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Research on Risk Assessment of Vietnam EPC Wind Power Projects based on Fuzzy Analytic Hierarchy Process

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Abstract: In the context of burgeoning renewable energy initiatives worldwide, wind power projects have emerged as pivotal players in the realm of clean energy. This is particularly pronounced in emerging markets like Vietnam, where rapid economic growth and escalating energy demands have spurred a surge in wind power endeavors. Focusing on the risk landscape of Engineering, Procurement, and Construction (EPC) wind power projects in Vietnam, this study endeavors to pinpoint and evaluate key risk factors impacting project execution while proposing tailored risk mitigation strategies. Through exhaustive literature reviews and consultations with industry experts, 18 principal risk factors spanning policy, social dynamics, natural conditions, and construction management were identified. Through the Fuzzy Analytic Hierarchy Process (FAHP) for quantitative evaluation, the study quantifies the impact of risk factors, ultimately determining a moderate overall risk level for a selected 130MW onshore wind farm project in Vietnam. Subsequent to risk assessment, the study advocates for a suite of responsive measures aimed at guiding project management teams in navigating operational challenges, encompassing strategies like enhanced stakeholder communication, financial risk hedging, shared risk allocation, and fortified contract management.

Keywords: Wind Power Project; Risks Management; EPC Contract; Vietnam; Fuzzy Analytic Hierarchy Process.

1. Introduction

Vietnam is a country rich in renewable energy resources. In recent years, in order to encourage investors and developers to develop new energy power generation projects, the Vietnamese government promulgated policies to encourage the development of wind energy power generation, which triggered a wave of investment from domestic and foreign investors in Vietnam. Vietnam is one of the countries along China's "Belt and Road Initiative" and is one of China's largest neighbors and largest trading partners in Southeast Asia. Vietnam is rich in wind power resources and has a large demand for electricity. It is an important area for Chinese wind power companies to "go global". In recent years, thanks to the encouragement of Vietnam's policies, the installed capacity of wind energy and photovoltaic power generation has grown explosively. Many of the project contractors are Chinese companies, and the more active contracting teams are basically Chinese state-owned enterprises, such as China Power Construction East China Branch, Zhongnan Institute, China Energy Construction Zhongnan Institute, Gezhouba, Guangdong Institute, China Communications Construction, Dongfang Electric, etc. According to China Power Construction's report, China Power Construction has built a total of 40 photovoltaic and wind power projects in Vietnam from 2018 to 2022, with a total installed capacity of 5070MW (https://www.powerchina.cn/art/2023/2/27/art_7440_1615441.html).

Therefore, the top priority is to study the risk management of wind power projects in Vietnam. This article will start from the perspective of the engineering, procurement, and construction (hereinafter referred to as EPC) contractor, and use the L wind power project case to identify risks for Vietnam wind power projects, build a risk assessment model, and provide risk response measures for the project based on quantitative analysis results.

2. Literature Review and Research Methodology

2.1. Literature Review

Based on different research backgrounds and objects, there may be differences in the understanding of risk management, and there are also differences in risk management process standards. Project Management Institute International (PMI) describes the risk management process in the Project Management System of Knowledge Guide (PMBOK) as: risk management plan, risk identification, risk qualitative analysis, risk quantitative analysis, risk response plan, risk monitoring and control process [1]. The International Project Management Association (IPMA) divides the project risk management process into five processes in the Project Management Professional Qualification Standard (ICB): risk identification, risk classification, risk quantification, risk response, and risk monitoring [2].

In terms of risk identification, Warszawski conducted a detailed study using survey methods and analyzed statistical data on risk identification, cost and control in power engineering projects [3]. Tiong divides various risk factors of power engineering projects into internal, external and project-specific risks [4]. Mnzdoganmetal emphasized the importance of risk identification, pointing out that various risk factors in power engineering projects originate from the changing economic structure and fierce market competition, these risk factors are interrelated and complex, if these risks factors cannot be effectively identified, may lead to project failure [5].

In terms of risk assessment, Townsend discussed the importance of risk assessment and emphasized that the risk assessment level of the project management organization has an important impact on the initial risk management level of power engineering projects [6]. Kull conducted a quantitative analysis of risks in power engineering projects and constructed a multi-factor analysis model, which greatly improved the accuracy of risk management in projects [7].

