stage, sensitivity analysis will be carried out by adjusting the weights of CRFs and parameter v in VIKOR method. In addition, considering that the technology and market of dispersed wind power will tend to be stable and mature in the future, the corresponding scenarios are set for further analysis. The summary of the process and method composition of the risk assessment model is shown in Figure 4.

5. Application

Figure 5 shows the distribution of wind resources in China from the perspective of wind speed. The evaluation object of this paper is the provinces that mainly develop dispersed wind power projects in low wind speed areas of China. To a large extent, these provinces can show the risk level of dispersed wind power development.

5.1. Acquisition and Processing of Evaluation Index Values. The reliability and accuracy of the evaluation information is the prerequisite to get good results. This study obtains evaluation information by repeatedly issuing questionnaires and holding seminars to the expert committee. The expert committee is composed of twelve members: two professors from electric power university, two researchers from energy research institute, two engineers from wind power investment company, and two researchers from the energy development think tank of government. The specific academic background and work experience of the members of the expert committee are summarized in Table 3. Before collecting evaluation information from the experts, this study provides a set of material for all experts to reference and assist decision-making. This data collection summarizes all kinds of policy documents, technical documents and environmental conditions of wind power in China. The material provided to the respondents in this study is shown in Table 7. Based on the method described in Section 4.1, the original evaluation information given by the experts will be expressed in the form of HFLTS. In order to ensure the following quantitative evaluation work, the original information would be converted into corresponding TFNs. Table 8 shows the evaluation information of Shaanxi Province under each index.

5.2. Acquisition of Evaluation Index Weights. This part utilizes the method described in Section 4.2 to calculate the weights of evaluation indexes. The core work of this process includes the acquisition of impact matrix and the determination of the centrality and causality of each index. The final weight results are determined based on the centrality R_i and causality C_j using equations (11) and (12).

The weight results summarized in Table 9 show that profitability risk C53, regional absorptive capacity C31, and on-grid price risk C12, have the largest weights. To some extent, the key CRFs affecting dispersed wind power in low wind speed area are economic, market, and policy risks. Therefore, the potential investors of dispersed wind power should focus on the three aspects of project risk to guide decision-making. The weighting results of the three risk factors impact on agriculture and tourism C55, demand risk of electricity consumption C32, and construction cost risk C51 all exceeded 6%, which needs attention. Although the weights of various factors of environmental risk are relatively low, enough attention should also be paid to the evaluation of project risk.

