 The Open Fuels & Energy Science Journal, 2015, *8*, 52-57

Risk Assessment of Wind Power Investment Project Based on Matter-Element Extension Model

Jinying Li[*,1,2] and Panjuan Li[1]

[1] *North China Electric Power University, Department of Economics and Management, Baoding 071003, China*

[2] *Research Center for Beijing Industrial Security and Development, Beijing 100000, China*

Abstract: The prospect of China's wind power industry is bright, but from the angle of investment, investment amount, operation and maintenance costs of wind power project are relatively high, at the same time, it is facing high policy risk and environment risk. Therefore, we should consider all kinds of risk factors to make appropriate risk management and control plan. Based on this, the paper analyzes the risk factors including risk of planning and construction, risk of finance and market, risk of management and operation, risk of environment and resources. And an assessment index system is obtained which can be applied to evaluate the risk level. Furthermore, the model of Matter-Element Extension is applied to quantify the risk of the project. Integrating the methods of the qualitative and quantification analysis, then it proposes a reasonable assessment about the risk factors of the project of wind power. Finally, it proves the methods and the model through the case of the project of wind Power. The results could help us improve the level of the management of the project of wind power, and bring down the risk of the project.

Keywords: Matter-element extension, risk assessment, wind power investment.

1. INTRODUCTION

With the enhanced awareness of environmental protection and development of energy saving and emissions reduction, more and more people pay attention to the development of new energy. Compared with other new energy, wind energy, with relatively mature technology development, flexible investment, rich resources, has the good economic efficiency and social benefits, and is getting the support of numerous national and local governments. Thus wind power development becomes the focus of investment project developers. But we must also be clearly aware that China is still in the early stage of development of wind power, there is still a big gap between China and the developed countries. In the process of construction and operation, we will encounter a lot of risks, making it necessary to seek the countermeasures which can improve the project to obtain maximum social and economic benefits from the angle of risk analysis and control.

At present, many scholars study on the project investment risk assessment. The literature [1] selects the indicators from the interest, opportunity, cost, risk these four aspects, and constructs assessment system of wind power project by using AHP method; literature [2] applies BP neural network to make risk analysis on the wind power project; literature [3] establishes wind power project investment risk assessment index system by using the theory of the whole life cycle; literature [4] makes an analysis of wind power projects in China, and uses support vector machine model to make risk assessment. The uncertain risk indicators of above assessment methods are insufficient and the issues that how to assess different attributes of risk indicators are to be studied. Matter-Element model, which is proposed to effectively solve the problem of different attributes [5, 6], can carry out comprehensive assessment of different attributes. So, this paper uses matter-Element Extension method to assess the investment risk of wind power project basing on the experience of predecessors.

2. MATTER-ELEMENT EXTENSION ASSESSMENT METHOD

2.1. Determine Classical Domain

Matter-element theory is to solve practical problems using the matter-element model. The concept of matter element correctly reflects the relationship between quality and quantity, can more accurately describe the change process of objective things. Different objects can have the same characteristic element, represented by the same syndrome element [7]. The possibilities for change are the extension of matter-element. Change of things is described as the transformation of matter element, the core of matter-element theory is to study the extension of matter element and transformation of material-element and transformation properties of matter element. The main contents of element are the quantitative description of the variability of things, which are calculated by establishing the correlation function [8].

The basic unit of matter-element theory is the matter element, which is composed of the things, characteristic of things and the characteristic values, described as R= (things, characteristics, value) [9].

*Address correspondence to this author at the North China Electric Power University, Department of Economics and Management, Huadian Road, Baoding City, Postcard: 071003, China; Tel: 0312-7525110;
E-mail: jgxljy@163.com

1876-973X/15

Set m matter-elements, which can be described as $N_1, N_2, ..., N_m$. The characteristic value range of each matter-element is [a_{ij}, b_{ij}]. Thus element R_0 can be [10]:

$$R_0 = \begin{bmatrix} N & N_1 & N_2 & \cdots & N_m \\ c_1 & [a_{11}, b_{11}] & [a_{12}, b_{12}] & \cdots & [a_{1m}, b_{1m}] \\ c_2 & [a_{21}, b_{21}] & [a_{22}, b_{22}] & \cdots & [a_{2m}, b_{2m}] \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ c_n & [a_{n1}, b_{n1}] & [a_{n2}, b_{n2}] & \cdots & [a_{nm}, b_{nm}] \end{bmatrix}$$

N_j is the *jth* element which is assessed; c_i is the ith index; $v_{ij} = [a_{ij}, b_{ij}]$ is the classical domain, that is, the range of N_j.