In terms of risk response, David et al. used work breakdown structure (WBS) technology to identify risk sources and established a conventional model of the interaction between risk response measures and project work packages to determine whether risk response measures will affect the occurrence of risks probability [8]. Cajueiro pointed out that power engineering projects have significant characteristics such as uncertainty, complexity and dynamic changes, indicating that risks exist objectively during the implementation of power engineering projects; It is necessary to identify and assess risks, formulate risk control plans, and formulate risk response strategies [9].

2.2. Research Methodolody

This study adopted the expert interview method and fuzzy analytic hierarchy process in order to comprehensively and accurately identify and evaluate the risk situation of EPC wind power projects in Vietnam.

(1) Expert interview method

Considering that the perspective of EPC general contractors is relatively limited in relevant literature, in order to ensure that the identification of risk factors is accurate and close to the specific conditions of EPC wind power projects in Vietnam, this study uses the expert interview method to identify risk factors. Through direct feedback from practical experience, the expert interview method enhances the comprehensiveness and accuracy of risk identification. The combination of literature research method and expert interview method ensures the scientificity and reliability of the risk identification process.

(2) Fuzzy analytic hierarchy process

This study adopted the Fuzzy Analytical Hierarchy Process (FAHP) to solve problems such as probability of occurrence, degree of loss, ranking and risk level of risks. Fuzzy Analytic Hierarchy Process (FAHP) method means that when conducting qualitative and quantitative analysis, the relevant elements of the decision-making problem are first decomposed into different target levels, different criterion levels and different plan levels. The first step: on the basis of risk identification, divide the identified risks into several groups, and then form different levels according to the establishment rules of the model hierarchy model, and then establish the risk factor hierarchical structure model; the second step: use 0.1 -0.9 Nine-scale method makes quantitative scaling between factors, compares each factor pairwise, and obtains the fuzzy judgment matrix; the third step: tests the consistency of the fuzzy complementary judgment matrix; the fourth step: obtains the hierarchical single ranking and The overall ranking of levels determines important risk factors [10].

3. Research Result

3.1. Introduction of L Wind Power Project

The L wind power project, with a scope of 130MW for the wind farm and a 220kV substation, situated in Soc Trang Province within the Mekong Delta region of southern Vietnam, represents a significant endeavor poised to harness the region's wind energy potential. Located approximately 300 kilometers from the bustling metropolis of Ho Chi Minh City, the project area presents a complex environment characterized by fishing ponds, shrimp ponds, and rice fields. With predominantly rural roads and challenging geological conditions, including proximity to the coastline necessitating new infrastructure such as a temporary dock and access road, the project confronts a series of logistical and operational hurdles.

The project is owned by Vietnam's prominent new energy investment entity, T&T Group, one of the leading energy investment groups in Vietnam with a huge amount of projects completed, on-going and to-be conducted. Envision Energy serves as the main equipment manufacturer, solidifying the project's foundation with established technology and reliable resources. The contract scope covers the entire wind farm area and 220kV booster station and transmission lines, including design, procurement, installation, construction and commissioning.

The project faces some challenges and risks, including: the site is mostly fish ponds, and it is necessary to focus on the wind turbine foundation waterproofing and temporary road engineering. The large 850T crawler crane resources are in short supply, and the geological conditions are poor. Regarding the foundation treatment, drainage and the hoisting plan, Company A, after investigation and evaluation, believed that local manpower and equipment resources could basically meet the construction needs.

In addition, based on the characteristics of wind power projects, project progress management is crucial. In order to ensure the realization of the goals during the construction period, it is first necessary to communicate effectively with the Vietnamese government to ensure the prerequisites for the start of construction. Secondly, the work progress and quality control in the design stage are key. The in-depth and accurate design directly affects the time for approval, adjustment and final drawing completion, which in turn affects the timeliness of submission to the Vietnamese government for approval. The third point is that the manufacturing, packaging and transportation time of domestic wind turbines in China require special attention. Finally, considering the planned economic system of the local government, the supply of materials and equipment and the organization of the labor force face many uncertainties, and these factors may affect the progress of the project.

3.2. Risk Factors Hierarchy

Since the relevant literature from the perspective of EPC general contractors is relatively limited, in order to ensure that the identification of risk factors is both accurate and close to the specific conditions of EPC wind power projects in Vietnam, an initially identified risk factors were established through expert interviews. The risk factors hierarchy is showned in table 3.1.