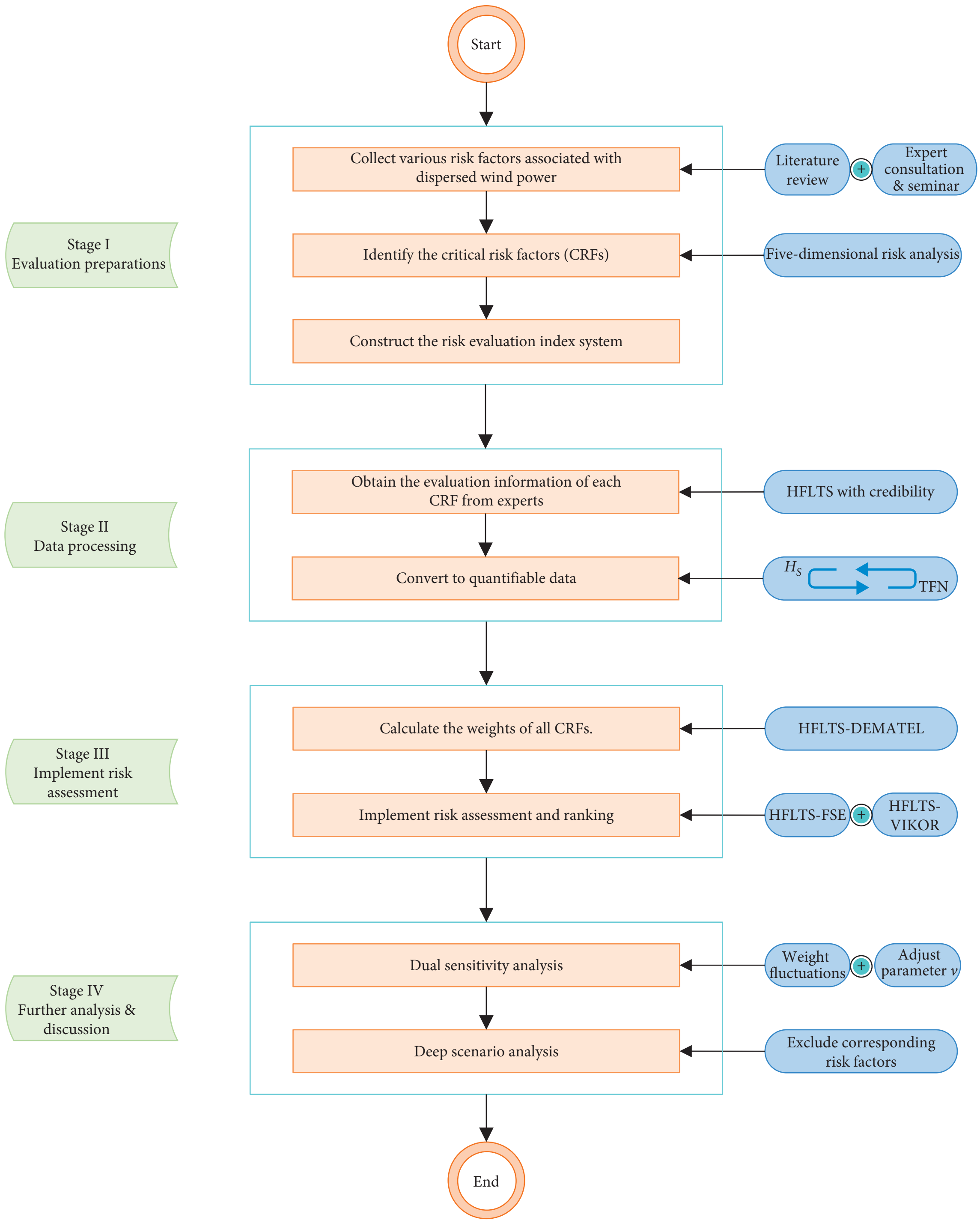

FIGURE 4: Overall risk assessment framework for dispersed wind power in low wind speed area.

5.3. Implement Risk Evaluation and Ranking. In this stage, the extended fuzzy synthetic evaluation method is used to evaluate the risk level of 10 low speed areas with dispersed wind power. After obtaining the evaluation value and weight of the index through the above two steps, the evaluation result in the form of TFN is obtained by using equation (15) aggregation. Finally, the risk level of each evaluation object is determined by the membership calculation method given in equation (16). The final evaluation results are shown in Table 10. Besides, Figure 5 visually shows the distribution of evaluation results for ten provinces.

The evaluation results in Table 6 can be divided into three categories: "Low," "Relatively Low," and "Medium." The risk level of dispersed wind power in Shanxi, Shaanxi, and Henan is at a "Low" level; the risk level in Anhui, Hubei, and other five provinces is "Relatively Low"; in general, the layout risk of most evaluation areas is at a relatively low level.

Figure 5: Regional map of China's terrestrial wind resources.

Table 7: Related reference documents.

No.	Specific species
1	Summary of national wind power policy
2	Provincial wind power policy summary
3	Dispersed wind power related policy statistics
4	Decentralized wind power planning in major provinces and cities nationwide
5	2020 national wind power planning installed targets in various provinces
6	Provincial wind/solar renewable energy green power certificate transaction data
7	Non-hydropower renewable energy power consumption in various provinces
8	Implementation of the minimum guaranteed acquisition year utilization hours
9	Clean energy consumption target completion status
10	National wind power industry related standard statistics
11	Summary of construction plans for dispersed wind power projects in various provinces
12	Topographic map of various provinces in China
13	Case summary of wind power project destroying ecological environment

However, the risk level of dispersed wind power projects in Guangdong and Fujian provinces is at a "Medium" level.

The better the evaluation result (Figure 6) is, the closer the color of the province is to dark green. It is easy to conclude that the risk level results are positively related to the distribution of wind resources to a certain extent. In addition, due to the large power demand in developed areas such as coastal areas, it is inclined to use stable and centralized power supply, and the inclusiveness of dispersed wind power is low.

Table 8: Evaluation information of Shaanxi Province under each index.

Object	Index	Evaluation linguistic values	HFLTS with credibility			Corresponding TFNs
Dispersed wind power in Shaanxi	C11	Between VL and RL	0.2 VL	0.3 L	0.5 RL	(0.0835, 0.2166, 0.3833)
	C12	Between L and M	0.2 L	0.4 RL	0.4 M	(0.2, 0.3666, 0.5334)
	C13	Between L and M	0.2 L	0.4 RL	0.4 M	(0.2, 0.3666, 0.5334)
	C21	Between L and M	0.2 L	0.2 RL	0.6 M	(0.2332, 0.4, 0.5668)
	C22	Between L and M	0.1 L	0.2 RL	0.7 M	(0.2665, 0.4333, 0.6002)
	C23	Between RL and M	0.5 RL	0.5 M		(0.25, 0.4165, 0.5835)
	C24	Between VL and RL	0.2 VL	0.3 L	0.5 RL	(0.0835, 0.2166, 0.3833)
	C31	Between VL and RL	0.2 VL	0.3 L	0.5 RL	(0.0835, 0.2166, 0.3833)
	C32	Between L and RL	0.3 L	0.7 RL		(0.1169, 0.2832, 0.4499)
	C41	Between L and M	0.2 L	0.2 RL	0.6 M	(0.2332, 0.4, 0.5668)
	C42	Between L and RL	0.3 L	0.7 RL		(0.1169, 0.2832, 0.4499)
	C43	Between L and RL	0.6 L	0.4 RL		(0.0668, 0.2334, 0.3998)
	C44	Between L and RL	0.3 L	0.7 RL		(0.1169, 0.2832, 0.4499)
	C51	Between VL and RL	0.2 VL	0.3 L	0.5 RL	(0.0835, 0.2166, 0.3833)
	C52	Between L and RL	0.3 L	0.7 RL		(0.1169, 0.2832, 0.4499)
	C53	Between L and RL	0.3 L	0.7 RL		(0.1169, 0.2832, 0.4499)
	C54	Between VL and RL	0.3 VL	0.4 L	0.3 RL	(0.0501, 0.1667, 0.3333)
	C55	Between VL and RL	0.2 VL	0.3 L	0.5 RL	(0.0835, 0.2166, 0.3833)