2.2. Determine Section Domain [11]

$$R_p = (P, C, V_{\text{p}}) = \begin{bmatrix} P & c_1 & [a_{1p}, b_{1p}] \\ & c_2 & [a_{2p}, b_{2p}] \\ & \vdots & \vdots \\ & c_n & [a_{np}, b_{np}] \end{bmatrix}$$

P describes categories of assessment; $[a_{ip}, b_{ip}]$ is section domain, that is, the range of P.

2.3. Determine the Element to be Assessed [12]

To the assessed thing, its monitoring data or analysis results can be expressed as:

$$R_0 = \begin{bmatrix} P & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix}$$

R_0 is the element to be assessed; V_i is the c_i value of the assessed thing.

2.4. Determine the Weights of the Index

This article uses the analytic hierarchy process method to determine the weights of the index. The method is a kind of evaluation method proposed by T.L. Saatty in twentieth Century, which is widely used in the field of management science and Economics. Generally speaking, it contains the following processes:

2.4.1. Construct Hierarchical Structure Model [13]

The basic method of analytic hierarchy process method is to establish the hierarchical structure model. To Establish the hierarchical model of mechanism, the first thing is to make clear understanding of the problem to be solved and its various elements, such as the total goals of the evaluation, sub goals and indicators at all levels, as well as the relationship of each element. Secondly, make the problem to be evaluated for hierarchical. That is to say, decision problems can be divided into several levels, generally divided into three layers, the first layer is the target layer, is the purpose of the evaluation; the second layer is the criterion layer, is the factors reflecting the target layer; the third layer is the index layer, is a specific reflection of target layer index, is also refinement of the criterion layer.

2.4.2. Establish Comparative Judgment Matrix [14]

The key of AHP method is to construct pair wise comparison judgment matrix. For example, there are n elements under the guideline H_s, and then the comparison judgment matrix is obtained in the form shown in Table **1**.

Table 1. Comparison judgment matrix of order *n*.

H_s	A_1	A_2	…	A_n
A_1	a_{11}	a_{12}	…	A_{1n}
A_2	a_{21}	a_{22}	…	a_{2n}
…	…	…	…	…

The element $a_{ij} = w_i/w_j$, the matrix A has the following properties:

$$a_{ii} = 1; a_{ij} = 1/a_{ji}; a_{ij} > 0; a_{if} = a_{ik} \cdot a_{kf}$$

2.4.3. Calculate the Weight of the Single Level

Set the comparison judgment matrix as A:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Make each column vector of the matrix A is normalized, that is

$$b_{ij} = a_{ij} / \sum_{k=1}^{n} a_{kj} \quad (i, j = 1,2,3,...,n)$$

and $B = (b_{ij})_{n \times n}$. Then sum the row vector of B, that is. $M_i = \sum_{\text{j}=1}^{N} \text{b}_{kj} (i, j = 1,2,3, \cdots, n)$ Make the M normalized, we can get

$$W_i = \frac{M_i}{\sum_{j=1}^{n} M_j} (i, j = 1,2,3, \cdots, n)$$

The feature vector is $W = (W_1, W_2, \cdots W_n)$. Finally, calculate the max feature value

$$\lambda_{\max} = \frac{1}{n} \sum_{i-1}^{n} \frac{(AW)_i}{W}$$

2.4.4. The Calculation of the Current Layer Element on the Overall Goal of the Ranking Weight

2.4.4.1. Consistency Test

Consistency index: $CI = \dfrac{\lambda_{\max} - n}{n-1}$.

Consistency ratio: $CR = \dfrac{CI}{RI}$.

If CR<0.10, then consistency meet the requirements, and the weight vector W can meet the requirements.

2.5. Determine the Correlation Degree by the Improved Algorithm

Use the traditional method to calculate the distance:

$$\rho(v_i, v_{ij}) = \left| v_i - \frac{1}{2}(a_{ij} + b_{ij}) \right| - \frac{1}{2}(b_{ij} - a_{ij})$$

$$\rho(v_i, v_{ip}) = \left| v_i - \frac{1}{2}(a_{ip} + b_{ip}) \right| - \frac{1}{2}(b_{ip} - a_{ip})$$

$\rho(v_i, v_{ij})$ describes the distance between v_i and v_{ij}. $\rho(v_i, v_{ip})$ describes the distance between v_i and v_{ip}.