Table 3.1. Risk Factors Hierarchy

First level indicator		Secondary indicators	
Policy and legal risks	B1	Policy instability	C1
		Changes in legal provisions	C2
Political and social risks	B2	Effectiveness of government actions	C3
		Residents' recognition of the project	C4
Economic Risks	B3	Price Fluctuations	C5
		Exchange rate fluctuations	C6
Natural Risks	B4	Natural disaster	C7
		Disease	C8
		Hydrogeological conditions	C9
Technical Risks	B5	Design data defects	C10
		Differences in technical standards and specifications	C11
		Design changes	C12
Contractual Risks	B6	Fixed price contract risk	C13
		Owner Risk	C14
		Sub-supplier risks	C15
Managing Risks	B7	Procurement and transportation management	C16
		Construction organization management	C17
		HSE	C18

3.3. Fuzzy complementary judgment matrix and consistency test

10 experienced experts were invited to conduct pairwise comparisons and scores on 18 indicators, including a total of 8 matrices, 1 first-level indicator matrix and 7 second-level indicator matrices. The scoring sheets of 10 experts were collected. Since there is no excessive deviation in the expert level, the expert weights are considered the same and the geometric mean method is used to integrate the matrix. The first-level index fuzzy complementary judgment matrix is as follows:

$$B = \begin{pmatrix} 0.500 & 0.530 & 0.575 & 0.690 & 0.370 & 0.315 & 0.285 \\ 0.470 & 0.500 & 0.590 & 0.705 & 0.335 & 0.245 & 0.225 \\ 0.425 & 0.410 & 0.500 & 0.540 & 0.295 & 0.240 & 0.225 \\ 0.310 & 0.295 & 0.460 & 0.500 & 0.265 & 0.220 & 0.195 \\ 0.630 & 0.665 & 0.705 & 0.735 & 0.500 & 0.415 & 0.375 \\ 0.685 & 0.755 & 0.760 & 0.780 & 0.585 & 0.500 & 0.440 \\ 0.715 & 0.775 & 0.775 & 0.805 & 0.625 & 0.560 & 0.500 \end{pmatrix}$$

Label the B weight vector as W_B, according to the weight calculation formula:

$$W_i = \frac{\sum_{i,\ j=1}^{n} a_{ij} + \frac{n}{2} - 1}{n(n-1)} \tag{1}$$

then $W_B = (0.137, 0.133, 0.122, 0.113, 0.155, 0.167, 0.173)$ The characteristic matrix of B is as follows:

$$W_B{}^* = \begin{pmatrix} 0.500 & 0.509 & 0.529 & 0.549 & 0.557 & 0.541 & 0.534 \\ 0.476 & 0.500 & 0.506 & 0.547 & 0.533 & 0.516 & 0.510 \\ 0.470 & 0.494 & 0.500 & 0.541 & 0.527 & 0.510 & 0.504 \\ 0.429 & 0.452 & 0.459 & 0.500 & 0.486 & 0.469 & 0.463 \\ 0.443 & 0.467 & 0.473 & 0.514 & 0.500 & 0.483 & 0.477 \\ 0.459 & 0.484 & 0.490 & 0.531 & 0.517 & 0.500 & 0.494 \\ 0.466 & 0.490 & 0.496 & 0.537 & 0.523 & 0.506 & 0.500 \end{pmatrix}$$

If the compatibility of the judgment matrix and its characteristic matrix $I(B, W_B^*)$ is <0.1 then the consistency is considered high [10]. Calculate the compatibility of the judgment matrix B and its characteristic matrix:

$$I(B, W_B^*) = \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} \left| a_{ij} + w_{ji} - 1 \right| \tag{2}$$

It is concluded that $I(B, W_B{}^*) = 0.096 < 0.1$, indicating that the consistency of the two matrices is high, and the corresponding weight set W_B is in terms of weight distribution, there is a high level of rationality.

Using the above calculation method, the weight vector and consistency test results of the secondary indicator layer are obtained, as described in Table 4.1-4.7.