Table 9: Summary of the weight of each evaluation index.

CRFs	R_i	C_j	$R_i + C_j$	$R_i - C_j$	W_{ij}	Order
C11	3.0153	2.8255	5.8407	0.1898	0.0543	11
C12	3.4275	3.3202	6.7478	0.1073	0.0627	3
C13	3.1572	3.1685	6.3258	−0.0113	0.0588	7
C21	3.2599	0.8581	4.1180	2.4018	0.0443	16
C22	2.8537	0.6908	3.5445	2.1629	0.0386	18
C23	2.8217	2.8146	5.6363	0.0071	0.0524	13
C24	2.9618	0.7341	3.6959	2.2278	0.0401	17
C31	3.2541	3.5782	6.8323	−0.3241	0.0636	2
C32	3.8428	2.4915	6.3343	1.3512	0.0602	5
C41	2.4369	3.2964	5.7332	−0.8595	0.0539	12
C42	2.5849	2.7880	5.3729	−0.2032	0.0500	14
C43	2.2563	2.8958	5.1521	−0.6395	0.0483	15
C44	2.4723	3.6973	6.1695	−1.2250	0.0585	8
C51	2.7452	3.6479	6.3930	−0.9027	0.0600	6
C52	2.1224	3.8678	5.9902	−1.7453	0.0580	10
C53	3.4703	4.7413	8.2115	−1.2710	0.0772	1
C54	2.3259	3.7863	6.1123	−1.4604	0.0584	9
C55	3.3596	3.1655	6.5252	0.1941	0.0607	4

Table 10: Risk evaluation result for dispersed wind power in each object.

Ranking	Object	Evaluation result	Risk level
A2	Shanxi	0.2776	L
A1	Shaanxi	0.2880	L
A3	Henan	0.2953	L
A4	Anhui	0.3502	RL
A5	Hubei	0.3595	RL
A6	Hunan	0.3611	RL
A7	Jiangxi	0.3624	RL
A8	Zhejiang	0.3924	RL
A10	Guangdong	0.4093	M
A9	Fujian	0.4205	M

In this stage, VIKOR method is used to rank the ten provinces. The coefficient v of the decision-making mechanism is 0.5, which means that the pursuit of maximization of group utility and the minimization of individual regrets are simultaneously pursued. After