Calculate the correlation coefficient:

$$K_j(v_i) = \begin{cases} \dfrac{\rho(v_i, v_{ij})}{\rho(v_i, v_{ip}) - \rho(v_i, v_{ij})} & v_i \notin v_{ij} \\[2ex] \dfrac{-\rho(v_i, v_{ij})}{\left| v_{ij} \right|} & v_i \in v_{ij} \end{cases}$$

$K_j(v_i)$ is the correlation coefficient, $\left| v_{ij} \right|$ is the length of $[a_{ij}, b_{ij}]$.

Once any of the indicators to be measured goes beyond the section domain, its correlation function will exceed the case which cannot be calculated. For the limitations of Matter-Element Extension method, we make forward the following improvements.

On the basis of the original Matter-Element Extension method, making the normalization process of the classic domain and each element to be assessed, that is to say, each number is divided by the value of the right end of the section field, and then we can get a new classic domain and matter-element by equations as follows.

$$R_p{'} = (P, C, V_{\mathrm{p}}{'}) = \begin{bmatrix} P & c_1 & [\dfrac{a_{j1}}{b_{p1}}, \dfrac{b_{j1}}{b_{p1}}] \\ & c_2 & [\dfrac{a_{j2}}{b_{p2}}, \dfrac{b_{j2}}{b_{p2}}] \\ & \vdots & \vdots \\ & c_n & [\dfrac{a_{jn}}{b_{pn}}, \dfrac{b_{jn}}{b_{pn}}] \end{bmatrix}$$

$$R_0{'} = \begin{bmatrix} P & c_1 & v_1 / b_{p1} \\ & c_2 & v_2 / b_{p2} \\ & \vdots & \vdots \\ & c_n & v_n / b_{pn} \end{bmatrix}$$

Then calculate D

$$D(v, V_p{'}) = \left| v - \frac{a+b}{2} \right| - \frac{b-a}{2}$$

v is the point value; a, b respectively is the value of the left endpoint and the right end of the interval point.

Use D_{ij} instead of the correlation function $K_j(v_i)$ to calculate the integrated correlation $K_j(p_0)$.

$$K_j(p_0) = 1 - \sum_{i=1}^{n} W_i D_{ij}$$

If $K_{\mathrm{j}}(p) = \max K_j(p)(j = 1,2,...,m)$, then the class is j.

$$\overline{K_j(p)} = \frac{K_j(p) - \min\limits_{1 \le j \le m} K_j(p)}{\max\limits_{1 \le j \le m} K_j(p) - \min\limits_{1 \le j \le m} K_j(p)}$$

Then level variable characteristic values of p is

$$j^* = \frac{\sum\limits_{j=1}^{m} j \bullet \overline{K_j(p)}}{\sum\limits_{j=1}^{m} \overline{K_j(p)}}$$

2.6. The Risk Assessment Index System of Wind Power Investment

Wind power project is usually a large project, involving in a wide range of construction projects, which will be affected by many factors in the planning, construction and operational process. Thus we need to build a comprehensive index system which can clearly describe various risks. According to the analysis of construction factors of wind power projects, combing with the characteristics of wind power projects, we will divide all stages of risk factors by which wind power projects may be affected into 18 sub-indicators, specifically as Table **2**.

3. EMPIRICAL ANALYSIS

3.1. Overview of the Project

Wengniute Baiyinhua farm Wind Project is located in north-central of Wengniute, Chifeng City, Inner Mongolia. It covers an area of 5,000 acres, the proposed elevation is 600-800 m and the type of landform is saline.

Table 2. Index system of wind power investment project.

Target Layer	Criterion Layer	Index Layer
Index system of wind power investment project	Risk of planning and construction	Construction preparation
		Supply of equipment and raw materials
		Project planning
		Risk of engineering quality
		The core equipment installation
	Risk of finance and market	Changes in tariff
		Competition in generation market
		Generation costs
		Changes in financing rates and exchange rates
	Risk of management and operation	Contracting risk
		Maintenance of equipment
		Coordination and management of the construction site
		Core technical personnel
		Quality of managers
	Risk of environment and resources	National policies and regulations
		Coordination of local residents
		Meteorological disasters
		Conditions of wind resources