Table 4.1. Judgment matrix B1

B1	**C1**	**C2**	**W**	**I(B1,$W_{B1}{}^*$)**
C1	0.50	0.60	0.550	0.075<0.1
C2	0.40	0.50	0.450	Passed

Table 4.2. Judgment matrix B2

B2	**C3**	**C4**	**W**	**I(B2,$W_{B2}{}^*$)**
C3	0.50	0.4 1	0.4 52	0.0 71 <0.1
C4	0.5 9	0.50	0.5 48	Passed

Table 4.3. Judgment matrix B3

B6	C14	C15	W	$I(B6,W_{B6}^{*})$
C14	0.50	0.55	0.490	0.0 15 <0.1
C15	0.45	0.50	0.510	Pass

Table 4.4. Judgment matrix B4

B3	C5	C6	C7	W	$I(B3,W_{B3}^{*})$
C5	0.50	0.56	0.62	0.362	0.0 17 <0.1
C6	0.45	0.50	0.58	0.338	Passed
C7	0.39	0.42	0.50	0.301	

Table 4.5. Judgment matrix B5

B4	C8	C9	C10	W	$I(B4,W_{B4}^{*})$
C8	0.50	0.47	0.54	0.335	0.011<0.1
C9	0.53	0.50	0.57	0.350	Passed
C10	0.46	0.43	0.50	0.315	

Table 4.6. Judgment matrix B6

B5	C11	C12	C13	W	$I(B5,W_{B5}^{*})$
C11	0.50	0.56	0.53	0.348	0.009 <0.1
C12	0.44	0.50	0.47	0.318	Passed
C13	0.47	0.53	0.50	0.333	

Table 4.7. Judgment Matrix B7

B7	C16	C17	C18	W	$I(B7,W_{B7}^{*})$
C16	0.50	0.58	0.58	0.360	0.023 <0.1
C17	0.42	0.50	0.55	0.328	Passed
C18	0.42	0.45	0.50	0.312	

From the above data, we can see that the compatibility index value of the fuzzy judgment matrix and the characteristic matrix is below 0.1, indicating that B, B1-B7 have achieved the correct configuration of the risk factor weights.

W_B=(0.137, 0.133, 0.122, 0.113, 0.155, 0.167, 0.173);

W_{B1}=(0.550, 0.450); W_{B2}=(0.452, 0.548); W_{B3} = (0.490, 0.510); W_{B4} =(0.331, 0.308, 0.362); W_{B5} =(0.335, 0.350, 0.315); W_{B6} =(0.348, 0.318, 0.333); W_{B7} =(0.360, 0.328, 0.312)

The weight calculation results point out that during the implementation of Vietnam wind power projects, wind power projects need to occupy and convert large areas of land to extend and arrange auxiliary facilities such as wind turbines and roads. However, the land property rights relations in various regions of Vietnam are relatively complex, and the government promotes land acquisition and transfer. The efficiency is low and it is often difficult to complete the land acquisition task within the expected project time. At the same time, the land acquisition compensation standards provided by the government are low and difficult to satisfy farmers. Therefore, the difficult progress of land acquisition for wind power projects often seriously affects the progress of subsequent project construction. Wind farm projects have large investment scales and are highly sensitive to construction schedules. If the land is not obtained in time, it will directly affect the start of the main project construction activities. This may also lead to the compression of the construction period in the later implementation phase of the project and the superposition of various risks. However, local people lack information transparency about wind power projects and are easily wary. If the land acquisition issue is not handled properly, it will intensify conflicts. Compared with other types of projects, wind farms have higher requirements for site selection land conditions, and the corresponding geographical scope of site selection is relatively fixed. If it is difficult to acquire land at the selected site, it will be difficult for the project to avoid this risk by changing its location. Therefore, land acquisition risks are more critical in affecting project progress.

3.4. Risk level determination

(1) Establish comprehensive evaluation set

The evaluation set is a collection of various evaluations made by experts on the evaluation object, represented by V, V={v_1, v_2,...v_n}. According to the needs of project risk assessment, the evaluation levels are divided into five categories, namely low risk, relatively low risk, medium risk, relatively high risk, and high risk, represented by V={low risk, relatively low risk, medium risk, relatively high risk, high risk}={1,2,3,4,5}. Table 4.11 above is the impact level standard of the evaluation set.

(2) Fuzzy membership relationship matrix

The main purpose of single-factor fuzzy evaluation is to obtain the fuzzy membership evaluation matrix. Invite experts to evaluate the criterion layer and obtain a single-factor evaluation matrix. For example, when evaluating the degree of political risk of a certain project, 80% of the experts think that the risk is "higher", 10% of the experts think that the risk is "average", and 10% of the experts think that the risk is "low", then the political risk of the project belongs to the evaluation set. The degree is r = {0.8, 0.1, 0.1, 0,0}.