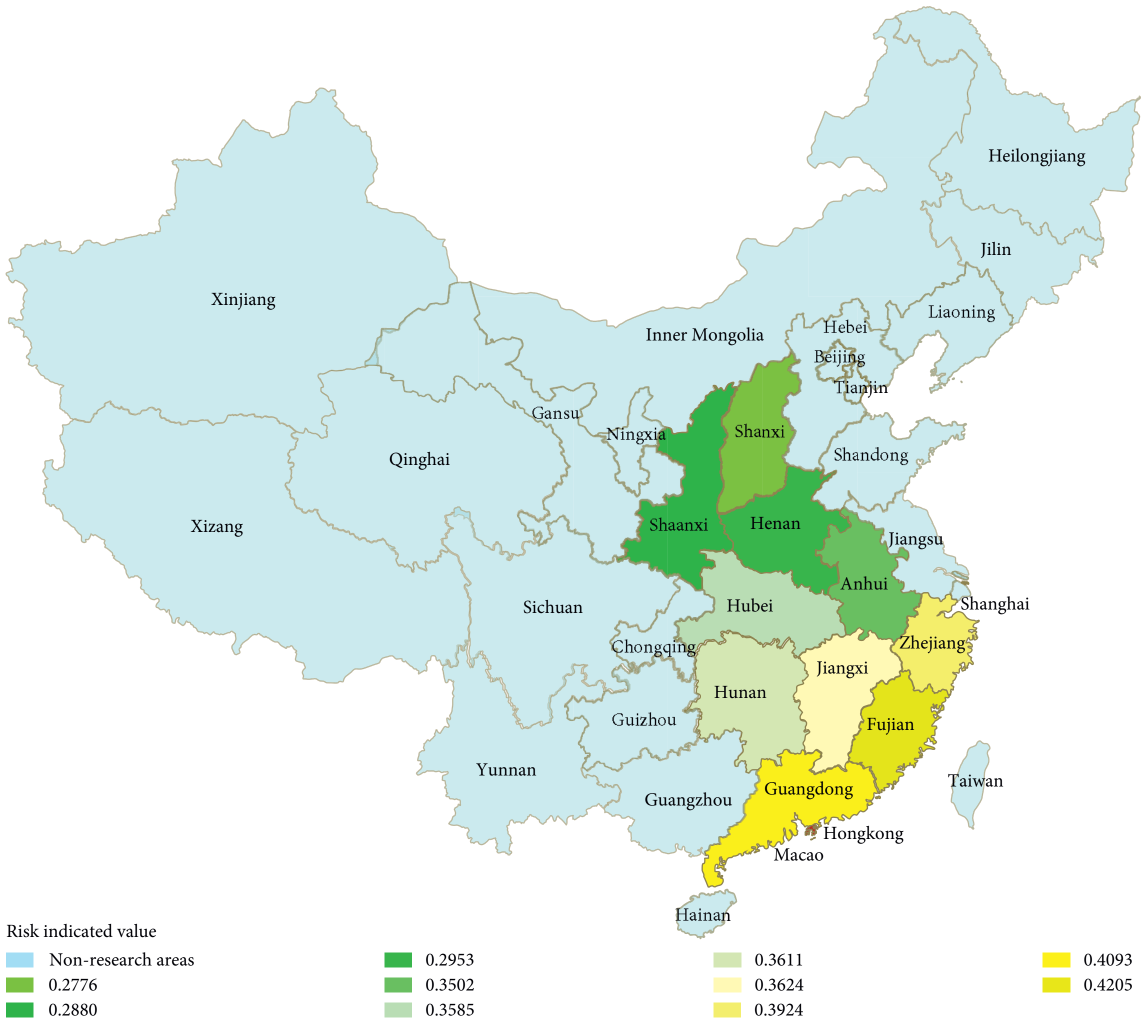

Figure 6: Results of risk indicated value for each research area.

conditional test, the results are shown in Table 11. The ranking results of VIKOR method show that the 10 provinces can be divided into four echelons: Shanxi, Henan, Shaanxi, and Hubei are the first echelon; Hunan is the second echelon; Anhui is the third echelon; other provinces are the fourth echelon. Decision makers can refer to this result to prioritize the layout of dispersed wind power in low wind speed area. It is worth noting that the results of VIKOR method and FSE method are basically consistent. Therefore, the comparison of the results of the two methods proves the reliability of the model.

6. Deep Discussion

6.1. Dual Sensitivity Analysis

6.1.1. Sensitivity Analysis I. FSE method is the core algorithm of risk evaluation model. An important step to obtain the result of risk level evaluation is to aggregate the indicator value and the indicator weight. Therefore, the weight of indicators is the basis of this method, and it is necessary to take tests to verify the impact of indicator weight on the results. This section sets the original weight of a single indicator to fluctuate under ±10% and ±20% [63], and the total number of tests is 72. The sensitivity analysis results of this part are shown in Figure 6.

From Figure 7, all curves are almost parallel to the x-axis. The risk indicator values of the 10 evaluation objects changed slightly, but did not affect the ranking results. This flat distribution of test results shows that the final evaluation results are not affected by the weight fluctuation of indexes (CRFs). Therefore, the reliability and stability of the evaluation model are verified.

6.1.2. Sensitivity Analysis II. When using VIKOR method to rank evaluation objects, decision mechanism coefficient v will be involved in the model. In general, the value of v is set to 0.5. But v can be taken from 0 to 1 to reflect the different preferences of decision makers. Therefore, it is necessary to analyze the sensitivity of parameter v according to the preference of decision-makers to test the influence of different preference on the final ranking results. Based on the various values of v from 0 to 1, the values of Q_i are shown in Figure 7, and the ranking order trend is vividly demonstrated in Figure 8.

Table 11: Ranking result for dispersed wind power in each province.