3.2. Matter-Element of the Assessment System

In the investment risk assessment of wind power, the classical domain, index value of the assessed matter-element are distinct in different risk levels. In this article, the risk is divided into five levels, that is: highly dangerous, more dangerous, dangerous, average, more secure. According to the 5 levels of risk, the qualitative index values in classical domain is: 85%-100%,70%-85%,60%-70%,40%-60%, 0-40%; the quantitative index values is: 70-90,50-70,30-50,15-30,0-15. So

$$R_P=\left\{\begin{array}{ccc} & c_1 & 0-100\% \\ & c_2 & 0-100\% \\ & c_3 & 0-100\% \\ & c_4 & 0-100\% \\ & c_5 & 0-100\% \\ & c_6 & 0-90 \\ & c_7 & 0-100\% \\ & c_8 & 0-90 \\ P & c_9 & 0-90 \\ & c_{10} & 0-100\% \\ & c_{11} & 0-100\% \\ & c_{12} & 0-100\% \\ & c_{13} & 0-100\% \\ & c_{14} & 0-100\% \\ & c_{15} & 0-100\% \\ & c_{16} & 0-100\% \\ & c_{17} & 0-100\% \\ & c_{18} & 0-100\% \end{array}\right\}\quad R_1=\left\{\begin{array}{ccc} & c_1 & 85\%-100\% \\ & c_2 & 85\%-100\% \\ & c_3 & 85\%-100\% \\ & c_4 & 85\%-100\% \\ & c_5 & 85\%-100\% \\ & c_6 & 70-90 \\ & c_7 & 85\%-100\% \\ & c_8 & 70-90 \\ P_1 & c_9 & 70-90 \\ & c_{10} & 85\%-100\% \\ & c_{11} & 85\%-100\% \\ & c_{12} & 85\%-100\% \\ & c_{13} & 85\%-100\% \\ & c_{14} & 85\%-100\% \\ & c_{15} & 85\%-100\% \\ & c_{16} & 85\%-100\% \\ & c_{17} & 85\%-100\% \\ & c_{18} & 85\%-100\% \end{array}\right\}\quad R_0=\left\{\begin{array}{ccc} & c_1 & 8\% \\ & c_2 & 10.3\% \\ & c_3 & 23.4\% \\ & c_4 & 11.8\% \\ & c_5 & 16.3\% \\ & c_6 & 78 \\ & c_7 & 32.3\% \\ & c_8 & 59.7 \\ P_0 & c_9 & 50\% \\ & c_{10} & 19.2\% \\ & c_{11} & 32.4\% \\ & c_{12} & 46.7\% \\ & c_{13} & 26.9\% \\ & c_{14} & 15.4\% \\ & c_{15} & 83\% \\ & c_{16} & 49.3\% \\ & c_{17} & 47.6\% \\ & c_{18} & 24.4\% \end{array}\right\}$$

3.3. Determine the Weights

The level of the index is assessd by 10 experts, forming a consensus on the investment plan of wind power project. Then us the analytic hierarchy process to determine the weight of each index as shown below:

$W_{U1}{}'$ =(0.4691,0.2010,0.0862,0.0427,0.2010);

$W_{U2}{}'$ =(0.1998,0.1998,0.5222,0.0781);

$W_{U3}{}'$ =(0.0309,0.2074,0.4569,0.0973,0.2074);

$W_{U4}{}'$ =(0.0447,0.1216,0.4169,0.4169)

The integrated weight is:

W=(0.0244,0.0105,0.0045,0.0022,0.0105,0.0196,0.0196, 0.0513,0.0077,0.0077,0.0515,0.1134,0.0242,0.0515,0.0269,0.0731,0.0883,0.0883).\

3.4. Determine the Distance Between Classic Domain and Indicators to be Assessed

According to the formula, calculate the classical domain distance on the indicators to be assessed, as shown in Table **3**.

3.5. Risk Grading of Wind Power Investment Project

According to the formula, calculate the correlation of wind power investment risk level:

$$K_1(P_0) = 1 - \sum_{i=1}^{18} w_{ij} D_{ij} = 0.793$$

$$K_2(P_0) = 1 - \sum_{i=1}^{18} w_{ij} D_{ij} = 0.935$$

$$K_3(P_0) = 1 - \sum_{i=1}^{18} w_{ij} D_{ij} = 0.988$$

$$K_4(P_0) = 1 - \sum_{i=1}^{18} w_{ij} D_{ij} = 0.708$$

$$K_5(P_0) = 1 - \sum_{i=1}^{18} w_{ij} D_{ij} = 0.560$$

We can see that, risk grade of the wind power investment project is average.

Table 3. The distance between classic domain and indicators to be assessed.