The weight vector of each indicator has been determined above, and 10 experts who are directly involved in the project, all of whom are middle and senior managers of the project department, are invited to evaluate the impact of project risks.

After the experts score, the expert judgment results are converted into an evaluation matrix to quantify the qualitative results. The evaluation results are quantified and transformed based on the proportion of the number of experts with different levels of evaluation to the total number of evaluations, as shown in Table 5.1.

Table 5.1. L project risk level membership degree

Risk factors	very high	high	middle	low	very low
Policy instability	0.5	0.4	0.1	0	0
Changes in legal provisions	0.1	0.4	0.2	0.3	0
Effectiveness of government actions	0.1	0.1	0.4	0.4	0
Residents’ recognition of the project	0	0.4	0.4	0.2	0
Price Fluctuations	0.3	0.2	0.3	0.1	0.1
Exchange rate fluctuations	0.2	0.4	0.2	0.1	0.1
Natural disaster	0	0.2	0.3	0.3	0.2
Hydrogeological conditions	0	0.1	0.2	0.4	0.3
Disease	0.1	0.4	0.4	0.1	0
Design data defects	0.2	0.2	0.3	0.2	0.1
Differences in technical standards and specifications	0	0.2	0.3	0.4	0.1
Design changes	0	0.1	0.3	0.4	0.2
Contractual terms risk	0.1	0.2	0.3	0.3	0.1
Owner Risk	0.1	0.2	0.4	0.3	0
Sub-supplier risks	0.1	0.3	0.3	0.2	0.1
Procurement and transportation management	0.1	0.2	0.3	0.3	0.1
Construction organization management	0	0.2	0.3	0.3	0.2
HSE	0.1	0.2	0.3	0.3	0.1

(3) Calculate fuzzy relationship matrix

Based on the above judgment matrix, the criterion layer is comprehensively evaluated, and then the target layer is evaluated as a whole. The weight coefficient of the target layer has been obtained by the analytic hierarchy process above:

W_B=(0.137, 0.133, 0.122, 0.113, 0.155, 0.167, 0.173);

The weight coefficients of each criterion layer are:

W_{B1}=(0.550, 0.450); W_{B2} = (0.452, 0.548); W_{B3}=(0.490, 0.510); W_{B4}=(0.331, 0.308, 0.362); W_{B5}=(0.335, 0.350, 0.315); W_{B6} =(0.348, 0.318, 0.333); W_{B7} =(0.360, 0.328, 0.312)

The result of the fuzzy relationship matrix is represented by S, and S1, S2, S3, S4, S5, S6, and S7 represent the calculation results of political risk, social risk, economic risk, natural risk, technical risk, contractual risk, and management risk, respectively.

The calculation formula of fuzzy comprehensive evaluation is as follows:

$$S = W \circ R \tag{3}$$

In which, W is the weight coefficient of the indicator $W=(W_1, W_2, W_3\ldots, W_n)$, and R is the fuzzy relationship matrix [11].

According to the above formula, the risk value S of project L is 3.08, which belongs to the medium risk level.

4. Conclusion

This study comprehensively utilizes literature analysis and interview methods to identify risk factors in the development stage of Vietnam's EPC wind power projects. Based on this, the study employs the fuzzy analytic hierarchy process to evaluate the risks of the project. This includes constructing a hierarchical model, using expert scoring to construct a fuzzy complementary judgment matrix, calculating the weight vector of risk factors, assessing the consistency of the fuzzy complementary judgment matrix, and obtaining the importance ranking of risk factors. From the analysis results, it is evident that the main risks of the Vietnam EPC wind power project include policy risks, resident interference risks, exchange rate risks, procurement and construction management risks, legal regulation changes, government action risks, price fluctuation risks, contract term risks, construction organization risks, and supplier risks, among others, while technical differences risks, design change risks, owner risks, HSE risks, and natural risks are relatively low.

However, the shortcomings lie in the incomplete analysis of risk factors and the need to broaden the breadth of risk factors. At the same time, the accuracy of scoring the importance of risk factors needs to be strengthened. It is recommended to use expert survey methods to select more experts with extensive overseas experience for scoring, hoping to supplement and improve in future research.

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