	A2 Shanxi	A3 Henan	A1 Shaanxi	A5 Hubei	A6 Hunan	A4 Anhui	A7 Jiangxi	A8 Zhejiang	A10 Guangdong	A9 Fujian
S_i	0.3156	0.4186	0.4125	0.6473	0.6845	0.6776	0.7044	0.7003	0.7028	0.8704
R_i	0.0627	0.0598	0.0602	0.0530	0.0543	0.0602	0.0602	0.0674	0.0772	0.0772
Q_i	0.2008	0.2332	0.2361	0.2989	0.3598	0.4750	0.4991	0.6442	0.8490	1.0000
Q_{i+1}-Q_i	0.0324	0.0029	0.0628	0.0609	0.1151	0.0241	0.1452	0.2047	0.1510	—
Condition test	×	×	×	×	√	×	√	√	√	—
Ranking by VIKOR	First echelon	Second echelon	Third echelon		Fourth echelon					
Evaluation result of FSE	A2 0.2776	A1 0.2880	A3 0.2953	A4 0.3502	A5 0.3595	A6 0.3611	A7 0.3624	A8 0.3924	A10 0.4093	A9 0.4205

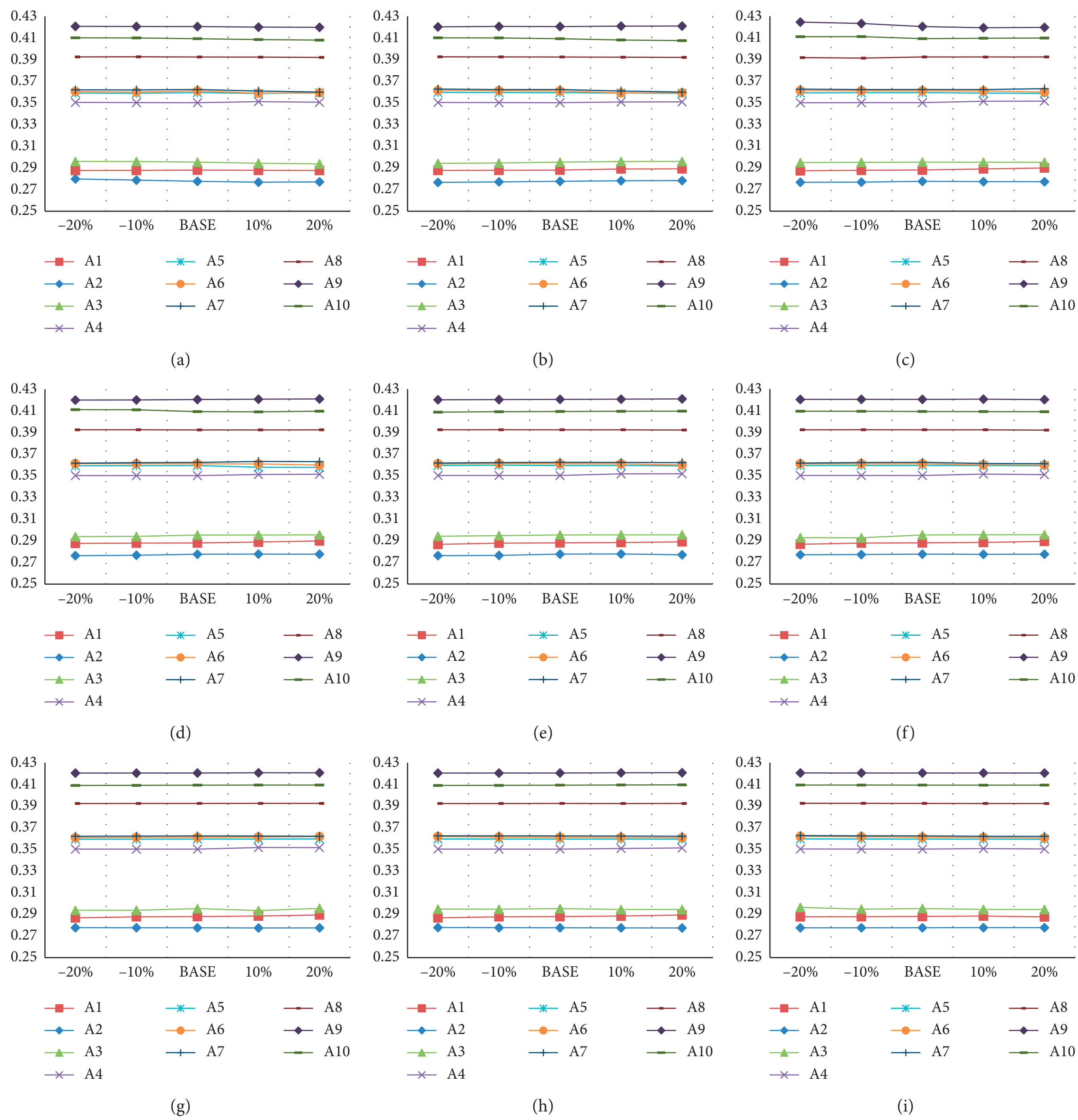

Figure 7: Continued.