Index	Highly Dangerous $D_1(V_i)$	More Dangerous $D_2(V_i)$	Dangerous $D_3(V_i)$	Average $D_4(V_i)$	More Secure $D_5(V_i)$
C_1	-0.08	0.32	0.52	0.62	0.77
C_2	-0.103	0.297	0.497	0.597	0.747
C_3	-0.166	0.166	0.366	0.466	0.616
C_4	-0.118	0.282	0.482	0.582	0.732
C_5	-0.163	0.237	0.437	0.537	0.687
C_6	0.38	0.18	-0.12	-0.07	0.07
C_7	-0.077	0.077	0.277	0.377	0.527
C_8	0.197	-0.003	0.003	0.103	0.253
C_9	0.1	-0.1	0.1	0.2	0.35
C_{10}	-0.192	0.208	0.408	0.508	0.658
C_{11}	-0.076	0.076	0.276	0.376	0.526
C_{12}	0.067	-0.067	0.133	0.233	0.383
C_{13}	-0.131	0.131	0.331	0.431	0.581
C_{14}	-0.154	0.246	0.446	0.546	0.696
C_{15}	0.43	0.23	-0.07	-0.02	0.02
C_{16}	0.093	-0.093	0.107	0.207	0.357
C_{17}	0.076	-0.076	0.124	0.224	0.374
C_{18}	-0.156	0.156	0.356	0.456	0.606

CONCLUSION

The development of Wind power has broad prospect in China, but it will certainly face some unforeseen risks. The risk research of wind power investment project contributes to a comprehensive and accurate understanding of the risks, helps to use effective methods to avoid the risk, so you can put an end to blind investment, which can promote the healthy development of wind power industry in China. This paper establishes the wind power project risk assessment index system and matter-element extension model. Studies have shown that the model can more accurately assess the risks of wind power projects, which has important practical significance.

The manuscript should be written in English in a clear, direct and active style. All pages must be numbered sequentially, facilitating in the reviewing and editing of the manuscript.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This paper belongs to the project of "the Postdoctoral Science Foundation of China", No. 2013M540852.

REFERENCES

[1] Liu, X.; Fu, Y. The assessment of wind power investment projects with BOCR. *J. North China Elect. Power Univ. (Soci. Sci.)*, **2012**, *5*, 6-9.

[2] Li, W.; Guo, S. Risk assessment of wind power investment project based on BP network model. *J. North China Elect. Power Univ. (Soci. Sci.)*, **2011**, *12*, 95-97.

[3] Li, F.; Liu, Z.; Jia, X.; Zeng, M.; Li, N. Investment risk assessment model for wind power projects baesd on full life-cycle theory. *East China Elect. Power*, **2012**, *4*(40), 531-535.

[4] Zhao, H.; Su, J.; Dai, J. Assessment on investment risk of wind power project based on support vector machine. *Technol. Econ.*, **2012**, *12*(31), 77-81

[5] Ma, Z.; Dai, J. Risk assessment of project bidding investment based on matter analysis model. *Economist*, **2011**, *3*, 281.

[6] He, Y.; Dai, A.; Yang, W. Risk assessment of urban network planning based on the matter-element model and extension analysis. *J. North China Elect. Power Univ.*, **2010**, *37*(6), 6-11.

[7] Li, C.; Lu, G.; Si, W. The investment risk analysis of wind power project in China. *Renewable Energy*, **2013**, *2013*(50), 481-487.

[8] He, Y. *Application of Power Comprehensive Assessment Method*. Beijing: China Electric Power Press, **2011**, pp. 103-108.

[9] He, F. *MATLAB to Achieve Comprehensive Assessment Method*. Beijing: China Social Sciences Press, **2010**, pp. 269-286.

[10] Gillenwater, M. Probabilistic decision model of wind power investment and influence of green power market. *Energy Policy*, *2013*(63), 1111-1125.

[11] Zhao, Z.; Sun, G.; Zuo J.; Zillante, G. The impact of international forces on the Chinese wind power industry. *Renewable Sustain. Energy Rev.*, **2013**, *24*, 131-141.

[12] Prostean, G.; Badea, A.; Vasar, C.; Octavian, P. Risk variables in wind power supply Chain. *Proc. Soc. Behav. Sci.*, **2014**, *124*, 124-132.

[13] Yan, N. *Research on Wind Power Project Investment Risk Assessment*. Baoding: North China Electric Power University, **2010**

[14] Tang, Y.; Wang, L.; Li, C.; Zeng, M. Seismic response of ACCC conductor-transmission tower system. *Water Resources Power*, **2013**, *5*(31), 186-193.

Received: November 26, 2014 Revised: January 21, 2015 Accepted: January 27, 2015