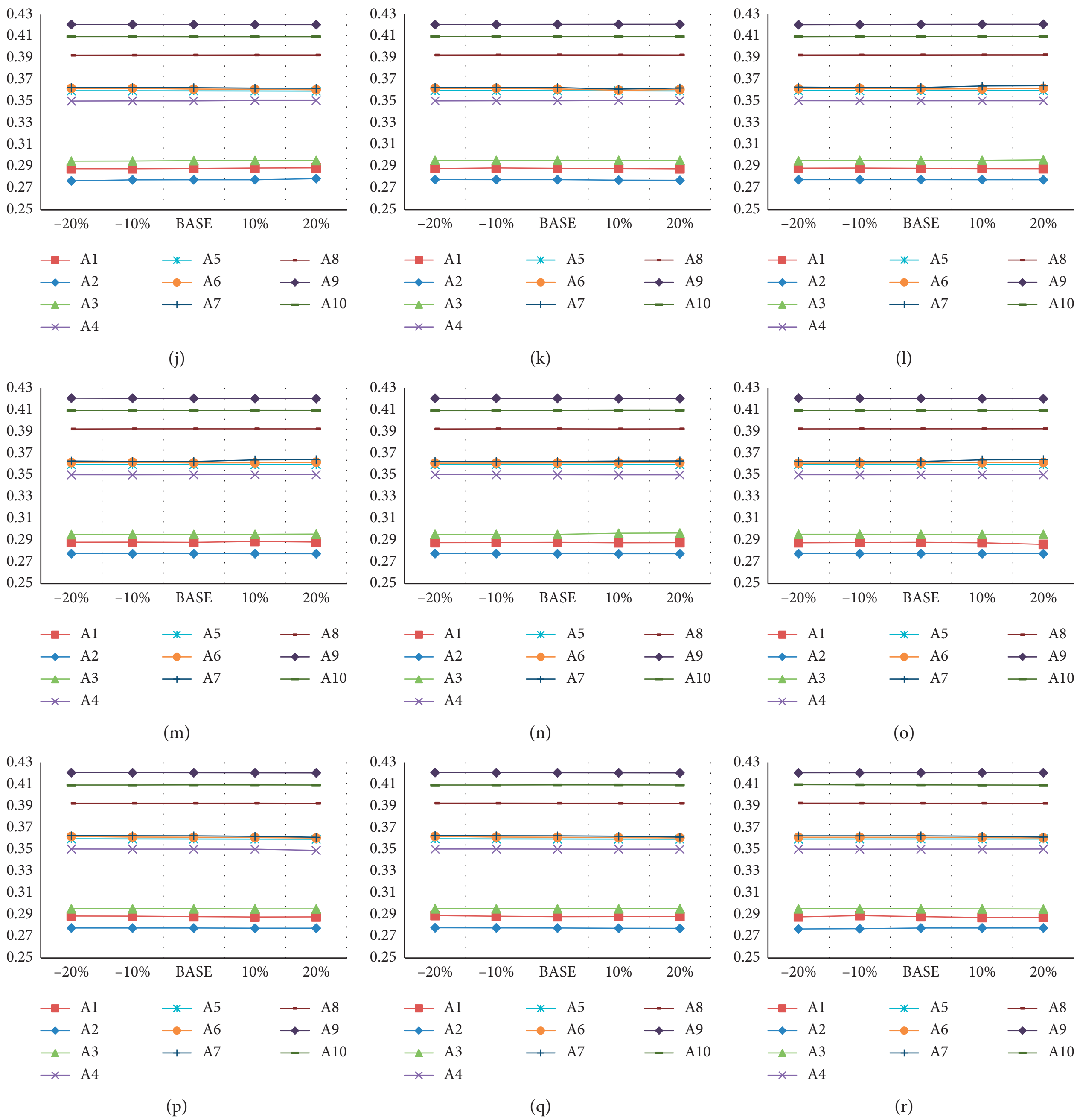

Figure 7: Sensitivity analysis results by changing the weights of each index. (a) C11 weight fluctuation. (b) C12 weight fluctuation. (c) C13 weight fluctuation. (d) C21 weight fluctuation. (e) C22 weight fluctuation. (f) C23 weight fluctuation. (g) C24 weight fluctuation. (h) C31 weight fluctuation. (i) C32 weight fluctuation. (j) C41 weight fluctuation. (k) C42 weight fluctuation. (l) C43 weight fluctuation. (m) C44 weight fluctuation. (n) C51 weight fluctuation. (o) C52 weight fluctuation. (p) C53 weight fluctuation. (q) C54 weight fluctuation. (r) C55 weight fluctuation.

It can be seen from Figure 8 that different values of parameter v will cause obvious changes in Q_i value. 0.5 can be regarded as the dividing point of result distribution. When the value of parameter v is more than 0.5, it means that the proportion of overall utility maximization is more than 50%. The ranking results of Figure 9 show that the evaluation objects A2, A3, A1, and A5 have higher prioritization in this case. When the value of parameter v is below 0.5, it means that the proportion of individual regret minimization is more than 50%. Currently, evaluation objects A5, A6, A3, and A1 have higher prioritization. It is worth noting that the A7, A8, A10, and A9 are always low-ranking. Therefore, this method can be used to select evaluation objects according to different preferences of decision makers in realistic decision-making practice.

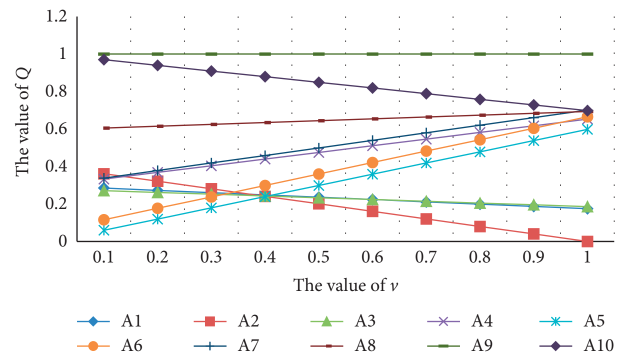

Figure 8: Sensitivity analysis results of the values of Q_i.

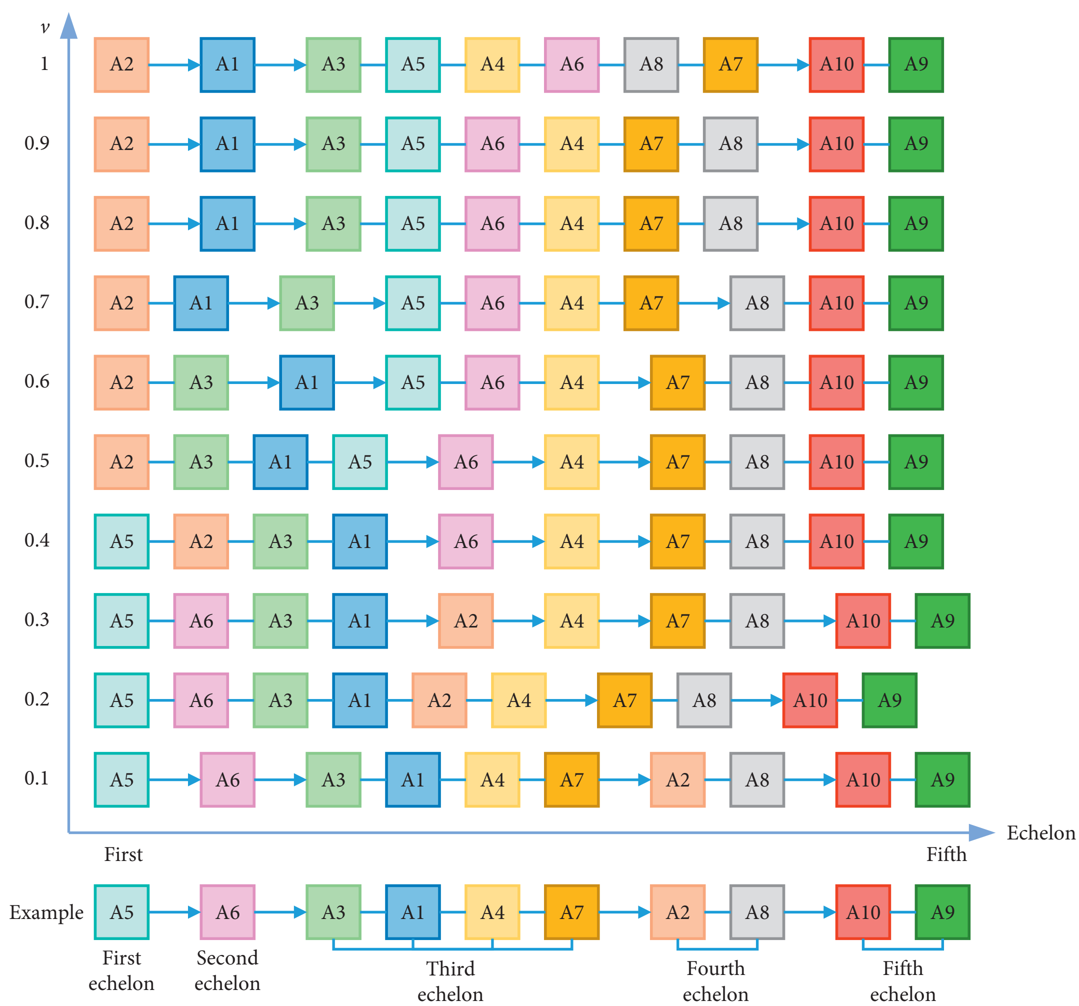

Figure 9: The ranking results corresponding to each parameter v.

6.2. Scenario Analysis. In order to analyze the impact of various risk factors on the final evaluation results, this paper further designs three possible scenarios in the future by excluding some risk factors. The index system shown in Figure 2 is the initial scenario, and then one or two types of CRFs are deleted from the initial index system to form other scenarios. The specific composition of the index system in various scenarios is shown in Table 12.

From Table 12, we can see that in scenario 1, the evaluation process does not consider market risk; in scenario 2, the evaluation process does not consider technology risk; in scenario 3, the market and technology risk are not considered. The index system under these three scenarios is introduced into the evaluation model constructed in this chapter, and the evaluation results are shown in Figure 10.

Table 12: Composition of indicator system in various scenarios.

Risk Group	Original scenario	Scenario 1	Scenario 2	Scenario 3
Policy risk	✓	✓	✓	✓
Environmental risk	✓	✓	✓	✓
Market risk	✓		✓	
Technology risk	✓	✓		
Economic and social risk	✓	✓	✓	✓

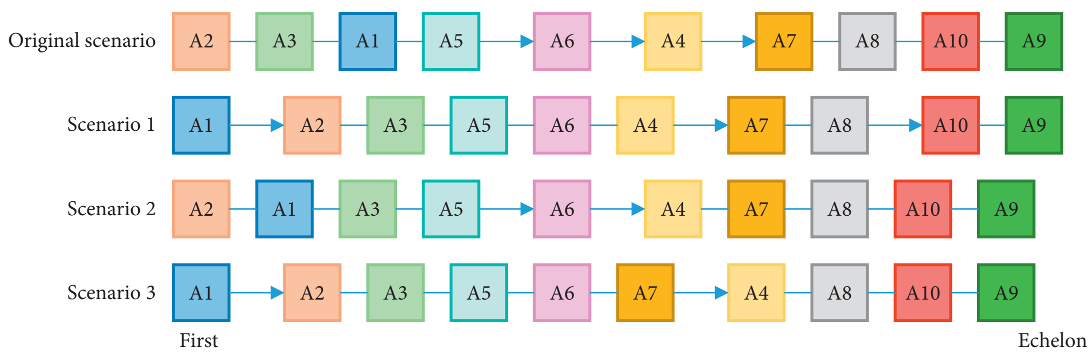

Figure 10: The ranking results corresponding to each scenario.

It can be seen visually from Figure 10 that the overall risk level of dispersed wind power in the A1 region is reduced after eliminating market risks or technical risks. A1 performs best in scenario 1 and scenario 3. It shows that A1 region is sensitive to market risk and technology risk. The key to improve the investment environment in A1 region is to prevent and improve the adverse effects of these two kinds of risks. In addition, the ranking of A7 in scenario 3 is also advanced by one compared to the original scenario. To some extent, it shows that the investment environment of A7 and A1 regions is similar.

7. Conclusions

China has made good achievements in large-scale development and utilization of wind power. However, since the high wind energy resource area is far away from the market terminal and the excessive development of wind power projects, acute problems of wind power curtailment appears in areas with better wind resources. The low wind speed region will become a strategic position to layout dispersed wind power during the "13th Five-Year Plan" period due to its proximity to the load and market advantages. However, the experience of large-scale centralized wind power development is no longer suitable for dispersed wind power in low-speed areas, and the current research has not formed a complete system for the investment risk assessment of dispersed wind power projects, which is difficult to guide the investment decision-making of dispersed wind power in the middle east and south, so it is necessary to carry out a more systematic research on it. Based on the above background, this paper studies the risk analysis and evaluation of dispersed wind power in low speed area.

First, in the process of risk analysis, a five-dimensional risk analysis model is constructed to select the CRFs. Based on the model, 18 CRFs of the dispersed wind power project are determined. The logic and process of the model can also be applied to the risk analysis of other objects. Second, the weight of 18 CRFs shows that potential investors should focus on policy and market risks when considering the layout of dispersed wind power projects. Then, the results of evaluation and ranking show that the risk levels of 10 evaluation provinces are divided into three categories: "Low," "Relatively Low," and "Medium," and the evaluation results are consistent with the distribution results of wind resources (wind speed). It shows that the government could consider to give some policy support and power subsidies to areas with poor wind resources, to stimulate the development of wind power market in these areas. In addition, the ranking results show that potential investors focusing on comprehensive benefits can prioritize projects in the three provinces of Shaanxi, Henan, and Shanxi. In the end, the four parts of risk analysis, weight determination of CRFs, implementation of risk evaluation and ranking, deep discussion, and analysis, constitute the risk assessment model (framework) of this research. The model has good reliability and practicability and can provide some reference and inspiration for colleagues in the field of risk study.

Data Availability

The related data used in this paper are all from "China Electric Power statistics yearbook" and National Bureau of Statistics (http://www.stats.gov.cn).

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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